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Requirements Knowledge Model Construction and Requirements Elicitation Method of Avionics Systems Software based on Multi-ontology

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***Abstract*—Avionics systems software usually has the characteristics of complex structure, wide function coverage, high reliability, and high safety. These characteristics have led to the increasing scale and complexity of software systems, and the increasing variety of research & development (R&D) personnel. This further intensify the knowledge-intensive trend of software development, and make the software requirements elicitation activities more complicated. In the knowledge engineering community, an ontology is an explicit specification of a conceptualization. This paper uses the ontology method to construct a requirement knowledge framework and requirement knowledge is expressed as a clear, complete, and consistent hierarchical ontology concept and association, which is more conducive to knowledge sharing and reuse as well as reflects multiple viewpoints of stakeholders. This paper builds a requirements knowledge multi-ontology framework which is divided into GO (generalization ontology), TO (task ontology), DO (domain ontology), and AO (application ontology). And it decomposes the GO into structure ontology and action ontology in the framework. It makes up for the deficiency of undifferentiated knowledge representation of the GO. Then, this paper proposes and integrates the concept of software requirement error pattern into the multi-ontology framework in a consistent form. In addition, this paper evaluates the quality of the constructed ontology and the evaluation results show that the constructed ontology in this paper has a high quality. Finally, this paper facilitates the requirements elicitation based on the multi-ontology framework to avoid errors and improve the quality and reliability of software products.**

***Keyword*—error, ontology, requirements elicitation, software requirements**

I. INTRODUCTION

SOFTWARE requirements elicitation (SRE) is the most critical knowledge-intensive activity in a software development process; however, implementing effective requirements elicitation and obtaining correct, complete, consistent, and unambiguous requirements specifications remains a problem that plagues system analysts and software developers. These issues also exist in avionics systems SRE activities and have a significant impact on their quality. An important reason for the above problems is the lack of an effective knowledge sharing bridge between system developers and domain users [1]. In practical applications, some system developers lack knowledge about software system problem domains. They passively wait for domain users to provide requirements and develop requirements specifications based on their own understanding. This inevitably cause a part of the requirements to be misunderstood, resulting in the generation of low-quality requirements specifications. On the other hand, although the domain knowledge possessed by domain users and domain experts plays an important role in high-quality requirements elicitation activities, they do not know how to accurately express requirements that developers can understand in accordance with software development guidelines. The above two reasons ultimately cause the **ambiguity** of requirements elicitation. In addition, the increasing scale and complexity of software systems increase the difficulties in acquiring complete knowledge and cause the **incompleteness** of requirements elicitation. Moreover, different teams with multiple-views and multi-paradigm development methods are widely used in the development of such complex software systems, which increases the heterogeneity of software requirements specifications (SRSs) and cause the **inconsistency** of SRSs [1].

A knowledge-based requirements elicitation method can be used to solve the above problems; its purpose is to use domain analysis and experience to help software system stakeholders understand the application domain and define requirements. The key is to model the domain knowledge as a shareable knowledge framework. Under this framework, domain users can more easily and conveniently express their needs, while the domain developers can understand the requirements more accurately. Moreover, the heterogeneity

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brought about by multiple viewpoints and paradigms can be minimized. Ontology is a logic theory that explains the expected meaning of formal vocabulary, i.e., its ontological commitment to a specific conceptual world. The expected model of logic language uses the vocabulary constrained by ontology commitment. And an ontology reflects this commitment (and potential conceptualization) indirectly by approximating the expected model [2]. In the knowledge engineering community, an ontology is a formal and explicit specification of a shared conceptualization [3, 4]. Therefore, introducing the ontology method into the SRE process is an effective way to solve the above problems. By adopting the ontology method, the requirement knowledge can be expressed as an ontological concept and association; therefore, it is clear, complete, and consistent and is conducive to the sharing and reuse of knowledge. Literature [5] designed an ontology in a case study for co-simulation in a model-based system engineering tool-chain. They argued that an ontology refers to content about the types of objects, their properties, and their relationships, which represent domain-specific knowledge.

This paper proposes a requirements knowledge multi-ontology framework (RKMOF) integrating information about software requirement error pattern (SREP) to solve the problems of ambiguity, incompleteness, and inconsistency in the requirements elicitation of avionics systems software. Then, this paper uses a criteria-based evaluation approach to evaluate the quality of the software requirements elicitation ontology, including ontology validation and ontology verification. Ontology validation checks if the correct ontology has been built, whereas ontology verification checks if the ontology has been built correctly [6]. Moreover, this paper studies the software requirements elicitation method based on the RKMOF. The rest of this paper is divided into the following sections: section 2 presents the state of the art of ontology-based requirements elicitation and ontology evaluation. Section 3 describes the construction of avionics systems RKMOF and obtains the quadruple representation including the generalized ontology (GO), the domain ontology (DO), the task ontology (TO) and the application ontology (AO). Section 4 describes the composition of avionics systems software requirements knowledge ontology, including its constituent elements and hierarchical structure, presents the definition and ontology representation of SREP, and describes the evaluation of avionics systems SRE ontology in terms of ontology validation and ontology verification. Ontology validation is achieved by applying two validation methods [6]. The first is the ontology content evaluation, and the second is answering competency questions. Ontology verification is achieved using two methods, also [6]. The first is the ontology taxonomy evaluation, and the second is the improved FOCA methodology [7] adding the metrics of ontology cohesion and ontology coupling [8]. On this basis, section 5 describes the RKMOF-based SRE method. Section 6 shows the results of engineering applications.

II. Related Work

The current state of the art of ontology-based requirements elicitation and ontology evaluation is presented in this section.

A. Ontology-based requirements elicitation

Nowadays the typical representatives of ontology-based requirements elicitation methods include, the requirements elicitation method based on a multi-ontology framework [9], the automatic elicitation method based on an enterprise ontology [10], the method of using a DO as the domain knowledge for requirements elicitation [11], the use of semi-formal representation of semantic guidance consisting of domain concepts, associations, and axioms to assist requirements elicitation activities [12], the use of formal ontology representation of original requirements based on the top-down refinement of meta-model to elicit and analyze requirements [13]. The first two methods mainly solve the problems of ambiguity and inconsistency in the process of requirements elicitation. The third method focuses on the ontology-based requirements elicitation and analysis, and the quality measurement of requirements document; however, it does not conduct in-depth research on how to construct a high-quality ontology. The semantic guidance proposed by the fourth method uses the concepts, associations, and axioms of a DO to provide a series of suggestions for requirements engineers to obtain requirements. The fifth method uses ontologies to elicit and analyze requirements, and studies how to evaluate the completeness and consistency of requirements to a certain extent. None of the above methods can simultaneously solve the problems of ambiguity, incompleteness, and inconsistency of requirements elicitation; thus, the scope of use and effect are limited.

Based on the above review and analysis, this paper proposes an SRE method based on a RKMOF integrating the information about SREP to solve the problems of ambiguity, incompleteness, and inconsistency simultaneously.

B. Ontology evaluation

Ontology evaluation can be defined as “a technical judgment of the content of the ontology with respect to a frame of reference during every phase and between phases of their life cycle” [14]. To achieve the best results and high-quality ontology, one needs to choose from the available list of aspects of ontology to be evaluated; the right approach to evaluation; the right mix of criteria to be evaluated; and also the right tools to be used [15].

1 ASPECTS

Aspects include the vocabulary, syntax, structure, semantics, representation, and context of the ontology, which are defined according to literature [15-17].

2 APPROACHES

The different known methods and techniques can be mainly assigned to four different kinds of approaches: technology-based, quality-attribute based, data-driven and application or task-based evaluation [15, 18]. Technology-based evaluation investigates the syntax, consistency and formal semantics and thereby ensures the correctness and usability of the ontology. Its typical representative is OOPS!, a web-based tool which is accompanied by a catalogue of potential and common pitfalls [19]. However, this approach cannot tell anything about the quality of the content and applicability of the ontology [20, 21]. Quality-based approach offers a quantitative evaluation which relies on a set of predefined metrics that measure individual quality attributes of an ontology. Yet, some of

those quality metrics tend to be hard to measure and might need human experts to evaluate [17]. Its typical representatives include, OntoClean methodology, OntoMetric [22], OntoQA [23], etc. Data-driven evaluation approach concentrates on the usability of an ontology considering its future application and has also been the current focus of recent research [24-26]. This approach attempts to analyze how adequate an ontology covers the domain but is not applicable to determine the correctness or clarity of the ontology [27, 28]. Application or task-based evaluation approach would typically involve evaluating how effective an ontology is in the context of a specific application [29]. This approach exhibits a limitation: the result obtained from one task may not be useful for another task as each task is different [18], i.e., it is not suited for a general evaluation, because every ontology must be evaluated individually depending on the application context [27].

3 CRITERIA

This kind of evaluation approach is done by humans who try to assess how well the ontology meets a set of predefined criteria, standards, requirements, etc. [30] Various criteria have been proposed in literature to evaluate the quality of ontology [15-17, 31]: consistency, completeness, accuracy, conciseness, correctness, computational efficiency, adaptability, clarity.

4 TOOLS

Various tools have been developed to support the task of ontology evaluation, each concerned with different aspects of evaluation. There exist tools for checking the consistency, the structure or modeling mistakes of the ontology [21]. Various available tools include: ODEClean, ODEval, AEON, Eyeball, Moki, XD-Analyzer, OQuaRE, OntoCheck, OntoQA, OntoClean, OntoMetric, ACTiveRank, OOPS!, ODEval, oQual [15].

Based on the above review and analysis, this paper adopts a criteria-based evaluation approach to evaluate the ontology quality, including ontology validation and ontology verification.

III. AVIONICS SYSTEMS RKMOF

To achieve high-quality requirements elicitation requires various of knowledge; therefore, knowledge aided design system (KADS) can be used to study knowledge system modeling [9]. The knowledge layers in this model are clearly divided, and each layer of knowledge has good maintainability and reusability; however, its shortcomings are also obvious: the lack of strong bonds between the knowledge at all layers; incomplete knowledge. Fig. 1. shows an example of a portion of knowledge system of an avionics system, which contains elements such as classes, instances, relationships, etc. However, these are not enough for building a complete knowledge system; in addition, there is also a lack of division of knowledge layers. In general, a complete and high-quality knowledge system should include: concepts (classes), object properties, data properties, restrictions on properties, property characteristics, relationships, class hierarchy, instances, mappings and rules. Therefore, for the above knowledge model to play a role in knowledge sharing and reuse, it is also necessary to integrate relatively independent knowledge layers to form a knowledge system. Ontology method is an effective way to achieve this goal.

Ontologies can be classified into different types, according to the level of abstraction of the universe of discourse the ontology models. According to Guarino [2], there are four types of ontologies: top-level ontologies, domain ontologies and task ontologies, application ontologies. Top-level ontologies describe very general concepts which are independent of a particular problem or domain. Domain ontologies and task ontologies describe general domains. These types of ontologies specialize in the concepts introduced in the top-level ontology. Application ontologies describe concepts depending on a particular domain and task,

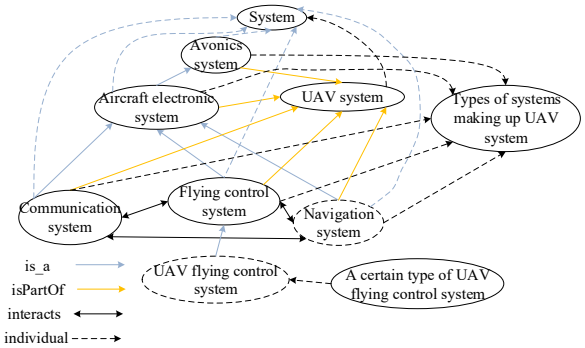

Fig. 1. Example of portion of knowledge system of avionics system

which are often specializations of both the related ontologies. On this basis, combined with existing research results [10, 32] and practical experience, this paper obtains the tuple of avionics systems RKMOF as follows:

Definition 1 RKMOF = <GO, DO, TO, AO>,

where:

GO, DO, TO and AO respectively represent the generalization ontology, domain ontology, task ontology and application ontology of avionics systems.

The relationships between various ontologies in this definition are shown in Fig. 2. A GO can be mapped to a TO, instantiated to a DO and eventually an AO. The GO can be divided into structure ontology and action ontology. Both the DO and the TO can be reused in the same domain, transformed into a domain requirements model (DRM) through domain analysis and an application requirements model (ARM) by reuse. In this framework, error data, domain knowledge and industry standards are the sources of DO. This framework is multi-viewpoint because domain experts, users and developers can all participate in the process of framework construction.

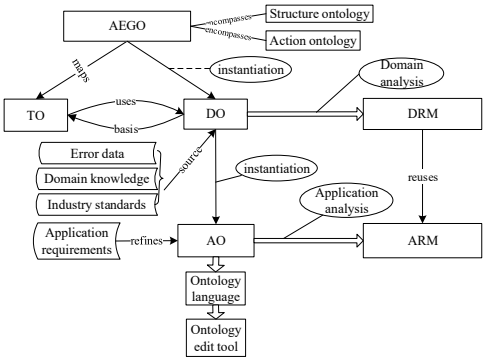

Fig. 2. Avionics systems RKMOF

IV. Construction of Avionics Systems Requirements Knowledge Ontology

This section presents the constituent elements of the requirements knowledge ontology of avionics systems and studies the hierarchical structure of the ontology.

A. Constituent Elements of Avionics Systems Requirements Knowledge Ontology

The universe of ontology constituent elements U is: U = {Concepts, Object properties, Data properties, P^R, P^C, Inherit-hierarchies, Relationships, Instances, Mappings, Rules}. Concepts, Inherit-hierarchies, Relationships, and Instances build the basic skeleton of a knowledge ontology. All other elements are attached to and refine the basic skeleton. Object properties and Data properties are two types of properties. The Object properties connect instances together, and the Data properties connect instances and values together. P^R indicates the restrictions on properties, including the restrictions on the type, range, and maximum/minimum number of property values. P^C indicates property characteristics. Mappings represent the mappings between different levels of ontology. Rules include axioms and custom rules. The Rules can be used to constrain information, prove correctness, or derive new information. The Rules can also be used to express richer relationships between concepts.

B. Hierarchies of Avionics Systems Requirements Knowledge Ontology

1 Avionics systems GO construction

Definition 2 Generalized ontology = <Concepts, Object properties, P^C, Inherit-hierarchies, Relationships, Rules>.

It is clearly that the construction of a GO can be achieved by constructing its concepts (classes), class hierarchy, relationships, properties, and property characteristics. The specific steps are shown in Fig. 3.

1 Determine the scope and purpose of an ontology and clarify the relevant knowledge of an avionics system
2 Acquire preliminary knowledge based on expert understanding and experience, and stakeholder needs
3 Acquire the description of conceptual terms/properties, hierarchies and relationships through conceptualization-relationship and other data analysis
  a Analyze the concept hierarchies of a GO
  b Analyze the concept relationships of a GO
  c Build the concept space of a GO
4 Build an initial informal ontology

Fig. 3. Specific steps of GO construction

1) GO concept classes and class hierarchy

Fig. 4. shows a portion of the class hierarchy of GO. The concept classes marked with an "*" are non-terminal concept classes, and the rest are terminal concept classes. Define an inheritance relationship as:

Definition 3 An inheritance relationship is a mechanism of a sub-class automatically sharing the properties and structure of a parent class in the GO concept class hierarchy.

Then, the sub-class and the parent class of non-terminal concept classes form an inheritance relationship. Therefore, a new class can be implemented based on an existing concept class by taking the content defined by the existing class as its own content and adding new content.

Fig. 4. also shows that the GO concepts contain both static and dynamic ontology elements.

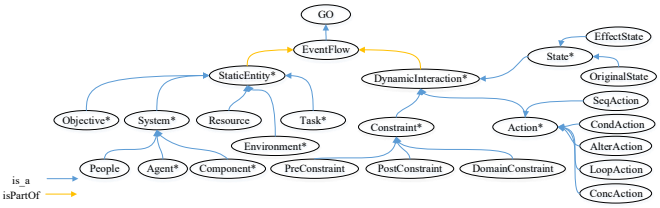

Fig. 4. Portion of the class hierarchies and relationships of GO

2) Decomposition of GO

The GO concept classes and relationships are indistinguishable representations of knowledge. This paper further divides the GO into structure ontology ($O_{structure}$) and action ontology (O_{action}), which describe the most basic structure and functions of a system, using the first-order predicate logic as: GO = $O_{structure} \cup O_{action}$.

- $O_{structure}$

Structure is a set of constraints on system actions, including a series of systems, people, agents, components, environments, static attributes, and dynamic interactions. A system has one or more tasks, and each task is defined by a series of goals that need to be facilitated. The system consumes some resources when performing actions and follows certain restrictions. The concept types of $O_{structure}$ are shown in Fig. 5.

Schema Structure
Signature
  hasMember: P Environment | P System | P Objective | P Task | Resource
  hasSubObjective: P Objective
  hasSubTask: P Task
  System:=People | Agent | Component
  Environment:= ExpEn | ImpEn
  has: Task+ Objective
  need: Task+ Resource
  interact: System+ Environment
  interact: Environment+ System
Constraints
  Member$\neq\phi$, Objective $\neq\phi$, Resource $\neq\phi$

Fig. 5. Concept types of $O_{structure}$

- O_{action}

An action describes the state transition of a system or an environment. An initial state triggers an action and the action generates a new state. An action is usually executed in the form of transition from an input to an output (with constraints, such as time, memory size, etc.). In addition, actions can be divided into simple actions and complex actions. The simple actions have the characteristics of the smallest granularity and the indivisibility of actions. The complex actions include sequential actions, conditional actions, alternative actions, loop actions, and concurrent actions. The concept types of O_{action} are shown in Fig. 6.

3) Concept relationships and concept space of GO

GO concept relationships can be obtained based on the class hierarchies. By integrating the concepts (classes), the class hierarchies, the concept relationships, the properties, and the property characteristics into a whole, a portion of the concept space of GO is obtained as shown in Table I. The left side of arrow is a source concept node, and the right side is a destination concept node. It can be proved that the inheritance relationship is a partial order relationship, expressed as: $a \preceq b$. The relationship "Interact" is a symmetric relationship.

```
Action := SimAction|ComAction
ComAction:=
SeqAction|CondAction|AlterAction|LoopAction|ConcAction
Actor := System|Environment
Schema SimAction        //simple action
Signature
    hasSubObjective: P Objective
    triggeredby: OriginalState
    produce: EffectState
Constraints
    hasSubObjective ≠ ϕ, operateOn ≠ ϕ
Schema SeqAction        //sequence action
Signature
    hasSubObjective: P Objective
    subAction: SeqAction
    triggeredby: OriginalState
    produce: EffectState
Constraints
    hasSubObjective ≠ ϕ, subAction ≠ ϕ, predecessor ≠ ϕ, successor ≠ ϕ
Schema CondAction     //conditional action
Signature
    hasSubObjective: P Objective
    subAction: CondAction
    triggeredby: OriginalState
    produce: EffectState
Constraints
    hasSubObjective ≠ ϕ, subAction ≠ ϕ, cond ≠ ϕ
Schema AlterAction     //alternative action
Signature
    hasSubObjective: P Objective
    subAction: AlterAction
    triggeredby: OriginalState
    produce: EffectState
Constraints
    hasSubObjective ≠ ϕ, subAction ≠ ϕ
Schema LoopAction       //loop action
Signature
    hasSubObjective: P Objective
    subAction: LoopAction
    triggeredby: OriginalState
    produce: EffectState
Constraints
    hasSubObjective ≠ ϕ, subAction ≠ ϕ
Schema ConcAction      //concurrent action
Signature
    hasSubObjective: P Objective
    subAction: ConcAction
    triggeredby: OriginalState
    produce: EffectState
Constraints
    hasSubObjective ≠ ϕ, subAction ≠ ϕ
```

Fig. 6. Concept types of O_{action}

TABLE I
PORTION OF ONTOLOGY CONCEPT SPACE BASED ON STRUCTURE AND ACTION CONCEPT TYPES

Concept types	Concept relationships	Relationship value types	P^C
Structure	Objective	P Objective	partial order
	Task	P Task	partial order
	has	Task+→Objective	-
	needs	Task+→Resource	-
	interacts	System+→Environment	symmetry
	interacts	Environment+→System	symmetry
Action	triggeredby	OriginalState	-
	produces	EffectState	-

2 Avionics systems DO construction

Definition 4 A domain is a collection of systems with similar or identical functions used to address specific domain issues. When dealing with different application needs, the systems have variability.

A DO is a special ontology used to describe the knowledge of the specified domain. It presents a description of domain concepts and relationships, domain activities, and domain characteristics and laws obtained by instantiating the corresponding content in the GO.

1) Definition of DO

Definition 5 DO = <DomConcepts, Object properties, Data properties, P^R, P^C, DomInherit-hierarchies, DomRelationships, Rules, Dommappings>,
where:
DomConcepts = < DomConceptname, DomConcept-ID>; DomInherit-hierarchies = < DomInherit-ID, Argument <Argument1 <cardinality, (status)>, Argument2< cardinality, (status)>>>, (Argument1, Argument2 ∈ DomConcepts); DomRelationships = < DomRelationships-name, DomRelationships-ID, Argument<Argument1<cardinality, (status)>, Argument2< cardinality, (status)>>>, (Argument1, Argument2 ∈ DomConcepts).

DomInherit-hierarchies are the inheritance relationships of domain concept classes. An inheritance relationship is defined as a binary relationship possessing two parameters. "Cardinality" and "Status" can be used to characterize each parameter. DomRelationships refer to the relationships in the DO except the inheritance relationships. Dommappings are the generic relationships of domain concepts. They are a total function from the DomConcepts to the Concepts. They map the concept classes in the DO to the concept classes in the GO. According to this function, the equivalence relationship on the DomConcepts can be defined as:

Definition 6 $a \equiv_{domain} b$ iff Dommappings (a) = Dommappings (b) = t, a, b ∈ DomConcepts, t ∈ Concepts. This equivalence relationship can be recorded as $[t]\equiv_{domain}$.

2) Concepts set and concept relationships set of DO

The construction steps of DO concepts set and concept relationships set can refer to the corresponding steps of GO, and is not repeated here. This paper limits the domain to flying control (FC) systems. For the specific contents of the concepts set and concept relationships set of FC systems, please refer to the reference [32].

3 TO construction

A TO is a collection of vocabularies that describes the structure of a problem-solving method (PSM). It provides several primitives, according to which domain experts can describe the PSM context and make the process of integrating domain knowledge into the PSM context easier. Since this paper studies the requirements elicitation method based on the ontology, the definition of requirements elicitation TO (RETO) is given as follows [32]:

Definition 7 RETO = <Requirements-Eliciting Task, Requirements-Eliciting Task-PSM, Requirements-Eliciting Taskmappings>,
Specifically expressed as:
Ontology name: RETO
Type: TO
{ID: // identifier
Requirements - Eliciting Task: = <Task ID, Circumstance>, Requirements - Eliciting Task - PSM: = <Competence, Operational specification, Requirements>, Competence: = <Input Action, Output Action, Objective>, Operational specification: = <Inference Steps, Control Flow between the Inference Steps, Data Flow between the Inference Steps>, Requirements: = <Requirements - Eliciting Task Concepts, Requirements - Eliciting Task Relationships, Requirements - Eliciting Task Facts, Rules>, Requirements - Eliciting Taskmappings:{Requirements - Eliciting Task Concepts → Concepts}

4 AO construction

The definition of AO is given below:

Definition 8 AO = <AppConcepts, Object properties, Data properties, P^R, P^C, AppInherit-hierarchies, AppRelationships, Appmappings, Rules>.

The detailed descriptions of AO constituent elements are similar to the DO and are not repeated here.

Similarly, the equivalence relationship on the AppConcepts can be defined according to the Appmapping.

Definition 9 $a \equiv_{app} b$ iff Appmappings (a) = Appmappings (b) = t, a, b ∈ AppConcepts, t ∈ Concepts. This equivalence relationship can be recorded as $[t]\equiv_{app}$.

C. Definition and Ontology Representation of SREP

SREP is a summary of experience of errors in requirements

engineering. Therefore, the definition of SREP can be given with reference to the definition of software error pattern [33].

Definition 10 The SREP refers to the error produced in the software requirement development stage, which occurs repeatedly in a specific error lifetime scenario, spreads in the subsequent design and implementation, and may cause a system (component) to fail to perform the expected function or affect the maintainability of the system. Such errors are general and common in a specific scenario and can be corrected by various means.

The definition shows that the core components of an SREP are "scenario", "error-manifestation" and "solution". In addition, "severity" should also be included.

Definition 11 The definition of SREP ontology (SREPO) is: SREPO = <Concepts, Object properties, Data properties, P^R, P^C, Inherit-hierarchies, Relationships, Rules, Instances>.

The SREPO concept space is shown in Fig. 7. The concept classes marked with an "*" are non-terminal concept classes, and the rest are terminal concept classes.

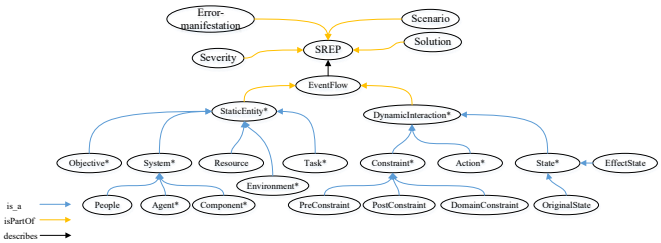

Fig. 7. SREPO concept space

This paper improves the ontology representation of the domain-related requirements error pattern proposed in [33], acquires a new ontology representation of requirements error pattern, and integrates it into the RKMOF. As a summary of experience, the role of SREP is to restrict new requirements elicitation activities in the form of rules. Since programming in logic (Prolog) can be used not only to represent factual knowledge such as states, concepts, etc., but also to represent the causality of things, i.e., rules, this paper uses the Prolog to represent the SREP. Then, this paper incorporates the SREP into a rule base.

This paper first builds a fact library based on the RKMOF, and then converts the Web Ontology Language (OWL) instances in the fact library into the facts that conform to Prolog syntax. The rules in the rule base are written in Prolog grammar, and no further conversions are required. The concepts and predicates used by these rules should also follow the definitions in the RKMOF, and maintain conceptual consistency with the fact library.

D. Ontology Evaluation

The development of ontology description languages and tools aids developers in building ontologies according to specific applications. However, due to the complexity of application semantics, ensuring ontology quality remains an important issue. In addition, the widespread use of ontologies has led to an explosive growth in the number of ontologies on the Internet. Ontologies enable reuse, but different ontologies have notable differences in domain coverage, comprehensibility, and accuracy. Thus, it is difficult for users to grasp ontology features as a whole and understand their application. Based on the above two points, it is necessary to evaluate ontology quality. According to ontology evaluation results, developers can reconstruct an ontology to optimize its structure, thereby creating high-quality ontologies. Meanwhile, users can also select an optimal ontology between different ontology systems. It should be noted that, this paper takes an unmanned aerial vehicles (UAV) FC systems SRE ontology in the application layer of RKMOF of the avionics systems for ontology evaluation.

1 Ontology validation

1) Ontology content evaluation

This method checks the content of the ontology based on the following main criteria [15-17, 31]: consistency, completeness, accuracy, conciseness, expandability, and sensitiveness. The criteria and their compatibility to UAV FC systems SRE ontology are shown in Table II.

TABLE II
ONTOLOGY CONCEPT EVALUATION

Criteria	Satisfaction
Consistency	Yes, since no contradictory knowledge can be inferred from all definitions and axioms. Also, reasoner shows no errors.
Completeness	Yes, it is complete based on specifications determined in the design phase of the ontology.
Accuracy	Yes, the activity of interviewing experts has been conducted. And experts participate in the ontology construction process.
Conciseness	Yes, the ontology is concise since does not contain any unnecessary concepts.
Expandability	Yes, it is easily expanded since there is no need to make big changes in a set of well-defined definitions when adding new definitions.
Sensitiveness	The ontology is not sensitive since small changes in definition will not alter a set of well-defined contents.

2) Competency questions evaluation

The competency questions for determining the scope and designing purposes of UAV FC systems SRE ontology are used here for the evaluation. Each competency question is answered and justified based on the UAV FC systems SRE ontology components. Answers and justifications are shown in Table III. Competency questions ensure that the ontology implementation fulfills the scope of UAV FC systems SRE ontology.

TABLE III
COMPETENCY QUESTION ANSWERS AND JUSTIFICATIONS

CQ#	CQ	Justification
CQ1	Why build a UAV FC systems SRE ontology?	Engineering experience has shown that the avionics systems software usually has the characteristics of complex structure, wide function coverage, high reliability and high safety. These characteristics have led to the increasing scale and complexity of software systems, and the increasing variety of research & development (R&D) personnel. This further intensify the knowledge-intensive trend of software development, make the software requirements elicitation activities more complicated, and also cause the issues of ambiguity, incompleteness, and inconsistency. An ontology is an explicit specification of a conceptualization. Therefore, introducing the ontology method into the SRE process is an effective way to solve the above problems. By adopting this ontology method, the requirement knowledge is expressed as the ontology concept and association; therefore, it is clear, complete, and consistent and is conducive to the sharing and reuse of knowledge. In addition, it greatly promotes the quality of UAV FC systems SRE and SRSs.
CQ2	Who needs this ontology?	The stakeholders, including system analysts/software developers, customers/users and domain experts, all need this ontology. The purpose of an ontology is to use domain

		analysis and experience to model domain knowledge as a shareable knowledge framework to help stakeholders understand the application domain and define requirements. Under this framework, system analysts and software developers can understand the requirements accurately, and the heterogeneity brought about by multiple viewpoints and paradigms can be minimized. Moreover, the implementation of a higher quality UAV FC systems SRE activity based on this ontology benefits the development of UAV FC systems software and the entire system, helps to obtain products with fewer defects and higher quality, and enables developers to shorten the development cycle and reduce costs in a highly competitive market. Meanwhile, because the domain knowledge possessed by customers, users, and domain experts plays an important role in high-quality SRE, this ontology can help them accurately express requirements that developers can understand in accordance with software development guidelines and improve system development quality and efficiency.
CQ3	Who is responsible for managing and maintaining this ontology?	This ontology exists as a part of UAV FC systems software and system development. Software and system developers are responsible for the management and maintenance of ontologies. In addition, there is a dedicated team in the development team responsible for the initial ontology development and subsequent ontology management and maintenance.
CQ4	What are the main contents in this ontology?	Contents include the GO, DO, and AO level ontology-related concepts, properties, hierarchies, and relationships. These are specifically based on: 1) the UAV FC systems software-related concepts and relationships, 2) the SREP-related concepts and relationships.
CQ5	When is this ontology needed?	This ontology is needed when developing the same or similar UAV FC software system, which can realize the sharing and reuse of the ontology.
CQ6	How is this ontology managed and maintained?	A dedicated team is responsible for the management and maintenance of the ontology. According to actual usage and user feedback, the ontology is continuously updated, including adding new necessary content and deleting outdated content. In addition, logs are used to record the management and maintenance process.

2 Ontology verification

1) Ontology taxonomy evaluation

The taxonomy evaluation method is used for checking the taxonomy of the ontology based on main criteria mentioned in [34]. These criteria and their compatibility to UAV FC systems SRE ontology are shown in Table IV.

TABLE IV
ONTOLOGY TAXONOMY EVALUATION

Criteria		Satisfaction
Inconsistency	Circularity errors	No error, reasoner shows no errors
	Partition errors	No error, reasoner shows no errors
	Semantic errors	No error, reasoner shows no errors
Incompleteness	Incomplete concept classification	No error, all concepts of the knowledge specified in the design phase are included.
	Partition errors	No error, because all the instances of the base classes belong to the sub classes.
Redundancy	Grammatical redundancy	No error, each class has only one definition.
	Identical formal definition of some classes	No error, there is no two classes with the same definition.
	Identical formal definition of some instances	No error, in domain ontology there are no instances

2)Improved FOCA evaluation

- FOCA method and its shortcomings

FOCA is a method that can be used for evaluating the quality of an ontology. FOCA includes determining the type of ontology, a questionnaire to evaluate the components, a framework to follow, and a statistical model that calculates the quality of the ontology. FOCA goes through three verification steps, as shown in Fig. 8. [7]. Ontology type verification defines two types of ontology: a domain or task ontology and an application ontology. Questions verification possesses questions to serve the goals. Quality verification calculates the ontology quality.

The real world is a complex network system, and an ontology is the result of modeling the real world. Therefore, the ontology can also be regarded as a complex network. It is an abstract network model of the real world; however, for the purpose of knowledge sharing and reuse, the network is expressed as a specific network structure using semantic standards such as RDF / OWL and other languages. Newman, a famous scholar of complex networks, argued that modularity should be one of the basic characteristics of

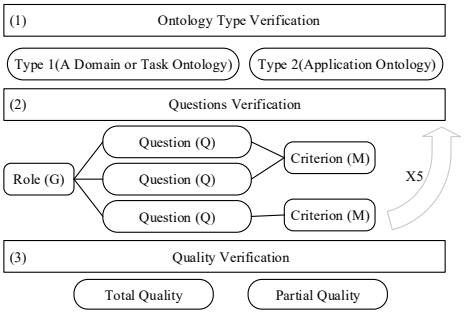

Fig. 8. FOCA method

complex networks [35]. Therefore, the evaluation of ontology quality should also consider ontology modularity. The notion of an ontology module relates to the design of ontology composed of well-defined components that can be managed and reused independently. An ontology module is used to reduce ontology complexity and to increase understandability, testability, maintainability, and reliability. The FOCA evaluation criteria do not include a quantitative evaluation of ontology modularity. This paper adds the quantitative indicators reflecting the degree of ontology modularization to the FOCA to evaluate the ontology quality.

- Ontology module and directed acyclic graph

An ontology module is a collection of the closely related concepts, relationships, and axioms reflecting a common theme. The ontology module is divided or extracted from an original ontology and is part of the original ontology (a sub-ontology) [8]. The sub-ontology needs to meet certain indicators or conditions to satisfy specific applications. The modularization of an ontology helps reduce complexity and enhances comprehensibility, testability, maintainability, and reliability. The structure of an ontology module is consistent with the structure of a software module in the software engineering and should meet the principle of "high cohesion, low coupling".

Ontology classes are arranged in a hierarchy from the general (high in the hierarchy) to the specific (low in the hierarchy). Despite the hierarchical organisation, most ontologies are not simple trees. Rather, they are structured as directed acyclic graphs (DAGs). This is because it is possible for classes to have multiple parents in the classification hierarchy, and furthermore ontologies include additional types of relationships between entities other than hierarchical classification (which itself is represented by is_a relations). All relations are directed and care must be taken by the ontology editors to ensure that the overall structure of the ontology does not contain cycles, as illustrated in Fig. 9. [37].

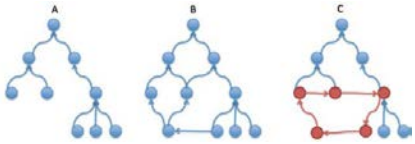

Fig. 9. (A) simple hierarchical tree, (B) DAG, (C) graph that contains a cycle, indicated in red.

● Cohesion and coupling of ontology

Cohesion and coupling are two important indicators to reflect the ontology modularity. Therefore, this paper selects these two indicators to reflect the ontology modularity, and then takes them as an aspect of ontology quality evaluation. The structure of an ontology is consistent with object-oriented structure and should also meet the principle of "high cohesion, low coupling". The cohesion describes the degree to which multiple concepts are combined into one module. It reflects the closeness of concepts. The higher the cohesion of an ontology module is, the closer relationship between the concepts and the more similar semantics of the concepts in the ontology module. This benefits the understanding, reuse, and maintenance of an ontology. Ontology module coupling can be regarded as the degree of correlation between ontology modules. The classes in one module are closely related to the classes in other modules, then the first ontology module has a high coupling value. The stronger the ontology module coupling is, the harder to understand, change, and correct the ontology. And it increases the complexity of the systems using the ontology.

In short, the cohesion reflects the closeness of the relationship between the concepts in an ontology module, and the coupling reflects the closeness of the connection between the ontology modules. Both reflect the characteristics of ontology structure and semantics, and should also be fully considered during the ontology quality evaluation and added to the FOCA method to achieve its improvement.

● Evaluation metrics of cohesion and coupling

In this paper, the metrics of cohesion Coh [8], and AOC [38], and the metrics of coupling NSHR [8], and NSNR [8] are used.

❖ Coh (M) is the ratio of the sum of the strength of relation to the number of all possible relations in a module M.

$$Coh(M)=\begin{cases}\sum_{c_i\in M}\sum_{c_j\in M}\dfrac{sr(c_i,c_j)}{\frac{|M|(|M|-1)}{2}} & if\ |M|>1\\ 1 & otherwise\end{cases} \quad (1)$$

$$sr(c_i,c_j)=\begin{cases}\dfrac{1}{distance(c_i,c_j)} & if\ \text{relations exist between } c_i \text{ and } c_j\\ 0 & otherwise\end{cases} \quad (2)$$

where,

distance (c_i,c_j) = a minimal path length between c_i and c_j. For class $c_i \in M$, $c_j \in M$, M: Module, | |: cardinality. If there is no concept in M, then Coh(M)=0. If there is only one concept in M, Coh(M)=1 because this concept does not depend on any other concept, and it is the closest structure. The range of Coh(M) is [0, 1] because the largest relation number in a DAG is the number of edges of the full connected graph.

❖ AOC is the original ontology cohesion.

$$AOC=\frac{\sum_{i=1}^{n}Coh(M_i)}{n} \quad (3)$$

where,

n is the number of modules partitioned by the original ontology, and Coh(M_i) is the cohesion of the ontology module M_i.

❖ An ontology has two types of relationships: hierarchical relationships and non-hierarchical relationships. The hierarchical relationships are stronger than other relationships, because the classes associated through the hierarchical relationships share and inherit more information between classes. This paper measures the coupling based on NSHR and NSNR. Using the proposed ontology coupling metrics, the consistency between modules and their original ontology should be considered. To be consistent with the original ontology, modules should preserve the classes and axioms of their original ontology. Thus, an ontology should be modularized to lessen the number of disconnected relations.

NSHR is the ratio of the number of hierarchical relations that are disconnected after modularization to the total number of relations. More disconnected hierarchical relations mean that more information about the hierarchical relation is lost. NSHR can be formulated as follows:

$$NSHR(M)=\sum_{c_i\in M}\sum_{c_j\in O-M}nshr(c_i,c_j) \quad (4)$$

O is the original ontology, M is the module, and – is the difference operation. nshr(c_i, c_j) is the number of hierarchical relations between c_i and c_j that is disconnected after modularization.

NSNR is the ratio of the number of disconnected non-hierarchical relations to the total number of relations after ontology modularization. NSNR can be formulated as follows:

$$NSNR(M)=\sum_{c_i\in M}\sum_{c_j\in O-M}nsnr(c_i,c_j) \quad (5)$$

O is the original ontology, M is the module, and – is the difference operation. nsnr(c_i, c_j) is the number of non-hierarchical relations between c_i and c_j that is disconnected after modularization.

In the following example, an original ontology O (a UAV FC systems SRE ontology) is partitioned into five modules, M1, M2, M3, M4, and M5, as shown in Fig. 10. This figure explicitly shows the disconnected relations between modules for explanation.

❖ r_{NSHR} (M) is the ratio of the NSHR of ontology module M to the total number of hierarchical relationships in the corresponding part of original ontology. The calculation formula is as follows:

$$r_{NSHR}(M)=\frac{NSHR(M)}{K} \quad (6)$$

where,

K is the total number of hierarchical relationships in the corresponding part of original ontology.

r_{NSNR} (M) is the ratio of the NSNR of ontology module M to the total number of non-hierarchical relationships in the

corresponding part of original ontology. The calculation formula is as follows:

$$r_{NSNR}(M) = \frac{NSNR(M)}{L} \quad (7)$$

where,

L is the total number of non-hierarchical relationships in the corresponding part of original ontology.

❖ $Aver_{r_{NSHR}}$ represents the average value of $r_{NSHR}(M_i)$ of all ontology modules after the division of original ontology.

$Aver_{r_{NSNR}}$ represents the average value of $r_{NSNR}(M_i)$ of all ontology modules after the division of original ontology.

The calculation formula is as follows:

$$Aver_{r_{NSHR}} = \frac{r_{NSHR}(M_i)}{n} \quad (8)$$

$$Aver_{r_{NSNR}} = \frac{r_{NSNR}(M_i)}{n} \quad (9)$$

where,

n is the number of modules after the division of original ontology.

❖ $S_{coupling}$ is the comprehensive coupling value of a module.

The calculation formula is as follows:

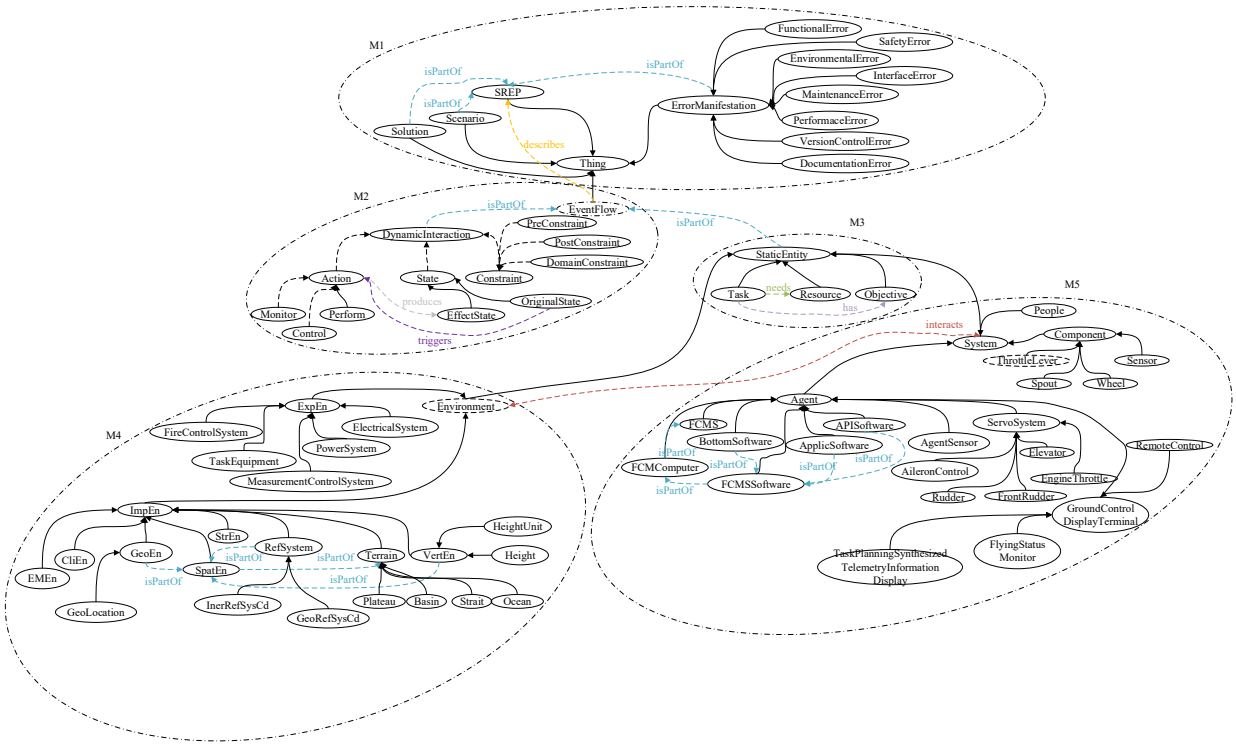

Fig. 10. Ontology modules M1~M5

$$S_{coupling} = \alpha * Aver_{r_{NSHR}} + \beta * Aver_{r_{NSNR}} \quad (10)$$

where,

α represents the weight of $Aver_{r_{NSHR}}$, β represents the weight of $Aver_{r_{NSNR}}$, $\alpha + \beta = 1$. This paper argues that the importance of hierarchical relationships is greater than that of non-hierarchical relationships. Generally speaking, $\alpha > \beta$. The values of α and β can be set according to experience.

