Study on CEP-Based BCEPS Model of RFID-Based RLTLUM System

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***Abstract*—RFID technology being applied for the field of tracking and locating application faces many challenges. In order to solve the problem, we design and construct a model of RFID-based tracking and locating system which is based on complex event processing, that is BCEPS model. BCEPS model consists of physical device layer, RFID data processing layer, event processing engine, application layer and data storage layer. BCEPS model filters the RFID data which is gathered in real time and then generates RFID events. At the same time, BCEPS model responses to the requirement coming from users and then generates user events. RFID and user events are sent to event processing engine and are processed. Finally, results are returned to users. To enhance the efficiency of processing massive events and the real-time performance of system, we first propose and design the real-time event scheduling algorithm for event processing engine. Finally, we verify BCEPS model by implementing RFID-based tracking and locating system in underground mine which uses the time-shifting tracking and locating algorithm which is designed by ourselves.**

***Index Terms*—RFID, complex event processing, BCEPS model system, PTSA event scheduling algorithm, TSTLA tracking and locating algorithm**

I. INTRODUCTION

At present, RFID technology has been applied for mobile commerce [1], pervasive computing [19]. For example, m-commerce based on NFC technology is the typical application which applies RFID to mobile business. RFID technology not only stores the information about objects, but also holds the promise of real-time identifying, locating and monitoring physical objects. Combined with information technology, RFID can provide location-based services which are fundamental and critical for context awareness service [20,21].

However, RFID used to track and locate objects faces the following challenges: 1) RFID reader could gather large quantity of primitive data that causes numerous primitive events. Primitive data may be duplicated and in conflict each other. So how to process conflicted data and filter duplicated data to avoid generating invalid or conflicted event is important to save storage spaces and improve performance of system; 2) because of the limitation of RFID reader's expression and logic complexity of applications, RFID reader only generate the primitive event that can not meet the real world requirement. However, applications require meaningful and actionable information. Thus, how to transform RFID data and generate complex event meeting the actual application requirement is important for functionality of system. 3) During the process of RFID readers gathering RFID tags, many kinds of events containing real-time and non real-time events will be generated. Scheduling events unreasonably and ineffectively will affect real time of BCEPS system. So, it is important for BCEPS system to schedule events reasonably and effectively.

It is proved that the newly complex event processing system contributes to reduce or solve the former two challenges discussed above. Some CEP systems such as SASE [2] have been designed for RFID information transformation. The third challenge can be solved by designing a real-time event scheduling algorithm.

Currently, the research on complex event processing in RFID mainly focuses on RFID data cleaning [17], RFID event detection [18] and the design of complex event processing language [2]. However, RFID devices will generate massive RFID data and events and cause "events flood". If events are scheduled unreasonably and disorderly, the results and real time of system will be affected heavily.

In this paper, we propose the BCEPS model system which is based on complex event processing. BCEPS model system is a general tracking and locating model which uses PTSA event scheduling algorithm that we design by ourselves to achieve purpose of tracking and locating objects and enhance real-time performance of system. It is noted that BCEPS model system separating mechanism and policy provides an interface for users to implement their own tracking and locating system. So we design the time-shifting tracking and locating algorithm (TSTLA) for the real-time tracking and locating underground mine prototype system (RLTLUM) which is used to verify the BCEPS model system

This paper is organized as follows. Section II presents the framework of BCEPS model system including the definition of RFID event and user event, complex event processing language and components of BCEPS model system. Section III presents PTSA event scheduling algorithm including definition of a general event, organizational structure and classification of events and execution process of PTSA algorithm. Section IV presents TSTLA tracking and locating algorithm including system topology structure, rules of distributing RFID reader, information presentation, execution process of TSTLA algorithm and analyzing the TSTLA algorithm. In section V we implement RLTLUM prototype system to verify BCEPS model system and illustrate the results. Finally, the conclusion and future works are presented in section VI.

II. BCEPS MODEL

A. RFID Event Definition

RFID primitive data streams gathered by RFID readers are independent and primitive information. RFID primitive data streams' formats are <r,o,t> which represent RFID reader r gathers RFID Tag o at time t which is generated by information system. Therefore, RFID primitive data streams need to be transformed into meaningful and actionable RFID events, illustrated by Figure 1.

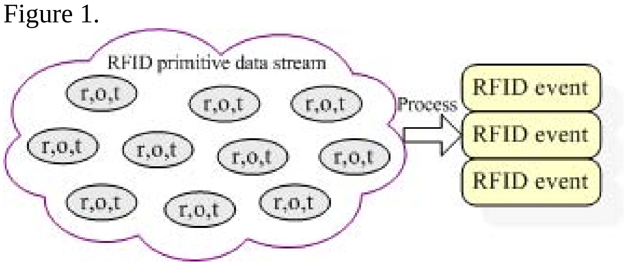


Figure 1. Transformation of RFID primitive data stream

RFID events have concrete meanings and can be processed by model system directly. The RFID event format is like:

Erfid (reader id, tag id, timestamp)

Where reader id represents the reader which exists in the event; tag id represents the tag which exists in the event; timestamp represents the time when RFID reader gathers the RFID tag. The event represents that RFID reader whose number is reader id gathers the RFID tag whose number is tag id at the time timestamp.

B. Complex Event Definition

Complex events represent the complex requisitions which come from users, called user events. User events can not be processed directly, so they should be transformed into several meta-events which can be processed directly. User events format is like:

Euser (CEP, rules, timestamp)

Where CEP represents a complex event which comes from user's requisition; rules are used to transform CEP into meta-events; timestamp represents the time when the user event is generated.

