Eighth Pacific-Rim International Workshop on Multi-Agents (PRIMA'05)

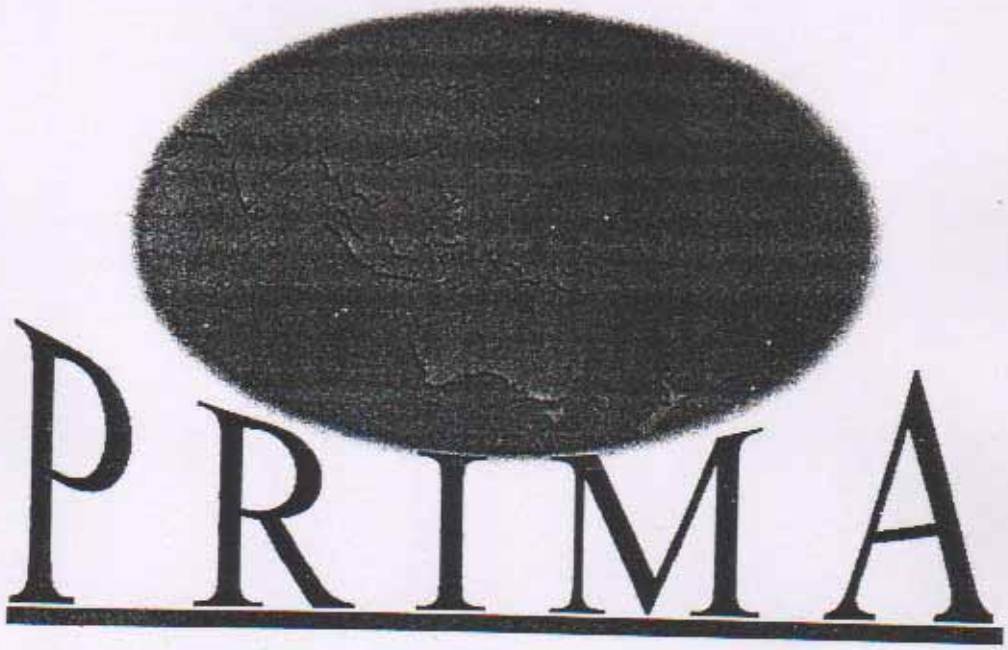

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Table of Contents

KEYNOTE PAPERS

Application of Information Processing Technology by Multi-Agent Simulation 1
Hideyuki Nakashima

Trading Agent Stories: Lesson from an International Trading Agent Competition (Abstract) 5
Michael P. Wellman

Cognitive Architectures and Multi-Agent Social Simulation 7
Ron Sun

Multi-Agent Robot System and Human-Robot Interaction 23
Shamsudin H.M. Amin, Rosbi Mamat, Norshelia Fisal, M.R. Ahmad, C.F Yeong and H.L.Wong

FULL PAPERS

A Co-operative Intelligent Assisting Agent Architecture for Web Searching and Desktop Management 1
Nandan Chaturbhuj and Shivashankar B. Nair

Prisoner's Dilemma Game on Network 9
Masahiro Ono, Mitsuru Ishizuka

Addressing Constraint Failures in Agent Interaction Protocol 23
Fadzil Hassan, Dave Robertson & Chris Walton

Accurate Neuro-Fuzzy Action Selection in MultiAgent Systems 39
Reza Zafarani, Mohammad Reza Yazdchi

Reasoning about Success and Failure in Intentional Agents 53
Timothy William Cleaver, Abdul Sattar, Kewen Wang

Agent-Based Workflow Management System Architecture – An Example on Conference Info System 67
Feng-Chao Yang

Diverse Applications of an Automated Argument System based on Logic of Multiple-Valued Argumentation 85
Hajime Sawamura and Go Wun Jeong

Dynamic Interaction Protocol Load in Multi-agent System Collaboration 101
Maoguang Wang, Zhongzhi Shi, Jiewen Luo,Jun Hu, Fen Lin

Towards a Component-Based Architecture for TeleAgents 117
Ockmer L. Oosthuizen and Elizabeth M. Ehlers

MARS – A Multi-Agent System Playing Risk..... 133
Stefan Johansson, Fredrik Olsson

Development of a Lightweight Middleware Technologies Supporting Mobile Agents 149
Gu Su Kim, Jaegon Kim, Hyun-jin Cho, Won-taek Lim, Young Ik Eom

The Roles of Active Perception in Intelligent Agent Systems 161
Raymond So, Liz Sonenberg

A Coloured Petri Net Based Strategy for Agent Based Grid Scheduling 175
Quan Bai, Jia Tang, Minjie Zhang

Fairness in Cooperating Multi-Agent System – Using Profit Sharing as an Example 187
Ming-Chih Hsu, Von-Wun Soo

Risk Strategies and Risk Strategy Equilibrium in Agent Interactions Modeled as Normal Repeated 2 x 2 Risk Games 197
Ka-man Lam, Ho-fung Leung

