그리드 네트워크를 위한 모니터링 시스템의 설계 및 구현

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요 약

그리드는 고속 네트워크로 연결된 지리적으로 흩어져 있는 이종의 자원을 연결하여 서로 협업하기 위한 기반구조이다. 그리드 응용을 수행하는데 있어 안정성과 신뢰성이 보장되기 위해서는 네트워크 자원이 관리되어야 한다. GGF의 그리드 모니터링 구조 워킹 그룹(GMAWG)은 대규모 분산 자원을 넓은 지역에 확장 가능하기 위한 효과적인 모니터링 구조를 제안하였다. 이 논문에서는 실제 네트워크 관리에 있어 GMA를 기반으로 하는 그리드 네트워크 모니터링 시스템을 설계하고 구현하였다. 본 시스템으로 네트워크 관리 센터는 그리드 네트워크의 유연하고 확장성있는 관리를 수행할 수 있을 것이다.

The Design and Implementation of Monitoring System for Grid Network

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ABSTRACT

The Grid is an infrastructure to connect heterogeneous resources that are scattered over areas with high-speed network and to cooperate with each other. To support Grid applications, network resources should be managed, since the network has to be safe and reliable. The Grid Monitoring Architecture Working Group (GMAWG) of the Global Grid Forum (GGF) proposed an effective architecture to be scalable across wide-area networks and encompass a large number of heterogeneous resources. In this paper, we describe the design and implementation of Grid network monitoring system based on the GMA for practical network management. By this system, network operations center can form a management system flexibly and scalably for Grid network.

키워드 : 그리드(Grid), GMA, 디렉토리 서비스(Directory Service), 모니터링 시스템(Monitoring System)

1. Introduction

The Grid is a technology and infrastructure to use resources that are scattered in network. To make Grid active, the technology for using Grid service needs to be standardized. In 1999, various groups organized the GGF (Global Grid Forum) for international mutual cooperation of Grid researches [1]. The GGF's Working Group has been formed according to technical issues and published records on the research activities. In Grid, high-speed network provides the basic function for the cooperation between resources. To perform Grid applications, network elements have to be safe and reliable. That is, network elements should be managed. The NMWG (Network Measurement Working Group) defines network metrics needed in Grid environment and researches the issues on that measurement. The GMAWG (Grid Monitoring Architecture Working Group) discussed an effective architecture for monitoring. In the GGF7, the main issue of the GMAWG is handled in the angle of monitoring service in the OGSA (Open Grid Service Architecture).

VO (Virtual Organization), which is scattered over areas and composed dynamically, jointly owns heterogeneous resources and cooperates by Grid technology and infrastructure. Also, in Grid environment, information can be greatly increased according to the scale of monitoring system. To reduce the monitoring overhead, system has to be organized to perform local management [2]. Current network monitoring architecture cannot provide the flexibility and scalability of monitoring domain for VO.

The GMA uses directory service for centralized information of various monitoring producers, which are scattered in network. The manager of VO stores the logical model of monitoring system in the directory [3]. When consumer, the user of monitoring information, requests a specific metric for resource, he can directly connect and get information from the monitoring producer whose information is provided by the directory. That is, central directory forms management organization and stores the naming and connection informa-

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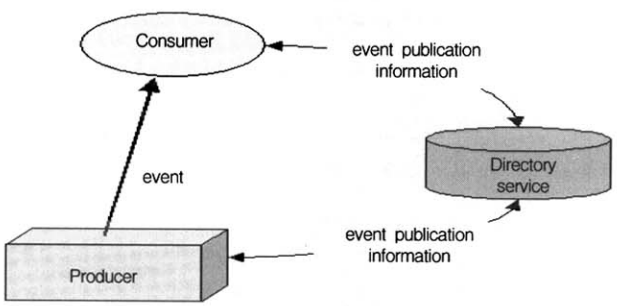
tion of network elements, providing a logical model. This can organize network management system flexibly and make the expansion of network management system easier. In this paper, we present the structure and the components to properly monitor network resources that are scattered over wide-area networks. Thus, web-based monitoring system, which is designed and implemented in this way, is expected to become the foundation for Grid network management system.

