Situation Aware RFID system: Evaluating abnormal behavior detecting approach

Heeseo Chae, Taek Lee, and Hoh Peter In†
Dept. of Computer Science & Engineering, Korea University,
Sungbuk-ku, Seoul, 136-701, Korea
{royalhs, comtaek, hoh_in}@korea.ac.kr

Abstract

SA-RFID system is a combination of Situation-Aware computing which is important and core field of Ubiquitous computing, and RFID system. The goal of this paper is to define a system that is suitable for detecting abnormal behaviors like a crime and an accident in a certain limited area. Our abnormal behaviors detecting system is designed by the architecture of transformational SA-RFID reader system and SA middleware specialized in it. In order to improve the reliability of the system, this paper offers abnormal behavior judging models and explains operation mechanism. We also integrate these models and present the prototype of the proposed system. It shows possibility of various expansions. Consequently, the contributions of this paper are as follow: defining the various models and evaluating it using SA-RFID system and providing a user-customized system in ubiquitous environment.

1. Introduction

The goal of ubiquitous computing environments is to integrate the pervasive systems so as to optimize them with their surrounding circumstances, and provide user-customized service. The most promising one of the existing research issues related to ubiquitous computing is Situation-Awareness. It plays a role to analyze and understand the relation between actions and multi-contexts in the user viewpoint [1]. Systems implementing ubiquitous environments don't work following their time-dependent processes, but following the situations come from the environments where the systems work. In other words, systems work according to the very situation derived from time, location, and user. Such a Situation-Aware system provides most optimized service for users with integrating and inferring a lot of situation information from numerous resources [5].

Among the emerging ubiquitous technologies, Radio Frequency Identification (RFID) supports a remote monitoring and its transaction by accessing some of information stored in a tag without any touching of human. These RFID systems are now being used in traffic, electronic currency, and Supply Chain Management field [4]. In the recent time, with the standardization trend of its technology, the existing RFID technologies were standardized so that RFID technology is now emerging as a fundamental infrastructure in ubiquitous environments with supporting recognition coverage extension and tag problems in economic and technologic perspectives.

This paper aims at integrating the general RFID system with the concept of Situation-Aware Computing, and ultimately, providing a user-customized secure service for users. For achieving such the purpose, this paper focuses on designing and implementing a limited detection system for detecting abnormal behaviors as a potential ubiquitous application.

This paper consists of six chapters. In the chapter 2, the definition, conceptual architecture, and four system approaches of SA-RFID are presented, and then the components of an abnormal behavior detecting system and the detail architecture of SA-middleware used by the detection system will be described in the chapter 3. In the chapter 4, four detection models are presented in detail and their evaluation for checking model dependability are presented. Finally, the potential usability of the proposed system is discussed with its evaluation and comparison in the chapter 5 and 6, including conclusion and future work.

2. Situation-Aware RFID system

2.1 Definition of SA-RFID system

SA-RFID system synthesizes a situation from tag information and circumstances so as to improve the

† Hoh Peter In is the corresponding author.

Proceedings of the Fourth IEEE Workshop on Software Technologies for Future Embedded and Ubiquitous Systems and Second International Workshop on Collaborative Computing, Integration, and Assurance (SEUS-WCCIA'06)
0-7695-2560-1/06 $20.00 © 2006 IEEE

system efficiency. In the contrast of an existing Situation-Aware system depending on traditional sensors and their network, our proposed system gathers information originally from RFID tags which are already popular in practical usage in the recent time, which makes our proposed system more utilizable and practical. So, it can improve the practicality of RFID system with applying situation-aware concept and then extending situation-inference capability beyond only identifying tags, which overcomes the conventional mechanism of legacy RFID system gathering and processing tags by a central server system.

2.2 Architecture concept of SA-RFID system

The following figure 1 is the architecture concept of SA-RFID system [1].