A Crowd Model for Emergency and Panic Situation: Structure, Characteristics and Behaviours 213
Mohd Bazli Ab Karim, Abdullah Zawawi Talib, Ahmad Izani Ismail, Bahari Belaton

Learning the Structure of Utility Graphs Used in Multi-Issue Negotiation through Collaborative Filtering 229
Valentin Robu, Han La Poutré

ARTISTE: Agent Organization Management System for Multi-agent Systems 245
Atsushi Terauchi, Osamu Akashi, Mitsuru Maruyama, Kensuke Fukuda, Toshiharu Sugawara, Toshio Hirotshu, Satoshi Kurihara

Autonomous Natural Language Translation to Agent Language for FIPA Compliant Multi-Agent Systems 261
Nauman Ahmed Qureshi, Arshad Ali, Hafiz Farooq Ahmad, Hiroki Suguri

Sensor Management Model using Multi-Agent in Small Area Sensor Networks 275
Keonsoo Lee and Minkoo Kim

Conflict Resolution Method for Multi-Context Situation 285
Keonsoo Lee and Minkoo Kim

Multi-Auction Approach For Solving Task Allocation Problems 295
Chi-Kong Chan, Ho-fung Leung

Significance of Semantic Language in Multi Agent Systems 311
Sana Khalique, Mobeena Jamshed, Hiroki Suguri, Hafiz Farooq Ahmad, Arshad Ali

Using Classification Learning in Companion Modeling 327
Daisuke Torii, Francois Bousquet, Toru Ishida, Guy Trébuil, Chirawat Vejpas

Hybrid Inference Engine for System Diagnosis 343
JinPyung Kim, MoonHyun Kim

Modeling a Multi-Agent Mobile Robotics Test Bed using a Biologically Inspired Artificial Immune System 359
Chingtham Tejbanta Singh and Shivashankar B. Nair

Deploying Multi-Agents for Intelligent Aspect-Oriented Web Services 373
Santokh Singh, John Hosking, John Grundy

xMDR for Data Synchronization using Mobile Agent System 387
Youn-Gyou Kook, R. Young-Chul Kim, Young-Keun Choi

An Interval-based Knowledge Model and Query Language for Temporal Information 401
He Hung, Zhongzhi Shi, Xiaoxiao He, Lirong Qiu, Jiewen Luo

Design of an Autonomic Agent Construction Model for Second-generation FIPA-Compliant Multi-Agent System 417
Amina Tariq, Amna Basharat, H.Farooq Ahmad, Hiroki Suguri, Arshad Ali

A Petri-Net-Based Modeling Framework for Automated Negotiation Protocols in Electronic Commerce 433
Shujuan Ji, Qijia Tian, Yongquan Liang

Agent-Based Interaction Model for Electronic Health Record System 447
Il Kon Kim, Sung Hyun Lee, Hyoung Jun Seo

Implementation of a MedVI Agent a Medical Vocabulary Interpreter for Medical Agents 461
Kambiz Houshiaryan, Il Kon Kim, Hune Cho, Yun Sik Kwak

Multi-Agent Cooperation: A Description Logic View 479
Jiewen Luo, Zhongzhi Shi, Maoguang Wang, He Huang

Enhancing Bidding Strategies in CDAs by Adaptive Judgement of Price Acceptability 495
Huiye Ma, Ho-fung Leung

Dealing with Objectives in a Constraint-Based Extension to AgentSpeak (L) 511
Aniruddha Dasgupta and Adithya K. Ghose

xMDR for Data Synchronization using Mobile Agent System

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Abstract. In this paper, we propose to extend MDR (Extended Metadata Registry) to ensure the interoperability of data in the synchronized multiple mobile environment, and describe data synchronization using the mobile agent system. The proposal of xMDR is to solve the problem of data heterogeneity and inconsistency in sharing and exchanging data. Data heterogeneity is generated by different definition or mismatched expression of the same-meaning data. Therefore, we define and design xMDR using XML documents by analyzing data elements based on MDR(ISO/IEC 11179) specification. We also implement our synchronizing mobile agent system, which use xMDR to solve data heterogeneity for data interoperability through synchronizing data. It provides more efficient agent through reducing errors that happened on synchronizing requests and adding new systems with their own data.

1. Introduction

As the necessity of information sharing for interoperating distributed data in synchronized multiple mobile environments is increased, current researches for data synchronization are progressing widely. Data synchronization in multiple mobile environments should be considered two aspects. First one is the aspect of system, which has many particular features, such as diverse types of platform, autonomous data manipulations, and network traffics. We solve these problems with mobile agent mechanism to guarantee 1) the independence from system platform, 2) the autonomy of data manipulations that is inserted, updated and deleted, and 3) the effectiveness on network traffics [1,7,9].

Second is the data aspect of the system, which has the data heterogeneity and inconsistency on synchronizing data. The data heterogeneity is classified with the schema and the data value heterogeneity. The former usually occurs on which have different structures at the same information or different naming at the same structure. The latter occurs on mismatched expression at the same data [4,8,19].

