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A Cell Biology Inspired Model for Managing Packet Broadcasts in Mobile Ad-hoc Networks

Sulochana J. Sooriyaarachchi*, Anil Fernando**, Chandana D. Gamage*
*Department of Computer Science and Engineering, University of Moratuwa, 10400, Sri Lanka
**Centre for Vision Speech and Signal Processing (CVSSP), Faculty of Engineering and Physical Sciences, University of Surrey, Guildford, Surrey, GU2 7XH
sulochanas@cse.mrt.ac.lk, w.fernando@surrey.ac.uk, chandag@cse.mrt.ac.lk

***Abstract*—The modern computing paradigm is moving towards personal devices that incorporate wireless networking, mobility, and collaborative applications. The networking paradigm that best matches this scenario is the mobile ad-hoc network (MANET). A common instance of a MANET is the dense MANET that can be expected in any setting where large number of people congregate such as movie theatres, sports stadiums, shopping malls, transportation hubs, lobby of public offices, lecture rooms, etc. The existing packet transmission protocols for MANETs are inefficient for dense MANETs due to packet broadcast storms for stateless protocols and non-availability of anchor nodes for stateful protocols. This paper presents a new packet broadcast model developed based on cell biology and provides simulation results on protocol efficiency. As smart phone devices and collaborative applications proliferate among users, the proposed dense MANET protocol could provide real benefits to Internet enabled users and devices.**

***Index Terms*—Mobile ad-hoc networks, Packet broadcasts, Cellular automata.**

I. Introduction

THE current trend in day-to-day communication of average people is towards the intensive use of mobile devices such as smart phones and slate type computers. These devices are generally capable of connecting via cellular networks, WiFi or Bluetooth. The abundance of such portable communication devices with wireless capabilities gives rise to potential ubiquitous computing experiences. For example a traditional classroom can be converted into a collaborative learning environment via a stand-alone ad hoc network of mobile phones. Another application would be for friends roaming in a shopping mall to detect each other and share ideas using an on-the-fly ad hoc network without the support of cellular networking infrastructure or WiFi hotspots in the arena. In this research we focus on a dense network of such mobile devices that could be visualized as a dense Mobile Ad-hoc Network (dense MANET).

MANETs are generally dynamic in terms of topology thus making it challenging to device a routing mechanism. There is added complexity into routing when these MANETs are dense in nature. For example the routing tables maintained in mobile nodes with the existing routing schemes such as AODV, TORA and DSR will become unmanageably large in size and the network will get overloaded with flooded control packets. Therefore, it is essential that the nodes in a dense MANET keep less or no state information, specifically pertaining to global network and even the neighboring nodes. It is also important that the nodes send the least amount of control packets to conserve resources such as battery life. Due to the unavailability of a suitable routing mechanism the users have to rely on cellular networks without utilizing the powerful near-field communication technologies such as Bluetooth even when the devices are at line of sight.

Blind rebroadcasting is the simplest form of packet routing that allows the nodes to be stateless. Consequently, there is high probability that the intended destination will receive the packet. However, this scheme will cause broadcast storms, thus, resulting in severe degradation in performance, scalability and efficiency. Hence our aim is to find a mechanism to send a data packet from one node to another in a dense MANET while minimizing broadcast storms and leaving the nodes to be stateless. However, this is a difficult problem.

Biological inspirations have given promising results in arriving at satisfactory solutions for difficult problems similar to above, especially in communication networks. For instance Wedde et.al proposes an energy efficient routing algorithm known as BeeAdHoc for MANETs inspired by the foraging principles of honey bees to address the energy dilemma in MANETs [1]. Gunes et.al in [2] addresses the issue of packet overhead in routing and proposes Ant-Colony-Based Routing Algorithm (ARA) inspired by swarm intelligence in ant colonies. Similarly a number of studies base their solutions on ant colony optimizations [3], [4]. Moreover, Sarafijanovic and Boudec address the problem of node misbehavior in MANETs and gain inspirations from the human immune system for their solution [5]. Similarly, Kefalas et.al bases their solution for the problem of modeling dynamic behavior of multi-agent systems on the evolution of human tissues [6].

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S. J. Sooriyaarachchi is with the Department of Computer Science and Engineering, University of Moratuwa, 10400, Sri Lanka, (corresponding author, phone: +94112640380, fax: +94112650912, e-mail: sulochanas@cse.mrt.ac.lk)

W. A. C. Fernando is with the Centre for Vision Speech and Signal Processing (CVSSP), Faculty of Engineering and Physical Sciences, University of Surrey, Guildford, Surrey, GU2 7XH, (phone: +441483682353, fax: +441483686031, e-mail: w.fernando@surrey.ac.uk)

C. D. Gamage is also with the Department of Computer Science and Engineering, University of Moratuwa, 10400, Sri Lanka, (phone: +94112640380, fax: +94112650912, e-mail: chandag@cse.mrt.ac.lk)

There are biological systems that show similar characteristics of a dense MANET that tries to achieve a common task by cooperating among autonomous entities. An organ in human body for instance is also made out of a dense population of biological cells. These cells divide themselves repetitively in the process called *cell proliferation* and that is analogous to re-broadcasting of packets in a MANET. It is an interesting question to ask "On what basis our ears end up growing into a particular size?". The nature has its regulatory mechanisms for controlling the cell division in an organ. These biological regulatory mechanisms would inspire us in finding a mechanism to manage redundant broadcasts in a dense MANET with a simple rebroadcasting scheme.

II. Related Work

This section briefs the routing approaches available in the area of MANETs and how our approach differs.

A. Traditional Approaches

Traditional routing approaches proposed and implemented in MANETs are based on existing routing protocols of wired networks. Data communication networks originated with the intention of connecting fixed wired terminals. Need for routing mechanisms arose as a result of the growth of the networks by size and geographical spread. The networks started to support wireless nodes with the intension of using existing communication networked resources [7]. Hence, the wireless nodes always had the support of some kind of fixed infrastructure so that the then-existed wired routing protocols were tweaked and customized to support a few number of wireless nodes. Dedicated fixed infrastructure were implemented such as base stations in cellular networks and wireless access points in local area networks when the mobile nodes increased in number [8]. However, the concepts behind almost all routing protocols used in MANETs are hooked to fixed infrastructure at least by assuming few key nodes in the network to act as fixed and routing nodes. The most recent work in the area of MANETs is IEEE 802.11s which defines MANETs as Wireless Mesh Networks. Mesh Stations even in IEEE802.11s standard act as Access Points in infrastructure mode wireless networks thus managing routing and control [9]. We consider the routing paradigm that bases on fixed infrastructure and requires to maintain routes as the *fixed-stateful approach*.

However, the current trend in MANETs seeks a paradigm shift in approaching the problem of routing as various mobile devices emerge in large numbers and with powerful near-field wireless networking capabilities. In parallel the supporting technologies and concepts for ubiquitous computing and connectivity develop at a rapid phase. For example IPv6 allow a large population of mobile devices to connect in a single network, while WiFi and Bluetooth provide powerful near field communication. Hence we seek routing mechanisms that base on the other extreme in contrast to fixed-stateful paradigm in traditional MANET routing. So we dare to take the opposite of the traditional routing paradigm and bases our solution on the *mobile-stateless approach*.

B. Mobile-stateless Routing Paradigm

A comparison of our approach and the traditional approaches of MANET routing is summarized in figure 1. The simplest and stateless mechanism of sending a packet from one node to another in a MANET is blind-rebroadcasting. In this mechanism a node re-broadcasts each and every packet it receives, except for those destined to the node itself. However, it causes unnecessary amount of redundant rebroadcasts especially when the MANET is dense. Hence we base our solution on blind-rebroadcast and try to reduce redundant rebroadcasts using biologically inspired regulatory mechanisms. These regulations in turn requires us to maintain certain amount of states thus shifting our approach slightly towards stateful side. Consequently, our approach is placed at a position shown in figure 1 rather than at the mobile-stateless extreme. However, the states maintained in our approach does not gather global information from nodes network-wide as in traditional routing approaches. Information that our approach requires is of itself and immediate neighborhood along with those carried by the received data packets.

Although there are routing protocols proposed based on cell biological inspirations, such as in [10] they also base their solution on existing AODV-like protocols and maintain routing tables while not considering node densities. Cellular Automata based models are also found as in [11] and [12] for mobile networks but they are not in the scope of dense MANETs or related to routing as in our work.

C. Network wide Reach in MANETs

It is often essential that the packets should be sent to every node in a MANET, at least for house keeping tasks such as discovering routes and updating routing tables in traditional MANET routing. For example, AODV which is the most popular routing protocol in MANETs, relies on Sequence Number Controlled Flooding as the mechanism to send RREQ packets throughout the network [13]. IEEE802.11s also uses AODV as the routing protocol [14]. Hence flooding is a decisive aspect of MANETs. The initial idea for our work was intended to route data packets based on blind rebroadcasting or on flooding. However, the findings are applicable in enhancing the available routing protocols which rely on some kind of flooding to reach all nodes in a network. Hence this work can also be considered as a contribution to the improvement of flooding in MANETs.

III. Biological Inspirations

This section explains the biological inspirations for limiting the packet rebroadcasts in a MANET based on biological literature related to organ growth.

A. Limiting the Packet Growth inside the MANET

Our aim was to control the growth of the number of rebroadcasts of a data packet inside the MANET with the inspiration from the organ growth control by inhibition of cell proliferation. Since a human organ is generally made out of millions of cells it is an ideal system to mimic the dense

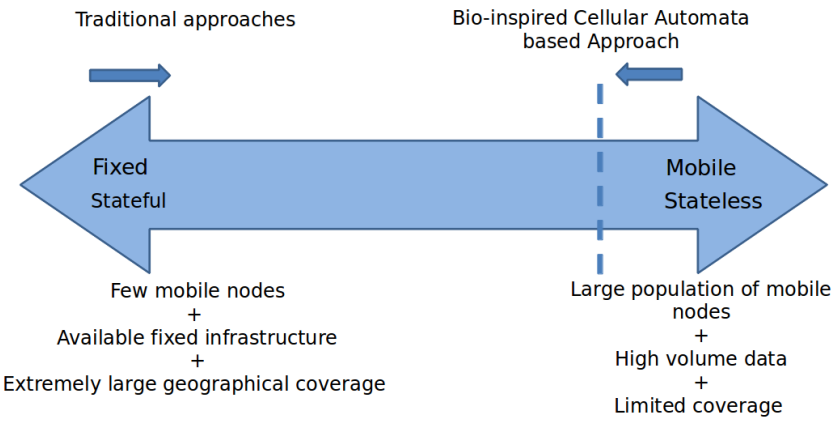

Fig. 1. Summary of comparison of our routing approach with reference to fixed-stateful and mobile-stateless routing paradigms

nature of the mobile network of our interest. Any regulatory mechanism that controls the cell proliferation in the growth of such organs would be a candidate biological inspiration to manage broadcast storms in the target network.

According to Lui and Baron [15], the human body has a growth deceleration mechanism driven at the physiological level by growth itself and at a molecular level by a cell intrinsic genetic program. This claim is supported by the authors in [16]. Lui and Baron in [15] further elaborate that the local communication mechanisms play the central role in growth deceleration rather than the systemic mechanism. Bryant and Simpson in [17] also highlight the evidence for organ intrinsic mechanisms in growth control in organs. However, the growth deceleration program is not cell autonomous but it depends on the interaction of the cell with the extra-cellular micro environment [15].

B. Using Growth as the Inhibitor of Growth

The genetic program explained in [15] is responsible for growth inhibition according to the inputs related to growth itself such as the number of accumulated cells, organ functionality and the number of cell divisions undergone. This genetic program up or down-regulates growth promoting genes according to a negative feedback loop. The hypothesis that the growth itself causes growth inhibition is also proved by Forcinito et.al in [18].

C. Terminal Conditions

According to the authors in [15] the Growth Program described above down-regulates the growth-promoting genes when (i) the accumulated number of cells reach the saturation level, (ii) the organ is adequately grown to perform the intended functionality or (iii) the number of divisions undergone is equal to the particular number set during the embryonic stage.

D. Growth Sensing Mechanisms

Individual cells sense the growth in terms of number of accumulated cells by means of the concentration of some secreted molecules known as *chalones* [15]. Bullough [19] coined the term chalone and hypothesized it as the inhibitors of cell growth by negative feedback to control the size of a tissue. A number of studies provide experimental evidence in support of this hypothesis [20], [21], [22], [23]. Growth in terms of the level of functionality is sensed for example in the liver by flux of bile acids. Bile acids are synthesized in liver and secreted into small intestine to facilitate digestion. Bile acid is then reabsorbed and returned to liver. The number of cell divisions undergone is measured using cell cycle counting mechanisms such as telomere shortening [15].

IV. Cell Biology Inspired Packet Transmission Model

Our work at the current stage is heavily inspired by the chalone method of growth inhibition in biological organ growth explained in section III-D. This section explains how we apply the chalone mechanism in order to limit the packet rebroadcasting in MANETs.

The number of packets in our MANET grows by rebroadcasts in analogy to the cells that proliferate by dividing themselves. Hence we map a data packet residing in a mobile node, to a biological cell in an organ. Also the packet rebroadcasting is mapped to biological cell division. Similar to the case that the biological cell has the growth-controlling-genetic program running inside itself the broadcast-controlling program runs in the mobile node that contains a packet. Table I summarizes the mapping from biological system to MANETs.

The chalone concentration sensed by a cell in its micro-environment represents the number of cells in the neighborhood in the biological system. Similarly we map chalone concentration to the number of neighbors who have already broadcast a particular data packet. We borrow the term *chalone* for the control packets that we introduce as cues for carrying information about the neighborhood in MANETs. Thereby we introduce a set of control packets that are never forwarded beyond the transmission range of a node. A node that receives a data packet obtains information in order to decide whether to rebroadcast the packet. The information requested is whether

TABLE I
SUMMARY OF MAPPING FROM BIOLOGICAL SYSTEM TO MANET

Biological System	**MANET**
Biological cell	Data packet in a node
Cell division	Packet rebroadcasting
Chalone	A control packet exchanged only with the neighbors. Neighbors are the nodes within the transmission range of a node.
Chalone concentration	Number of neighboring nodes who have already broadcast the Data Packet.
Chalone threshold	Threshold for the number of neighboring nodes who have already broadcast the Data Packet for rebroadcasting.
Organ maturity	The state that the Data Packet reached its destination.

the neighbors have already rebroadcast the particular data packet in hand. We name the control packet that does the above request as *chaloneInit* to denote the initiation of chalone mechanism. The control packet sent by neighbors in response to chaloneInit is named *Chalone* packet.

V. THEORETICAL MODEL

A. Operational Model based on Cellular Automata

Typically cell biological systems are modeled in terms of Cellular Automata as in [24], [25], [26], [27]. In analogy the biologically inspired MANET model is theoretically analyzed based on Cellular Automata in this section.

Cellular Automata (CA) are defined as mathematical idealization of problems or physical systems in which space and time are discrete and the physical values take on finite set of discrete values [28]. This was invented by John von Neumann in 1940s as a result of biological motivation with an intention to design self-replicating artificial systems. Power of CA lies in its fundamental properties that are also found in the physical world: CA are massively parallel, homogeneous and all interactions are local [29]. Therefore a variety of physical and biological systems have successfully been modeled and simulated using CA [30], [25], [31], [32], [33].

One-dimensional two-state CA is extensively elaborated in [28]. Formalism of CA is found in [34] for multi-dimensions which is an exhaustive algebraic treatment of the subject. The type of CA of our interest is two-dimensional as the nodes in the MANET lie effectively on a plane. Authors in [35] further analyze two-dimensional CA and cites [34] for *additive two-dimensional* CA. According to [35], a two-dimensional CA consists of a regular lattice of sites. Each site takes on k possible values. Each site is updated in discrete time steps according to a rule ϕ that depends on the values of sites in some neighborhood around it at the previous time step. Authors in [35] addresses the special class of ϕ known as *totalistic rules* in which the values of a site depends only on the sum of values of the neighbors.

Our CA model of MANET is also viewed as a regular lattice on which mobile nodes are randomly placed. Each site takes only two values: 1 - node has rebroadcast a specified data packet, 0 - otherwise. Neighborhood for our CA is the circular region captured by the radio range of a mobile node. Any node within the range will respond as a neighbor. We also apply totalistic rule in which we count the total number of neighbors who have rebroadcast a specified data packet. We set a threshold for this number so that a node decides to rebroadcast a received data packet only if the number of neighbors who have already rebroadcast the packet does not exceed the threshold. This threshold will be referred to as *chalone threshold* hereafter.

B. Graph based Evaluation Model

We also assess the reachability of our protocol against that of flooding. As our protocol suppresses broadcasts using a threshold value there is a possibility that the data packet may not be received by certain nodes in the network. However flooding will make sure that all nodes in an unpartitioned network will receive a broadcast message.

In order to assess reachability we model the MANET as a unit disk graph of the following manner: vertices are the mobile nodes and the edges denote the availability of a direct wireless link between nodes at a given point in time. We first take the Euclidean distance between every node pair and then determine the immediate neighborhood by considering the transmission ranges. It is analogous to superimposing the communication ranges of nodes on the physical location map of the network. The graph may also change as the nodes connect or disconnect due to mobility, user actions or power availability.

In order to evaluate reachability of the resulting graph, we use Floyd-Warshall algorithm for its simplicity, parallel computation for all node pairs, and less pre-processing needs. If a path can be found by the algorithm then we can conclude that a node can reach any other node by simple flooding.

VI. SIMULATION

We used OMNET++ 4.4 with inet-2.2.0 for our simulation. OMNET++ is an event-driven and modular simulation framework [36].

The simulation model under study comprises an array of hosts configured as nodes of a single private network. The number of nodes is specified as a parameter at runtime as directed by the omnetpp.ini configuration file. We identify a data packet uniquely by its source address and a sequence number which in combination referred to as *Packet ID* hereafter. The sequence number is assigned to a packet by the originator of that packet. A node maintains a list of Packet IDs it sees or it creates. It also keeps a list of neighbors who responds for a chaloneInit Message. When a node receives a data packet the flow of events occurs as given in figure 2.

