

RFID Infrastructure Management Based on Event Correlation Analysis

Ho Sung Lee, Se Won OH

Electronics and Telecommunications Research Institute, Korea

hosung.lee@etri.re.kr, sewonoh@etri.re.kr

Abstract— This research is about detecting operation failures or faults from RFID infrastructure and coping with them to recover its normal operation. While the traditional RFID systems have provided limited functions about monitoring its operation status, only a few have some capability to notify system alarm to its manager or user in order to request some manual recovery procedures. This research analyses the existing methods for monitoring RFID infrastructure, and then proposes a functional system for the failure management of RFID infrastructure, called RIM (RFID Infrastructure Management) which are able to diagnose RFID system status and to execute the recovery plan for coping with, if any, failure on the RFID system. RIM takes advantage of event correlation analysis to recognize the failure type from the several RFID system events information, and to find the root cause of the failure type which may consist of one or more RFID events. This research is expected to help to maintain RFID system readily and to manage its operation status autonomously.

Keywords— RFID, System Monitoring, Event Correlation, Failure Management, Root Cause, GLIS

I. INTRODUCTION

These days RFID (Radio Frequency Identification) is no more new term to everyday-life as well as to the industries. RFID technology has been applied to office access control, transportation fare, high-value products identification, logistics assets and library book management [1][2].

In general, as shown in Figure 1, RFID infrastructure consists of RFID devices (e.g. RFID reader and RFID tag), and RFID software modules (e.g. RFID middleware and data storage) [3]. Through the radio frequency communication, RFID reader reads or writes the data which are stored in a RFID tag memory [4]. The data collected from RFID reader are sent to RFID middleware for information processing such as filtering, grouping, and report formatting. Then, the processed data is stored to RFID database which provides query interface for the data exchange.

The industries and the end-users are demanding a way to manage these RFID infrastructure components remotely and reliably [5]. The traditional studies on RFID infrastructure monitoring have focused mainly on RFID reader characteristics [3], [6], [7], based on SNMP (Simple Network Management Protocol) and have not considered RFID software modules. Since RFID software modules are

important elements for deploying RFID application service, the scope of this research accommodates both RFID devices and RFID software modules for monitoring their status.

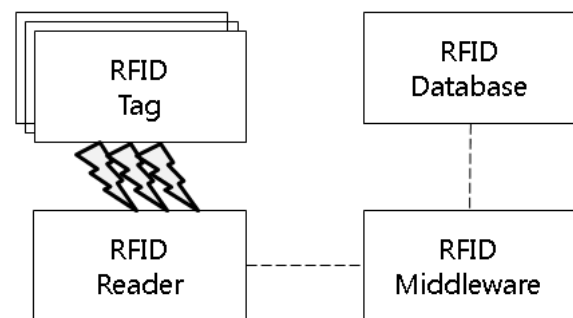


Figure 1. Components of RFID Infrastructure

As RFID technology supports automatic data capturing from things such as products and items, RFID infrastructure can handle large amount of data events in relatively short time [8], when compared to other identification techniques such as barcode. At the same time, RFID software modules have to communicate with RFID devices in order to control and manage, so lots of system information is generated from the RFID infrastructure. Thus, this research analyses the existing methods for monitoring RFID infrastructure, and specifies status attributes as well as meaningful events for signalling status change of RFID infrastructure. Then, we propose a system architecture, called RIM (RFID Infrastructure Management), which is for monitoring the status as well as the event information about RFID readers, RFID middleware, and RFID data storage.

This research further specifies a method for deciding operation status (e.g. either 'Normal' or 'Abnormal'), based on event correlation analysis. Furthermore, the proposed method recognizes the root cause among one or more failure events. In other words, RIM is able to detect operation failures or faults from RFID infrastructure and to cope with them to recover its normal operation.

The remainder of this paper is organized as follows: Section 2 introduces the related study for this research. Section 3 proposes the system architecture of RIM which accommodates RFID infrastructures and describes functions of RIM. Section 4 presents a method of how to recognize the

event pattern which includes one or more RFID events, and specify how to find its root cause. Finally, concluding remarks are provided in Section 5.

II. RELATED WORK

A. RFID System Management

There have been many researches on analysing the requirement for RFID system management [2], [8]-[10]. Also, as listed in Table 1, several international standard specifications about RFID system management have been published for the last decade, since the industries have requested interoperability among various types of RFID devices from a number of device vendors.