2. Related Studies

The GMA-WG of the GGF developed an architecture of monitoring components that specifically addresses the characteristics of Grid platforms. (Figure 1) shows three components of the GMA. Producers, which makes performance data available monitoring data, transfer the performance events to the consumer. Consumers, which receive performance data, requests to the producer and receives events. The directory service is used to locate producers and consumers. It supports information publication and discovery.



(Figure 1) GMA component

In the Grid, the amount of available performance information will increase greatly, and searches of this space will have unpredictable latencies. Therefore, a monitoring system must have precise local control of the overhead and latency associated with gathering and delivering the data. In the GMA, the existence of event is placed in the directory in order to separate data discovery form data transfer. Producer provides management information into the event stores meta-data in the directory. Even though matching pair of producer and consumer is dispersed, it can find each other. Therefore communication of data occurs directly between each pair [4].

The GMA is an abstract description of the components needed to build a scalable monitoring system. The followings are lists implementations that contain these components.

As being one of the DIDC (Data Intensive Distributed Computing Projects) of Lawrence Berkeley National Laboratory, the JAMM (Java Agent for Monitoring and Management) is the sensor management system. The JAMM consists of sensors, sensor managers, event gateways, directory service, event consumers, and event archives. The sensor produces managing data, and the sensor manager exists as an agent that controls the starting and stopping of the sensors. Event gateways receive requests from event consumer and performs producer's duty sending relevant event. The directory service is used to publish the location of all sensors and their associated gateway. Publishing meta-data of available information, an event directly occurs from producer to consumer by the request of the consumer. The JAMM controls execution and allocation of monitoring sensors in Grid environment [5]. The JAMM puts the sensor manager before the event gateway that sends an event for integrated management of resources and applications, controlling various kinds of sensors.

The NWS (Network Weather Service) provides performance forecasting service of scattered resource for meta-computing. The NWS consists of sensor process that collects performance measurements from a resource, persistent state process that stores and reads information from persistent storage, name server process that provides directory function of connection information of scattered process, and forecaster process that produces predicted value of performance. Since the NWS performs the forecast based on historical measurements, each sensor sends measurements to the storage. Name server has contact information of persistent state for sensors, so it is connected with persistent state that has historical information of resources to be forecasted [6]. In this manner, a producer of the NWS has peculiarity of making the information from persistent state to follow forecaster process.

Autopilot is an infrastructure for dynamic performance tuning of computational Grid. Autopilot consists of sensors which measure the performance of application, actuators which configure the resource management policies and the application behavior, name server which keeps the information of the remote sensors/actuators and sensor/actuator of the client [7]. For sensor/actuator of remote place that has no location information, a client of the application that performs the computational Grid of Autopilot gets connection information through the name server, thus directly communicating with the media that performs the application.

The R-GMA makes an alternative proposal about the structure that uses directory service based on LDAP in the GMA model. LDAP is a well-defined protocol, but it cannot provide calculating ability of different objects. Relational database provides various queries and it also provides plenty

of questioning ability like *join* operation. In the R-GMA, by using meta-information of producer and consumer as relational database, the structure combined with information service and monitoring service is proposed.

In our system, function of the directory service is limited to naming and containing connection information and don't have the necessity of complex queries. We build hierarchy of directory for extension's ability. Also, we have designed and implemented the monitoring system for elements in Grid network, not for measuring the application performance.

