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ITJ

ISSN 1812-5638

INFORMATION TECHNOLOGY JOURNAL

ANSInet
Asian Network for Scientific Information
308 Lasani Town, Sargodha Road, Faisalabad - Pakistan

Information Technology Journal 10 (1): 168-174, 2011
ISSN 1812-5638 / DOI: 10.3923/itj.2011.168.174

Local Positioning Systems for Mobile Devices based on Ontology

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Abstract: In order to get services continuity and integrity in wide range of pervasive environments for mobile computing devices, Local Positioning Systems (LPS), recognized as the key prerequisite of dependability for many fundamental network services, has attracted a lot of research efforts in recent years. This study attempts to propose a method, based on Ontology using Jena to implement the context awareness technology, for local positioning systems to facilitate effective communications and service applications. First of all, the study introduces Local Positioning Systems in relation to the modern daily life and then the paper expounds on the context-related elements in the locating process. Secondly, the semantic by formal method based on Ontology for efficient application of services is analyzed. Thirdly, the paper proposes a model for mobile devices and gives a connective workflow example. In conclusion, the experiments show that the proposed approach is an improvement to conventional practices.

Key words: Local positioning systems, Ontology, mobile devices, formal method, semantics, context awareness

INTRODUCTION

Mobile devices have become common in our daily life. These years have witnessed a rise of use of mobile handsets in the complexity of pervasive computing environment. It is believed that Local Positioning Systems (LPS) has become a critically essential and indispensable factor in today's wireless communication network. LPS is used to address the problem of mobile devices location, the way to meet the services with the expected timeliness. Generally, it is an expensive burden for most resource limited wireless and suffers from high hardware cost, for example, AI (Artificial Intelligence) heart is designed to aid people's heart beat and meanwhile, it is connected to the computer center for doctors to analyze the data and monitor the patient's situation (Varshneyy, 2003; Borriello *et al*., 2007). Agricultural sensors are used to monitor the quality of air, moisture of unexpected temperature and to detect the pollutions source in real time. An important fact is that, these services cannot get continuity and integrity when the request is denied or inappropriate location service is occurred, the system may face a break-down.

In the development and deployment of application, the context for location information is indispensable in pervasive computing environments. It includes not only the information where the mobile devices are located, but also some potential semantic to improve the effectiveness of LPS. For example, (1) Routing (Chen and Chiang, 2009), it is used as a path selection for sending data traffic; (2) Cos (Content of services), it is used to record the interaction information between the mobile devices and servers when we adjust network parameters when the location changes, more importantly, using location information as prior knowledge for forecast; (3) Qos (Quality of services), it refers to the ability of services. Suppose we encounter the situation when two processes need the unique service at same time, we should ensure that appropriate service will be available for each requester.

Two fundamental techniques of LPS are context awareness and semantic compatibility. For instance, if there exists a deadlock, we should make a decision to hang up one or switch it to another server. The assurance of full compatibility and integration of using context is a major challenge for LPS, which leads to the study of all recordable information methodology in runtime and the solutions to reliability enhancement. The effort must be made to minimize the possibility of an undetected or unrecoverable failure in the process of local positioning.

THE SEMANTICS FORMAL METHOD IN ONTOLOGY

The challenges to implement the LPS technology grow both in scope and extent. One method of determining the location of mobile device is to adopt manual configuration and management, which is not

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applicable in large-scale deployments and distributed systems. This study proposes a method based on Ontology to formal describe the knowledge of location and record the related context. The scheme can sense their locations by monitoring the information of their location and their neighboring nodes. Apart from helping finding and getting the necessary information, the solution also aims to help the users to reason the knowledge from the existing information for new semantic knowledge.

The context awareness of location information includes the quality of service, the distance between the mobile device and the server and the runtime information. It is as essential a part in the whole system as the context in a specific essay or the volume of a piece of music played. In a word, there is an increasing need for developing formal concept models to facilitate context representation, context sharing and semantic interoperability of heterogeneous systems. Ontology could be defined from many aspects. Schreiber *et al.* (1995) defined it as follows: Ontology provides a clearly description and conceptualization to express the knowledge. As well as, concepts or terms of a certain field are used to organize the higher level of abstract concept which we called as domain of special knowledge.