TABLE 1. RFID SYSTEM MANAGEMENT STANDARDS

Title	Organization (Year)
ISO/IEC 15961:2004 (Data protocol: application interface)	ISO/IEC JTC 1/SC 31 (2004)
RP (Reader Protocol) v1.1	EPCglobal (2006)
RM (Reader Management) v1.0.1	EPCglobal (2007)
LLRP (Low Level Reader Protocol) v1.0.1	EPCglobal (2007)
DCI (Discovery, Configuration, and Initialization) for Reader Operations v1.0	EPCglobal (2009)
ISO/IEC 24791-3 (Software system infrastructure – device management)	ISO/IEC JTC 1/SC 31 (under development)

Particularly, EPCglobal RM focuses on both status monitoring and alarm control of RFID reader device. DCI specifies initial configuration requirements between RFID reader and RFID software modules. ISO/IEC 24791-3 which embraces DCI, SNMP, and DPWS (Device Profile for Web Services) provides the following interface definitions for RFID device management.

- discovery of the RFID devices in the network
- management service with operation configuration
- monitoring service for reporting alerts, diagnostics, performance information

However, the interfaces and functions from all these documents are limited on setting RFID reader operation parameters and on simple monitoring on RFID reader attributes, while they have not considered either about correlation about the RFID events or about failure recovery in aspects of RFID infrastructure.

B. Researches on Event Correlation

There are many approaches for analysing the event correlation [11]-[14]. For instance, [11] suggested the conceptual model for describing causal and temporal relationships between network events in order to propose a general correlation model. In the meantime, [12] introduced alarm correlation analysis which is based on the model-based reasoning for intelligent network management and [13] suggested the event correlation matrix between problems and symptoms. Traditionally the following three types of

approaches have been used for finding correlation among a series of events.

1) Rule-Based Approach: The rule-based approach finds event correlations using a set of rules which should be defined in advance of event occurrences [15], [16]. And these rules are generated by experts in that domain. A rule based reasoning system is organized in three components shown in Figure 2.

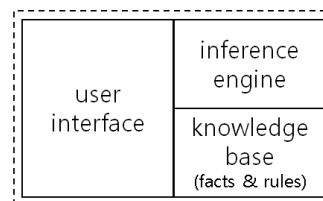


Figure 2. Components of Rule-based reasoning system

However, this approach has a major drawback when applying for the dynamic and flexible system environment, because the given rules necessarily rely on human knowledge.

2) Case-based Approach: The case-based approach solves new problems using the experience of the past cases. As shown in the Figure 3, when a new problem is entered, a case-based system retrieves the closet cases, reuses a solution to the new problem, revises the suggested solution and retains this experience [17].

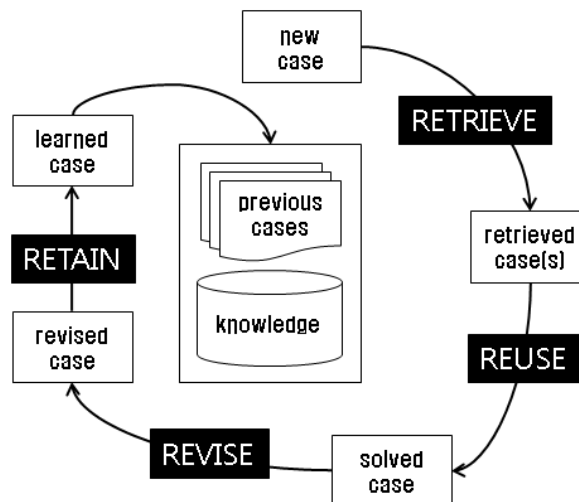


Figure 3. Case-based reasoning procedure

But, if there is no matching case for a problem, the problem cannot be solved.

3) Neural Network Approach: The neural network approach is an event correlation technique based on the artificial neural network [18]. This approach has a network of processing nodes called 'neuron's, which perform operations on the weighted inputs to generate an output [16]. That is, the neural network requires sufficient and valid information in advance of event analysis, since this approach needs a learning period.