Several rules by which complex events are transformed into meta-events are defined in advance. Complex events are transformed into several meta-events by complex event processing language, illustrated by the part of Figure 2 which is surrounded by the dotted line. Model system processes meta-events and return results of meta-events. Finally, the result which meets requirement of the complex event is generated by combining these results of meta-events, illustrated by the part of Figure 2 which is surrounded by the real line.

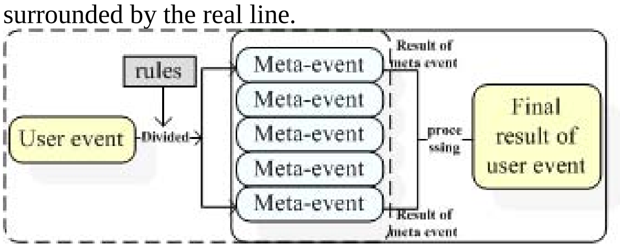


Figure 2. Division of complex events and generation of results

C. Complex Event Processing Language

Complex event processing language can transform user events (complex events) into meta-events and return final results which meet the requirement of user events. Complex event processing language makes the transformation between user events and meta-events transparent and convenient. The grammar of complex event processing language is similar to SQL and its format is like:

SELECT [result] FROM [meta-events] LIKE [CEP] WHERE [condition]

Where SELECT clause sends final result into result; FROM clause specifies the range of meta-events which is related to CEP, if not declared, default range of meta-events is used; LIKE clause represents the complex event to be processed, WHERE clause represents the extra conditions which come from users.

D. BCEPS Model

We design and construct tracking and locating model system which is based on complex event processing, called BCEPS model system. Figure 3 illustrates the architecture of BCEPS model system.

BCEPS model system consists of physical device layer, RFID data stream processing layer, event processing engine, application layer and data storage layer. In physical device layer, RFID readers gather RFID tags which hold real-time information and generate RFID primitive data stream which will be sent to RFID data stream processing layer finally. RFID data stream processing layer filters RFID primitive data stream to eliminate redundant, duplicate and abnormal data streams and produces RFID events which will be sent to event processing engine. At the same time, application layer yields several users' requisitions which will be encapsulated in user events and sent to event processing engine. All kinds of events received by event processing engine are stored in a temporal buffer called event pools. Event processing engine picks out the most appropriate event according to the real-time event scheduling algorithm which we will refer to in the following section. Event processing system in event processing engine processes the chosen event and returns the final result to users. The details of BCEPS model system are as follows.

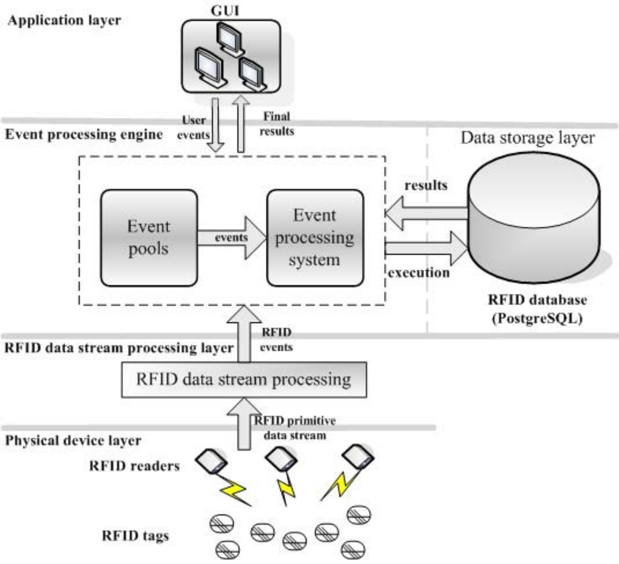


Figure 3. BCEPS model system

(1) Physical device layer

The layer consists of RFID readers and RFID tags. RFID readers gather RFID tags in real time.

(2) RFID data stream processing layer

This layer consists of event filtering layer and event generating layer, illustrated by Figure 4. Event filtering layer eliminates duplicate, redundant and abnormal RFID primitive data streams generated by physical device layer. Event generating layer yields the RFID events which are constructed from filtered primitive data streams.

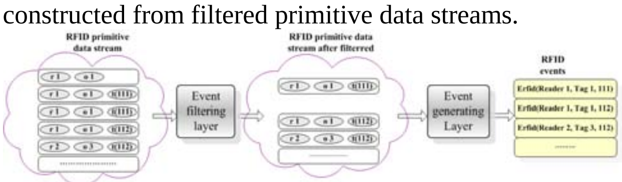


Figure 4. RFID data stream processing layer

Figure 4 demonstrates the process of RFID data stream processing layer. At first there are five RFID primitive data. The fist data is a invalid data because it loses the timestamp. The second data and the third data are duplicated. And then, the five RFID primitive data are processed by event filtering layer and there are three RFID primitive left which are valid. Finally, three RFID events are generated by event generating layer.

(3) Event processing engine

Event pools and event processing system constitute event processing engine. Event pools are a temporary space to store all events to be processed. There are tow kinds of events including RFID events and user events.

Event processing engine chooses the most superior event according to some real time event scheduling algorithm which will be introduced in the next section. Event processing system processes events in different ways in the light of the class of the events. In regard to RFID events, event processing system processes RFID events by the algorithm dependent on specified application to update real time information. In regard to user events, event processing system divides the user event into several meta-events, processes meta-events in multithread technology and returns the results meeting the requirements of users to application layer.

(4) Application layer

The layer provides users with convenient interface to produce appropriate user events in accordance with users' requirements. And it shows the final results returned by event processing engine in the way of graphical mode.