Ontology first appears in philosophy and now refers to the existing subject (Perez and Benjamins, 1999), which holds conceptual instances of a domain. It provides richer and explicit descriptions of resources online for knowledge management, mainly used as knowledge sharing, logic inference and knowledge reuse. (1) Knowledge Sharing, the set of concepts of world entities about the context while interacting with others, such as boss and employee. (2) Logic Inference, to facilitate user reasoning, Ontology proposed some theorem rules and mechanisms to deduce complex-level from simple-level. (3) Knowledge Reuse, using the standard or strait domain description, we can composed more large-scale and plentiful-semantic.

In order to describe the information in the form of a computer comprehension, Tim Berners-Lee, the founder of WWW, formally proposed the conceptualization of the semantic Web in 2001 (Berners-Lee *et al*., 2001). It is mainly based on XML and RDF/RDFS standard documents, by which we can build Ontology and do some logical inference.

Triples representation: With the contained set of entities, relations, functions, axioms and instances to describe the domain knowledge, each Ontology document using XML to express in form of triple and its elements consist of three types of objects. (1) Resources, using Uniform Resource Identifiers (URIs) to identify resources and information. (2) Properties, It describes the attributes or characteristics of resources. (3) Statements, it is an extension of resources attributes. And using predicate to bind objects for the logic related, in the way of directed graph, we can see that a triple contains the tags called the subject, predicate and object, which maps to node-edge-node. For examples, student→teacher can be changed into triples: (student, associate, teacher).

With the help of Ontology, the abstract of the objective world can be divided into five categories. (1) Class, which means any description of the abstract set can organized into domain knowledge. (2) Relations, with the purpose of describing the interaction between the conceptualization, it defined as the n-dimensional subset of the Cartesian product: R: C_1 *C_2. ... .. C_n. Such as the relations Sub Class Of (3) Function, it is a special kind of relationship, from this functions, we can get the n'th elements from the former n-1 elements F:C_1* C_2……C_{n-1}→ C_n, such as father_of (x, y) means that y is x's father. (4) Axioms, which means the assertion is always true. (5) Instances, which is an instance of an object or class.

Using the rich elements of Ontology, this technical fosters two novel ranging approaches that we can model the objective world and identify the semantic. The main work of this study is to use Ontology methodology to achieve LPS technology for mobile devices.

Ontology query: Open source Jena, a famous Ontology editor, supports some APIs and functions of Ontology query and reasoning. It is employed to attain context or semantic for the world abstract.

Query example: As the Table 1 shown, the code contains some predicate relations in triples model, we will query the collection of the users current appliances by ? Appliances interaction with the equations ? appliances ==current in Ontology description. Form the code, we can see that the SQL-like query statement means multi-map between parameters ?mobile and parameters ?appliances.

Table 1: Code of retrieving property form Ontology

```
Code:
PREFIX info: http://www.shu.edu.cn/ContextInfor#
SelECT ? student
WHERE {
?mobile info: Owned ?appliances,
FILTER(?appliances ==’current’)}
Results:
-----------------------------------------------------------------------------------------
| appliances |
=====================================================================
| Video |
| Music |
| QQ    |
| Search engine |
| FTP |
```

Table 2: First-order logic axioms

```
( (PropertyValue subclass ?p ?q)
  ∧(Type ?p rdfs:class )
    ∧(Type ?q rdfs:class )
      (forall(?x)
        →(Type ?x ?p)
          (Type ?x ?q) ) )
```

Ontology reasoning: Another inherent characteristic of Ontology is reasoning. It is mainly based on mathematics method and provides a non-ambiguous formal expression for reasoning.

Reasoning example: As the Table 2 shown, the code contains the predicate (subClass) in triples model, we describe the relations that (?c rdfs:subClassOf ?b),(?b rdfs:subClassOf ?a) ? (?c rdfs:sub Class Of ?a), which means that if c is subclass of b and b is subclass of a, then we known that c is subclass of a and for all the property x belong to class c, also x is belong to class a.

ARCHITECTURE DESIGN

Architecture: Taken in order of appearance, the section shows an elaborate architecture, which consists of two parts: the Event Management in Mobile Devices (EMMD) and the Positioning Management in Services (PMS).

From the Fig. 1, the Event Management in Mobile Devices (EMMD) is seen as a collection container for recording global and local variables and its values as the following models show:

Location IP model: The goal of this model is to record IP information of the used or current services. Perhaps the most basic positioning technique is to inform the whereabouts of the appropriate services available, including some simple tables used as the database to write the services name, the services IP and the services protocol.