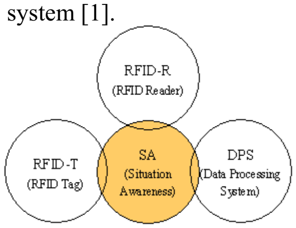

Figure 1. Architecture concept of SA-RFID system

In figure 1, the RFID-T (RFID tag) means general RFID tags and it plays a role of storing identification information. RFID-R (RFID reader) reads and interprets the information from RFID tags, and Data Processing System (DPS) processes and utilizes the information gathered by the RFID-R. SA core has the information related to usage-policy and determines a proper action after interpreting the situation information passed.

- In order to develop such as RFID system supporting Situation-Awareness concept, the following functions are required.
- A function to gather situation information from tags
- Pre-defined Situation-Aware Interface Definition Language (SA-IDL) applying SA technology, and its usage-policy
- Inferring function to reason and determine valid system action from tag information gathered.

Basically, the functions above are all of components consisting of SA-RFID system, and the abnormal behavior detecting system proposed by this paper takes advantage of them, providing a practical ubiquitous application environments.

2.3 Classification of SA-RFID system architecture

The conceptual architecture of SA-RFID system can be classified as follows. Four different types of SA-RFID system architecture can exist in the importance viewpoint of each component. Whereas, it is the notable point that the SA-RFID system previously achieved by us includes not only RFID system but also sensors.

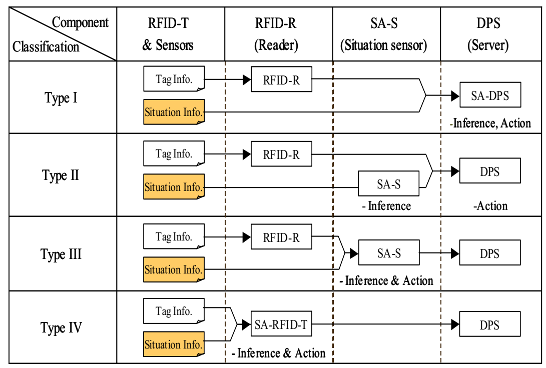

Figure 2. SA-RFID system architecture classification [7]

- Type I : it means SA-DPS(Data Processing Server) based RFID architecture system. In Type I, the traditional DPS part and SA core are combined into a component, SA-DPS, so that it processes wholly the tag information coming from RFID reader and the situation information gathered.
- TYPE II : Sensors and SA core are combined into one component. Particularly sensors gather the information and send it to DPS after finishing its situation inference. Tag information is separately processed in DPS.
- TYPE III : SA-Sensor plays a role of gathering simultaneously sensor information and tag information and passing the inferred situation information to DPS. In this case, even though sensor has high privilege, overhead is a problem.
- TYPE IV : Like a traditional RFID system architecture, this type means a case of extending RFID reader's function. In other words, in this architecture type, RFID reader functions not only basic tag identification but also capability in which it gathers, analyze, and reason on situation information from sensors all around.

Among the four types of SA-RFID system, the concept of TYPE IV will be applied to our proposed abnormal behavior detecting system. This paper took advantage of the type of architecture and presents a detection model with a scenario.

3. Abnormal behavior detecting system

SA-RFID based abnormal behavior detecting system plays a role of predicting a kind of crimes and accidents in limited location, and the system aims at preventing and responding quickly such as mishaps in advance. In order to develop such the system, some of assumptions are required as follows

Table 1. Assumptions of abnormal behavior detecting system

Assumptions	Contents
scope	Limited public space (e.g. subway and theater)
user	Entrance into the limited space means an implicative agreement willing to use the service (user's location and tag information)
RFID-T	They are installed in several places of public space having a certain gap
RFID-R	Small reader which can be equipped into mobile device
DPS	They exist in every limited public space

3.1 System architecture

The architecture among SA-RFID system architectures [1] which is applied to abnormal behavior detecting system, has a kind of capability enhancing SA-RFID reader system extended from the concept of a traditional RFID system. Therefore, the proposed system has not only advantages in terms of remodeling and utilizing, but also an advantage of low system complexity. In addition, because RFID tag identifying and situation information processing of a mobile device are conducted just by one component, the system has consistency in terms of channel using.

Nevertheless, this architecture has an overhead disadvantage when comparing with other architectures because of the telecommunication between RFID reader and DPS and additional functions for gathering the information from tag and mobile device.