(5) Data storage layer

The layer stores the basic data and rules which are used by event processing engine.

III. PTSA ALGORITHM

Event processing engine of BCEPS model system receives two kinds of events including RFID events and user events. RFID events are the foundation of BCEPS model system. The results of user events are obtained by analyzing and processing the information which comes from RFID events. If event processing engine processes events only according to the time when the events arrive at the event pools, it will happen that users get the results which are inconsistent with the reality. In order to guarantee that the results are right and real time, we propose PTSA event scheduling algorithm based on priority and timestamp.

A. *Event Definition*

We encapsulate RFID events and user events in a general format. The format is like:

EVENT (type, Etype, priority, timestamp)

where type represents the type of the event which refers to rfid and user; Etype represents the content of the event which is in detail introduced in the Section 2 and 3; priority represents the priority of the event, the bigger the value of the priority is, the higher the priority of the event is; timestamp is not the time when the event arrives at event pools but the time when the event should be completed. For RFID events, timestamp is equal to the timestamp of Efid. For user events, if the CEP of Euser includes timestamp, timestamp is equal to the timestamp of CEP of Euser. If the CEP of Euser does not refer to timestamp, timestamp is equal to the timestamp of Euser. For example, Euser('query the location of miner A at time 111', rules, 112) represents a user event and the timestamp of EVENT(user, Euser, 3, 112) is equal to 111. Euser('get the list of miners', rules, 112) represents the other user event and the timestamp of EVENT(user, Euser, 3, 112) is equal to 112.

B. *Organizational Structure and Classification of Events*

Events in event pools are organized in terms of two different structures. One organizational structure is FIFO event queue which is according to the time when the events arrive at event pools. The other organizational structure is priority-based event queue which is according to the priorities and timestamp of events. Fig.5 illustrates the two kinds of organizational structures. The event pools in the Figure 5 have eight events. Figure 5 (a) represents the FIFO event queue and Figure 5 (b) represents the priority-based event queue.

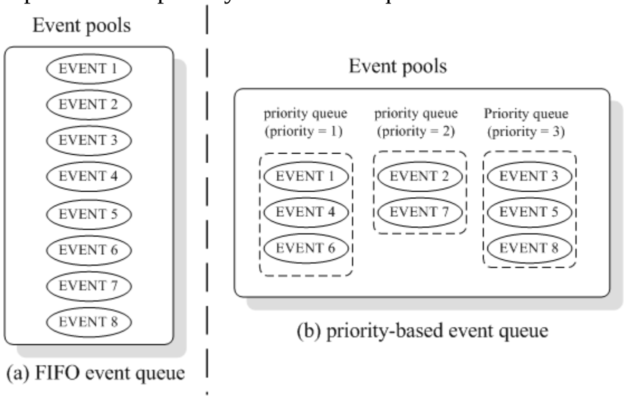


Figure 5. Two kinds of structures of organizing events in event pools

From the perspective of real-time, events include hard real-time events and soft real-time events. The priority of hard real-time events is always higher than soft real-time events. Soft real-time events could be preempted by hard real-time events. Currently PTSA event scheduling algorithm does not refer to hard and soft real-time events scheduling.

C. PTSA Event Scheduling Algorithm

The process of PTSA event scheduling algorithm is as follows (illustrated by Figure 6):

(1) Choose the earliest event from FIFO event queue to be processed as EVENT A which exists in event pools.

(2) If EVENT E is RFID event, it will be sent to event processing system and PTSA algorithm finishes.

(3) IF EVENT E is user event, choose all priority-based event queues that have the bigger priorities than EVENT E, called the priority-based event queue set {PQ | the value of priority of PQ_i > the value of priority of EVENT E, PQ_i is a priority-based event queue}

(4) Choose all RFID events from priority-based event queue {PQ} that have relation with EVENT E and have earlier timestamp than EVENT E, called the RFID events to be processed set {PE | PEj is a RFID event existing in {PQ} which has relation with EVENT E and has earlier timestamp than EVENT E }.

(5) Before sending EVENT E to event processing system, send all events in {PE} to event processing system to be processed.

(6) Send EVENT E to event processing system to be processed.

(7) PTSA algorithm finishes.