Since each RFID application service has a different deployment environment with a various vendors of RFID infrastructure components, it takes time to have adequate number of rules or cases in advance. And RFID infrastructure may be re-organized dynamically, the given rule does not always match the real situation. In addition, the conventional approaches do not consider the characteristics of RFID infrastructure regarding both data flow and management flow among RFID infrastructure components. For instance, the events from RFID reader may influence the operation of RFID middleware, while the events from RFID database rarely influence the operation of RFID reader. Therefore, this research proposes a functional system which can provide the correlation analysis for RFID infrastructure events, by using the hierarchical topology information as well as timestamp of each event.

III. PROPOSED SYSTEM ARCHITECTURE

For the comprehensive system management for RFID infrastructure, it is important to reflect the characteristics of RFID infrastructure, as shown in Figure 2. For instance, a RFID middleware can be connected with one or more RFID readers. Also, a RFID database can be connected with one or more RFID middleware. Meantime, in RFID system environment, a series of events are correlated. For example, operation failure from RFID reader's antenna influences on the data collection operation of RFID middleware, since the RFID reader of which antenna is out of order is unable to communicate with any RFID tag.

While data from a RFID reader can flow to RFID database, as already described in Figure 1, all the event and status information should be notified directly or indirectly to a management module. In this research, RIM (RFID Infrastructure Management) is proposed for this purpose. So, through the correlation analysis with both the informed status attributes and events from RFID infrastructure, RIM can decide whether a specific RFID infrastructure component has a problem on its operation.

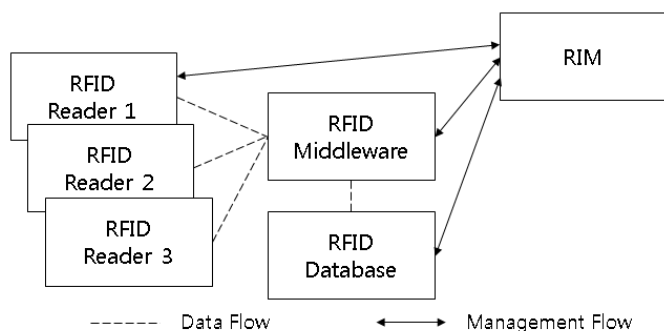


Figure 4. RFID Infrastructure with RIM

A. RFID System Information

As shown in Figure 4, each RFID infrastructure component can send its status information periodically or on request from RIM. And each one also have to notify RIM of either its status change or alarming event. Table 2 lists the major events from

RFID infrastructure, while Table 3 lists the common attributes to represent the status of each RFID infrastructure component.

TABLE 2. EVENT FROM RFID INFRASTRUCTURE

Category	Event	Description
RFID Reader	TagOperationEvent	Event from RFID tag access
	ReaderDeviceEvent	Operation status change
	IOPortEvent NetworkEvent AntennaEvent PowerSupplyEvent	Event from RFID Reader components
	DataManagementEvent - DataCollectionFault - DataProcessingFault - DataReportTransmissionFault	Event from Data Management Operation
RFID Middleware	MiddlewareOperationEvent	Operation status change
	NetworkEvent	Network Event
RFID Database	WebServiceIEvent	Event from
	RepositoryOperationEvent	RFID Database

TABLE 3. COMMON STATUS ATTRIBUTE

RFID Device Attribute	Description
OperationStatus	On/ Off/ Unknown/ Reserved
ProcessorUsage	Value of CPU in usage
MemoryUsage	Value of Memory in usage
NetworkStatus	Networking operation status
BatteryStatus	Value of Battery Supply

Additionally, RFID Reader may provide more information from the following attributes:

- I/O Port
- Antenna
- Radio Frequency Noise
- Forward Power Reflection

Also, RFID Middleware may provide more information from the following attributes:

- TagDataCollection
- DataProcessing
- DataReporting

B. RFID Event Correlation

Figure 5 describes a RFID infrastructure example which includes 2 RFID middleware(e.g. MW-1, MW-2), 2 RFID database(e.g. DB-1, DB-2), and m RFID readers(e.g. from RD-1 to RD-m).