Event records model: This model holds up the runtime information and puts these into an interception, such as the function call, the running processes, the running services, as well as the error information and the movement event. The interception's information can be of future use.

Services state model: Services state has three types, ready state, exaction state and waiting state. We can find that when we move to another room, the mobile will wait for the functional similarity of services to come into ready state. Unlikely, in shortage of service, mobile devices should stay at wait state until the destination services enter the available circumstances.

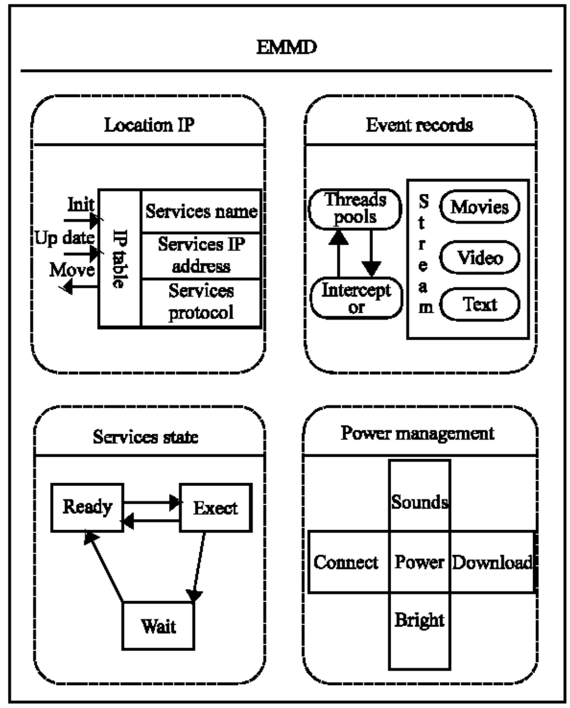

Fig. 1: The event management in mobile devices

Power management model: it is a feature of some electrical appliances, that they would power off or switch the system to a low-power state when inactive, for its limited power. In this power management model, it is used as the context knowledge to control the volume of sound and the brightness of the light according to the Ontology for the lower power consumption.

The Positioning Management in Services (PMS) is used for the management for processing the information. For example, it collects context knowledge sent from the mobile. And it is the entrance of the service accession port, which receives the message package form mobile devices and has following models.

Consistency center: To detect whether there is a conflict in services access process. This guarantees that every request is valid and effective and avoids unwanted negotiation failure, through checking identified software configuration items and determining the number of software versions and their interaction.

Verification center: To check the validity of users' identification and the location, it is to eliminate all invalid connection and illegal access

Error handling center: The main function is to check whether the services are available for users. In addition, the matching service must ensure that the important content of user's services should not be disrupted. However, we can use the records to do some inference, form the mobile device, which are described in form of the formal knowledge based on Ontology. It has ability of a fault masking, error detection, fault diagnosis and system recovery, which increases the possibilities of trusted services before they can cause consequent failures.

Feedback center: As a user-oriented interface, it is started when the access is denied, which will show mobile devices the feedback information, includingthe classification of error information and failure notice. It provides a mechanism to maintain and organize the data and information, to make the system inactive with certain special mobile devices to avoid processing chaos.

Workflow process: Clearly, it is difficult to apply LPS to communications of mobile devices without the context knowledge; it can't continuously deliver the required services. Together with the focus on message, the abstract process of the workflow for processing mobile devices requests is shown in Fig 2, where the sequence is a target-oriented transfer through step. The verification center is the concatenation of all the messages exchanged among the routing function, Qos function and Cos function. Look at these scenarios: when the mobile devices request services to a location services connect