Therefore, we propose a synchronizing mechanism with the mobile agent system for the interoperation of the distributed data environments. The proposed mobile agent system includes xMDR(Extended Metadata Registry) to resolve the data

heterogeneity. xMDR is designed with 1) XML as web document standard and 2) MDR as data integration standard. MDR is suggested by ISO/IEC 11179 which standardizes and registers data elements, and describes a data elements registry [15]. Therefore we design to extend MDR (called xMDR) for shared data. It is used by mobile agent system for conversion from transmitted XML to a data of local system, vice versa.

The remainder of this paper is organized as follows. The section 2 describes the structure of xMDR, section 3 describes a synchronizing mechanism with mobile agents system, and section 4 presents implementation of the system. Finally, we conclude in section 5.

2. Design of xMDR(Extended Metadata Registry)

ISO/IEC 11179 part 3 [15] mentions that a metadata model for data processing and electronic data interchange heavily relies on accurate, reliable, controllable, and verifiable. It provides the introduction and standard for the data element's constructions which are shared by users or data processing systems on the distributed environment.

Figure 1 shows a conceptual view of xMDR which defines xMDR from local systems (within a domain) through designing Metadata Registry for interoperating data on distributed locations.

We define xMDR for data sharing and exchange through the designed MDR, which designs based on MDR (ISO/IEC 11179-3) specification.

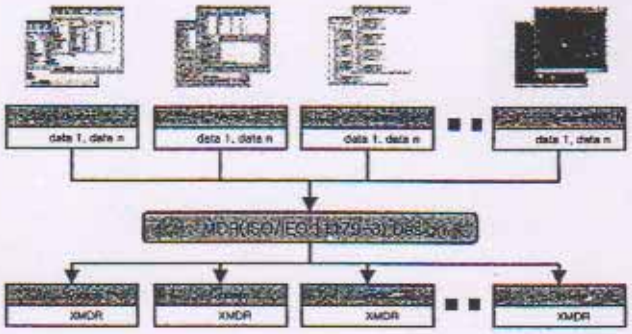


Fig.1 . The outline of xMDR

The Metadata Registry for data processing and data interchange is shown in Figure 1. Through analyzing and gathering each local MDR from each local mobile system, we can make Metadata Registry which includes all local MDRs of all local mobile systems like Figure 2.

Figure 2 shows to extend MDR for data synchronization on the environment of multiple mobile systems.

In MDR, there are classified by 4 field areas, that is, four attribute's types, which contain their own attributes as follows:

- Identifying : attributes that are applicable for the identification of a data element (MDRID)
- Definitional : attributes that describe the semantic aspects of a data element (FIELD)
- Relational : attributes that have associations among data elements and associations between data elements and classification schemes, data element concepts, objects, entities (TABLE, DATA, DOMAIN_CATALOG)
- Representational : attributes that describe representational aspects of a data element (TYPE, LENGTH, NULL, KEY, FORMAT)

When the data was modified at the local system, the system requests the synchronization to the other systems. If the synchronization starts, data and query of local system will be converted to the synchronization XML document using xMDR mapping. After each local system receives the synchronization data, it converts XML documents to the local-acceptable data and query using its own xMDR mapping. This procedure and system will be described at section 2.

Identifying Attributes	Definitional Attributes	Relational Attributes			Representational Attributes				
MDRID	FIELD	TABLE	DATA	DOMAIN_CATALOG	TYPE	LENGTH	NULL	KEY	FORMAT
MDR0000	ProductCode	StockControl	ProductControl	DC1	varchar	15	not	yes	
MDR0102	ProductName	StockControl	ProductControl	DC1	varchar	50	not		
MDR0103	ProductDate	StockControl	ProductControl	DC1	datetime				yyyy-mm-dd
MDR0104	ProductState	StockControl	ProductControl	DC1	int	5			
MDR0000	stock_code	tbl_stock	db_product	DC1	varchar2	15	not	yes	
MDR0102	stock_name	tbl_stock	db_product	DC1	varchar2	50	not		
MDR0103	stock_date	tbl_stock	db_product	DC1	date				yyyy-mm-dd
MDR0104	stock_state	tbl_stock	db_product	DC1	number	5			
MDR0000	ST001_CO	ST001	DEST	DC1	varchar	15	not	yes	
MDR0102	ST001_NA	ST001	DEST	DC1	varchar	50	not		
MDR0103	ST001_DT	ST001	DEST	DC1	datetime				yyyy-mm-dd
MDR0104	ST001_MO	ST001	DEST	DC1	integer				
MDR0000	CODE		product	DC1	string	15	not		
MDR0102	NAME		product	DC1	string	50	not		
MDR0103	DATE		product	DC1	string				yyyy-mm-dd
MDR0104	STATE		product	DC1	integer				
MDR0000	ProductCode	WareControl	ProductControl	DC1	varchar	15	not	yes	
MDR0102	ProductName	WareControl	ProductControl	DC1	varchar	50	not		
MDR0000	ware_code	tbl_warehousing	db_product	DC1	varchar2	15	not	yes	
MDR0102	ware_name	tbl_warehousing	db_product	DC1	varchar2	50	not		
MDR0000	WT001_CO	WT001	DEST	DC1	varchar	15	not	yes	
MDR0102	WT001_NA	WT001	DEST	DC1	varchar	50	not		
...	...	...	...	...	...	...	...	...	...