On the receipt of a chaloneInit message the source node ignores it while the destination is supposed to initiate another type of negative feedback mechanism similar to mechanism (ii) given in section III-B. However, the feedback mechanism is not in the scope of this paper. Flooding is for the global broadcast in a MANET in typical routing mechanisms and the terminal condition is when a packet reaches all the nodes

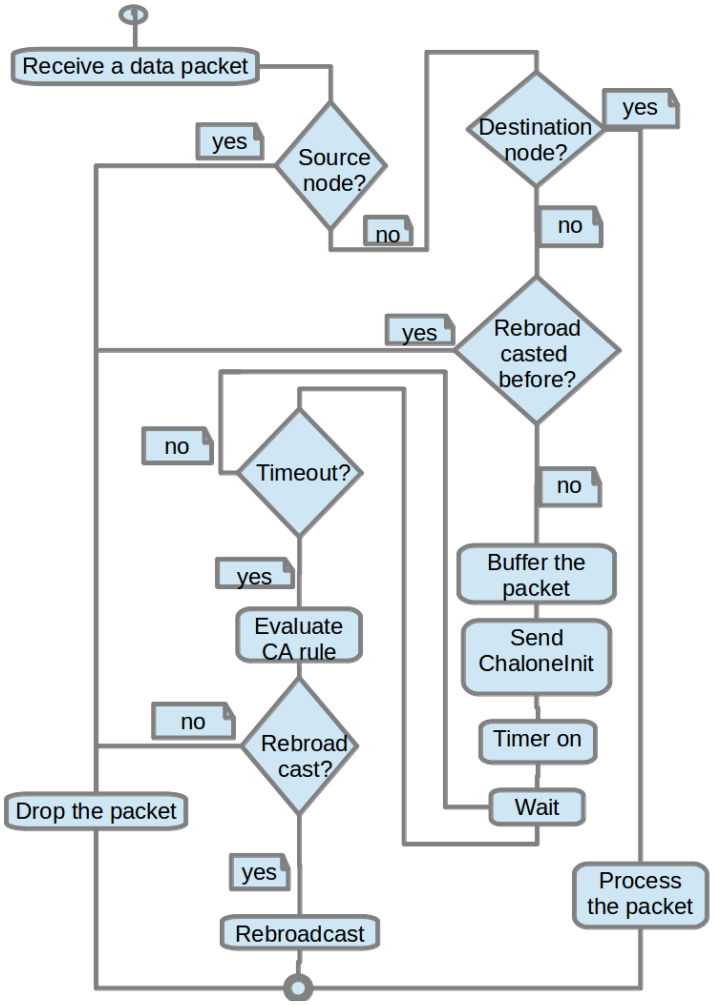

Fig. 2. Event flow at a receipt of a data packet by a node

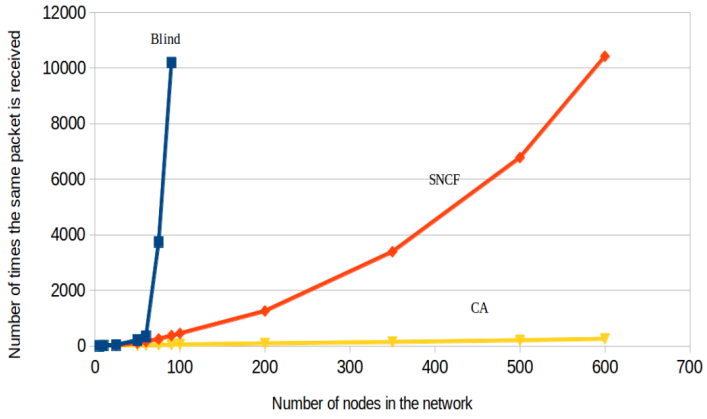

Fig. 3. Performance of Cellular Automata based Rebroadcasting (CA) protocol compared with Blind Rebroadcasting (Blind) and Sequence Number Controlled Flooding (SNCF)

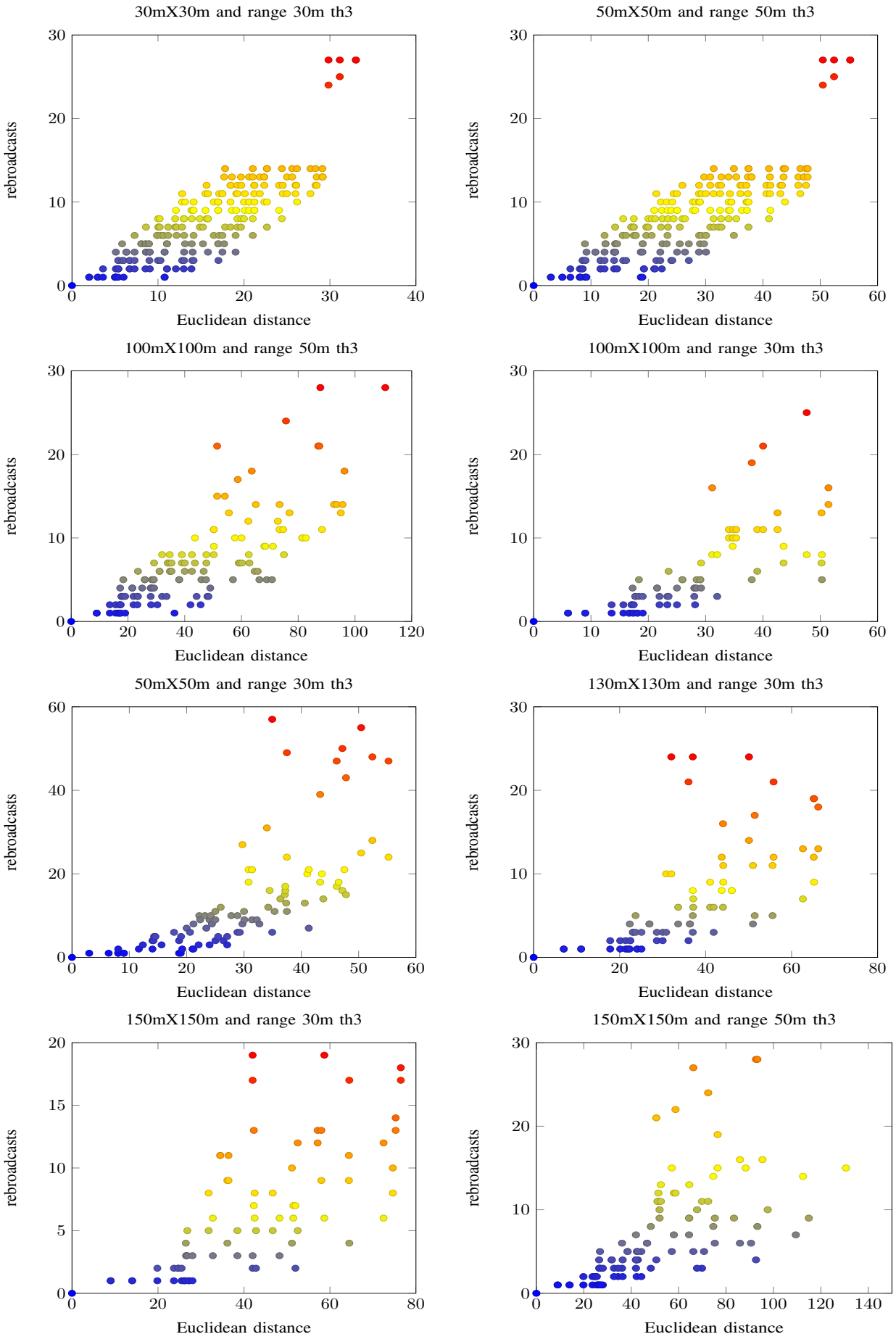

Fig. 4. Number of rebroadcasts Vs distance between node pairs

TABLE II
SIMULATION PARAMETERS

Parameter	Value
number of nodes	15
playground sizes	30m×30m, 50m×50m, 100m×100m and 150m×150m
transmission ranges	30m and 50m
threshold values	1,2,3 and 4

at least once. For unicast the terminal condition is reached when the packet reaches its intended destination. The negative feedback initiated by destination therefore is supposed to reduce the redundant rebroadcasts upon reaching the terminal condition at unicast in a MANET. Nodes other than the source and the destination that receive a chaloneInit would respond with a Chalone message. Chalone message carries the neighbor state defined in section V.

In this paper we investigate the case of unicast by specifying a source node and a destination for a data packet, thus the success of a transmission is indicated when the packet reaches the destination. We compare blind-rebroadcasting, sequence number controlled flooding and cellular automata based rebroadcasting in Section VII.

We test whether the reachability depends on node densities and chalone threshold. We first set the chalone threshold at 3 and assess reachability for different node densities by placing 15 nodes randomly on maps of different sizes and changing the transmission ranges as given in table II. Values for transmission ranges were selected based on commonly operational distances of commercial WiFi products. The node placement was decided based on common application scenarios for dense and extremely-dense MANETs.

VII. Results and Discussion

Performance metric for the protocol evaluation is the number of times a particular data packet is received by all the nodes in the MANET until the specified destination is reached. The scenario at startup is for the MANET to have a single data packet originated by the specified source node. Figure 3 illustrates the obtained results for the comparison of the proposed protocol (CA protocol) against simple flooding (SNCF) and blind rebroadcasting for different node densities of the MANET. The reachability is assessed in terms of the ratio between the number of node pairs reached using the protocol and the theoretically reachable number of node pairs.

According to figure 3 the CA protocol outperforms both blind rebroadcasting and SNCF for all node densities. For example in a MANET with 50 nodes, blind rebroadcast caused the network to reach the same packet 206 times while SNCF recorded 104 times. CA protocol however reported only 23 times. Thus the CA protocols saves nearly 90% of redundant rebroadcasts compared to blind rebroadcasting whereas the saving is nearly 80% compared to SNCF. Also for node density of 100, the counts were: more than 80000 packets for blind rebroadcasting, 451 for SNCF and just 49 packets for CA protocol. Blind rebroadcasts are unacceptable for MANETs beyond 100 nodes in terms of redundant rebroadcasts as the growth of the curve is steeply exponential. Though SNCF is

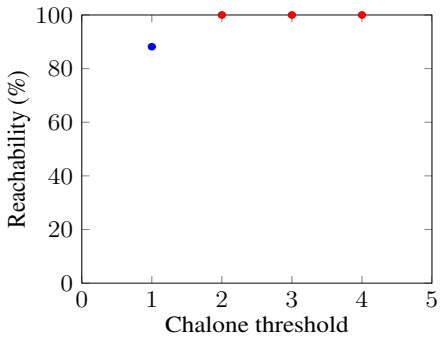

Fig. 5. Reachability as a percentage of node pairs reached with respect to theoretically reachable number of node pairs for the case of 150mX150m and range 30m

better compared to blind rebroadcasting, it does not perform acceptably beyond 600 node density. CA on the other hand shows a slow growing curve thus making it a better protocol for all node densities shown. Further analysis into the CA protocol alone for higher node densities such as 2000 nodes proves the satisfactory performance and the usability of our protocol in dense MANETs as the number of redundant rebroadcasts has linear and slow growth against node density.

According to figure 4 it was observed that in a map of 30m×30m with range of 30m and 50m×50m with range of 50m the data points show similar clustering. Hence we define the case of map sizes of $r \times r$ with range of r where r is the transmission range as *extremely dense MANETs* that have highly specific behavioral characteristics. Therefore, these extremely dense MANETs cannot be studied alongside the dense MANETs which are the focus of this research. Rest of the graphs in figure 4 show no such special clustering of data points and are considered dense MANETs in this study.

In order to assess the impact of chalone threshold on reachability we selected the case of 150m×150m with range of 30m and evaluated for chalone threshold 1, 2, 3 and 4 as shown in figure 5. Theoretically reachable number of node pairs for this MANET configuration was 76. It was observed that chalone threshold 1 fails to deliver the data to destination for 9 of the reachable node pairs. In contrast, chalone thresholds 2 and above gives full reachability.

It was also noted in figure 6 that chalone threshold 2 and above gives the same numbers of redundant rebroadcasts. This is due to the fact that maximum number of neighbors in this configuration is 3 and that gives same number of redundant rebroadcast as of chalone threshold 2. Therefore the chalone threshold value depends on number of neighbors and should be tuned for each node for optimal reachability and reduction in redundant rebroadcasts.

VIII. Conclusion

Network wide packet broadcasting is an essential aspect of any routing protocol including AODV which is the Wireless Mesh Routing protocol in the latest IEEE 802.11s standard. However AODV uses flooding as the mechanism to broadcast its control packets throughout the network. We

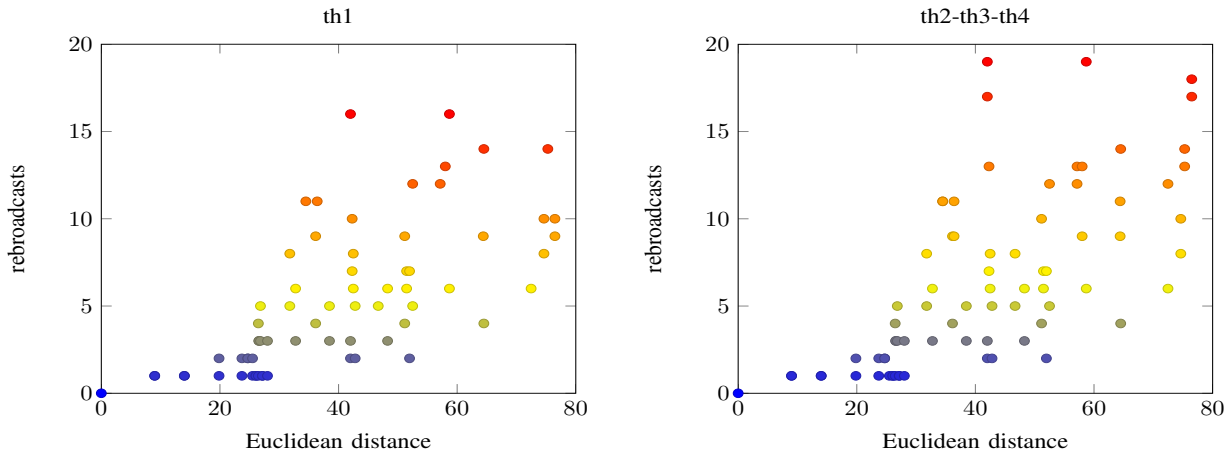

Fig. 6. Number of rebroadcasts Vs distance between node pairs for the case of 150mX150m and range 30m

found through the simulations that flooding as well as the blind-rebroadcasting is unusable at higher node densities in MANETs. In contrast we propose a Cellular Automata based broadcast mechanism inspired by biological cell proliferation in human organs. We borrow the chalone mechanism from organ growth process into MANET rebroadcasting and propose a limited broadcast scenario which gives a saving of over 80% of redundant rebroadcasts compared to both sequence number controlled flooding and blind rebroadcasting. Our protocol is also proved to be usable in MANETs with much higher node densities compared to networks that the flooding can support. The chalone threshold should be a function that partly depends on number of neighbors of each node for optimal results in terms of redundant rebroadcasts and reachability.

IX. Future Work

In the next phase of this research project, the *bio-inspired CA based MANET routing approach* presented in this paper will be tested with different mobility models applicable in practical dense MANETs. It is proposed to simulate the developed solution in a scenario such as a smart classroom of hundreds of students which allows collaborative learning.

Acknowledgments

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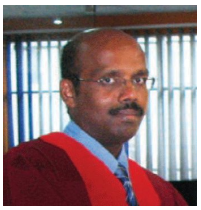
Sulochana Sooriyaarachchi was born in Anuradhapura, Sri Lanka on the 18th of October 1981. She obtained her BSc Eng. (Hons) in Electrical and Electronics Engineering from the University of Peradeniya, Sri Lanka in 2006. She then joined the Department of Computer Science and Engineering in the University of Moratuwa as a lecturer and obtained her MSc in Computer Science from the same department in 2010. She is currently pursuing her PhD in the University of Moratuwa conducting research in the area of routing and control mechanisms in mobile ad-hoc networks.



Anil Fernando leads the Video Communications group at the University of Surrey, UK. He has been working in video coding and communications since 1998 and has published more than 270 international refereed journal and proceeding papers in this area including a book on video communications. Furthermore, he has published more than 150 international refereed journal and conference papers in multimedia communications. He has contributed to several international (ROMEO, MUSCADE, DIOMEDES, VISNET, etc) projects and currently he is leading an interactive video communications project (ACTION-TV) funded by the European Union on Media communications.

Chandana Gamage is a senior lecturer in the Department of Computer Science and Engineering, University of Moratuwa, Sri Lanka. He received his PhD from Monash University, Australia, MEng from AIT, Thailand and BSc Eng Hons from University of Moratuwa and worked as a postdoctoral research scientist in Vrije Universiteit Amsterdam, The Netherlands. Dr Gamage has research interests in computer security and cryptography, enterprise software architectures and embedded systems and has published in leading conferences in these areas.

MPEG-SCORM: an Ontological Approach of Interoperable Metadata for Digital Television and e-Learning

Marcelo Correia Santos, Yuzo Iano

Department of Telecommunications of the Electrical and Computer Engineering School, UNICAMP (São Paulo State University of Campinas) Campinas-SP, Brazil 13083-852

m134163@dac.unicamp.br, yuzo@decom.fee.unicamp.br

***Abstract*— The convergence of digital media offers an integration of ICT focused on telecommunications and multimedia domain (under responsibility of the Moving Picture Experts Group, ISO/IEC JTC1 SC29) and the ICTE (the ICT for Education), managed by the ISO/IEC JTC1 SC36, highlighting the MPEG standards, employees as content and metadata to the multimedia Digital TV and the technologies applied to e-Learning. Regarding this, there is the problem of developing an interoperable matching for normative bases, achieving an innovative proposal in the convergence between digital telecommunications and applications for e-Learning, also essentially multimedia. To reach this purpose it is proposed to create a standard ontology of interoperable metadata for web, digital TV and extensions for mobile devices based on the integration between MPEG-21 and SCORM metadata standards. The methodology used consists on building ontology between MPEG-21 SCORM which can be achieved on making a correspondence through the XPath language, managed by the W3C. The employ of the XPath language is desirable for matching and mapping both metadata schema patterns – integrating MPEG-21 (mostly Digital Item Declaration Language) and SCORM metadata schema. The practical purpose is the creation and storage of objects for use in digital telecommunications as Digital Television, in an interoperable way with the e-Learning industry, here as description metadata for all sorts of media and hypermedia to create learning objects.**

***Keywords*— Digital Television, e-Learning, Metadata, MPEG, SCORM**

I. INTRODUCTION

THE technological innovation issue comprehends a research in a hybrid field that comprises a breakthrough on the media convergence process, on purposing an interface between the norms and standard implemented in the field of interactive multimedia, highlighting the Digital Television (standardized by the ISO SC29 subcommittee), and the field of the technologies for e-Learning (standardized by the ISO SC36 subcommittee).

The whole bunch of ICT is subject to convergence and interdependence of media. These techniques rely heavily on standards that are negotiated and designed in standard-setting bodies. An important role of ISO / IEC JCT1 is to converge instances that define both components and services attached to these topics.

It is proposed to analyze the constraints of possible convergences between the MPEG family norms (conceived by the JCT1 SC29, the standards body that carries MPEG) and those of the ICTE (the ICT for Education, work under responsibility of the JCT1 SC36), in particular the SCORM metadata standard, as well the future "SCORM 2.0" standard.

As a second decisive state, it is therefore mapped the prospective normative framework matched between MPEG-21 multimedia document and the normative world of ICTE - SCORM. The purpose of the project is to provide the specification of a hybrid Ontology mapping the MPEG-21 and SCORM metadata standards.

From this context, the research in conclusion propose the study based on the convergence of digital media working on the hypothesis of the integration of both ICT and ICTE focused on the telecommunications and the multimedia domain.

This convergence covers two breaking questions up to be solved in our digital era: the interoperability of data and formats; and the integration of cited ISO working groups

Technically, Digital Television lies within the field of MPEG multimedia, since it employs as its exhibition format the digital video standard MPEG-4 AVC H264, the worldwide industry standard today.

However, the standardization of the multimedia MPEG is not restricted to MPEG-4, since other MPEG technologies are in process of specification by the SC29 subcommittee and actually are more powerful in terms of metadata description and so on, as MPEG-7 and MPEG-21.

These distinct MPEG norms and its main defining characteristics are highlighted in the Fig. 1, translated from the source reference in French [1]:

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Marcelo CORREIA SANTOS is a researcher in the Electrical and Computer Engineering School, São Paulo State University of Campinas, SP 13083852 Brazil (Corresponding author, phone: 019-3521-3809; fax: 019-3521-3703; e-mail: m134163@dac.unicamp.br).