● Calculation of values of cohesion and coupling

In this paper, the values of cohesion and coupling are calculated based on the ontology module division shown in Fig. 10.

❖ Calculation of cohesion value

Using (1) for M1 to M5, Coh(M1)=0.14, Coh(M2)=0.23, Coh(M3)=0.83, Coh(M4)=0.14, Coh(M5)=0.14. Substituting these values into (3), AOC=0.296. It should be noted that the AOC value is low, indicating that the relationship between the concepts in the ontology is not very close. The main reason for the above results is that the hierarchical structure of the conceptual classes in the ontology is not sufficiently complete; meanwhile, there are limited connections between the concepts other than the hierarchical relationships.

❖ Calculation of coupling value

Using (4) to (9) in turn for M1 to M5, the values of NSHR, NSNR, $r_{NSHR}(M)$, $r_{NSNR}(M)$, $Aver_{r_{NSHR}}$, and $Aver_{r_{NSNR}}$ of each module can be obtained as Table V. Let α =0.7, β =0.3, Substituting the values of $Aver_{r_{NSHR}}$ and $Aver_{r_{NSNR}}$ into (10), $S_{coupling}$=0.1706. According to experience, this value is less than 0.2, indicating that the coupling is not high, and the consistency between the ontology modules and the original ontology is good. This also shows that the correlation between ontology modules is not high, and the connection is loose. The concepts of each module focus on its own theme; therefore, it is easier to understand and reuse the ontology module.

TABLE V
COUPLING METRICS FOR M1 TO M5

No.	NSHR	$r_{NSHR}(M)$	NSNR	$r_{NSNR}(M)$
M1	1	0.077	1	0.25
M2	1	0.083	2	0.4
M3	2	0.4	1	0.33
M4	1	0.04	1	0.2
M5	1	0.04	1	0.17

$Aver_{r_{NSHR}}$	0.128	$Aver_{r_{NSNR}}$	0.27

● Improved FOCA evaluation method

This paper uses the improved FOCA to evaluate the ontology quality.

❖ Ontology type verification

FOCA defines two types of ontology, a domain or task ontology and an application ontology. The UAV FC systems SRE ontology is an AO (type 2); therefore, a type 2 ontology should answer Q4 instead of Q5 for Goal 2 shown in Table VI.

❖ Questions verification

When a cohesion metric and a coupling metric are added, it needs to answer the 13 questions in Table VI (should answer Q4 instead of Q5). These answers should then be scored by the evaluator. The set of questions corresponding to Goal 2 is expanded by adding two questions of **"Was the ontology cohesion metric value acquired?"** and **"Was the ontology coupling metric value acquired?"** The scores partly refer to the experimental data in [38]. The cohesion metric values and corresponding scores are shown in Table VII. The coupling metric values and corresponding scores are shown in Table VIII. These 13 questions serve five goals. The goal/question/metric (GQM) approach for the improved FOCA is shown in Table VI.

TABLE VI
GQM FOR IMPROVED FOCA

Goal	Question		Metric
1.Check if the ontology complies with Substitute.	Q1.Were the competency questions defined?	Does the document define the ontology objective? Does the document define the ontology stakeholders? Does the document define the use of scenarios?	Completeness
	Q2.Were the competency questions answered?		Completeness
	Q3.Did the ontology reuse other ontologies?		Adaptability
2.Check if the ontology complies Ontological Commitments.	Q4.Did the ontology impose a minimal ontological commitment?（application ontology）		Conciseness
	Q5.Did the ontology impose a maximum ontological commitment?（domain/task ontology）		Conciseness
	Q6.Are the ontology properties coherent with the domain?		Consistency
	Q7.Was the ontology cohesion metric value acquired?		**Cohesion**
	Q8.Was the ontology coupling metric value acquired?		**Coupling**
3.Check if the ontology complies with Intelligent Reasoning.	Q9.Are there contradictory axioms?		Consistency
	Q10.Are there redundant axioms?		Conciseness
4.Check if the ontology complies Efficient Computation.	Q11.Did the reasoner bring modelling errors?		Computational efficiency
	Q12.Did the reasoner perform quickly?		Computational efficiency
5.Check if the ontology complies with Human Expression.	Q13.Is the documentation consistent with modelling?	Are the written terms in the documentation the same as the modelling? Does the documentation explain what each term is and does it justify each detail of modelling?	Clarity
	Q14.Were the concepts well written?		Clarity
	Q15.Are there annotations in the ontology that show the definitions of the concepts?		Clarity

TABLE VII
COHESION METRICS VALUES AND CORRESPONDING SCORES

M	M<0.25	0.25≤M<0.5	0.5≤M<0.75	0.75≤M<1
score	25	50	75	100

TABLE VIII
COMPREHENSIVE COUPLING METRICS VALUES AND CORRESPONDING SCORES

N	N<0.25	0.25≤N<0.5	0.5≤N<0.75	0.75≤N<1
score	100	75	50	25

❖ Quality verification

Ontology quality can be calculated in two ways: total quality and partial quality. This paper uses the total quality verification because most goals are considered in the evaluation. Total quality verification is calculated using beta regression models, proposed by Ferrari [39], and shown in (11).

$$\hat{\mu}_i = \frac{\exp\{-0.44+0.03(Cov_S \times Sb)_i + 0.02(Cov_C \times Co)_i + 0.01(Cov_R \times \mathrm{Re})_i + 0.02(Cov_{Cp} \times Cp)_i - 0.66LExp_i - 25(0.1 \times Nl)_i\}}{1+\exp\{-0.44+0.03(Cov_S \times Sb)_i + 0.02(Cov_C \times Co)_i + 0.01(Cov_R \times \mathrm{Re})_i + 0.02(Cov_{Cp} \times Cp)_i - 0.66LExp_i - 25(0.1 \times Nl)_i\}} \quad (11)$$

where,

Cov_S is the mean of the grades from Goal 1;

Cov_C is the mean of the grades from Goal 2;

Cov_R is the mean of the grades from Goal 3;

Cov_{Cp} is the mean of the grades from Goal 4;

LExp is the variable for evaluator experience, with 1 being very experienced and 0 being not experienced at all;

Nl is 1 only if some Goal is impossible for the evaluator to answer all the questions;

Sb=1, Co=1, Re=1, Cp=1, because the total quality considers all the roles.

By Substituting these values into (11), the following result is obtained,

$$\hat{\mu}_i = \frac{\exp\{-0.44+0.03\times(100\times1)+0.02\times(87.5\times1)+0.01\times(100\times1)+0.02\times(87.5\times1)-0.66\times1-25\times(0.1\times1)\}}{1+\exp\{-0.44+0.03\times(100\times1)+0.02\times(87.5\times1)+0.01\times(100\times1)+0.02\times(87.5\times1)-0.66\times1-25\times(0.1\times1)\}} = 0.9802$$

The total quality of the ontology is 0.9802, which is near to 1. This shows the high quality of the UAV FC systems SRE ontology.

V. RKMOF-BASED REQUIREMENTS ELICITATION APPROACH

In addition to the basic knowledge required for the SRE, the avionics systems RKMOF established in this paper also contains the SREP knowledge, which greatly enriches the prior information of SRE; therefore, the knowledge is relatively complete. The ontology quality evaluation result

shows that the UAV FC systems SRE ontology has high quality.

Fig. 11. shows the schematic diagram of the ontology-based SRE method. It can be seen that each main step of elicitation process has two branches: If there is no existing ontology, an ontology is first established; if there is an existing ontology, it is reused and tailored / expanded according to actual needs. By building ontologies layer-by-layer, the corresponding concepts and relationships are obtained. A DRM can be obtained through the domain analysis on a DO and an ARM can be obtained through the application analysis on the DRM and an AO. The following are the specific steps of the ontology-based SRE method.

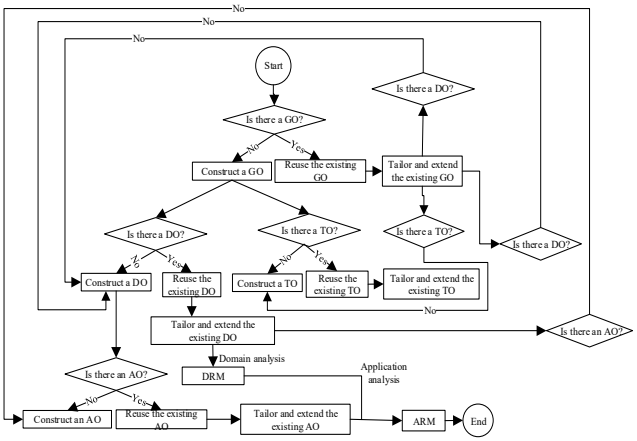

Fig. 11. Schematic diagram of SRE method based on multi-ontology

A. Preliminary stage

The accumulation of experience is crucial to the ontology-based SRE method. Therefore, before formal SRE, it is necessary for testers and domain experts to jointly build a SREP library as shown in Fig. 12.

Preliminary stage
Construct a SREP library
1) Collect and summarize SREPs based on developing and testing experience;
2) Use ontology language to represent the SREPs and store them in the library.

Fig. 12. Specific steps of preliminary stage

B. Implementation stage

Fig. 13 shows the specific steps of implementation stage of the ontology-based SRE method.

The steps 1 to 10 in Fig. 13 are introduced earlier; however, it is insufficient for the actual application to build an AO only, because its granularity cannot satisfy the requirements of application software specification, and is indirect. Unified modeling language (UML) has been widely used and has become a standard. Therefore, UML class diagrams, use case diagrams and activity diagrams are used in this paper to assist AO modeling and application requirements eliciting to obtain detailed application software specification.

1 Application of class diagrams

An AO can be constructed by eliciting and classifying the concepts and relationships in an application domain. Because an AO reflects the static knowledge of a system, the UML class diagrams can be used in the process of AO construction. Fig. 14. shows a portion of concept classes (hierarchies) of the UAV FC systems SRE ontology.

2 Application of use case diagrams

An ARM can be established based on a DRM and an AO. Because an ARM reflects the dynamic knowledge of a system, the UML use case diagrams and activity diagrams can be used in the process of ARM construction. The specific steps are:

1) Determine the boundaries of use cases;
2) Determine scenarios, including: preconditions, postconditions and steps;
3) Use the use case diagrams and activity diagrams to represent the use cases.

The use case diagrams reflect the system functions that users can observe; therefore, they are relatively stable. An example of a use case diagram is shown in Fig. 15.

3 Application of activity diagrams

The activity diagrams can be used to model the workflow between different components, and describe the conditions of use cases and system states; therefore, they are variable. An example of an activity diagram is shown in Fig. 16.

As shown in Fig. 16, an alternative path is represented by a diamond. The activity diagrams can represent parallel expressions; therefore, the same actions and control flows can be represented in the RETOs. The RETOs describe the objectives, inference steps and control flows of requirements elicitation activities. Therefore, the activity diagrams can be transformed into the RETOs. UAV FC systems software communication link interruption processing RETO is shown in Fig. 17.

Implementation stage
1 Identify the objectives and boundaries of a system;
2 Construct a GO;
3 Collect user needs and expectations;
4 Identify concepts and relationships by requirements analysts:
1) Familiar with a domain;
2) Based on the GO, collect and classify domain concepts and relationships from domain experts and users according to mapping relationships;
3) Complement and optimize domain knowledge according to the existing documents, industry standards and software systems;
5 Create a TO by the domain experts:
1) Identify the objectives and inputs/outputs a PSM achieves;
2) Describe inference steps, the control structure between the inference steps, the data flow and knowledge flow between the inference steps;
3) Establish a TO requirements library, including the static domain knowledge required by the PSM and the dynamic knowledge that constitutes the inference steps;
6 Construct a DO by the domain experts and the requirements analysts;
7 Construct a DRM based on the TO and the DO;
8 Refine initial requirements:
1) Detect requirements missing errors and feasibility errors;
2) Add the missing requirements items;
3) Remove the unrealistic contents according to the feasibility errors;
9 Create an AO:
Based on the GO and the DO, collect and classify application domain concepts and relationships according to mapping relationships. Unified modeling language (UML) class diagrams can be used in the AO construction process;
10 Evaluate the quality of the AO;
11 Based on the DRM and the AO, establish an ARM. Use cases can be used in the above process;
12 Determine the priority of the requirements items;
13 Write requirements specification;
14 Verify application requirements.

Fig. 13. Specific steps of implementation stage

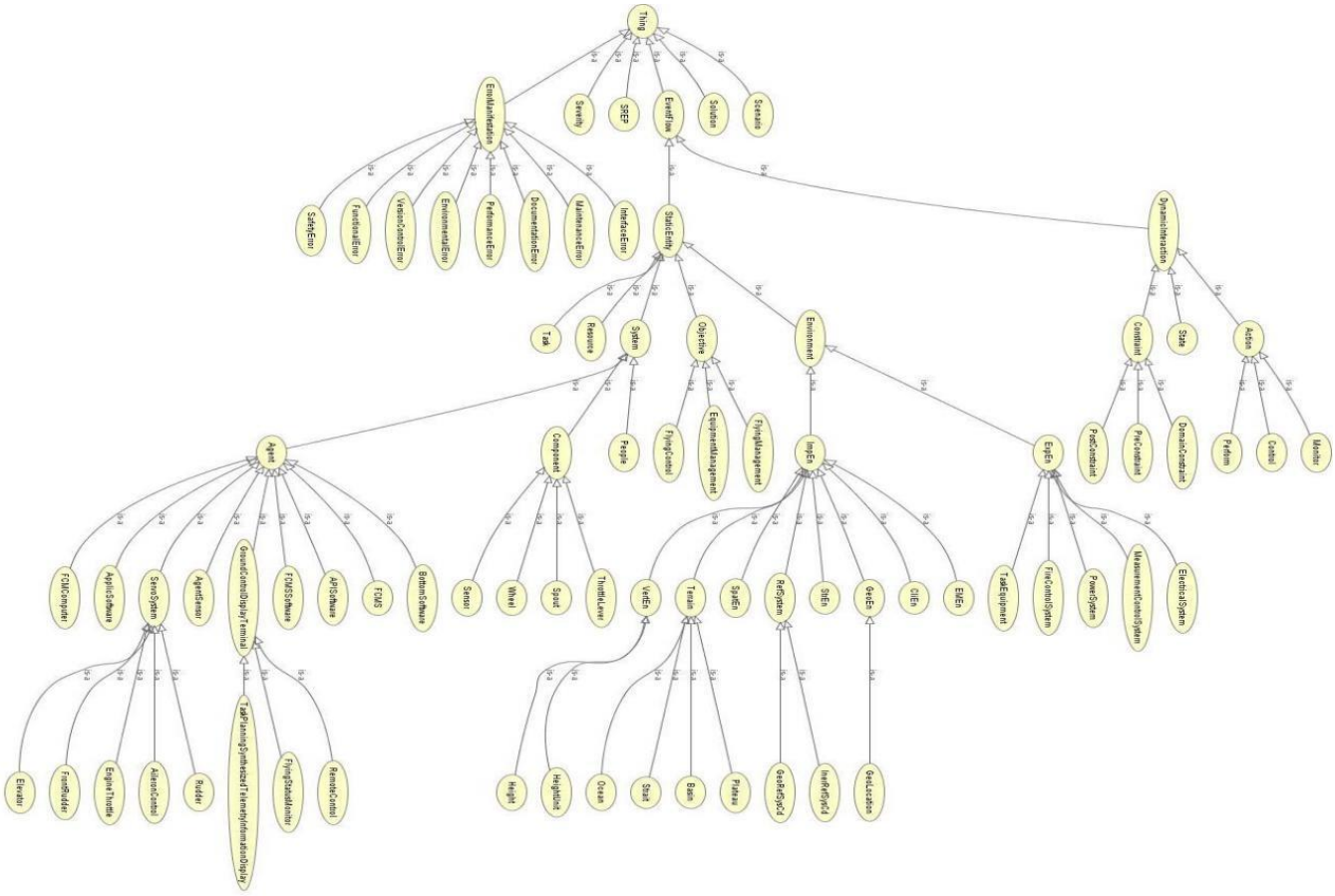

Fig. 14. Portion of concept classes (hierarchies) of UAV FC systems SRE ontology

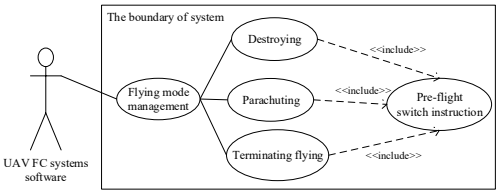

Fig. 15. Example of use case diagram of UAV FC systems software

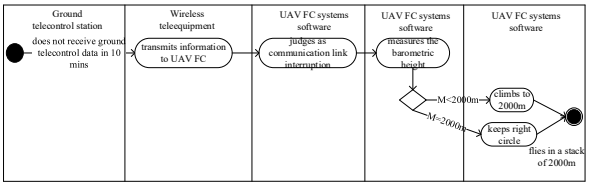

Fig. 16. Example of activity diagram of UAV FC systems software

```
Ontology name: RETO
Type: TO
{ID: (omitted)
Requirement-Elicitation Task: = <Task ID, (A UAV is in flight) && (Wireless teleequipment does not
receive ground telecontrol data in 10 mins)>
Requirement-Elicitation Task-PSM: = < Competence, Operational specification, Requirements >
Competence: = <(UAV FC systems software judges the system to be communication link interruption.) && (The
UAV outputs the height and attitude information in normal condition.) && (The UAV obtains the sequence of
actions of UAV FC system in corresponding condition.)>
Operational specification: = < Inference Steps and Control Flow between the Inference Steps:
{
If (Wireless teleequipment does not receive ground telecontrol data in 10 mins to cause)
UAV FC systems software judges the system to be communication link interruption,
UAV FC systems software determines the state of UAV,
If (barometric height<2000m)
UAV FC systems software determines the height of climbing,
Else
UAV FC systems software determines to hold UAV flying in a stack && keep right circle,
Return this requirements item
}
Requirements: = < Concepts∈DomConcepts, Relations∈DomRelations, Rules∈Domrule >
Requirement-Elicitation Taskmap: {(Requirement-Elicitation Task Concepts∈DomConcepts)      Concepts}
}
```

Fig. 17. UAV FC systems software communication link interruption processing RETO

4 Application of SREP

The use of several types of UML diagrams in normal scenarios are introduced earlier; however, abnormal scenarios also affect systems in practical applications. Since an SREP library is constructed in the preliminary stage, which contains many historical error data; therefore, the SREP can be used to study the SRE in abnormal scenarios.

1) Map an SREP from the GO layer to the AO layer.

Putting the SREP in the GO layer is too abstract to use; therefore, it is necessary to map it to the AO layer. The specific steps are based on the inverse mapping of Appmappings in the AO definition.

2) Generate the use cases corresponding to the non-functional requirements in abnormal scenarios based on the SREP.

The following takes the safety requirements of non-functional requirements as an example to illustrate the steps of use cases development:

- Step a): The concerns of software requirements are divided into general concerns and cross-cutting concerns. This paper treats functional requirements as the general concerns and the non-functional requirements as the cross-cutting concerns.
- Step b): All cross-cutting concerns called by each general concern are confirmed.
- Step c): UML use case modeling technology is used to obtain the functional requirements according to the step 2) in 2. This paper uses Rational Rose, a UML modeling tool, to describe the use cases based on the scenarios, including the preconditions, the postconditions, and the steps. Then, the scenarios are further divided into the general scenarios corresponding to the functional requirements and the cross-cutting scenarios corresponding to the non-functional requirements (the safety requirements).

A scenario in an activity diagram is defined as:

Definition 12 A scenario in an activity diagram is a sequence of events describing agent actions, the changes in the state of environment, and the interactions between the agents and the environment.

The description template of a scenario segment is shown in Fig. 18.

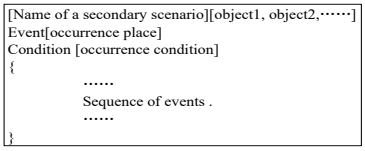

Fig. 18. Description template of scenario segment

- Step d): Rational Rose is used to build the cross-cutting scenarios, and further generate a set of cross-cutting use cases based on the SREP library.
- Step e) The step b) is executed iteratively, and the cross-cutting use cases corresponding to the cross-cutting concerns called by each general concern are integrated into the general scenario corresponding to the functional requirements in turn according to the calling relationships.

An example of use case development is shown in Fig. 19. according to the Step a) to e).

VI. CASE STUDIES

In this paper, a part of a UAV FC system is selected for ontology modeling. The effectiveness of the ontology-based SRE method is verified by a comparative experiment. Since several continuous versions of the software are developed after the ontology modeling, the research selects two continuous versions of the software and adopts a conventional method for the requirements elicitation of a version 3.3.x; after a defined period, the requirements of a version 3.3.(x+1) are elicited based on the ontology-based method this paper proposes. Table IX records the detected SREP error-manifestations and number distributions of these two SRSs by a requirement inspection. The same group of inspectors is used to conduct the comparative experiment. SRS I is developed based on the conventional method, and SRS II is developed based on the ontology-based method proposed in this paper.

The results that the total number of errors in SRS I is much higher than in SRS II. In addition, the severity of the errors detected in SRS I is higher, and they occur in more significant error types such as functional errors, interface errors, safety errors, and environmental errors. The direct cause of the above results can be initially identified as SRS II using the ontology-based method; SRS I uses the conventional method.

Intuitively, because the ontology is a complete set of domain knowledge, the quality information of SRS can be obtained indirectly by considering the correspondence between the SRS and ontology element. This paper evaluated the quality of SRS based on the metrics in [40]. The quality metric results of the SRS I and SRS II are shown in Table X.

TABLE IX
SREP ERROR-MANIFESTATIONS AND NUMBER DISTRIBUTIONS

Error-manifestations	SRS I				SRS II			
	C	I	A	T_t	C	I	A	T_t
Functional errors	4	1	1	6	0	1	1	2
Performance errors	0	0	1	1	0	0	1	1
Interface errors	3	6	0	9	1	2	0	3
Safety errors	4	1	0	5	1	0	0	1
Environmental errors	2	2	0	4	0	0	0	0
Maintenance errors	0	1	1	2	0	0	2	2
Documentation errors	0	3	4	7	0	2	4	6
T_s	13	14	7	-	2	5	8	-
T	34				15			

Notes: C—"critical", I—"important", A—"average". T_t—"total number of errors in each type", T_s—"total number of errors in each severity", T—"total number of errors".

TABLE X
QUALITY METRIC RESULTS OF SRS I AND SRS II

Metrics	SRS I	SRS II
Correctness	23/29=79.3%	28/29=96.6%

From the results, the difference between SRS I and SRS II in "Correctness" is more obvious. An ontology is a semantic basis for building a specific problem domain. Ideally, all requirements items should be able to find the corresponding elements in the ontology. (the number of items that can be mapped to the ontology / the total number of requirements items) can reflect the proportion of the mapped elements. The higher the ratio is, the higher the SRS quality. This ratio of SRS I to SRS II is significantly lower. This shows that some of the requirements items of SRS I are not included in the ontology library, implying nonconformity with the actual application. This fact also explains the results of the requirement inspection in Table IX. Therefore, the requirement knowledge ontology has a major impact on the entire requirement development process. In general, the quality of the SRS obtained based on the proposed ontology is higher than the quality of the SRS obtained based on the conventional method. Therefore, the ontology elements, i.e., the knowledge elements, should be fully integrated in the early stage of the requirement development process.

VII. CONCLUSION

The RKMOF proposed in this paper fully considered the needs of complete knowledge basis for requirements elicitation activities, adopted various ontologies to reflect all aspects of requirements knowledge, divided and stored knowledge hierarchically, and blended static knowledge with dynamic knowledge to make them a whole. At the same time, the empirical knowledge such as SREP was integrated into RKMOF in a consistent form. The framework is universal and suitable for any avionics system. Based on the framework, the construction of DRMs and ARMs can be further realized to guide requirements elicitation activities to obtain SRSs with fewer defects, thereby improving the quality of SRSs and further improving the reliability of software systems.

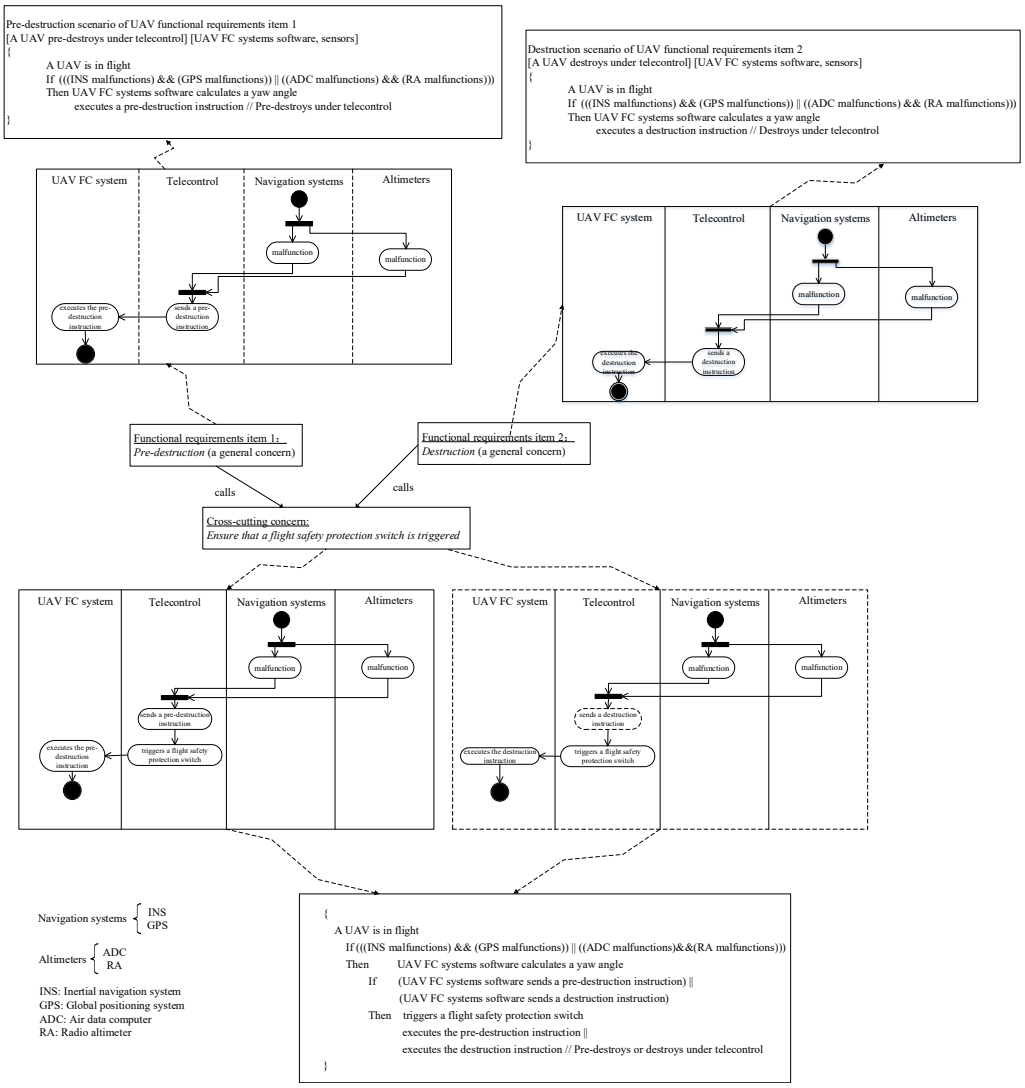

Fig. 19. Example of use case development

REFERENCES

[1] Xuan Hu, "Study on Ontology-based Avionics Systems Requirements Knowledge Model Construction and Software Requirements Elicitation Method," *Ph.D. dissertation, Dept. of reliability and systems engineering, Beihang University*, BeiJing, China, 2009.

[2] Guarino, N., "Formal ontology in information systems," *Proceedings of the first international conference (FOIS'98)*, Trento, Italy, 1998.

[3] Cf. T. R. Gruber, "A translation approach to portable ontologies," *Knowledge Acquisition*, 5(2):199-220, 1993.

[4] Thomas R. Gruber, "Toward Principles for the Design of Ontologies Used for Knowledge Sharing," *International Journal of Human-Computer Studies*, vol. 43, Issues 5-6, pp. 907-928, 1995.

[5] Jinzhi Lu, Guoxin Wang and Martin Törngren, "Design Ontology in a Case Study for Cosimulation in a Model-Based Systems Engineering Tool-Chain," *IEEE Systems Journal*, Early Access, pp. 1-12, June. 2019.

[6] Abeer Abdulaziz Alsanad, Azeddine Chikh, Abdulrahman Mirza, "A domain ontology for software requirements change management in global software development environment," *IEEE ACCESS*, vol 7, pp. 4935249361, Apr. 2019.

[7] Judson Bandeira, Ig Ibert Bittencourt, Patricia Espinheira, Seiji Isotani, "FOCA: A Methodology for Ontology Evaluation," *eprint arXiv:1612.03353*, 2016. 12.

[8] Sunju O., Heon Y Y., Joongho A., "Cohesion and coupling metrics for ontology modules," *Information Technology Management*, vol. 12, no. 1, pp. 81-96, 2011.

[9] LI Zong-yong, WANG Zhi-xue, YANG Ying-ying, WU Yue, LIU Ying, "Towards a Multiple Ontology Framework for Requirements Elicitation and Reuse," *31st Annual International Computer Software and Applications Conference (COMPSAC 2007). IEEE*, 2007.

[10] Z.Jin, "Ontology-based Requirements Elicitation," *Chinese Journal of Computers*, 23(5): pp. 486-492, 2000.

[11] Haruhiko Kaiya, Motoshi Saeki, "Using Domain Ontology as Domain Knowledge for Requirements Elicitation," in *Proceedings of 14th IEEE International Requirements Engineering Conference*, pp. 186-195, 2006.

[12] Farfeleder, S. et al., "Ontology-Driven Guidance for Requirements Elicitation," *ESWC 2011: The Semantic Web: Research and Applications*. pp. 212 - 226, 2011.

[13] Y. Lee and W. Zhao, "An ontology-based Approach for Domain Requirements Elicitation and Analysis," in *Proceedings of the First International Multi-Symposiums on Computer and Computational Sciences*, pp. 364-371, 2006.

[14] A. Gómez-Pérez, M. Fernandez-Lopez, and O. Corcho, "Ontological Engineering with Examples from the Areas of Knowledge Management," *E-commerce and the Semantic Web*. London, U.K.: Springer, 2004.

[15] Sarika Jain, Valerie Meyer, "Evaluation and refinement of emergency situation ontology," *International Journal of Information and Education technology*, vol. 8, no. 10, pp. 713-719, 2018.

[16] D. Vrandecic, "Ontology Evaluation," *Ph.D. dissertation, University of Karlsruhe,* 2010.

[17] J. Pak and L. Zhou, "A framework for ontology evaluation," in *Workshop on E-Business: Springer Berlin/Heidelberg*, 2009, pp. 10-18.

[18] Ravi Lourdusamy, Antony John, "A review on metrics for ontology evaluation," in *Proc. ICISC 2018,* Coimbatore, India, 2018, pp. 1415-1421.

[19] M. Poveda-Villalón, M. C. Suárez-Figueroa, and A. Gómez-Pérez, "Validating ontologies with OOPS!," in *Proc. 18th international conference, EKAW 2012,* Galway City, Ireland, 2012, pp. 267-281.

[20] N. Casellas, "Ontology evaluation through usability measures," in *Proc. OTM'09*, Vilamoura, Portugal, 2009, pp. 594-603.

[21] A. Gangemi, C. Catenacci, M. Ciaramita, and J. Lehmann, "Modelling ontology evaluation and validation," in *Proc. ESWC 2006*, Budva, Montenegro, 2006, pp.140-154.

[22] J. Hartmann, P. Spyns, A. Giboin, D. Maynard, R. Cuel, M. C. Suárez-Figueroa, and Y. Sure, "D1.2.3 Methods for Ontology Evaluation,"

EU-IST Network of Excellence IST-2004-507482 KWEB Deliverable D, vol. 1, 2005.
[23] S. Tartir, I. B. Arpinar, and A. P. Sheth, "Ontological evaluation and validation," in *Theory and Applications of Ontology: Computer Applications*, Springer, Dordrecht, Netherlands, 2010, pp. 115-130.
[24] C. Brewster, H. Alani, S. Dasmahapatra, and Y. Wilks, "Data-driven ontology evaluation," in *Proc. 4th International Conference on Language Resources and Evaluation*, Lisbon, Portugal, 2004.
[25] H. Hlomani and A. D. Stacey, "Contributing evidence to data-driven ontology evaluation: workflow ontologies perspective," in *Proc. 5th International Conference on Knowledge Engineering and Ontology Development*, Vilamoura, Portugal, 2013.
[26] O. Liubo, Z. Beiji, Q. Miaoxing, and Z. Chengming, "A method of ontology evaluation based on coverage, cohesion and coupling," in *Proc. 2011 8th International Conference on FSKD*, Shanghai, China, 2011, pp. 2451-2455.
[27] G. Bilgin, I. Dikmen, and M. TalatBirgonul, "Ontology evaluation: An example of delay analysis," *Procedia Engineering*, vol. 85, pp. 61-68, 2014.
[28] A. Zouaq and R. Nkambou, "Evaluating the generation of domain ontologies in the knowledge puzzle project," *IEEE Transactions on Knowledge and Data Engineering*, vol. 21, no. 11, pp. 1559-1572, Nov. 2009.
[29] Hlomani Hlomani, and Deborah Stacey, "Approaches, methods, metrics, measures, and subjectivity in ontology evaluation: A survey," http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.682.1950&rep=rep1&type=pdf
[30] Maziar Amirhosseini, Juhana Salim, "OntoAbsolute as an ontology evaluation methodology in analysis of the structural domains in upper, middle and lower level ontologies," in *Proc. the 2011 International Conference on Semantic Technology and Information Retrieval*, Putrajaya, Malaysia, 2011, pp. 26-33.
[31] A. Gómez-Pérez, "Ontology evaluation," in Handbook on Ontologies (International Handbooks on Information Systems), S. Staab and R. Studer, Eds. *Berlin, Germany: Springer*, 2004, pp. 251–273.
[32] X.Hu, et al., "Construction and Estimation of Requirement Knowledge Ontology for Avionics Electronics System Software," *Computer Engineering*, 39(2): pp. 56-62, 2013.
[33] X.Hu, et al., "Application of Software Requirement Error Pattern Based on Ontology," *Journal of Beijing University of Aeronautics and Astronautics*, 35(6): pp. 723-727, 2009.
[34] S. Lovrenčić and M. Čubrilo, "Ontology evaluation-comprising verification and validation," in *Proc. the 19th Central European Conference on Information & Intelligent Systems (CECIIS)*, Varaždin, Hrvatska, 2008, pp. 657-663.
[35] Newman M E J., "Detecting community structure in networks," *The European Physical Journal B-Condensed Matter and Complex Systems*, 2004, 38(2): 321-330.
[36] Page-Jones M., "Practical Guide to Structured Systems Design," *New York: Yourdon Press*, 1980.
[37] Christophe Dessimoz, Nives Škunca, "The Gene Ontology Handbook," *Humana Press, Springer*, 2017.
[38] Liao Lili, Shen Guohua, Huang Zhiqiu, Kan Shuanglong, "An approach for ontology cohesion metrics based on directed acyclic graph," *Computer Engineering & Science*, vol. 37, no. 7, pp. 1297-1303, 2015.
[39] Ferrari, S., "Beta regression for modelling rates and proportions," *Journal of Applied Statistics*, vol. 31, no.7, pp. 799-815, 2004.
[40] Hiroya Itoga and Atsushi Ohnishi, "Security Requirements Elicitation via Weaving Scenarios based on Security Evaluation Criteria," *7th International Conference on Quality Software(QSIC 2007)*, IEEE.

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Evaluation of A Mesh Network based on LoRa Technology

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***Abstract*—In the last decade, the Internet of Things (IoT) technologies have brought many applications in different fields. Many communication technologies have been developed to communicate everything to each other and the Internet. Besides, the long-range power-efficient wireless technologies have emerged, such as LoRa (Long Range), which enables transmission over long distances with low energy consumption and can work within p2p, star, or mesh topologies. In this paper, we analyze a model of a mesh network based on the LoRa technology. The model considers various parameters of nodes and communication channels in the network. Based on a simulation model on OMNET++, a series of computer experiments are performed to analyze the delivery latency and packet delivery ratio (PDR) in different cases. According to the analytical results, conclusions are drawn about the possibility of using a LoRa mesh network to expand the network coverage and integrate with other short-range networks.**

***Keyword*—IoT, LoRa, mesh network, routing method, latency, packet delivery ratio**

I. INTRODUCTION

NOWADAYS, info-telecommunication technology is one of the main infrastructures of any country or company. The advent of the Internet has helped change the approach to information. The Internet brings information to users, communicates people to the other, human to machine, and machine to machine. This term is called the Internet of Things (IoT), where every device can communicate over the Internet, as described in [1], [2]. This leads to the expectation of the revolution of Industry 4.0.

The Internet of Things has been attracting many interests in both scientific and commercial fields [3]. Many IoT applications have been developed as Smart Devices, Smart Home, Smart City, Smart Factory. Besides, communication technologies also have contributed greatly to the development of IoT applications. Many technologies have been proposed to ensure the network's quality of connection while the number of connected devices does not stop increasing. Each technology has different characteristics such as data rate, transmission distance, power consumption. Based on those technologies, network models are considered for different requirements. Low Power Wide Area Network (LPWAN) is a networking group, which allows long-range transmission and requires small power consumption [4]. Among LPWANs, LoRa (Long Range) is a promising technology for IoT applications, which do not need high-speed data rate and require energy saving with long-range transmission [5], [6].

Using LoRa as the physical layer, the project LoRaWAN (Long Range Wide Area Network) has been developed widely with a large contribution by LoRa Alliance. In the LoRaWAN, the devices are managed by Gateway or Base Station. In this case, the star topology is used for constructing LoRa Networks. On the other hand, the mesh topology also is considered in different cases. In Wireless Sensor Networks (WSN), for instance, ZigBee, Z-Wave, Bluetooth Low Energy 5.0, devices are connected in the mesh topology, each device can be a router relaying the packet of the other devices to the destination [7], [8]. The highlight difference of LoRa respected to these technologies is the ability of long-range transmission. This advantage can help expand the network model without needing additional base stations.

Smart City is a typical IoT application, where many devices in the city are expected to communicate with each other and send data to the cloud server. For instance, a bus can inform the bus station directly about the destination time. The buses and bus stations communicate in the network and exchange information with each other. The decentralized or mesh topology is applied to manage such applications.

Moreover, the mesh topology also is used in networks such as VANET or FANET. In a search and rescue application, as

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can be seen in [9], [10], the UAVs (unmanned aerial vehicles) are connected to others in a mesh topology. So, the data are transmitted through several UAVs to the destination.

The mesh topology for the LoRa network is a solution to expand the number of connected nodes and the network coverage area. We propose a LoRa-based network model using the mesh topology for these goals in this paper. In this topology, the routing option is an important parameter to ensure the quality of service. While considering the network model, the optimal route selection is found between the nodes based on the link quality. Moreover, we consider the delivery latency in the influence of the load intensity and the number of relay nodes.

The rest of the paper is organized as follows: Section 2 gives an overview of LoRa technology and its related works. Section 3 presents a mesh network model based on LoRa technology and a simulation model to analyze the latency distribution and packet delivery ratio in the network. Obtained analytical results are presented in Section 4. And the conclusion is concluded in Section 5.

II. LoRa Overview

Semtech Corporation is one of the leaders developing wireless chipsets for IoT applications. Since when the company launched the first LoRa chipset, the LoRa technology has been attracting much interest in the development of IoT applications. In 2015, LoRa Alliance was established to develop and support the global network LoRaWAN. It is observed that LoRa has become a promising technology at the moment.

The key parameters used to configure the LoRa radio module are modulation method, frequency range, bandwidth (BW), spreading factor (SF), coding rate (CR), and transmission power [5], [6]. At the LoRa physical layer, a chirp spread spectrum (CSS) modulation method is used, providing an increased channel budget and better noise immunity. In the LoRa network, there are some options to choose the used bandwidth, such as 125, 250, and 500 kHz. The low bandwidths make LoRa resistant to channel noise, long-term relative frequency, Doppler effects, and fading.

Coding rate (CR). A forward error correction technique is used to increase reception sensitivity. The coding rate is denoted as *k/n*, where *k* represents useful information, the encoder generates *n* output bits, i.e. *n-k* will be redundant bits. Redundancy allows the receiver to detect and correct errors in messages, as well as reduces data rate. There are coding rates such as 4/5, 4/6, 4/7, or 4/8 used in the LoRa network.

Spreading factor (SF). In the LoRa technology there are several spreading factors from 7 to 12 used to expand the transmitted bits. The SF parameter defines two values: the number of source bits that can be encoded for one symbol, and each symbol can contain 2^{SF} chips. With a higher spreading factor, the data rate is lower, and vice versa. Each symbol is spreading in the length of 2^{SF} chips, i.e. 2^{SF} chips are required to expand one symbol. The method of replacing one symbol with several elements of information shows the influence of the spreading factor on the transmission speed. Therefore, if the value of SF increases, then the data rate decreases.

Bandwidth (BW). There are different values such as 125, 250, or 500 kHz used to configure LoRa radio models. Data are propagated at a chip frequency equal to the throughput in chips per second. Hence, 125 kHz corresponds to a chip speed of 125 kilo-chips per second.

The combination of between SF, BW, and CR determines the data rate as (1):

$$\mathrm{DR} = \mathrm{SF} \times \frac{\mathrm{BW}}{2^{\mathrm{SF}}} \times \mathrm{CR} \tag{1}$$

$$\text{where} \begin{cases} \mathrm{SF} = \{7,8,9,10\}; \\ \mathrm{BW} = \{125,250,500\}, \text{кГц}; \\ \mathrm{CR} = \{4/5,4/6,4/7,4/8\}. \end{cases}$$

The high BW increases the DR, but it decreases the decoding sensitivity. The high SF increases the decoding sensitivity but decreases the DR. Therefore, with the low BW, and high SF, the decoding sensitivity and transmission distance are increased, but the DR will be decreased. Depending on the application requirements, this combination of parameters can be configured.

Studies on LoRa technology get much attention from the physical layer to the application deployment. In recent years, research and development based on LoRa have gained many prospects. In the context of Smart Cities, there are several LoRa-based applications, such as for waste management [11], water quality monitoring [12], or street lighting.