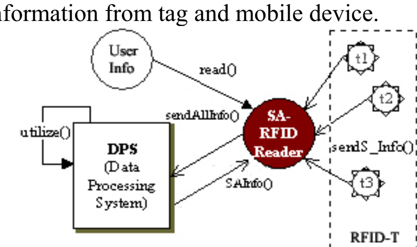

Figure 3. Redesigned architecture of SA-RFID system

Situation-Aware Middleware [2], which is a core of abnormal behavior detecting system, is remodeled and then embedded in a small mobile RFID reader.

As the figure 4, SA middleware consists of four parts. SA DB stores circumstance situation information. Resource Manager processes a variety of data and resources. SA-IDL pico-compiler converts the processed data into SA-IDL format understandable to SA manager which plays a role of customizing and providing a user service

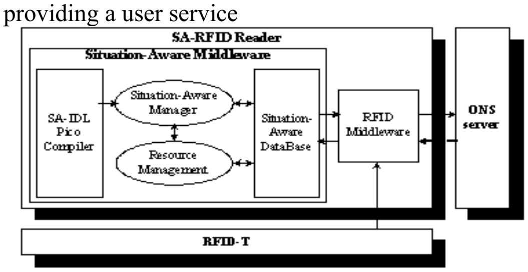

Figure 4. The detail architecture of SA middleware

3.2 Model of Abnormal behavior detecting system

Operation mechanism of abnormal behavior detecting system Using SA-RFID is as follows.

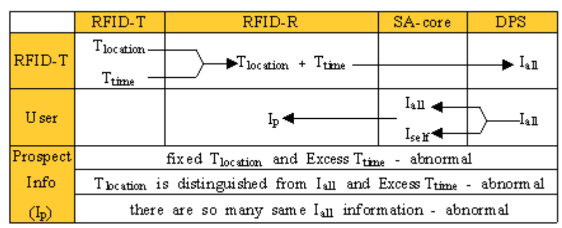

Figure 5. Scenario of abnormal behavior detecting system

Information of user's location is collected from RFID-T and at that moment also information of current time is collected, then this situation information is transmitted to DPS (Data Processing System) in allotted area from RFID-R. DPS receives information from user in Limited location then it transmits the encrypted information which is composed of user's location report in time sequence to RFID-R again. In this process, DPS sends I_{all} to RFID-R and SA Middleware which is the internal parts of RFID-R compares I_{all} with self-information and judges the current situation. Hence, it offers I_p, a final product, to user. User is ensured security in limited place like public area through the abnormal behavior detecting information which is proposed by I_p.

Estimating basis about I_p which is a final product will be expanded by the continuous study but current research suggests following models [3].

- **T_{time}::$T_{location}$** ： T_{time} exceeded the limited time boundary In fixed $T_{location}$
  - Regarding to being in a space during the abnormal time.
  - Determining as an abnormal behavior.
- **$T_{location}$::I_{all}::T_{time}** ： $T_{location}$ is contrasted with I_{all} and T_{time} exceeded a limited time boundary
  - Regarding to being in a by-corner space during the abnormal time
  - Determining as an abnormal behavior.
- **$I_{all}(k)$::$I_{all}(k+1)$** ： Situation information represented by $T_{location}$ and T_{time} is considerably equal to I_{all} information
  - Regarding as crowd to being in a space.
  - Determining as an abnormal behavior.

4. Models for detecting abnormal behavior

Parameters composing our proposed models are as follows.

Table 2. Parameters of abnormal behavior detecting system

Parameter	Description
$T_{location}$	Location information from RFID Tag
T_{time}	the current time when reading tag information
I_{all}	Location and time information of people who are same place. ($T_{location}$, T_{time})
I_p	Information of the outbreak alarm about abnormal behavior in current situation. ($T_{location}$, T_{time})
I_{self}	User's current Situation information. ($T_{location}$, T_{time})
T_{time_sa}	The limited time of SA-core which is criterion of judgment
SA_n	The limited person number of SA-core which is criterion of judgment

Procedures composing our proposed models and operating our system through these parameters are as follows.