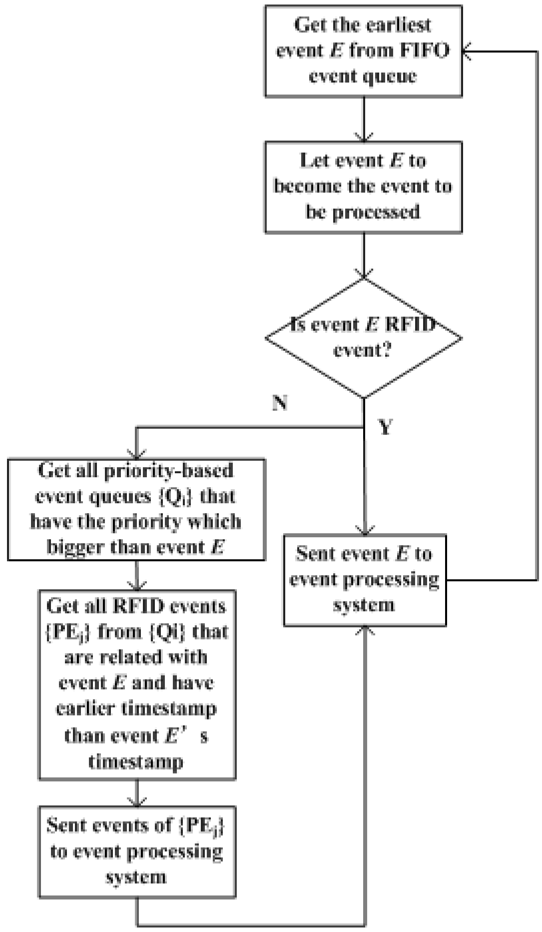


Figure 6. PTSA algorithm

D. Complex Event Processing Mechanism Based on Multithread

When a user event is being processed, we can use multithread mechanism to process the user event to enhance responding time and real-time performance of system. User events must be transformed into several meta-events processed directly by model system. Some meta-events have interrelationship, but others are independent, illustrated by Figure 7. Meta-event 2 and 3 require the output of meta-event 1 as input. However, there is not interrelationship between meta-event 2 and 3. Therefore, we process independent meta-events using multithread technology to enhance real-time of model system and improve responding time of model system.

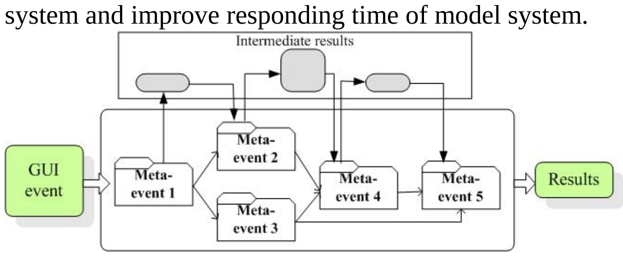


Figure 7. Processing complex events in parallel

IV. TSTLA ALGORITHM

Radio Frequency IDentificatioin (RFID) is expanding rapidly in commercial. The popularity of RFID provides an excellent opportunity to real-time location system (RTLS) based services in underground mime where others technologies of wireless communication can not achieve goals of tracking and locating. Currently, RFID researches focus on hardware and firmware components, including RFID tags, readers, embedded software, error reduction, and conflict detection, while applications of RFID are limited to indoor, outdoor and ground.

Security of mines is the hot spot of the field of coal mime all the time. How to protect persons working in underground mines is one of the most important issues of security of the mine [23]. Because of the limit of communications in underground mine and intricacy of laneways in underground mime, once accidents take place, it will be difficult to rescue. RFID technology is one of the new modes of wireless communication. RFID can identify objects and gather information of objects' positions automatically in real time. Therefore, RFID has the ability to be applied to underground mine because of its characteristic. RFID-based tracking and locating system in underground mine may help improve management of mines and save more losses caused by the accidents. Integrating RFID with information system yields RFID-based tracking and locating system in underground mine [22]. The paper aims to research RFID-based locating system in underground mine.

However, the tracking and locating algorithm of RFID applications in underground mine is decided by the characteristics of chosen RFID hardware to a great degree. Once RFID hardware changes in the same application, we will have to discard the old tracking and locating algorithm of the application and design the new tracking and locating algorithm for the application once again. Then, the whole logical structure of the RFID application will be redesigned and a lot of extra time and capital will be invested.

In this section, we design and implement a new tracking and locating algorithm for applications in underground mine, called TSTLA algorithm. TSTLA algorithm is a general tracking and locating algorithm. The logical structure of TSTLA algorithm is independent of RFID hardware. Although RFID hardware is upgraded, the TSTLA needn't to be changed.

A. System Topology Structure

The critical factor of designing a general tracking and locating algorithm for underground mime is the abstractions of the structure of tunnels in underground mine. System topology structure of the application depends on layout of tunnels in underground mine. In order to describe and analyze conveniently, we express the structure of tunnels in underground mine using graph. Figure 1 presents the structure of tunnels in underground mine. In figure 8, a, b and c represents the intersections connecting tow or more tunnels, which is called joints. The numbers such as 1, 2 and 3 represent the tunnels in underground mine. The tunnels are straight or curved.

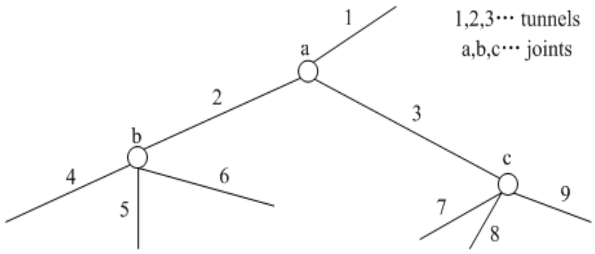


Figure 8. The Sketch Map of Tunnels

While every person working in underground mine must wear RFID tags, every joint must be installed with RFID readers. It is possible to track, locate and identify everyone with RFID tags in every tunnel.

It is noted that every tunnel can be installed with extra RFID readers besides joints [24]. The more RFID readers are installed, the more precise tracking and locating system is. The place where RFID readers are installed is called nodes, illustrated by Figure 9. In figure 9, node a, node b and node c which are the purple points belong to the same tunnel surrounded by the dotted line.

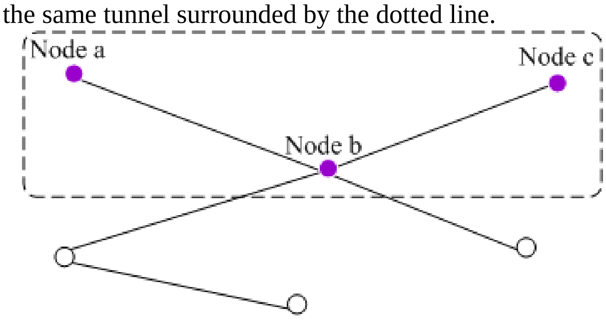


Figure 9. Examples of Nodes

B. Rules of Distributing RFID Readers

Although the logical structure of TSTLA algorithm is not affected by the RFID hardware, the rightness and accuracy of TSTLA algorithm will be affected by distribution of RFID hardware in underground mine. In order to meet the requirement of TSTLA algorithm, we make some rules of distributing RFID readers. The rules are as follows:

(1) A RFID reader must be installed in the joint.