Since LoRa has high sensitivity, tracking, or positioning solutions were proposed in [13], [14]. It can be seen that the applicability of LoRa is used for many IoT applications. It is relevant to discover the other possibility of LoRa technology. Almost LoRa-based applications are deployed in cases required to transmit on long-distance and save energy consumption. According to different requirements, the parameters can be set up in the LoRa network.

Thus, to use the LoRa's advantages, a mesh topology model is analyzed for LoRa networks in the next sections.

III. Analytical Model

A. Network Model

In a mesh topology model, a network can be presented as a connected graph. For instance, as shown in Figure 1, the network includes device nodes and gateways connected in a graph. The device node can be either the end-device or relay node, via which the data are relayed. The data received by the relay node will be forwarded to the next node according to the optimal route to the destination.

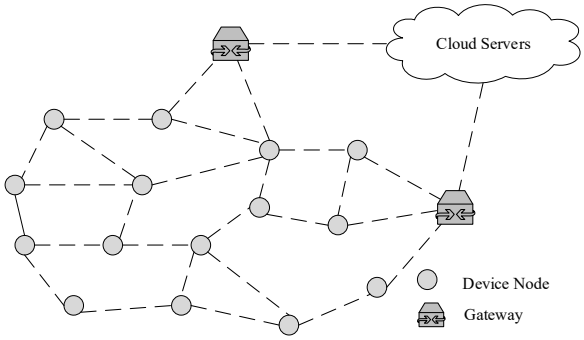


Figure 1. Network model

As shown in Figure 1, the mesh network model can be described by a Graph $G(V,E)$ with a set of Vertices – V, and a set of Edges – E. The set of vertices $V=\{v_i\}, i=1\ldots n$, which represents the set of device nodes in the network. The set of edges $E=\{e_{ij}\}, j=1\ldots n$, which represents the set of communication links between the nodes in the network. Each node has a maximum communication radius R; the nodes can communicate with the others within this distance. If the coordinates of a node are described as (x_i, y_i), the distance between 2 nodes i and j follows as:

$$d_{\text{ij}}=\sqrt{(x_i-x_j)^2+(y_i-y_j)^2} \tag{2}$$

Hence, there is a communication link between 2 nodes if the distance between them is less than R. It can be illustrated by the following: if $d_{ij}\le R$; $\exists e_{ij}$ and $E=\{e_{ij}\}$ with $i,j=1\ldots n$.

Each edge between vertices is weighted by a set of link costs $\mathbf{C}=\{c_{ij}\}$ with $i,j=1\ldots n$, which represents the possibility of data transmission between two nodes. A low link cost means that this link is more suitable to exchange information.

B. Route selection

In this case, the routing path is calculated to find the optimal route to the destination. The link cost is denoted by the parameter RSSI (Received Signal Strength Indication), which can be considered the signal strength between the transmitter and receiver. The link cost is represented as a dependent function of RSSI:

$$c_{ij}=f(RSSI_{ij}),\ \left|RSSI_{ij}\right|\le threshold \text{ and } i,j=1\ldots n$$

The matrix $\mathbf{C}=\{c_{ij}\}$ with $i,j=1\ldots n,s$ contains the characteristics of all communication links of the network (weights of edges of the graph).

$$\mathbf{C}=\begin{bmatrix} c_{1,1} & c_{1,2} & \cdots & c_{1,n} & c_{1,s} \\ c_{2,1} & c_{2,1} & \cdots & c_{2,n} & c_{2,s} \\ \vdots & \vdots & \ddots & \vdots & \vdots \\ c_{n,1} & c_{n,1} & \cdots & c_{n,n} & c_{n,s} \end{bmatrix}$$

There is a set of possible paths $\Omega=P_{i,s}=\{P_1,P_2,\ldots,P_k\}$ between a node i and a sink node in graph G.

Thus, the total link cost of the path from node i to the sink node – s (gateway) is defined as follows:

$$w_{i,s}=\sum_{j=1}^{j=\left|P_{i,s}\right|-1} c_{i,j+1} \tag{3}$$

The optimal route from node i to the sink node is computed as:

$$Route_{i,s}=\arg\min_{P_{i,s}\in\Omega}(w_{i,s}) \tag{4}$$

C. Queueing system

In the network, each node perceives and transmits data to the other. There are incoming packets and outgoing packets through the nodes. To evaluate the performance of this topology, we can assume that each node in the network is represented as a queueing system, which serves the incoming and outgoing requests, as shown in Figure 2.

In Figure 2, the incoming traffic is denoted by mean arrival intensity – λ_i and is served by the node i with a mean service intensity – μ_i. There is an intensity of loading the system that is calculated by $\rho_i=\frac{\lambda_i}{\mu_i}(Erl)$. The load factor influences serving time in the system, i.e. the delivery time will be influenced. By considering the queueing system, the network performance is evaluated to see the usage possibility in application deployment.

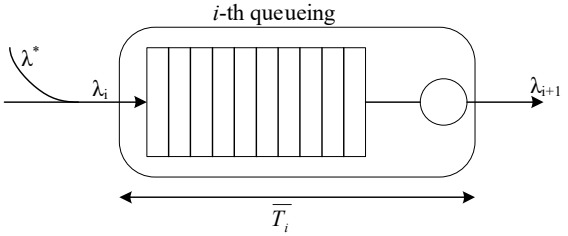


Fig. 2. A node is represented as a queueing system

When considering the M/M/1 model for each node, we will use the formula to calculate the time of the application in the system [15]:

$$T_i=\frac{t_i}{1-\rho_i} \tag{5}$$

where T_i is the mean delivery time to the node i , and t_i is the mean duration of service request.

As described above, the transmission time of a LoRa data frame on-air depends on several parameters. This time on-air can be considered as the average time t_i . The calculation of the time on-air is described in [6].

The number of relay nodes is denoted by m . Hence, the total delivery latency of a data frame through m nodes to the target node is computed as:

$$T=\sum_{i=1}^{m+1}T_i=\sum_{i=1}^{m+1}\frac{t_i}{1-\rho_i} \tag{6}$$

D. Propagation model

In the LoRa network, radio configuration parameters such as operating frequency, SF, BW, CR, and transmission power influence the communication range and reception accuracy. If the received signal power is greater than the receiver sensitivity, we can say that the transmission was successful. Transmission power decreases as it propagates over the air to the recipient. Thus, the received power depends on the transmission power and losses due to signal attenuation. As know well in wireless communication, a log-distance propagation model has been used in indoor and outdoor environments. Pathloss varies with logarithmic distance according to the following equation:

$$PL(d)=PL(d_0)+10\gamma\log_{10}\left(d/d_0\right)+X_{\sigma}, \tag{7}$$

where $PL(d_0)$ is the average path-loss at a reference distance d_0 ; γ is the path-loss exponent; d is the distance between the receiver and the transmitter; X_σ is a random value in the Gaussian distribution with zero mean and standard deviation σ .

While considering the application of LoRa technology in the urban environment and dense urban development, which are the main obstacle to signal propagation. Based on research in [16], the parameters of path-loss propagation are set for the simulation model in the urban environment with $d_0 = 40$, $PL(d_0) = 127.51$, $\gamma = 2.08$, and $\sigma = 3.57$.

E. Simulation Model

The OMNET++ and inet frameworks are used to model the network [17], [18]. They are known well to be used in numerous domains for simulating wired and wireless networks. Based on these frameworks, we have developed a module of the LoRa node. Since the OMNET++ library and frameworks are designed based on modular and component-oriented principles, the LoRa node can be integrated with the build-in modules from the inet framework.

A LoRa node consists of modules modeling radio and upper-layer protocols. In the LoRa radio module, we can configure radio parameters corresponding to our hardware model. The other parameters, such as the spreading factor and coding rate, are configured for the LoRa node in addition to the usual configurations. In this case, the radio parameters taken from the datasheet of the SX127x LoRa chipset [5] are used for the simulation model.

Moreover, in the LoRa medium module, the path-loss propagation model is chosen in considering data transmission in the urban environment, as mentioned above. In this work, the propagation model parameters have been received from a series of measurements presented in [16]. The measurements in [16] correspond to the build-up urban environment, where devices are partially deployed indoors.

A sink node (gateway) is located at the center of the network. The locations of end nodes are randomly generated in the range of field simulation size.

The payload length is generated randomly from the end nodes in the interval from 20 bytes to 150 bytes.

According to the exponential distribution, the sent intervals between messages are random values with a mean equal to 120 seconds.

In each experiment, we analyze the delivery latency and packet delivery ratio to the sink node. The obtained results are presented in the next section.

The simulation parameters and values are shown presented in Table 1.

TABLE I
SIMULATION PARAMETER

Parameter	Value
Frequency, MHz	868
Bandwidth, kHz	{125, 250}
Spreading factor	{7, 8, 9, 10}
Coding rate	4/5
Transmission power, dBm	14
Antenna, dBi	5
Payload length, B	Random (20, 150)
Sent interval, s	Exponential(120s)
Number of nodes	{10, 20, 40, 100}
Field size, m^2	2000 x 2000
Simulation time, s	20000

IV. ANALYTICAL RESULTS

A. Delivery latency

Each device node is considered as a queueing system. Hence, the delivery latency in a communication link between two neighbor nodes is calculated according to the formula (5). Moreover, the delay time for transferring a payload size of 80 bytes is calculated when changing the load intensity. The calculation results are shown in Figure 3 with configuration parameters SF = {7, 8,9, 10} and BW = {125, 250} kHz.

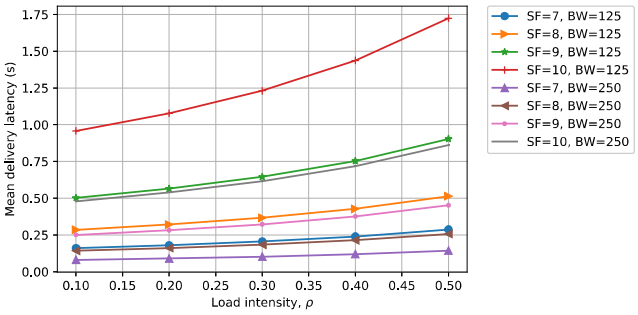


Fig. 3. Influence of load intensity on the delivery latency

As shown in Figure 3, the data transmission time increases when increasing the load intensity. It can be seen that a low spreading factor and a wide bandwidth provide low delivery latency. In the case of using SF = 10 and BW = 125 kHz, the delay time increases significantly up to 2 seconds. Hence the transmission latency via the relay nodes with such radio modules parameters will also be high and can increase up to tens of seconds as shown in Figure 4, where packets are transmitted via several relay nodes to the sink node.

In the mesh topology model, the node receives and relays the packets to the next destination. Therefore, the number of relay nodes that packet passes influences the delivery latency to the destination. With the load factor equal to 0.4 and the payload size of 80 bytes, as shown in Figure 4, the delivery latency increases linearly with the number of relay nodes.

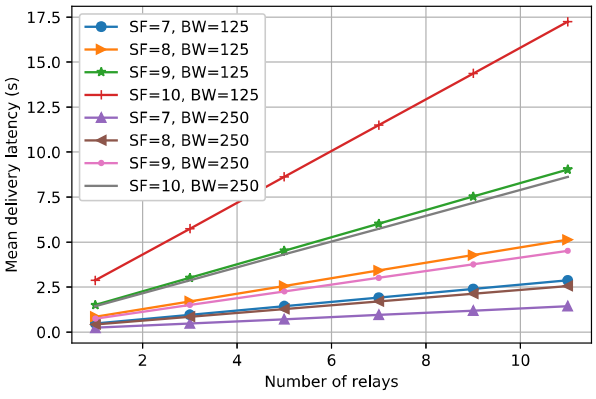
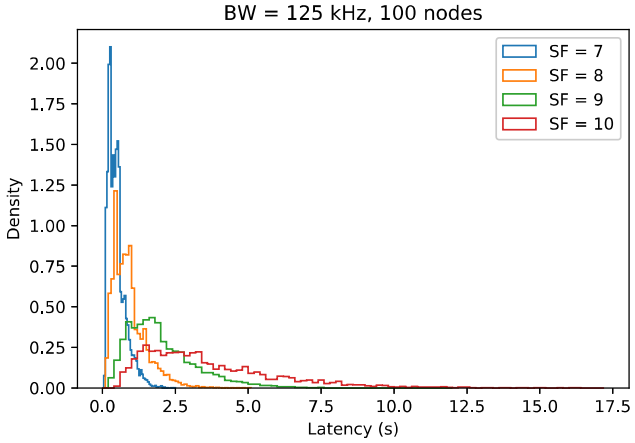


Fig. 4. Influence of the number of relay nodes on the delivery latency

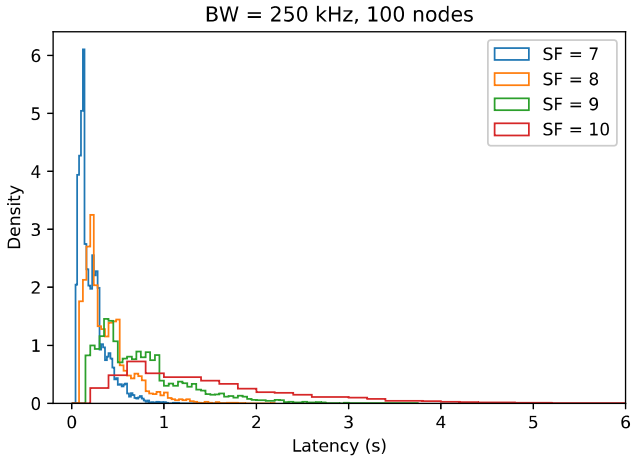
According to Figure 4, when using a bandwidth of 125 kHz and spreading factors SF = {9, 10}, the transmission delay increases to tens of seconds while packets are relayed via 10 nodes. Depending on the requirements of IoT applications, the parameters SF and BW can be selected accordingly. On the other hand, using a wider bandwidth (BW = 250 kHz) provides a short delivery latency through several relay nodes.

Moreover, we can see the differences in latency distributions in the networks using the narrow and wider bandwidth in Figure 5.

When considering the impact of the spreading factor in the network of 100 nodes, different distributions of delivery latency are collected from device nodes to the target node. Figure 5 shows the latency distributions in various SF = {7, 8, 9, 10} and BW = {125, 250} kHz configured for LoRa nodes. Data delivery time is longer with a high spreading factor and a narrow bandwidth. The SF parameter represents the number of encoded chips, so a high SF value requires a longer transmission time.



a)



b)

Fig. 5. Latency distribution in different SF and BW

Moreover, the latency is obtained in the networks having a different number of nodes. Figure 6 shows the latency distribution in the networks with 20 nodes and 100 nodes with the same configuration parameters. As more nodes in the network, there are more generated packets. In the relay nodes, received packets are waited in the queue to transmit to the next destination. Besides, the packets are relayed via several nodes to the sink node. The delay is high in the network of many nodes. Thus, we can use a Long-Range mesh network to connect other networks that cannot transmit data over a long distance. There may be 20 nodes in the mesh network. However, these nodes can communicate with each other and establish communication in a large area, where the short-range networks are used to collect data.

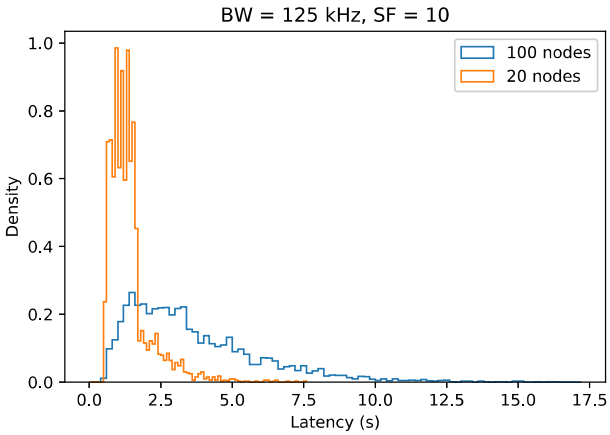


Fig. 6. Latency distribution in the network with different number of nodes

B. *Packet delivery ratio*

Considering the packet delivery ratio, the number of nodes in the network affects the packet delivery ratio. As shown in Figure 7, the results are received from experiments in the networks using SF = 10 and BW = 250 kHz. As the number of nodes increases in the network, the packets also are generated more. Hence, the latency of data transmission and packet loss may increase.

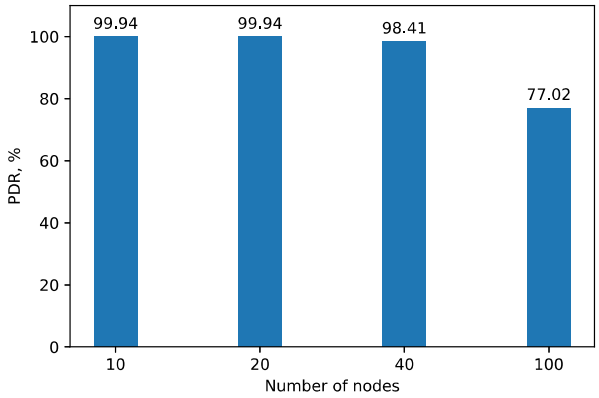


Fig. 7. Packet delivery ratio in the network with different number of nodes

V. Conclusion

Nowadays, LoRa technology is used in the communication part for many IoT applications. Taking the advantages of a LoRa mesh network, the network coverage area can be expanded without adding more base stations. The mesh network model based on LoRa technology was analyzed while considering the delivery latency and packet loss ratio with different configuration parameters.

Based on the analytical results, we can see the influence of configured parameters of the LoRa nodes on the latency distribution and the percentage of delivered packets to the destination node. Besides, the number of nodes in the network also affects the transmission latency and PDR. As using a high SF and a low BW, the transmission delay increases in the network, but it increases the reception sensitivity. Data transmission takes a long latency in the LoRa mesh network. However, it opens the ability to integrate with the other short-range networks in the mesh topology.

Thus, the mesh networks combined with LoRa technology

can bring more advantages in the application of the wireless sensor network in terms of increasing the coverage area and low power consumption.

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REFERENCES

[1] M. H. Miraz, M. Ali, P. S. Excell, and R. Picking, "A review on internet of things (IoT), internet of everything (ioe) and internet of nano things(iont)," *in 2015 Internet Technologies and Applications (ITA)*. IEEE, 2015, pp. 219–224.

[2] R. Kirichek, A. Koucheryavy, "Internet of things laboratory testbed," *in ser. Lecture Notes in Electrical Engineering*. Springer, 2015, vol. 348, pp. 485-494.

[3] O. Khutsoane, B. Isong, and A. M. Abu-Mahfouz, "IoT devices and applications based on Lora/LoRaWan," *in Industrial Electronics Society, IECON 2017-43rd Annual Conference of the IEEE*. IEEE, 2017, pp.6107–6112.

[4] R. Kirichek, V. Kulik, "Long-range data transmission on flying ubiquitous sensor networks (fusn) by using lpwan protocols," *in ser. Communications in Computer and Information Science*. Springer, 2016, vol. 678, pp. 442-453.

[5] "Sx1276/77/78/79 datasheet, rev. 5," *Semtech Corporation*, August 2016.

[6] "SX1272/3/6/7/8 LoRa Modem Design Guide AN1200.13," *Semtech Corporation*, July 2013.

[7] I. Nurilloev, A. Paramonov, and A. Koucheryavy, "Connectivity estimation in wireless sensor networks," *in Internet of Things, Smart Spaces, and Next Generation Networks and Systems*. Springer, 2016, pp. 269–277.

[8] V. D. Pham, T. D. Dinh, and R. Kirichek, "Method for Organizing Mesh Topology based on LoRa Technology," *in 10th International Congress on Ultra Modern Telecommunications and Control Systems and Workshops (ICUMT)*, 2018, pp. 1–6.

[9] T. D.Dinh, V. D. Pham, R. Kirichek, A. Koucheryavy, "Flying network for emergencies," *in ser. Communications in Computer and Information Science book series*. Springer, 2018, vol. 919, pp. 58-70.

[10] T. D. Dinh, R. Pirmagomedov, V. D. Pham, A. A. Ahmed, R. Kirichek, R. Glushakov, A. Vladyko, "Unmanned aerial system-assisted wilderness search and rescue mission," *International Journal of Distributed Sensor Networks*, vol. 15(6), June 2019.

[11] T. Addabbo, A. Fort, A. Mecocci, M. Mugnaini, S. Parrino, A. Pozzebon, and V. Vignoli, "A Lora-based IoT sensor node for waste management based on a customized ultrasonic transceiver," *in 2019 IEEE SensorsApplications Symposium (SAS)*. IEEE, 2019, pp. 1–6

[12] B. Ngom, M. Diallo, B. Gueye, and N. Marilleau, "Lora-based measurement station for water quality monitoring: Case of botanical garden pool," *in 2019 IEEE Sensors Applications Symposium (SAS)*. IEEE, 2019, pp. 1–4.

[13] P. Gotthard and T. Jankech, "Low-cost car park localization using RSSI in supervised LoRa mesh networks," *in 2018 15th Workshop on Positioning, Navigation and Communications (WPNC)*. IEEE, 2018, pp. 1–6.

[14] J. G. Panicker, M. Azman, and R. Kashyap, "A LoRa wireless mesh network for wide-area animal tracking," *in 2019 IEEE International Conference on Electrical, Computer and Communication Technologies (ICECCT)*. IEEE, 2019, pp. 1–5.

[15] L. Kleinrock, "Queueing systems, volume 2: computer applications", *New York: Wiley*, 1976, pp. 1–20.

[16] M. Bor, U. Roedig, T. Voigt, and J. M. Alonso, *"Do LoRa low-power wide-area networks scale?,"* in Proceedings of the 19th ACM International Conference on Modeling, Analysis and Simulation of Wireless and Mobile Systems. 2016, pp. 59–67.

[17] OMNeT++, "OMNeT++ Network Simulation Framework," *OMNeT++ Community*, 2013.

[18] OMNeT++, "What Is INET Framework?," *OMNeT++*, 2018.

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Orthogonal Defect Classification-based Ontology Construction and Application of Software-hardware Integrated Error Pattern of Software-intensive Systems

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***Abstract*—Orthogonal defect classification (ODC) is a multi-dimensional measurement system with both qualitative and quantitative characteristics. And it is currently widely used in the software industry. However, its high level of abstraction leads to limited semantic information. Therefore, it seems to have a limited role in the process of software engineering of software-intensive systems (SISs). To solve this problem, this paper first analyzes software error lifetime from the perspective of knowledge-based software engineering and proposes an error generation model. Then, the paper proposes the concepts of software error pattern (SEP) and software requirements error pattern (SREP) based on the ODC. Then, according to an error generation mechanism, four types of software-hardware integrated error pattern (SHIEP) in the requirement stage, which is a sub-category of SREP, and corresponding ontology representation are given, focusing on "scenario", "error manifestation" and "solution". Finally, this paper takes a certain type of airborne radar software system as an example, uses protégé to edit the SHIEPs and instances, and further introduces the application of software FMEA based on the above work. The results show that the prior information based on the SHIEPs is helpful to discover potential failures and failure modes that may adversely affect the function or performance of SISs. Therefore, the proposed SHIEP is of great significance for improving the quality of software development and verification.**

***Keyword*-orthogonal defect classification, ontology, pattern, software error**

I. INTRODUCTION

HOW to provide developers with fast and effective feedback in a controlled and measurable way is a problem that plagues the software industry [1]. There are two common forms of software defect analysis: statistical defect models and root cause analysis. The first is a quantitative method with good repeatability, but cannot provide feedback to developers timely in the way of available process control. The second is a qualitative method focusing on process details and therefore cannot be applied as an engineering method to full process control [1]. Orthogonal defect classification (ODC) is a technique that can bridge the gap between quantitative methods and qualitative analysis [2]. It extracts semantic information in defects via classification, converting what is semantically very rich into a few vital measurements on the product and process. Thus, essentially it is a multi-dimensional measurement system that transforms qualitative information into quantitative measures [1].

There are some researches on ODC recently, e.g., the applications of "defect triggers" during a testing process [3] and the researches on Bohr-Mandel errors using the "defect triggers" [4], the researches on ODC applications of safety, critical errors of spacecraft systems [5], [6], the researches on modeling Y2K errors through ODC [7], the researches on a defect tracing system based on ODC [8], the researches on automated generation of ODC [9], [10], the researches on in-process usability problem classification, analysis and improvement based on ODC [11]. In all, the representative researches on ODC tend to focus on its macroscopic characteristic as a measurement system. However, it is too abstractive to reflect individual gaps because of the consistency across phases and the uniformity across products [2]. Therefore, it can measure software processes only and cannot guide verification directly. In addition, it is difficult to apply ODC to the application scenario of software-intensive systems (SISs). Nowadays, SISs have become a developmental direction of large-scale systems, and the application ranges of SISs involve the embedded systems for automotive industry and aerospace applications, the dedicated systems for wireless communications [12]. A software product always stems from a defined requirements set. For SISs, the formation of a requirements set is a long-term and complicated process, and a main reason is: two problems of system complexity and sudden behavior are increasingly highlighted in the application process of SISs.

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The root cause of these two problems lies in the uncertainty of environment and the unpredictability of operation and scenario. ODC is on a higher level and has limited semantic information. Thus, it is difficult to describe the complicated scenarios of SISs via ODC. And it hinders the researches on the above problems through ODC.

Experience has shown that some abnormal events that occur under certain extreme conditions, although they have a low probability of occurrence, are extremely harmful. These problems need to be collected through long-term accumulation. In addition, there is a kind of errors depending on both operating time of hardware and operating state of software. Thus, one important source of an SISs requirements set is the error set obtained according to experience.

The rest of this paper is divided into the following sections: section 2 analyzes the lifetime of software errors and proposes an error generation model from the viewpoint of knowledge-based software engineering. Section 3 and section 4 present the definitions of software error pattern (SEP) and software requirements error pattern (SREP) based on ODC, respectively. Section 4 also describes four types of software-hardware integrated error pattern (SHIEP) according to an error generation mechanism, and constructs an SHIEP ontology (SHIEPO) by an object-oriented ontology representation method focusing on "scenario", "error manifestation" and "solution". In the knowledge engineering community, an ontology is a formal and explicit specification of a shared conceptualization [13]. This work unifies the SHIEP concept in the ontology framework. Section 5 presents a case study, taking an airborne radar software system as an example to introduce the application of above researches on software failure mode and effects analysis (SFMEA). Finally, section 6 concludes the study.

II. Lifetime and Generation Model of Software Errors

Software is a sequence of computer knowledge that describes human knowledge and the correct usage of human knowledge [14]. And it can be regarded that software errors are the reflection of inconsistency between the knowledge produced in the process of creating a software product and the original knowledge, and such reflection is regarded as necessary adjustments [15]. Fig. 1 shows that software error lifetime runs throughout developing, verification and field usage. The reliability test at the verification stage refers to a test type for hardware systems. It is a necessary means to improve product design, and evaluate and assess product quality characteristics during product development and production. There are several forms of incorrect software knowledge, (1) incorrect knowledge points or implicit software errors induced by man-made mistakes, (2) using correct knowledge in a wrong way [14].

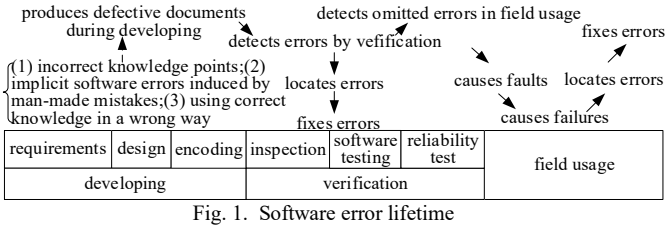

Fig. 1. Software error lifetime

Fig. 2 shows an error generation model. It is noted that these errors do not include system software errors and operator errors. This figure shows that a software error is generated during the process of software developing. Knowledge problems include domain knowledge problems and software engineering knowledge problems. Actions and artifacts vary from one stage to another. In horizontal direction, in-process errors may occur at various stages of software development. In vertical direction, knowledge inconsistencies between adjacent and non-adjacent layers may lead to inter-process errors. Software errors exist in artifacts and are expressed in a certain form. The intra-layer and inter-layer causes of errors are the scenarios of SEPs. The scenarios can be generalized, such as in-layer or inter-layer inconsistencies; they can also be relatively specific in combination with specific patterns.

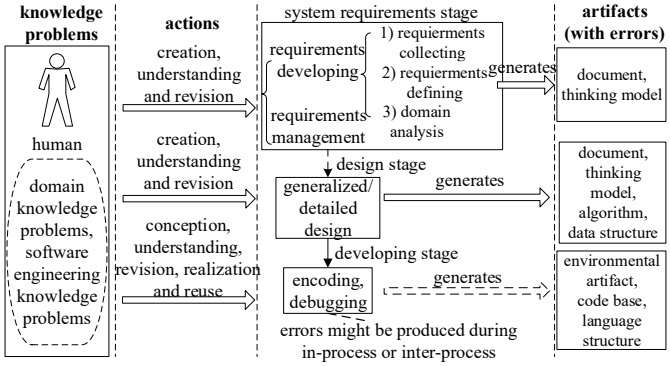

Fig. 2. Software error generation model

III. Software Error Pattern

The above researches show the software error lifetime throughout the software developing, verification and field usage. Therefore, the related researches should consider the multiple viewpoints of developers, testers, and users.

ODC is an error classification method that helps to obtain error information at a higher level. Its elements include "defect triggers", "defect types", "targets", etc. They are independent and orthogonal with each other. A "defect trigger" is a condition that allows a defect to surface **(What)**. The "defect type" reflects the nature of errors and guides how to amend them **(How)**. Experience shows that, (1) the contexts in which errors are generated are similar, and the effect is similar to the "defect triggers" attribute; (2) errors have similar manifestations and can be modified, i.e., there is a software implementation that satisfies the correct intent. The effect is similar to the "defect types" and "targets" attributes. These inspire the paper to study software errors with the help of the concept "Pattern" [16].

Definition 1 The SEP refers to the error produced in the software development stage, which occurs repeatedly in a specific error lifetime scenario, and may cause a system (component) to fail to perform the expected function or affect the maintainability of the system. Such errors are general and common in a specific scenario and can be corrected by various means. SEP's components can be instantiated.

Therefore, SEP:= < Scenario, ErrorManifestation, Solution, Severity, DetectionStage, GenerationStage, Instance >.

This definition distinguishes the generation and survival

stages of errors. Furthermore, it is multi-viewpoint. Its core components are: “Scenario”, “ErrorManifestation” and “Solution”. “Scenario” reflects tester and user viewpoints, and is the basis for test cases and the catalyst that causes a failure. “ErrorManifestation” and “Solution” reflect developer viewpoint, express the nature of errors, and give a way to eliminate the errors. SEP also has other components, such as, “Severity”, “DetectionStage”, “GenerationStage” and “Instance”. An “instance” is the result of mapping a SEP concept at a higher level of abstraction to a specific case. The components of SEP are shown in Fig. 3. Most error classification systems use 5 to 15 defect attributes [1]. The number of SEP components is in this range. The SEP components are independent and orthogonal with each other. Thus, SEP can be regarded as a point in Cartesian space.

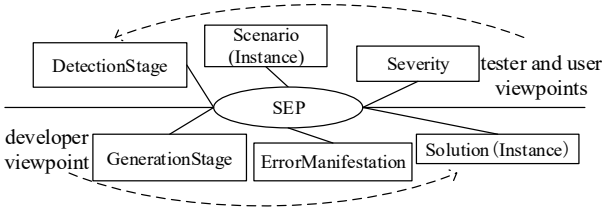

Fig. 3. SEP Components

Fig. 4 presents SEP and its components value sets in the form of classes based on experience and related references [1], [17]. Both SEP and its components can be regarded as classes. The relationships between SEP and the components are aggregation relationships. The “Scenario” class has 6 sub-classes. The “SEP” class has 3 operations of “measurement”, “software development”, and “software verification”. The operation of “Scenario”, “ErrorManifestation”, “DetectionStage”, “GenerationStage”, and “Severity” classes is “1-dimension measurement” in common. The sub-classes of “Scenario” class have the operation of “measure data supply” in common. The values of components are the attributes of the corresponding classes. These classes can be instantiated, corresponding to the “Instance” of the components of SEP. The role of the operation “measurement” is similar to the metric of ODC attributes, i.e., the semantic information in errors is extracted by classification and converted into a metric. For example, the distribution and trends of various types of errors at each stage can be analyzed, and the deviation from an expected situation can indicate problems in a development process. This provides timely feedback to developers and can guide bug fixes. The operation “software development” is given from the developer viewpoint; while the operation “software verification” is given from the tester and user viewpoints. In addition, the difference between the attribute “software workload change” and the attribute “system workload change” is that the “software workload” directly affects the software product itself, exposing software product defects by imposing the behaviors that may result in exceeding software product resource limits or capacity limits, whereas the “system workload” directly affects the entire system, and generally has an indirect effect on software, such as the vibrations generated during an aircraft flight. The “safety error” of “ErrorManifestation” refers to the error that may cause failures of casualties, property damage or environmental damage. Such errors are very important in the SISs.

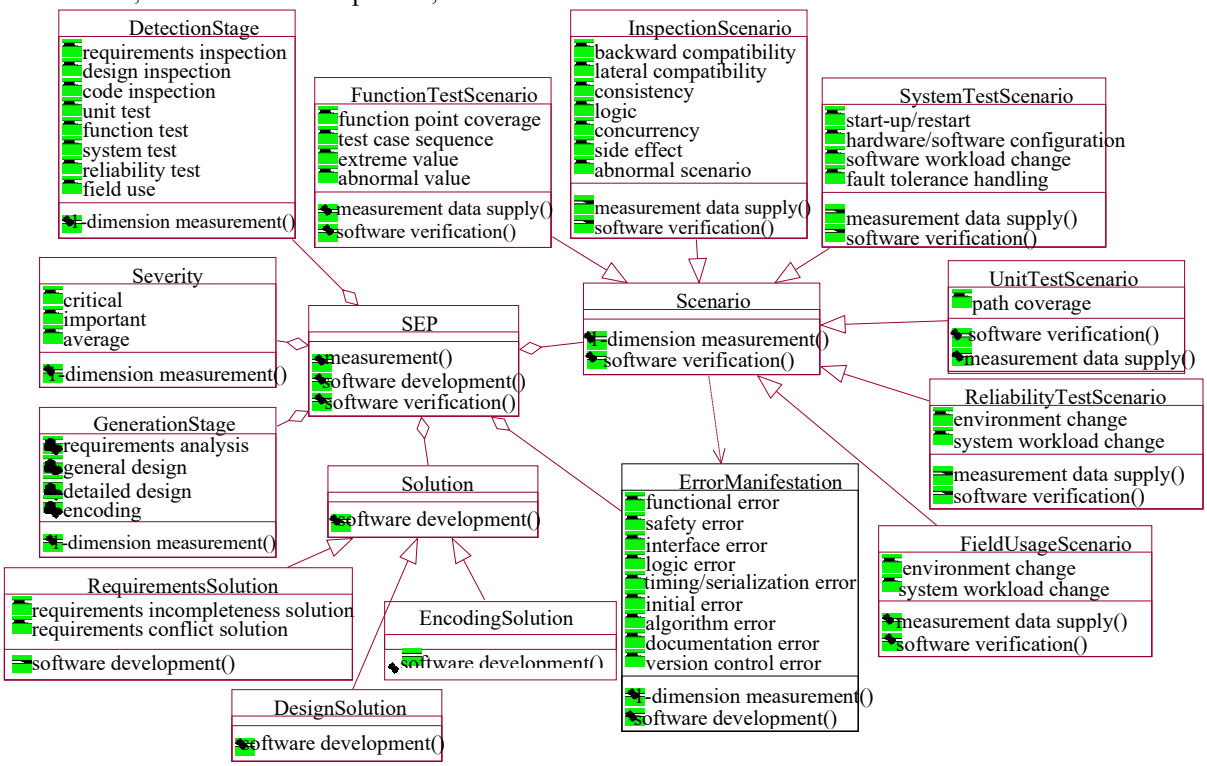

Fig. 4. Class representation of SEP and its components

IV. SREP ONTOLOGY

4.1 Ontology structure of SREP

SEP-related domains include the corresponding domains in the stages of requirements, design, and coding according to the "error generation stage". And the results of a follow-up survey of 8,000 software projects across the United States showed that the problems related to requirements processes account for 45%, and the lack of end user participation and incomplete requirements are two main reasons, each accounting for 13% and 12% [18]. In addition, extensive engineering experience has shown that requirements problems are one of the main sources of engineering problems; therefore, the research in this paper is limited to the stage of requirements analysis, and below, SEP (s) are replaced by SREP (s). Requirements analysis mainly solves the problem of what a product should do [15]. The main reason for requirements problems is the problems of knowledge sharing and reuse, and ontology is an effective means to solve these two problems. In addition, objects (classes) do not always play a primary role in a domain, and sometimes it is more important to identify relationships between objects (classes) [19]. Therefore, it is necessary to characterize other associations between SREP objects (classes). This paper uses an object-based ontology method to characterize the SREP and define its semantics.

4.1.1 Definition of SREP

SREP is a summary of experience often making mistakes in requirements engineering. Thus, this paper proposes the definition of SREP according to the definition of SEP.

Definition 2: The SREP refers to the error produced in the software requirements development stage, which occurs repeatedly in a specific error lifetime scenario, spreads in the subsequent design and implementation, and may cause a system (component) to fail to perform the expected function or affect the maintainability of the system. Such errors are general and common in a specific scenario and can be corrected by various means.

The definition shows that the core components of an SREP are ''Scenario'', ''ErrorManifestation'' and ''Solution''. In addition, "Severity" should also be included. There is a class inheritance relationship between SEP and SREP as shown in Fig. 5.

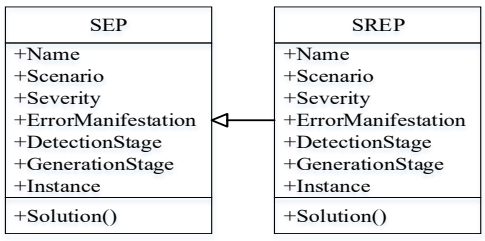

Fig. 5. Class inheritance relationship between SEP and SREP

4.1.2 Constituent components of SREPO

The universe of SREPO constituent components U is: U = {Concepts, Object properties, Data properties, P^R, P^C, Inherit-hierarchies, Relationships, Instances, Mappings, Rules}. Concepts, Inherit-hierarchies, Relationships, and Instances build the basic skeleton of the SREPO. All other components are attached to the basic skeleton and refine the basic skeleton. Object properties and Data properties are two types of properties. The Object properties connect instances together, and the Data properties connect instances and values together. P^R indicates the restrictions on properties, including the restrictions on the type, range, and maximum/minimum number of property values. P^C indicates property characteristics. Mappings represent the mappings between different levels of ontology. Rules include axioms and custom rules. The Rules can be used to constrain information, prove correctness, or derive new information. The Rules can also be used to express richer relationships between concepts.

4.1.3 Construction of SREPO

This paper builds the SREPO according to the "error generation stage".

Definition 3 SREPO := <Concepts, Object properties, Data properties, P^R, P^C, Inherit-hierarchies, Relationships, Rules, Instances>.

The concept classes of SREPO is shown in Fig. 6. The concept classes marked with an "*" are non-terminal concept classes, and the rest are terminal concept classes.

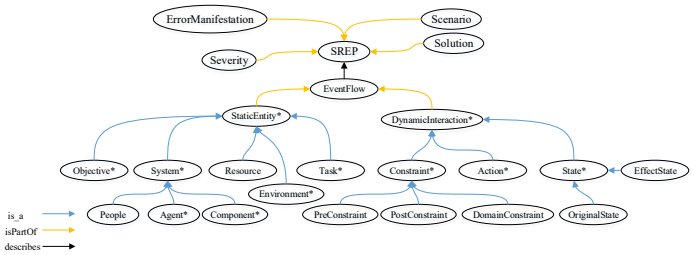

Fig. 6. Concept class hierarchies of SREPO

Define an inheritance relationship as:

Definition 4 An inheritance relationship is a mechanism of a sub-class automatically sharing the properties and structure of a parent class in the SREPO concept class hierarchy.

Then, the sub-class and the parent class of non-terminal concept classes form an inheritance relationship. Therefore, a new class can be created based on an existing concept class by taking the content defined by the existing class as its own content and adding new content. A portion of the concept relationships of SREPO is obtained as shown in Table. I. The left side of arrow is a source concept node, and the right side is a destination concept node. Take an example of "subObjective". Its property characteristic is partial order. That is because it satisfies

"reflexivity", "symmetry" and "transitivity" simultaneously, i.e.,

(1) $\forall a \in A,(a,a) \in I$

(2) $\forall a,b \in A,((a,b) \in I) \cap ((b,a) \in I) \rightarrow (a=b)$

(3) $\forall a,b,c \in A,((a,b) \in I) \cap ((b,c) \in I) \rightarrow (a,c) \in I$

and it can be represented as $a \preceq b$.

TABLE I
A PORTION OF CONCEPT RELATIONSHIPS OF SREPO

Relationship types	Relationships	Property characteristics
subObjective	Objective→Sub-objective	partial order
interact	System→Environment	symmetry
has	System→Objective	-

Furthermore, a portion of the concept space of SREPO is shown as Fig. 7.

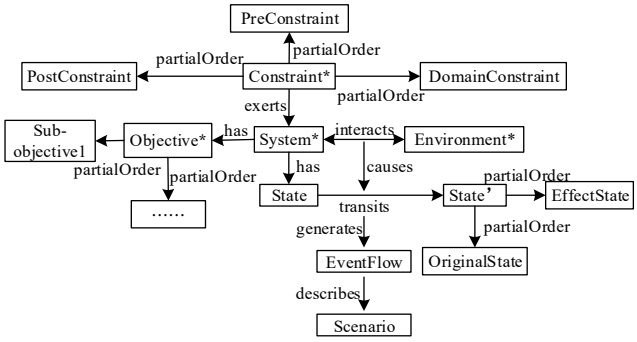

Fig. 7. A portion of concept space of SREPO

4.2 Ontology representation of SHIEP

4.2.1 Ontology representation framework of SHIEP

For the SISs, software requirements (SRs) can be divided into two categories: internal requirements and external requirements from the perspectives of macro function and internal structure. The internal requirements describe the connotation of requirements, i.e., the internal structure of a software system; the external requirements describe the extension of requirements, reflecting the interaction between a software system and its environment. The environment here includes the entities of people or other systems in contact with the software system. The external requirements determine the internal requirements. The external requirements can be further divided into explicit requirements and implicit requirements. The explicit requirements describe the direct interaction and constraint between a software system and its environment; the implicit requirements describe the indirect interaction and constraint between a software system and its environment. Thus, SRs := < internal requirements, external requirements < explicit requirements, implicit requirements > >. Then, Environment Ontology := < ExplicitEnvironment, ImplicitEnvironment>. Moreover, the set of implicit environment can be obtained based on experience: ImplicitEnvironment = <OtherEnvironment < StressEnvironment<TemperatureEnvironment, VibrationEnvironment, HumidityEnvironment, ElectricityEnvironment, CombinedStressEnvironment>, EMEnvironment, GeographyEnvironment, AtmosphereEnvironment>, OperationEnvironment>,

where CombinedStressEnvironment = TemperatureEnvironment ∪ VibrationEnvironment ∪ ElectricityEnvironment ∪ HumidityEnvironment.