Table 3. Procedures of abnormal behavior detecting system

Procedure	Description
read_location()	Reading location information of RFID-T
getTag_time()	Recording the current time when reading tag information
send_SAInfo()	Transmitting various situation information to DPS
send_Allinfo()	Transmitting all people's situation information to user (encryption)
judgment()	Inferring Situation through SA middleware and producing Ip

These parameters and procedures organize proposed system model and aid recognizing detail model framework and detection probability.

4.1 T_{time}::$T_{location}$ Model

T_{time}::$T_{location}$ model is initiated with reading the RFID-T by read_loaction(), and then RFID-R receives $T_{location}$ information. The time when reading $T_{location}$ is checked by getTag_time() and it is T_{time}. These time and location information are gathered other situation information, then this information unit is sent to DPS from RFID-R by send_SAInfo(). DPS organizes the transmitted information from each user, then sends the encrypted all user's situation information to each user again by send_Allinfo(). The characteristics and detection rate of the model is decided by how to handle the accumulated situation information on the connected process at a certain stage.

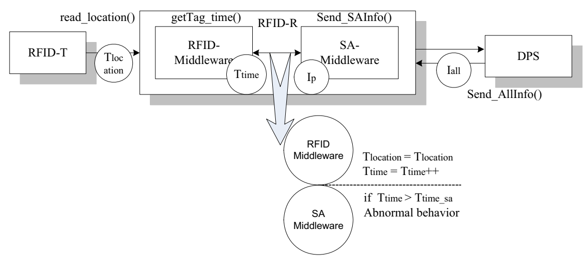

Figure 6. T_{time}::$T_{location}$ model

T_{time} by getTag_time() increases with the passage of time but $T_{location}$ by read_location() is not changed, then this model regard current situation as abnormal situation and inform a warning. At that moment The limited time which is criterion of judgment, is T_{time_sa} in SA-database that is the internal parts of SA-middelware(SA-core). If the model informs a warning but the current situation is judged normal situation, the model updates the SA-database. On the other hand, the model informs a warning and it is judged abnormal situation, then the model recognizes success of detection and maintain the SA-database.

$$T_{location} = T_{location}, \quad T_{time} = T_{time}++ \qquad (E1)$$
$$\text{If } T_{time} > T_{time\_sa} \qquad \text{abnormal}$$

Consequently, Detection probability is analogized by update frequency of SA-database and it is aid to evaluate the system.

4.2 $T_{location}$::I_{all}::T_{time} Model

Initiation of T_{time}::$T_{location}$ model is not different from T_{time}::$T_{location}$ model. The connected process, Information exchange among components, is advanced

Proceedings of the Fourth IEEE Workshop on Software Technologies for Future Embedded and Ubiquitous Systems and Second International Workshop on Collaborative Computing, Integration, and Assurance (SEUS-WCCIA'06)
0-7695-2560-1/06 $20.00 © 2006 IEEE

and the change of T_{time} on the relationship between $T_{location}$ and I_{all} among accumulated situation information, decide the system operation.

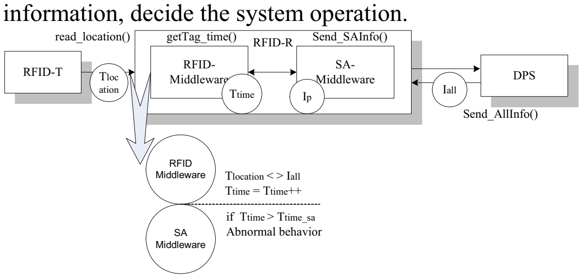

Figure 7. $T_{location}$::I_{all}::T_{time} model

$T_{location}$, which is not corresponding with I_{all} come from send_SAInfo(), is recognized, and when the T_{time} matching with the $T_{location}$ among situation information increases, the system regards the situation as abnormal case and then alerts. Like aforementioned model, T_{time} which is criterion of judgment, is T_{time_sa}.

$T_{location} <> I_{al}$ $T_{time} = T_{time}++$	*(E2)*
If $T_{time} > T_{time\_sa}$	*abnormal*

Success or failure of detecting abnormal behavior is concluded by update frequency of SA-database. It is the same as T_{time}::$T_{location}$ model.