Fig. 2. Metadata Registry for shared data

After we will partition each local own MDR from a whole MDR in figure 2, send each local own MDR to each local system.

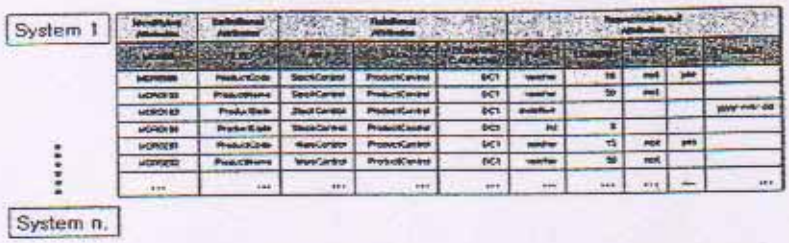


Fig.3 . Metadata Registry for shared data of each Local System

Figure 3 shows a part of each local MDR from A whole MDR designed for data sharing and exchange. We will locate each local own MDR for guaranteeing the independency and extensions of data.

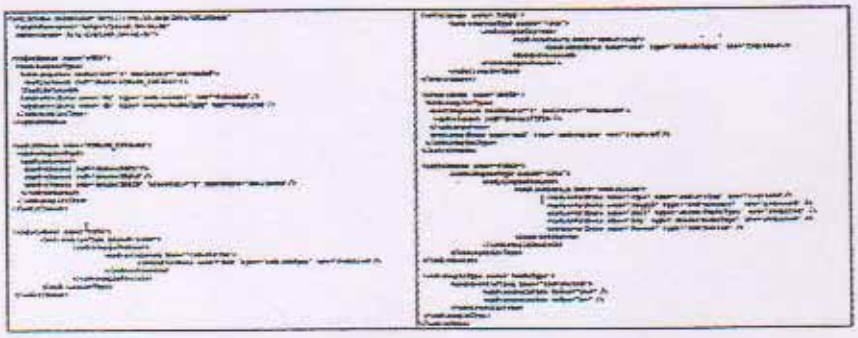


Fig.4 . XML Schema for xMDR

Figure 4 shows a schema of xMDR for defining MDR of local system.
xMDR should be designed based on predefined MDR, and it is necessary to make the standard for the transmission of local data from mobile local systems during synchronization process. So, xMDR has the validation restriction through definition of document structure. xMDR's structure is standardized by defining XML schema with all local MDR's composition information, so MDR's modification does not affect the xMDR's structure, because the reliance of document and data exchange have to be guaranteed.
xMDR's schema defines the elements which are suitable to the synchronizing data structure. DOMAIN_CATALOG element can be created multiply and it is constructed for the one synchronizing data set. DOMAIN_CATALOG has DATA, TABLE and MDRID as child elements, and MDRID including FIELD as data column's attribute. FIELD includes data type and length, and existence of null and primary key can have 'yes' or 'no' attribute.

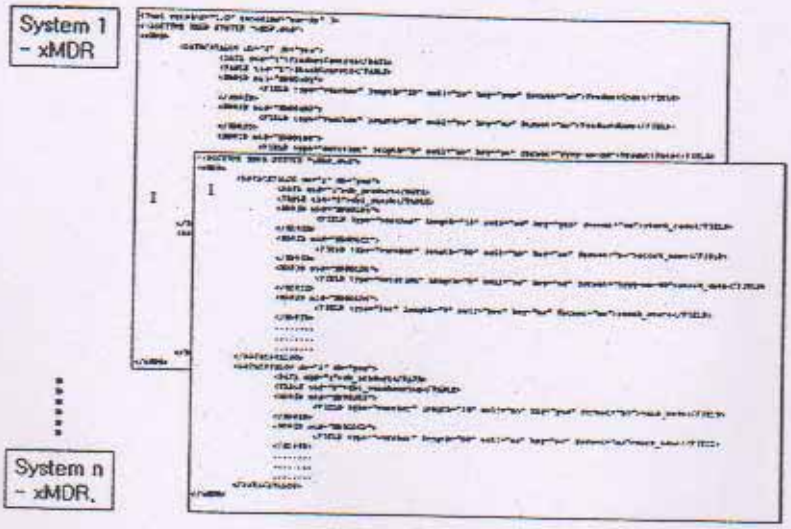


Fig.5 . xMDR Document of Local Systems

Figure 5 shows to define xMDR with local MDR of each local system based on predefined MDR of Figure 3. This has restricted to the document validation of xMDR schema. xMDR also defines DOMAIN_CATALOG for different groups of each specific local systems in the global environment.