Requirements engineering focuses on the expected goals and corresponding scenarios of software systems [20]; therefore, it can be considered that the SRs are the environmental state changes and goal realization caused by the interaction between a software system and its environment. Then, SRs:=<System <Agent, Entity>, Environment<ExplicitEnvironment, ImplicitEnvironment>, Interact<Control, Monitor, Perform>, Objective<Avoid, Cease, Achieve, Maintain>>, where "Agent" represents a special object, not a person, but only a machine or other mechanism, and must be autonomy, initiative and intelligence. "Entity" refers to any static thing that constitutes the basic structure of a software system. "Interact" refers to the interaction between a software system and its environment.

An event flow describes the sequence of interactive actions, including how to start, end, and how to interact. The semantics of SRs also describe the sequence of interactive actions changing the states of environment. Therefore, state transition models can be adopted to describe state transitions and event flows, i.e., the formation of scenario. Then, an environment framework can be defined as follows,

State< OriginalState, EffectState > ≠ NULL

interact→transit: T (State, State')

transit: T (State, State')→EventFlow

Constraint< PreConstraint, PostConstraint, DomainConstraint {Trigger, Pred, Synch, Conseq}>

"Constraint" acts on "interact", "transit" and "EventFlow", respectively. "DomainConstraint" includes "$\text{Trigger}_{\text{domain}}$", "$\text{Pred}_{\text{ddomain}}$", "$\text{Synch}_{\text{domain}}$" and "$\text{Conseq}_{\text{domain}}$". And domain knowledge can be described by the state transition of environment.

"Environment" can be described as,

Environment = < ExplicitEnvironment, ImplicitEnvironment < OperationEnvironment, OtherEnvironment <StressEnvironment < TemperatureEnvironment, VibrationEnvironment, HumidityEnvironment, ElectricityEnvironment, CombinedStressEnvironment >, EMEnvironment, GeographyEnvironment, AtmosphereEnvironment >> >, where TemperatureEnvironment = {t-Envi_1,…, t-Envi_{s1}}, VibrationEnvironment = {v-Envi_1,…, v-Envi_{s2}}, HumidityEnvironment = {h-Envi_1,…, h-Envi_{s3}}, ElectricityEnvironment = {e-Envi_1,…, e-Envi_{s4}}, CombinedStressEnvironment = {c-Envi_1,…, c-Envi_{s5}}, EMEnvironment = {EM-Envi_1,…, EM-Envi_{s6}},

GeographyEnvironment = {g-Envi$_1$,…, g-Envi$_{s7}$}, AtmosphereEnvironment = {a-Envi$_1$,…, a-Envi$_{s8}$}.s1,⋯,s8 $\in \mathbb{N}$. Interact = {interact$_1$,…, interact$_n$}, $n \in \mathbb{N}$. State={state$_1$, ⋯⋯, state$_t$}, $t \in \mathbb{N}$. Constraint = {constraint$_1$, constraint$_2$,…, constraint$_l$}, $l \in \mathbb{N}$. They are all obtained based on the inference of domain ontology.

4.2.2 Types and ontology representations of SHIEPs

Most of the current software requirements elicitation (SRE) methods do not consider prior information such as SEPs at the beginning of SRE, resulting in incomplete knowledge. SIS software generally has the following characteristics: (1) SIS software is closely connected with hardware, and has strong requirements of dedicated external equipments; (2) SIS software is usually strong real-time; (3) SIS software usually operates in specific conditions, and relates to interactive environments; (4) SIS software has high safety requirements. The above characteristics also spawn the SHIEPs (SHIEs). The SHIEPs (SHIEs) arise from requirements analysis stage and are a sub-class of SREPs (SREs). They have gradually become an important part of error patterns (errors) during the field usage of SISs, and they are extremely harmful. Therefore, it is necessary to study the SHIEPs (SHIEs). Moreover, the collection of SHIEPs (SHIEs) mainly depends on the field usage of SISs. That is because the environment of field usage or field test of SISs is relatively real, and the exposed problems can reflect actual situations. The types of SHIEP according to an error generation mechanism are shown in Fig. 8. The core components of SHIEP are: “Scenario”, “ErrorManifestation” and “Solution”.

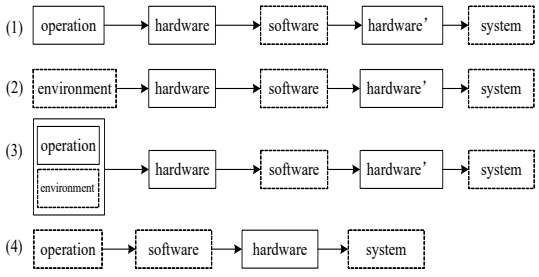

Fig. 8. Four types of SHIEP

1) Type 1 of SHIEP

The type 1 of SHIEP in Fig. 8 is described as, the unpredictable changes in operating conditions directly affect hardware and eventually lead to a system failure. The changes directly affect the hardware components of a system, accumulate over time, and gradually penetrate the internal units of the components, thereby affecting the characteristics of the components or circuits. Then, the generated abnormal electrical signals act as software inputs through software-hardware interfaces to software, resulting in abnormal software operations, and then react to the components or the system, and in turn cause global or local failures of the system. The complete process is shown in Fig. 9. The “ units of hardware components’ ” and “ hardware components of system’ ” in this figure represent the state change of corresponding part (normal to abnormal), respectively. This process is a closed loop feedback process, and every step is accompanied by a state transition.

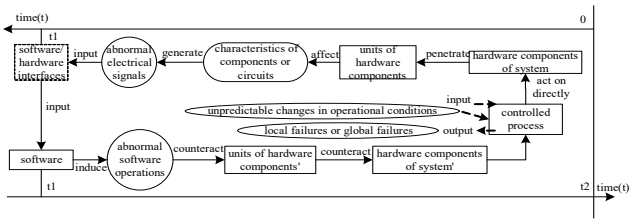

Fig. 9. Type 1 of SHIEP

The specific contents of the core part of type 1 of SHIEP are as follows,

Scenario of requirements incompleteness:

Scenario 1:

constraint$_k$(interact$_i$) ∈ Constraint($1 \le k \le l$, $1 \le i \le n$, $k \in \mathbb{N}$, $l \in \mathbb{N}$, $i \in \mathbb{N}$, $n \in \mathbb{N}$),

$\exists$ (interact$_i$ $\notin$ Interact) → (state$_i$(hardware) $\notin$ State(hardware)) → (state$_i$(software) $\notin$State(software)) → (state$_j$(hardware) $\notin$State(hardware))

ErrorManifestation: safety error

Solution: A complete set of predefined operating conditions and a complete set of domain constraints are given to build a complete domain knowledge ontology.

2) Type 2 of SHIEP

The type 2 of SHIEP in Fig. 8 is described as, unpredictable environmental changes directly affect hardware and eventually lead to a system failure. The changes directly affect the hardware components of a system, accumulate over time, and gradually penetrate the internal units of the components, thereby affecting the characteristics of the components or circuits. Then, the generated abnormal electrical signals act as software inputs through software-hardware interfaces to software, resulting in abnormal software operations, and then react to the components or the system, and in turn cause global or local failures of the system. The complete process is shown in Fig. 10. The “ units of hardware components’ ” and “ hardware components of system’ ” in this figure represent the state change of corresponding part (normal to abnormal), respectively. This process is a closed loop feedback process, and every step is accompanied by a state transition.

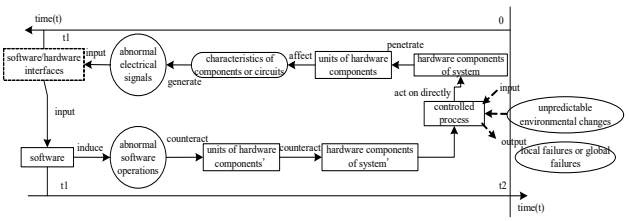

Fig. 10. Type 2 of SHIEP

The specific contents of the core part of type 2 of SHIEP are as follows,

Scenario of requirements incompleteness:

Scenario 2:

$constraint_k(interact_i) \in Constraint(1 \le k \le l,\ 1 \le i \le n, k \in N, 1 \in N, i \in N, n \in N)$,

Sub-scenario 2-1:

$\exists$ (t-Envi$_s$ $\notin$ ImplicitEnvironment) $\rightarrow$ ((t-Envi$_s$ $\cup$ ImplicitEnvironment) $\subset$ Environment) $\rightarrow$ (state$_i$(hardware) $\notin$State(hardware)) $\rightarrow$ (state$_i$(software) $\notin$ State(software)) $\rightarrow$ (state$_j$(hardware) $\notin$State(hardware)) $(s1 \le s, s \in N)$

Sub-scenario 2-2:

$\exists$ (v-Envi$_s$ $\notin$ ImplicitEnvironment) $\rightarrow$ ((v-Envi$_s$ $\cup$ ImplicitEnvironment) $\subset$ Environment) $\rightarrow$ (state$_i$(hardware) $\notin$State(hardware)) $\rightarrow$ (state$_i$(software) $\notin$ State(software)) $\rightarrow$ (state$_j$(hardware) $\notin$ State(hardware))$(s2 \le s, s \in N)$

Sub-scenario 2-3:

$\exists$ (h-Envi$_s$ $\notin$ ImplicitEnvironment) $\rightarrow$ ((h-Envi$_s$ $\cup$ ImplicitEnvironment) $\subset$ Environment) $\rightarrow$ (state$_i$(hardware) $\notin$State(hardware)) $\rightarrow$ (state$_i$(software) $\notin$ State(software)) $\rightarrow$ (state$_j$(hardware) $\notin$State(hardware)) $(s3 \le s, s \in N)$

Sub-scenario 2-4:

$\exists$ (e-Envi$_s$ $\notin$ ImplicitEnvironment) $\rightarrow$ ((e-Envi$_s$ $\cup$ ImplicitEnvironment) $\subset$ Environment)$\rightarrow$ (state$_i$(hardware) $\notin$State(hardware)) $\rightarrow$ (state$_i$(software) $\notin$ State(software)) $\rightarrow$ (state$_j$(hardware) $\notin$State(hardware)) $(s4 \le s, s \in N)$

Sub-scenario 2-5:

$\exists$ (c-Envi$_s$ $\notin$ ImplicitEnvironment) $\rightarrow$ ((c-Envi$_s$ $\cup$ ImplicitEnvironment) $\subset$ Environment) $\rightarrow$ (state$_i$(hardware) $\notin$State(hardware)) $\rightarrow$ (state$_i$(software) $\notin$ State(software)) $\rightarrow$ (state$_j$(hardware) $\notin$State(hardware)) $(s5 \le s, s \in N)$

Sub-scenario 2-6:

$\exists$ (EM-Envi$_s$ $\notin$ ImplicitEnvironment) $\rightarrow$ ((EM-Envi$_s$ $\cup$ ImplicitEnvironment) $\subset$ Environment) $\rightarrow$ (state$_i$(hardware) $\notin$State(hardware)) $\rightarrow$ (state$_i$(software) $\notin$ State(software)) $\rightarrow$ (state$_j$(hardware) $\notin$State(hardware)) $(s6 \le s, s \in N)$

Sub-scenario 2-7:

$\exists$ (g-Envi$_s$ $\notin$ ImplicitEnvironment) $\rightarrow$ ((g-Envi$_s$ $\cup$ ImplicitEnvironment) $\subset$ Environment) $\rightarrow$ (state$_i$(hardware) $\notin$State(hardware)) $\rightarrow$ (state$_i$(software) $\notin$ State(software)) $\rightarrow$ (state$_j$(hardware) $\notin$State(hardware)) $(s7 \le s, s \in N)$

Sub-scenario 2-8:

$\exists$ (a-Envi$_s$ $\notin$ ImplicitEnvironment) $\rightarrow$ ((a-Envi$_s$ $\cup$ ImplicitEnvironment) $\subset$ Environment) $\rightarrow$ (state$_i$(hardware) $\notin$State(hardware)) $\rightarrow$ (state$_i$(software) $\notin$ State(software)) $\rightarrow$ (state$_j$(hardware) $\notin$State(hardware)) $(s8 \le s, s \in N)$

ErrorManifestation: safety error

Solution: A complete set of predefined operating conditions and a complete set of domain constraints are given to build a complete domain knowledge ontology.

3) Type 3 of SHIEP

The type 3 of SHIEP in Fig. 8 is described as, unpredictable changes in operating conditions and unpredictable environmental changes directly affect hardware and eventually lead to a system failure. The changes directly affect the hardware components of a system, accumulate over time, and gradually penetrate the internal units of the components, thereby affecting the characteristics of the components or circuits. Then, the generated abnormal electrical signals act as software inputs through software-hardware interfaces to software, resulting in abnormal software operations, and then react to the components or the system, and in turn cause global or local failures of the system. The complete process is shown in Fig. 11. The " units of hardware components' " and " hardware components of system' " in this figure represent the state change of corresponding part (normal to abnormal), respectively. This process is a closed loop feedback process, and every step is accompanied by a state transition.

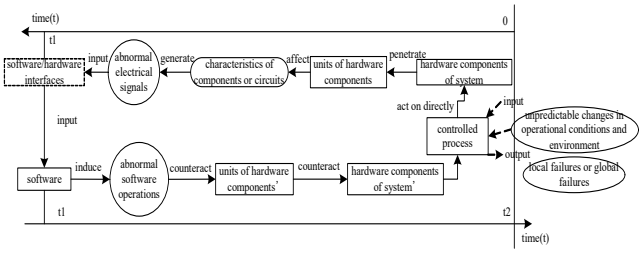

Fig. 11. Type 3 of SHIEP

The specific contents of the core part of type 3 of SHIEP are as follows,

Scenario of requirements incompleteness:

Scenario 3:

$constraint_k(interact_i) \in Constraint(1 \le k \le l,\ 1 \le i \le n, k \in N, 1 \in N, i \in N, n \in N)$,

Sub-scenario 3-1:

$\exists$ ((operation$_i$ $\notin$ Operation) $\cap$ ((t-Envi$_s$ $\notin$ ImplicitEnvironment) $\rightarrow$ ((t-Envi$_s$ $\cup$

ImplicitEnvironment) ⊄ Environment))) → (state$_i$(hardware) ∉State(hardware)) → (state$_i$(software) ∉ State(software)) → (state$_j$(hardware) ∉State(hardware)) (s1 ≤ s, s ∈ N)

Sub-scenario 3-2:

∃ ((operation$_i$ ∉ Operation) ∩ ((v-Envi$_s$ ∉ ImplicitEnvironment) → ((v-Envi$_s$ ∪ ImplicitEnvironment) ⊄ Environment))) → (state$_i$(hardware) ∉State(hardware)) → (state$_i$(software) ∉ State(software)) → (state$_j$(hardware) ∉State(hardware)) (s2 ≤ s, s ∈ N)

Sub-scenario 3-3:

∃ ((operation$_i$ ∉ Operation) ∩ ((h-Envi$_s$ ∉ ImplicitEnvironment) → ((h-Envi$_s$ ∪ ImplicitEnvironment) ⊄ Environment))) → (state$_i$(hardware) ∉State(hardware)) → (state$_i$(software) ∉ State(software)) → (state$_j$(hardware) ∉State(hardware)) (s3 ≤ s, s ∈ N)

Sub-scenario 3-4:

∃ ((operation$_i$ ∉ Operation) ∩ ((e-Envi$_s$ ∉ ImplicitEnvironment) → ((e-Envi$_s$ ∪ ImplicitEnvironment) ⊄ Environment))) → (state$_i$(hardware) ∉State(hardware)) → (state$_i$(software) ∉ State(software)) → (state$_j$(hardware) ∉State(hardware)) (s4 ≤ s, s ∈ N)

Sub-scenario 3-5:

∃ ((operation$_i$ ∉ Operation) ∩ ((c-Envi$_s$ ∉ ImplicitEnvironment) → ((c-Envi$_s$ ∪ ImplicitEnvironment) ⊄ Environment))) → (state$_i$(hardware) ∉State(hardware)) → (state$_i$(software) ∉ State(software)) → (state$_j$(hardware) ∉State(hardware)) (s5 ≤ s, s ∈ N)

Sub-scenario 3-6:

∃ ((operation$_i$ ∉ Operation) ∩ ((EM-Envi$_s$ ∉ ImplicitEnvironment) → ((EM-Envi$_s$ ∪ ImplicitEnvironment) ⊄ Environment))) → (state$_i$(hardware) ∉State(hardware)) → (state$_i$(software) ∉ State(software)) → (state$_j$(hardware) ∉State(hardware)) (s6 ≤ s, s ∈ N)

Sub-scenario 3-7:

∃ ((operation$_i$ ∉ Operation) ∩ ((g-Envi$_s$ ∉ ImplicitEnvironment) → ((g-Envi$_s$ ∪ ImplicitEnvironment) ⊄ Environment))) → (state$_i$(hardware) ∉State(hardware)) → (state$_i$(software) ∉ State(software)) → (state$_j$(hardware) ∉State(hardware)) (s7 ≤ s, s ∈ N)

Sub-scenario 3-8:

∃ ((operation$_i$ ∉ Operation) ∩ ((a-Envi$_s$ ∉ ImplicitEnvironment) → ((a-Envi$_s$ ∪ ImplicitEnvironment) ⊄ Environment))) → (state$_i$(hardware) ∉State(hardware)) → (state$_i$(software) ∉ State(software)) → (state$_j$(hardware) ∉State(hardware)) (s8 ≤ s, s ∈ N)

ErrorManifestation: safety error

Solution: A complete set of predefined operating conditions and a complete set of domain constraints are given to build a complete domain knowledge ontology.

4）Type 4 of SHIEP

The type 4 of SHIEP in Fig. 8 is described as, unpredictable changes in operating conditions directly affect software and eventually lead to a system failure. The changes directly affect the software and cause abnormal software operations generating abnormal electrical signals through software-hardware interfaces. Then, the abnormal electrical signals directly act on the units of hardware components and then the hardware components of a system, and in turn cause global or local failures of the system. The complete process is shown in Fig. 12. This process is a closed loop feedback process, and every step is accompanied by a state transition.

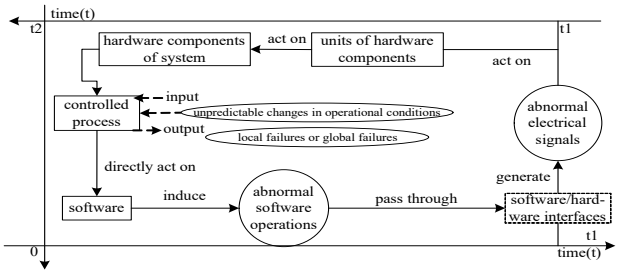

Fig. 12. Type 4 of SHIEP

The specific contents of the core part of type 4 of SHIEP are as follows,

Scenario of requirements incompleteness:

Scenario 4:

constraint$_k$(interact$_i$) ∈ Constraint(1 ≤ k ≤ l, 1 ≤ i ≤ n, k ∈ N, l ∈ N, i ∈ N, n ∈ N),

∃ (interact$_i$ ∉ Interact) →(state$_i$(software) ∉ State(software)) → (state$_j$(hardware) ∉State(hardware))

ErrorManifestation: safety error

Solution: A complete set of predefined operating conditions and a complete set of domain constraints are given to build a complete domain knowledge ontology.

V. Case Study

Various applications can be implemented based on the SHIEP, e.g., using the instances of SHIEP to guide the applications of failure mode and effect analysis (FMEA) method to detect the potential failure modes that may adversely affect system functions or performance. This is because the three core components of SHIEP represented by the ontology method are conducive to FMEA analysts familiar with the actual usage of a system and the weaknesses of a design. Then, the followings can be

achieved: (1) identify known or potential failure modes in a system; (2) assess the effect of the failure modes; (3) propose improvement suggestions to reduce or eliminate these failures. The above effects are particularly significant under the current software-intensive developmental trend of large-scale systems. And the basic work is to summarize test experience and collect related SHIEP instances, and then to represent them by the ontology and store them in an ontology library.

This paper takes a certain type of airborne radar software system as an example, uses protégé to edit the SHIEPs and their instances, and further introduces the applications of software FMEA (SFMEA) based on the above work.

5.1 Introduction of radar systems

Because SHIEP instances need to use the domain concepts of radar systems, the functional principle of radar systems is first introduced. Radar is a system that uses radio waves to find the position and movement of objects. Its basic task is discovering the interested objects, measuring the state parameters of distance, direction, and speed, etc. And it is mainly composed of an antenna, a transmitter, a receiver, a signal processor, a data processor, an indicator, and a display, as shown in Fig. 13 [21].

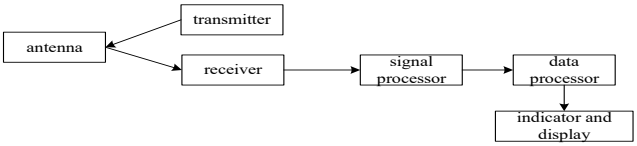

Fig. 13. Composition of radar systems

5.2 Ontology edit of SHIEP and SHIEP instances

Protégé is an extensible, cross-platform and open source development environment for generating and editing ontologies. It has been widely used and promoted in many countries. Protégé is one of the most popular ontology editing tools currently, capable of defining classes and class hierarchies, attribute relationships and attribute-value constraints, and the relationships between classes and attributes. Instance tags can be used to obtain the instances of classes defined in an ontology. This paper adopts Protégé to edit ontologies. Specifically, first establish an SHIEP class, and then establish its constituent component classes. For the sake of brevity, this paper only gives the three core component classes of SHIEPs: "Scenario" class, "ErrorManifestation" class and "Solution" class. Fig. 14 shows that an SHIEP class relates to its constituent component classes by an object property "isPartOf". After the completion of ontology editing, the description logic (DL) query in Protégé can be used for class queries or simple reasoning, which is not repeated here.

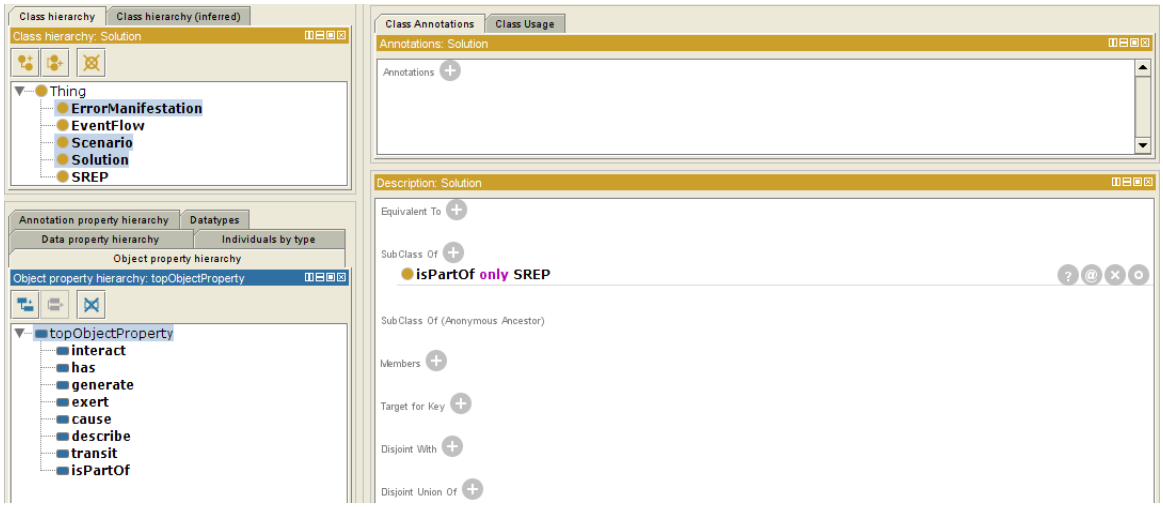

Fig. 14. Object property "isPartOf"

Experience has shown that the number of the failures based on SHIEs of radar systems found in reliability tests or in field usage is limited, far less than traditional failures. Therefore, the case study of SFMEA given below does not distinguish specific types of radar, but analyzes a specific type of error related to a certain type of stress, trying to reveal the effect of such stress on the SHIEs and the failures based on the SHIEs of radar systems.

5.3 FMEA based on SHIEP

1 System definition

1) Analyzing functions

The functions of the radar sub-system of a certain type of mission electronic system are to detect a target and measure the state parameters of distance, direction, and speed. A functional schematic diagram is shown in Fig. 15.

The dashed box of the "servo" in the figure indicates that this part is not available in all radar. For example, phased array radar (PAR) does not have a servo system.

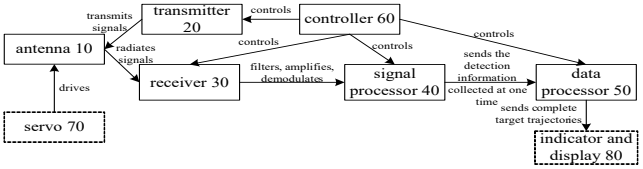

Fig. 15. Functional schematic diagram of radar sub-system of a certain type of mission electronic system

2) Drawing a block diagram

• Drawing a functional block diagram: the correspondence diagram of function level and structure level of a certain type of radar is shown in Fig. 16.

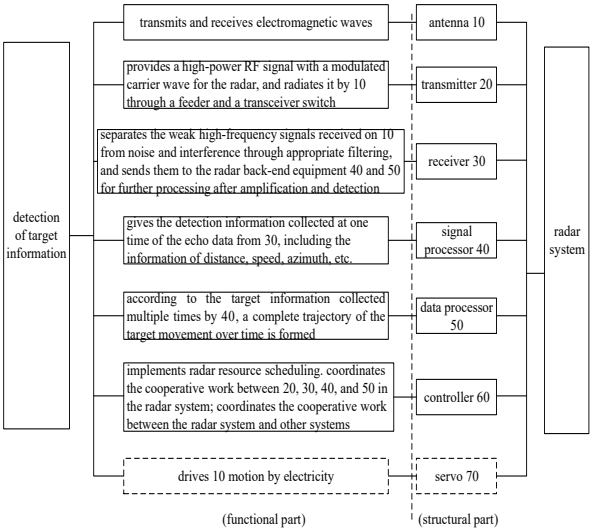

Fig. 16. Correspondence diagram of function level and structure level of a certain type of radar

2 Indenture levels

As shown in Fig. 18, an initial indenture level is "aircraft"; an indenture level is "radar system"; the lowest indenture levels are "antenna (10)", "transmitter (20)", ……, "controller (60)", etc.

3 Severity definition

The systems on an aircraft can be divided into two categories: (1) the systems that perform basic flight functions, e.g., power supplies, flying control (FC) systems, etc.; (2) the systems that perform specific tasks, e.g., mission electronic systems including radar systems and electronic countermeasures, etc. Although systems

• Drawing a mission reliability block diagram: the mission reliability block diagram of a certain type of radar system is shown in Fig. 17.

Fig. 17. Mission reliability block diagram of a certain type of radar system

that perform specific missions generally do not affect basic flight functions, they have a decisive effect on operational effectiveness and affect the reliability and safety of aircraft systems. Therefore, the definition of severity is given based on combat effectiveness and basic usage as shown in Table. II.

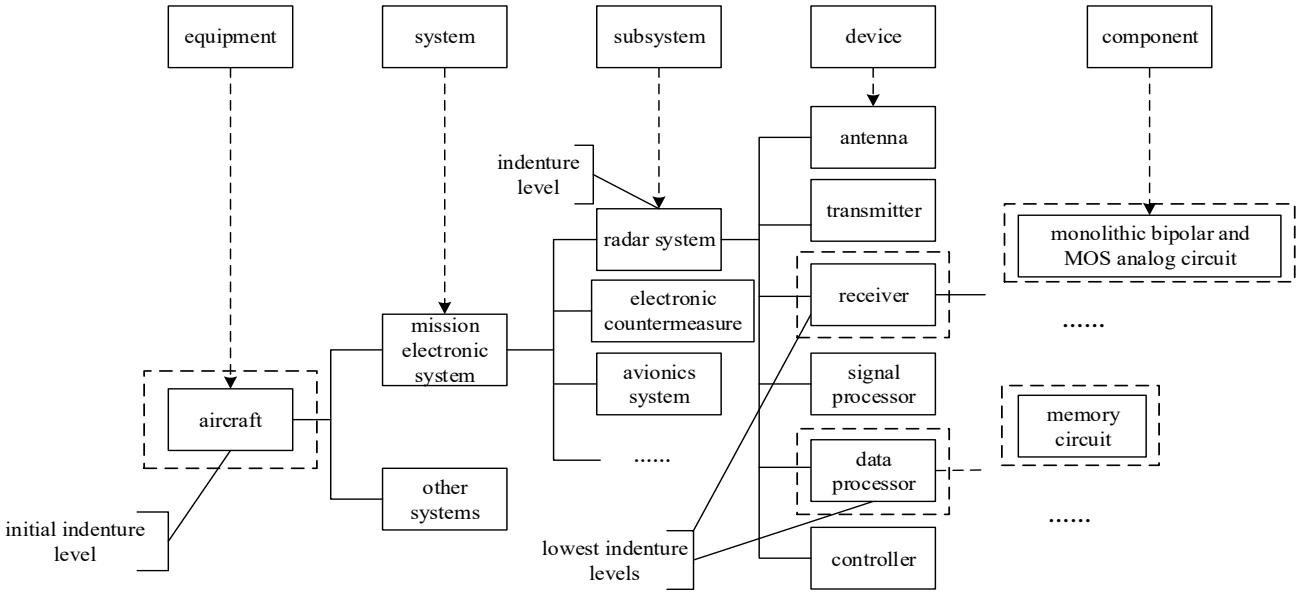

Fig. 18. An example of indenture level division of a certain type of mission electric system

TABLE II
TYPES AND DEFINITIONS OF SEVERITY

Types	Definitions
Type Ⅰ (hazardous)	Mission failures cause a complete loss of combat effectiveness, and may endanger the safety of personnel or aircraft.
Type Ⅱ (moderate)	The decrease in mission completion effect causes the decline in operational effectiveness (such as flight delay, suspension or cancellation of flight, declined flight quality, increased landing difficulty, moderate environmental damage, etc.), and may cause moderate injury to personnel or moderate damage to systems.
Type Ⅲ (minor)	No effect or little effect on operational effectiveness, but may increase unplanned maintenance or repair.

4 Failure mode analysis

The failure modes based on the SHIEPs of a certain type of radar system are mainly obtained from relevant information analysis. The occurrence probability levels of failure modes based on SHIEPs are divided into five levels: A, B, C, D, and E. Table. III shows the specific definitions.

TABLE III
OCCURRENCE PROBABILITY LEVELS OF FAILURE MODES

Occurrence probability levels	Severity levels* Ⅰ (catastrophic)	Ⅱ (moderate)	Ⅲ(slight)
A(frequently)	1	5	13
B(sometimes)	2	7	16
C(occasionally)	4	8	18
D(rarely)	8	12	19
E(nearly impossible)	12	16	20

Note: the shadow part of table should be paid special attention to. The smaller the value is, the greater the risk.

5 FMEA table filling

The software/hardware integrated FMEA method is an extension of traditional FMEA methods. A risk index table and a risk level table are shown in Table. IV and Table. V, respectively.

TABLE IV
DEFINITIONS OF RISK INDEX

Levels	Definitions	Occurrence probability characteristics	Ocurrence probability P (during product usage time)
A	frequently	very high probability	$\geqslant$ 20%
B	sometimes	medium probability	10% $\leqslant$ P < 20%
C	occasionally	relatively low	1% $\leqslant$ P < 10%
D	rarely	low	0.1% $\leqslant$ P < 1%
E	nearly impossible	very low	$\leqslant$ 0.1%

TABLE V
TYPES OF RISK LEVEL

Risk evaluation indexes	Risk levels	Evaluation criteria
1-5	very high	unacceptable
6-9	high	unexpected (generally not accepted)
10-17	moderate	acceptable (need to review)
18-20	low	acceptable

According to the specific analysis of this case, the software/hardware integrated FMEA table of a certain type of radar system is shown in Table. VI.

Traditional software testing methods have limitations in detecting the SHIEPs. For type 1, type 2 and type 3 of SHIEPs given in section 4, software testing usually assumes that a hardware platform on which it operates has always been in an ideal state, without considering the actual environmental conditions or workload of the product, which may change the hardware characteristics or performance of the product, and eventually affect software operations. Software problems caused indirectly by environmental stresses, e.g., vibration stresses or temperature stresses, need to be detected by the hardware environment on which reliability tests operate. This also shows the limitations of software as a downstream product that must be attached to hardware.

Take a failure instance detected in domain usage as an example: this failure is caused by the error that the delay error of a delay device increases at a low temperature. The delay error causes the timing signals unmatched, resulting in the wrong signal value received by software, and further causes the operation error of the software, which acts on system hardware and eventually causes the system to malfunction. Although the direct cause is a design problem, the root cause is that the changes in component characteristics under extreme temperature conditions are not considered in the requirements analysis stage. After the detailed analysis of the problem, the problem-related knowledge can be incorporated into the ontology library as new knowledge. The scenario where this error occurs is: "Environment → AtmosphereEnvironment → ExtremeTemperature" + "interaction between software and hardware". Similarly, there are errors that occur under extreme vibration conditions or external interference represented by EMI, which are not listed here.

In short, based on the collected SHIEPs and their instances, we can elicit the corresponding scenarios and error manifestations, analyze solutions, further guide the implementation of FMEA method, identify all possible SHIEPs, analyze the causes and possible effects of SHIEPs, determine the severity and risk of SHIEPs, eliminate or control the dangerous failures of safety-critical products, and formulate effective improvement measures to improve product reliability and quality.

VI. CONCLUSION

This paper first analyzed software error lifetime from the perspective of knowledge-based software engineering and proposed an error generation model. Then, it proposed the concepts of SEP and SREP based on the ODC. According to an error generation mechanism, four types of SHIEP in the requirement stage, and

TABLE VI
SHIEP-BASED FMEA TABLE OF A CERTAIN TYPE OF RADAR SYSTEM

Initial indenture level: aircraft | Analyze: XXX | Approve: XXX

Indenture level: radar system | Check: XXX | Date: XX, XX, XXXX

Codes	Identifiers of product (function)	Functions	SHIEPs	Failure causes		Mission phases and work modes	Failure effects			Severity types	OP levels of SHIEPs	REI	Failure detection methods	Improvement measures
				Mechanisms	Stresses		Local	Higher level	Final					
10	antenna	transmits/receives electromagnetic waves	type 1	the chip of control antenna enters a power saving mode under low temperature conditions			a chip enters the power-saving mode under low temperature conditions and does not communicate with a servo system	the screen does not show the built-in test (BIT) process of antenna	no pitch display on the screen	type III	C	18	vision	add a pull-up resistor to the chip's read-write end
20	transmitter	provides a high-power RF signal with a modulated carrier wave for the radar	-	-			-	-	-	-	-	-	-	-
30	receiver	Separates the weak high-frequency signals from noise and interference through appropriate filtering, and sends them to radar back-end equipment after amplification and detection	type 1	the error of a delay component (a linear integrated circuit) increases under low temperature conditions			causes mismatch between related timing pulses, resulting in timing waveform distortion	using the timing signal to control the data transmission of receiving channel causes transmission dislocation	causes the radar cannot track the target under low temperature conditions	type I	C	2	vision	uses a software delay to replace a hardware delay
			type 1	the delay time of a delay component (a linear integrated circuit) changes with temperature rise.	temperature stress	detection of target information	the failure of an external component causes the other component to dissipate insufficient heat, and the temperature rise changes the delay time of the delay device	causes a data conflict	causes the software to fail and further causes the mission to fail	type I	C	4	vision	strengthens component screening and improves component reliability
40	signal processor	gives the detection information collected at one time of the echo data from the receiver, including the information of distance, speed, azimuth, etc.	-	-			-	-	-	-	-	-	-	-
50	data processor	according to the target information collected multiple times by the signal processor, a complete trajectory of the target movement over time is formed.	type 1	data processing bus arbitration timing is closer to the critical value under low temperature conditions			reports a flight failure, a maintenance failure, no echo signal on the picture under an imaging state	reports a data processor failure, a transmitter failure, a receiver failure	cannot intercept a target during an aerial combat	type I	B	2	vision	improves the algorithm design of data processing bus arbitration timing
60	controller	implements radar resource scheduling. coordinates the cooperative work between the transmitter, the receiver, the signal processor, and the data processor in the radar system; coordinates the cooperative work between the radar system and other systems.	-	-			-	-	-	-	-	-	-	-

Notes:

REI: Risk evaluation indexes; OP levels of SHIEPs: Occurrence probability levels of SHIEPs

corresponding ontology representation were given. The results showed that the prior information based on the SHIEPs was helpful to discover potential failures and failure modes that may adversely affect the function or performance of SISs. Therefore, the proposed SHIEP was of great significance for improving the quality of software development and verification. However, the current application scope of this method is relatively limited, and the experimental results obtained are still lacking in quantity. This is because the construction of ontology is a time-consuming and laborious task, requiring the participation of domain experts, software engineers, etc. On the other hand, the collection of error data is also a long-term task, especially for today's increasingly complex software systems, there are many reasons for software errors. Moreover, there are constantly new errors and their causes with the development of new technologies. However, once the ontology is built, it will contain rich experience and domain knowledge, which provides the possibility for the reuse of data resources, as well as the possibility of resource conservation and efficiency improvement. In addition, an increasingly complete SEP set also lays the foundation for a comprehensive understanding of software systems to ensure their quality.

The defect analysis method of ODC is of great significance and has a profound impact on the software industry. How to use the ODC method more reasonably and effectively under the development trend of large, open, dynamic and non-deterministic software systems will be a continuous research topic.

REFERENCES

[1] M. R. Lyu, "Handbook of software reliability engineering," *Los Alamitos, California: McGraw-Hill Companies*, 1996.

[2] R. Chillarege, Bhandari, I.S., Chaar, J.K., Halliday, M.J., Moebus, D.S., Ray, B.K., Wong, M.-Y., "Orthogonal defect classification: a concept for inprocess measurements," *IEEE Transactions on Software Engineering*, 18(11), pp. 943-956, 1992.

[3] R. Chillarege, "Test and development process retrospective: a case study using ODC triggers," in *Proc. International Conference on DSN'02*. Washington, DC, USA, 2002, pp. 669-678.

[4] R. Chillarege, "Understanding Bohr-Mandel bugs through ODC Triggers and a case study with empirical estimations of their field proportion," in *Proc. 3th International WoSAR'11.* Washington, DC, USA, 2011, pp. 7-13.

[5] Lutz, R.R., Mikulski, I.C., "Empirical analysis of safety-critical anomalies during operations," *IEEE Transactions on Software Engineering*, 30(3), pp. 172-180, 2004.

[6] Nuno Silva etc., "Experience report: orthogonal classification of safety critical issues," in *Proc. IEEE 25th International Symposium on Software Reliability Engineering*, Naples, Italy, 2014, pp. 156-166.

[7] Raymond A. Paul, et al., "Defect-based reliability analysis for mission-critical software," in *Proc. 24th Annual International Computer Software and Applications Conference*, Taipei, Taiwan, 2000, pp. 439-444.

[8] Pan Tiejun etc., "Defect tracing system based on orthogonal defect classification," in *Proc. 2008 International Conference on Computer Science and Software Engineering*, Wuhan, China, 2008, pp. 574-577.

[9] LiGuo Huang, et al., "AutoODC: automated generation of orthogonal defect classifications," *Automated Software Engineering*, Springer, 22(1), pp. 3-46, 2015.

[10] Ferdian Thung, et al., "Automatic defect categorization," in *Proc. 19th Working Conference on Reverse Engineering*, Kingston, Ontario, Canada, 2012, pp. 205-214.

[11] Ruili Geng, et al., "In-process usability problem classification, analysis and improvement," in *Proc. 14th International Conference on Quality Software*, Dallas, TX, USA, 2014, pp. 240-245.

[12] Martin Wirsing, "Beyond the horizon-final report, thematic group 6 on software intensive systems," June 2006, pp: 1-39.

[13] T. R. Gruber, ‘‘Toward principles for the design of ontologies used for knowledge sharing?’’ *Int. J. Hum.-Comput. Stud.*, vol. 43, no. 5-6, pp. 907-928, Nov. 1995.
[14] Renzuo Xu, “The testing method based on software knowledge,” *J. Wuhan Univ.* (*Nat. Sci. Ed.*), 46(1), pp. 61-62, 2000.
[15] Xuan Hu, Bin Liu, Yichen Wang and Chongwu Jiang, “Application of software requirement error pattern based on ontology,” *Journal of Beijing University of Aeronautics and Astronautics*, vol. 35, no. 6, pp. 723-727, 2009.
[16] C. Alexander, “The timeless way of building,” *UK: Oxford University Press*, 1979, pp. 5-20.
[17] Xizi Huang, “Software reliability, safety and quality assurance,” *Beijing: Publishing House of Electronics Industry*, 2002.
[18] Zhijin, Linliu, Yingjin, “Software requirements engineering method,” *Beijing: Science Press,* 2008.
[19] Ruqian Lu, et al., “Ontology-oriented requirements analysis,” *Journal of Software*, 11(8), pp. 1009-1017, 2000.
[20] Jon G. Hall, Ivan Mistrík, Bashar Nuseibeh, Dr Andrés Silva, “Editorial relating software requirements and architectures,” *IEE Proc.-Softw.*, 152(4), pp. 141-142, 2005.
[21] Lufei Ding, Fulu Geng, Jianchun Chen, “Radar Principles,” *Beijing: Publishing House of Electronics Industry*, 2009.

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Estimation of Network Type Based on The Response Delay Property

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***Abstract*—The large number of Internet of things (IoT) terminals increases the cost and difficulty of IoT network management such as network scan. Some wireless IoT networks that have low transmission data rate especially require low overhead for network management to avoid interruption. Hence, it is important to make automatic identification of network type for effective network management. In this study, we at first carry out laboratory experiments of network scan to wireless terminals in wireless LAN (WLAN), Long Term Evolution (LTE) and Low Power, Wide Area (LPWA) networks that include Wi-SUN and LoRa network. From the result of response delay obtained from each network in the experiments, we then examine the basic property of the response delay, especially about the minimum response delay. Finally, we propose a scheme of network-type estimation based on the property of the minimum delay in different networks. The performance of the proposed scheme of network-type estimation is evaluated regarding the network objects of WLAN, LTE and LPWA networks. The evaluation results show that the scan response delay is a useful factor for successfully identifying different types of IoT networks.**

***Keyword*—Internet of things, response delay, network estimation**

I. INTRODUCTION

With the advances in Internet of things (IoT) technologies, the number of IoT terminals is rapidly increasing. In addition to conventional communication networks, a number of IoT networks emerge in recent years to meet requirements of IoT use on energy efficiency, long-time operation, and large coverage. For instance, Low Power, Wide Area networks (LPWANs) provide wireless communication with large coverage with low power consumption. In LPWANs, there are diverse network types, includes Wi-SUN and LoRa, each of which has its specification in communication [1], [2]. In this paper, the term of IoT networks refers to the broad scope networks that involve conventional networks and LPWANs because both networks are employed for operating IoT applications.