Yuzo IANO is a professor in the Electrical and Computer Engineering School, São Paulo State University of Campinas, SP 13083852 Brazil (e-mail: yuzo@decom.fee.unicamp.br).

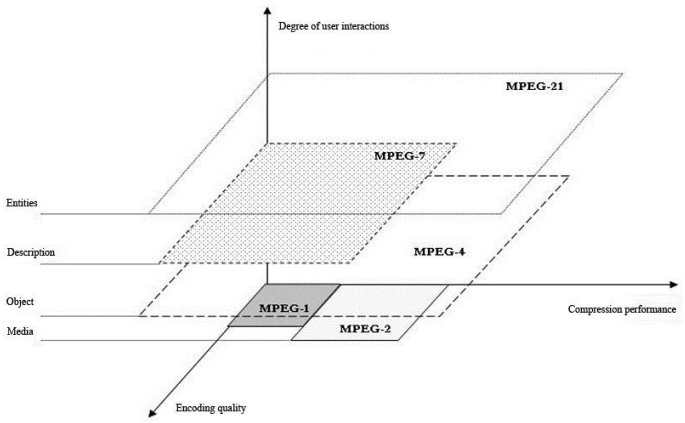


Fig. 1 Different MPEG norms and its main characteristics in terms of encoding quality, compression performance and user interaction [1].

According the *Moving Picture Experts Group* (MPEG), MPEG-1 is a "suite of standards for audio-video and systems particularly designed for digital storage media". MPEG-2 is a "suite for standards for digital television". On the other hand, MPEG-4 is a "suite of standards for multimedia for the fixed and mobile web"; and MPEG-7 is a "suite of standards for description and search of audio, visual and multimedia content".

MPEG-21, however, is a "suite of standards that defines a normative open framework for end-to-end multimedia creation, delivery and consumption that provides content creators, producers, distributors and service providers with equal opportunities in the MPEG-21 enabled open market, and also be to the benefit of the content consumers providing them access to a large variety of content in an interoperable manner".

It can be noticed from these definitions and from the interpretation of the graphic demonstrated in Fig. 1 that the main characteristic for MPEG-4 is the possibility of object creation and manipulation.

For MPEG-7, the main gain achieved by its adoption would be the metadata description of all media content only.

MPEG-21, as its major characteristic, allows the modelling of entities, entities which could comprehend content and an object oriented domain of descriptors as well.

Still from the perspective of this analysis, in this research we could conclude that MPEG-21 become the most suitable option for metadata description as a breakthrough in this field since its framework allows not only content description, but all kinds of elements presented within the consumption channel, from the content and object creation, through broadcasting and reaching the end user (who otherwise can perform the role of a producer as well).

Regarding this, the main objective on this work is contributing on the development of an interoperable matching between the normative bases in question, achieving an innovative proposal in the convergence between digital telecommunications and applications for e-Learning, also essentially multimedia, integrating MPEG-21 (mostly its *Digital Item Declaration Language*) and SCORM metadata schema. To reach this purpose the proposition is developing a standard ontology of interoperable metadata for web, digital TV and extensions for mobile devices based on the integration between MPEG-21 and SCORM metadata standards.

This hybrid ontology, possibly claimed as a new hybrid metadata standard, would allow the creation and storage of objects for use in digital telecommunications, operating on media like Digital Television, in an interoperable way with the e-Learning industry, which in its turn employs all sorts of media and hypermedia technologies to create learning objects.

Regarding the challenges for the standardization of the ICT applied to e-Education, it comprises a telecommunications engineering problem still in developing the issue concerning how the MPEG Video family, specially the MPEG-21 [2] standard, could offer a normative basis for the implementation of multimedia metadata related to e-Learning.

This development demands the adoption and employ of some tools to match all these learning and media objects, further to the content itself (video, still images, sound, text, hypertext etc), and must lie within a normative frame to guarantee interoperability, reusability and referring to the major platforms or digital environments in both fields, multimedia and e-learning.

For this purpose it was adopted in this research the XPath language, managed by the W3C.

The software engineering to support this normalization comprehends XML, MPEG-7, MPEG-21, themes approached by the SC36. Otherwise, experts from ADL, entity which developed the SCORM standard, are engaged in SC36 subcommittee too, and already proposed to in a certain way explore the capabilities of MPEG-21 to make this idea viable.

ADL strategy lies on capitalize the other subcommittees norms, and encourage the adoption of the Part 5 of MPEG-21 [3] (REL, or Rights Expression Language), to solve copyright issues, besides it delegates to the LOM standard its metadata description (or parts to other standards like IMS or DCMI – Dublin Core). This reveals a very converging approach and acceptation concerning the metadata and MPEG-21 issue on the industry and market.

II. Learning Objects and Metadata Standards

A Learning Object can be defined, in a perspective of Engineering, according to IEEE 1484.12.1 standard (Standard for Learning Object Metadata) [4], "For this standard, a learning object is defined as any entity, digital or non-digital, that may be used for learning, education, or training".

According to the IEEE LTSC [4], the LOM standard focus on the minimum attributes needed to allow a learning object to be found and evaluated. Metadata allow the cataloging and coding of the objects to turn them comprehensible within most e-learning platforms.

For instance, SCORM doesn't define itself a metadata model – it recognizes the LOM standard as the standard in fact [5]. Yet, SCORM defines XML as the syntax for metadata representation (process called *XML binding*). That is the

reason why the LOM standard is used for represented metadata on SCORM mapped elements on this research.

Actually, the standard SCORM 2014, or SCORM 1.4, presents 3 Parts (or sub-specifications) [5]:

- Content Packaging (CAM) section: specifies how content should be packaged and described. It is based primarily on XML.
- Run-Time section: specifies how content should be launched and how it communicates with the LMS. It is based primarily on ECMAScript (JavaScript).
- Sequencing section: specifies how the learner can navigate between parts of the course (SCOs). It is defined by a set of rules and attributes written in XML.

Within its CAM model published by ADL [5], SCORM defined in its part related to Metadata nine categories to describe learning objects attributes. The definition must be applied to assets, SCO (groups of assets), activities, content organizations and content aggregations, for their identification, categorization, consult and findability, to facilitate sharing and reusability.

For instance, it is presented an example of SCORM metadata XML coding in Fig. 2:

```
<resource identifier="RES-D2D28CCE" type="webcontent" adlcp:scormType="sco"
href="dd_sepsis.html">
  <metadata>
   <lom:lom>
    <lom:general>
     <lom:title>
      <lom:string language="en">Sepsis</lom:string>
     </lom:title>
     <lom:language>en</lom:language>
     <lom:description>
      <lom:string language="en">An introduction to Sepsis...</lom:string>
     </lom:description>
     <lom:keyword>
      <lom:string language="en">intro, sepsis</lom:string>
     </lom:keyword>
     <lom:structure>
      <lom:source>LOMv1.0</lom:source>
      <lom:value>hierarchical</lom:value>
     </lom:structure>
    </lom:general>
   </lom:lom>
  </metadata>
  <file href="dd_sepsis.html"></file>
  <file href="dd_sepsis.mov"></file>
  <file href="AC_QuickTime.js"></file>
  <file href="SCOHelper.js"></file>
 </resource>
```

Fig. 2 SCORM metadata file highlighting the description of a hypermedia document resource for the web.

To match specifications of theses metadata standards the proceeding is mapping their categories using, in this research, the XPath language, as it was primary done mapping and matching DCMI–Dublin Core and SCORM metadata standards, as shown in Table I. Mapping is expressed in *XPath syntax*.

As we can observe in Table I, these identifiers cover from the most generic ones to the most specifics, related to the Rights, for example, which is a focus of ADL standardization concerning MPEG-21 and SCORM.

TABLE I
MAPPING OF SCORM AND DCMI METADATA (XPATH SYNTAX)

Matching SCORM (LOM) / DCMI	
SCORM	**DCMI**
/lom/general/identifier/entry	/dc/identifier
/lom/general/title	/dc/title
/lom/general/language	/dc/language
/lom/general/description	/dc/description
/lom/general/keyword or /lom/classification/keyword com classification/purpose equals to “Discipline” or “Idea”	/dc/subject
/lom/general/coverage	/dc/coverage
/lom/educational/learningresourcetype	/dc/type
/lom/lifecycle/contribute/date com lifecycle/contribute/role equals to “Publisher”	/dc/date
/lom/lifecycle/contribute/entity com lifecycle/contribute/role equals to “Author”	/dc/creator
/lom/lifecycle/contribute/entity with the contributing type specified in lifecycle/contribute/role	/dc/othercontributor
/lom/lifecycle/contribute/entity com lifecycle/contribute/role equals to “Publisher”	/dc/publisher
/lom/technical/format	/dc/format
/lom/rights/description	/dc/rights
/lom/relation/resource/description	/dc/relation
/lom/relation/resource com relation/kind equals to “IsBasedOn”	/dc/source

From the Table I, concerning the matching between SCORM and Dublin Core metadata standards, it is possible to analyze a projection for the expected results achieved through the work on the further mapped hybrid ontology proposed, implying in its turn SCORM and MPEG-21 metadata standards.

It can be noticed the syntax of the XPath language used for the mapping and matching system, in a neutral way, between both metadata structures of representation.

It were found out the matches among the 15 (fifteen) elements presented in the Dublin Core standard and in the other hand 15 equal elements found within the SCORM metadata structure, actually LOM structure, as already explained in this article.

III. DIGITAL TELEVISION AND E-LEARNING METADATA

The metadata systems integration is already a longtime issue of investigation for the telecommunications community, mostly linked to Digital Television. In [1], [6], [7] and [8], we have samples of the discussion involving MPEG-7, MPEG-21 and TV-Anytime. Even the issue of Digital TV and SCORM was initially discussed [11].

MPEG-21 became the modular development and standardization platform (a *framework*) [12] towards global integration of all multimedia documents. The multimedia are not the product of an specific area of knowledge, but is a direct consequence of standardization of digital practices such as telecommunications, audiovisual, informatics.

Although the fact that MPEG-21 came up from a community that focuses on audio and video, the so called *MPEG-21 Framework* [12] can host all kinds of complex digital objects, such as electronic text, digital magazines, scientific data etc.

As can be seen from the scientific literature [13], [7] and [1] and from the norm itself [3], the MPEG-21 standard have a non-rigid structure of metadata, and Part 2 standard, DID, exposes the digital Item as the most generic approach for this purpose structural description of use of metadata in digital objects of all kinds.

The MPEG-21 standard holds today 21 parts [3]. MPEG-21 is an XML-based metadata specification that brings two fundamental pillars:

- The definition of a unit or essential object of distribution and transaction, which is called *Digital Item*;
- And the notion of "reader" – the concept of users interacting with it.

The MPEG-21 metadata standard, however, is currently partitioned in 22 parts, as follows [3]:

1. Vision, Technologies and Strategy (Digital Item definition)
2. Digital Item Declaration
3. Digital Item Identification
4. IPMP (Intellectual Property Management and Protection)
5. Rights Expression Language
6. Rights Data Dictionary
7. Digital Item Adaptation
8. Reference software
9. MPEG-21 file format
10. Digital Item Processing
11. Evaluation methods for persistent association Technologies
12. Test bed for MPEG-21 resources delivery
13. *Scalable Video Encoding – Transferred to MPEG-4 AVC standard*
14. Conformance testing
15. Event reporting
16. Binary format
17. Fragment identification of MPEG-21 resources
18. Digital Item Streaming
19. Media Value Chain Ontology
20. Contract Expression Language
21. Media Contract Ontology
22. User Description

The central concept within the MPEG-21 metadata standard can be understood as the DI - Digital Item, as defined in Part 2 of the standard [12].

The DID, or Digital Idem Declaration, relates a digital product, which can be simple or composite. A typical example is a webpage, containing different multimedia resources.

The use of MPEG-21 DIDL (Digital Idem Declaration Language) as a generic standard for the representation, cataloging and storage of digital learning objects in the library has been proposed by [14]. It demonstrated the applicability of the DIDL for representing complex objects of any type of media or content to create a digital collection in the library.

The second key concept in MPEG-21 format is the description of the production and interaction with the media, for all stakeholders in the process, from content producer to the end user. Therefore, it can be said that the main objective of MPEG-21 is to define the technologies needed to support the exchange, access, consumption, trade or handling of Digital Items in an efficient and transparent way [12].

A workflow exemplifying the metadata representation of a media like a digital music album, in the MPEG-21 standard, can be represented as designed on Fig. 3:

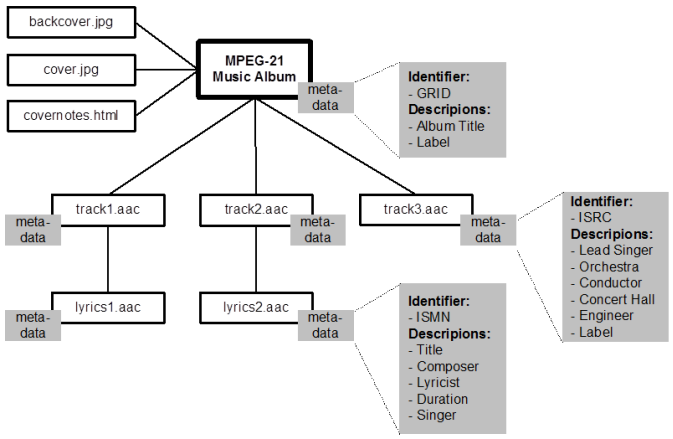


Fig. 3 MPEG-21 metadata representation of a descripted media – a digital music album [3].

As we can infer from the Fig., there are key elements like an identifier and a descriptor whose coding is mandatory for representing data aspects of each subpart of the hereby exemplified digital media.

IV. Methodology: A Convergent Ontology for the Integration Between MPEG-21 SCORM

The intended Ontology between SCORM and MPEG-21 can be carried out by matching their syntax correspondences, through the W3C XPath language.

The use of XPath language is directed to carry out the comparative study of mapping between the standards of SCORM metadata and MPEG-21, applying this methodology. XPath is a language maintained by the W3C with the primary objective of addressing parts of an XML document, and it is also used to test whether a code matches a pattern, or another code.

There are some key features regarding XPath language which were strongly considered on the decision for this proposed methodology:

- XPath is a syntax for defining parts of an XML document
- XPath uses path expressions to navigate XML documents
- XPath contains a library of standard functions
- XPath is a major element in XSLT*
- XPath is a W3C recommendation

*XSL stands for *EXtensible Stylesheet Language* (and it is applied on XML files).

The MPEG-21, as already stated, provides the DIDL (*Digital Item Declaration Language*), but also other schemes and their languages, within other of the many parts of the standard, for the cataloging of objects and the flow of information, the case also DII (*Digital Item Identification*), and DIA (*Digital Item Adaptation*); but also for dealing with copyright data (MPEG-21 Part 5 REL - *Rights Expression Language*), CEL (*Contract Expression Language*), IPMP (*Intellectual Property Management and Protection*); and even use cases (UD - *User Description*).

The orientation of the work of JTC1 SC36, as can be accompanied by papers published by IEEE [13] and [17] is based essentially on the portability, interoperability and adaptability of technologies for education, teaching and learning. The SC36 does not, therefore, calling to extend the work carried out by other technical committees, such as the SC29 itself, the media committee, which deals with sound encoding, image, multimedia and hypermedia information.

However, the SC36 was a pioneer in pointing to the need for synergy with the SCORM MPEG-21 standard, proposition however limited to addressing issues of copyright and eventually the e-commerce of ICTE (Part 5 of the standard).

The MPEG-21 normalization lies in perfect continuity with the ones previously carried out within the *MPEG-7 framework*. And many MPEG-7 standard descriptors are part of the MPEG-21 metadata schema [12] scope.

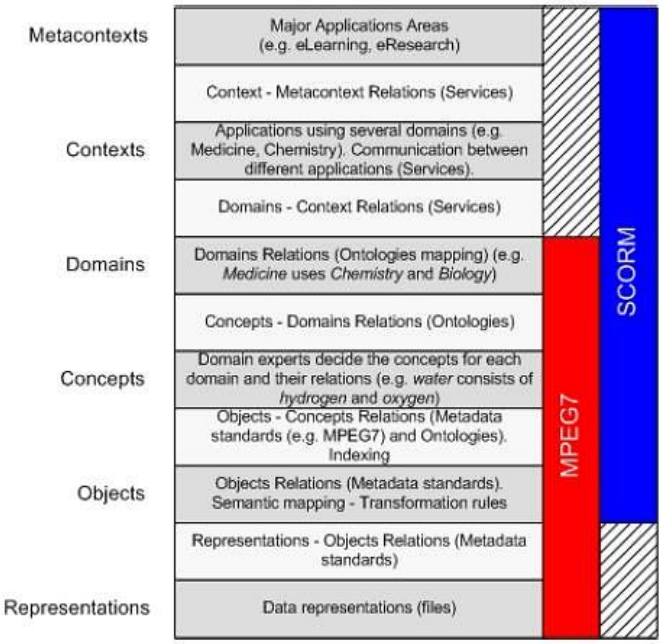
The descriptors and corresponding description schemes are developed under the responsibility of MDS group, whose data description is founded on the semantics of XML markup language.

The interrelationships between MPEG and e-Learning metadata standards are outlined in Table II [15] and in Table III [16]:

TABLE II
MAPPING AMONG THE MPEG AND E-LEARNING MAIN METADATA STANDARDS [15]

	Métacontextes des applications	Relation métacontextes - contextes	Contexte des applications	Relation contextes - domaines	Domaines	Relation domaines-concepts	Concepts	Relation concepts-objets	Objets	Relation Objets-représentations	Représentations	Relation représentations-échanges	Echanges
DUBLIN CORE													
SCORM													
LOM													
MPEG-7													
MPEG-21													

TABLE III
MAPPING BETWEEN MPEG-7 AND SCORM [16]



DIDL documents are actually XML 1.0 documents. The DIDL syntax is based on an abstract structure defined in the *Digital Item Declaration Model*.

This model defines the DIDL elements, namely: *Container; Item, Component, Anchor, Descriptor, Choice, Selection, Condition, Annotation, Assertion, Resource, and Statement*. Thus structurally represented as Fig.s 4 and 5:

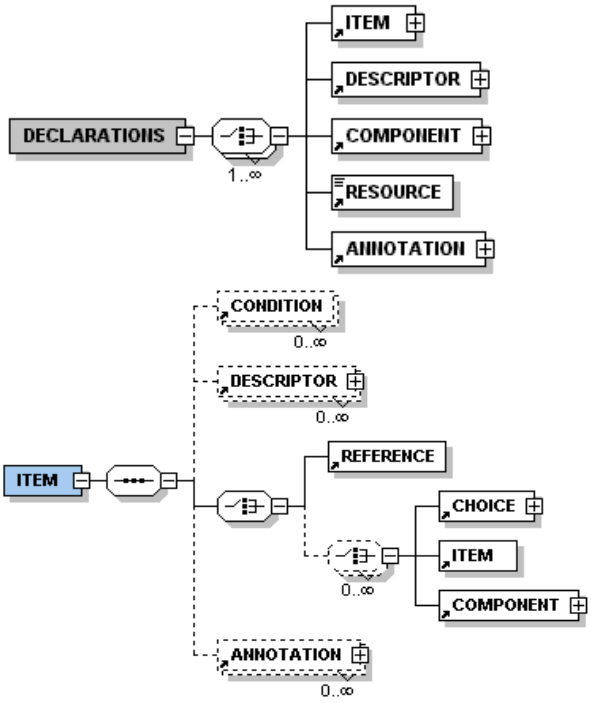


Fig. 4 Partial graphical representation of DIDL schema [12]. Highlighting the Declarations and Item elements.