In this paper, we would like to mention that the types of data heterogeneity for data interoperation are very diverse and that semantic heterogeneity, type heterogeneity and expression heterogeneity will also be resolved. The characteristics for resolving data heterogeneity are described below. The data semantic heterogeneity is generated from the different structure at the same information, so the elements which make meaning sameness are included. DATA and TABLE are relational elements. MDRID element identifies the same semantic data sets as a target of synchronization, and it has FIELD and GLOBAL as child elements. FIELD defines the attributes of data, and it has many attributes to represent data. GLOBAL has the actual MDRID value. The type heterogeneity is resolved by the type, length, null and key attributes in FIELD, and the expression heterogeneity can be eliminated by format attribute in FIELD. The remained elements in Schema are used for the semantic heterogeneity. Figure 5 is xMDR document which defines local data's xMDR. It is located at the local synchronizing mobile agent system, and resolves the distributed data heterogeneity through converting local data to XML data for global transmission. Also the distributed data's autonomy and independent are assured by using xMDR.
When the global synchronization is requested by local data's event, local database and table information is classified by 'did' and 'tid' which are their own attribute, and create the same attribute at the synchronizing XML. Also local data's column information is mapped MDRID value and synchronizing XML is created. This created synchronizing XML is transmitted globally.

The local systems which receive the synchronizing XML map synchronizing XML to the local repository's data and query by xMDR. The relational attributes, table and column information are extracted, and data type, length and expression are converted to local suitable type. This conversion resolves the data heterogeneity, and this system which is in charge of converting them is described next section

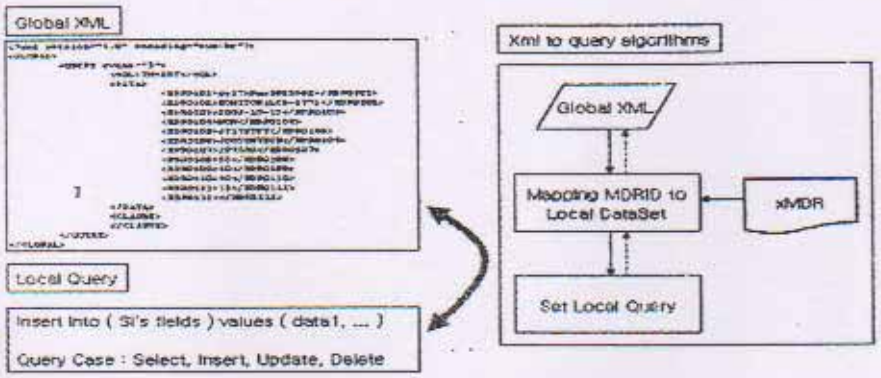


Fig.6 . Converting XML to Local Query using xMDR

Figure 6 shows a procedure to convert XML into query through xMDR for data interoperability on local system. A query happened from local system can generate XML through this conversion's procedure, which is transmitted to all global area Moreover, through XML-to-query algorithm, we can automatically convert XML, which transmitted from global one, into local query for which is applied on local system

When the query manager converts data to the XML, it is composed differently as the kind of data changed event. The data changed event is classified with the data insert, delete and update. The synchronizing XML includes query attributes, QUERY and SQL which includes events as content. The QUERY attribute is composed differently as the event. The insert event's synchronizing XML includes data's MDRID and the other contents followed by MDRID. The update event's synchronizing XML includes CLAUSE element which is the where clause in SQL, and MDRID which will be updated, and data which will use for updating. The delete event's synchronizing XML includes only CLAUSE attribute for deleting.

3. Mobile Agent System

This section describes a synchronizing mechanism with the mobile agent system which resolves the problem of data heterogeneity. Figure 7 shows a whole infrastructure of mobile agent system. We would like to use xMDR to solve the problem of data heterogeneity with mobile agent against heterogeneous differences between distributed systems.

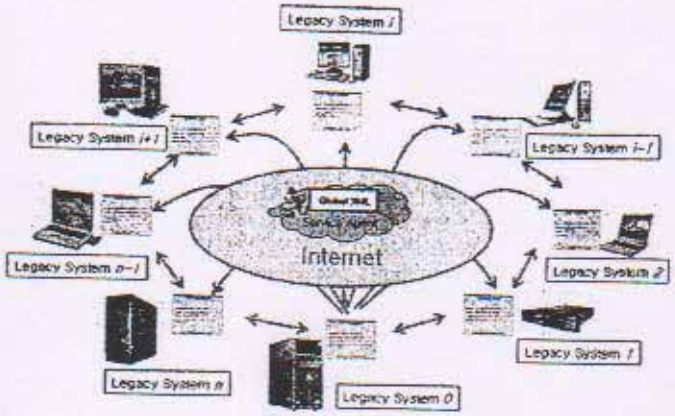


Fig.7 . The infrastructure of Mobile Agent System

The direction of arrows in figure 7 appears the migration method of mobile agent. Each Legacy system must have its autonomous mechanism with mobile agent system as the independent distributed system.