For the large number of networked IoT terminals, efficient network management is important for reliable and safe communication. Network scan, including TCP port scan and ping-based scan using Internet Control Message Protocol (ICMP), is an important way to detect the network connection status and vulnerable terminals [3–6]. In a scan event, a scanner probes the target network terminals to acquire information such as the port usage state as well as the response delay. Those kinds of information is helpful for network administrator to monitor network congestion status and to detect the vulnerable IoT terminals.

Due to the large population of IoT terminals, the network management employing network scan may incur large traffic overhead that causes the interruption on IoT networks and operation of IoT terminals. The impact of network scan traffic on IoT networks differs according to the types of IoT networks that have different amounts of available communication resources, transmission data rates, and allowable energy consumption.

Hence, automatic identification of IoT network type is a key technology to realize the successful network scan. Identification of the network type assists the scheduling of scan and to alleviate interruption to the IoT networks. It also helps the estimation of the underlying causes of network malfunctions and failure of scan events [7].

The studies of identification of IoT devices have been introduced in reference in [8–9]. The methods include classifying the IoT devices based on TCP port status or network traffic from the devices. On the other hand, these studies have not addressed how to identify the network type of IoT devices. In reference [5], we introduced a preliminary study about the estimation of network types. However, the paper focuses on examining only the object networks of LPWAN and wired LAN. Moreover, the network estimation method is limited to use the information of the average response delay of the known IoT networks.

This paper is an extended version of the reference [6]. From the reference [6], we extend the network objects for examination by including Long Term Evolution (LTE) network in addition to WLAN and LPWA networks. First,

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the properties of the network LTE network are measured and added to the set of delay properties regarding minimum delay of each network type. Furthermore, due to the increase of the number of objects to estimate, the evaluation of network estimation is re-conducted according to the new configuration of the set of minimum delay at object networks. Consequently, in the evaluation results, we show the performance of network-type estimation from the response-delay sample for WLAN, LTE, Wi-SUN and LoRa network.

In this paper, to enable network type estimation, we at first examine the response delay property of IoT networks that include wireless LAN (WLAN), LTE, and LPWAN with laboratory experiment. We propose a network estimation method utilizing the minimum response delay of each IoT network. We also carry out the comparison with the average delay based method [5] regarding the correctness of network type judgement. The evaluation results show that the proposed method is able to successfully identify the network type from the response delay of scan events.

The rest of this paper is organized as follows. Section II introduces the system model. Section III describes the property of response delay in IoT networks. Section IV describes the proposed method of network-type estimation and evaluation results. Section V concludes this article.

II. SYSTEM OVERVIEW

The network scan system utilizes a network scanner to measure the status of various IoT terminals. An example of the scan system is illustrated in Fig. 1. We consider several target wireless networks such as WLAN, LTE and LPWANs including Wi-SUN and LoRa network. To assess the status of IoT terminals, the scanner probes the IoT network by issuing a series of scan events to the IoT terminals. (In this paper, the terms of device and terminal have the same meaning.) A scan event in this paper refers to an ICMP ping operation. That is, in a scan event, the scanner issues a ping packet that traverses between the scanner and a target IoT terminal.

The network scan system measures the round trip time (RTT) spent in the target access network (ARTT) [5]. ARTT may have different properties according to the network type. Hence, the ARTT information will be used for network type estimation. In the following parts of this paper, the term of response delay refers to the ARTT in a scan event. The network estimation can be expressed as follows. Suppose that there are K network types to which the scanner monitors and performs network scan. The scan system tries to estimate the network type from the response delay data in terms of the ARTT.

The study of network type estimation introduced in this paper consists of two parts. (1) Preliminary investigation of the ARTT property with experimental measurement, especially with a focus on the minimum response delay of each network type. Measurement of the response delay in scan events is carried out by experiment on WLAN, LTE, and LPWA networks including Wi-SUN and LoRa network; we then investigate the characteristics of the response delay, especially the minimum response delay, from the results obtained through the experiments. (2) Estimation of the network type according to the response delay property of the minimum response delay in each network.

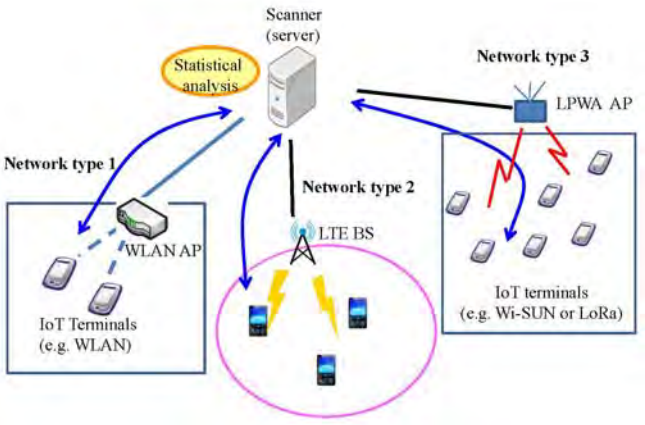

Fig. 1. An example of network scan system.

III. THE MEASUREMENT OF RESPONSE DELAY IN IOT NETWORKS

A. Measurement of Response Delay Property

We examine the properties of response delay of network scan in WLAN, LTE, Wi-SUN and LoRa network. These properties include the minimum, average and maximum of ARTTs, as well as the empirical probability distribution function (PDF) of ARTT result in each network type. Although the laboratory experiments on measurement of ARTT in different networks have constraints regarding to the scale of networks and diversity of environment, such basic experiments provide the basic properties of ARTT in each object networks.

The scenario of WLAN experiment setup is shown in Fig. 2. The network consists of a scanner, a WLAN access point (AP) and the terminal. The connection between the AP and the terminal is IEEE 802.11b/g/n WLAN in 2.4 GHz band. The connection between the scanner and the AP is by Ethernet.

The scenario of measurement in LTE simulator testbed is shown by Fig. 3. The experiment involves a scanner, an LTE BS simulator MD8475B and a LTE-handset terminal. The link between the scanner and the BS simulator is Ethernet. The link between the BS simulator and the terminal is LTE based wireless connection using Band 21 (1.5 GHz).

The scenario of experiments in Wi-SUN or LoRa network is shown by Fig. 4. The experiment involves a scanner, an LPWA access point (AP) and terminals of Wi-SUN and LoRa. The link between the scanner and the AP is Ethernet. The link between the AP and the terminal is wireless connection of Wi-SUN and LoRa network in a channel of 920 MHz band.

In the experiment, a series of scan events is issued to each network to measure the response delay. The interval between scan events in WLAN, LTE, and Wi-SUN is set to one second. While the interval between scan event in LoRa is set to 5 seconds due to the low data rate of LoRa. We measure response delay RTT, which is used as ARTT because the transmission delay in the wired network is much smaller than that in the wireless networks. Then, we construct the property database of each network type from the collected information of 500 samples of response delay in each network.

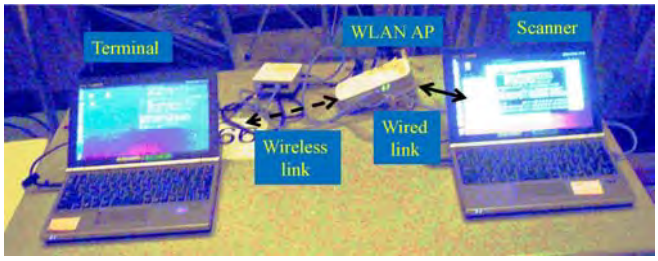

Fig. 2. Experimental scenario of WLAN.

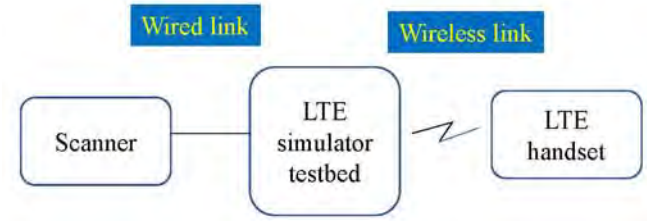

Fig. 3. Experimental scenario of LTE.

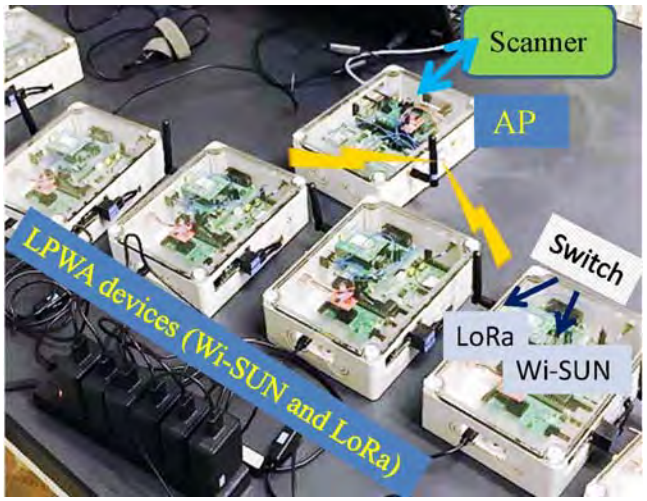

Fig. 4. Experimental scenario of LPWA network: Wi-SUN and LoRa network.

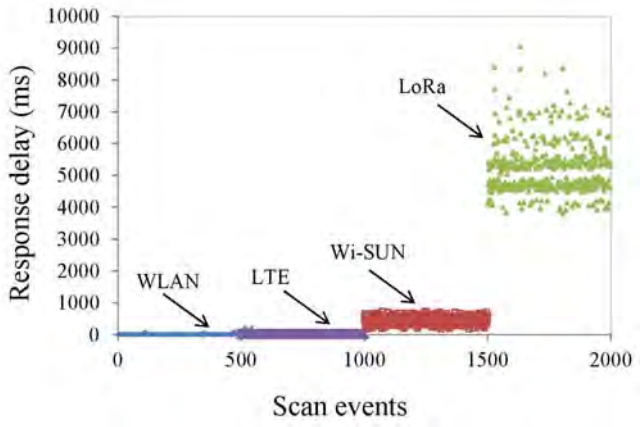

Fig. 5. Response delay in WLAN, LTE, Wi-SUN, and LoRa network.

B. *Property of the Response Delay in Different Networks*

Fig. 5 illustrates measured samples of response delay in the experiment of WLAN, LTE, Wi-SUN and LoRa network. The response delay in WLAN is distributed between 0 and 84 ms. The average delay of scan evens in WLAN is 2.16 ms. The response delay in LTE is distributed between 19.28 ms and 137.95 ms. The average delay of scan evens in LTE is 24.48 ms. The response delay in Wi-SUN is distributed between 180 and 738 ms. The average delay in Wi-SUN is 460.4 ms, which is much larger than those in other networks. The response delay in the LoRa network is distributed between 3808 and 9047 ms. The average delay in the LoRa network is 5250 ms, which is much larger than those in WLAN, LTE and Wi-SUN.

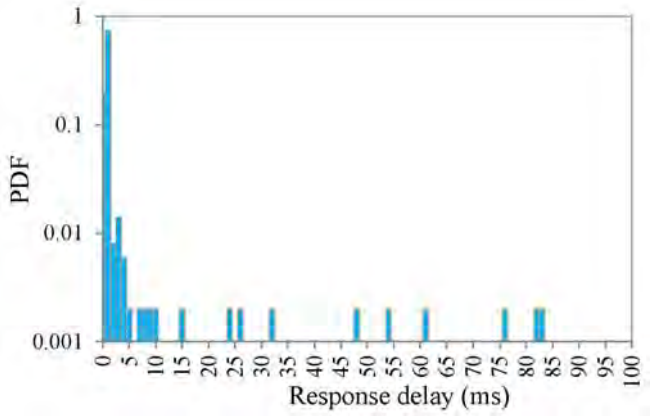

Fig. 6. The empirical PDF of response delay in WLAN.

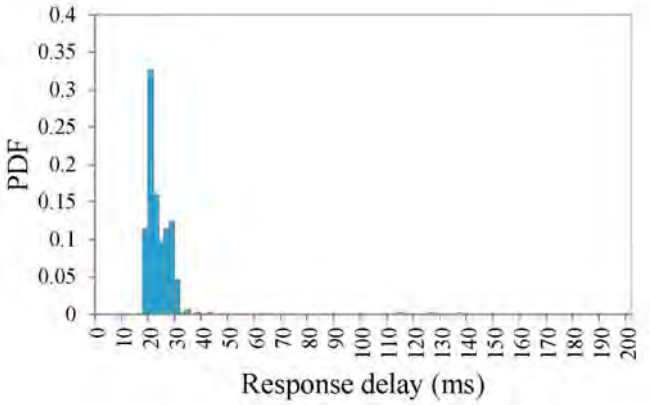

Fig. 7. The empirical PDF of response delay in LTE.

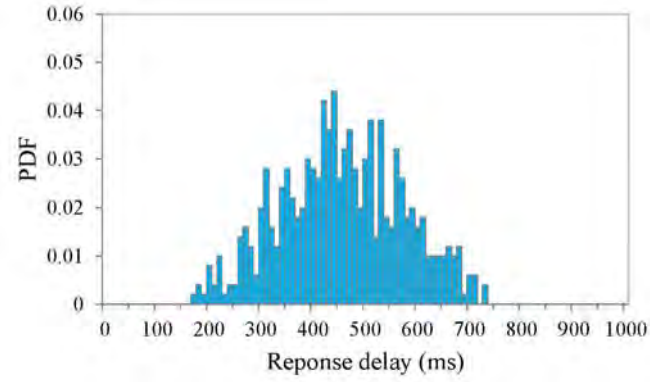

Fig. 8. The empirical PDF of response delay in Wi-SUN.

TABLE I
ESTIMATION RESULT FROM THE RESPONSE DELAY DATA OF WLAN, LTE, WI-SUN AND LORA ACCORDING TO THE MINIMUM DELAY PROPERTY OF EACH ETWORK TYPE. (FROM 200 OBSERVED SAMPLES FROM EACH NETWORK TYPES.)

Scan object network	The number of WLAN judgements	The number of LTE judgements	The number of Wi-SUN judgements	The number of LoRa judgements
WLAN	199	1	0	0
LTE	0	197	3	0
Wi-SUN	0	0	200	0
LoRa	0	0	0	200

TABLE II
ESTIMATION RESULT FROM THE RESPONSE DELAY DATA OF WLAN, LTE, WI-SUN AND LORA ACCORDING TO THE AVERAGE DELAY PROPERTY OF EACH ETWORK TYPE. (FROM 200 OBSERVED SAMPLES FROM EACH NETWORK TYPES.)

Scan object network	The number of WLAN judgements	The number of LTE judgements	The number of Wi-SUN judgements	The number of LoRa judgements
WLAN	199	1	0	0
LTE	0	200	0	0
Wi-SUN	0	7	193	0
LoRa	0	0	0	200

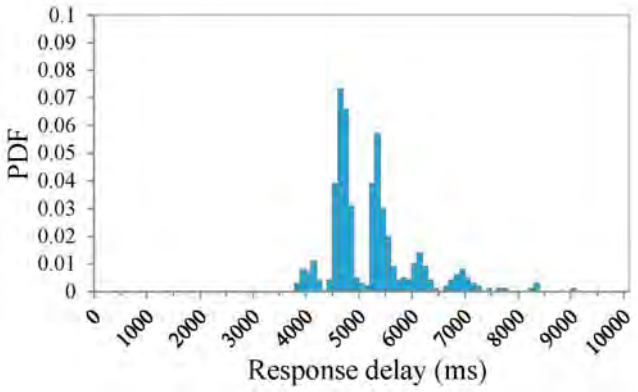

Fig. 9. The empirical PDF of response delay in LoRa network.

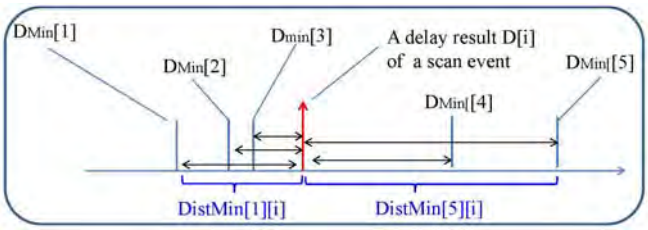

Fig. 10. Distance to the minimum response delay (K = 5).

IV. METHOD OF NETWORK-TYPE ESTIMATION BASED ON THE PROPERTY OF THE MINIMUM RESPONSE DELAY

A. Network Type Estimation Scheme

Suppose that there are K types of the object networks, to which the scan events are issued. We denote the set of object networks to be examined by $N_A = \{N_1, N_2, \ldots, N_K\}$. For an object network x in N_A, the minimum response delay is denoted by $D_{Min}[x]$, where x is a member in N_A. A set of minimum delays corresponding to all network types is denoted by $\{D_{Min}[N1],\ldots, D_{Min}[N_K]\}$. This minimum delay information is obtained by the preliminary experimental measurement in each object IoT network. Let DistMin[x][i] stand for the distance between a result of response delay D[i] to $D_{Min}[x]$, as illustrated in Fig. 10 that assumes K is 5.

As shown in Algorithm 1, the proposed method estimates network type according to DistMin[x][i]. For each result of response delay regarding the i-th scan event, the scan system computes the DistMin[x][i] corresponding to all network types in NA by DistMin[x][i] = $|D[i]-D_{Min}[x]|$, as shown in Fig. 10.

As a consequence, the scan system collects a set of DistMin[x][i], x is a member in N_A. Let Z be the network type that gives the least DistMin[x][i]; x is a member in N_A. Then, Z is the result of network estimation. (For multiple networks that has the same least DistMin[x][i], the estimation result can be set to unknown or either of the network types that gives the least DistMin[X][i] for X in NA).

B. Evaluation of network estimation

We examine the effectiveness of the proposed method by utilizing the measurement results obtained from the experiment scenarios introduced in Section III. The minimum response delay of each object network is obtained

Algorithm 1: The proposed algorithm of network type estimation

Input: $D[i]$: the response delay of the i th scan event; $D_{Min}[x], x \in N_A$: the minimum delay of each network type x.
Output: The result of estimated network type

```
for x ← 1 to x = k do
    DistAve[x][i] ← |D[i] − D_Min[x]|;
    if x = 1 then
        DistLeast ← DistMin[x][i];
        Z ← x;
    if x > 1 then
        if DistLeast > DistMin[x][i] then
            DistLeast ← DistMin[x][i];
            Z ← x;
EstimatedNetwork ← Z; return The estimated network type EstimatedNetwork
```

from 500-sample data of scan events. Network type estimation is carried out from response delay results in 200 scan events in each object networks. These result data belong to the 500-sample data of scan events from which the minimum response delay is derived, while each of which are independent to each other. The results of network type estimation from the response delay information in WLAN, LTE, Wi-SUN and LoRa network are shown in Table I. The proposed method is able to successfully identify WLAN, LTE, Wi-SUN and LoRa in all judgements. We also carry out the network estimation based on the property of average response delay to make a comparison with the proposed method [5]. The result of network type estimation based on average delay property is shown in Table II.

We can find the proposed method have a higher success rate than that the method based on average delay property. The largest number of failed judgements in the proposed method is 3 in 200 judgements for LTE. While the method utilizing the average delay property fails 7 times in 200 estimation tests for Wi-SUN. We consider the reason why the proposed method shows better performance is the minimum response delay reflects the distinct network property much more than that of average response delay with respect to the distribution of response delay.

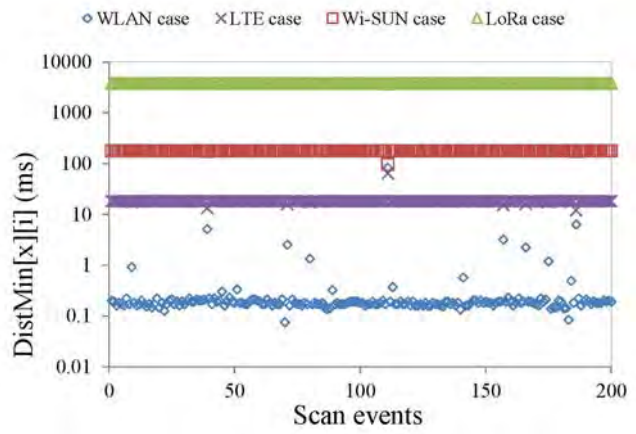

Fig. 11. WLAN case: distances between the response delay (D[i]) of each scan event in WLAN and the minimum response delay of each network type (DMin[x]).

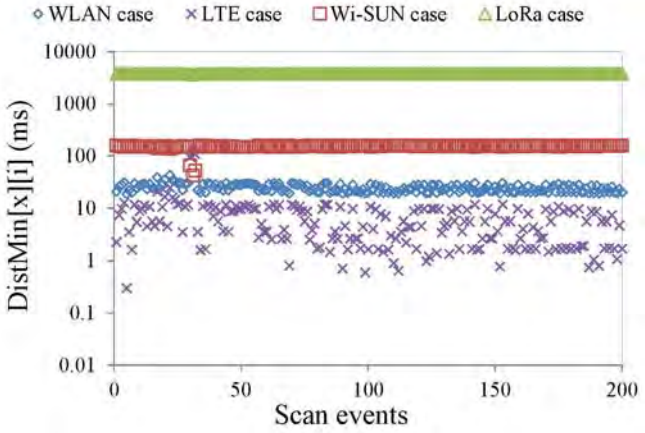

Fig. 12. LTE case: distances between the response delay (D[i]) of each scan event in LTE and the minimum response delay of each network type (DMin[x]).

Fig. 11, Fig. 12, Fig. 13, and Fig. 14 show the distances between the response delay (D[i]) of each scan event and the minimum response delay of each network type obtained in the learning ($D_{Min}[x]$). Fig. 11 illustrates that the response delay in WLAN is closest to the minimum response delay of WLAN, with the distance ranging from 0.075 ms to 82.66 ms. Fig. 12 illustrates that the response delay in LTE is closest to the minimum response delay of LTE, with the distance ranging from 0.3 ms to 118.67 ms. Fig. 13 illustrates that the response delay in Wi-SUN is closest to the minimum response delay of Wi-SUN, with the distance ranging from 10 ms to 554 ms. Fig. 14 illustrates that the response delay in LoRa network is closest to the minimum response delay of LoRa network, with the distance ranging from 34 ms to 5239 ms.

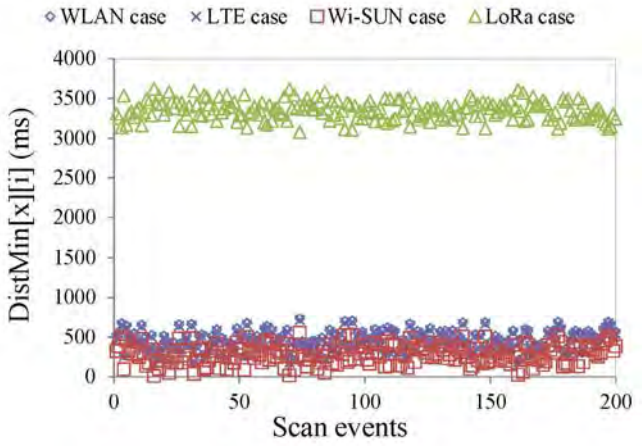

Fig. 13. Wi-SUN case: distances between the response delay (D[i]) of each scan event in Wi-SUN and the minimum response delay of each network type (DMin[x]).

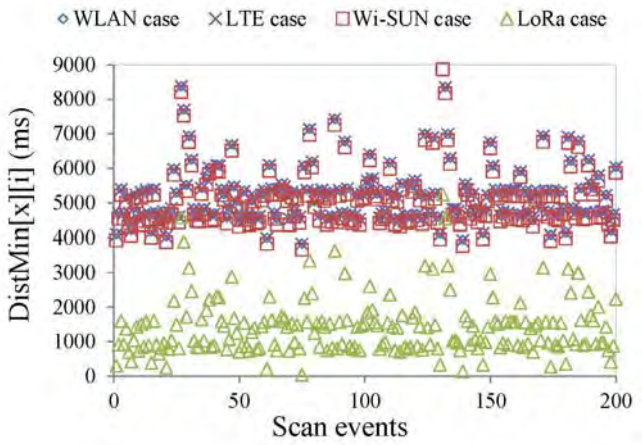

Fig. 14. LoRa network case: distances between the response delay (D[i]) of each scan event in LoRa network and the minimum response delay of each network type (DMin[x]).

V. CONCLUSION

In this paper, we investigated the basic properties of the minimum response delay in the network scan in WLAN, LTE, Wi-SUN and LoRa network. By laboratory experiments, we found that each network has quit different distribution of response delay. We then proposed a method to estimate network type from response delay. The proposed method determines the network type whose minimum response delay

is nearest to the instantaneous one of the target scan events. The effectiveness of proposed method was verified by using experimental results of response delay and the network property of the minimum response delay. The evaluation results of network estimation showed that the proposed method successfully identifies the three object networks of WLAN, LTE, Wi-SUN and LoRa network in scan events.

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REFERENCES

[1] H. Harada, K. Mizutani, J. Fujikawa, K. Mochizuki, K. Obata, and R. Okumura, "IEEE 802.15.4g Based Wi-SUN Communication Systems," *IEICE Trans. Commun*., vol.E-100B, no 7, pp.1032–1043, July 2017.

[2] F. Adelantado, X. Vilajosana, P. Tuset-Peiro, B. Martinez, J. Melia-Segui and T. Watteyne, "Understanding the Limits of LoRaWAN," *IEEE Commun. Mag*., vol.55, Issue 9, pp.34–40, Sept. 2017.

[3] K. Yano, N. Egashira, T. Kurihara, S. Shimizu, and Y. Suzuki, "Research and Development on Wide Area Network Scan Techniques for IoT Wireless Equipment," *IEICE Tech. Rep.*, NS2019-85, pp.203–208, July 2019.

[4] R. Das, N. Baranasuriya, V. Padmanabhan, C. Rodbro, and S. Gilbert "Informed Bandwidth Adaptation in Wi-Fi Networks using Ping-Pair," in *Proc. CoNEXT 2017*, pp.376–388, Dec. 2017.

[5] R. Teng, S. Araki, K. Yano, and Y. Suzuki, "Statistical Study on Response Delay Characteristics of Network Scan to IoT Devices – The Base for Estimation of IoT Device Attributes," *IEICE Tech*. Rep., NS2019-142, pp.45–49, Dec. 2019.

[6] R. Teng, K. Yano, and Y. Suzuki, "Identification of IoT Network Type Based on The Response Delay Property," in *Proc. IEEE 22nd International Conference on Advanced CommunicationsTechnology (ICACT2020)*, Pyeongchang, Korea, pp. 319–324, Feb. 2020.

[7] B. Ojetunde, N. Egashira, T. Kurihara, K. Yano and Y. Suzuki, "Factor Discrimination of Scanning Failure and Delay for Efficient Network Scanning of IoT Wireless Equipment," in *Proc. CCNC 2020*, pp. 1-2, Jan. 2020.

[8] A. Sivanathan, H. Gharakheili, and V. Sivaraman, "Can we classify an iot device using tcp port scan?" in *Proc. IEEE ICIAFS*, pp.1–4, Dec. 2018.

[9] Y. Meidan, M. Bohadana, A. Shabtai, J. D. Guarnizo, M. Ochoa, N. O. Tippenhauer, and Y. Elovici, "Profiliot: a machine learning approach for iot device identification based on network traffic analysis," in *Proc. the Symposium on Applied Computing*, pp. 506–509, April 2017.

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Determination of Subscribers Coordinates using Flying Network for Emergencies

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***Abstract*— In the last decade, unmanned aerial systems have emerged in different fields, such as entertainment, military, Internet of Things, emergencies. In these systems, unmanned aerial vehicles (UAVs) communicate with each other based on a flying network to provide services to customers such as live streaming, high-speed access point, etc. The mobility of UAVs can bring numerous advantages in emergency cases, for example, rescuing and searching victims in areas where the network infrastructure is not available. However, the crucial task needed to be done first is to locate the victims' coordinates. In this paper, we propose a method for detecting the coordinates of subscribers with the Wi-Fi signals generated from victims' phones in the absence of network infrastructure of communication operators using a flying network for emergencies based on UAV-swarms. We develop a new protocol for communication between UAVs and UAV-swarms. A structure of UAV-swarms is considered to optimize the searching time. The results of the proposed method are achieved by simulation.**

***Keyword* — SAR, UAV, Flying Network, positioning, Wi-Fi, IEEE 802.11p**

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I. Introduction

EVERY year, a significant number of people around the world die as a result of untimely assistance. Examples include earthquakes, tsunamis, and other natural disasters of natural and artificial origin. In addition, a considerable number of individuals disappear in forests due to the inability to contact emergency services. The effectiveness of searching and rescuing operations can be improved by using new approaches to detect victims, which are based on using a UAV group with attachments - a flying network [1], [2]. Such a network can reduce the time required to locate victims as well as reduce the number of people involved in the operations [3], [4].

When a disaster occurs, infrastructure and the communication systems in this area are destroyed, and they cannot be able to operate. The rescue team comes to the area and deploys UAVs to operate missions. UAVs will fly, do the searching and rescuing operations and establish a quick deployment flying network to make it possible for rescue teams on the side to contact each other, as well as victims who can contact outside for help. The first and most important thing is to identify the victim's location in the search area, and thanks to the UAVs, searching operations become time-saving and highly accurate. After a disaster, it's also challenging to find people, who were buried under debruises, or they were unconscious. There are many ways to determine the victim's location, but searching through beacon signals from devices attached to the victims, such as smartphones, laptops, and tables, which have a Wi-Fi connection, becomes useful and easy to deploy. To identify the victim's location through the location of the phone that the victim carries with him, at least UAV-swarms need to receive three signals [5], [6].

Nowadays, smartphones and smartwatches have become indispensable things for humans, and almost everyone carries these devices with them at any time. This factor also is an essential part of smart cities, smart countries when everything needs to be connected seamlessly. In smart cities, a public Wi-Fi network is always designed for the people in order for everyone to connect to this network and use the services of the

smart city [7]-[9]. Thanks to that, the process of searching and rescuing through finding signals from the victim's phone also becomes easier. When UAV-swarms, which have functioned as an Access Point (AP), use this public Wi-Fi network to send beacon signals to the victim's phone, the phone will confirm and respond to the signals that is the basis for detecting the location of the victim.

Related papers using UAVs to find signals from the victim's phone can be found in some studies, such as in [10], [11]. The authors of [10] proposed a system named Krypto, which addressed the challenges of maximizing the size of the searching area and minimizing the location errors with different approaches. In this paper, however, the authors did not consider the UAV-swarm Fixed-Wing type, as well as the influence of the distance measurement error and the number of received signals, and the considered area was small in comparison with our targeted area. In [11], the authors used the UAV to track indoor smartphones or watches owned by the victim by sending to the UAV the received signal's strength and the UAV location with a shallow Q-learning algorithm. However, the paper studied only one single UAV with an indoor search and rescue mission.

In this paper, we propose a method for detecting subscribers' coordinates with the Wi-Fi signals generated from victims' phones in the absence of network infrastructure of communication operators using a flying network for emergencies based on UAV-swarms. On the basis of this work, a draft Recommendation ITU-T Q.ETN-DS "Signalling architecture of the fast deployment emergency telecommunication network to be used in a natural disaster" is being developed in the 11th research commission of the standardization sector of the international telecommunication union "Signalling requirements, protocols, test specifications and combating counterfeit products" (SG11 ITU-T). The protocol of inter-communication between UAVs in flying network for emergency systems is present in Section II. The flying network and deployment models are described in Section III. The positioning methods and the assessment of positioning errors are considered in Section IV. The conclusion of the article is shown in Section V.

II. PROTOCOL OF INTER-COMMUNICATION BETWEEN UAVs IN FLYING NETWORK FOR EMERGENCY SYSTEMS

A. Basic statements

In recent years, a group of UAVs working together as a network has proven to be effective, useful, and flexible. This network often is called Flying Ad-hoc Networks (FANET), which is considered a subset of Vehicular Ad-hoc Network (VANET) and Mobile Adhoc Network (MANET). The development of an autonomous FANET depends on the quality of inter-communication between UAVs. Currently, however, there is no technology for inter-communication between UAVs and UAV groups. Since FANET is seen as a subnet of VANET, inter-communication technology in VANET is one of the great candidates.

The current inter-communication technology in VANET mainly uses IEEE 802.11p. In the process of developing to 5G, there are new technologies for VANET such as C-V2x, IEEE 802.11bd, or 5G NR (5G and new radio). However, the C-V2x technology is still in the process of being completed, it has only been simulated on models, and it works well thanks to the existing foundation of cellular network, therefore, in the case of emergency rescue when the network infrastructure is not working, it cannot be applied. IEEE 802.11bd is a new technology that is under development based on IEEE 802.11n/ac, promising to be able to replace and be compatible with IEEE 802.11p, but there is still a long way to go. Similarly, C-V2x, 5G NR are future technologies for inter-communication of vehicles, but it is now just in the early development process [12]-[15].

IEEE 802.11p [16] protocol is a modified version of the familiar IEEE 802.11 (Wi-Fi) standard, which was originally developed for VANET. The IEEE 802.11p standard was adopted as Medium Access Control (MAC) and Physical Layer (PHY) specifications for the lower-layer Dedicated Short-Range Communication standard (DSRC), which has characteristics such as frequency range - 5.9 GHz (5.85-5.925 GHz), wide coverage (up to 1000 m), fast transmission rate (up to 27 Mbps), self-organization and fast convergence. This approach is commonly referred to as vehicle-to-any (V2X) communication. Compared to cellular networks, Wi-Fi-based V2X communication does not offer a pre-installed infrastructure and (almost) full spatial coverage. However, its direct communication capabilities among nodes with short communication latency make it a strong candidate for vehicle safety and traffic efficiency applications [17].

B. Proposed work

In a flying network for emergencies, which focuses on searching for victims of natural disasters, UAV-swarms move with a certain flight mission and have a geographical limitation. In such a network, UAVs interact with each other to receive a flight task from the mobile base station (MBS), or send the collected data to MBS.

In [18], a modified MAC sublayer was proposed based on the IEEE 802.11p and IEEE 1609.4 protocols for communication between UAVs and UAV-swarms. IEEE 1609.4 protocol [19] allowed adding a seven-channel MAC scheme to the MAC layer of IEEE 802.11p. Each channel has a total bandwidth of 10 MHz. These channels consist of one control channel (CCH - Control Channel 178) for managing the network and transmitting safety messages and six service channels (SCH - Service Channels 172, 174, 176, 180, 182, 184) for other traffics. All vehicles must monitor the control channel with safety/control messages during the CCH period and will be able to switch to the service channel to exchange only non-safety applications.

The proposed protocol (Fig. 1) includes three different sub-protocols:

- Cluster management protocol (CMP);
- Intra-cluster communication protocol (IntraCP);
- Intercluster communication protocol (InterCP).

We denote the combination of these protocols as cluster-based Multichannel MAC IEEE 802.11p protocol (CMMpP). In this case, the UAV-swarm is considered as a cluster and the UAV as a node. The protocol is focused on data transmission between mesh network elements, in which routing should be performed at the data link layer, or, in other words, based on MAC addresses. This is the difference from mobile Ad-hoc networks, in which the focus is on standardizing the functions of the network layer [26].

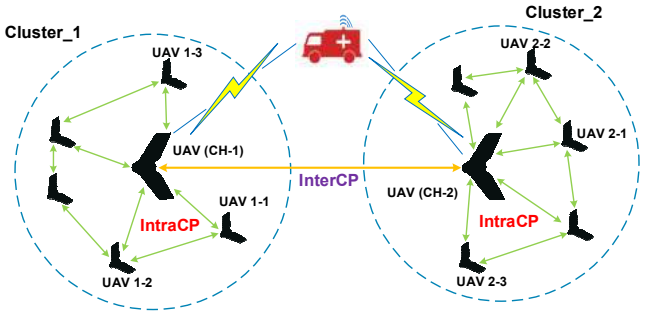

Fig. 1. UAV-swarms using protocol CMMpP

In the first step of the searching operation, the MBS moves to the searching zone. Next, UAV-swarms (clusters) are deployed to collect information, establish communications and exchange data. These clusters use the CMP protocol to select a cluster head (CH). The CH node can be reassigned during the task's execution depending on the location, and the speed of nodes in the cluster. The CH node is responsible for collecting information from cluster members (CM - cluster member) and subsequent transmission to the MBS or CH nodes of other clusters. The CH nodes also act as an intermediate for transmission, scheduling, channel assignment through message management.

Nodes will use IntraCP and InterCP for data transmissions. These protocols use the IEEE 1609.4 and IEEE 802.11p multi-channel MAC sublayer in conjunction with TDMA for each communication session. In particular, the IntraCP protocol performs the following main tasks:

- Collecting/Delivering control messages from/to CM on CCH channel;
- Allocating the available SCH channels to CM for data traffic;
- Contending to transmit data on the SCH in the cluster.

Meanwhile, the InterCP protocol is responsible for establishing communication between different clusters (transmission of both control messages via CCH and data via SCH). In the CMMpP protocol, each node is equipped with two transceivers, designated respectively "Trans_1" and "Trans_2". They can work simultaneously on different channels. "Trans_1" is always set to CCH for monitoring and transmitting control messages on the CCH channel, and "Transmit_2" is set to any SCH channel (channels 174, 176, 180, 182) to perform data transmission. Therefore, instead of the CCH (CCHI) and SCH (SCHI) intervals of 50 ms for each transceiver, the entire synchronization interval of 100 ms can be used. In addition to using the CCH channel 178 for control messages, the SCH channel 182 is proposed exclusively for InterCP. Thus, SCH channels 174, 176, 180 will be used to assign to CM nodes for IntraCP transmission data. It should be noted that only SCH channels 174, 176, 180 can be used for data transmission in a cluster (IntraCP). However, inter-channel communication (InterCP) will be carried out on SCH channel 182. These operations occur in non-overlapping channels, so they do not affect each other.

C. Simulation and results

The simulation was performed in the Riverbed Modeler, and the performance of the proposed CMMpP protocol was evaluated based on the results. As shown in [20, 21], the Riverbed Modeler package does not have an IEEE 802.11p module designed for operation in flying networks. When setting the initial data, all models with a bandwidth of 10 MHz were selected. The data transfer rate was set to 12 Mbit/s, and CH nodes are used as the access points. As for the CCH simulation, all vehicles must operate at the center frequency with the channel 178 in the range 5885-5895 MHz. Therefore, the minimum frequency should be 5885 MHz. Other parameters are set by default or as in [21].

Four scenarios are evaluated with one central BS, one MBS, and five clusters, each of which has 1 CH node, and the numbers of its member nodes (CM) for each scenario are 4, 8, 16, and 32, respectively. The mobility of nodes with trajectories is determined by the Mobility Config and Trajectory modules. Application and profile configurations are used to create messages and configure scripts. The duration of each simulation scenario is 60 minutes, and the EDCA parameters are set by default. We analyze the transmission of service messages and voice traffic in simulation.

As an example of these four scenarios, we study five clusters, each of which has 8 CM and 1 CH. Fig. 2 shows the average throughput for each member of the nodes in one cluster (Cluster_1) from those five. The average throughput of the CH-1 node is proven to be the highest since it is the head cluster.

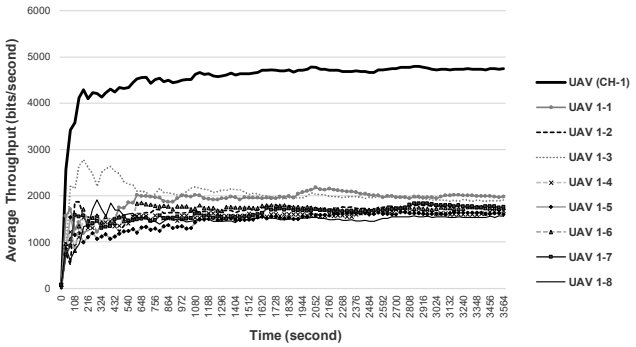

Fig. 2. The average throughput for each UAV in one cluster

The number of retransmission attempts for different scenarios is shown in Fig. 3. The result shows that an increase in the network size leads to the increase of the number of nodes using the same channels SCH. This also results in conflicts during transmission, and therefore, the number of retransmission attempts increases with time. It should be noted that the vertical axis of the graph shows the ratio of the number of packets to be retransmitted to the total number of packets.

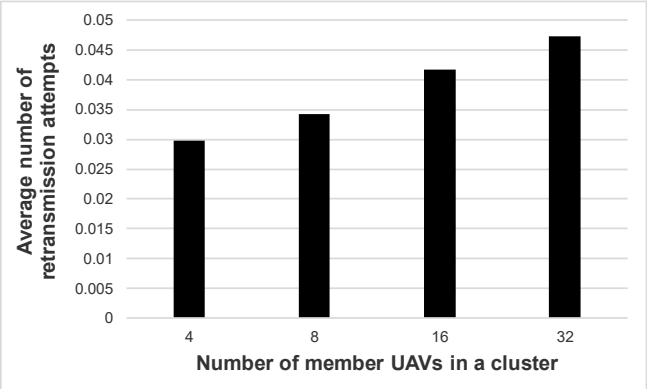

Fig. 3. The average number of retransmission attempts for different numbers of CM nodes in one cluster

Since each of the initial network configurations will produce results with different absolute values, it is important to focus on comparing the scenarios. Fig. 4 shows the normalized graphs (normalized average delay) for representing the average delay when transmitting packets in the CMMpP protocol in a scenario with one cluster, but with a different number of CM nodes. This figure indicates that the more the number of CM nodes in the cluster, the higher the transmitting delay in the network becomes.

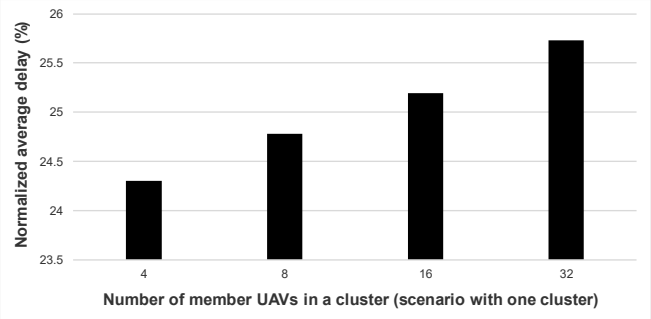

Fig. 4. Normalized average delay for a scenario with one cluster

III. FLYING NETWORK FOR EMERGENCY SYSTEMS

A. System Model

In the proposed flying network for emergencies, the UAV-swarms move with specific purposes and are subject to geographical restriction. In a mission-oriented flying network environment, UAV-swarms cooperatively communicate with each other to receive their missions from the mobile base station (MBS) or forward the collected data to the MBS.

In particular, MBSs will send UAV-swarms to scan areas around MBS and gather information, which will be disseminated among UAV-swarms and transmitted to the MBS. Besides, the UAV-swarms also act as intermediaries to make connections and transfer data between the MBS. Together, they create a timely, efficient, and effective rescue system and increase the coverage area of the flying networks. In general, there are two types of UAVs: Multi-Rotor and Fixed-Wing. For searching operations, fixed-wing UAVs are more suitable than the others because they have a high velocity and long flying time, up to several hours. An architecture of a flying network for emergencies is presented in Fig. 5.

A flying network for emergencies consists of two parts: the flying segment and the terrestrial segment. In the flying segment, UAV-swarms are interconnected by the IEEE 802.11p, using CMMpP, which is a mesh network deployed on UAV-swarms so that they can locate and communicate with each other and retransmit data to the MBS. Furthermore, UAV-swarms are equipped with IEEE 802.11n technologies to capture signals as well as communicate with devices on the terrestrial segment [18].