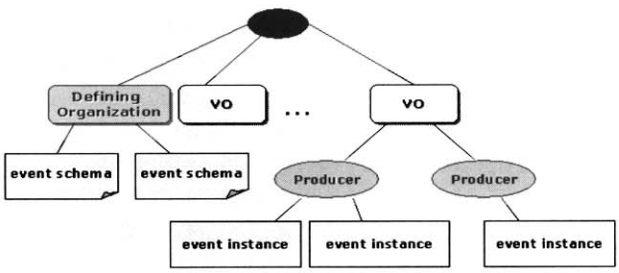
3. Structure of Grid Monitoring System

VO of the Grid can operate one monitoring system which has various producers monitoring the network resources. Producers collect the monitoring data of resources to send management data to the customer. The monitoring system of VO stores the contact information of the producer and the event provided by the producer in a common directory service. Consumers search the information of various producers that can receive monitoring data from the directory, thus directly connect to the producers.

3.1 Directory Service

To own a monitoring service of the network resource jointly, meta-information of different kinds of components should be centralized. To discover performance data of network elements on the Grid, a distributed directory service for publishing and searching of components must be available[8]. In our system, LDAP is used. It is easy to apply an architecture that has extension's ability to manage network elements that are scattered as standardized protocol approaching to the directory.

(Figure 2) shows DIT (Directory Information Tree), which is designed for the Grid monitoring system. A VO forms entries for a monitoring system and puts the information of producers that are formed in the monitoring system. The monitoring information of producers is stored as events. By storing information of producers that provide events, a consumer can get the information that it wants. Events need to maintain conformity to be available with one another through different monitoring systems on the Grid [9]. This is the part that will be defined in NMWG, and since there's no standardized part. We define a optional organization that defines the network metric to save schemas. By this, consumers can search the producer that provides the event interested in.



(Figure 2) DIT

To design the above directory entries into LDAP object schemas, we request OID to IANA and receive 1.3.6.1.4.1.13418. It is used in defining new objectclass and attributes. <Table 1> shows the defined directory objects.

3.2 Producer

A producer provides monitoring data to a consumer that requests it. By using the type attribute, producer sorted the type.

- Line Monitoring Producer : monitors interface of router or switch.
- System Monitoring Producer : monitors system.
- Trap Monitoring Producer : receives trap from equipment and manages it.
- Topology Producer : visualizes topology of network in the range of management system.

Basing on SNMP agent, network monitoring producer can become SNMP manager that collects and analyzes data. Since network elements do not perform applications itself, it can achieve data from the agent of a resource, like SNMP agent. Topology information of resources becomes a producer that provides management information to consumer. Each producer is described in the following.

3.2.1 Line Monitoring Producer

Line Monitoring Producer provides monitoring data of

〈Table 1〉 Definition of Object

Item	Objectclass	Description
VO	organization, organizationRole	It shows organizations that performs Grid project, and information of its monitoring system
Producer	eventProducer	It shows connection information of producers and resources that are registered to producer.
Event instance	eventInstnace	It shows the event that producer uses and parameters when requesting event.
Event schema	eventSchema	It defines the schema of an event that is used in Grid monitoring.

interfaces. It collects SNMP MIB values and analyzes these into meaningful items [10]. The items are defined in utilization rate, error rate, and packet loss rate. <Table 2> indicates MIB values and analytical formula to extract items.

Real-time performance analysis is a module that sends the management items real-time when a consumer requests it. It sorts requested messages and polls SNMP MIB values of the resources. Then by using the difference between previous polling value and present polling value, it calculates the management item of the event and sends it the consumer. Failure notification module gets the threshold that is set in the event from the directory and gets the item periodically. When it exceeds the threshold, it is notified in the consumer that set the threshold.

3.2.2 System Monitoring Producer

As the event that system monitoring producer provides, memory load rate is defined. Load factor is used as a parameter, which measures load of system occurred by the problem in performance of memory according to transmitting-receiving packet. The same as line monitoring producer, system monitoring producer performs real-time analyzing module, failure notification module and others.

These monitoring producers of line and system can be performed in one or more servers, issuing the existence to the directory. Producer can be organized according to the position of management resources and management items, forming management range flexibly.