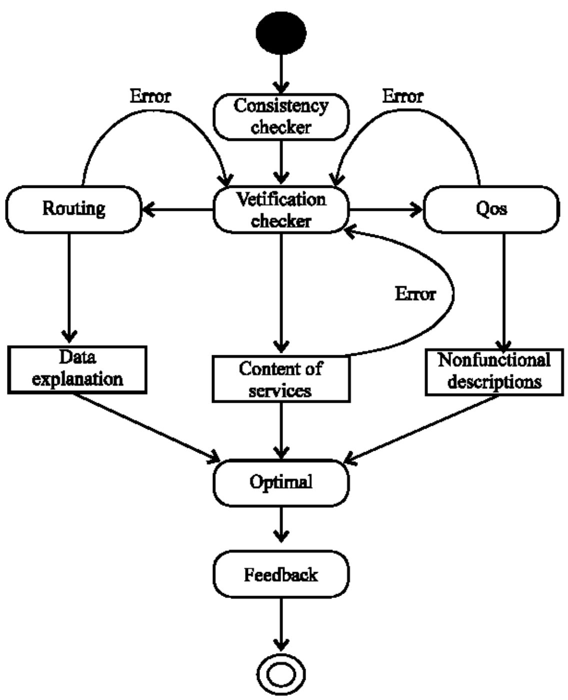

Fig. 2: The workflow of the connection for LPS

port, the server's consistency checks the message, as the EMMD-supported function or what we call knowledge and analyzes the interaction behavior to prevent the deadlock of composed services interrelation and judge the time tag to solve the request process starvation problem. Then the verification center is to check the validity of users and the process, whether it carry enough message and context for validating. The next steps are divided to three paths: one is to calculate the routing path for sending data to the distributed services. The other operation is to analyze the content of the mobile devices that had been used or being used while it changes the location and the last one is to carry nonfunctional descriptions, such as the corresponding time. One should emphasize that each step is a reexamination, possibly leading to changes of previously business. Finally, the feedback center is used as the results returned to mobile devices. On the other hand, if error appears in these processes, the error handling model will have to deal with these problems automatically.

Based ontology reasoning semantic: Another important aspect of the comprehension of knowledge is through reasoning the logic by using a restricted set of first-order formulas, we can make use of the rules entailed by Description Logic (DL) to reason with context related information. DL is more expressive when it comes to the properties that most users would be interested. Computer can understand what we input and give us appropriate results after searching the engine.

As in the definition in Ontology, these predicate relations include concept satisfiability, class subsumption, class consistency and instance checking (Hanus, 1994).

Definition 1: Sub Class Of, (c, rdfs: sub Class Of, c') state that c is subclass of c', it is described in form of $c \subseteq c'$. The semantic Ontology-based tree algorithm for Chinese word splitter as we take about, which mainly uses sub Class Of relation to organize the rules for composition.

Definition 2: Same As, (x, same As, y) state that x is equal to y, it is described in the form of $x = y, \exists x \in \mu\,(p) \Rightarrow \exists y \in \mu\,(p)$.

Definition 3: function Property, (x, function Property, owl:type) state that y is property of x function and y has owl type, it is described in form of $(x, y),(x, z) \in \mu(p) \Rightarrow y = z$.

Definition 4: Inverse, (p, inverse of, p') state that p is inverse of p', it is described in form of $(x, y) \in \mu\,(p) \Rightarrow (x, y) \in \mu\,(p')$ and $(x', y') \in \mu\,(p) \Rightarrow (x', y') \in \mu\,(p')$.

In addition, flexible reasoning mechanism (Hanus, 1994), but particularly a wide range of higher-level semantic, is user defined inference rules by the first order logic to describe the concept. Such as:

Definition 5: User define relation: for example, (?s OwnOf ?function) ? (?location HasProperty ?s) ⇒ (?location owl:Support ?s). Suppose one arrives at a new location, the mobile send a request to server for getting the services by reasoning the defined relation that services own some function, meanwhile, these services is already described in a location, so we get a conclusion that this location supports such services.

It also has a partially ordered relation, which satisfies the transitivity, asymmetry and irreflexivity properties. We can build the complete lattices for all the concepts knowledge in Ontology (Karvounarakis *et al.*, 2002). For example, (?a property ?m) ?(?b property ? n) ?(?m subClassOf ?n)⇒ (?a subSetOf ?b). Consider that one concept A contains some attributes ($a_1, a_2, \ldots\ldots, a_n$), which is belong to set (b_1, $b_2, \ldots\ldots$, b_n) included in concept B. The expression A=B and the signal = represents the sub partial order relation, because there is a gradual reduction subset, illustrated by$\{ a_1, a_2, \ldots\ldots, a_n \} \subseteq \{ b_1, b_2, \ldots\ldots, b_n \}$ and n less than m. On the contrary, if we find a relation that B≥ A, all the properties used in A can be reused in B. So, it is useful for mobile devices during the critical tasks of services location that when mobile devices moves from location A to location B and the B has same function (such as music function and {music,vodie} ⊆{music,vodie,game}) compared with A, On the other hand, if the system exits anther partially ordered relation C = B, so the current playing application on our mobile client can be used continuously from A to C location. It also is used to terminate under decreased lattices reasoning for the complex described relation in Ontology.