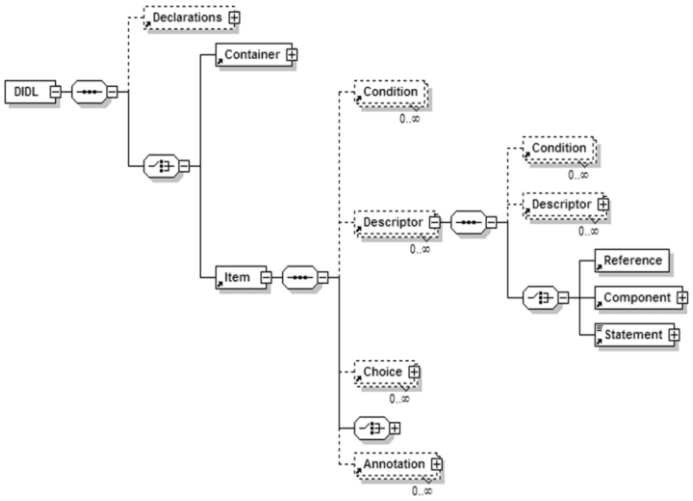


Fig. 5 Partial graphical representation of the DIDL schema generalized from the ISO/IEC norm 21000-2:2003 [12].

The DIDL XML code for *Declarations* element (a special element that defines a selection of elements without instantiate them) would be displayed in the following generic form [12]:

```
<xsd:element name="DECLARATIONS">
    <xsd:complexType>
        <xsd:choice maxOccurs="unbounded">
            <xsd:element ref="ITEM"/>
            <xsd:element ref="DESCRIPTOR"/>
            <xsd:element ref="COMPONENT"/>
            <xsd:element ref="RESOURCE"/>
            <xsd:element ref="ANNOTATION"/>
        </xsd:choice>
    </xsd:complexType>
</xsd:element>
```

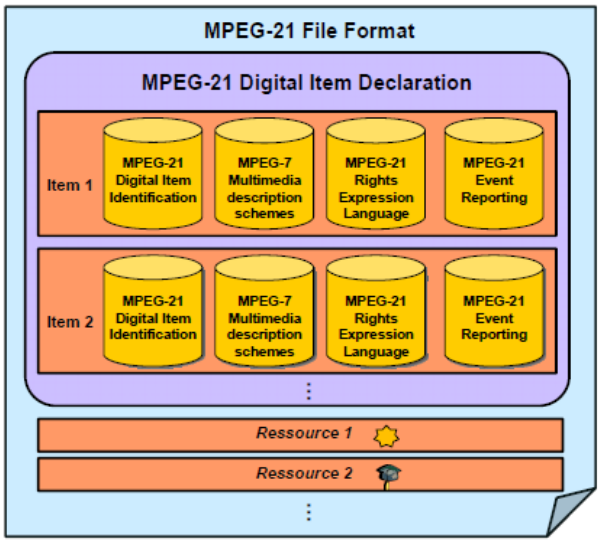


Fig. 6 Hierarquical metadata structure within an expected MPEG-21 general purpose file in its complete structure [18].

To perform the integration of standard patterns, the solution being implemented is to make the correspondence between the categories of SCORM metadata and those defined by MPEG-21 metadata schema.

Using the XPath language as the default to format the taxonomies and create a new ontology, there were first mapped the following standard SCORM metadata (LOM), which would correspond to the multimedia standard MPEG-21, aligned to the concept of platforms convergence. As follows in Table IV:

TABLE IV
SCORM AND MPEG-21 METADATA STANDARDS MAPPED

SCORM Multimedia Metadata	MPEG-21 Metadata (under development)
/lom/general/identifier/entry	<mpeg21>
/lom/general/title	<mpeg21>
/lom/general/language	<mpeg21>
/lom/general/description	<mpeg21>
/lom/general/keyword	<mpeg21>
/item[@identifier]	<mpeg7>
/lom/general/coverage	<mpeg21>
/lom/educational/learning/resource/type	<mpeg21>
/lom/lifecycle/contribute/role	<mpeg7>
/lom/lifecycle/contribute/date	<mpeg7>
/lom/technical/format	<mpeg7>
/lom/technical/size	<mpeg7>
/lom/technical/location	<mpeg7>
/lom/technical/duration	<mpeg7>
/lom/rights/description	<mpeg21>
/lom/relation/kind	<mpeg7>
/lom/relation/resource/description	<mpeg21>
/lom/relation/resource/catalogentry	<mpeg21>

Table IV stands for the mapping and matching between both metadata standards: SCORM and MPEG-21.

The mapped elements of both standards are up to be matched, on the purpose of achieving the hybrid ontology witch establishes the convergence between e-learning SCORM metadata standard with multimedia MPEG-21 metadata standard, interoperable and applicable for the wide range of digital media, including the web, mobile media or even digital television.

This proposed interoperable SCORM MPEG-21 ontology, employing the W3C XPath language, focus on the main items whose approaching is mandatory for achieving a significant representation of the metadata elements necessary to both a multimedia digital item description and a learning object description as well, developing a common hybrid new ontology based on the body and syntax of the existing ones.

V. CONCLUSIONS

Until the present moment it was possible to obtain successful results concerning the stages already overcame on this research, which progresses at an advanced pace regarding to the implementation of the specific goal of correspondence between metadata standards of the knowledge domains issued.

The development work has consisted in creating an Ontology focused on these mapped taxonomies in order to propose, from this ontology, an integration between the fields of Multimedia (comprehending Digital Television) and MPEG ICTE for distance education / e -Learning.

In other words, the convergence between MPEG-21 and SCORM as a standard for describing objects used for cataloging and for use in e-learning, in a broader sense, and e-learning via Digital Television in a specific perspective of the field of research.

A SCORM MPEG-21 Ontology, employing the W3C XPath language, is already in an advanced stage in order to make its contribution to the body of knowledge and the process of standardization in the metadata study domain, as well to further the research there have been in development the run-time and sequencing sections within this ontology.

It also contributes to a latent need for integration between the universes of Multimedia and ICTE, represented by working groups of SC29 and SC36 standards subcommittees, ISO / IEC JTC1, in this context of convergence.

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Marcelo CORREIA SANTOS. Marcelo Correia Santos received his B.S. in Communication from the University of São Paulo, Brazil; MSC. degrees in Communication and Informatics Applications from the University of São Paulo State and University of Paris Sorbonne Nouvelle, in São Paulo and Paris, respectively, and is currently a researcher finishing his Ph.D. followed since 2012 in Electrical Engineering for Telecommunications at Campinas State University of São Paulo. He worked as a researcher at University of São Paulo and São Paulo State from 2003 to 2006. He worked as Assistant Professor of University of São Paulo State in 2012 and as Titular Professor of the National Commerce Service University, in São Paulo, since 2013.

Yuzo IANO. Yuzo Iano, IEEE Member, received the B.S., M.S. and Ph.D. degrees in Electrical Engineering from the Campinas State University of São Paulo in 1972, 1974 and 1986, respectively. He joined that University as a Titular Professor in 1991, where he also worked as an Assistant Professor since 1975. He served as a Telecommunications Researcher at Telebras, the Brazilian Telecommunications agency, from 1986 to 1990.

APEM: Automatic paraphrase evaluation using morphological analysis for the Korean language

Sung Won Moon*, Gahgene Gweon*, Hojin Choi**, Jeong Heo***

*Dep. Of Knowledge Service Engineering, KAIST, Daejeon, Rep. Of Korea

** Dep. Of Computer Science, KAIST, Daejeon, Rep. Of Korea

*** Knowledge Mining Research Team, ETRI, Daejeon, Rep. Of Korea

augustmoon@kaist.ac.kr, hojinc@kaist.ac.kr, ggweon@kaist.ac.kr, jeonghur@etri.re.kr

***Abstract*— Paraphrase evaluation is used to determine whether two input sentences share a same meaning. The automatic analysis for paraphrase evaluation technology has a potential use in the area of information retrieval technology since correctly paraphrased sentences can be used as alternative input sentences in the retrieval process. In this paper, we suggest an automatic paraphrase evaluation method using morphological analysis (APEM), which is suitable for the Korean language. Using APEM and its variations, we present preliminary results on how our automatic evaluation scores compare to the existing method of bilingual evaluation understudy (BLEU).**

***Keyword*— Morphological analysis, Paraphrase evaluation**

I. INTRODUCTION

PARAPHRASE EVALUATION is used to determine whether two input sentences share a same meaning. In this paper, we suggest an automatic evaluation method given a pair of paraphrased sentences. An evaluation is a necessary step in order to use paraphrased sentences in various applications, since we need to first determine whether the paraphrased sentences are suitable for such usage. Thus far, research on paraphrase evaluation has been largely conducted for the English language [1], [2], [3]. Therefore, for other languages, such as Korean, modified versions of evaluation methods used in the English language have been used. However, such methods are not ideal considering that the two languages differ in structure. Given such need, we suggest an automatic paraphrase evaluation method using morphological analysis (APEM) for the Korean language. Automatic evaluation for paraphrase technologies has potential use in the area of information retrieval technology since paraphrased sentences can be used as alternative input sentences in the retrieval process. For instance, if a user wants to know in what countries U2 has held concerts, he can ask, "What nations have U2 held concerts in". A Google search with this query sentence yields 19,200,000 answers. However, the top ten returned pages do not contain the answer. Instead, if a paraphrased sentence "What countries have U2 played in?" is used as a query sentence, google outputs 1,240,000 answers. Although the number of answers has decreased by tenfold, the top page among the returned pages lists the intended answer by listing all the countries where U2 has played a concert. Figure 1 shows the screen capture from the Google search engine using these two paraphrased sentences.

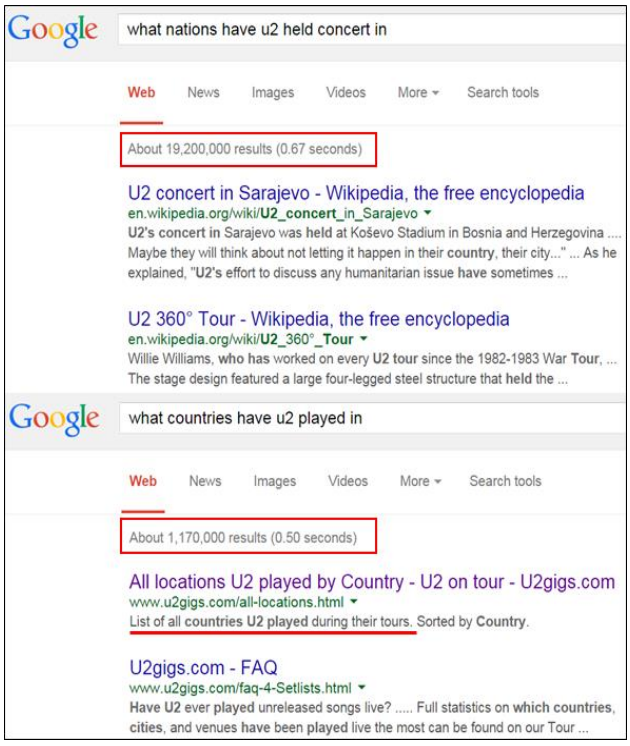

Fig 1. Example of different results using paraphrased sentences

As seen in the example above, despite the advancements in hardware and information retrieval techniques, there is room for improvement in the area of information retrieval by using alternative search phrases. Obtaining a desired answer to a query is not a matter of increased number of returned answers,

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S. Moon is with the Department of Knowledge Service Engineering, Korean Advanced Institute of Science and Technology, Daejeon, Rep, of Korea (phone: 82-10-9028-8724; e-mail: augustmoon@kaist.ac.kr).

G. Gweon is with the Department of Knowledge Service Engineering, Korean Advanced Institute of Science and Technology, Daejeon, Rep, of Korea (corresponding author phone: 82-42-350-1618; fax: 82-42-350-1610; e-mail: ggweon@kaist.ac.kr).

H. Choi is with the Department of Computer Science, Korean Advanced Institute of Science and Technology, Daejeon, Rep, of Korea (phone: 82-42-350-3561; fax: 82-42-350-3510; e-mail: hojinc@kaist.ac.kr).

J. Heo is with the Automatic Speech Translation and Knowledge Analytics Research Center, Electronics and Telecommunications Research Institute (ETRI), Daejeon, Rep. of Korea (phone:82-42-860-6870; fax:82-42-860-4889; e-mail: jeonghur@etri.re.kr)

but more about providing a query that captures a user's intention. Therefore, evaluation of the resulting paraphrased sentences is also an important research field that can be used in the process of information retrieval along with research on automatic paraphrase techniques. In addition, the paraphrase evaluation technique can be used in natural language processing applications such as text-to-text generation or information extraction applications [4].

Our proposed evaluation methodology of APEM is suitable for the Korean language, which is an agglutinative language. This method is valuable in that much of the existing work in paraphrase evaluation has been geared towards inflectional language, such as English. We consider two characteristics of agglutinative language in our suggested method: use of endings and postpositions. In agglutinative languages, "endings" are added at the end of a verb to convey information such as tense, mood, or social relationships between speaker and listener. In contrast, an inflectional language, such as English, makes extensive use of auxiliaries to convey such information. In addition to endings, postpositions are used in agglutinative languages to determine a case of a noun or relationship between multiple words. Since an agglutinative language has many variations using endings and postpositions, using the same evaluation methodology as that used in inflectional language yields evaluation results that are too strict. Therefore APEM discards morphemes that do not carry meanings, such as endings and postpositions, to reflect the characteristics of agglutinative languages.

We also examine whether two types of APEM variation methods would improve the performance of paraphrase evaluation, namely APEM+synonym dictionary (APEM_SD) and APEM + synonym dictionary +Google distance (APEM_SDGD). In the rest of this paper, we first present existing work on paraphrase evaluation. Next, a simple experiment that is designed to assess our proposed evaluation method is presented, followed by the results of the experiment.

II. BACKGROUND

The task of paraphrase evaluation has recently been receiving increased attention along with the advancement in the task of paraphrase generation [5]. The evaluation task is one of the three main subtasks of the paraphrase generation process, i.e. extraction, recognition/evaluation, and generation [6]. The paraphrase evaluation task can be conducted either manually or automatically. Table 1 summarizes previous research on paraphrase evaluation using both manual and automatic evaluation processes.

TABLE I
RESEARCH ON PARAPHRASE EVALUATION

FirstAuthor	Year	Method
Bangalore [7]	2000	String accuracy, Bag accuracy
Barzilay [8]	2002	Readability, Fidelity
Papineni[1]	2002	N-gram precision (BLEU)
Fujita [9]	2004	Longest Common Subsequence(LCS)
Glickman [10]	2004	A case study for verbs
Dolan [11]	2005	Correctness
Snover[2]	2006	Translation Edit Rate (TER)
Callison-Burch [12]	2008	5-point Likert scale
Snover[13]	2009	TER, Stem match, Synonym match
Chen [3]	2011	Paraphrase In N-gram Changes (PINC)
Fujita [14]	2012	5-point Likert scale

For a manual evaluation, human evaluators assess the quality of paraphrased sentences according to the provided standards. The main advantage of a manual evaluation is that human judgment, which is difficult to capture with rules, such as idioms or jokes, can be correctly evaluated. However, due to the nature of human judgement, different evaluators will assign varying scores even if they are using the same standards. Therefore, a method for checking the reliability of the evaluated scores, such as a correlation analysis, should follow a manual evaluation process. In addition to variations in judgement, a manual evaluation has limitations in terms of the number of sentences that can be evaluated due to time and monetary constraints.

An automatic evaluation can address some of the disadvantages of a manual evaluation. Compared to a manual evaluation, an automatic evaluation is cheaper and can yield results that are more consistent when the system is provided with a clear set of rules. However, it is difficult to provide such clear rules and there exist limitations on the level of expressions that machines can comprehend. Despite such difficulties of automatic evaluation, as the amount of data that needs evaluation increases, it becomes infeasible for researchers to conduct a manual evaluation. Therefore, attempts in improving the accuracy of automatic evaluations are increasing.

Automatic paraphrase evaluation can be conducted using features at the surface or semantic level. The main surface level feature used for paraphrase evaluation is n-gram, which is a simple yet powerful feature in that the methods using n-gram yield paraphrase evaluation results with high performance. Popular methods that use n-gram as a main feature are Bilingual evaluation understudy (BLEU), Translation edit rate (TER), and Paraphrase in n-gram changes (PINC) [1], [2], [3]. However, using n-gram without any processing is not suitable for an agglutinative language such as Korean. In an agglutinative language, a word can take many different surface forms by using various endings or postpositions. Therefore, using n-gram as a feature would be too strict of a rule for detecting words that are different on the surface but are semantically identical in Korean. Therefore a different evaluation method adapted to the agglutinative language in paraphrase needs to be developed. Thus, in this paper we suggest automatic paraphrase evaluation using morphological analysis (APEM), which accounts for the variations of surface forms in agglutinative languages.

In addition to APEM, which mainly uses surface level features for evaluation, we also suggest two additional variations of APEM by considering semantic level features as used in existing methods [13], [15], [16]. In particular, a popular semantic tool used for paraphrase evaluation is synonym dictionaries as used in the Translation edit rate – plus (TERp) method. We suspect that APEM + synonym dictionary (APEM_SD) could improve APEM's performance since words that are paraphrased with a different syntactic form, yet carry the same semantic meaning can be evaluated as having the same meaning. However, APEM_SD is a very naïve approach in that it uses data from synonym dictionaries without addressing word sense disambiguation (WSD). For example, consider the following sentence: "The power went out last night". In this example, although 'power' and 'force' are synonyms in a dictionary,

they cannot be replaced with each other due to inappropriate context. Therefore, we also propose a third method of APEM + synonym dictionary + Google distance (APEM_SDGD) that considers context by using semantic similarity of words in a sentence. In the next section, we explain how the three methods of APEM, APEM_SD, and APEM_SDGD are implemented.

III. Methods

This section describes the data source as well as the details on how the manual and automatic evaluations are conducted.

A. Data source

As stated in the introduction, one application of the paraphrased sentences is using them as alternative input sentences in question and answering (QA) systems. Thus, we selected one hundred question sentences from a QA system, which is a Korean quiz show called "Janghak quiz". These hundred sentences were given as inputs to an automatic paraphrase generation system to produce paraphrased pairs that were evaluated using manual and automatic evaluation methods [17].

B. Gold standard using manual evaluation

To validate the quality of the paraphrased Korean sentences generated by the automatic system, we conducted a manual evaluation. Three human evaluators were asked to assess one hundred sentences using the guidelines proposed by Callison-Burch et al [12]. Figure 2 shows the specific guidelines. The interclass correlation (ICC) score of 0.87 suggests that our manual evaluations results are reliable.

The gold standard value was determined by calculating the mean value of the three human evaluators' scores [3]. The mean value of the gold standard evaluation scores for the one hundred sentences is 2.89 (s.d=1.08). Since the scales for the manual and automatic evaluation score are difficult to compare due to the difference in the scales, we normalized each score by converting it into a standardized score. The mean value of the manual evaluation scores using standardization is 0.47 (s.d=0.27).