(2) RFID readers must be installed in every inflection point of the curved tunnel.

(3) RFID readers should be installed on the top of tunnels.

(4) In the same tunnel, RFID readers should be distributed in the interval of equal length.

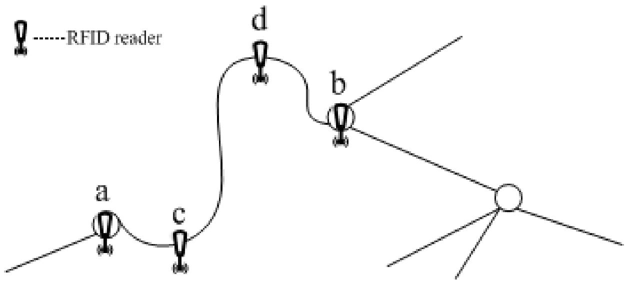


Figure 10. Example of distributing RFID readers

Figure 10 illustrates an example of distributing RFID readers. The curved line including a, b, c and d is a tunnel in underground mine. In the tunnel, there are two inflection points that are node c and node b. Therefore, there are four nodes: node a, node b, node c and node d where RFID readers must be installed.

C. Information Presentation

Although the logical structure of TSTLA algorithm is not affected by the RFID hardware, the rightness and accuracy of TSTLA algorithm will be affected by distribution of RFID hardware in underground mine. In order to meet the requirement of TSTLA algorithm, we make some rules of distributing RFID readers. The rules are as follows:

RFID readers gather RFID tags and get many primitive data which is meaningless. RFID readers and tags having their own unique identifiers can provide basal data about information of persons' location. Entire system is based on these data. However, these data is disordered and simple. Therefore, these data must be organized and then transformed into some certain standard information presentation so that they can be processed by application software directly.

In order to track and locate persons, application still needs some extra data such as detailed information about persons wearing tags, time to read these information and auxiliary information. Combining basal data with extra data can implement functions of tracking and locating persons.

In order to understand and describe conveniently, we use table form to present the essential information. The descriptions of information are as follow:

(1) reader-tag table

The reader-tag table (illustrated by Table I) describes that readers gather tags at some time. Every record in the table contains four fields: the identifier of the tag, the identifier of the reader capturing the tag, the time when the reader captures the tag and flag indicating the times of reading the record. If flag is equal to 1, the record marked by the flag will be an new position information. If flag is bigger than 1, the record marked by the flag will be obsolete position information. The records whose flags are equal to 1 only contribute to tracking and locating objects in real time.

TABLE I.
READER-TAG TABLE

Reader	Tag	Time	Flag
		T 1	flag 1
		T 2	flag 2
…	…	…	…
		T n	flag n

(2) person-tag table

The person-tag table (illustrated by Table II) describes detailed information of persons who wear RFID tags including name, age and address and so on. The extra information is useful for managing persons in underground mine.

TABLE II.
PERSON-TAG TABLE

Tag	Name	Age	Others
tag 1	name 1	age 1	
tag 2	name 2	age 2	
…	…	…	…
tag 3	name 3	age n	

(3) node-tunnel table

The node-tunnel table (illustrated by Table III) represents the relation between nodes which are installed with readers and tunnels. Every record includes three fields: Node1 and Node2 are starting point and ending point of the tunnel respectively. Tunnel is the identifier of tunnel.

TABLE III.
NODE-TUNNEL TABLE

Node1	Node2	Tunnel
		L 1
		L 2
…	…	…
		L n

(4) node-reader tables

The node-reader table (illustrated by Table IV) represents the relationship between nodes and readers. Every record includes two fields: Node is the identifier of the node with RFID readers. Reader is the identifier of RFID reader.

TABLE IV.
NODE-READER TABLE

Node	Reader
N 1	R 1
N 2	R 2
…	…
N n	R n

(5) time-tunnel-tag table

The time-tunnel-tag table (illustrated by Table V) represents who are in some tunnel at some interval of time. Every record includes four fields: Start_time is the starting time, End_time is the ending time, Tunnel is the identifier of tunnel and Tag is the identifier of RFID tag. The table is the most important information table for tracking and locating persons. Application can get the position information directly. The table is generated by integrating above tables. Implementation of tracking and locating persons in underground mine is decided by the design of time-tunnel-tag table.

TABLE V.
TIME-TUNNEL-TAG TABLE

Start_time	End_time	Tunnel	Time
st 1	et 1	L 1	tag 1
st 2	et 2	L 2	tag 2
…	…	…	…
st n	et 3	L n	tag n

D. TSTLA Algorithm

RFID readers gather RFID tags and a lot of position information are generated [5] [6] [7]. In order to achieve the purpose of tracking and locating persons, position information gathered by readers must be processed according to some certain algorithm called TSTLA algorithm. TSTLA algorithm processes position information and produces the final results meeting requirement of application.

The algorithm aims to get the number of persons who are in some laneways at some time by combining new data from readers with old data in database. The description of the algorithm is as follows.