To begin searching and rescuing operations in a flying network for emergencies, the MBSs will move to the rescue area. There they will deploy UAV-swarms by clusters, which include a head cluster UAV (UAV (CH)) and members cluster UAV, to collect information, make connections, and exchange data. Member clusters UAV scan the area, collect information, and send this information to MBS through head clusters UAV (Fig. 5).

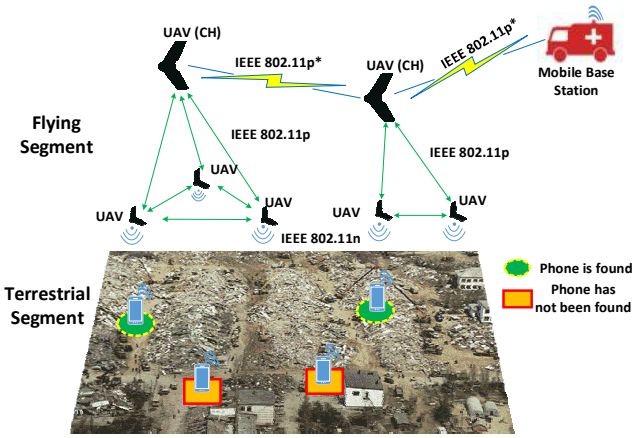

Fig. 5. An architecture of flying network for emergencies

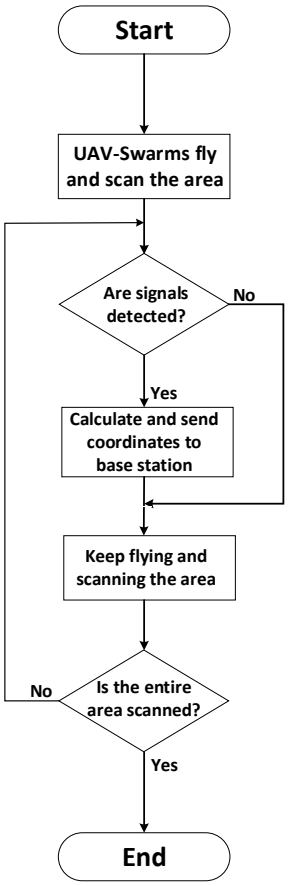

Fig. 6. Scheme of the searching process of UAV-swarms

As mentioned above, the first task of the operation is finding the location of victims. Assuming that the victims always have their smartphone and an automatically accessible Wi-Fi as well as UAV-swarms has enough power to work in the target area. Firstly, UAV-swarms receive information about the scanned area and start flying and scanning. When UAV-swarms get more than two signals from the victim's phone, they start to calculate the phone's coordinator. After getting one more new signal, UAV-swarms need to repeat the calculation of the phone's coordinator. These signals contain the phone's MAC address, which helps us distinguish among phones on the ground. Then, UAV-swarms send the latest calculation of the phone's coordinator back to MBS when no more signal of that phone is sent to them. UAV-swarms continue scanning the entire area to find all signals from smartphones of victims. The scheme of the searching process of UAV-swarms is presented in Fig. 6.

B. Deployment Models

When UAV-swarms fly for the searching, they continuously send beacon signals about the public Wi-Fi at a frequency of about 100ms. When the phone on the ground captures these beacon signals and knows about the Wi-Fi availability, it will start to feedback to UAV-swarms. Figure 7 describes the geometry approach to defining the coordinate. Assuming that the phone lay on the ground $(z_0 = 0)$, therefore the coordinate of the phone's location needed to be found is $(x_0, y_0, 0)$, and the *i*-th position of UAV when receiving the phone signal is (x_i, y_i, z_i). If the UAVs receive *m* signals from the phone, the coordinates of the searching point are required to satisfy the equations:

$$\begin{cases} (x_1 - x_0)^2 + (y_1 - y_0)^2 + (z_1)^2 = (d_1)^2 \\ \dots \\ (x_i - x_0)^2 + (y_i - y_0)^2 + (z_i)^2 = (d_i)^2 \\ \dots \\ (x_m - x_0)^2 + (y_m - y_0)^2 + (z_m)^2 = (d_m)^2 \end{cases}, \quad (1)$$

with d_i is the distance between the UAV and phone location.

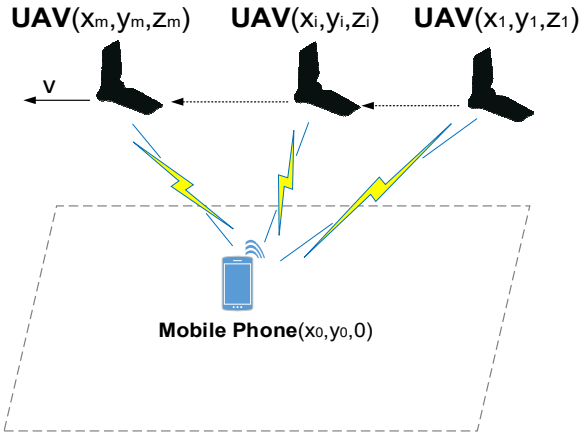

Fig. 7. The geometry approach to defining the coordinate

From a practical perspective, the UAV-swarm can consist of 3-10 UAVs [22]. In this paper, for the aim of searching victims, we assume that members cluster UAV have three fixed-wing UAVs, which always move forward with the same constant velocity $v = 25\ m/s$ at altitude $h = 50m$, as well as being able to capture signals with a radius of coverage circles in the ground of about $R = 50m$ by using the technology IEEE 802.11n.

There are three cases for the structure of the UAV-swarm in the searching process (Fig. 8): Horizontal line (Fig. 8a), Triangle (Fig. 8b), and Vertical line (Fig. 8c). By comparing different structures of the swarm, we can select the best structure for finding victims due to the time and accuracy during the searching process as UAVs have speed and energy limits.

With the parameters given above, there is time given for UAVs to be able to scan an area of 5 km × 5 km, as shown in the Table I. This table shows that horizontal line gives us the shortest scan time, but the main purpose of the article is to find out victims, so our top priority is to receive as many signals as possible because the more signals we get, the higher accuracy of the searching process for the victim's location we will have.

TABLE I
TIME TO SCAN AN AREA OF 5 KM × 5 KM FOR THREE CASES

	Horizontal line	Triangle	Vertical line
Time to scan (s)	4400	7224	13056

Assuming that there is a phone located in a certain zone and in a certain flying time *t* (time of receiving-signals) through this zone, the UAV group always is able to receive at least one signal from the phone. Figures 8a, 8b, 8c, the time *t* is illustrated according to three considered cases. With different UAV structures, this time is different and is calculated according to the following formulas:

$$t_{horizontal\ line} = \frac{2 \cdot R}{v}, \quad (2)$$

$$t_{triangle} = \frac{2 \cdot R + R \cdot \sqrt{\frac{3}{2}}}{v}, \quad (3)$$

$$t_{vertical\ line} = \frac{3 \cdot 2 \cdot R}{v}, \quad (4)$$

The experiments were performed to measure the number of signals sent from the phone to UAV-swarms and the time of the receiving-signals process, which can be calculated from equations (2), (3), (4). The results in Table II show that the Vertical line shape has the possibility of getting a maximum number of signals, which means that the Vertical line shape is capable of finding the victims with the highest probability.

TABLE II
MAXIMUM NUMBERS OF RECEIVED SIGNALS

	Time of receiving signals (s)	Maximum number of received signals
Horizontal line	4	31
Triangle	6.45	42
Vertical line	12	53

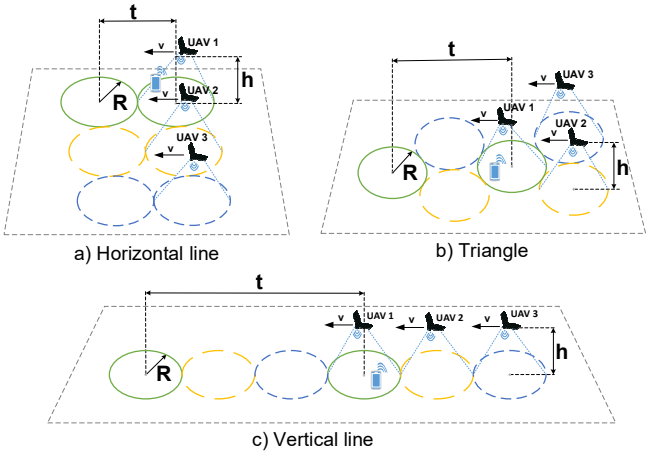

Fig. 8. Three cases of the structure of UAV-swarm for searching

IV. POSITIONING METHOD

A. Distance Calculation

In wireless communication, the radio propagation models are considered to evaluate the path loss when a signal encounters barriers over a distance. The power of the received

signal is less than the transmitted signal. A measurement of the power in each received radio signal is presented by Received Signal Strength Indicator (*RSSI*) to predict the difference between the transmitted and received signals in a transmission range [23], [24]. *RSSI* distance measurement generally is calculated in the logarithmic distance path-loss model as:

$$RSSI = A - 10 \cdot n \cdot \log\left(\frac{d}{d_0}\right) + X_\sigma, \quad (5)$$

where d is the distance between the transmitter and the receiver;
A is the path loss at the reference distance d_0;
n is the path loss exponent related to a specific wireless technology;
X_σ is a Gaussian-distribution random variable with zero mean and variance σ^2.

In the calculation, d_0 usually is chosen to equal 1 meter. Hence, A is the *RSSI* at a distance of 1 meter. Since the X_σ has zero mean, *RSSI* can be expressed as follow:

$$RSSI = A - 10 \cdot n \cdot \log(d), \quad (6)$$

According to equation (6), the distance between transceivers can be calculated by:

$$d = 10^{\frac{A - RSSI}{10 \cdot n}}, \quad (7)$$

In our proposed system, UAVs act as Wi-Fi Access Points (AP), which are always ready to capture any signals from clients. The AP can evaluate the received signal's strength generated from the phone when it is connected to the AP. Hence, the distance from the AP to the phone can be determined by equation (7).

Since the path loss depends on the environment, in order to increase the positioning accuracy in our system, there is a need to estimate the parameters (A, n) before deploying the searching mission. Therefore in each specific searching environment, the UAV-swarm is set up to calibration mode, i.e., the *RSSI*, the distance between the UAVs and the starting point are measured several times. Then, the non-linear least square method is used to find the optimal parameters (A, n). With the m measurements, these parameters are founds as:

$$(A, n) = \arg\min_{A,n}\left(\sum_{i=1}^{m} 10^{\frac{A - RSSI_i}{10 \cdot n}} - d_i\right)^2, \quad (8)$$

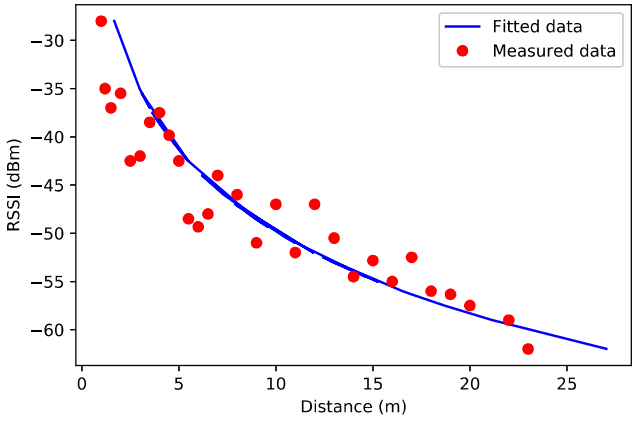

Fig. 9. Distance determination based on RSSI

The experiments were performed to measure *RSSI* and distance from a phone to an AP. The received measurements were used to estimate the parameters (A, n) in the distance calculation model (8). The comparison of the received data and estimated data is shown in Fig. 9.

B. Coordinate Calculation

After the UAVs measure the distance to the signal source, the next task is the coordinate calculation. Assuming that the phone position is $p_0(x_0, y_0, 0)$ on the ground and the UAV receives a signal from the phone at the position $p_i(x_i, y_i, z_i)$. The distance between these two points is calculated with the measurement error $\xi_{\mu,\sigma}$, set during the experiment. With each received signal from the mobile phone, the distance from UAV to it will be:

$$d(p_i, p_0) = \sqrt{(x_i - x_0)^2 + (y_i - y_0)^2 + (z_i)^2} + \xi_{\mu,\sigma}, \quad (9)$$

Therefore, the number of received signals and the measurement error influence the accuracy of the positioning process. The position $p_c(x_c, y_c)$ is found by minimizing the expression:

$$\arg\min_{x_c, y_c} \sum_{i=1}^{m}\left(\sqrt{(x_i - x_c)^2 + (y_i - y_c)^2 + (z_i)^2} - d(p_i, p_c)\right)^2, \quad (10)$$

where m is the number of received signals from the phone.

As the result of minimization, the coordinates and their estimation errors are found.

C. Result Assessment

In order to evaluate the positioning capability based on the Wi-Fi signal, the model is simulated in consideration of the number of received signals and the measurement error. According to Fig. 8 and Tables II, III, the group of UAVs can cover a certain zone in the t seconds. In that interval of time, the UAVs can receive at least one signal or more.

A comparison of distances between the given point and the found point is considered as a positioning error. The difference between them is calculated as:

$$d(p_0, p_c) = \sqrt{(x_0 - x_c)^2 + (y_0 - y_c)^2}, \quad (11)$$

The simulation gives the density of positioning error when changing the number of detected signals. Figures 10 and 11 show the probability density of positioning error when 30 and 3 signals are received, respectively, with a relative error of distance measurement of 20%.

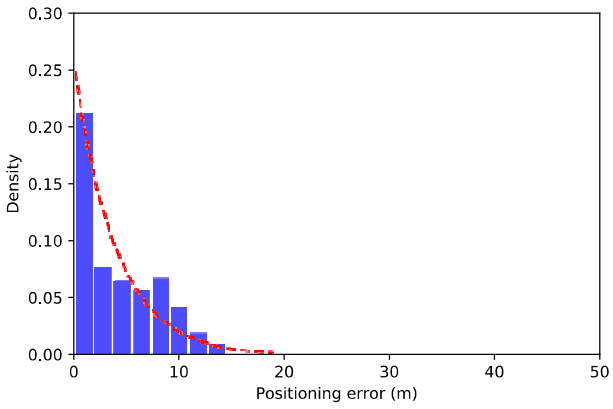

Fig. 10. Density and histogram of positioning error when 30 signals are received

The dependence of the positioning error on the number of received signals is shown in Figure 12.

According to Figure 12, the coordinates are determined with less error when more signals are detected.

On the other hand, distance measurement accuracy is an important factor that affects the positioning error. Figure 13 shows the dependence of the positioning error on the relative accuracy of distance measurement, which is generated in the simulation. The number of received signals is assumed with 30.

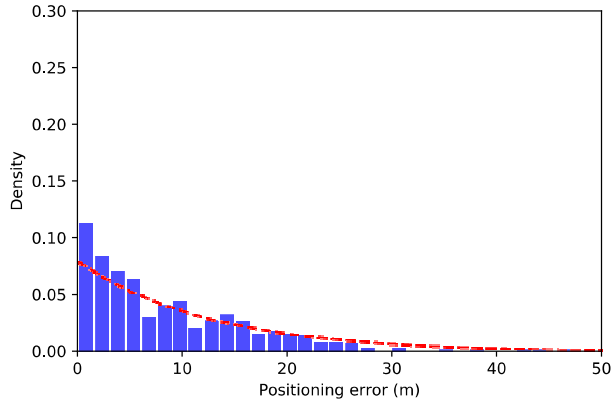

Fig. 11. Density and histogram of positioning error when three signals are received

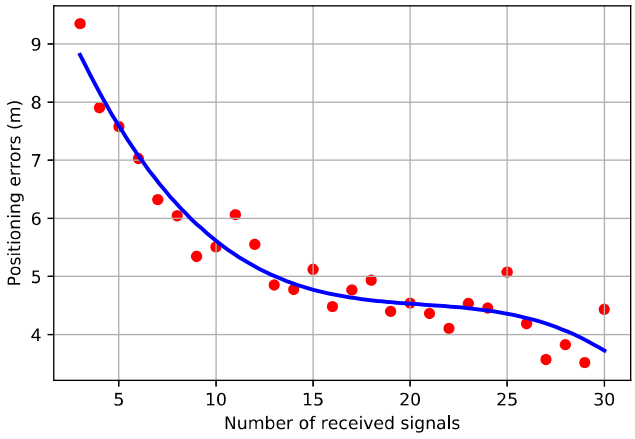

Fig. 12. The dependence of the positioning error on the number of received signals

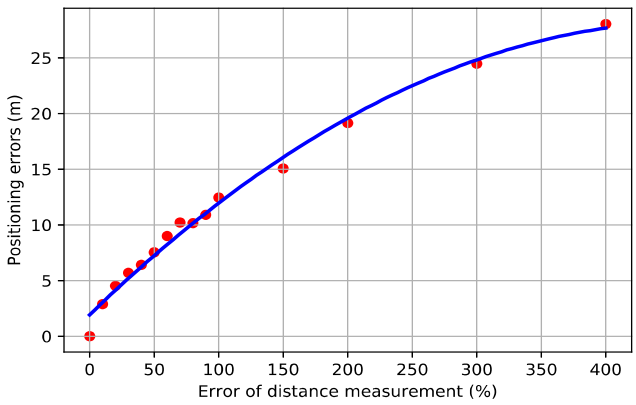

Fig. 13. The dependence of positioning error on the relative accuracy of distance measurement

The simulation results show that the positioning error increases when the error of distance measurement increases. Hence, the positioning accuracy can be achieved by increasing distance measurement quality and ensuring more signals are detected. The distance measurement mostly depends on a specific technology and the environment. Therefore, some models of distance measurement can be used in different cases. In addition, the UAV-swarm's ability to receive signals also depends on communication technology and the environment, as well as on the number of used UAVs and their speed.

IV. SIMULATION FOR POSITIONING METHOD

In order to evaluate the effectiveness of the search and recuse operation using the three cases of the UAV-swarm as mentioned above, a simulated scenario of UAV-swarm's mobility was developed by network simulator Omnet++ [25]. Assuming that the victim is in the subarea 500m x 500m, the ability to receive signals from the UAV-swarm is considered when this entire subarea is being scanned. The UAV system is designed to receive signals from the victim's phone on the 2.4 GHz frequency band with the average rate is 1 signal/second (1 signal generated per second) and with the transmission power is 10 mW. The victim location is randomly chosen 50 times (black points) in the subarea, as shown in Fig. 14. The search mission is simulated 50 times corresponding to the victim position, which also is randomly generated in each simulation time. As shown in Fig. 14, there are 50 victim positions that the UAV system needs to find. After each scanning mission, the coordinates of the victim are calculated and compared with initial random coordinates. We can conclude which structure provides the most accurate results for UAV-swarm in search and rescue operation.

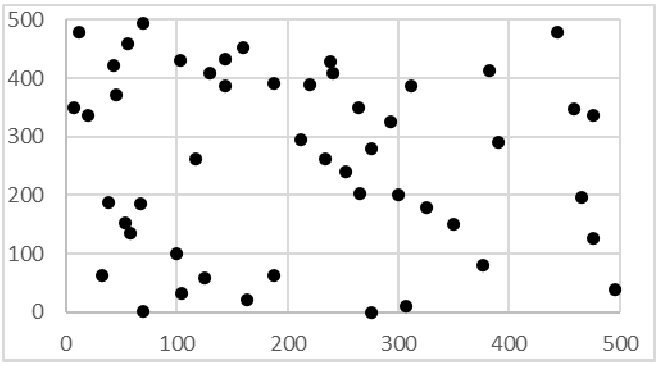

Fig. 14. Random positions for the victim in the subarea

The results shown in Fig. 15-17 indicate the locations of the UAV receiving a signal from the victim's phone in three cases (gray points) where the location of the victim is at coordinates (300,200) (black point). Fig. 15 shows the number of received signals of UAV-swarm for the Horizontal line shape is 9, whereas that for the Triangle shape in Fig. 16 is 14. Lastly, for the Vertical line shape in Fig. 17, there are 37 received signals. It is clear that the collecting-signals position within a radius of around 150m from the victim and the Vertical line shape gives us the most significant number of received signals, which makes it the most effective approach in terms of positioning accuracy for the searching operation.

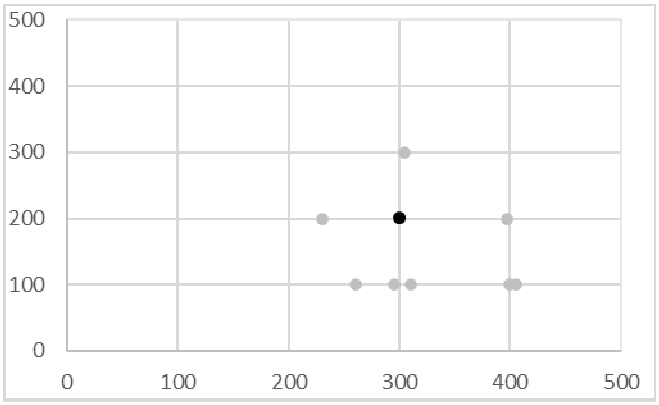

Fig. 15. Coordinates of UAVs, when receiving signals in search used the Horizontal line shape for UAV-swarm

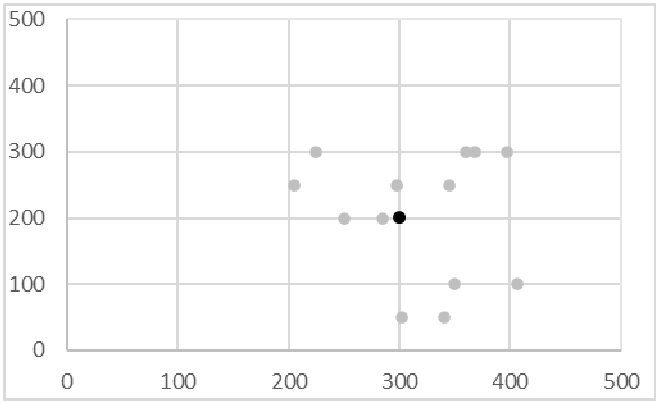

Fig. 16. Coordinates of UAVs, when receiving signals in search used the Triangle shape for UAV-swarm

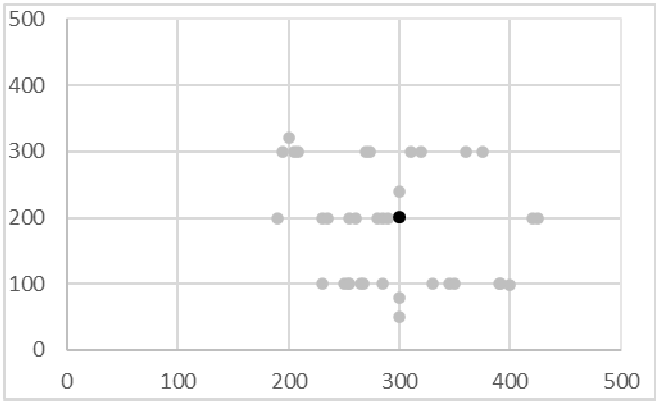

Fig. 17. Coordinates of UAVs, when receiving signals in search used the Vertical line shape for UAV-swarm

Through 50 simulations run for each case, the number of received signals in each case is presented in Fig. 18. This figure shows again that using the Vertical line shape for UAV-swarm, we might receive more signals from the victim's phone. The probability density of the number of received signals for three cases is shown in Fig. 19. There is a higher probability of receiving 20-30 signals using the Vertical line shape, whereas the probability of receiving 5-15 signals is highest by using the Horizontal line shape, and for the Triangle shape, the highest probability of receiving signals is in an interval of 10-17 signals.

The number of received signals is averaged after the whole 50 simulation times. The mean and standard deviation values are shown in Fig. 20. With the results from Fig. 20, the average numbers of received signals in each case are as follows:

- Horizontal line (10 signals with the standard deviation of 3),
- Triangle (13 signals with the standard deviation of 4),
- Vertical line (20 signals with the standard deviation of 5).

Approximately, the ratio of received signals for three cases is as follows (Horizontal line, Triangle, Vertical line) = (1: 1,5: 2). According to Fig. 21, Vertical line and Triangle provide small distance errors (at around 2.2 m with the standard deviation of 0.9 m and 2.1 m with the standard deviation of 1.2 m, respectively). A conclusion that can be extracted from this result is that the positioning method is more accurate when there are more received signals. This is aligned with the statement mentioned above.

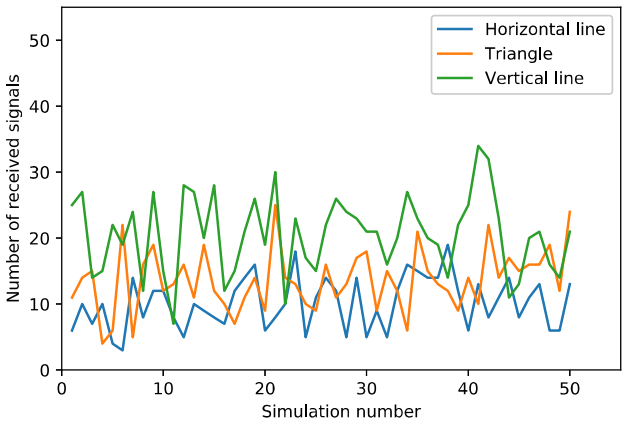

Fig. 18. The number of received signals for UAVs in three cases

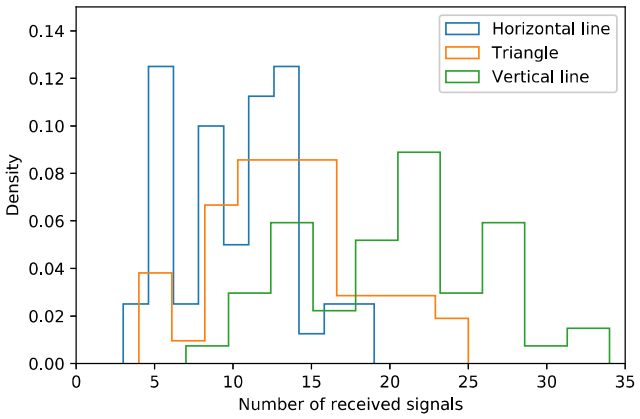

Fig. 19. Density and histogram of the number of received signals for three cases

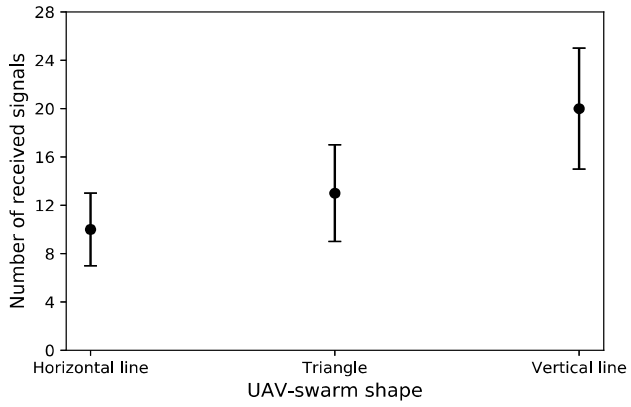

Fig. 20. The average number of received signals for different UAV-swarm shapes

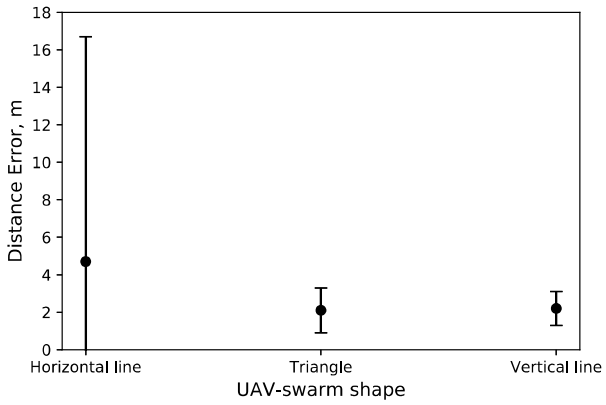

Fig. 21. The distance errors for different UAV-swarm shapes

V. Conclusion

In the paper, the method for detecting the coordinates of subscribers by catching the Wi-Fi signals generated from their phones in the absence of infrastructure of networks of communication operators using a flying network for emergencies based on UAV-swarms was proposed. In the flying network for emergencies, UAV-swarms use a new protocol, known as Cluster-based Multichannel MAC IEEE 802.11p protocol, for communication between UAVs and use technology IEEE 802.11n to capture signals. We propose a scheme of searching process of UAV-swarms and study three cases of UAV-swarm structure for searching. The results of experiments show that the Horizontal line shape gives us the shortest scan time while the Vertical line shape is capable of finding the victims with the highest probability. The simulation's results for detecting the coordinates of subscribers show that the probability density of positioning error is much better when there are more signals, which UAV-swarm received from the victim's phone. Besides, the phones' coordinates are determined with less error when more signals are detected, and the positioning error increases when the error of distance measurement increases. In considered three cases, the Vertical line shape provided the best result of positioning methods and continuously received the highest signals.

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References

[1] R. Kirichek, A. Paramonov, A. Koucheryavy "Swarm of public unmanned aerial vehicles as a queuing network," *International Conference on Distributed Computer and Communication Networks. Communications in Computer and Information Science (CCIS)*, vol. 601, pp. 111-120, 2015.

[2] A. Koucheryavy, A. Vladyko, R. Kirichek "State of the art and research challenges for public flying ubiquitous sensor networks," *Lecture Notes in Computer Science (LNCS)*, vol. 9247, pp. 299–308, 2015.

[3] V. Sharma, F. Song, I. You and M. Atiquzzaman "Energy efficient device discovery for reliable communication in 5G-based IoT and BSNs using unmanned aerial vehicles," *Journal of Network and Computer Applications*, vol. 97, pp. 79-95, 2017.

[4] T. D. Dinh, R. Kirichek and A. Koucheryavy "Flying network for emergencies," *In International Conference on Distributed Computer and Communication Networks, Springer, Cham*, pp. 58-70, Sep. 2018.

[5] T. D. Dinh, R. Pirmagomedov, V. D. Pham, A. A. Ahmed, R. Kirichek, R. Glushakov and A. Vladyko "Unmanned aerial system–assisted wilderness search and rescue mission," *International Journal of Distributed Sensor Networks*, 15(6), 1550147719850719, 2019.

[6] Y. Zhuang, Z. Syed, J. Georgy and N. El-Sheimy "Autonomous smartphone-based Wi-Fi positioning system by using access points localization and crowdsourcing," *Pervasive and Mobile Computing*, 18, pp. 118-136, 2015.

[7] I. Zubizarreta, A. Seravalli and S. Arrizabalaga "Smart city concept: What it is and what it should be," *Journal of Urban Planning and Development*, 142(1), 04015005, 2015.

[8] I. Yaqoob, I. A. T. Hashem, Y. Mehmood, A. Gani, S. Mokhtar and S. Guizani "Enabling communication technologies for smart cities," *IEEE Communications Magazine*, 55(1), pp. 112-120, 2017.

[9] A. Yastrebova, R. Kirichek, Y. Koucheryavy, A. Borodin, and A. Koucheryavy "Future networks 2030: Architecture & requirements," *In 2018 10th International Congress on Ultra Modern Telecommunications and Control Systems and Workshops (ICUMT), IEEE*, pp. 1-8, Nov. 2018.

[10] Y. H. Ho, Y. R. Chen, and L. J. Chen "Krypto: assisting search and rescue operations using Wi-Fi signal with UAV," *In Proceedings of the First Workshop on Micro Aerial Vehicle Networks, Systems, and Applications for Civilian Use, ACM*, pp. 3-8, May 2015.

[11] M. M. U. Chowdhury, F. Erden, and I. Guvenc, "RSS-based Q-learning for indoor UAV navigation," *arXiv preprint arXiv*:1905.13406, 2019.

[12] A. Bazzi, G. Cecchini, M. Menarini, B. M. Masini, and A. Zanella "Survey and perspectives of vehicular Wi-Fi versus sidelink Cellular-V2x in the 5G era," *Future Internet*, 11(6), pp. 122, 2019.

[13] Y. Xiang, T. Su, X. Liu, and M. Geimer "Realtime Estimation of IEEE 802.11 p for Mobile working Machines Communication respecting Delay and Packet Loss," *arXiv preprint arXiv*:2003.02108, pp. 1-6, 2020.

[14] S. C. Choi, J. H. Park, and J. Kim "A Networking Framework for Multiple-Heterogeneous Unmanned Vehicles in FANETs," *In 2019 Eleventh International Conference on Ubiquitous and Future Networks (ICUFN), IEEE*, pp. 13-15, 2019.

[15] W. Anwar, N. Franchi, and G. Fettweis "Physical layer evaluation of V2X communications technologies: 5G NR-V2X, LTE-V2X, IEEE 802.11bd, and IEEE 802.11p," *In 2019 IEEE 90th Vehicular Technology Conference (VTC2019-Fall), IEEE*, pp. 1-7, 2019.

[16] *802.11 p-2010-IEEE standard for information technology-local and metropolitan area networks-specific requirements-part 11: Wireless lan medium access control (mac) and physical layer (phy) specifications amendment 6: Wireless access in vehicular environments.* IEEE Standards Association, 2010. Available: http://standards. ieee.org/findstds/standard/802.11p-2010.html

[17] A. Festag "Standards for vehicular communication—from IEEE 802.11 p to 5G," *E & I Elektrotechnik und Informationstechnik*, 132(7), pp. 409-416, 2015.

[18] T. D. Dinh, D. T. Le, T. T. T. Tran, and R. Kirichek "Flying Ad-Hoc Network for Emergency Based on IEEE 802.11 p Multichannel MAC Protocol," *In International Conference on Distributed Computer and Communication Networks, Springer, Cham*, pp. 479-494, Sep. 2019.

[19] *IEEE 1609 Working Group. IEEE Standard for Wireless Access in Vehicular Environments (WAVE)-Multi-Channel Operation*. IEEE Std: 1609-4, 2016.

[20] T.D. Le, O. Simonina, M. Buinhevich, and A. Vladyko "A multi-criteria priority-based V2I communication for information dissemination at RSU in VANET," *JP Journal of Heat and Mass Transfer, Special Volume, Issue II, Advances in Mechanical System and ICI-convergence*, pp. 195-203, 2018.

[21] N. Sun "Performance study of IEEE 802.11p for vehicle to vehicle communications using OPNET," Ph.D. Diss., Massey University, 2011.

[22] A. Viseras, T. Wiedemann, C. Manss, V. Karolj, D. Shutin, and J. Marchal "Beehive-Inspired Information Gathering with a Swarm of Autonomous Drones". Sensors, 19(19), 4349, pp. 1-20, 2019.

[23] W. Y. Chung "Enhanced RSSI-based real-time user location tracking system for indoor and outdoor environments," *In 2007 International Conference on Convergence Information Technology (ICCIT 2007), IEEE*, pp. 1213-1218, Nov. 2007.

[24] X. Zhu, and Y. Feng "RSSI-based algorithm for indoor localization," *Communications and Network*, 5(02), pp. 37-42, 2013.

[25] OMNET++ https://omnetpp.org/

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Role of Teachers in Developing Learning Pedagogy

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Abstract—**The rapid development of science and technology such as multimedia technology has offered a better tool to explore the new teaching method. In fact, multimedia technology has played an important role in English language teaching, especially, in the non-native speaking of English situations. It also aims to make non-native speakers of English as language teachers aware of the strategies to use it in an effective manner. This paper aims to analyze the use of technology to English language teaching in the non-native speaking countries and to bring out the problems faced by both teachers and learners of English. Multimedia teaching method has been used in college English teaching wider and wider. It has contributed a lot to higher teaching quality. Chalk and Talk teaching method is not enough to teach English effectively. There should change in the methodology of teaching and free from all kind of biasism. Not only that a teacher must have the quality of adapting himself/herself to the new technological revolution by incorporating it into teaching practices. This paper gives an in depth analysis of the new methodology that could be adopted in teaching practices inorder to make teaching effective and student centric.**

Keywords—Multimedia, learning strategies, personality, technology, Web based learning

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I. INTRODUCTION

The learners Carrier, Damerow and Bailey's book offers a wide-ranging perspective on digital learning, highlighting cutting-edge research and recent developments in the use of learning technologies in language education both in terms of theory and practice. In fact, one of the particular strengths of the book is how well the pedagogy and technology are orchestrated to reflect the essence of digital learning. The significance of 'learning to learn' has stimulated considerable debates in both theoretical and practical fields of education being a very strident and accountable process to develop reading, comprehension, expression, curriculum, instruction and assessment.Relatively, the principle inherent in comprehending various processes of learning styles and strategies on the basis of learners' autonomy has become equally important for the teachers and the learners as well. Research shows that the learning strategies of our learners today display puny extension in some essential skills like note taking, note making, idea organizing etc resulting abysmal performance.

However, last decades surge in the study of language pedagogy lending for cognitive strategies has retained enormous discretionary power that eventually led to a ray of positive hope in the fairness of the education system. The ultimate intention of making aware of the learning styles and strategies is to enable students encounter the problems they face both academically and non-academically. Focusing the significance of the strategies required for learning, Deshler & Schumaker in 'Multipass: a learning strategy for improving reading comprehension', [1] state that through the strategies we not only train the students for the fulfillment of immediate requirements but also help them to generalize those in other situations over time.Hence the exposition of the special individual potentiality of a child is the key factor demanding a serious, substantive, contextual and conducive atmosphere. The pedagogic perception of language as skill, as a matter of socialization, is no more a matter of fact memorizing or information collecting from various sources, rather an understanding of the learners' characteristics congruously.

A system of burdened and impulsive education devoid of individual learning styles doesn't awaken the mind and the dormant intelligence in it but stuffs it mechanically creating some chaos and conflictions hemorrhaging the talent. It is a common acceptance that different learners have different attitude to learning a language for their individual differences. Taking these important faculties into consideration some successful pedagogic efforts and innovative ideas are

contemplated as learning styles and strategies of the learners. Moreover, these differences determine their response to different teaching styles and techniques and those shouldn't be unheeded. These differences include a learner's motivation, personality, language level, learning style, learning strategies, and age and past language experiences. [2]

The structure of the paper is organized as follows: Section II presents the past work related to this field. Section 3 describes about the methodologies used for this research work. Section 4 describes about teaching folklore through web based learning. Section 5 describes about the conclusion and future work.

II. TEACHING ENGLISH AS SECOND LANGUAGE

The concept of second language holds its position in between a first or native language and a foreign language, having profuse interactive scope outside and lacking the scope inside the home. Concept of second language acquisition is inclusive of applied linguistics with effectiveness of two prominent disciplines; psychology and education. The combined endeavor of the two important faculties takes care of making learners active processors of information, creating comprehension of materials, establishing relationships between new knowledge and previous knowledge. Language learning is not the acquisition of a conscious set of rules or facts but a process of understanding, speaking, writing and expressing the thoughts and emotions.

The philosophy of active learning can be best done when the surrounding environment is contextual and learners get optimum opportunity to exploit it. Teaching is a sub-social process which technically sits on the triangle of teacher, student and subject matter having the interior area filled with general learning styles and specific learning strategies. The effectiveness of the teaching process amounts high when the vertex of student's corner becomes more significant. The scope of high degree of interaction involves facilitating, motivating, enabling, engaging the students according to their own style rather than plain presentation of facts and figures didactically before them. Here the improvement and desirable changes are brought about in the behavior of learners are perpetually under the scanner of experiences and responses of their own. Our main focus is on learning of a second language, which encompasses a setting where it has abundant inputs in the surrounding with wider scope of daily communication. We need to remove veil after veil until we reach the inmost depths and touch the pure white individuality and specialty in order to naturalize the target language.

III. CONCEPT OF LEARNING STYLE

Learning style is predisposition to behave in a particular way when engaged in the learning process. Learning strategies are the methods employed by the learner to achieve learning. Research is being done taking various factors to investigate links between learning style and strategy and multimedia. Such knowledge could prove invaluable when attempting to design multimedia learning materials for the widest possible educational use. The viewpoint to learning is relatively sturdy and it gives general direction to learning behavior being a key component in effective teaching. Style is a motif of a person to execute a specific assignment. Learning styles are the ways in which a learner naturally prefers to take in, process and output the information and acquire the skill. This is the way of interpreting, organizing and representing information. It reveals the way one learns the best thus having a great impact on academic life and career as well. The theory of individual learning style took effort in the 1970s and since then it has been exerting a greater impact on the realm of pedagogy. The classroom methods are suitably affected by the individual learner preferences. As the interest towards a rhyme, TPR (Total Physical Response), physical game, story, picture displayed in a classroom is not always the same.

The focus and intensity for different styles differ depending on their grades, personality, academic competence etc. David A. Kolb in his experiential learning model spells out "five particular levels of behavior: personality types, early educational specialization, professional career, current job role, and adaptive competencies." The analyses show that learning styles have a significant influence on learners' learning strategy choices. There is evidence that the Judging scale correlates positively with seven sets of learning strategies. Thus it turns out to be the most influential learning style variable affecting learners' learning strategy choices. Compared with low achievers, high achievers are more capable of exercising strategies that are associated with their non-preferred styles.

The statement of Dunn and Griggs can be most suitable here; "learning style is the biologically and developmentally imposed set of characteristics that make the same teaching method wonderful for some and terrible for others" (Dunn & Griggs, 1988, p.3). Pertaining to this the theory of multiple intelligence proposed by American Howard Gardner such as musical-rhythmic, visual-spatial, verbal linguistic, logical-mathematical, bodily- kinesthetic, interpersonal, intrapersonal, naturalistic, existential and moralgeneral abilities contributes a lot in the field of multiple learning and teaching styles. The Experts give a significant emphasis on the individual styles and thus classify the learning styles distinctly as below.

A. Visual style of learning:

Out of all the three methods of learning strategies, Visual Learning is one of most important strategy that was popularized by Neil D. Fleming in his VAK model of learning. The visual learning style, often referred to as the spatial learning style, is a way of learning in which information is associated with images. This learning style requires that learners first see what they are expected to know. People with a visual learning style are often referred to as visual-spatial learners. Basically, the visual learning style means that people need to see information to learn it, and this "seeing" takes many forms from spatial awareness, photographic memory, color/tone, brightness/contrast, and other visual information. Naturally, a classroom is a very good place for a visual learner to learn. Teachers use overheads, the chalkboard, pictures, graphs, maps, and many other visual items to entice a visual learner into knowledge. This is great news for you if this is the way you typically learn.

Advantagesof Visual Learning

Visual learners typically do really well in a modern classroom setting. After all, there are just so many visuals in classrooms - whiteboards, handouts, photos and more! These students have much strength that can boost their performances in school. Here are just a few of the strengths of this learning type:

- Instinctively follows directions
- Easily visualizes objects
- Has a great sense of balance and alignment
- Is an excellent organizer
- Has a strong sense of color, and is very color-oriented
- Can see the passage from a page in a book in his or her mind
- Notices minute similarities and differences between objects and people easily
- Can envision imagery easily

B. Auditory style of learning:

The Auditory style is learning by hearing. This type of learning is helpful in the classroom environment. During a lecture, an auditory learner is able to easily comprehend process and retain information. Auditory learning is not only the ability to listen to spoken word and interpret tone, but to do so with a high level of accuracy and efficiency. Learners with strong auditory ability are able to hear and comprehend without missing much.Some people prefer to learn by hearing what they want to learn. Theirs is the auditory learning style. To learn, such people would prefer listening to discussions, talking matters over, reading out of texts or making use of e-courses containing audio recordings. One special advantage of this style is that you assimilate and retain information without having to see it in texts or pictures. However, the difficulty of learning among silently reading learners – in a library, for example – is one disadvantage.