	MEANING
5	All of the meaning of the original phrase is retained, and nothing is added
4	The meaning of the original phrase is retained, although some additional information may be added but does not transform the meaning
3	The meaning of the original phrase is retained, although some information may be deleted without too great a loss in the meaning
2	Substantial amount of the meaning is different
1	The paraphrase doesn't mean anything close to the original phrase

Fig 2. Evaluator rated paraphrases along a 5-point Likert scale

C. Bilingual evaluation understudy (BLEU)

BLEU is a popular method used for various tasks in the area of machine translation, including automatic paraphrase evaluation [1]. Since BLEU was developed originally for conducting evaluations of foreign language translations, the original sentence is in a different language than the candidate and reference sentences that are used for paraphrase evaluations. Here the candidate sentence is the target sentence that will be evaluated in terms of paraphrase accuracy compared to a set of reference sentences. Typically BLEU calculates an evaluation score between the candidate and four reference sentences. The final evaluation score is the maximum score of these four scores. Note that both the candidate and reference sentences are translated versions of the original sentence. To calculate the evaluation score, the number of identical words in the candidate and reference sentences is divided by the total number of words in the candidate sentence.

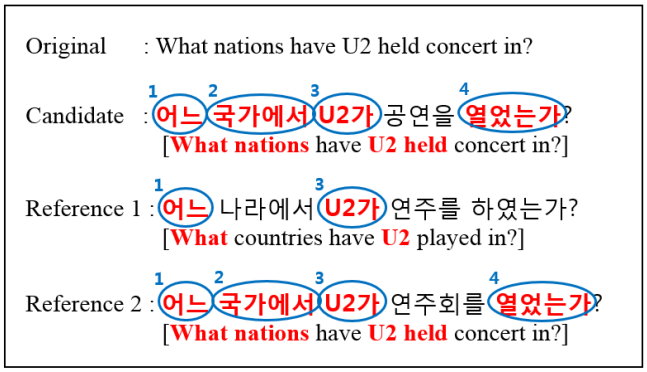

Fig 3. Example of paraphrased sentences. Circles are words that are identical across the given sentences.

Figure 3 shows sample sentences with two reference sentences as an example. The evaluation score for the candidate and reference 1 is 2/5, whereas the score for the candidate and reference 2 is 4/5. Thus the final BLEU score is 4/5, which is the maximum score between these two scores.

D. Automatic paraphrase evaluation using morphological analysis(APEM)

In this section, we introduce APEM along with its two variations, APEM_SD and APEM_SDGD.Figure 4 shows an example pair of sentences that will be used to explain the three evaluation processes. Sentence 1 is the original input sentence, and sentence 2 is the paraphrased sentence.

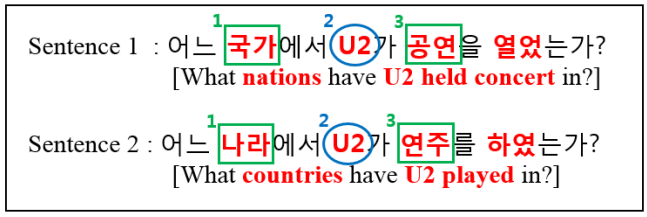

Fig 4. Example of paraphrased sentences. Circles are words that are identical whereas rectangles are words in synonym relationships.

To implement APEM, we first extracted morphemes for an input sentence using ETRI morpheme analyser [18]. Next, we removed morphemes that are labeled as endings and postpositions and kept the ones that carry real meaning in a sentence, such as nouns or predicates. The highlighted words in Figure 4 indicate morphemes that are kept after removing the unnecessary morphemes. Note that the unhighlighted words are discarded because these do not involve the essential meaning of the sentence, but merely function to make a sentence grammatically correct.

After identifying the critical morphemes that carry meanings, we calculate the evaluation score according to the equation (1). The numerator is the number of identical words

in sentence 1 and sentence 2. In our example sentences, the word pairs "U2/U2" are identical words. Thus, the numerator is one. The denominator is the number of meaningful morphemes in sentence 1, which is four in our example sentence. Therefore, the evaluation score for the paraphrased sentences in our example is 0.25. Note that according to the formula presented in equation (1), the evaluation score can range from 0 to 1, unlike the manual evaluation score, which ranges from 1 to 5.Using APEM, the mean value of the 100 sentences is 0.76 (s.d=0.17).

$$\text{Score} = \frac{Number\ of\ matched\ morphemes}{Number\ of\ meaningful\ morphemes\ in\ one\ sentence} \quad (1)$$

For APEM_SD, the method for calculating the numerator differs from APEM. In APEM_SD, if paired words are synonyms, they are regarded as "matched" whereas in AEPM, only identical words were counted as matched morphemes. Therefore, in our example sentences, the word pairs of "countries/ nations", "U2/U2", "held concert/ played" are pairs that are either identical or share synonyms. Thus, the numerator is three. The denominator is the number of meaningful morphemes in sentence 1, which is four. Therefore, the APEM_SD evaluation score for the paraphrased sentences in our example is 0.75.

For APEM_SDGD, we conduct an additional step from APEM_SD to calculate the numerator of the equation (1) by using an API from the Mechanical Cinderella project [19]. Since using APEM_SD yields "matched" words that are not in synonym relationships when considering context, we used Google distance to measure semantic similarity of words. The main assumption of the Google distance measure is that words that are used in a similar context would have a higher probability of appearing together in a document. Therefore, if a paired set of words has a high level of semantic similarity, the number of web pages that are returned in the Google search engine using those words would be higher compared to words with a low level of semantic similarity. Based on this idea, the equation uses four main numbers to calculate Google distance between two words, x and y as shown in equation (2). In the equation, f(x) and f(y) are the number of pages returned by the Google search engine using each term. F(x, y) is the number of pages where both x and y occurs, and M is the total number of web pages returned by the Google search engine.

$$\text{NGD}(x,y) = \frac{\max\{\log f(x), \log f(y)\} - \log f(x,y)}{\log M - \min\{\log f(x), \log f(y)\}} \quad (2)$$

We selected the threshold of Google distance score as 0.35 for filtering the synonyms. The threshold is heuristically calculated based on the normalized Google distance scores for a set of randomly selected words from the sentences in our dataset. We calculated approximately 600 pair of words and observed that, in general, a score of 0.35 or larger is calculated for correctly paired synonyms. For example, for the words used in Figure 4, the Google distance score between 'nations' and 'countries', which are commonly used together, is 0.352. The Google distance score for the words that do not appear frequently together, such as 'power' and 'force'is 0.163.

IV. RESULTS AND DISCUSSION

In this section, we present the correlation scores among the gold standard, BLEU, and the three variations of APEM. The positive medium correlation between the gold standard and the comparison method suggests that our automatic evaluation score captures some part of human evaluation scores. However, we acknowledge that at the current stage, the correlation is not accurate enough for use in place of human evaluation.

TABLE Ⅱ
PERFORMANCE OF THE PARAPHRASE EVALUATION

Method	Correlation
BLEU	0.57
APEM	0.62
APEM_SD	0.30
APEM_SDGD	0.60
BLEU_APEM(2:8)	0.64
BLEU_APEM(5:5)	0.64
BLEU_APEM(8:2)	0.61

As seen in Table 2, BLEU_APEM, which mixes the scores of both BLEU and APEM, performed best. In addition, our suggested method of APEM and APEM_SDGD performed slightly better than the existing method of BLEU. It was surprising to see that APEM_SD scores were much lower at 0.3 compared to other methods. Thus, our experiment shows that using synonyms without considering context has a high penalty.

V. CONCLUSION

Korean paraphrase evaluation is an important research area that has much room for improvement. Research from this area can help improve the effectiveness in information retrieval technology. Although the Korean evaluation method that we suggested in this paper is a beginning step towards automatic paraphrase evaluation, the higher correlation of APEM compared to BLEU shows promise in that using morphemes in agglutinative languages is helpful. However, APEM_SD, which is our naïve approach for including a semantic feature that simply utilizes a synonym dictionary, hurts performance. Efforts for considering contextual information, such as in APEM_SDGD, are necessary if semantic features are to be used.

In future work, we plan to extract more features of agglutinative languages for use in evaluation. For example, our current method uses a single morpheme as a feature. A more advanced approach would be considering multiple morphemes that constitute a meaningful unit as a feature. Additionally, the inclusion of advanced measurements that consider context would increase the accuracy of our technique. For example, compared to using synonyms from dictionaries, the use of words from sentences with varying expressions in Wikipedia could be helpful.

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Sungwon Moon is a master student in the department of knowledge service engineering, Korea Advanced Institute of Science and Technology (KAIST). He received his Bachelor's degree from Handong Global University, Korea (2013). His current interests are in the area of natural language processing, data mining and computer supported collaborative learning.

Ho-Jin Choi is an associate professor in KAIST Computer Science Dept. In 1995, he received a PhD in artificial intelligence (AI) from Imperial College London. Since 2010, he participates inSystems Biomedical Informatics Research Center at Seoul National University Medical School. He is in the boards of directors for Software Engineering Society of Korea, for Artificial Intelligence Society of Korea, and for Korean Society of Medical Informatics. His current interests include AI, knowledge engineering, data mining, topic mining, intelligent personal assistant, natural language QA, and biomedical informatics.

GahgeneGweon is an assistant professor in the department of knowledge service engineering, Korea Advanced Institute of Science and Technology (KAIST). She received her PhD in human computer interaction from Carnegie Mellon University, United States (2012). Her current interests are in the area of human computer interaction, computer supported collaborative learning, and natural language processing.

Jeong Heo is a senior researcher in Electronics and Telecommunications Research Institute, Daejeon, Rep. of Korea, He received his MS degree in computer science for the University of Ulsan(2001), His research interests include natural language processing, text mining, social big data analytics, and question answering.

Fault Resilient Communication Network Architecture for Monitoring and Control of Wind Power Farms

Shahid Hussain*, Young-Chon Kim**

* *Department of Computer Engineering, Chonbuk National University, Jeonju 561-756, South Korea*

** *Smart Grid Research Center, Chonbuk National University, Jeonju 561-756, South Korea*

***shahiduop@jbnu.ac.kr, **yckim@jbnu.ac.kr**

Abstract— **Real time monitoring and control of wind power farm (WPF) require a highly reliable communication network infrastructure. The monitoring and control can be guaranteed through the communication network by using redundant resources and ensuring quality of service (QoS) for different applications. In this paper, we study and simulate fault-resilient network architecture for monitoring and controlling of WPF. First, communication network topologies are explored. Then we propose a fault-resilient communication network architecture which consists of three different levels: (1) data generation level, (2) data aggregation level, and (3) control center level. Each level is defined by its function, physical location, network topology, communication link bandwidth, redundant nodes, and links. In accordance to IEC 61400-25 standard, the monitoring traffic of wind turbine is classified into critical and non-critical data according to the required QoS. Due to low cost, non-proprietary standard, and guaranteed real-time services, the Ethernet technologies are currently used in various industrial applications. Several network failure scenarios based on Ethernet technology are used to simulate the network architecture through OPNET. The performance of the network architecture is evaluated on the basis of the amount of received data, end-to-end delay, and data loss at control center. The simulation results show that the communication network architecture can guarantee the transmission of WPF critical data.**

***Keyword*— Communication Networks; IEC61400-25; Monitor and Control; Reliability and Resiliency; Wind Power**

I. INTRODUCTION

WIND is a natural and low cost resource that is never depleted and can be used for an environment friendly renewable energy production. These characteristics of wind lead to a fast increase in WPF around the world. Mountains and offshore locations are the suitable choices for wind power because of stable and strong wind with space availability. Some European countries such as Germany, Denmark, and United Kingdom are rapidly installing offshore WPF with larger size wind turbines (WTs) and higher power capacity. The offshore wind power generation is facing several issues: high construction cost, offshore installation, and maintenance cost. The construction and installation are considered to be initial investment expenditure. However, the maintenance and repair need a special attention because it is a long term and continuous task. The communication networks can play a significant role in the reduction of maintenance and repair expense by providing real time monitoring and control mechanism to these WPF. Communication networks can enable the control center (CC) to monitor the status of WTs in real time. The CC then controls the operation of the WT with control commands. Currently, various monitoring techniques such as sensor and infrared camera based monitoring are used [1,2]. Fig.1 shows a schematic diagram of WPF communication network. In this figure, the monitoring and control system for WPF is divided into three parts. In the first part, all WPF are connected to a remote terminal through a wired communication link. The second part is the communication network by using wired or wireless according to the requirements. At the third part, there is a CC with different monitoring and control servers system. An efficient monitoring and control operation strongly relies on the high availability of data with a minimum latency. In view of communication network, the resiliency can be defined that the communication network should be able to route the traffic via secondary resources to ensure the data transmission under any failure of device and link. The issues in communication network that can influence the WPF system include plane maintenance, component failure and accident/disaster [3]. Therefore, designing a fault-tolerant communication network is highly required for WPF. In this regards, several communication architectures have been proposed in the literatures. The authors in reference [4] proposed an Ethernet passive optical network (EPON) based communication network architecture. The communication network was modeled through optical network unit (ONU) and optical line terminal (OLT). In reference [5] a resilient communication network for large-scale offshore wind farm was proposed with the focus on redundant resources in the network. An open shortest path first (OSPF) protocol and rapid spanning tree protocol (RSTP) was used for avoiding loop in the network.

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Shahid Hussain is with Department of Computer Engineering, Chonbuk National University, Jeonju 561-756, South Korea. (e-mail: shahiduop@jbnu.ac.kr).

Young-Chon Kim is with Smart Grid Research Center, Chonbuk National University, Jeonju 561-756, South Korea.(Corresponding author, phone:+82-63-270-2413; fax: +82-63-270-2394;
e-mail: yckim@jbnu.ac.kr).

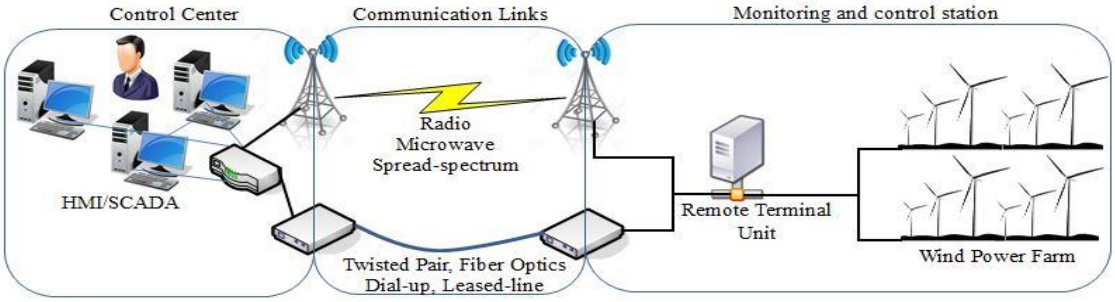

Fig. 1. Schematic diagram of communication network for wind power farm monitoring and control

Resilient wireless communication network architecture for smart grid in building area network (BAN) was proposed by the authors in reference [6]. To achieve resiliency with high degree, the paper focused on wireless mesh network among the different communicating entities in BAN. To the best of our knowledge, simulation study towards the fault-resilient communication network for monitoring and control of WPF has not been considered.

In this paper, we extend our previous work titled "Simulation Studies of Resilient Communication Network Architecture for Monitoring and Control Wind Power Farms" [7]. First, we explore various topologies that can be applied to the communication network for WPF. The advantages and disadvantages of each topology are discussed. Then, fault-resilient communication network architecture with hybrid topology is proposed. To achieve fault-tolerance in the network with a higher degree, we considered redundant resources at WPF, offshore platform, and control center level. The IEC 61400-25 standard is used for monitoring various components of WT. The standard mapped the physical components of WT into different logical nodes (LNs). Some of the LNs are mandatory while the others are optional. These different kinds of LNs have different QoS requirements. According to the IEC 61400-25 standard optional and mandatory LNs, the monitoring data are classified into critical and non-critical data to satisfy the QoS requirements. Several network failure scenarios are simulated through OPNET to evaluate the proposed architecture performance. The performance of the communication network architecture is analyzed in terms of end-to-end delay, data loss, and the amount of received data.

The rest of this paper is organized as follows: related work is discussed in Section II. The different network topologies and the proposed communication network architecture are presented in Section III. WPF communication network with data modeling and simulation set-up is given in Section IV. Simulation results and discussion is presented in Section V. Finally, Section VI summarizes the paper with concluding remarks and related future work.

II. RELATED WORK

A. The Horns Rev Communication Network

Elsam, a Danish energy company, installed the first largest offshore WPF in the North Sea. It consists of 80 Vestas V80-2.0 MW unit WTs with 160 MW power capacities. The 80 WTs are connected in 10 rings with a total of 8 WTs in each ring. The network architecture is designed with a primary wired and secondary wireless radio communication channels [8]. Fig 2 shows the Horns Rev communication network diagram. The network is equipped with redundant devices both at offshore (WPF site) and onshore (CC) locations. All the communication is made through the primary wired link. This wired link uses a single mode fiber with link bandwidth of 1Gbps to support the 80 WTs traffic and cover longer distance between WPF and CC. An open platform communication (OPC) interfaces are enabled within the network equipment. The data is transmitted through file transfer protocol (FTP), serviced by TCP/IP. The secondary wireless radio communication channels use a 34Mbps channel bandwidth. The secondary wireless channel has the advantages of low installation cost, simple configuration, and is easy to deploy. When the primary link fails the traffic is routed to the secondary wireless channels for data transmission. However, some of the limitations associated with this architecture are: According to the IEC 16400-25 standard LNs, a WT generates approximately 1.8 Mbps of monitoring data [9]. In the case of Horns Rev WPF the fiber link has a huge capacity of 1Gbps which is not utilized. Also, the secondary wireless channels have a limited bandwidth of 34 Mbps. The limited channel capacity may result in data loss with an increased latency. Furthermore, different applications require different service qualities but the Horns Rev WPF do not consider any QoS requirements.

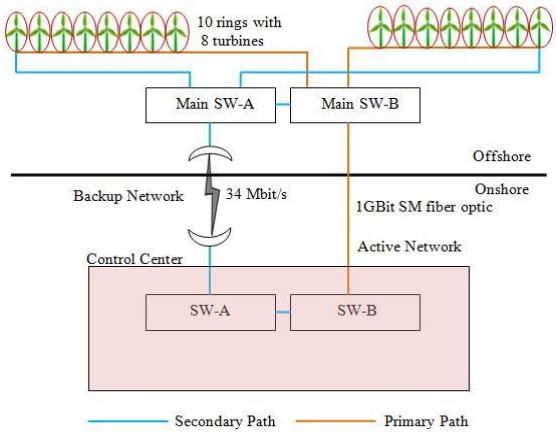

Fig. 2. Horns Rev Communication Network

B. The Greater Gabbard Project Communication Network

The Greater Gabbard project is developed by Scottish and Southern Energy (SSE) Company. The project covers a load of 40% with a total annual production of 1,900-GWh electricity. The project consists of 140 WTs with 3.5 MW power generations for a WT. The turbines are located around two sand banks called Inner Gabbard and the Galloper in the North Sea, off the coast of Suffolk in Eastern part of England. The total distance of these wind farms is about 25 kilometers

off the coast. The turbines are installed in water depths of between 24 and 34 meters. The WTs are connected to two transformers located at the offshore platform via 33kv cable. The power is then exported to the onshore substation through 132kv submarine cable. The WPF is connected to the onshore substation through three different set of backbone gigabit Ethernet based communication networks. The network infrastructure consists of 8-rings connected to offshore substation with 10-20 switches. Each of the communication networks is designed to support different type of applications. A virtual local area network (VLAN) is used to isolate the traffic for each of the application. The RSTP protocols are adopted for network loop avoidance and traffic re-routing in case of any failure in the network. The details of these dedicated networks are discussed as follows.