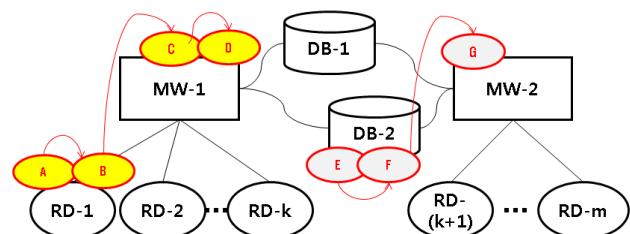


Figure 5. RFID Infrastructure Example to describe RFID Event Correlation

In this case, as listed in Table 4, RD-1 can generate event A and B, while MW-1 can generate event C and D. In the mean time, DB-1 can generate event E and F, while MW-2 can generate event G. While traditional RFID monitoring solutions are paying attention to catch only about RFID reader such as event A and event B, it is important to get all the system information from event A to event F, and further to detect that RD-1, MW-1, MW-2, and DB-2 may have problem to be resolved. Surely, one of the simplest way to cope with all the events is to check all the event one by one. However, this way requires much more time as well as cost than the way of analysing correlation among the events.

TABLE 4. SYSTEM INFORMATION EXAMPLE FROM RFID INFRASTRUCTURE

Status, Event	RFID infrastructure	Description
A	RD-1	Antenna is disconnected from RD-1
B	RD-1	RD-1 is now unable to collect data from RFID tags.
C	MW-1	MW-1 does not receive any data from RD-1 during a period of time.
D	MW-1	MW-1 cannot make a specific data report which is related with RD-1
E	DB-2	DB-1 has problem in its operation
F	DB-2	DB-1 is unable to provide reliable data retrieval service.
G	MW-2	MW-2 is unable to send data report to DB-2

In other words, through the event correlation analysis of RIM, all the events from the previous example can be classified as two failure types, such as {A, B, C, D} and {E, F, G}. Then the root causes, event <A> of RD-1 and <E> of DB-2, for each failure type can be detected from the correlation. That is, RIM plays a role of ‘event correlator’, as shown in Figure 6, and the both events <A> and <E> can be ascribed to the other events in RFID infrastructure. Therefore, by solving <A> and <E> first, not necessarily all the events, efficient system recovery can be executed. The detailed method of analysis is described in Section 4.

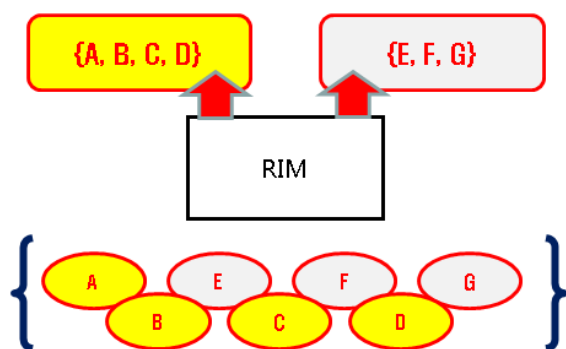


Figure 6. RIM proposes a method of RFID correlation analysis

C. Function Modules of RIM

Figure 7 shows the function modules of RIM. RIM is composed of the five modules including RFID System

Interface, Information Analyzer, Pattern Repository, Recovery Manager, and Recovery Planner.

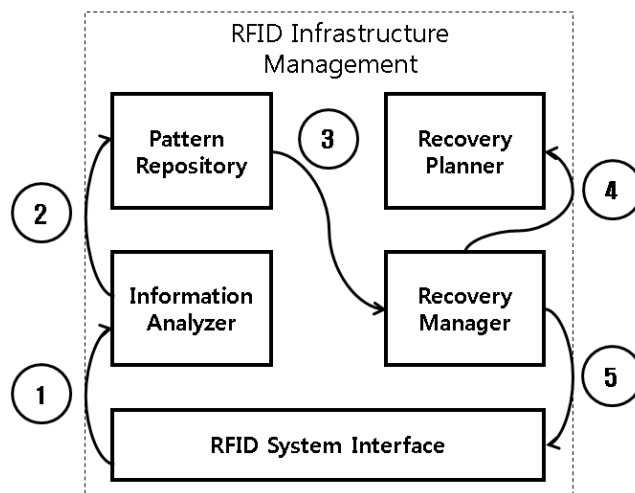


Figure 7. Function modules of RIM

As the first step, RFID System Interface receives both status and event message from RFID infrastructure, and let Information Analyzer know what kinds of system information have collected. RFID System Interface may produce alarm report after checking the change of values about RFID system status information. As the second step, Information Analyzer check if the system information received from RFID System Interface is the result of a system failure. At this same time Information Analyzer decides if a series of system events are correlated and ask Recovery Manager for executing relevant recovery procedure as the third step. Information Analyzer is able to query Pattern Repository if there is a registered pattern about the correlated system events. This pattern can signal what is the root cause among the correlated system events.