C. Kinesthetic style of learning:

These learners experience learning by actions; doing or being physically associated with the process. They prefer to connect their learning with real-life experiences. Hands on experiment are more conducive for them in an active lab setting demanding more physical involvements. They prefer to the concreteness of the learning such as class demonstrations and field work outside the class room to understand and remember things. They remain focused on the topic, come prepared prior to class teaching, and take note actively throughout the teaching. Studies in short intervals of time having gaps of short breaks retain the memory of these children. The stimulations of almost all the senses like sight, touch, smell, hearing and speaking through energetic activities like TPR (Total Physical Response), music, rhyme, video, power point presentations, field trips, real life examples, collections, project work, role play, exhibitions, group presentations etc are mostly preferred by the learners. They often love to work on trial and error method. Discussions with other kinesthetic learners are found to be useful for them. Application of the knowledge, comparison and analysis of ideas, taking help of references, scrutinizing samples, study through screenshots and photographs are their interest area.

D. The Reading and Writing learning style:

This form of learning includes both talks and texts. Children of this kind love to play with the words such as rhymes, guessing words, tongue twisters, limericks and activities like public speaking, debating, politics, writing and journalism. They often record their speaking, speak before mirrors, and talk themselves through simulators. They are adept at expressing themselves verbally. [7] Collaborative teaching- learning, oral lectures, use of mnemonics and acronyms for remembering things and other verbal tools are preferred by such learners. They normally have good memory power. Scripting of memorable words and sentences, reading things dramatically and in a varied manner, setting some key points to familiar song, jingle and rhyme, working with others, doing verbal exchanges are found to be useful for such learners. They have fascination for performing arts, old writings, music and lyrics, novels and fictions in order to satisfy their linguistic needs.[8]If you learn best by reading texts or writing down notes from what you read, see or hear; then you are defined as a read & write (R&W) learner. R&W learners need writing materials to take down points they think are important from what they read, hear or see. The R&W style has the advantage of making students more independent. With note-taking, they can learn and retain more of the concepts on their own with learning style that works for them. However, they also face the disadvantage of not being able to learn easily with only visual or audio instruction or where they do not have access to writing materials.

E. The social-interpersonal learning style:

Learners having such learning style interact well with people both by face to face conversation and by non verbal expressions like proper posture, gesture or body movements. They are sensitive to the feelings, emotions and sentiments of other persons and listen sincerely to other peoples' style of expressions. They are typically fond of working through vivid discussions in a group. The preference of social activities rather than individual activities is high in case of them. Social learners often create a study group or any specific club, may be of same or different age and work taking feedbacks from them trying some techniques of memory development. They stuff their learning through varied responses, imaginative associations, role-playing techniques etc in a social setting and creative suggestions of the group members, analyzing the errors of others. As class room is a risk-free environment to make mistakes than the real life situations, this kind of learners experiment more in groups to learn. [10]

Women studies plays an important role in imbibing a socio-interpersonal learning style as it helps n every class from English to history, math to science, parenting to auto mechanics, there is room for feminism. It could be something

as grand as teaching about women's roles in history to something as simple as asserting that girls can work on cars, too, but it should be a part of every class, every day. Historically, women — and other oppressed groups — have been marginalized. We have been relegated to boxes in the margins of textbooks as if to say, "This is what the women were doing back at home while the men were off at war.It fits into this little box which must mean that it wasn't that important and it won't be on the test." Imagine what that does to the self-esteem of the girls seated in the classroom.

Incorporating feminism in the classroom is so much more than doing a lesson about the Suffragettes. It's about showing girls that they matter, too, by giving them books written by women. It's about teaching boys to respect women. It's about encouraging girls to take math and science classes. It's about privileging the voices and fostering the interests of all of the students in the classroom, regardless of gender.

The study of feminism is also intersectional with other topics. It isn't just about women, but about all oppressed groups. Teaching feminism in the classroom is not only about women; it's about civil rights, LGBTQ rights, and rights for people with disabilities just to name a few. Teaching respect and acceptance of all people is teaching feminism. If we can incorporate feminism in the classroom, the benefits would be endless. Men would be taught to respect women, making sexual assault and sexual harassment in schools a thing of the past. Women would follow their passions rather than what society wants of them. Bullying would virtually disappear because respect and acceptance would triumph. [15].

Various cognitive styles of learning and activities followed for the respective ones have been depicted below.

IV. Role of Teachers in Developing Learning Styles

Teachers, however have to call to mind that learners may not always stick exactly to one stipulated type but they may alter or develop their learning styles in course of time.The first four styles of learning; visual, auditory, kinesthetic and tactile refer to the physical, perceptual learning mediums and can be categorized under 'sensory preferences'. Visual students enjoy a lot all activities of visual stimulations. They make their learning by reading, observing pictures, chat models, written work on the black board, movies, slide show, flash card, projector etc moreover, oral discussions and lectures without any visual backup make them bored and confusing. In contrast, auditory students are very much comfortable with dry, undistorted lectures or plain oral conversations. [11] Their excitement lies in role plays, mock interview, debate, elocution, quiz, interactions among peer and with the teacher etc. kinesthetic and tactile students however prefer to learn by frequent movements, physical responses, tangible objects, realia, collages, models, experiments, action works etc. They can't endure constant sitting for a period of time and need short breaks in times.

The most significant factor associated with learning style is 'the personality type'. The diversities in personalities determine the learning styles of a learner. They may be extrovert or introvert, may be intuitive-random or sensing sequential, may be thinking or feeling type or closure vs. open perceiving category. The extroverted types of students are more expressive, friendly, and interactive. On the other hand introverted students are having their own internal world, scanty friend circle and often derive bliss from solitude. Intuitive random students better understand theoretical phenomenon and new abstract interpretations, often regulating self learning, on the contrary sensing sequential students show more interest for facts rather than theories, depend on specific instructions and guidance of the teachers. Thinking learners are more straightforward and hardly care for others concern while expressing their own views, whereas feeling students are empathetic and compassionate in their words valuing others ideas. While closure oriented students are serious, hard working, need written information and like tasks with deadlines. On the contrary, the open learners are very much perceiving, light, fun loving and enjoy language as a game instead of taking it seriously of task completion activity. The teacher being a keen observer and style instructor makes the learners aware about their specific preferences and designs the best strategies for the purpose.

V. Concept of Learning Strategies

The word 'strategy' has a significant place in the world chart being associated with many ups and downs of many nations and people. Though it has a military origin, it still connects with wisdom, science and craft and application of skills. It first sprung from the need of the people making plans to defeat their enemy. This is derived from the Greek word 'strategos' which means 'general' or 'stratagems' which means 'tricks of war'. Alfred Chandler wrote in 1962 that: "strategy is the determination of the basic long term goals of an enterprise, and the adoption of the courses of action and the allocation of the resources necessary for carrying out those goals". Bruce Henderson defines "strategy depends upon the ability to foresee future consequences of present initiatives. Strategy mainly involves two significant processes: formulation and implementation. The former deals with analyzing and diagnosing the situation developing guiding policies, and the latter includes the action plans to attain the destination."

According to Chamot "learning strategies are techniques, approaches, or deliberate actions that students take in order to facilitate the learning and recall of both linguistics and content area information. Studies indicate that "learning strategies is a technical phrase that means any specific conscious action or behavior student takes to improve his or her own learning". It is considered that "any specific action taken by the learner to make learning easier, faster, more enjoyable, more self-directed, more effective, and more transferable to new situations" is a language learning strategy (LLS). Strategies are the conscious steps of behavior used by language learners to enhance the acquisition, storage, retention, recall and one of new information .The concept of learning strategy is still a fuzzy one and not easy to have a final definition, though it has been over thirty years since researchers began the study of learning strategies.

Strategy is a very important phenomenon in any field as the resources available for any specific purpose is limited. The adversary's capability and intentions are uncertain. The resources are irreversible. Strategies improve student

performance in spite of lacking a good cognitive skill earlier. These also help in increasing student independence and engagement with learning. Through various strategies learners realize the best one and find out the weakness in ineffective strategies in order to augment the performances and thus ultimately take new challenges. Thus their opportunities to practice skills become wider.

As students step up from one class to another, they confront greater challenges of imbibing much information, working independently, comprehending the extended and complicated written text, expressing themselves properly, presenting well in tests etcin their academic classes. To induce the concentration of the mind and to increase its potentiality they have to apply some learning strategies to accomplish any task more effectively and efficiently despite their knowledge and versatility deficits. Various studies in this field expose three main rationales related to learning strategies; first, according to Armbruster older students show better proficiency in use of such behavior than the younger ones as these are related to age. Secondly Deshler &Schumaker opine that students who learn how to learn are more expert in learning new information and adapting to changing conditions of future. Thirdly this requires the learners to welcome the accountability for their learning. [11] Thus the age, learning how to learn and acceptance of major responsibility are three significant factors paramount to make a learner independent.

Learning strategies are the specific conducts and mentation detected by the learners to learn language. These refer to learners' self created thoughts, actions and ways which are directed to the achievement of the learning goals in an organized manner. The learning tricks or the academic skills followed by the learners to excel their performances are named as learning strategies. Weinstein and Mayer (1986) opined about learning strategies that "they are behaviors and thoughts that a learner engages in during learning, which are intended to influence the learners' encoding process"(p.315). According to JasminaHasanbegovic "learning strategies refer to students' self generated thoughts, feelings and actions, which are systematically oriented towards attainment of their goal".Scarcella defines learning strategies as "specific actions, behaviors, steps or techniques; such as seeking out conversation partners, or giving oneself encouragement to tackle a difficult language task used by students to enhance their own learning"(scarcella& Oxford).

Considering the vitality of learning strategies Allwright states, "learning strategies can also enable students to become more independent, autonomous, lifelong learners"(Allwright, 1990). Students apply a broader range of learning strategies with their consciousness sometimes and acquire the skills of language and sometimes the skilled teachers make them adopt the appropriate ones. Schumaker and Deshler (2006) have the opinion on learning strategies as "an individual's approach to a task. It includes how a person thinks and acts when planning, executing and evaluating performance on a task and its outcomes." Thus it is a deliberate individual practice to organize and remember things in learning process. "Learning strategies are intentionally used and consciously controlled by the learner" [12] let's say for example a teacher is going to conduct a brainstorming activity in a class; she has to make a plan first about the way she is proceeding. Taking consideration to the number of the students in the class, she sets the strategies. Oxford (1990) compiles the learning strategies briefly as "any specific action taken by the learner to learning easier, faster, more enjoyable, more self directed, more effective and more transferable to new situations, is a language learning strategy." Rubin (1987) opines "learning strategies are strategies which contribute to the development of the language system which the learner constructs and affects learning directly". Cohen gives his consent "second language learner strategies constitute those processes which are consciously selected by learners and which may result in actions taken to enhance the learning or use of a second or foreign language, through storage, recall application of information about the language." [4] Seliger (1984) defines "strategies as basic abstract categories of processing by which information perceived in the outside world is organized and categorized into cognitive structures as part of conceptual network."

The different definitions and opinions on language strategies can be presented in brief as follows. Learning strategies are learners' actions or behavior for improvement of their own apprehensions and internalization. These may be behavioral or cognitive. They may have direct or indirect effect on language development. They are flexible and often conscious. They are problem oriented and solution intended. These may be conscious or subconscious steps towards goal. Use of right strategies at right time helps the learners learn the language in a better way i.e. in an autonomous and independent manner. The learners can be trained to use strategies. The right choice of strategies that fit the learning style of the learner presents a meaningful, active and successful self regulative learning. Some learning strategies adopted by different learners are; repeating new words in mind thereby memorizing it, trying to use the language that they have already learnt during conversations, making predictions of new word meaning by requestingopinions from others about their use of language, throwing themselves into critical situations of using the language, recording, judging and correcting by self for fluency and accuracy, asking a learner to revise what they have learnt, discovering ways of remembering new vocabulary, exploring own area of weakness and deciding the ways of improvement etc.

VI. TYPES OF LEARNING STRATEGIES

According to the two psychological scientists Dr. Yana Weinstein and Dr. Megan Smith the six research-based learning strategies are spaced practice (learning to be done in smaller chunks over regular interval of time), retrieval practice (recalling learnt information putting all the learning materials away), elaboration (asking students open ended questionsto elaborate their understanding as much detail as possible), interleaving (practicing different skills one after another interrupting the repetitive monotony of the same thing), concrete examples (showing concrete examples for the abstract phenomena), dual coding (combining words with visuals for durable learning). The combined effort of all the strategies instead of isolated try outs makes the learning more permanent. [13]

VII. TEACHER'S ROLE IN DEVELOPING LEARNING STRATEGIESE

The Learners are expected to be individualistic executants by controlling the learning situation with required focus and intention. In order to teach learning strategies teachers as strategy instructors have to learn about students' interests, motivations and learning styles and strategies. So the basic thing that a teacher always needs to carry in his mind is the ways of acquiring information for a good impact on overall scholastic accomplishment and life adaptation process of the learners. Teacher as an ardent strategy instructor first has to identify the type of curriculum demand the child fails to meet, so that he can determine the task specific strategy as a required remediation for the student. Secondly the new strategy is introduced to the learners by breaking down it into simpler components. Thirdly the strategy is modeled in detail before the students demanding their full involvement and at the fourth step students use the verbal rehearsal to learn the steps systematically. In the fifth step the students practice the up to date strategy to a desired level of performance in controlled (simple, short, easy) materials. The next step is to practice the strategy to master over that with proper reinforcement and corrective feedback from the teacher. The final step is determined by a post test to mark the satisfactory progress in the target strategy. For instance, the teacher puts an eye at introducing the students with one strategy at a time, presents approaches age and grade appropriately, makes explicit instruction about strategies.

The instructions should include elements that help students generalize a strategy and apply it to other tasks. A good strategy instructor should introduce the strategy by modeling it and describing it, sell the strategy by telling how it works, generalize the strategy by telling where else it is useful and help students perfect the strategy by providing practice opportunities.

VIII. LEARNING STYLES VS. LEARNING STRATEGIES

The Learning styles are the general approaches –for example, global or analytic, auditory or visual –that students use in acquiring a new language or in learning any other subject. These styles are"the overall pattern that give general direction to learning behavior Of greatest relevance to this methodology book is this statement: Learning style is the biologically and developmentally imposed set of characteristics that make the same teaching method wonderful for some and terrible for others.This chapter explores the following aspects of learning style: sensory preferences, personality types, desired degree of generality, and biological differences. Learning strategies are defined as "specificactions, behaviors, steps, or techniques-- such as seeking out conversation partners, or giving oneself encouragement to tackle a difficult language task -- used by students to enhance their own learning" When the learner consciously chooses strategies that fit his or her learning style and the L2 task at hand, these strategies become a useful toolkit for active, conscious, and purposeful self-regulation of learning. Learning strategies can be classified into six groups: cognitive, meta-cognitive, memory-related, compensatory, affective, and social.

Stylesandstrategieshelpdetermineaparticularlearner'sability andwillingnessto work within the framework of various instructional methodologies. It is foolhardy to think that a single L2 methodology could possibly fit an entire class filled with students who have a range of stylistic and strategic preferences. Instead of choosing a specific instructional methodology, L2 teachers would do better to employ a broad instructional approach, notably the best version of the communicative approach that contains a combined focus on form and fluency. Such an approach allows for deliberate, creative variety to meet the needs of all students in the class.

While learning style refers to the relationship of an individual with his method of learning, learning strategies mention the attitude and actions related to the learning objectives. While learning style deals with the cognitive level and learners' preferences, learning strategies deal with meta-cognitive level and learners' competence. Moreover, learning style refers to approach whereas learning strategy refers to the actions taken for learning. According to Scarcella and Oxford in "The Role of Styles and Strategies in Second Language Learning", while learning styles reveal the preferred system of brain response and biological reciprocation to certain sensory stimuli, learning strategies explicate distinct actions, techniques, strides and stances adopted by the learners to amplify their learning. Learning strategies are dependent of learning styles. The former deal with specific approach and the latter refer to general approach of learning. [14]

Direct strategies refer to subconscious tasks, which are inherently learnt while indirect strategies refer to conscious strategies. These two classes are then subdivided into six sub-groups of memory, cognitive, compensation, social, affective and meta-cognitive. These subsets are interwoven with each other, creating an occasional overlap in the strategy groups. According to Oxford direct and indirect strategies and these six strategy categories function as a mutual support network within which various types of strategies enhance second language learning. Oxford's inventory is designed in a way to suit not only students learning English as a second/foreign language (ESL/EFL) in America but also students of any country. The inventory has already been translated into many languages and used as an effective tool for measuring strategy preferences and 10 developmental stages in strategy usage. [15]

IX. CONCLUSION

Summing up the significant factors of the general approach of learning style or the specific action of learning strategy on the considerations of the cognitive, affective or the behavioral aspects of the learners the teacher has to deliberately develop the appropriate plan, material and course of action in order to get the maximum learning outcomes for the growing academic challenges. There is a need of a harmonic relationship between the two in order to achieve the best result among the learners. The more the balance between style and strategies is found, the less the anxiety and the more the confidence among the learner is to be paramount. Increasingly the intensity is about learning by doing. So the issue of building capacity for learning with a range of key constructs including motivation, propensity, and application of strategies to produce an effective language learner with a base of full fledge rich and extensive language

proficiency is solicited. In a word, multimedia teaching method belongs to CAI (computer-aided instruction) in substance, and we can heighten efficiency substantially, which is a kind of trend. We should make best use of its advantages and bypass its disadvantages. Of course it can't replace all other teaching methods and we can apply several methods together in one class. Only under the background of quality education can we use advanced educational theory and we can fulfill the target of college English teaching by utilizing modern education technology reasonably. [16]

REFERENCES

[1] Deshler, D. D. & Schumaker J.B.,"*Learning Strategies: An Instructional Alternative for Low-Achieving Adolescent",* (vol 52, No. 6, pp. 583-590) (1986) The Council for Exceptional Children

[2] Ehrman, M.,*"Second Language Learning Difficulties: Looking Beneath the Surface."* Thousand Oaks, CA: Sage.

[3] Cornett, C., "*What You Should Know about Teaching and Learning Styles*." Bloomington, IN (1983): Phi Delta Kappa.

[4] Cohen, A.D., "*Strategies in Learning and Using a Second Language."*Essex, U.K., Longman.

[5] Chandler, A., "Strategy and Structure: Chapters in the history of industrial enterprise",(1962)Doubleday, New York.

[6] Cohen, A.D. & Scott, K., "*A Synthesis of Approaches to Assessing Language Learning Strategies. In R. Oxford (Ed.), Language Learning Strategies around the World."* Cross cultural Perspectives (pp. 89-106). (1996):Manoa: University of Hawaii Press.

[7] Dunn, R. & Griggs, S.,"*Learning Styles: Quiet Revolution in American Schools*." Reston, VA: National Association of Secondary School Principals (1988)

[8] Alley, G.R., & Deshler, D. D., "*Teaching the learning disabled adolescent: strategies and methods*." Denver: Love Publishing.(1979)

[9] Brown, A. L. *"Metacognitive development and reading.*" In R. J. Sipro, B. B. Bruce, & W.F. Brewer(Eds.), Theoretical issues in reading comprehension. NJ: Lawrence Erlbaum Associates.(1980).

[10] Mishra, Deepanjali. *"Impact of Sociolinguistics in Technical Education"*Research Chronicler, 3(1) 95-101.(2015)

[11] Schumaker, J.B., Denton, P.H.,& Deshler, D.D. *"Learning Strategies Curriculum: The Paraphrasing Strategy.*" Lawrence :University Of Cansas.(1984)

[12] Schumaker, J.B., Deshler, D.D. Alley, G. R., & Denton, P. H.,*"Multipass: a learning strategy for improving reading comprehension."*Learning disability quarterly, 5(3), 295-304.(1982)

[13] Kolb, D.,*"Experiential Learning Experience as the Source of Learning and Development*." New Jersey: prentice hall, inc. (1984)

[14] Spratt, M., Pulverness, A., Williams, M., "*The Teaching Knowledge" Test Course,* Cambridge University Press.(2009)

[15] Samsa, Ashley Lauren. Teaching Feminism., *"Why Should We?"//*http. care2.com/causes/teaching-feminism(2009)

[16] Oxford, R.L., "Language Learning Strategies: What Every Teacher Should Know." Boston: Heinle & Heinle1990

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A Survey on the Security in Cyber Physical System with Multi-Factor Authentication

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***Abstract*—Cyber-physical Systems can be defined as a complex networked control system, which normally develop by combining several physical components with the cyber space. Cyber Physical System are already a part of our daily life. As its already being a part of everyone life, CPS also have great potential security threats and can be vulnerable to various cyber-attacks without showing any sign directly to component failure. To protect user security and privacy is a fundamental concern of any kind of system; either it's a simple web application or supplicated professional system. Digital Multifactor authentication is one of the best ways to make secure authentication. It covers many different areas of a Cyber-connected world, including online payments, communications, access right management, etc. Most of the time, Multifactor authentication is little complex as it requires extra step from users. This paper will discuss the evolution from single authentication to Multi-Factor Authentication (MFA) starting from Single-Factor Authentication (SFA) and through Two-Factor Authentication (2FA). This paper seeks to analyze and evaluate the most prominent authentication techniques based on accuracy, cost, and feasibility of implementation. We also suggest several authentication schemes which incorporate with Multifactor authentication for CPS.**

Keywords—Authentication, Multifactor Authentication, Cyber Physical System, Sensors, Cryptography, Face recognition

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I. INTRODUCTION

We live in a world that is changing at a much faster pace than ever before. More than any other time in our history, there is a pressing need for a new way of looking at science, technology, and social phenomena to help us understand our planet, ourselves, and how we can take control of our collective destiny. Without a doubt, our knowledge in the areas of science, technology, and social sciences has played a key role in shaping the modern world. In simple words Cyber-Physical Systems (CPS) is an engineered system in which a physical system or a process is augmented with cyber components s such as computational hardware and communication network. All these components are tightly integrated with each other that's the reason functionality of one component is dependent on the functionality of other component. each other. CPS are systems of collaborating computational entities which are in intensive connection with the surrounding physical world and its on-going processes, providing and using, at the same time, data-accessing and data-processing services available on the internet. With other words, CPS can be generally characterized as "physical and engineered systems whose operations are monitored, controlled, coordinated, and integrated by a computing and communicating core" [1].

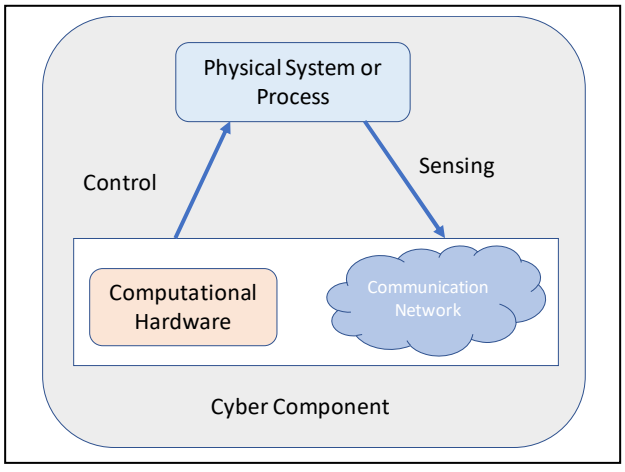

Fig. 1. Cyber Physical System Architecture

The interaction between the physical and cyber elements is of key importance: "CPS is about the intersection, not the union, of the physical and the cyber. It is not sufficient to

separately understand the physical components and the computational components. We must understand their interaction". [2]

Population and our consumption of the Earth's resources are soaring. Estimates put the world's population beyond 7 billion, and annual per capita energy consumption at about 20 MWh/year or 1,800 kg oil equivalent. Fortunately, with the development and availability of powerful communications infrastructure, our awareness of the state of the world and our ability to influence it are also improving: It is remarkable, for example, that the number of smartphones on the planet has already topped one billion. Some of the most exciting innovation these days are from cyber physical system. Some of the examples of CPS include smart grid, autonomous automobile systems, medical monitoring, process control systems, robotics systems, and automatic pilot avionics.

With the recent development and exponential growth of CPS, new security challenges have emerged. New type of security threats, attack and controls have been introduced for the new generation of CPS. However, there lack a systematic study of CPS security issues. In particular, the heterogeneity of CPS components and the diversity of CPS systems have made it very difficult to study the problem with one generalized model. [3]

Authentication is the case of verifying the claimed identity of an entity. The process involves the verification of one or more of some knowledge (like a parole), something in possession (like a RFID access card) or inherence (like the fingerprint) of the entity. Main authentication process verifies anyone of the above information. In theory, authentication is simple process where a user provides some sort of credentials like a password, smartcard, finger print, digital certificate-which identifies that user as the entity which it claims to be. There can be many ways and protocol that can be used to achieve this. Regardless of the method, the basic authentication process remains the same. Authentication is an absolutely essential element of any typical security model. Multi-Factor Authentication (MFA) is a form of strong authentication which uses more than one information among the above. Multi-factor authentication techniques operate multiple authentication programs to confirm the identity of the user and eliminate the risk of compromise of secret or token in basic authentication methods. Each authentication program is a basic authentication process. Thus, the overhead involved in a multi-factor authentication process is multiple times that of a basic authentication process. This makes the process fewer flexible.

In cyber physical system digital multifactor authentication is one of the best ways to make secure authentication. It covers many different areas of a Cyber-connected world, including online payments, communications, access right management, etc. Most of the time, Multifactor authentication is little complex as it requires extra step from users. With two-factor authentication, user also needs to enter a special code or key number which can be generated by mobile, Internet, or some special device or some special code which was generated at the time of registration. In some case these steps can be more than 2 where security level can be increase by adding special code or Token. By introducing additional authentication factors, it greatly increases the level of security, but it could also become frustrating for end users. This paper surveys the already available and emerging sensors (factor providers) that allow for authenticating a user with the system directly or by involving the cloud. The corresponding challenges from the user as well as the service provider perspective are also reviewed.

Rest of the paper is organized as follow. In the first section we have discuss about the evolution from single authentication to Multi-Factor Authentication (MFA). In section III several Multi –Factor Authentication scheme are discussed. In section 4 we have done some comparative analysis and finally in section 5 describes about the conclusion and future work.

II. CONCEPTOF SINGLE AUTHENTICATION TO MULTI-FACTOR AUTHENTICATION

In the opening scene of Hamlet, Bernardo is asked to identify himself by reciting a password before he can take over his castle post from Francisco: "Long live the king!" [4] This exchange, from Shakespeare's prolific tragedy, is one of the most famous examples of passwords in literature. This ancient collection of Arabic stories was officially published in English in 1706. In one of the most famous stories, a woodcutter named Ali Baba overhears a secret phrase used by a group of thieves to protect their treasure. While the thieves aren't watching, Ali Baba utters the phrase "Open sesame" and takes the treasure.

With the development digital technology devices are getting cheaper, smaller, more portable, and much more powerful. Due to advancements in network, connectivity is faster, easier, and wireless is available almost everywhere. However, one thing stills the same, the way we authenticate our device. We still using the same style of user names and passwords that was devised almost 50 years ago at MIT to control the amount of time students and professors could spend on the university's timeshare computer. In the beginning single password-bases approach was enough to access to digital information and resources. Fig 2 shows Initially, only one factor was utilized to authenticate the subject. By that time, Single-Factor Authentication (SFA) was mostly adopted by the community due to its simplicity and user friendliness [5, 6].

Fig.2. Single Factor Authentication

But once we start sharing much more sensitive personal and financial information it was necessary to come up with alternative authentication solutions. In addition, with the development of high-speed computing device it was easy to use several algorithms like brute force to generate millions of passwords per second. To counter those attacks, Multifactor authentication (MFA) security systems come in to solve these problems. Fig 3 shows In MFA mechanism the user must present more than one credential in order to be authenticated. These credentials or authentication factors varies according to the security needs of the application. The user should submit

several authentication factors to the security system consecutively. These factors must be independent to avoid breaking the whole security system in case of compromising one of these credentials. [7]

Biometric technology is among these new approaches validates identity. The move from passwords to fingerprint identification is already implemented in most of smart phones. For the first time PayPal and Samsung worked together to make the Galaxy S5 enables people to shop and pay in a store or on their mobile device using just a fingerprint for authentication. But it wasn't just a simple new authentication step, it open new window how digital commerce be safer and more secure. Up to now, using cryptic and hard to remember passwords were normal and it was always recommended to use maximum available symbols such as upper, lower case, special character, numbers etc. Now that we can begin to move from passwords to biometric information like fingerprints, we're reaching the point where we won't have to make this kind of compromise any more.

Fig.3. Multi Factor Authentication

Fingerprints are not the only form of biometric information used for authentication today. There are many devices that use technologies such as voice impressions, iris scans, and personal physical signals such as unique heart rate information. Other types of advanced authentication technologies are also used. Organizations are already experimenting with various forms of "multifactor authentication" that combine different types of information, location, audio and gestures to verify that you are the one who claims to be you. With technological advances, we can have multi-level authentication that works in the background, so that the user does not even know what's going on.

To do that, you have to know what is needed in the future. Leading the way for these efforts is called Fast Identity Online or FIDO for short. Founded in 2012, FIDO What's new and what does it mean? PayPal is one of the founders of FIDO and now includes a large part of leading technology companies such as Google, MasterCard, Microsoft, RSA, Netflix and dozens of other companies. As it is so urgent to improve security and simplification, there are many companies working hard to offer new solutions. And while it's still too early to say which approach will ultimately replace the current system, I'm sure things are much safer and easier to use than the password-based approach.

III. MULTI-FACTOR AUTHENTICATION METHODOLOGIES

3.1 A Cyber Situational Awareness Framework Based on Digital Twins

Proposed Solution

To improve the cyber defense capabilities of CPS, A cyber situational awareness framework based on Digital twins were developed. As we know staff who operated these systems need better and need more accurate situational awareness, as they have to be ready to intervene in the case of any cyber threat. In As can be seen in Fig. 3, the virtual environment, which hosts the digital twins, lies at the heart of the proposed framework. Data (e.g., system logs, network traffic, sensor measurements) is passively collected from the physical environment to mirror the program states of real devices to digital twins [6].

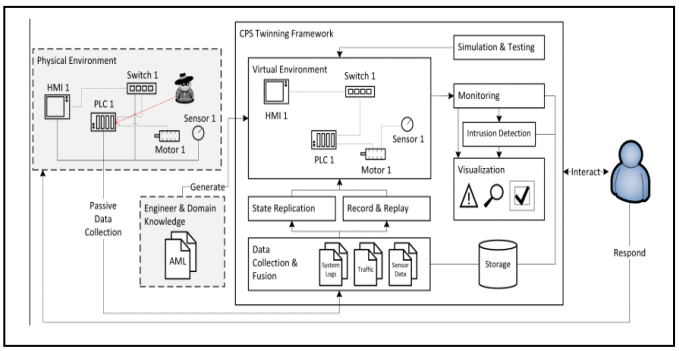

Fig.4. the architecture of the proposed digital-twin cyber situational awareness framework

From the Fig.4's architecture, the behavior of digital twins can be monitored on the program and network layer and potential intrusions can be detected. In this case, digital twins should show the correct, benign behavior of other physical counterparts, because they are generated from the CPS's specification. It also possible that they not show actual state of real devices, but they will still able to spot the deviations that could indicate malicious activity. If there are some vulnerability or if there are some errors, digital twins will show malicious behavior similar to their physical counterparts. Above proposed framework provides enough veracity to advance cyber situational awareness. As a result, the functionality of devices (i.e., programs, network communication) can be emulated or simulated.

3.2 Multi-Factor Authentication based on multimodal Biometric (MFA-MB) for Cloud Computing

Proposed Solution

The A. Mansour et al. [8] present a Multi-Factor Authentication based on Multimodal Biometrics called MFA-MB solution aiming to enhance the security level at the authentication and access control process for the tree cloud computing service models (SaaS, PaaS and IaaS). An authentication server is introduced in the authentication and access control process. The server provides an authentication response (Auth Response) to the user authentication request (Auth Request) for cloud PaaS or SaaS; and allow access to cloud resources for user's access demand for cloud IaaS.

3.2.1 FaMSL-MBS

Based on Ross et al. [9] observations and recommendations, that the fusion at the match score level is usually preferred as it is relatively easy to access and combine the scores presented by the different modalities. In this work, the authors suggest to

use a MBS method integrating multiple biometric traits (Fusion) at the Match Score Level. The proposed system is called FaMSL-MBS, see Fig. 5 for detailed architecture. Depending on the number of traits, sensors, and feature sets used, a variety of scenarios are possible in a MBS. Hereafter, the authors have chosen to integrate multiple sensors and multiple biometric traits.

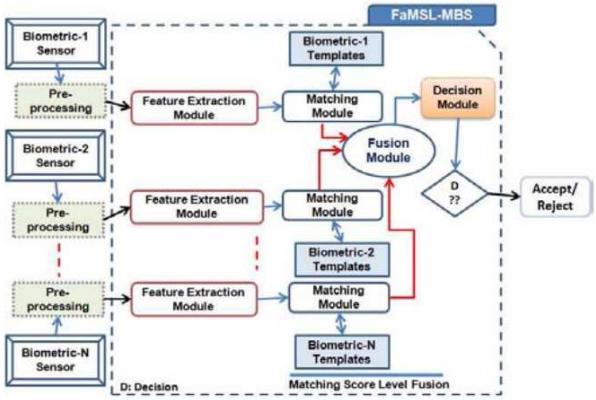

Fig. 5. FaMSL-MBS scheme

3.2.2 Security of biometric templates

Having established the need for MFA and challenges involved in secure storage of authentication data; Khan et al. [10] have proposed a Keyed Random Projections and Arithmetic Hashing (KRP-AH) scheme for generating secure, efficient and renewable authentication templates. This scheme involves random projections of biometric data using a random key derived from a user's password, and arithmetic hashing of the resulted projections.

3.2.3 MFA-MB for Cloud SaaS or PaaS

For End-Users authentication in cloud SaaS or PaaS, the scheme in Fig.6 is proposed as a solution and privacy-preservation for cloud environments. Now, it is assumed that the user has already registered in the database. Moreover, it is important to notice that the relationship between End-Users (cloud consumers) and cloud SaaS/PaaS providers takes place in a trusted environment introducing a Trusted Third Party (TTP); This is why they adopt the Secure Sockets Layer (SSL) security technology.

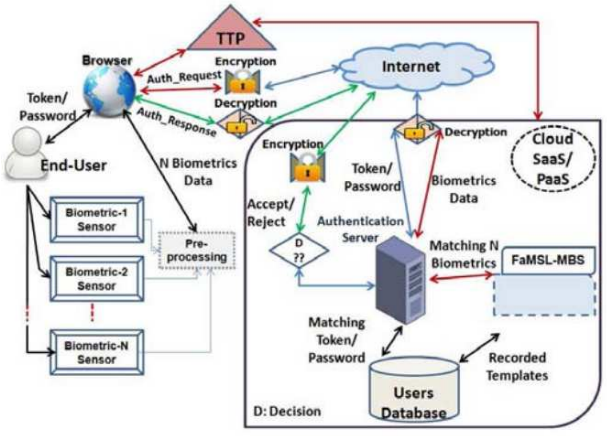

Fig.6. MFA-MB for authentication in cloud SaaS or Paas

6.4 MFA-MB for Cloud IaaS

In order to control access of authorized or unauthorized users to the cloud infrastructure, it depicts in Fig. 7 solution to provide privacy and security for cloud consumers data-owners. Also, in the present case it requires that the user*c*is already registered in the database. Thus, Fig. 7 presents the sequence diagram to allow access based on MFA-MB to cloud resources.

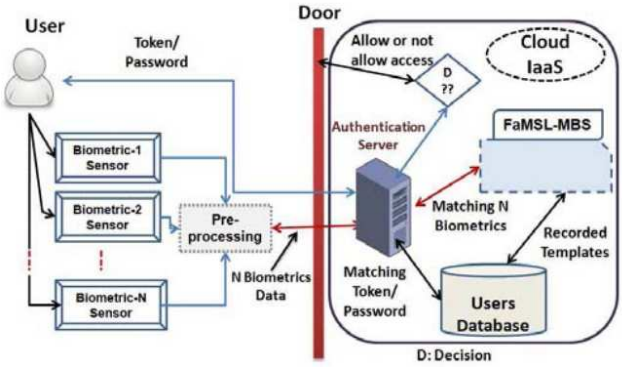

Fig. 7. MFA-MB to allow access to cloud IaaS

3.3Prioritized access control enabling weighted, fine-grained protection in CPS

The public report from the National Electric Sector Cybersecurity Organization Resource (NESCOR) project highlighted the importance of access control. [11]This report identifies possible cybersecurity failure scenarios in six domains of smart grid applications; they are Advanced Metering Infrastructure (AMI), Distributed Energy Resources (DER), Wide Area Monitoring, Protection, and Control (WAMPAC), Electric Transportation (ET), Demand Response (DR), and Distribution Grid Management (DGM). As shown, the top four action groups relate to access control as follows:

1. Control access: block unauthorized access;
2. Authenticate only qualified users;
3. Detect abnormal or unauthorized activity;
4. Verify that systems operate as they should (audit).

A security policy addressing the prioritization is to distinguish and prioritize access operations and strengthen protection level for highly prioritized ones. However, MFA increase the security level with most of the application but it does not work well in CPS environment, specially when it comes to smart grid. An access control mechanism must be able to adjust protection level accordingly that MFA cannot do.

Proposed Solution

To overcome the security weakness in smart grid, Lee et el. introduces a priority-based access control, find grained protection in cyber physical system. [12]

*a) **Attribute-based identification***

In CPS, there are number of devices are connected which generate a large amount of data and that data makes it more difficult to manage communication a non-trivial task. With the help of attribute-based identification, each user does not remember the ID of partners. Instead, it describes data of interest using keywords and/or attributes and communicates with any users who store contents matching the description.

*b) **Attribute-based encryption***

In attribute-based encryption (ABE), a user encrypts data using a set of descriptive attributes, not using a specific user's public key.[13,14] It also creates an access policy tree, representing a Boolean formula defining the combination of attributes. Any user who can present credentials that correspond to the attributes, that is, satisfying the tree, can decrypt the ciphertext.

*c) **Decentralized access control entry***

In Access Control Entry (ACE), each file (object) maintains an ACE that predefines three user classes (owner, group, and others) and determines which privileges (read, write, and execute) are assigned to each class. The privilege for each class is represented by a three-digit code so that a user is authorized to read from, write to, or execute the file. DeACE decentralizes ACE by exploiting ABE and capability-based security. That is, a user is granted a capability "object_1 = 101" by an authority. When the user accesses the object_1, he or she is authorized to read and execute, but not to write. The capability is realized by number-assigned attributes using ABE.

Access Control Decision

In a MFAC system, there exist three types of entities—authorities CA$\in \mathcal{CA}$, users $u \in \mathcal{U}$, and objects $\tilde{u} \in \tilde{\mathcal{U}}$. An authority CAj maintains its own set of attributes, Lj, that can be in various forms. Fig.8 illustrates a protocol for access control in MFAC.

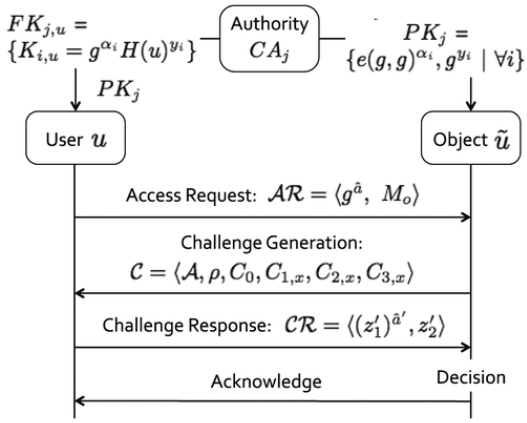

Fig.8. Authentication and authorization protocol. A protocol for an access control decision in MFAC

The proposed MFAC can be applied to various situations in many CPS applications as prioritization occurs everywhere. This article considers a fine-grained access control in a smart building context as a sample scenario. As introduced in section "Prioritization in access control," people perceive the access operations of "reading" and "controlling" with different priorities. The use of additional channel strengthens the level of verification independence. In MFA, a factor represents a very low computation complexity; numbers of 4–6 bits are generated and matched. This simplicity is mainly attributed to human being's involvement in the verification process. This article adopts PBC, LSSS matrix, and DeACE, which represent expensive computation costs. Unlike in MFA, qualification of factors and independence between factors are defined and verified via more complicated mathematical computation processes in MF authorization.

3.4Anonymous and Efficient Message Authentication Scheme for Smart Grid

In smart grid, network communication forms the core of the electric system automation applications. The deployment of one-way information flow communication networks is similar to that in the traditional smart grid. But when it comes to two-way information flow communication network, it involves a neighborhood gateway which collects the electricity consumption records from corresponding consumers via wireless network connections [15].In next step, neighborhood gateway sends its collected data to the control center for detailed consumption analysis via a wired network connection. Finally, the control center sends the electric control information to relieve the burden of electricity demand peak or responds with real-time pricing information to the smart grid consumers.

It is necessary to select the internet Protocol based communication to enable network communications in the smart grid. Unfortunately, such networks are prone to a number of external attacks, such as impersonation attack, tracking attack, and denied of service (DoS) attack [16]. Most recently, Li et al. [17] proposed a provably secure message authentication scheme with high efficiency for smart grids. However, this scheme fails to provide mutual authentication and cannot mitigate the impersonation attacks and DoS attacks. [18]To overcome the weakness of Li et al.'s scheme, they have proposed an improved anonymous message authentication scheme for the smart grid. Similar to Li et al.'s scheme, proposed scheme also has three phases: the initialization phase, the authentication and key agreement phase, and the message transmission phase.

***3.4.1** Security Initialization Phase*

In this phase, the registration center (RC) generates the system parameters and private-public key pair for each registered entity user ($i.e., HAN_{GW_i}$ *and* NAN_{GW_j})

Step 1. The RC chooses a multiplication cyclic group G with order q, and the generator is g. Next, the RC selects a secure one-way hash function $h'(\cdot): \{0,1\}^* \rightarrow \{0,1\}^{*log_2 q+|ID|}$ and a secure hash function $h'(\cdot): \{0,1\}^* \rightarrow Z_q^*$.

Step 2. For each registered entity, RC generates a distinct random number$x$as private key and compute g^x as the

corresponding public key. Here, let$x_i \in Z_q^*$.be the i-th HAN-GW's private key, and P_i=g^{xi} be i-th HAN-GW's public key.

Step 3. The RC sends the key pair (x_i, P_i) toHAN_{GW_i} (i.e., the i-th HAN-GW) via a secure channel, whereP_i can be revealed to others.

Similarly, the j-th NAN_{GW} can obtain its own key pair as (y_j,Q_j = g^{Yj}) from the RC as described in Step 3.