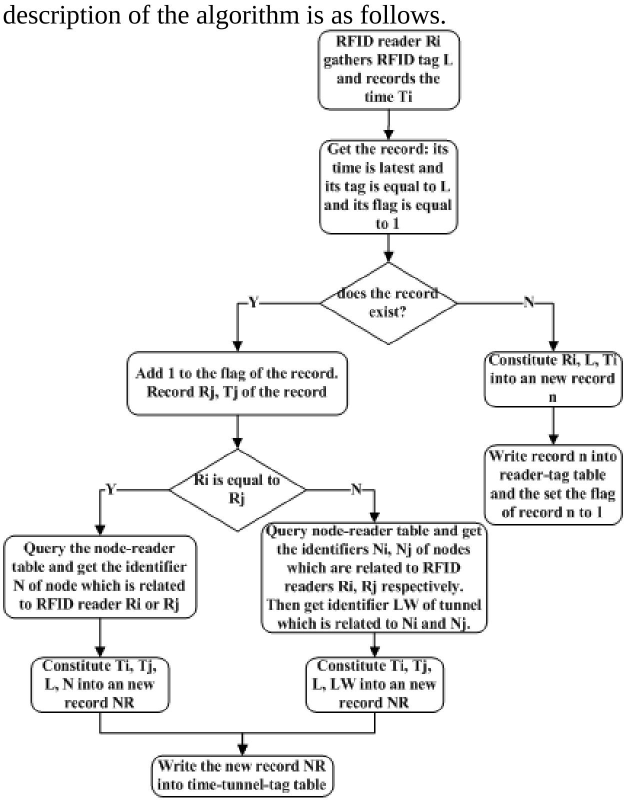


Figure 11. Flow chart of TSTLA algorithm

When new position information arrives, the steps of TSTLA algorithm processing the new position information are as follows (illustrated by Figure 11):

(1) RFID reader Ri gathers RFID tag L and records the time Ti. And then find the record from TABLE I: its time is latest and its tag is equal to L and its flag is equal to 1. If the record exists, the step 3) will be performed. If the record does not exist, step 2 will be performed.

(2) Constitute Ri, L, Ti into an new record n. Write record n into reader-tag table and the set the flag of record n to 1. The algorithm finishes.

(3) Add 1 to the flag of the record. Record Rj, Tj of the fields of Reader and Tag of the record. If Ri is equal Rj, step 4) will be performed. If Ri is not equal Rj, step 5) will be performed.

(4) Query the node-reader table and get the identifier N of node which is related to RFID reader Ri or Rj. Constitute Ti, Tj, L, N into an new record NR. Write the new record NR into time-tunnel-tag table. Algorithm finishes.

(5) Query node-reader table and get the identifiers Ni, Nj of nodes which are related to RFID readers Ri, Rj respectively. Then get identifier LW of tunnel which is related to Ni and Nj. Constitute Ti, Tj, L, LW into an new record NR. Write the new record NR into time-tunnel-tag table. Algorithm finishes.

E. Analysis of Complexity of TSTLA Algorithm

Analysis of algorithm aims to measure time and space efficiency. As hardware develops rapidly, space has less effect on efficiency of algorithm. So time efficiency is the most important factor affecting efficiency of algorithm. The running time of an algorithm is [25]:

$$T_{avg}(n) = \sum_{i \in I} p(i) \sum_{j=1}^{k} t_j . e_j (n,i) \qquad (1)$$

Where n is the scale of problem, i is the input of algorithm, P(i) is the probability of input i, ej is the number of meta operations and ti is the running time of single atomic operation.

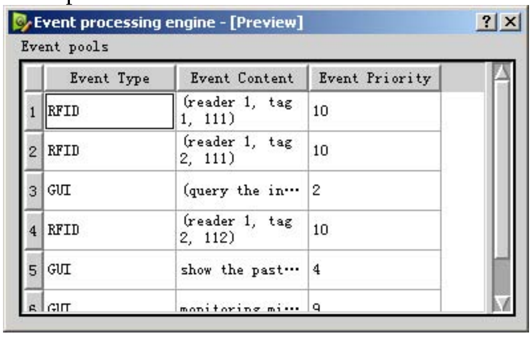
The atomic operation of TSTLA algorithm is comparison between two objects. It is supposed that Table 1 has n records, Table 3 has m records. The most number of the TSTLA algorithm's operations is m + n. It means that TSTLA algorithm is a linear algorithm.

V. EXPERIMENT

The proposed BCEPS model system was tried in the following environment. Due to the restriction on the organization of an environment with mobile business, it was simulated with RFID-based tracking and locating system underground mine (RTLUM). RTLUM was building based on BCEPS model system. RTLUM consisted of data collection module and graphic monitoring module. Data collection module gathered real-time position information about miners tied with RFID tags, filtered RFID real-time position information, generated RFID events and sent RFID events to event processing engine. Graphic monitoring module generated user events and showed the results graphically which came from event processing engine. We used time shifting tracking and locating algorithm described in section IV.

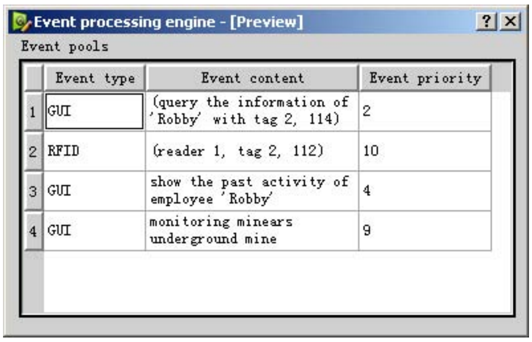
For verifying TSTLA algorithm, we propose, design and implement a real-time tracking and locating underground mine prototype system (RLTLUM). Due to the restriction on experiment environment, we construct a underground mine model in the lab, and we use high frequency RFID readers and tags. RLTLUM achieves the goal of tracking and locating persons in underground mine by using TSTLA algorithm. RLTLUM consists of data collection module and monitoring graphically module. Data collection module includes RFID readers, RFID tags and data processing software. RFID readers gather RFID tags and produce RFID data which is sent to data processing software. Data processing software receives and processes RFID data using TSTLA algorithm. Finally, information meeting the requirement of tracking and locating persons is generated. Monitoring graphically module is responsible for showing the moving path of persons in underground mine graphically in real time and showing the distribution map of persons in underground mine.