In our approach, mobile agent can be extended as service agent for data synchronization, and also include global XML converted with local query.

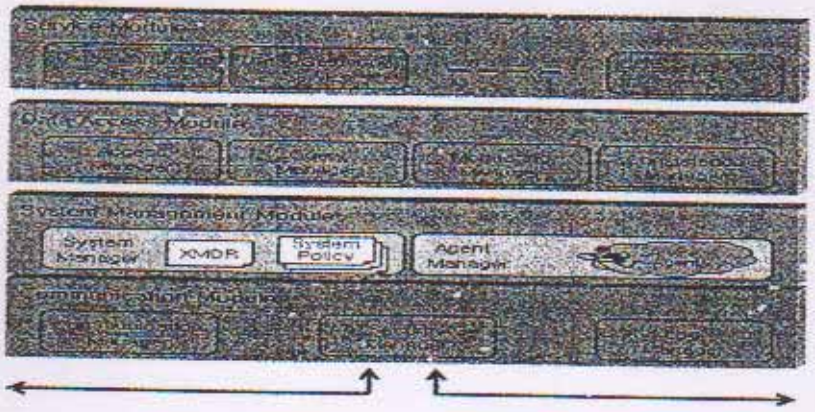


Fig.8 . The architecture of Mobile Agent System

The synchronizing mobile agent system consists of four layers. Each layer is communication module, system management module, data access module, and service module respectively. First, communication module should be a role of communication between agent systems and also consist of communication manager, security manager and log manager. Communication manager initiates and manages to communicate between one system launched and other system which launches mobile agent. Security manager is responsible for the authorization of mobile agent.

Log manager manages and registers all events happened in agent system and all transmission/receipt of mobile agent. In this paper, this manger uses Java's basic security package to authenticate mobile agents. So the security policies of mobile agent's transmission are limited to the agent server's authentication, and further researches are necessary.

Second, system management module sets the priority of synchronization according to the target system's path and importance of system, and defines the basic information to access data. This module includes agent manger and system manger. The agent manager manages and controls policies between synchronizing systems, and records all the events from the synchronizing mobile agent system. Also it authenticates synchronizing agent and manages related agents. The system manager defines xMDR based on MDR which is a standard for data exchange and XML which is the document standard. xMDR is used for the conversion of XML, local data and query when synchronizing data's global transmission upon synchronizing request.

Third, data access module accesses data of legacy system. This module includes access manager, query manager, monitoring manager, and consistence manager. The access manger manages association among data, the query manger manages local query and global XML through xMDR, the monitoring manger requires data synchronization on global after recognizing the happened events from each autonomous and independent legacy system, and consistence manger avoids congestion from the data synchronization, and detects the event which changed data, and requests synchronization globally. This module's data consistency managing process is shown at [17].

Finally, service module may be very important one for practical application of data and also for providing diverse services with mobile agent. This module also includes data-modifying service and data-gathering service.

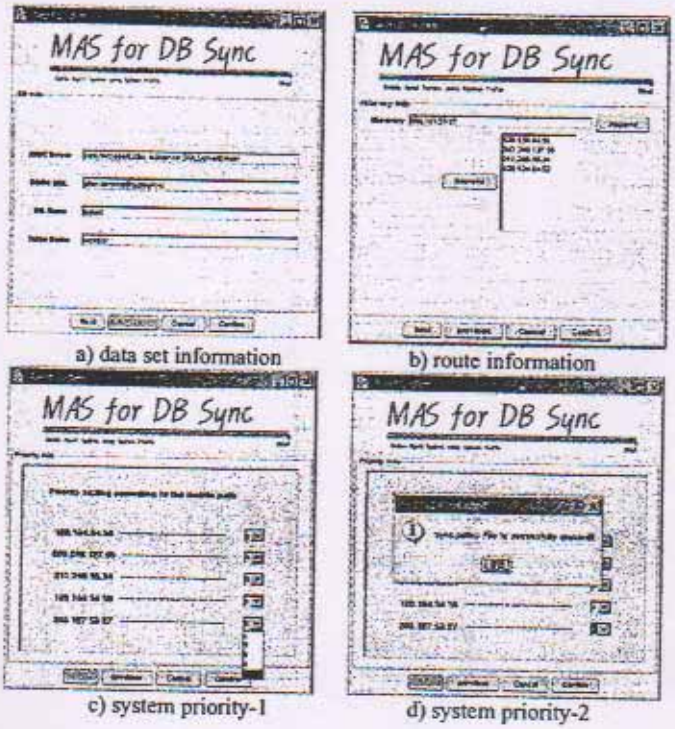
4. Implementation of the system

For the data synchronization at the distributed environment, 1) the platform should be independent, and 2) the data autonomy for update and delete operations should be assured and 3) the network traffic problem should be considered. To solve these problems, we use the mobile agent which reduces the network load and traffic, and runs at the local system after receiving data and code at run time from remote system. Java is the development language in this paper. In addition, XML is used as the standard document of resolving data heterogeneity for the interoperation, so JAXP1.0 is selected for the XML parser.