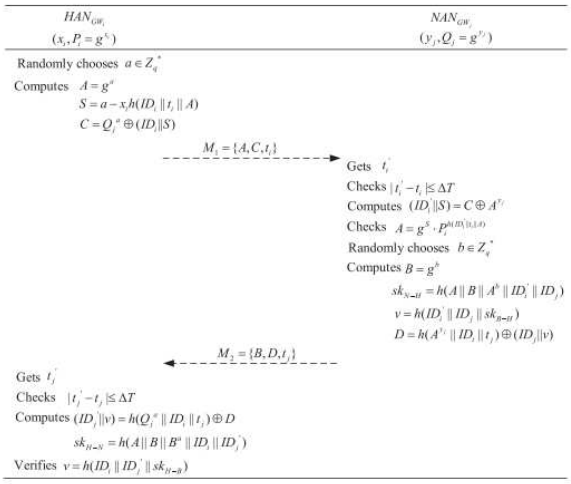

Fig.9. Authentication phase of the proposed scheme

3.4.2 Authentication Phase

In this phase, HAN_{GW_i} and NAN_{GW_j}authenticate with each other. In addition, a temporary session key is created and used for encrypting subsequent transmitted messages, as depicted in Fig. 8.

3.4.3 Message transmission phase

In this phase, a secure symmetric encryption algorithm (i.e., Advanced Encryption Standard, AES) and a secure one-way hash function are used to guarantee the message's confidentiality and integrity.

This paper also demonstrates how their improved scheme achieves the mutual authentication, session key agreement, user anonymity, perfect forward secrecy, and resistance to several attacks [19-23].

3.5Cloud-based Authentication Infrastructure

Users need to perform authentication whenever try to login from different application systems, for example input username and password to authenticate, one-time token authentication [24], or smart card authentication, etc.

Cloud terminals include personal computer, mobile phone, etc. Each terminal user is assigned a smart card with unique identity in this solution, including USB key, SD key, etc. these smart cards provide encryption and decryption functions. Users perform smart card authentication and password authentication while login application systems.

Cloud application systems provide service and need secure identity authentication for users[25]. A third-party authentication center can provide authentication and log service for different users. Encryption cards or encryption machine are adopted to provide encryption and decryption functions. Cloud application servers convey the strong authentication tasks to authentication servers, and deal with the users' access control according to the authentication result returned from authentication server. The proposed cloud-based authentication infrastructure is shown in Fig. 10 as follow:

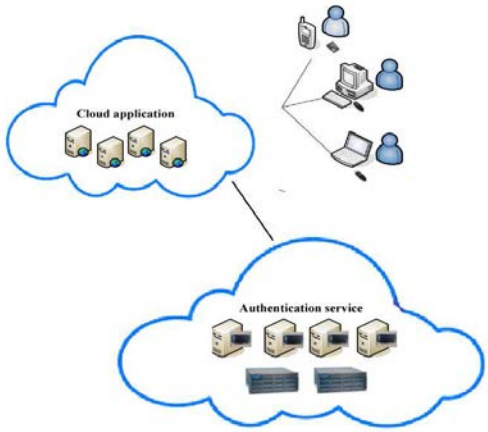

Fig. 10. The cloud-based authentication infrastructure

7.1 Initialization

While initializing, authentication server update user's smart key information, set up the distribution system identity, user identity, key seeds and transmission key. Meanwhile set up the related parameters of encryption cards or encryption machine at server, including transmission key, storage key, etc.

7.2 Registration

If a user needsto access cloud resources, a user should register firstly. When asking for registration request, users enter username and password, and select whether use the proposed multi-factor authentication based on smart key or not, and then sent them to cloud server.

After receiving the information, cloud server checks the username. If it has been registered, the user need enter another username, if not, complete the registration process. For those multi-factor authentication users, cloud server label and storetheir user identity, and carry out the multi-factor authentication protocol when authenticating.

7.4 Authentication Protocol

The proposed asynchronous challenge-response solution presents time factor as a challenge to the user when it tries to login cloud server. Each time cloud server generates a new challenge for user when it wants to login. This challenge is obtained and injected by the client software. Then the client software uses the smart card to generate a unique random number factor, and then use the cryptography technique to generate a unique password according to challenge and random number factor. The cloud server checks username and password, and the authentication server checks the generated one-time password. Only the authenticated legal user can access cloud resources at server. Consequently, the solution

offers good security.

IV. Security Analysis and Comparisons

In the following section we will discuss and compare some of popular and improved Multifactor authentication schemes which we discussed in this paper. in Cyber Situational Awareness Framework Based on Digital Twins provide an advanced monitoring, inspection, and testing capabilities. They also introduced technical use cases illustrate how these features support operations staff in gaining situation perception, comprehension, and projection. But it still needs lots of improvement as author suggested that for further development effort is required to improve the visualization of digital twins and to bring the record-and-replay feature to completion.

In Multi-Factor Authentication based on multimodal Biometric (MFA-MB) for Cloud Computing authors first discuss about security issues (authentication, identity and access management) of cloud computing as well as an overview of biometrics-based solutions were presented. Next, they propose FaMSL-MBS which is a multimodal biometric fusion system at the Match Score Level. Later, they present a multimodal biometric authentication scheme for CC systems aiming to enhance and to increase the security level in terms of authentication and access control. The proposed approach is more efficient as it overcome all the drawbacks related to Tokens and Passwords authentication technologies based on single factors and the limitations imposed by UBS.

In Prioritized access control enabling weighted, fine-grained protection in CPS author presented a novel access control mechanism, MFAC, that employs an MF technique to solve the prioritization problem. In addition, it is implemented using an ABAC model working well in a large-scale CPS network. implemented and applied MFAC to a fine-grained access control scenario in our smart building testbed. The experiments measured its computation cost and showed reasonable performance. They also develop an automated, prioritized smart building control in which protection levels changed along with real-time power price.

In Anonymous and Efficient Message Authentication Scheme for Smart Gridauthor first address the weaknesses in Li et al.'s scheme, and later proposed an improved message authentication scheme which does not incur additional computation and communication costs. A security analysis demonstrates that our proposed scheme can satisfy various security requirements for the smart grid. demonstrate how their improved scheme achieves the mutual authentication, session key agreement, user anonymity, perfect forward secrecy, and resistance to several attacks.

After going through with all above example, we conclude that Multi-factor is getting popular but still it's not that popular and as it needs extra step for authentication people often avoid that. Although some defensemechanisms have been proposed/deployed, new and systemspecificsolutions are still expected in response to the newlyidentified threats and vulnerabilities [26-28].Wang and et al [29] stated that it is not even possible to build an ideal two-factor authentication system and therefore research into this critical issue will continue. Designing a perfectly balanced authentication solution that fits all is probably infeasible. However, designing an authenticationsolution that is well suited for a particular application is certainly doable.Kumar et al. [30] proposed an efficient two-factor userauthentication framework for wireless sensor networks, whichis based on password and smart card and it uses one-way hashfunction. This scheme provides mutual authentication andgives user facility to change password at need. But theproblem here is, it does not provide privileged insider attackas the password is sent to the base station in plain text. It alsosuffers from the synchronization problem as it uses the timestamp for avoiding replay attack.

TABLE 1.

MULTIFACTOR AUTHENTICATION COMPARISION

	Mutual Authentication	Session Key Agreement	cryptographic technique	Resistance to Several Attacks	User Anonymity
A Cyber Situational Awareness Framework Based on Digital Twins	✓	✓	✓	✓	
Prioritized access control enabling weighted, fine-grained protection in CPS	✓	✓	✓		✓
MFA based on multimodal biometrics (MFA-MV) for Cloud Computing	✓	✓		✓	
Anonymous and Efficient Message Authentication Scheme for Smart Grid	✓	✓	✓	✓	✓
Cloud based authentication	✓	✓	✓		

V. Conclusion

With the exponential growth of cyber-physical systems (CPSs), new security challenges have emerged. Various vulnerabilities, threats, attacks, and controls have been introduced for the new generation of CPS.In this paper we discuss the evolution of security from single authentication to Multi-Factor Authentication (MFA) starting from Single-Factor Authentication (SFA) and through Two-Factor Authentication (2FA). In addition, this paper also presents some of the latest multifactor authentication scheme available for different part of Cyber Physical System which demonstrate several features of features of user authentication in the gadget-free world including security, privacy, and usability aspects. These are adapted and extended from earlier research on web authentication methods. In conclusion, we compare all these methodologies available and try to compare with some key attributes such as mutual authentication, Session Key Agreement, cryptographic technique, Resistance to Several Attacks and User Anonymity. this paper gives future research directions and open problems that stem from our observations.

REFERENCES

[1] Rajkumar R, Lee I, Sha L, Stankovic J (2010) Cyber-physical systems: the next computing revolution. In: *Proceedings of the design automation conference* 13–18 June 2010, Anheim, pp 731–736

[2] Lee EA, Seshia SA (2014) Introduction to embedded systems – a cyber-physical approach, LeeSeshia.org., Edition 1.5. http://LeeSeshia.org

[3] Konoth, R.K.; van der Veen, V.; Bos, H. How anywhere computing just killed your phone-based two-factor authentication. *In Proceedings of the International Conference on Financial Cryptography and Data Security*, Christ Church, Barbados, 22–26 February 2016; Springer: Berlin, Germany, 2016; pp. 405–421.

[4] http://shakespeare.mit.edu/hamlet/full.html

[5] Kim, J.J.; Hong, S.P. A method of risk assessment for multi-factor authentication. *J. Inf. Process. Syst*. 2011, 7, 187–198.

[6] AJ Abboud "Multifactor Authentication for Software Protection", Diyala *Journal of Engineering Sciences* 8 (4), 479-492

[7] E. T. Anzaku, H. Sohn and Y. M. Ro, "Multi-Factor Authentication Using Fingerprints and User-Specific Random Projection," 2010 12th *International Asia-Pacific Web Conference*, Busan, 2010, pp. 415-418.

[8] A. Mansour, M. Sadik and E. Sabir, "Multi-factor authentication based on multimodal biometrics (MFA-MB) for Cloud Computing," 2015 IEEE/ACS 12th *International Conference of Computer Systems and Applications* (AICCSA), Marrakech, 2015, pp. 1-4.

[9] Arun Ross and Anil K Jain. Multimodal Biometrics : an Overview. In 12th *European Signal Processing Conference (EUSIPCO),* pages 1221–1224, Vienna, 2004. IEEE.

[10] Salman H Khan, M Ali Akbar, Farrukh Shahzad, Mudassar Farooq, and Zeashan Khan. Secure biometric template generation for multi-factor authentication. *Pattern Recognition*, 48(2):458–472, 2015.

[11] Electric Sector Failure Scenarios and Impact Analyses . *NESCOR, http://www.smartgrid.epri.com/nescor.aspx* .

[12] Lee, E.-K., Lim, J.-H., & Kim, J. (2017). Prioritized access control enabling weighted, fine-grained protection in cyber-physical systems. *International Journal of Distributed Sensor Networks*.

[13] Bethencourt, J, Sahai, A, Waters, B. Ciphertext-policy attribute-based encryption. In: *IEEE symposium on security and privacy*, Berkeley, CA, 20–23 May 2007. New York: IEEE.

[14] Goyal, V, Pandey, O, Sahai, A. Attribute-based encryption for fine-grained access control of encrypted data. *In: CCS'06 Proceedings of the 13th ACM conference on computer and communications security,* Alexandria, VA, 30 October–3 November 2006. New York: ACM.

[15] H.Li,R.Lu,L.Zhou,B.Yang,andX.Shen,"AnefficientMerkletree-basedauthenticationschemeforsmartgrid,"*IEEESystems Journal*,vol.8,no.2,pp.655–663,2014.

[16] A. O. Otuoze, M. W. Mustafa, and R. M. Larik, "Smart grids security challenges: classification by sources of threats," *Journal of Electrical Systems and Information Technology*, vol. 5, no. 3, pp. 468–483, 2018.

[17] X. Li, F. Wu, S. Kumari, L. Xu, A. K. Sangaiah, and K.-K. R. Choo, "A provably secure and anonymous message authentication scheme for smart grids," *Journal of Parallel and Distributed Computing*, 2017.

[18] Libing Wu, Jing Wang, Sherali Zeadally, and Debiao He, "Anonymous and Efficient Message Authentication Scheme for Smart Grid," *Security and Communication Networks,* vol. 2019, Article ID 4836016, 12 pages,

[19] D. He, N. Kumar, S. Zeadally, A. Vinel, and L. T. Yang, "Efficient and privacy-preserving data aggregation scheme for smart grid against internal adversaries*," IEEE Transactions on Smart Grid*, vol. 8, no. 5, pp. 2411–2419, 2017.

[20] D. He and D. Wang, "Robust biometrics-based authentication scheme for multiserver environment," *IEEE Systems Journal*, vol. 9, no. 3, pp. 816–823, 2015. View at Publisher

[21] Q. Feng, D. He, S. Zeadally, N. Kumar, and K. Liang, "Ideal lattice-based anonymous authentication protocol for mobile devices," *IEEE Systems Journal*, pp. 1–11, 2018.

[22] C. Lin, D. He, X. Huang, K. R. Choo, and A. V. Vasilakos, "BSeIn: A blockchain-based secure mutual authentication with fine-grained access control system for industry 4.0," *Journal of Network and Computer Applications,* vol. 116, no. 1, pp. 42–52, 2018. View at Publisher ·

[23] D. He, N. Kumar, H. Wang, L. Wang, K.-K. R. Choo, and A. Vinel, "A provably-secure cross-domain handshake scheme with symptoms-matching for mobile healthcare social network," *IEEE Transactions on Dependable and Secure Computing*, vol. 15, no. 4, pp. 633–645, 2018.

[24] Sanjeet Kumar Nayak, SubasishMohapatra, BanshidharMajhi. An Improved Mutual Authentication Framework for Cloud Computing. *International Journal of Computer Applications* (0975¯8887) Volume 52¯No.5, August 2012. pp: 36-41.

[25] G. Zhao, Y. Li, L. Du and X. Zhao, "Asynchronous Challenge-Response Authentication Solution Based on Smart Card in Cloud Environment," 2015 *2nd International Conference on Information Science and Control Engineering,* Shanghai, 2015, pp. 156-159. doi: 10.1109/ICISCE.2015.42

[26] A. Humayed, J. Lin, F. Li and B. Luo, "Cyber-Physical Systems Security—A Survey," in *IEEE Internet of Things Journal,* vol. 4, no. 6, pp. 1802-1831, Dec. 2017.doi: 10.1109/JIOT.2017.2703172

[27] P. Kumar, A. Gurtov, M. Sain, A. Martin and P. H. Ha, "Lightweight Authentication and Key Agreement for Smart Metering in Smart Energy Networks," in *IEEE Transactions on Smart Grid*, vol. 10, no. 4, pp. 4349-4359, July 2019. doi: 10.1109/TSG.2018.2857558

[28] N. Bruce, M. Sain and H. J. Lee, "A support middleware solution for e-healthcare system security," *16th International Conference on Advanced Communication Technology,* Pyeongchang, 2014, pp. 44-47, doi: 10.1109/ICACT.2014.6778919.

[29] D. Wang, D. He, P. Wang, C.-H. Chu, Anonymous two-factor authentication in distributed systems: certain goals are beyond attainment. *IEEE Trans. Dependable Secur. Comput*., 12(4) (2015) 428-442.

[30] P. Kumar, M. Sain and H. J. Lee, "An efficient two-factor user authentication framework for wireless sensor networks," *13th International Conference on Advanced Communication Technology* (ICACT2011), Seoul, 2011, pp. 574-578.

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Web based Learning: A Methodology to Teach Literature in a Classroom

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Abstract—**The internet has succeeded in emerging as a major component in our daily lives, and its presence in education sector is outstanding. Web-based syllabuses have been enjoying an upper hand and have succeeded in getting attention of learners and the instructors. If presentations at international conferences are any indication, the interest in this new instructional medium is indeed commanding. Web-based learning involves the use of appropriate technology with the corresponding pedagogical approaches managed in the context of today's educational setting. Web-based learning encompasses all educational interventions that make use of the internet. There are currently three broad classifications or configurations within WBL: tutorials, online, discussion groups, and virtual patients. The distinctions between these configurations are often blurred, and in fact a given WBL intervention might use a combination of two or three, but the implications for teaching warrant a conceptual, albeit at times arbitrary, separation. Therefore the objective of this paper is to understand the concept of Web based learning and its advantages along with its use in literature, culture and folklore studies, and the various methodologies to implement it in a class of Folklore studies.**

Keywords—Web based learning, literature, techniques, folklore, culture

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I. INTRODUCTION

The learners understand the concept of cultural differences, and get acquainted with the concept of the term review of peers and enhance their own knowledge. Jakes (2006) confirmed digital storytelling helps students explore the meaning of their own experience, give value to it, and communicate the experience on multiple levels to others. Sadik indicated that including storytelling in the social studies curriculum develops students' understanding of democratic ideals, other cultures and citizenship; improves their communication skills; motivates them to connect the past and the present; and shared experiences.[1]

Web-based learning is a type of learning process which utilises the system of Internet as a mode of delivery method of instruction for accomplishing different types of activities of learning. It is an online learning process where the learning methodology is carried out and conducted without face to face interaction between the instructor and the learners, Or it could also be put in this way where the instructor interacts with the students either by being physically present in the classroom or imparts education through virtual medium depending on the need of the syllabus. Web-based learning can be integrated into a curriculum that turns into a full-blown course or as a supplement to traditional courses. It is a form of education where the resources are imparted between student faculty and student-student interactions which take place on the World Wide Web. There are various online courses which are taken as primary sources of learning and have successfully caught attention of faculties as well as learners. Sometimes when it becomes difficult to be physically present in various conferences and present their paper, then a scholar can present his or her paper through video conferencing or sending the recorded video of the presentation by the presenter. At the same time a scholar can directly watch the proceeding of the conference through various social networking sites. Web-based learning includes every intervention related to education which uses digital mode which is also known as local intranet. Web Based learning is broadly classified and configured into three types namely tutorials, online discussion groups, and virtual patients. This difference between the aforesaid configurations may not be very much clear and it may be that Web based learning could utilise not one or two but multiple combination of Medias and its implications in teaching generate aconceptual and arbitrary outcome.

"Web teaching is nothing but building network. It helps to build strong bonding with one's students and help them identify and utilize the resources all over the world irrespective of distance. combining different materials – music, motion, text, narration – into one presentation; collecting related information from multiple sources... enable students to make their own connections by offering materials for download and use in their scholarship or by having them construct web documents as part of their coursework. And this process of making meaningful connections is at the core of all learning." [2]

Web based learning is conceptualized as a mode of online learning process or e-learning because all the online course content are included in the database. Discussion forums can be created online through formation of various groups, pages etc on various social networking .Web based courses also has facility of accessing various printed course materials in pdf form and they also provide http link which can direct a learner to the course. After clicking on the link, the learner visits the page in the web and the reader can easily access the course materials and then again the reader may find hyperlink which can easily be opened thereby leading to various other linked documents. There are two types of learning environment which are VLE, virtual learning environment and MLE, managed learning environment. The VLE is a combination of functions operated by discussion boards, chat rooms, online assessment, tracking of students' use of the web, and course administration. VLEs are like a general learning environment which provides information to learners. VLEs have the ability to share information to the end, and collaborate on different academic assignments. A managed learning environment is a learning system of the electronic management which support teaching and learning. The learners ofMLE could be tutors, students or mentors. Sometimes it is very common to interchange Management Learning Environment with Virtual Learning Environment. However, the basic objective of both of these courses is to benefit the learners.

Web based learning is often called online learning or e-learning because it includes online course content. Discussion forums via email, videoconferencing, and live lectures (video streaming) are all possible through the web. Web based courses may also provide static pages such as printed course materials. [3] The advantages of Web based learning is that it provides ample opportunities to learn and getting assessment to a enormous amount of knowledge and data collection and its information. The role of teachers is vital to make the learners culture through web based learning. They also need to take stock of the learning environment that is provided to the students which should be learner friendly. It should also be seen that the needs of the learners are adequately supplemented and taken care of. There are many advantages of Web based learning but it has to be supplemented with adequate technology requirements. If this is not provided, then the student can easily get distracted and disturbed. It should not be made optional in classrooms, rather there should be appropriate utilization of technology and should never be experimented with students in a very casual form or out of curiosity. Sometimes there is a pressure among the teachers to use this technology in their classroom which might be interesting to a teacher. In such cases, the learning fails because of lack of interest.

The structure of the paper is organized as follows: Section II presents the past work related to this field. Section 3 describes about the methodologies used for this research work. Section 4 describes about teaching folklore through web based learning. Section 5 describes about the conclusion and future work.

II. RELATED WORKS

There have been many definitions about digital storytelling in related literature Porter (2004) defined storytelling as combining authentic stories with image, music, graphs and voice over while Dupain and Magure (2005) described it as creating a story by integrating multimedia elements such as visuals, audio, video and animation as well as Chung (2007) highlighted it as a harmonious multimedia presentation composed of digital components such as text, visuals, video and audio. However, digital storytelling are overall considered as generating a story about a subject by using multimedia tools and software and sharing this story in multimedia environment (Nguyen, 2011; Robin, 2008). Nearly all digital stories are originated via combining components (text, voice-over, video, music, and visuals) with an authentic story on a particular subject. Digital stories , altogether, are short videos created by integrating image, video, background music and audible or written narration via some basic hardware and software (Microsoft Photo Story, Windows Movie Maker, Wevideo, Web 2.0 etc.) with authentic story (Wang and Zhan, 2010). Nevertheless, digital storytelling is not just a plain power point presentation (Dreon, Kerper, and Landis, 2011). Robin and Pierson (2005) noted that digital storytelling is the activity of producing meaningful stories that reflect individuals' imagination. Digital stories can have aim of informative, instructive and personal narration (Robin, 2008). Digital stories can rise up in different types ranging from personal narratives or instructional stories to narratives that recount historical events and in many different fields ranging from social science to science Coutinho, (2010). Banaszewski (2005) pointed out that educational technologies have progressively taken place in education and instruction environment, accordingly, digital story have become widespread in classroom setting and in various fields of study as stated by many academicians, researchers and educators. Though the term "digital storytelling" is, generally familiar to educators, many still don't know what it is or how it works.

Digital storytelling is a process where the narration is usually done through first person. It is usually done by showing visuals like videos, and other multi- media and music played at the background. The main aspects of storytelling are, it should have a basic idea or viewpoint which addresses a question which is important from the point of view of the story teller as well as to the listener. Two other key features are the economical use of words in the written script and appropriate pacing and rhythm in the oral narration [4] Secondly, Creativity of the story teller too is an important aspect of storytelling. Thirdly, the fluctuations in the tone of the speaker, because if the narration is monotonous, it will fail to generate interests among the audience. In case of narrating it through

multimedia, if shocking images or a laughing icon is shown, then listeners would find it interesting. While choosing the topic, the story teller could choose from a wide range of biographical, anecdotal, historical, cultural theme depending upon the audience.

There is no specific discipline of Digital storytelling. It could be chosen from a wide range of topics and could be even incorporated as the basic syllabus of language and literacy courses and its application. Storytelling can be relevant in all streams of education like humanities, culture, management and engineering at all levels like school, college and professional degrees. The benefit of using narrative writing at college level is that it can part of a curriculum development or sometimes it may also be used in order to motivate those students who need moral support. In a situation where the instructors find biggest challenges to provide moral support, narrative story telling will come to their rescue. . Hung, Hwang, and Huang (2012) have shown that digital storytelling projects can improve student motivation and problem- solving abilities. [5] Gunter (2012) opines that digital storytelling could be beneficial in motivational aspects, distinguishing between "extrinsic" and "intrinsic" motivation. Gunter further says that students could be motivated externally by giving them prizes or some marks. whereas intrinsic motivation could be an "authentic artefact" in order to establish a "personal investment" [6] thus it could be said that digital storytelling techniques is reliable and beneficial to impart external as well as intrinsic motivation which is very much beneficial in the long run for the students as well as the teachers. "Newer technologies such as computers and video conferencing are not necessarily better (or worse) for teaching or learning than older technologies . . . they are just different . . . The choice of technology should be driven by the needs of the learners and the context in which we are working, not by its novelty."[7].

The issue that has been mentioned is connected with the use of technology. These issues could be easily sorted out when the students get used to computer and know how to handle it. In order to use the Digital Story telling methodology and teaching literature is concerned, in the classroom, the instructors must prepare themselves and should be technology competent. It is true when Boase (2007) says, "the challenge the digital storytelling in education poses is how to harness the massive potential of the story form, with its possibilities to inspire, engage, transform, through a process that will endow it with opportunity for reflection, critical thinking, and problem solving." [15]

III. METHODOLOGIES

The Digital storytelling is one of the innovative approaches of giving instructions, learning, planning and result oriented approach, yielding positive outcome. Iannotti (2005) pacifies, "digital storytelling can be overwhelming if it's not well thought out". [8] At the same time, Robin and McNeil (2012) opine for implementation of an instructional design framework by using ADDIE (analyze, design, develop, implement, and evaluate). Another important aspect of teaching through DST is the instructor does not need to be formal while taking the class. However one needs to understand various critical issues while using this story telling technique. The issues are appropriate technology must be used, there should be support services availability, the students as well as the instructors should be interested in technology-based learning. at the same time the educators must caution the students regarding technical considerations like how to save files, how to get a backup and other sophisticated features. Robin and McNeil (2012), Digital Storytelling Cookbook (Lambert, 2010),guide the students on these technical sophistication of computer and multi media. The software which could be used are Adobe Premiere Elements, MS MovieMaker, Photostory, and WeVideo which are available for free versions. WeVideo does not require to be downloaded because it is cloud based. it is just that the user has to sign up for a free account. MovieMaker and Adobe Premiere have a built-in recording feature, while Moviemaker does not have a built-in recording feature so the students can do so through their phones or any other device after which they can upload it. All the Adobe Reader needs to be brought but it is very essential because it has so many features that it has the ability to generate much advanced quality video. The instructor can experiment with the free options for those classes with more number of students. There are many advanced quality videos that are available which does not have fancy features and are expensive which might not be needed for the purpose of teaching students.

A Digital Storytelling Pilot Technique was implemented by some teachers in their classes at a community college in New York City in 2013 after getting enriched by the workshop that was organized on Digital Story Telling. The technique that is discussed was organised one of the participants of the workshop who intended to make an assessment regarding the technical practicability and pedagogical implications of this process of digital storytelling in an ESL class. [9]

It is a fact that the culture of the post modern era is conceptualizedas 'digital', 'cyber culture', 'Internet culture'. For any researcher of culture studies or a folklorist, web based technology or the tech culture might appear to be more necessary because digital technology also involves deriving thousands of years old data and reviving the culture and age old tradition and retrieving archaic texts through digital remixing and other methodologies. The modern digital culture plays pivotal role in continuous process of globalization which is again conceptualized as "the process of increasing interconnectedness between societies such that in one part of the world more and more have effects on peoples and societies far away".[10] This over emphasizing feature of globalization consist of developing the structures of transnational and transcontinental framework along with the rampant outgrowth of technology, economy of the market , consumerism, information and culture ethics and so on. The concept of digital culture that is elaborated deviates from the original concept and it has indeed brought about invention of new communication strategies among different people and people who can easily communicate with their office, institutions, organizations and other professional spheres.

The quantity of e-folklore is vast. Furthermore the number of outlets is enormous, with source addresses changing constantly. Much of this outpouring is highly ephemeral in nature, but on the other hand it is clear that such ephemera are prolific breeders of new ephemerides on an almost exponential

scale. Research in this area is often exasperating as even the best of Internet search engines fail to reveal stories just a month or so old – and even solemn prayers to the Internet patron saint St. Isidore of Seville (Isidorus Hispanensis, 560–636 A.D.) seem to fall on deaf ears! A characteristic of e-folklore in its various manifestations is the use of specific language forms. Probably, partly by virtue of its status as the language of technologists, English has become the basis of many new 'e-languages', for example Cyberspeak, Netlish, Weblish, Internet Language, etc. Many natural languages have also absorbed or adapted English words or acronyms to create, specific 'e-dialects' or 'e-jargons'. The multilingual term "blog", for instance, derived from the English "weblog", has assumed an international meaning and is used world-wide. Sub-jargons have also emerged for mobile phone and Internet users, often merged with elements of secret languages or special codes for the exclusive use of certain groups such as children and prisoners. An example is "A-leet", also known as "leetspeak" or just "1337", a strange slang based upon the transliteration of words into a mixture of figures, letters and graphic symbols.

A. Teaching Folklore Through Web Based Learning:

A visualization of a literature or a cultural classroom would certainly not be a one which imparts teaching through online mode because of the fact that the methodology of taking classes is believed to be conventional which would imply professors would be taking classes chalkboard method. But with the advancement of technology, faculties and instructors have begun using technology in their classrooms as a methodology of teaching. This would be beneficial in making the learner engaged and succeeded in generating interest among the students. There are various research guide, manuals and online websites for the trainers who have developed the methodology of teaching literature, culture and folklore online. These aids provide theoretical usage as well as practical manuals to these faculties which are reader friendly and can easily be read and incorporated in their teaching. This would enable the students to learn literature and culture in a virtual environment.

B. Preservation of Folklore and Culture Through Digital Technology:

The concept of cultural heritage safeguarding is linked to the notion of ethnic and cultural identity, and its modern connotations give rise to interesting issues surrounding the problem of identity and multiplied identities created by global multi-media. On the one hand lie considerations of human rights and acceptance of individual and collective identity. On the other, there are the social, political, and economic issues connected with progressive globalisation and the omnipotential cultural power of electronic devices. The holistic approach to cultural heritage is the subject of UNESCO governance on a global level. The definition of cultural heritage is vast, mainly because the concept contains an expression of human knowledge and creativity, and the ways of life developed by communities and passed on from generation to generation. These include customs, practices, places, artifacts, artistic expressions and values. It originates out of the interactions between people and places over time, and influences contemporary life in all aspects; social, economic and technological. From architecture to transport, technology, museology, ethnic studies, folklore and oral culture, language, education, and audiovisual heritage amongst many others. These resources are obviously non-renewable and unique and as such are of great importance for its sustainability and benefit to future generations. Furthermore the definition of cultural heritage is subject to a constant evolution. What one generation considers 'cultural heritage' may be rejected by the next generation, only to be revived by a subsequent generation. In summary, the cultural heritage of any world region consists of all the resources that are inherited from its past in all forms including tangible, intangible and – in the postmodern world – a digital heritage as well. That is why digital heritage10 safeguarding is a matter not only of the past but more so of the future.

The heritage digital movement includes not only digitisation of libraries and archives, but also archiving of digitally created sources such as graphics, design, digital storytelling, etc. Here we should mention the project called DIHE (Digital Intangible Heritage of Europe) that has been Swedish reply to DIHA (Digital Intangible Heritage of Asia).[11] DIHE was founded in 2012 as a joint venture between The Interactive Institute and the Digital Heritage Center in Sweden as "a truly unique initiative, which focuses on aesthetics and creativity by combining artistic development with research in design and technology. In addition, it is a real-life experiment in the organization of cross-discipline research combining art, design, anthropology, computer science, interaction design, ethnography and many other disciplines".[12] DIHE develops the interdisciplinary and cross-sectoral methodological approach that spans across visitor and museum studies, interaction design, human computer interaction, cultural studies and ethnography. Special attention is put to related fields such as cognitive and affective disciplines, or cognitive semiotics helping to understand the meaning making processes within the framework of communication channels and modalities.

C. Teaching Folklore through Web Based Technology:

The visual practice of web posting differs from the vernacular use of photography, photocopying, and faxing because it is more widely available and can be more thoroughly personalized. In Dundes's joke, the machine runs by itself; on the Web, people imagine that they personalize the machine in their own image and often approach it like a workshop in which the screen constitutes a virtual canvas or desktop. Users can arrange and symbolize material on the Web as virtual reality to create a persona that was literally screened through postings and sought-out kindred spirits. The wonder of the Web is the graphic material open to view—graphic in a visual sense and also in its uncensored quality, suggesting the freedom of expression of a folk, or informal, commons in which participants regulate action through tradition rather than through arbitrarily imposed rules. Cognitively, a binary has been constructed between analog print as the regulated, institutional world of potential censorship and the digital Web as the open, uncensored folk domain. Theoretically a wide

open field, the Internet's cultural hangout has proved especially attractive to youth, who, the public imagines, better their elders with the informational capital of new media and often use it as a secret language beyond parental and professorial monitoring (Bronner 1995, 232–46; Sullivan 2005). In an individualistic society placing faith in technological progress, the energy of youth is channelled into innovation that will displace the establishment culture of older stuffed shirts; fashion, fads, and trends of the young dictate the popular culture, media and retail outlets remind consumers. Children embrace the communication potential of the folk Internet and shape it into their own image and culture supposedly because they are preoccupied with social and pubertal concerns rather than business applications.

Besides freedom of expression, the Internet putatively liberates artistic communication from materiality, but hardly immaterial, the folklore of the Internet is consequential stuff that invites human participation. In this way, it is conceivable to envision the difference in method and theory between natural and virtual reality that Kirshenblatt-Gimblett invited folklorists to contemplate by thinking about the betwixt and between characteristic of Internet communication. Additionally virtual traditions deviate from the definition of folklore as artistic communication in small groups, which Dan Ben-Amos inventively suggested as a modern definition of folklore in context; in a digital age they appear as layered (and often non-linear) symbolizations or processes in multivariable, interactive networks (Ben-Amos 1972; Labbo 1996; Laske 1990; Sommerer and Mignonneau 1999). Although naturalistic tradition is often associated with precedent from way back when, the Internet's flattening, or disregard, of time invokes the view that something being on the Internet is sufficient to show this pre-existent characteristic of tradition. The implication is that this something has its own independent existence that involves an artificial fusion of new and old, text and image, and creativity and tradition. Folklorists and other cultural scholars may be concerned that in this kind of tradition the electronic tools of forwarding and copying and pasting standardize and stabilize texts, taking away the variability that marks cultural identities in natural contexts, but the serial reproductive process of homepages and forums appears to foster commentary and communal alteration, often with an instrumentality that signifies cultural space (Baker and Bronner 2005, 346).

There are various ways by which folklore can be taught to students:

A) Teaching Folklore to students:

Student will explore the common elements of folktales and tall tales while learning how these tales built the spirit of American people. Students will identify the tall tale elements. Students will also write responses to these tales, including a composition in the form of a monologue or a news report. They will perform these compositions for the class.

Learning Objectives

- To activate prior knowledge and relate it to the reading selection.
- To demonstrate grade-level proficiency in writing to inform and explain concepts, and express personal ideas in order to persuade.
- To demonstrate grade-level proficiency to read for literacy experience using before, during, and after strategies.
- To identify meanings of terms unique to literary language.
- To identify the structure of literary or narrative text.
- To Interact with text using the four stances:
  Global understanding
  Developing interpretation
  Personal reflections and responses
  Critical stance
- Interpret tall tales.
- Present a report to the class in the form of a dramatic monologue or a news report.
- Read for literary experience.
- Respond to literature through writing and discussion.
- Use strategic reading behaviours to construct, extend, and examine meaning for a variety of texts.
- Write for various audiences and address the following purposes:
  To inform
  To persuade
  To express personal ideas

B) *Tell Tales:*

In this lesson, students are introduced to the genre of American tall tales. Students are exposed to several traditional tall tales, then prompted to write an original tall tale set in contemporary America. The tall tale must address a current event or issue and must feature a "larger-than-life" main character. The students use exaggeration and hyperbole to portray the way in which the main character resolves the issue or problem. Students then dramatize their tall tales for the class.

Learning Objectives

- to Recognize tall tales as a vehicle of entertainment and identity for the pioneers
- to Read for literary experience several American tall tales from the different regions of the United States
- to Identify and analyze components of a tall tale
- to Create an original tall tale
- to Perform original tall tales for classmates

Teaching Methods

- Guided Listening
- Discussion

- Lesson Set up

a) Teacher Background

b) Background knowledge of the students:

- Have some experience with the writing process.
- Know the term "pantomime" and have some experience of miming actions.
- Be familiar with newspapers and the concept of current events.

c) Grouping Process

- Small Group Instruction
- Large Group Instruction

d) Performance:

Teacher should prepare a brief story to tell in Step 1 below. Choose a fairly plain narrative that can be transformed into a tall tale: a vacation trip, for example, running an errand, or something seen on the way to school.

C) Writing Folktales:

Students identify and analyze folktales. They learn the characteristics of folktales and use them to evaluate existing tales and to create original tales of their own. Students apply the writing process to strengthen writing skills and to develop creativity.

Learning Objectives

Students will:

- Identify, examine, analyze, and evaluate folktales
- Incorporate the elements of traditional folktales in original folktales of their own
- Write for literary purposes and for a variety of audiences: peers, teachers, parents, school-wide community, and beyond
- Pre-write, draft, revise, and proofread as part of the strategic approach to effective writing

Teaching Methods

- Hands-On Learning
- Visual Instruction
- Group or Individual Instruction
- Guided Practice
- Independent Practice

Grouping Process

- Small Group Instruction
- Individualized Instruction

Staging Performance:

Arrange handouts in the order the class will address them. Post content vocabulary words for easy reference. If you choose to reference props during the telling of the folktale, have them placed in the appropriate places.

2) Assesment:

- Arrange srrange seating so that deaf/hard of hearing students are close to where instruction will be delivered.
- Blind/Low Vision students will benefit from handouts with large print or braille.
- English Language Learners may benefit from supplemental vocabulary sheets that define literary terms and difficult words.
- An adjusted workload (brief examples of folktales) will help struggling/striving readers.
- Interpersonal and Intrapersonal learners may want to develop the characters in their folktales. Provide a list that outlines all folktale components so that their characters do not overpower the tales.
- Folktales may include animals as characters and highlight setting. Naturalist learners may benefit from stories that use animals to relay events and that vividly relay setting.

IV. LIMITATIONS

A. Technical problems:

Web based learning is no doubt advantageous to the students, yet it is not free from drawbacks. As it is media based, therefore it is evitable that all instructional media failure can occur. For example, while planning to teach the students through power-point presentation and it may so happen that there is a power failure without any power backup. The traditional method of teaching through chalk board might be less lucrative but it is free from these hassles. The students as well the teachers might face problems if they are not net savvy and a small problem could lead to everlasting consequences.

B. Poor instructional design:

There is a variance in the pattern of quality of all the teaching process. But in case of Web based learning, it has to be explicitly planned and executed because once it is uploaded; it is seen as well as evaluated by others. And if an instructor is very much efficient, he/ she can take a class with minimum preparation which is not possible in case of Web based learning. It is also seen that WBL course structure has inferior. For instance, shoomp.com, spark notes etc' which publishes notes and critical analysis of various text books in literature which cannot be considered as scholarly. These types of courses are less advantageous and are not suitable for the learners and the instructors. WBL also pose challenges of implementing online with unknown users.

C. *Ignorance of the users as well as the trainers:*

There It is also seen that the users are not much techno savvy and hence they have difficulty in handling technology during the classes. Similarly there are some trainers who are also unaware of the process of using computers and online technology to impart education due to which the education cannot be imparted.

V. CONCLUSION

Technological expansion which is taking place at a very faster rate with increased software capacity has succeeded in motivating the learners and the educators. The rapid expansion of the Internet and increasing software capabilities are influencing the entire teaching process at different starts. The students learn how to learn, organize, build and relate. Their analytical skills develop. The students get to know about different culture along with their own. Their writing skills develop in a very constructive way. During presentation of the story, the student's oral skills also develop. The Students were advised to use Skype as an option, but it was not possible for some students to get an access to Skype.However, due to the collaborative efforts of the students with a positivity attitude appeared to enrich the projects quality in which they are involved. The students collaborated with their fellow students of different sections but sometimes it was difficult for those students to use computers who stay in the campus premises of a non commuter college. Therefore it is suggested to allow the students more time for such classes which can give peer feedback as well as teachers comments. The students could involve themselves in a group activity where a group of 7 to 8 students can form a story together thereby each student supporting other students in the group. It is definitely true when Iannotti (2005) states, "Having fewer projects to manage would make it more feasible for the instructor to provide substantial feedback to students. As with the implementation of any new tool, digital storytelling requires a high level of commitment and effort throughout the process. [13] ". As a whole, there are benefits of the process which involves teaching and learning. The process is very easy because once the student knows how to use the technology it becomes less weird. The learner will understand how much beneficial it is to the them. Most of the digital preservation projects focus mainly on digitizing artifacts, in which the crafts of how to make them and skills of how to use them are neglected. Besides, folklore and religious rituals embed spiritual meanings. Step-by-step procedure of a ritual is not trivial for a people or a religion. A website served as an extension to digital library of folklore artifacts has been constructed to be used as an e-learning platform for folklore education in obligatory and higher education. The system not only constructs a digital library for folklore preservation but provides instructional interactive materials with media richness to support a more effective method for folklore education than non-interactive or traditional classroom learning. [14]

REFERENCES

[1] Sadik, A.,"Digital storytelling: A meaningful technology-integrated approach for engaged student learning."*Education Tech Research,* 56(4), 487-506.(2008). doi: http://dx.doi.org/10.1007/s11423-008-9091-8

[2] Jakes, D.,"Standards-proof your digital storytelling efforts."*Tech Learning.*(2006).

[3] Karakoyun, F.,"Examining the views of elementary school students and preservice teachers about digital storytelling activities in online environment."*Ph.D Thesis*. Anadolu University, Institute of Educational Science, Eskişehir, Turkey(2014).

[4] Lambert, J.,"Digital storytelling cookbook and traveling companion." Berkeley, CA: *Digital Diner Press*(2010).

[5] Nguyen, A. T.,"Negotiations and challenges in creating a digital story: The experience of graduate students."*Dissertation (Ed. D.)*, University of Houston(2011).

[6] Gunter , B.,"Remembering televised news: Effects of visual format on information gain."*Journal of Educational Television*, 6, 8–11. (1980).

[7] Judy McKimm, Carol Jollie, Peter Cantillon.,"Web Based Learning"*The BMJ Vol 326*(7394) 870-74(2003).

[8] Porter, B.,"Digitales: The art of telling digital stories."*USA: Bernajean Porter Consulting.*(2004).

[9] Reiner, M.,"Sensory Cues, Visualization and Physics Learning."*International Journal of Science Education*,31(3), 343–364(2009).

[10] Robin, B.,"The educational uses of digital storytelling." In *Proceedings of Society for Information Technology & Teacher Education International Conference*, Chesapeake, VA: AACE(2006).

[11] Violetta Krawczyk,"Oral and Visual Folklore as an expression of Global Fear Conscious."*Literature and the Arts Vol 4 No 3*(2012).

[12] Fleetwood J, Vaught W, Feldman D.,"MedEthEx online: a computer-based learning program in medical ethics and communications skills."*Teach Learn Med 2:96–104*(2000).

[13] Robin, B.,"The effective uses of digital storytelling as a teaching and learning tool"*Handbook of research on teaching literacy through the communicative and visual arts* New York. Lawrence Erlbaum Associates(2008).

[14] Bates AW. "Technology, open learning and distance education." London: *Routledge*, 1995

[15] Boase, K. "Digital storytelling for reflection and engagement: A study of the uses and potential of digital storytelling."*International Journal of Information and Communication Technology Education*, 6(2), 76-87(2008).

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