4.3 $I_{all}(k)$::$I_{all}(k+1)$ model

Initiation of $I_{all}(k)$::$I_{all}(k+1)$ model is not also different from T_{time}::$T_{location}$ model. Coincidence Degree of I_{all} among accumulated situation Information, determined that the situation is abnormal case or not.

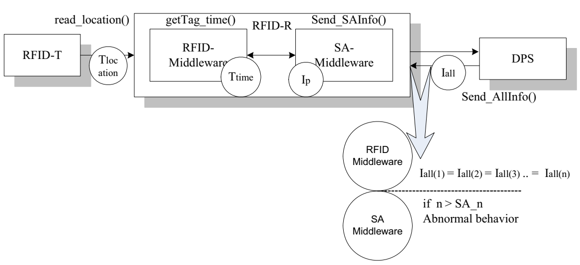

Figure 8. $I_{all}(k)$::$I_{all}(k+1)$ model

The collected User's I_{all} coming from send_SAInfo() in DPS is transmitted to SA-core by send_SAInfo(), at that time, the majority of I_{all} are expressed correspondence or similarity, and then this model regard current situation as abnormal case and inform a warning. Differently from other models, the criterion value of judgment is not T_{time} but SA_n which is correspondence or similarity number of I_{all} in SA-DB.

$I_{all}(1) = I_{all}(2) = I_{all}(3) .. = I_{all}(n)$	*(E3)*
If $n > SA\_n$	*abnormal*

Like other models, success or failure of detecting abnormal behavior is concluded by update frequency of SA-database but this model doesn't use Ttime_sa but SA_n.

4.4 Integration model for detecting abnormal behavior

For enhancing detection rate, the three models are simultaneously applied to abnormal behavior detecting system. In other words, T_{time}::$T_{location}$ model, $T_{location}$::I_{all}::T_{time} model, and $I_{all}(k)$::$I_{all}(k+1)$ model are synthetically used to detect abnormal behaviors.

Table 4. Coverage evaluation for integration model

	T_{time} ::$T_{location}$	$T_{location}$::I_{all} ::T_{time}	$I_{all}(k)$ ::$I_{all}(k+1)$	coverage
$T_{location}$	Fixed place	Distinguished place	Fixed place	H
T_{time}	Excess time	Excess time	Little interaction	H
I_{all}	Little interaction	Distinguished situation	Consistent situation	H
I_p	Situation result	Situation result	Situation result	L
I_{self}	Time primacy	Location primacy	Number primacy	H
T_{time_sa}	Standard	Standard	Little interaction	-
SA_n	Little interaction	Little interaction	Standard	-

For implementing abnormal behavior detecting system, each of abnormal behavior models has its own coverage at which the system can determine whether the observed case is in abnormal boundary or not. Table 4 presents the possibility of coverage extension when applying three models simultaneously. The approach of coverage extension makes the system more dependable in the aspect of detecting abnormal behaviors

5. Evaluation

In this chapter, the prototype of abnormal behavior detecting system is presented. It is evaluated in terms of detection rate at SA-DataBase update frequency as mentioned in the previous chapter. In addition, detection failure rate is checked by reader's performance when reading tag information and processing them.

5.1 Detection rate of the prototype

Proceedings of the Fourth IEEE Workshop on Software Technologies for Future Embedded and Ubiquitous Systems and Second International Workshop on Collaborative Computing, Integration, and Assurance (SEUS-WCCIA'06)
0-7695-2560-1/06 $20.00 © 2006 IEEE

The following figure 9 is the log of the abnormal behavior detecting system.