4.1 Setting up the System Policy

The policy at the synchronizing agent system is consists of 3 parts, which are database information, path information and system priority. First, the database information sets JDBC which is the basic information to access database, URL and DB, table information which are necessary to synchronize. Second, the path information sets the unicasting information for the synchronizing agent's migration. Third, the system

priority information sets the high priority to the frequently data changed systems without concerning the path information. The data consistency is maintained based on the time-stamp by synchronization policy. If the same time-stamp value makes data conflict, the system priority will decide the data's validation or invalidation. System priority value cannot be duplicated. Figure 9 is system policy setting dialogs.



a) data set information b) route information

c) system priority-1 d) system priority-2

Fig. 9. Setting up system policy

4.2 Migration Mechanism

4.2.1 Mechanism of Synchronizing Agent

The consistence manager which recognizes data modification by external application requests data synchronization to agent manager. The consistence manager sends information of the event. The agent manager sends synchronizing agent through given path, and requests records of the event in the system to log manager. The security manager of the destination node authenticates synchronizing agent, and sends policy information to the communication manager. The synchronizing agent migrates with information which includes data modified by data update, insert and delete operations and status of source system. Fig. 10 shows migration mechanism of synchronizing agent.

4.2.2 Mechanism of Data Synchronization

The agent manager received the synchronization request will demand the detail information of log from log manager and the status of data collision from the consistence manager. The consistence manager decides whether it executes synchronization by status of data collision or not. Then it sends the result to the agent manager. The consistence manager executes data synchronization, and sends the result to the agent manager. The agent manager is authenticated by the next destination node and sends synchronizing data, server status and results of synchronization. Fig. 11 shows mechanism of data synchronization.

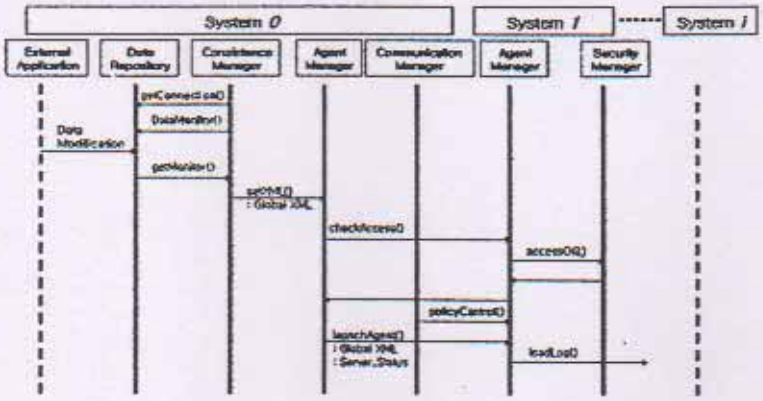


Fig.10 . Migration Mechanism of Synchronizing Agent

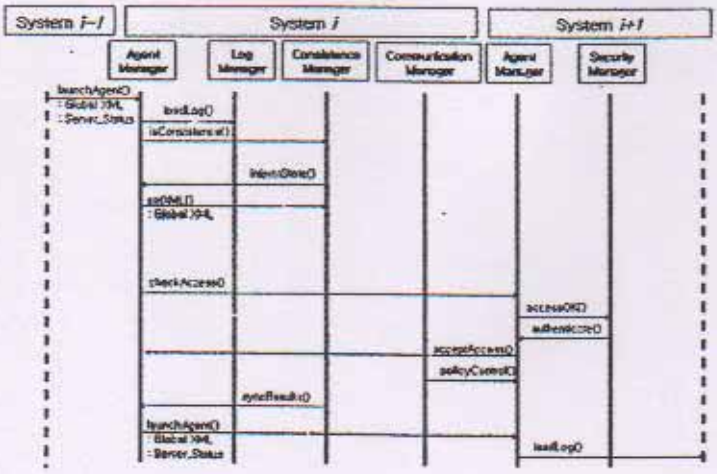
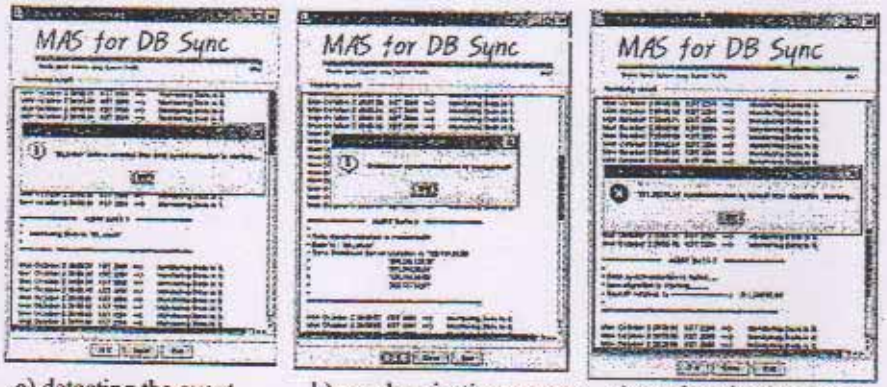