Recovery Manager, then, can execute recovery control in order to cope with system failure. Since there may be several recovery ways for each system failure, Recovery Manager can query Recovery Planner to look up an adequate recovery plan. as the fourth step. Finally, as the fifth step, Recovery Manager sends control request to RFID infrastructure via RFID System Interface.

IV. RFID EVENT CORRELATION ANALYSIS

This section specifies the detailed procedure for analysing RFID event correlation, with using the previous example of Table 4, Figure 5, and Figure 8.

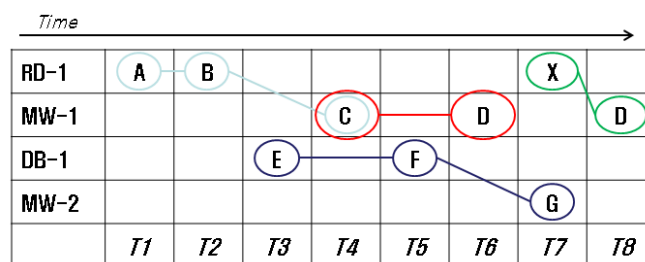


Figure 8. Example RFID events with timestamp

Due to the characteristics of the RFID Infrastructure, the event from RFID reader is followed by some event from RFID middleware. Also the most recent event from RFID reader is likely to have a relation with the event from RFID middleware. Thus, at the minimum, several rules to detect event pattern can be defined considering this conditions. Then, at the time T4 in Figure 8, RIM can check whether {A, B, C} matches any event pattern registered. At time T6, RIM can check {C, D}, as well RIM finds {X, D} at time T8. Through the pattern matching process with the defined pattern, three event pattern as well as its root cause can be represented as the following: {<A>, B, C}, {<C>, D}, and {<X>, D}.

In the meantime, RIM can elaborate its defined rules gradually with its recovery execution procedure. When RIM execute a control on RD-1 for coping with <A>, the potential root cause of event pattern {A, B, C}, there could be the three cases of recovery results, as shown in Figure 9. Case 1 shows event A and C are recovered, but not B. Likewise Case 2 shows all events are recovered, while Case 3 shows event B and C does not recovered. Then, these correlations can be represented with event correlation graph which will be updated the pattern matching mechanism.

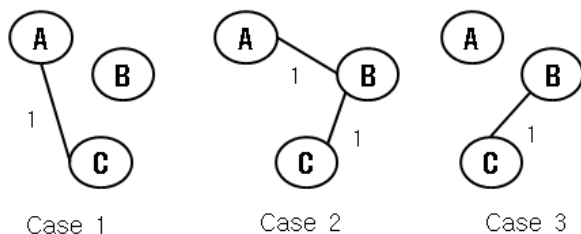


Figure 9. RFID event correlation graphs

Further, RIM can also reflect the other results, as shown in Figure 10. Following Case 2, if {<C>, D} results in success, then Case 4 can be represented, so {<A>, B, C, D} can be inferred afterwards. And, following Case 4, if {<X>, D} results in success, then Case 5 can be represented.

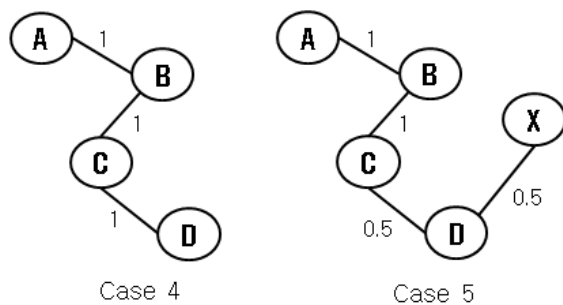


Figure 10. RFID event correlation graphs

V. CONCLUSIONS

The proposed system architecture, RIM, is expected to improve efficiency for managing RFID infrastructure against any system failure. This research uses event correlation analysis to recognize a failure type from a series of events from RFID infrastructure, in order to recover the 'normal'

operation. Thus, this research will help to minimize any confusion in coping with RFID system failure, and to promote RFID application service development.

Recently, RIM has been adopted as a core functional module in developing global logistics information synchronization service by LG Hitachi Consortium since last year [19]. As many RFID applications appears, RIM is expected to help the integrated control for the large-scale RFID infrastructure deployment and further make RFID service development efficient.