3.2.3 Trap Monitoring Producer

Trap Monitoring Producer receives trap messages from equipments, and sends it to consumer real-time. In our system, Trap Monitoring Producer attains connection information about Topology Producer of VO from directory to show it on the map of manager.

3.2.4 Topology Producer

Topology Producer exposes the topology of network elements, and provides real-time traffic information and failure information on the map. Through this, failure situation and usage situation of network resources can be seen at a glance.

3.3 Consumer

A consumer is any component that requests the monitoring data and uses it. By the directory service, a consumer finds information of the producer that provides data to be monitored, and request it to the producer. A consumer consists of the various modules.

Directory watching module shows the structure of Grid monitoring directory. It shows producers that is used by monitoring system of each VO and events provided by producers, providing information of each entry. Directory search module searches information of the producer, the event and the resource in Grid network. By watching present state of the directory and searching functions, we can know the dynamic organization of large-scaled resources.

Threshold setting module sets the threshold of events in the directory, a producer that provides events, can be noticed when it exceeds the threshold. Analyzing request is a module that requests the event to a producer for the management item of the resource. Notification receiving module performs the management when a producer that registered notice of the failure receives the notice.

4. Design and Implementation of Grid Monitoring System

We designed architecture for Grid monitoring system. Consumer which requests a specific metric for resource directly connect and get information from the monitoring producer whose information is provided by the directory. It can make network monitoring flexibly and scalably.

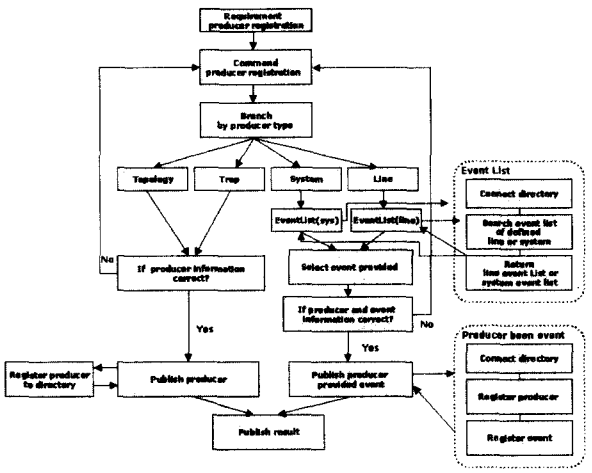
4.1 Monitoring Components Publication Flows

(Figure 3) shows process publishing producer. By registering information of producer and event in the directory, we can inform Grid monitoring system of producers that provide available events. First, it gets connection information of producer and the type of producer. If it is the producer that provides events, chooses events provided by the producer from the defined events. This registration information

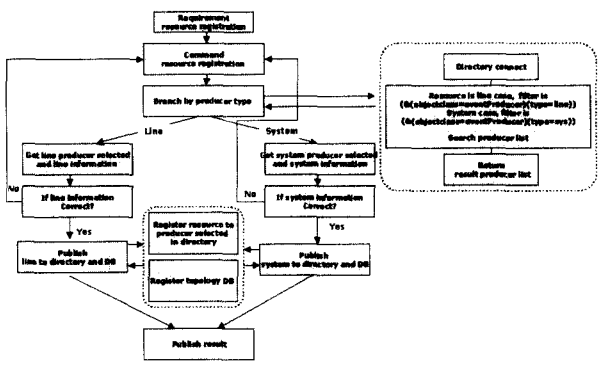
〈Table 2〉 Management item

Item	Collected MIB	Analysis Formula
Utilization Rate	ifInOctets, ifOutOctets, sysUpTime, LineSpeed	$\frac{Max(ifInOcters,\ ifOutOcters)*8*100}{(sysUpTime/100)*LineSpeed}$
Error Rate	ifInErrors, ifInUcastPkts, ifInNUcastPkts	$\frac{ifInErrors}{ifInUcastPkts+ifInNUcastPkts}$
Packet Loss Rate	ifOutDiscards, ifOutErrors, ifOutUcastPkts, ifOutNUcastPkts	$\frac{ifOutDiscards+ifOutErrors}{ifOutUcastPkts+ifOutNUcastPkts}$
Memory Load Rate	ipInDiscards, ipOutDiscards, ipRoutingDiscards, ipInReceives, ipOutRequests	$\frac{IpInDiscards+ipOutDiscards+ipRoutingDiscards}{ipInReceives+ipOutRequests}$