Fig.11 . Data Synchronization Mechanism

4.3 Running the synchronizing agent

The monitoring activity and the result of synchronization for the data modified event at the consistence management module are described below. The synchronizing agent system always monitors the event which modified data. If the event is detected like figure 12-(a), the data and query are converted to the GLOBAL XML by query manager. The query manager sends GLOBAL XML to the agent manager for requesting synchronization globally. The agent manager runs synchronizing to the established path's target system which was set at the system management module. If the data synchronization is success, the synchronization complete message will be shown like figure 12-(b). In addition, failed node of synchronization will show the failure message like figure 12-(c), and retry to send the synchronizing agent to that node.



a) detecting the event b) synchronization success c) synchronization failed

Fig. 12. Running Synchronizing Mobile Agent

4.4 Analysis of result

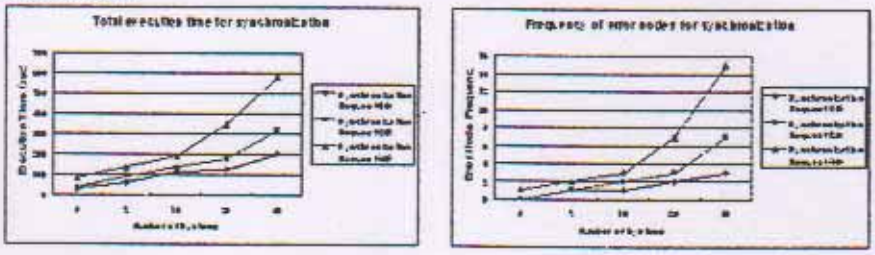
The solution of data heterogeneity to ensure an interoperability of distributed data has studied at many research organizations since several years ago. There are some of data exchanging system using meta data, the well-known Microsoft's BizTalk[17] and X-MAP[4] system which David Wang suggested. BizTalk changes the data through making maps between schema using Mapper, and X-MAP system associates the meaning of schema factors, and it is suggested for the data interoperation of multiple heterogeneous systems.

Table 1. The comparison of Data exchanging system

	BizTalk	X-MAP	This system
MDR(ISO/IEC 11179) support	No	No	Yes
Data automatic exchange	Yes	Yes(partly)	Yes
System independency	No	Yes	Yes
Data Synchronization	Yes(partly)	No	Yes

The proposed system's objective is data synchronization at the multiple mobile environments, so the system comparison for the data exchange has 4 parts like shown in Table 1. First of all, the data integration standard MDR(IDO/IEC 11179)'s support and data automatic exchange after MDR schema design, system independent at the distributed system and data synchronization support. At the part of data synchronization support, BizTalk supports only local area network, and X-MAP does not support it. However this system considers the only part of differentiation from the data synchronization, so further studies of data differentiation is necessary.

Fig. 13 is the performance test result of synchronizing agent system. We did our experiment in Windows environment. We report result on two kinds of variations of the number of system nodes and synchronization request number. Fig. 13-(a) shows total execution time in the process of synchronization and total execution time increased linearly when the number of system nodes and synchronization requests are raised. It is because transmitting and synchronizing execution time is raised as synchronizing agent that uses unicasting which is serial transmitting method. We will improve this to parallel transmitting method for decreasing total execution time as future works.



(a) Total execution time (b) Frequency of error nodes

Fig. 13. Performance test of synchronization requests

Fig. 13-(b) shows increasing total execution time due to occurrence of error nodes which is caused raising synchronization requests. Here, error means failure of synchronization due to instability of system, network overload and software fault. As it shows in the result, when they process 40 times of synchronization in 40 systems, 1600 times of synchronization, under 10 times of errors were occurred. Even though total execution time of synchronization is relatively increased caused by error occurrence, there are little errors due to the experiment in intranet. However experiment of synchronization system which is constructed in internet environment is needed for confidence of this system.

5. Conclusion

As the information sharing for interoperation is very important, the research for the data synchronization is increased. For the data synchronization, data heterogeneity should be resolved. The data heterogeneity usually occurs when the same information

or meaning is used or expressed differently. Therefore this paper designs xMDR to resolve the data heterogeneity for the interoperation of distributed data, and proposes the synchronizing agent system using it.

We define our proposed xMDR using XML as the document standard to resolve data heterogeneity during synchronization and MDR as the data integration standard. This will be used for the converting local data, query and for synchronizing XML with the synchronizing mechanism of mobile agent system. In addition, this system has the system priority and time-stamp transaction as a basic synchronization policy, and synchronizing mobile agent runs the synchronization with converting data and query to XML based on xMDR.

Therefore we propose the synchronizing mechanism that guarantees system stability, confidence, and extension with mobile agent system.

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