- ✧ **Balance of plant network**: This network is called as "substation protection and control network" with the main function to connect all the protection and control IDE's at WTs, offshore and onshore substation.
- ✧ **Wind turbine generator network**: The WT controllers are connected to central supervisory controlled and data acquisition (SCADA) control system through Ethernet communication link.
- ✧ **Telephone and security network**: The video surveillance cameras and IP telephony services are provided by this network.

All these networks are connected to the onshore substation through gigabit Ethernet backbone with redundant switches and routers [10]. The network provides resiliency with higher degree using ring topology and redundant network resources. The QoS can be achieved through independent network for each application. However, some of the associated limitations are: the physically connected network is logically separated through VLAN for three different types of applications. The VLAN can cause an increasement in the delay of sensitive or time critical data. Another limitation is the cost factor, because the network infrastructure is fully connected with a bundle of resources (network switches and links) which associates a high cost. Hence, in view of cost it cannot be considered as an optimized solution.

III. Proposed Fault Resilient Communication Network Architecture For WPF

In this section, we discuss various communication network topologies that can be used for monitoring and control of WPF. Then, we define the level of the communication network architecture according to the network topologies.

A. Communication Network Topologies

Linear Topology: In this topology the WTs are connected in a point-to-point communication link. The communication among WTs, offshore platform, and CC is carried out through the same point-to-point links. The advantage of this type of topology is that, it is simple to install and configure. However, the failure of a node/link results in disconnecting rest of the WTs. A variation of this topology is that each of the WT is directly connected to the offshore platform with a separate dedicated link. In this case the failure of a link/node does not affect the communication of other WTs. However, in view of cabling requirements and cost, it is a complex and costly solution. Fig. 3a and Fig. 3b show the two kind of linear topology.

Star Topology: All WTs are connected to the Ethernet switch (ESW) of a central WT. This ESW operates as a coordinator for all the others WTs. The central WT has a point-to-point communication link with the offshore platform. A second kind of this topology is star-ring topology. All the WTs are connected to the central WT through a ring topology. The star topology is simple to setup and configure where the star-ring is more robust. However, failure of central WT in star topology could result in disconnecting the reaming WTs. The star-ring topology is more robust than simple star, but in this case failure of central WT results in linear topology. Fig. 3c and Fig. 3d show star topology and star-ring topology, respectively.

Ring Topology: In this topology, all WTs are connected in ring. This topology is high robust, simple, and cost effective. The failure of WT or link does not affect the communication of other WTs. A point-to-point redundant communication to the offshore platform provides a higher reliability in the network. Ring topology can be a fully connected or partially connected. The fully ring-topology is more reliable and robust but require more cables, devices and ports. Fig. 3e and Fig. 3f show the partial and fully connected ring topologies.

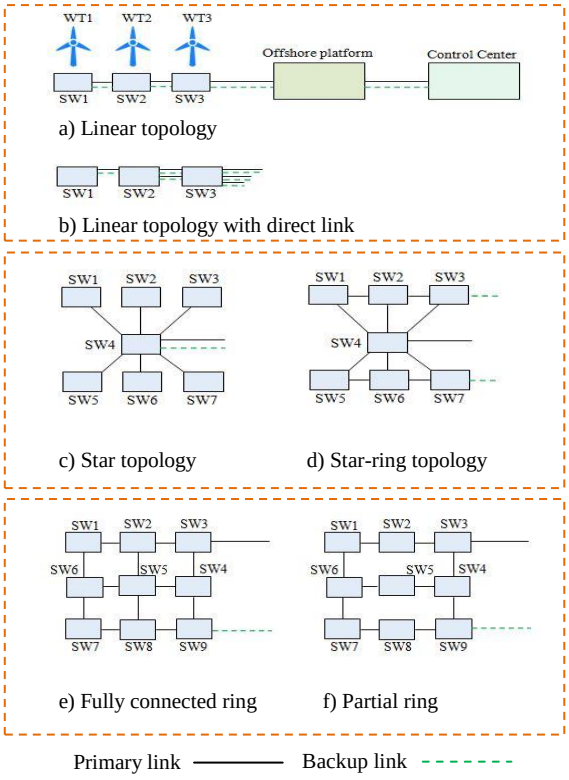

Fig. 3. WPF Communication Network Topologies

B. Three Level Communication network architecture

In this study, we consider an Ethernet based resilient communication architecture for WPF. A schematic diagram is shown in Fig 4. To obtain reliability with a higher degree, the aforementioned architecture is divided into three levels: data generation level, data aggregation level, and control center level. Each level is based on a specific function, location, and network topology. To maintain fault-tolerance in the network, each level has redundant network resources. The WPF and offshore platform are located at offshore site while the CC is

located at onshore. Rapid spanning tree protocols (RSTP) are adopted to avoid loop in the network. The following section describes these levels in detail.

Data generation level (DGL): Embedded sensors continuously monitor the components of WTs at DGL. Each WT has a WT controller (WTC) at its bottom. An ESW located at WTC maintains communication with previous and next WTC through an Ethernet link. The WTs within the WPF is connected through partial ring topology. The partial ring topology provides resiliency with higher degree at the DGL. The WPF is connected to the offshore platform through point-to-point connection. The resiliency between WPF and offshore platform is achieved through a secondary point-to-point link. The traffic is routed to the alternate backup link if the primary link fails.

Data aggregation level (DAL): DAL is the middle level of the communication network architecture between WPF and CC. The function of this level is to aggregate the WPF data to the CC. The offshore platform has redundant resources to maintain primary and secondary links. Primary ESW maintains a point-to-point primary link while the secondary ESW is reserved for backup. To provide resiliency with higher degree the primary and secondary ESW at this level are also connected through point-to-point link.

Control center level (CCL): The CC collects data through the offshore platform for processing. Control commands are then transmitted to WTs within WPF for appropriate action using primary and/or secondary link. At CCL the SCADA systems are connected through LANs using star topology. The resiliency at this level is achieved through redundant switches and links. The secondary network resource is used with the failure of primary network resources.

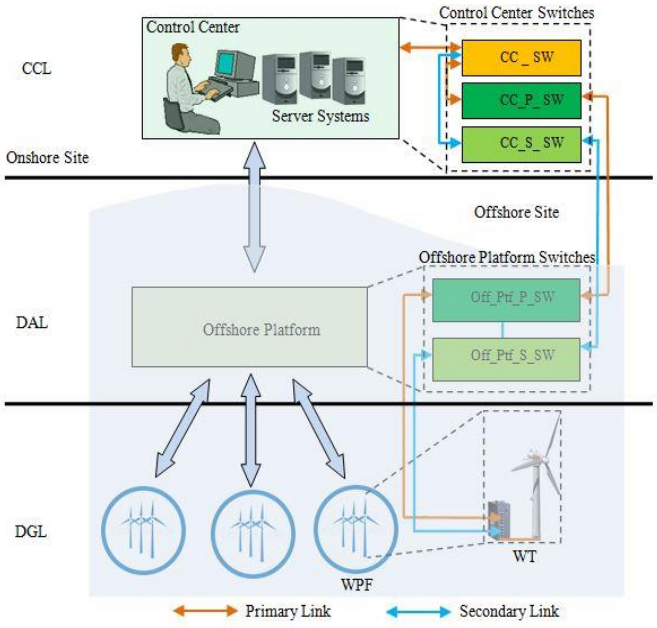

Fig. 4. Schematic diagram of network architecture with three levels

C. *Proposed fault-resilient communication architecture*

The proposed communication network architecture is based on hybrid network topology. The proposed architecture is shown in Fig 5. A partially connected ring topology is used to connect WTs within the WPF at the DGL. The WPF, offshore platform, and CC communicate through a point-to-point linear link.

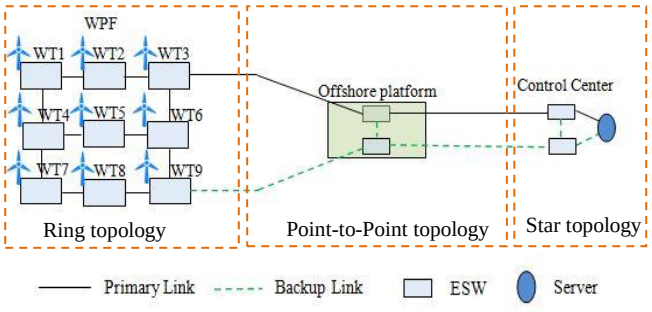

Fig. 5. Proposed architecture with hybrid communication network Topology

Within the CC the devices are connected through local area network using star topology. All the monitoring and control operations are performed through primary ESWs and links. For resiliency reserved backup network resources are used at each level of the architecture.

IV. WPF Network Modeling

A. *Traffic Modeling*

The integration of WPFs into electricity grid explores new requirements in communication capabilities of WTs and electricity grid. The standard information model and communication system can make it possible to integrate the WPF into the electricity system. The IEC standard series 16400-25 defines a standardized way for accessing wind power data [11]. As discussed previously that this standard relates the components of WT into LNs. This work considers nine LNs including WROT, WTRM, WGEN, WCNV, WNAC, WYAW, WTOW, WTRF, and WMET. These LNs are categorized into status, analogue, and control information. Each category is sub-divided into different attributes. Table I shows the details about WROT and its associated attributes [12]. In accordance to the mandatory and optional LNs concept, we classified the WT monitoring data into critical and non-critical data to support different QoS requirements. Table II shows the critical and non-critical data for one WT.

TABLE I
SUB-ATTRIBUTES FOR WROT LN

Category	Attribute	Explanations
Status Information	RotSt	Status of rotor
	BlStB1	Status of blades
	PtCtlSt	Status of pitch control
Analogue Information	RotSpd	Value of rotor speed at rotor side
	HubTmp	Temperature in the rotor hub
	PtHyPresB1	Pressure of hydraulic pitch for blades
	PtAngValB1	Pitch angle for blades
Control Information	BlkRot	Set rotor to blocked position
	PtEmgChk	Check emergency pitch system

TABLE II
CLASSIFICATION OF WT CRITICAL AND NON-CRITICAL DATA

LN Class	Description	M/O	Type
WROT	WT rotor information	M	Critical Data
WGEN	WT generator information	M	
WNAC	WT nacelle information	M	
WYAW	WT yawing information	M	
WTOW	WT tower information	O	Non-critical Data
WMET	WPF meteorological information	O	
WTRF	WT transformer information	O	
WCNV	WT converter information	O	
WTRM	WT transmission information	O	

TABLE III
WT MONITORING MEASUREMENTS

Measurement	Sampling Frequency	Number of Channels	Data Transmissions(bytes/s)	No. of Measurement Devices
Temperature	1 Hz	1	2	16
Speed	3 Hz	1	6	3
Pressure	100 Hz	1	200	7
Pitch Angle	3 Hz	1	6	6
Vibration	200 Hz	3	1200	2
Voltage	2048 Hz	3	12288	12
Current	2048 Hz	3	12288	6
Power	5 Hz	1	10	2
Power Factor	1 Hz	1	2	2
Humidity	1 Hz	1	2	3
Wind Direction	3 Hz	1	6	3
Wind Speed	3 Hz	1	6	3
Displacement	10 Hz	2	40	2
Oil Level	1 Hz	1	2	4
Frequency	10 Hz	1	20	1
Torque	50 Hz	3	300	1
Status	1 Hz	1	2	29
Temperature	1 Hz	1	2	16
Total				**102**

The WT monitoring traffic depends on the sampling frequencies, the number of channels, and the number of sensors nodes. Table III shows monitoring measurements for 102 sensors. In our previous work we, proposed multilayer communication network architecture for WPF [13]. We considered 102 sensors that generate a total of 225,602 byte/sec (approximately 1.8 Mbps) monitoring traffic for a WT. The following formula is used to calculate the monitoring traffic for one WT.

$$\text{Data rate} = 2*N_C*F_S$$

Where N_C is the number of channels or measurements devices (sensors) and F_S is the sampling frequency of each device. Each sample is of 2-byte in size. For example the vibration sensor generates 200 samples/sec, thus the total amount of traffic is 1200 byte/sec for 3 channels with 2 byte of data for each sample. Based on mandatory and optional data shown in Table I, the WT critical and non-critical monitoring traffic can be calculated. Table IV shows the critical and non-critical traffic for stand-alone WT.

TABLE IV
WT CRITICAL AND NON-CRITICAL TRAFFIC DATA

Traffic calculation for mandatory LNs		
LN Classes	**No of sensors**	**Data transmission byte/s**
WROT	14	642
WGEN	14	73764
WNAC	12	112
WYAW	7	220
Sub-total	**47**	**74,738 byte/sec**
Traffic calculation for optional LNs		
LN Classes	**No of sensors**	**Data transmission byte/s**
WTOW	4	8
WMET	7	228
WTRF	12	73740
WCNV	14	74060
WTRM	18	2828
Sub-total	**55**	**150,864 byte/sec**
Total	**102**	**225,602 byte/s ≈ 1.8Mbps**

By considering the above classification for critical and non-critical data, Table V shows the amount of traffic for single WT and for a small scale WPF consisting of 12 WTs. The overall traffic is then summed up as cumulative traffic.

TABLE V
CRITICAL AND NON-CRITICAL TRAFFIC FOR SMALL SCALE WPF

WT/WPF	No of WTs	WT/WPF monitoring data in Mbps		
		Critical data	Non-critical data	Total
Stand-alone WT	1	0.57	1.15	1.8
Small Scale WPF	12	6.84	13.81	20.64

B. Network Modeling

The communication network for WPF can be defined on the basis of electric power system topologies. The authors in reference [14] defined various electric topologies for WPF. To achieve high reliability the proposed communication network architecture in this paper follows hybrid topology. Fig 5 shows the OPNET [15] topology of a small scale WPF. It consists of 12 Ethernet work stations. Each workstation represents one WT. Offshore platform consists of primary and secondary ESWs. WPF is connected to primary ESW through primary link while the secondary link maintains a secondary connection. The CC uses three ESWs. The primary ESW maintains a primary connection with offshore primary ESW. The secondary ESW is used for backup/secondary connection. Both the primary and secondary ESWs are connected to the CC central ESW. The SCADA servers are connected to the central ESW. A link bandwidth of 100Mbps is used for the primary connection to support the WPF monitoring traffic. Similarly, link bandwidth of 10Mbps is used for the secondary connection. A low link bandwidth for the secondary link provides a cost effective solution. The SCADA servers system supports critical and non-critical data of WPF. In order to execute the network topology, different type of OPNET objects are needs to be configured. In our simulation scenarios, the following objects are used:

1. Application configuration: The application object is used to define and configure the traffic according to the user requirements. This object defines six common applications including: HTTP, E-mail, video, FTP, Voice, and database. In this work, we used this object as *WT_Application* and configure for two FTP applications (i.e. critical_app & non_critical_app) to generate two different types of WT monitoring traffic at application layer of the OSI model.

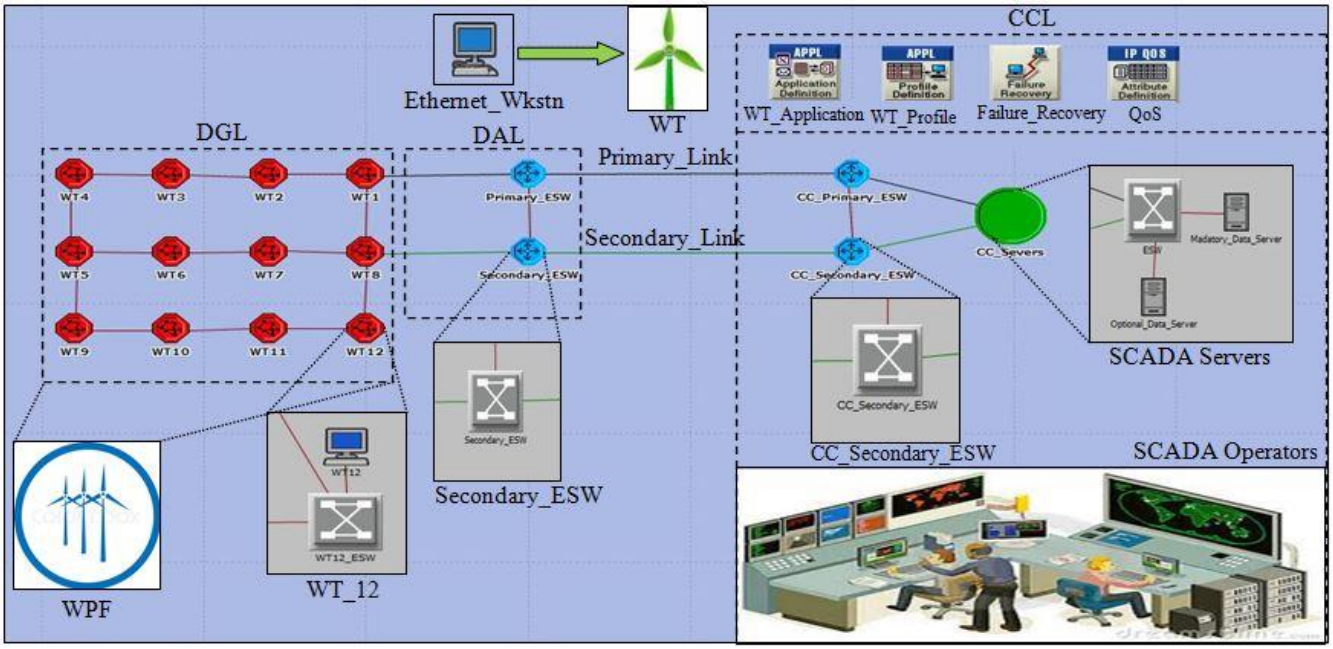

Fig. 5. OPNET Model for WPF Communication Network

2. Profile configuration: The profile object is used to create user profiles, which can support one or more application. The profile configuration defines the type of application to be used for the transmission of the traffic between the communicating nodes. It provides the starting and ending time for each application within the profile. In our work, we used the profile object as *WT_Profile.* This WT_Profile supports both critical and non-critical FTP applications. All the Ethernet work stations and server system support this profile. It enables the transmission and receiving of the WTs monitoring data between work stations and server systems across the network.

3. Failure recovery configuration: The failure recovery object is used to configure different failure points for link and nodes. The configuration of this object defines the type of failure, the time of failure (failure point), and the time of recovery (recovery time). In our simulation we used this object as *Failure_Recovery*. It is configured for primary link failure and recovery at three different times.

4. QoS configuration: This object is required for resource allocation to support the different QoS requirements. This object mainly deals with the three queuing policies: First in First out (FIFO), Priority queuing (PQ), and weighted-fair queuing (WFQ). These policies are discussed as follows.

4.1 FIFO Queue: The FIFO queuing discipline is simple as the first packet that arrives at a node is the first packet to be transmitted. The buffer space is finite and the nodes (Switch or router) discard an incoming packet if the buffer is full. This policy does not care, whether a packet is important or not. Hence it cannot support any QoS requirements.