Figure 12 illustrates event pools at time t. At time t, the earliest event is Erfid(reader 1,tag 1,111). According to PTSA algorithm, it will be processing directly. Figure 13 illustrates event pools at time t+1. At time t+1, the earliest event is Euser(query the information of 'Robby' with tag 2, 114). Because some RFID events referring to tag 2 and their timestamps are prior to the user event, these RFID events should be processed prior to the user event. Therefore, at time t+1, Erfid(reader 1,tag 2,112) should be processed.



	Event Type	Event Content	Event Priority
1	RFID	(reader 1, tag 1, 111)	10
2	RFID	(reader 1, tag 2, 111)	10
3	GUI	(query the in…	2
4	RFID	(reader 1, tag 2, 112)	10
5	GUI	show the past…	4
6	GUI	monitoring mi…	9

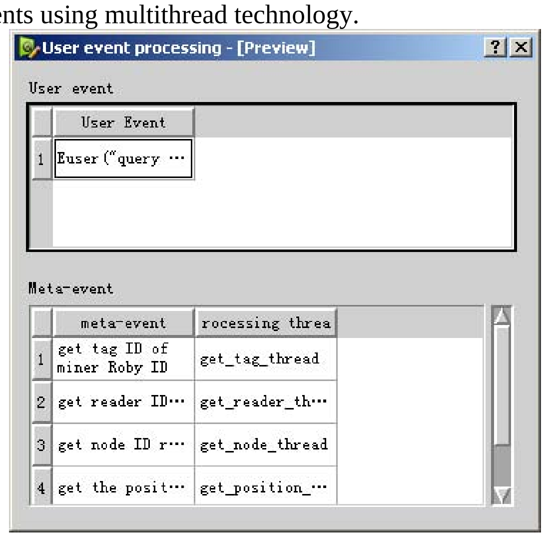
Figure 12. State of events pools at time t



	Event type	Event content	Event priority
1	GUI	(query the information of 'Robby' with tag 2, 114)	2
2	RFID	(reader 1, tag 2, 112)	10
3	GUI	show the past activity of employee 'Robby'	4
4	GUI	monitoring minears underground mine	9

Figure 13. State of events pools at time t+1

Figure 14 illustrates the scene of processing user events using multithread technology.



	User Event
1	Euser("query …

	meta-event	rocessing threa
1	get tag ID of miner Roby ID	get_tag_thread
2	get reader ID…	get_reader_th…
3	get node ID r…	get_node_thread
4	get the posit…	get_position_…

Figure 14. Event processing engine module

Figure 15 illustrates the view of tracking and locating a person in underground mine. Every yellow filled circle represents a node in which RFID reader should be installed. A straight line represents a tunnel. The human shape represents a person in underground mine who is being monitored. The whole graph represents there is a person at some node at this moment.

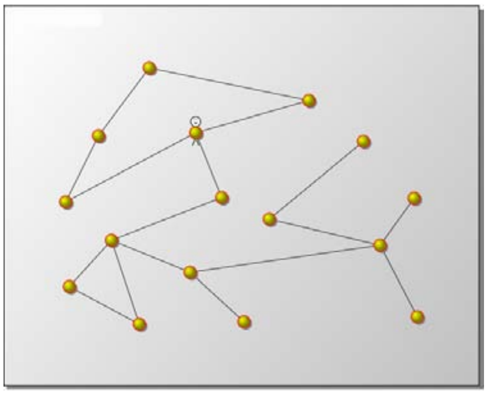


Figure 15. The view of tracking and locating a person

Figure 16 illustrates the distribution map of persons in underground map. In figure 16, there are four persons in underground mine at this moment and they are located at four different tunnels.

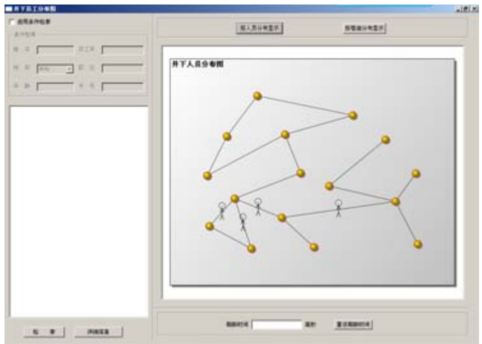


Figure 16. Distribution map of persons in underground mine

RLTLUM prototype system has some basic auxiliary function including management of persons, RFID readers and RFID tags, drawing, deleting and setting up map of tunnels in underground mine.

VI. CONCLUSION

This paper proposes BCEPS model system which is based on complex event processing. BCEPS model system involves two kinds of events: RFID events and user events and gives the detailed definitions of them. Then we describe the architecture and components of BCEPS model system. In order to improve responding time and enhance real time, we propose PTSA event scheduling algorithm and the mechanism of processing user events using multithread technology. Finally, we design and implement the TSTLA tracking and locating algorithm for RLTLUM prototype system. We implement RLTLUM prototype system to verify the BCEPS model system.