EXPERIMENTS

As the Fig. 3 shows, there is a sensor in every room, from which the mobile devices can get the supported appliances and services. For example, while listening to the music, user moves from room 1 to the room 5. Conveniently, state B represents the current information mobile devices obtained and the function being used, we understand that some services switch to port 5 automatically for the location beyond to the scope of $port_1$'s services capabilities. If the system doesn't clearly understand the $port_5$ services' parameters and values, such as how long the music has been played before the user moves to room 5, as a result, the services in room 5 will start form the initialization state. It's a waste of time

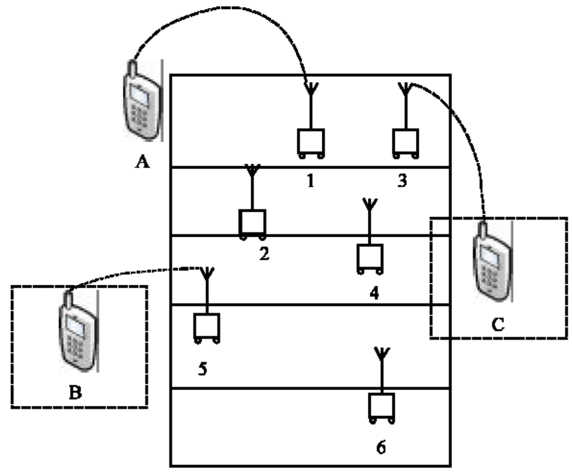

Fig. 3: A instance of location services for mobile

and resources. Furthermore, the music stream should be coherent when the user moves to room 3, in C state. Although, $port_3$ is near $port_1$, it lacks the music function. The requests are sent to $port_3$ repeatedly, it will fail because of service disruption, furthermore a breakdown of the services.

We present the experiments of the proposed methodology, which aims to show the high performance of the LPS method for mobile devices based on Ontology. Unsurprisingly, the performance of each mobile in ubiquitous environment corresponds to more flexible movement. To verify the experiment group really gets higher users' satisfaction, the comparative experiments are applied. Then, we will analyze the results of our experiments into two steps.

First, we construct the scenarios that we change our location in order to test the modules functions serviced on the corresponding situation. The efficiency ratio and the accuracy are counted to evaluate the performance of the utilization of the resources and functions for mobile devices, which are dispensable factors in testing the method this paper proposed. One can consider this as an experiment in which a person takes mobile devices and plays the supported appliances, with each part working to its best despite the change of location. Meanwhile, the data as how many devices work normally and whether the services content are working correctly or not by Boolean, is shown in Table 3.

In music services, we find that the event Continues, which refers to playing music without interruptions, has higher efficiency ratio and accuracy than the others. The event Forward and Backward ave lower index because we should do some calculating or reasoning to get the context. In video services, the average is lower than music services because it requires the records of the current

Table 3: The results of test some module at different event

Module name	Target function name	Response event	Ratio (%)	Accuracy (%)
Music services	Song 1	Continue	97.5	92.4
	Song 2	Replay	84.7	75.5
	Song 3	Forward	81.5	80.5
	Song 3	Backward	83.5	77.5
Video services	Video 1	Replay	70.1	78.4
	Video 2	Stop	80.4	84.5
	Video 3	Continue	69.5	78.7
Game services	Game 1	Switch	48.3	95.5
	Game 2	Login	95.5	90.3
	Game 3	Logout	98.3	86.4
Search engine	Key word	Search	86.4	87.5
	Semantic	Search	75.9	76.4
FTP services	Movie	Connect	80.5	92.5

Table 4: Dynamic movement with Ontology

Ratio (%)	20	25	30	40	45	50
Accuracy (%)	20.4	60.4	64.4	78.4	85	90.4

Table 5: Dynamic movement without Ontology

Ratio (%)	20	25	30	40	45	50
Accuracy (%)	18	22.3	28.4	35.3	43.6	46.3

Table 6: Dynamic evolution of services in LPS

Ratio (%)	20	25	30	40	45	50
Accuracy (%)	80.3	23	34	32	75.5	80

video position and the length of the clips played. In game services, when we play two services in two different mobile devices, for the real-time requirements, the more thread played, the lower ratio system is ensured with the event “Switch”. In search engine and FTP services, it’s just a process of communicating with text or byte stream, such as the upload and download operation, the performance is in the middle level with less context or computing. In summary, the smaller the stream files are transported the higher performance it possesses.