4.2 Priority Queue (PQ): In the PQ configuration each packet is marked with a priority in the IP Type-of-Service (ToS) field. The communicating nodes then maintain multiple FIFO queues, one for each priority class. Within each priority class, the packets are still managed in a FIFO manner. This queuing discipline allows packets with a high priority to be transmitted before those with a low priority. The PQ policy supports the QoS requirements for different application.

4.3 Waited-Fair Queue: In the weighted-fair queuing (WFQ) discipline multiple queues are maintained by the nodes. For each packet a weight is assigned in the ToS field of the IP header. This weight effectively controls the percentage of the link bandwidth. According to the link bandwidth, it transmits the data with high priority. The nodes manage the WFQ services through round robin manner. In our simulation model we configure the *WFQ* queuing policy to prioritize the critical data over the non-critical data. Thus, the transmission of critical data is guaranteed with secondary link in case of primary link failure.

V. Simulation Results and Discussion

The performance of the proposed fault-resilient communication network architecture is analyzed through end-to-end delay, data loss, and data received. Several link failure and recovery scenarios are simulated. The first scenario is normal network operation without any failure. The result in Fig. 6 shows that the amount of data received, which is 6.84 Mbps and 13.81 Mbps for critical and non-critical monitoring traffic, respectively. These results are validating our simulation according to the numerical calculation in Table V. The Fig. 7 shows that the end-to-end delay is 6.5 ms and 9.5 ms for critical and non-critical monitoring data, respectively.

The second scenario considers link failure. In this scenario, the primary link is failed and recovered at three different points. Fig. 8 shows the cumulative transmitted and received traffic. The result indicates data drop in the received traffic with the failure of primary link. This data drop is in total (cumulative) traffic, and it difficult to differentiate whether critical or non-critical data are lost. This is because in this scenario no QoS requirements are considered. This data drop is due to the fact, that with the primary link failure the traffic diverts to the secondary link. The peak lines in the figure shows the retransmission of the data packets in the waiting queue. The third scenario considers QoS of requirements. The WFQ policy configuration is adopted to prioritize the critical

data. In this scenario, the primary link is also failed and recovered at three points. Fig. 9 shows the amount of received traffic for critical and non-critical monitoring data. The result clearly indicates that with failure of primary link the non-critical data is dropped. The transmission of critical data is guaranteed. Thus the non-critical data are sacrificed for the transmission of critical data. The result in Fig. 10 shows that the end-to-end delays are 69 ms and 353 ms for critical and non-critical data, respectively. There are two main reasons for this increased delay. First, the secondary link has a lower link capacity. Second, the queuing delay is increased by the packets waiting for retransmission at the time of primary link failure.

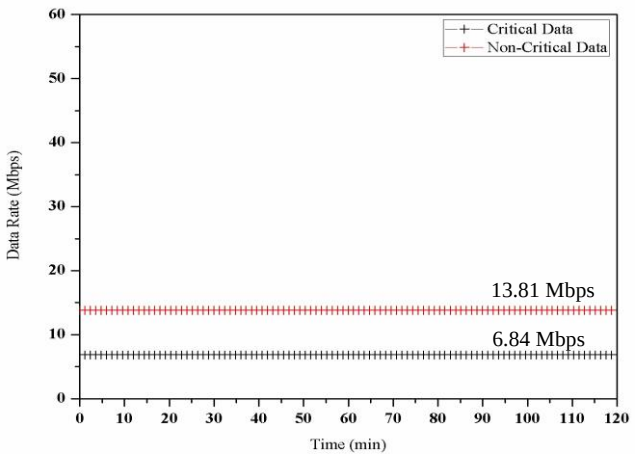

Fig. 6. Total amount of received data without failure

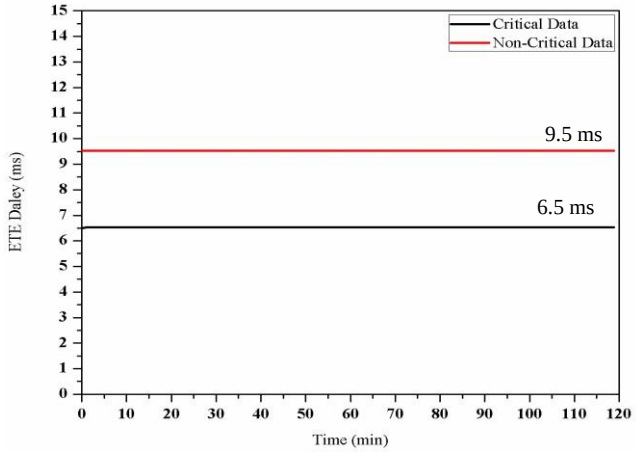

Fig. 7. ETE delay under normal operation

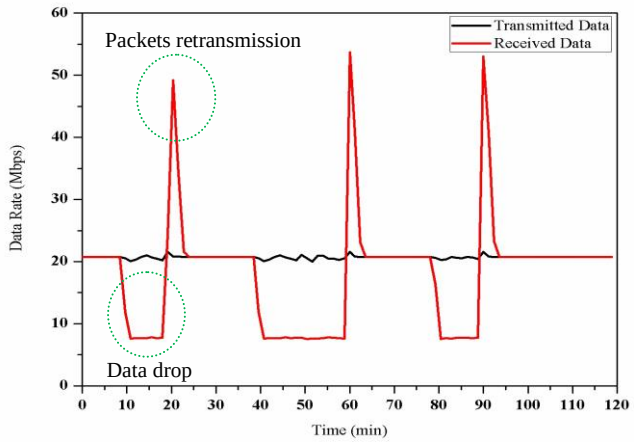

Fig. 8. The impact of primary link failure

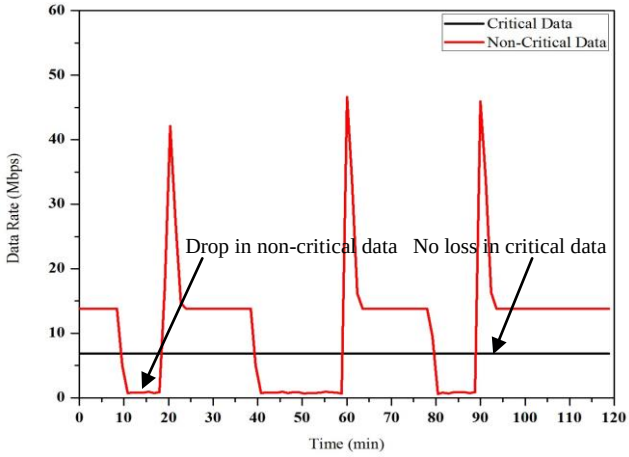

Fig. 9. Total amount of received data with primary link failure

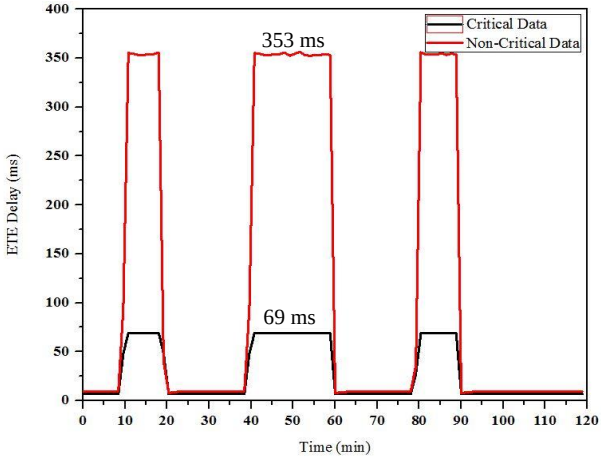

Fig.10. ETE delay with primary link failure

VI. CONCLUSION

In this paper, we proposed fault resilient communication network architecture for monitoring and control of WPF in real time. The proposed architecture was based on a hybrid topology consisting of three levels: DGL, DAL, and CCL. At the DGL, the WTs are connected in a ring topology. DAL supports the connection through point-to-point linear topology between the WPF and CC. The communication network architecture was designed with different link bandwidth of 100Mbps and 10Mbps for primary and secondary link, respectively. The traffic of LNs was modeled into critical and non-critical data according to the IEC 61400-25 standard. The monitoring data was prioritized by WFQ policy according to the required QoS. We investigate the end-to-end delay, data loss, and data received with different scenarios. Under the normal, operation the end-to-end delay was about 6.5 ms and 9.5 ms for critical and non-critical data, respectively. In the case of primary link failure the data was lost. However, considering the QoS the critical data (6.84 Mbps) was successfully received. The non-critical data sacrificed for the transmission of critical data. Thus it can be concluded that in the case of network fault the proposed fault-resilient communication architecture can support the transmission of critical data. In future, the work will be extended for large scale WPF.

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Shahid Hussain (M'15) was born in 1982 at Wazir Garhi, District Nowshera, Khyber Pakhtunkhwa, Pakistan. He received his B.Sc in mathematics 2002 and M.Sc in computer science 2005 from University of Peshawar, Peshawar Pakistan. He worked as Network Administrator at Pakistan Oilseed Development Board (PODB), Agricultural Research Institute (ARI) Tarnab Farm Peshawar, Pakistan from July, 2005 to Oct. 2008. Then he joined CSD zonal office Peshawar Pakistan as Network Engineer. He also worked as lecturer at department of computer science, university of Peshawar, Peshawar Pakistan. He is currently working toward his MS in Computer Engineering at the Chonbuk National University, South Korea. His research interests include wireless sensor networks, and communication networks for next generation wind power farms.

Young-Chon Kim: He received the B.S., M.S., and Ph.D. degrees from Korea University, Seoul, South Korea, in 1980, 1982, and 1987, respectively. He joined the Department of Computer Engineering at Chonbuk National University, Jeonju, South Korea, in 1986 and is now a Professor in the School of Information Technology at Chonbuk National University. From 1989 to 1990, he was a post-doctorate fellow at the University of California, Irvine. Also, from 1998 to 2000, he worked as a visiting researcher at the Network Research laboratory at the University of California, Davis. He was awarded Best Professor from the College of Engineering, Chonbuk National University, in 2002. He was also awarded the Motorola Academic Excellence award in 2003. His research interests include high-speed optical communication networks, next generation IP networks, and broadband wireless communication networks.

A Practical RFID Grouping Authentication Protocol in Multiple-Tag Arrangement with Adequate Security Assurance

Jian Shen* ** *** ****, Haowen Tan****, Yongjun Ren****, Qi Liu****, Baowei Wang****
*Jiangsu Engineering Center of Network Monitoring, Nanjing University of Information Science & Technology, China
**Jiangsu Technology & Engineering Center of Meteorological Sensor Network, Nanjing University of Information Science & Technology, China
*** Jiangsu Collaborative Innovation Center on Atmospheric Environment and Equipment Technology, Nanjing University of Information Science & Technology, China
**** School of Computer & Software, Nanjing University of Information Science & Technology, China
s_shenjian@126.com, tan_halloween@foxmail.com, renyj100@126.com, qrankl@163.com, wbw.first@163.com

***Abstract*—Radio Frequency Identification (RFID) is considered to be an authentication technology of great potential. Due to the bright future of low-cost RFID tags in practical situations, the authentication towards multiple tags and tag groups has become the research hotspot. However, there are many concerns about the security risks and privacy issues in lightweight RFID authentication scenarios. Many researches achievements have been made focusing on the existence of single tag in one object, while the arrangement that multiple tags attached to one object is out of consideration. In this paper, we propose a practical RFID grouping authentication protocol in multiple-tag arrangement with adequate security assurance. In our assumption, one object to be authenticated is attached with a group of RFID tags. The feedback towards various cases of the RFID tags is timely provided, which is necessary in practical situations. Additionally, the probable position and status of the object can be ascertained with a number of tags combined with the object. Moreover, the protocol is proved to offer enough security assurances and have resistance to various attacks under the security analysis. The regular operation of RFID system will not be severely damaged by the incidents occurred during the authentication process.**

***Keywords*—RFID, lightweight, grouping authentication, multiple tag, security.**

I. INTRODUCTION

RFID technology does not require line-of-sight contact in the communication process, which is superior to the barcodes. The basic structure of RFID system is composed of three parts: the reader, the BPS and the RFID tags. The reader can contact with more than one RFID tags and acquires related information from the tags. Consequently, the evidence that one or more RFID tags are verified at the same time is generated after several communication passes. Note here that the RFID tag cannot directly contact with the BPS. Instead, the reader performs as the bridge between the tag and the BPS. As a result, the reader is assumed to have enough computation power and storage. As a matter of fact, the communication channel between the reader and the tag is not secure. The transmitted information is vulnerable to eavesdropping as well as other kinds of attacks. For example, the RFID tag releases radio signals to the reader through the wireless channel. Thus the location of the RFID tag can be acquired by the malicious reader from eavesdropping only with small expenses. The tracing towards the tag can be possible in this occasion.

The BPS, regarded as the database containing important information, also plays the role of verifier which decides the validity of the generated evidence received from the reader. Thus the BPS is considered to be trustworthy and reliable during the entire authentication procedure. Actually the BPS is assumed to have full authority of the entire RFID system.

The RFID tag, which can be divided into three varieties: active tag, passive tag and semi-passive tag, is the most concerned RFID device that is vulnerable to security risks. Thanks to the recent technology development, the cost of RFID tags

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J. Shen (corresponding author, phone: 86-25-5873-1400, fax: 86-25-5873-1323, e-mail: s_shenjian@126.com) is with Jiangsu Engineering Center of Network Monitoring, Jiangsu Technology & Engineering Center of Meteorological Sensor Network, Jiangsu Collaborative Innovation Center on Atmospheric Environment and Equipment Technology, School of Computer & Software, Nanjing University of Information Science & Technology, Nanjing, 210044, China.

H. Tan is with School of Computer & Software, Nanjing University of Information Science & Technology, Nanjing, 210044, China, phone: 86-151-5181-3390, fax: 86-25-5873-1323, e-mail: tan_halloween@foxmail.com.

Y. Ren is with School of Computer & Software, Nanjing University of Information Science & Technology, Nanjing, 210044, China, phone: 86-187-6187-0612, fax: 86-25-5873-1323, e-mail: renyj100@126.com.

Q. Liu is with School of Computer & Software, Nanjing University of Information Science & Technology, Nanjing, 210044, China, phone: 86-185-5171-9567, fax: 86-25-5873-1323, e-mail: qrankl@163.com.

B. Wang is with School of Computer & Software, Nanjing University of Information Science & Technology, Nanjing, 210044, China, phone: 86-139-1292-6757, fax: 86-25-5873-1323, e-mail: wbw.first@163.com.

has been dropped to a relatively low level. At the same time, these low-cost tags have large probability to suffer from security attack and privacy leakage due to resource limitation in terms of computation, communication and memory. We assure that these security and privacy problems can be solved by adopting impeccable authentication protocols and secure strategies. Note here that the RFID tag referred in this paper is low-cost passive tag which gets power from the interaction with the reader.

As a matter of fact, many RFID authentication schemes have been presented in order to improve the security level and guarantee the regular operations of the RFID system. The researches focusing on grouping authentication of multiple tags and tag groups have become the primary tendency in RFID authentication field, while the security problems along with the privacy leakages remain barriers of practical use [1], [2].

As assumed in most of the protocols devoted to grouping authentication, single RFID tag is attached on one object. However, in the situation that the object is of big size, the RFID tag on a part of the object may not be within the communication range. Consequently, the object with other parts of it staying in the communication range cannot be identified. In other words, the detection probability of the object with single tag is not large in practical situations. The BPS cannot ascertain whether all parts of the object with large size is precisely in the supposed position so that the controlling power of the entire RFID system towards the objects is not adequate [3], [4], [5].

To meet the practical requirements, one object can be attached with multiple RFID tags in different parts. In this assumption, if all the tags on the object are identified, it is obvious that the object is well arranged in the right position. Note that the RFID tags on the object guarantee the integration of the object and increase the detection probability as well [6], [7], [8]. Even in the harsh situations where some tags on the same object may be compromised or missed, the RFID system can still identify the existence of the object with the rest of the tags. On the other hand, the precise location of the object can be arranged by identifying the tags, which indicates the new attempt for locating on low-cost RFID tags.

In this paper we propose a practical RFID grouping authentication protocol in multiple-tag arrangement with adequate security assurance. In our assumption, all the tags on one object are considered as one tag group. The BPS takes control of behaviors of all these tags and reader. The object can be placed in the accurate spot with small deviation according to our design, which is practical and creative in real applications.

This paper is organized as follows. In the following section, the related original protocols about grouping authentication are presented in brief. The detailed scheme of the proposed protocol is shown in Section III. Next is the security analysis of the protocol in Section IV. Then we conclude all this paper in Section V.

II. Related Work

Many RFID grouping authentication protocols have been presented with the purpose of offering enough secure requirements and preventing possible attacks to the RFID system. J. Saito and K. Sakurai [9] proposed the original grouping proof using time stamp in order to alleviate the weakness of the protocol presented by Ari Juels [10], [11]. Generally speaking, it is the relatively earlier protocol in multiple tags authentication. In this protocol, the reader derives the time stamp from database and submits it to all the RFID tags. The tags of the protocol are divided into two parts: the ordinary product tags and pallet tag. However, the entire RFID system in this protocol does not provide enough resistance to replay attack.

The chaining proof protocol is proposed in 2007 [12]. The main idea of this protocol is to combine all the tags intended to be authenticated together and form a chain with purpose of integrity preserving. However, the identities of the tags under authentication are transmitted in plaintext, which makes the tags vulnerable to illegal tracing. In addition, this protocol also depends on certain reading order of the tags, which is not convenient for practical situation.

Reading order independent grouping proof [13] is proposed in order to meet the practical requirements. In the assumption, the reader has enough computational power and the pallet tag can be merged into the reader. As a matter of fact, this protocol is applicable for special use in supply chain. The structures that the reader is bound to the pallet tag offers new research topic.

H. Liu *et al.* proposed grouping-proofs-based authentication protocol [14] for distributed RFID systems. In this protocol, all the tags are divided into several groups and are sequentially checked. This protocol provides strong protection on privacy and is resistant to various attacks. However, the checking sequence of the tags is required to be arranged in advance.

A RFID authentication protocol for multiple tag arrangement [15] is proposed by S. Dhal and I. S. Gupta in 2014. In the assumption multiple numbers of RFID tags are attached in one object in order to increase the detection probability. Based on it, we propose our grouping authentication protocol in this paper, which is relatively available in the practical situations.

III. Proposed Authentication Scheme

In this section we describe our RFID grouping authentication protocol which is available for the scenario that multiple tags are attached to one object with large size. Note that these tags in one object are classified into the same tag group. In our assumption, the sequence numbers of the tags in the group are delivered to the reader after mutual authentication with each other. We would like to emphasize that the real identifiers of the RFID tags are not used in our protocol, preventing the RFID system from tracing problem. The reader communicates with each tag according to their sequence number of the group and gathers all the secret information to generate the proof. The authentication process completes when all the tags in the group are verified successfully, which means that the tags are in the right position so that the object is safe and well arranged. In addition, unusual situations are under consideration [15], [16], [17]. For example, when some of the tags are broken or damaged, the reader can generate the proof containing other tags' secrets. Consequently, the BPS acquires the information

that some specific tags need to be repaired but the object remains safe, which is practical in real applications.

A. Problem Definition

We assume the occasion that a set of objects with large size need to be verified where each of the objects is attached with more than one RFID tags in its different parts. Note that the tags combined with the same object are considered as one tag group. The object is arranged to be successfully authenticated after all the tags of the tag group are fully verified, which guarantees that the object is precisely in the scheduled location. The proposed RFID authentication scheme should meet most of the security requirements without affecting its efficiency or increasing the cost. Moreover, the BPS should be available with the feedback of all the tags of the group. The disabled tag should be notified to the BPS for convenience of the facilities maintenance. Hence the invalid tag can be removed from the RFID authentication system in time.