Currently PTSA event scheduling algorithm does not involve hard and soft real-time events scheduling. In the future, we will study further on scheduling hard and soft real-time events. And we will apply RLTLUM prototype system to the practical application and improve TSTLA algorithm.

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REFERENCES

[1] Shang Gao, “RFID applications toward mobile business”, *Sixth International Conference on Mobile Business (ICMB 2007)*, 2007.
[2] Daniel Gyllstrom, Eugene Wu, Hee-Jin Chae, et al, “SASE: Complex Event Processing over Streams”, *CIDR, Asilomar*, CA, 2007.
[3] Jin Xingyi, Lee Xiaodong, Kong Ning, et al, “Efficient Complex Event Processing over RFID Data Stream”. *Seventh IEEE/ACIS International Conference on Computer and Information Science*, 2008.
[4] E. Masciari, “RFID data management for effective objects tracking”. *The 23rd Annu. ACM Symposium on Applied Computing*, 2007.
[5] SHENG WANG, SHAORONG LIU, PEIYA LIU, et al, “Bridging Physical and Virtual Worlds: Complex Event Processing for RFID Data Streams”, *the 10th Int. Conf. on Extending Database Technology*, Munich, Germany, 2006.
[6] B. Yijian, T. Hetal, L. Chang, et al, “A Data Stream Language and System Designed for Power and Extensibility”, *the 15th ACM Conf. on Information and Knowledge Management*, Virginia, 2006.
[7] Zimmer, D. and Unland R., “On the semantics of complex events in active database management systems”, *ICDE*, 1999.
[8] F. WANG, P. LIU, “Temporal management of RFID data”, *the 31st VLDB Conf.*, New York, 2005.
[9] Kaushik Dutta, Krithi Ramamritham, Kamlesh Laddhad, et al, “Real-Time Event Handling in an RFID Middleware System”, *Workshop on Databases in Networked Information Systems (DNIS)*, 2007.
[10] So Young Choi, Ho Min Jung, Ki Seok Bang, et al. “Real-time Data Stream Management System for Large Volume of RFID Events”, *International Conference on Convergence and Hybrid Information Technology*, Daejeon, 2008.
[11] S. CHAKRAVARTHY, V. KRISHNAPRASAD, E. ANWAR, “Composite events for active databases: Semantics contexts and detection”, *the 20th VLDB Conference*, Santiago Chile, 1994.
[12] H. Gonzalez, J. Han, X. Li, D. Klabjan, “Warehousing and Analysis of Massive RFID Data Sets”, *Proc. 2006 Int. Conf. Data Engineering (ICDE'06)*, Atlanta, Georgia, April 2006.
[13] Y. Wei , S.H.Son, J.Stankovic, “RTStream: Real Time Query Processing for Data Streams”, *IEEE Symposium on Object-Oriented Real-Time Distributed Computing (ISORC'06)*, Gyeongju, Korea, April 2006.
[14] C.M Krishna, Kang G. Shin, *Real-time Systems*, McGRAW-HILL Internationl Edition, 1997.
[15] C.L.Liu, J.W.Layland, “Scheduling algorithms for multiprogramming in a hard read-time environment,” *Journal of ACM*, 1973
[16] Sven Schmidt, Thomas Legler, Sebastian Schar, et al, "Robust Real-time Query Processing with QStream", *VLDB*, 2005.
[17] GU Yu, YU Ge, ZHANG Tiancheng, “RFID complex event processing techniques”, *Journal of Computer Science and Frontiers*，2007.
[18] LIU Hai-long, LI Zhan-huai, CHEN Qun, et al, “Study and improvement on RFID complex events detecting methods”, *Computer Engineering and Applications*, 2008, 44(11): 5- 8.
[19] JIANG Lifen, LU Guizhang, XIN Yunwei, “Formal Context-aware Model in Pervasive Computing Environment Based on RFID”, *Journal of Computer Engineering*, 2007.6.
[20] A.K. Dey, G.D. Abowd, “Towards a Better Understanding of Context and Context-Awareness”, *Technical Report GIT-GVU-99-22*, Georgia Institute of Technology, College of Computing, 1999.7.
[21] Abowd G D, Ebling M, Hunt G, et al. “Context-aware Computing”. *IEEE Pervasive Computing Journal*, 2002, 1(3): 22-23.
[22] Wang Xianzheng, *New technology of Coal Mine*, China Coal Industry Publishing House, Beijing, 2004:57-63.
[23] Wang Jiefan, Li Wenjun, *Zhong Guo Mei Kuang Shi Gu Ji Zhuan Jia Dian Ping Ji*, China Coal Industry Publishing House, Beijing, 2002:14-18.
[24] Agarwal, “Assessing the benefits of Auto-ID Technology in the Consumer Goods Industry”, *Auto-ID Center – Massachusetts Institute of Technology Research*, 2001.
[25] THOMAS H.CORMEN, CHARLES E.LEISERSON, RONALD L.RIVEST, et al, *Introduction to algorithm*, The MIT Press, Massachusetts, 2007.
[26] Sungjun Kim, Doohyun Ko, Sunshin An, “Geographical location based RFID tracking system”, *World of Wireless, Mobile and Multimedia Networks*, 2008.
[27] Al-Ali, A.R., Aloul, F.A., et al, “Mobile RFID Tracking System”, *the 3rd Information and Communication Technologies: From Theory to Applications*, 2008.
[28] Chansud, W., Wisanmongkol, J., Ketprom, U., “RFID for poultry traceability system at animal checkpoint”, *the 5th Electrical Engineering/Electronics, Computer, Telecommunications and Information Technology*, 2008.