Secondly, we pay attention to the devices’ dynamic movement and the services dynamic evolution in runtime. Its objective is to minimize the possibility of fault. Strong emphasis has been directed to the application of semantic context in LPS in order to attain services continuity and integrity, including the tolerance of services faults in runtime.

Table 4-6 show the simulation results. In Table 4-5, the dynamic movement of devices is shown to be tested, the comparative experiments are composed of two activities: Table 4 uses the formal method of Ontology to record the context; the other is tested by contraries. In Table 6, it specifies the concurrent test of LPS processes while the services on server may be dynamic evaluated. The descriptions of the incorporated activities results and the performance are presented next.

The data of Table 4 are tested by concurrent with the help of the semantic of Ontology. When the ratio of the mobile devices decreases gradually, we find that high performance of the local positioning services appears. This reflects that the lesser number mobile devices concurrent executed, the better performance is ensured. Using the normal way without recording the context, compared with the Table 4, without Ontology, Table 5 shows that the accuracy is equal to the percentage of the mobile devices in dynamically movement, with greatly reduced accuracy and poorer efficiency than Table 4.

The existing services in location will also be dynamically changed, because of the limitations of services when dealing with the failures. In fact, given that the dynamic evolution occurred, it should restart or recover the services within the specified time. Table 6 shows that there is great difference between 40 and 45%. The mobile devices get lower satisfaction on the decreasing services sets in location at the rate between 25-40%. More than 45%, the accuracy rises again due to the knowledge described in Ontology, which used to notify the mobile there exists catastrophe or the current service has been stopped. Then the mobile will change the communication to the neighbor node.

CONCLUSION

As previous studies, (Liao and Chao, 2008) address the problem of data transmission among mobile users, a location-dependent approach, called Location-Dependent Data Encryption Algorithm (LDEA), is proposed in their study. But their approach only focus the data encryption and unable to support the context awareness.

Weihong *et al.* (2007) aimed at the contradiction question between terminal resources limited and terminal computation in mobile collaboration, a case-based reasoning computation migration mechanism (CBRCMM) was proposed. But implementing the mechanism is not easy and error-prone.

Computation migration provides an efficacious method for wireless, David *et al.* (2002) gave a module-based mobile agent and its schedule method. However, the mobile agent does not correspond very well to the architecture of dynamic services evolution for mobile computing devices.

Abreu *et al.* (2004) proposed a cost-effective architecture for such a system based on Time Difference of Arrival (TDoA). But delay of very small time intervals is not easy measured by the exiting tools.

Transaction processing is of growing importance for mobile computing. Laux *et al.* (2008) introduced a transaction model that allows higher concurrency for a certain class of transactions defined by its semantic. But the temporarily disconnected situations have more complex semantic, which needs to be recorded and do some reasoning.

Location is key feature of the mobile devices in runtime, including routing knowledge, services' content, Qos description, etc. In order to get services continuity and integrity with the change of locations, this study focuses on Ontology technology to construct architecture and to propose a method for Local Positioning Systems (LPS). Ontology, based on XML and RDF/RDFS standard documents, formally describes the semantic, which helps us to solve the problem of context and location awareness problems under wireless infrastructure. This research is expected to share the descriptions in Ontology and to reason the semantic.

However, the LPS technologies involve more research areas other than the applications mentioned in this paper, such as hardware cost, computing energy consumption. How to extract proper domain knowledge would be a critical problem when our system is implemented. It requires more research efforts in the future and is a promising solution for series of problems.

ACKNOWLEDGMENTS

This study is supported by the Special Funds for Key Program of the China No. 2009ZX01039-002-001-04, 2009ZX03001-016, 2009ZX03004-005, National Natural Science Foundation of China (NSFC) under grant No. 60673115 and 60970007, National High-Technology Research and Development Program (863 Program) of China under grant No. 2007AA01Z144, the National Grand Basic Research Program (973 Program) of China under grant No. 2007CB310800, the Natural Science Foundation of Shanghai Municipality of China under Grant No. 09ZR1412100 and Shanghai Leading Academic Discipline Project (Project Number: J50103).

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