B. Protocol Design

The protocol we propose in this paper is divided into four phases for better description. In the initialization phase, the RFID tags are initiated with group identifiers along with the sequence numbers as soon as being attached to the object. The number of the tags in the group g is assumed to be n. The reader acquires n tags' identities and combines them with the received random numbers from the BPS in the tag acquisition phase. The proof of group g is generated in the main authentication phase, which links the entire tag group. In the verification phase, the proof is delivered to the BPS. It is necessary to emphasize that the communication between the BPS and the reader and through secure channel, while that between the reader and the RFID tags are not safe and vulnerable to various attacks. The notations used in our proposed protocol are provided in Table I.

TABLE I
NOTATIONS

Notation	Description
BPS	Backend processing system
R_m	The m-th reader
g	The g-th tag group
T_i	The i-th tag of tag group g
n	Number of tags in tag group g
r_{R_m}	Pseudo-random number generated by the BPS
ID_{R_m}	Identifier of reader R_m
GID_g	Group identifier of tag group g
r_{T_i}	Pseudo-random number generated by the tag T_i
e_i	Sequence number of the tag T_i
S_g	Group secret of the tag group g
$r_{e_1}, ..., r_{e_i}, ..., r_{e_n}$	Pseudo-random numbers generated by the BPS
S_{T_i}	Secret of the tag T_i
Z_{GID_g}	Generated proof of the tag group g

1) Initialization Phase: In this phase, the initialization of the RFID tags is conducted. As we describe above, one object is assumed to be combined with several tags in order to ensure that this object is totally in the right position. The group information as well as the sequence number e_i is input in the memory of RFID tag. Note that the tag referred to here can be the reusable tag, which means that the RFID tag can be attached to another object after the authentication process is completed. In this assumption, the tag will be through the initialization phase again and equipped with new secrets.

2) Tag Acquisition Phase: In this phase, the tags responding to the reader are registered after verification. According to our design, it is not necessary for the RFID system to collect all the *n* tags. The RFID system allows authentication towards more than one tag. We assume there are *j* tags in group that are successfully registered. When in extreme situations, only one tag which passes the authentication of the RFID system can prove that the object is not missing. But whether the object is precisely in the right position remains a question.

The detailed steps of this phase are as follows:

- The BPS generates a pseudo-random number r_{R_m} for the reader R_m. Then the BPS chooses the tag group to be authenticated and delivers $(ID_{R_m}, GID_g, r_{R_m})$ to the reader R_m through secure channel.
- The reader R_m computes $M_g = (GID_g \oplus ID_{R_m}) + (S_g \vee r_{R_m})$ and broadcasts (ID_{R_m}, M_g, r_{R_m}) to all the tags.
- The tag T_i of group g checks the validity of the received M_g and generates its own pseudo-random number r_{T_i}. Then T_i computes $N_{T_i} = [M_g - (GID_g \oplus ID_{R_m})] \vee r_{T_i}$ and $Q_{T_i} = e_i \oplus (S_g \vee r_{T_i})$. Next the tag T_i responds $(N_{T_i}, Q_{T_i}, r_{T_i})$ to the reader R_m.
- After receiving the information form the tag, the reader R_m checks validity of the acquired N_{T_i} and derives e_i from Q_{T_i}. After all the n tags have been collected or the timer has timed out, the reader sends $(ID_{R_m}, GID_g, e_1, ..., e_j)$ to the BPS in the secure way.
- The BPS compares the received information with data in the database and replies to the reader with $(ID_{R_m}, GID_g, r_{e_1}, ..., r_{e_j})$, where $r_{e_1}, ..., r_{e_j}$ denote the pseudo-random numbers generated for each tag separately. The reader stores all this in its memory for the authentication in the next phase.

The brief description of this phase is shown in Fig. 1.

3) Main Authentication Phase: As the important section of the entire authentication process, this phase focuses on gathering the secrets of each tag and combining them following their sequence numbers e_i. Instead of using the tag's identifier, we compute $TempID_{T_i}$ as the temporary identifier during the communication between the reader and the tags, which shows enough resistance to the tracing problem towards the RFID tags. In the authentication process, the reader will not terminate the authentication process when the requested tag does not give the respond. Instead, the reader will skip to the next tag after the timer times up. The entire RFID system will not be interfered by abnormal tags or tag groups, which makes it more efficient.

The detailed steps of this phase are as follows:

- The reader R_m computes $r'_{T_1} = r_{T_1} \oplus r_{e_1}$ and $TempID_{T_1} = (GID_g \oplus e_1) \vee (r'_{T_1} \oplus ID_{R_m})$ and delivers $(Q_{T_1}, TempID_{T_1}, First, r_{e_1})$ to the first tag in group g.
- The first tag T_1 checks the validity of the received $TempID_{T_1}$ from the reader and computes $Z_{GID_g} =$

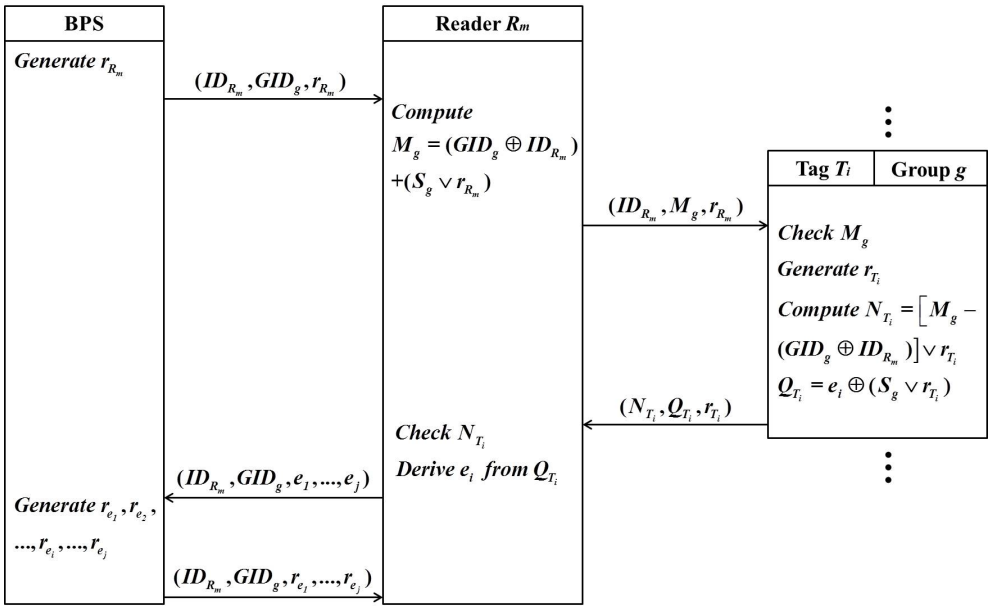

Fig. 1. Tag acquisition phase of the proposed protocol

$TempID_{T_1} \vee (r_{e_1} + S_{T_1})$ and $C_{T_1} = (e_1 \oplus r'_{T_1}) \vee N_{T_1}$. Then $(TempID_{T_1}, C_{T_1}, Z_{GIDg})$ is replied to the reader.

- The reader checks the validity of C_{T_1} and sends $(Q_{T_2}, TempID_{T_2}, Z_{GIDg}, r_{e_2})$ to the next tag of the group.
- The tag T_2 computes $Z_{GIDg} = [TempID_{T_2} \vee (r_{e_2} + S_{T_2})] \oplus Z_{GIDg}$ and $C_{T_2} = (e_2 \oplus r'_{T_2}) \vee N_{T_2}$. Note that Z_{GIDg} is generated with the value from the previous tag T_1.
- The process continues to operate in this way and finally the reader acquires private secret information of all the activated legal tags.

The brief description of this phase is shown in Fig. 2.

4) Verification Phase: In this phase, the reader sends the generated proof Z_{GIDg} as well as the sequence numbers of all the legal tags to the BPS through secure channel. When all the tags in group g pass the authentication, it is certain that the object is in the right place. However, if only some of the tags are successfully authenticated, we can still guarantee that the object is here, while it is not totally in the right place. In addition, the BPS can be aware of the identities of the disabled tags, which is convenient for facilities maintenance without checking all the tags.

The brief description of this phase is shown in Fig. 3.

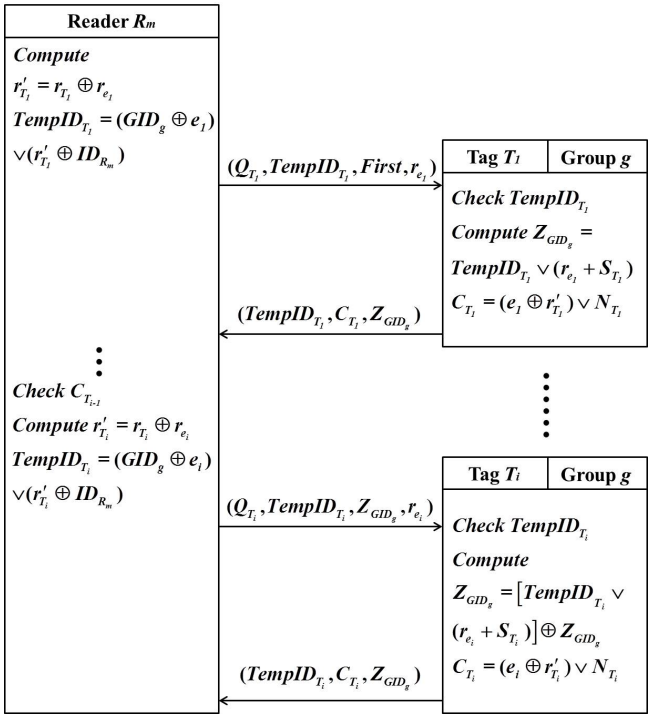

Fig. 2. Main authentication phase of the proposed protocol

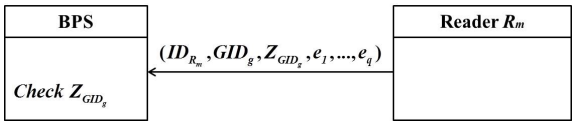

Fig. 3. Verification phase of the proposed protocol

IV. Security Analysis

In this section, we analyze the security properties of our protocol in order to prove that our protocol is reliable. The proposed protocol is resistant to various kinds of attacks. The RFID system has large potential in the practical situations because it is convenient for the system to deal with different kinds of occasions. Moreover, only simple computations are required for the RFID tag, which is appropriate for market promotion of low-cost passive tags. In addition, the key information of the tag is preserved in every communication session, showing strong privacy protection to the tags. In addition, the

proposed protocol is resistant to the tracing problem towards the specific RFID tags. The BPS takes control of all the authentication processes and can monitor the changes of the entire system, which improves the security and is available for practical use.

A. Replay Attack

In our protocol, the pseudo-random number generator is in use with the purpose of preventing the replay attack. As we describe above, in the tag acquisition phase, the random numbers r_{R_m} and r_{e_j} are all generated by the BPS and delivered to the reader through secure channel. In this situation, the BPS takes full control of the key generation. As for communication between the reader and the RFID tags, the tag itself generates the random number in the tag acquisition phase of every session. Thus the reuse of the previous messages cannot pass the verification of both the tag and the reader. As a result, the replay attack is prevented.

B. Eavesdropping

The malicious reader may try to get the secret information through eavesdropping during the communication process, which is the most common way for the adversary to damage the RFID system. In our scheme, the identifiers of the tags as well as the secret keys are all under encryption. We apply temporary identifier $TempID_{T_i}$ to the communication between the tag and reader so that it is not easy for the adversary to acquire key information of the specific tag through eavesdropping. The transmitted messages don't directly reveal the identifier of the tag so that the detected information is unreadable for the adversary. Moreover, the BPS takes control of the generation of all the random numbers. Consequently, these random numbers are necessary ingredients of the final generated proof, which ensures the variability. As a result, the entire RFID authentication system in our protocol is resistant to eavesdropping.

C. Physical Attack

In our design of this protocol, we assume that the adversary is able to destroy the tags physically and get all the secret information of the destroyed tag. The physical attack is always possible if the adversary can get access to the RFID tag physically. In this situation the detailed information stored in the memory of the tag is not safe anymore. The adversary can get full authority of the RFID tag and acquire the secret information. In RFID authentication field, physical attack is inevitable so that we have to take it into our security consideration. Our purpose is to ensure that the entire RFID system will not be compromised because of the acquired information from the tag. In some occasions, the adversary may even manage to clone the tag and use it to cheat the RFID system. However in our protocol, one object is attached with a group of RFID tags. The object can be authenticated with several disabled tags in the group. In order to interrupt the authentication process, the adversary has to damage all the tags in the group, which is difficult and worthless. As the important facility of the entire RFID system, the reader and the BPS are assumed to be well protected in safe place [1], [10], [18]. As a result, physical attacks towards the reader and the BPS are not taken into consideration in this paper. As a matter of fact, we attach significance to the security requirements of the RFID tag more than the reader and the BPS.

D. Man-In-The-Middle Attack

Our protocol is resistant to man-in-the-middle attack. As we describe above, in our protocol, the adversary cannot collect the *ID* or secret key of the tag. In the main authentication phase, we assume the situation that the message $(TempID_{T_i}, C_{T_i}, Z_{GID_g})$ sent by the RFID tag is blocked by the adversary. The adversary cannot get the real *ID* and sequence number of the RFID tag. The reader will skip to the next tag after the timer times out, and the object can still be recognized without the message of the blocked tag. In conclusion, the man-in-the-middle attack is prevented [15], [19], [20].

E. Tracing attack

In the RFID authentication area, tracing attack towards the RFID tag, especially the low-cost passive tag, remains big threat to both the RFID system and the users of the RFID tags. Tracing attack can be classified into two kinds: tracing attack during the session and tracing attack between two successful sessions. On the one hand, in order to prevent tracing attack during one session, the delivered messages between the reader and the tags are all under encryption. The use of temporary identifier provides strong protection through tracing during the session. On the other hand, with the use of random number r'_{T_i}, the temporary identifier of the tag is changed after every successful authentication session. Thus it is difficult for the adversary to trace the specific tag through the relevance between two successful authentication sessions. As a result, tracing attack between two successful sessions is still impossible.

F. De-Synchronization Attack

In the de-synchronization attack, an adversary disturbs the interactions between a tag and a reader by intercepting or blocking the messages. In our protocol, the real *ID* of the tag is not applied in the authentication process. Instead, temporary identifiers are used in our protocol and these identifiers are available for one session. As a result, it is not necessary for the low-cost RFID tags to update their secrets in every session. In addition, the RFID tags are relatively independent of each other. The privacy information stored in one tag is not relevant to that of the others. The compromising through single tag will not affect the entire group and the RFID system. In this occasion, if one or more tags are blocked for several times, the tags can also contact with the reader. In a word, the RFID tags in the group will not suffer from de-synchronization attack according to our design [15], [21], [22].

G. Forward Security

In our protocol, if the adversary obtains the secret information of the RFID tag in the present session, the secure information of the previous sessions will not be leaked to the adversary. The temporary identifier in every session is generated and valid only in the present session, which means that the secret information is not related to the previous session. The secret information as well as the identifier of the RFID tag will be initialized at the beginning of every authentication session. The adversary cannot acquire essential messages of the previous sessions from the compromised tag since the information is only used for one session. In a word, the forward security property is provided in the proposed protocol.

Comparison of security assurance: We have compared the proposed protocol with some existing RFID authentication protocols. The result of the comparison is given in Table II below. The possible attacks are specified using the symbols *a*, *b*, *c*, etc. The meanings of the symbols are written under the table.

TABLE II
COMPARISON RESULT

	a	*b*	*c*	*d*	*e*	*f*	*g*
Grouping proof [9]	*N*	*P*	*N*	*N*	*N*	*P*	*N*
Chaining proof protocol [12]	*Y*	*P*	*N*	*P*	*N*	*N*	*P*
GUPA [14]	*Y*	*Y*	*N*	*Y*	*Y*	*Y*	*P*
APCMA [15]	*Y*	*Y*	*N*	*Y*	*Y*	*Y*	*Y*
Our protocol	*Y*	*Y*	*Y*	*Y*	*Y*	*Y*	*Y*

a: Replay attack, *b:* Eavesdropping, *c:* Physical attack, *d:* Man-in-the-middle attack, *e:* Tracing attack, *f:* De-synchronization attack, *g:* Forward security, *Y:* Satisfy, *N:* Not satisfy,*P:* Partially satisfy

V. Conclusion

In the grouping authentication of RFID tags, the use of multiple tags in one object not only increases the detection probability, but also provides the chance for accurate positioning of the object, which satisfies the practical requirements. In this paper we propose a practical RFID grouping authentication protocol in multiple-tag arrangement with adequate security assurance. In our assumption, the entire authentication process is in the control of the BPS. The feedback towards various cases of the authentication process is also provided. Moreover, with multiple tags combined with the object, the accurate position of the object can be arranged. The RFID system in our protocol shows enough resistance to various attacks and security risks. We are working to improve our protocol in order to make it more efficient and practical in the future work.

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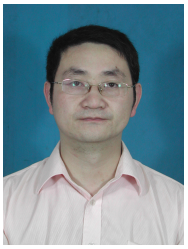
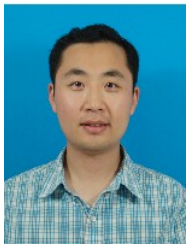
Jian Shen received the B.E. degree from Nanjing University of Information Science and Technology, Nanjing, China, in 2007 and the M.E. and Ph.D. degrees in Computer Science from Chosun University, Gwangju, Korea, in 2009 and 2012, respectively. Since late 2012, he has been a faculty member in the School of Computer and Software at Nanjing University of Information Science and Technology, Nanjing, China. His research interests include computer networking, security systems, mobile computing and networking, ad hoc networks and systems, and ubiquitous sensor.

Haowen Tan received the B.E. degree in 2013 and is currently working toward the M.E. degree at Nanjing University of Information Science and Technology, Nanjing, China. He focuses on the security and privacy issues in radio frequency identification. His research interests include authentication protocol design, security formal modeling and analysis.



Yongjun Ren obtained the PhD degree in the computer and science department at the NanJing University of Aeronautics and Astronautics, China, in 2008. Now he is serving as a full time faculty in the NanJing University of Information science and Technology. His research interests include network security and applied cryptography.



Qi Liu received his BSc degree in Computer Science and Technology from Zhuzhou Institute of Technology, China in 2003, and his MSc and PhD in Data Telecommunications and Networks from the University of Salford, UK in 2006 and 2010. His research interests include context awareness, data communication in MANET and WSN, and smart grid. His recent research work focuses on intelligent agriculture and meteorological observation systems based on WSN.

Baowei Wang received his B.S. and Ph.D. degrees in Computer Science from Hunan University in 2005 and 2011, respectively. He is currently working as a lecturer in School of Computer and Software, Nanjing University of Information Science and Technology. His research interests include steganography, wireless networks and securing ad hoc networks.

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Global IT Research Institute

1713 Obelisk, 216 Seohyunno, Bundang-gu, Sungnam Kyunggi-do, Republic of Korea 463-824

Business Licence Number : 220-82-07506, Contact: secretariat@icact.org Tel: +82-70-4146-4991