Autonomous RFID system management is still a challenging task to be done when RFID infrastructure changes dynamically and there are a number of RFID devices as well RFID software modules. Moreover, event correlation techniques have evolved continuously, there should be more efforts for enhancing the performance of RIM and for elaborating the event correlation analysis for RIM.

ACKNOWLEDGMENT

This work was supported by the Ministry of Knowledge Economy (MKE) of the Republic of Korea. [100035448, Development of Global Logistics Information Synchronization Technology for QoS]

REFERENCES

- [1] B. Nath, F. Reynolds, and R. Want, "RFID Technology and Applications," *Pervasive Computing, IEEE*, vol.5, no.1, pp. 22- 24, Jan.-March 2006
- [2] Q. Z. Sheng, X. Li, and S. Zeadally, "Enabling next-generation RFID applications: Solutions and challenges," *Computer*, vol. 41, pp. 21-28, Sept. 2008.
- [3] P. Krishna and D. Husak, "RFID Infrastructure," *Communications Magazine, IEEE*, vol.45, no.9, pp.4-10, September 2007.
- [4] K. Finkenzeller, *RFID handbook: fundamentals and applications in contactless smart cards and identification*, 2nd ed., R. Waddington, Ed. West Sussex, England: John Wiley & Sons Ltd, 2003.
- [5] H. Chen, P.B. Chou, S. Duri, J.G. Elliott, J.M. Reason, and D.C. Wong, "A model-driven approach to RFID application programming and infrastructure management," *e-Business Engineering, 2005. ICEBE 2005.*, pp.256-259, Oct. 2005.
- [6] *Reader Management (RM) Standard v1.0.1*, EPCglobal RM, 2007.
- [7] *Discovery, Configuration, and Initialization (DCI) for Reader Operations v1.0*, EPCglobal DCI, 2009.
- [8] C. Floerkemeier and M. Lampe, "RFID middleware design: addressing application requirements and RFID constraints," *Proc. Joint sOc-EUSAI conference*, p. 219, 2005.
- [9] S. Oh, Y. Kim, and Y. Lee, "RFID-based Middleware System for Providing Ubiquitous Information Service," *IPSIJ SIG Technical Reports*, vol. 2005, pp. 461-466, 2005.
- [10] Se Won Oh; Hyochan Bang; Jae Gak Hwang; , "Light-weight RFID device interface for controlling RFID tag memory access," *The 12th International Conference on Advanced Communication Technology (ICACT) 2010*, vol.2, pp.1516-1521, Feb. 2010.
- [11] M. Hasan, B. Sugla and R. Viswanathan, "A Conceptual Framework for Network Management Event Correlation and Filtering Systems", *Proc. 6th IFIP/IEEE International Symposium on Integrated Network Management (IM 1999)*, Boston, MA, USA, pp. 233-246, May 1999.
- [12] G. Jakobson and M. Weissman, "Alarm Correlation", *IEEE Network*, Vol. 7, No. 6, pp. 52-59, November 1993.
- [13] S. Klinger, S. Yemini, Y. Yemini, D. Ohsie and S. Stolfo, "A Coding Approach to Event Correlation", in *Proc. 4th IEEE/IFIP International Symposium on Integrated Network Management (ISINM 1995)*, Santa Barbara, CA, USA, pp. 266-277, May 1995.
- [14] J.P. Martin-Flatin, G. Jakobson and L. Lewis, "Event Correlation in Integrated Management: Lessons Learned and Outlook", *Journal of Network and Systems Management*, Vol. 17, No. 4, December 2007.

- [15] Gardner, R.D., Harle, D.A., "Methods and Systems for Alarm Correlation", *Global Telecommunications Conference, 1996. GLOBECOM '96.*, vol.1, pp.136 - 140, 1996.
- [16] Andreas Muller, "Event Correlation Engine", Swiss Federal Institute of Technology Zurich, Department of Information Technology and Electrical Engineering, Master's Thesis, 2009.
- [17] Dae Sun Kim, Shinbo, H., Yokota, H., "An alarm correlation algorithm for network management based on root cause analysis", *The 13th International Conference on Advanced Communication Technology (ICTACT) 2011*, pp. 1233 - 1238, 2011.
- [18] Michael Tiffany, "A Survey of Event Correlation Techniques, and Related Topics", <http://www.tiffman.net/netman/netman.pdf>, 2002.
- [19] (2011) GLIS Consortium, [Online]. Available: <http://glis.re.kr/>