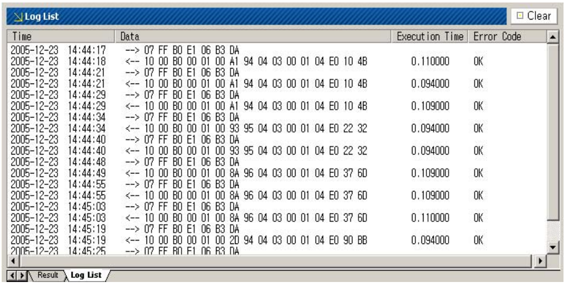

Figure 9. Log list of the prototype

According to the value from *read_location(),* $T_{location}$ of a unique tag is read and T_{time} is recorded by *getTag_time()*. If originally-constant execution time was increased, the internal SA-DB must be updated. In the prototype, even though the execution time is fixed to 0.094, it rises to 0.100 in the case that SA-DB needs to be updated. In the figure 9, the increase of execution time can be confirmed. Although SA-DB is often updated in the early system operation time, the frequency is decreased and maintained to a stable level eventually as the operation time flows. Thus, we can make sure the fact that the detection rate is increased in proportional to operation time.

5.2 Detection failure rate of the prototype system

The prototype of abnormal behavior detecting system looks like the figure 10.

Figure 10. Prototype system

The figure10 is for RFID-T and RFID-R consisting of the prototype. The windows are for count_form and login shown in administrator mode. The detection failure rate of the prototype is as follows.

Table 5. The number of detection failure errors of the prototype system

Number of Measurement	Average Reading Error
320	6

The detection failure rate is very small and the reason for the errors is a congestion problem between tags. In order to reduce error rate, sensitiveness calibration between RFID-R and RFID-T is necessary.

6. Conclusion

Based on Situation-Aware computing technology and RFID system popularly used in the recent time, this paper proposed an abnormal behavior detecting system designed on the fundamental technologies: SA-RFID reader based system architecture and as its core, SA middleware technology. For the purpose of detecting abnormal behaviors, three abnormal behavior models were presented and their evaluation was conducted with a prototype. Our proposed system can be easily utilized in practical cases because it uses the existing general RFID tags easy to access and has an advantage for no heavy redesigning work started from a traditional legacy system.

In the future, the extension and refinement of specification language and compiler for Situation-Aware computing are needed. Additionally, the study for inference engine update is needed in order to provide a quick and accurate response, and refining feedback for our abnormal behavior models are needed through continual system experiments and evaluation.

References

[1] D. Jeong, Y.-G. Kim, and H. P. In, "New RFID System Architectures Supporting Situation Awareness under Ubiquitous Environments," Science Publications, Journal of Computer Science, Vol. 1, No. 2 (2005) 114-120

[2] Dong-Hyun Lee, H. P. In, Situation-Aware Ubiquitous Entertainment" Korea Computer Conference, Vol. 32, 2005, No.1, P445-447

[3] Didier Aubert, "Passengers Queue Length Measurement", Image Analysis and Processing, 1999. International Conference on. 1999, 1132-1135

[4] K. Finkenzeller, "RFID Handbook: Radio-Frequency Identification Fundamentals and Applications," John Wiley & Sons, 2000.

[5] S. Yau, Y. Wang, and F. Karim " Situation-Awareness in Middleware for Environments," Proc. 26th Int'l Computer and Applications Conference (COMPSAC 2002), pp. 233-238.

[6] Dongwon Jeong, Heeseo Chae, and Hoh Peter "The Performance Estimation of the Situation Awareness RFID System from Ubiquitous Environment Scenario" International Conference EUC 2005, Nagasaki, Japan, December 6-9, 2005. Proceedings p. 987-995

[7] Rao, S, Sastry, P.S, "Abnormal activity detection in video sequences using learnt probability densities" TENCON 2003. Conference on Convergent Technologies for Asia-Pacific Region Volume 1, 15-17 Oct. 2003 Page(s):369 - 372 Vol.1

[8] Kojima, A, Tamura, T.Fukunaga, K. "Textual description of human activities by tracking head and hand motions" Pattern Recognition, 2002. Proceedings. 16th International Conference on Volume 2, 11-15 Aug. 2002 Page(s):1073 – 1077

Proceedings of the Fourth IEEE Workshop on Software Technologies for Future Embedded and Ubiquitous Systems and Second International Workshop on Collaborative Computing, Integration, and Assurance (SEUS-WCCIA'06)
0-7695-2560-1/06 $20.00 © 2006 IEEE