of the producer is confirmed by a manager and is published in the directory.



(Figure 3) Producer Publication Flow



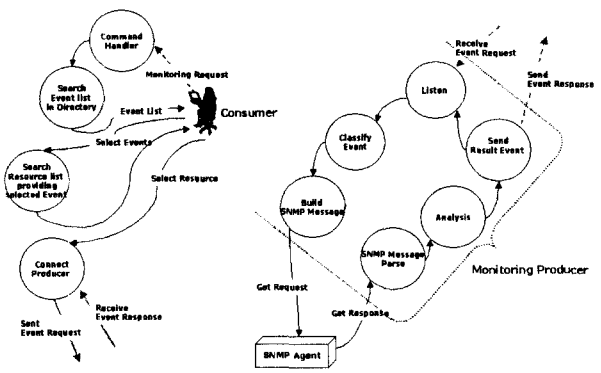
(Figure 4) Resource Publication Flow

(Figure 4) shows process registering a resource. There are numerous producers which are providers of management information. When adding a resource to manage, we can select producers that provide monitoring data of the resource. Each producer provides its available event to the resource. First, it gets the type of system or line and the list of producer from the directory that is registered in relevant VO's monitoring system. When selecting producers that provide monitoring data of the resource, it publishes the resource in the directory entry of chosen producers. Also it stores details of the resource in relevant database in order to provide the topology of VO's resources.

4.2 Monitoring State Transition Diagrams

4.2.1 State Transition Diagrams according to Consumer's Request

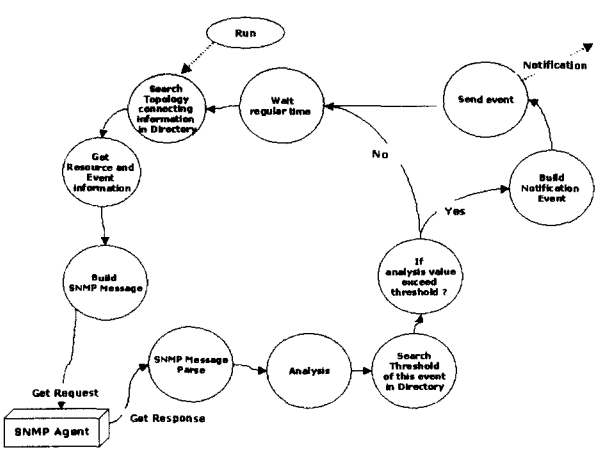
(Figure 5) shows process monitoring a resource, which will be executed by a consumer. A consumer searches for the event defined in Grid monitoring environment and then chooses an event that want to request. This process selects a resource for monitoring among the resources that are registered in producer that provides the chosen event. The relevant information is requested to the producer. If the producer used SNMP information, it analyzes request and makes SNMP messages. Then by performing the polling toward the relevant resource, MIB values are attained. After these collected and analyzed, and the event is organized and is sent to consumer that had requested.



(Figure 5) Monitoring State Transition Diagram

4.2.2 State Transition Diagrams of Failure Notification

(Figure 6) displays process of failure notification. The threshold of an event becomes the basis to judge the failure. Failure notification, first, gets the information of location that received the failure message. Our system implements the topology producer of VO as a receiver. If the analyzed value of the monitoring item of each event exceeds the relevant threshold that the consumer had set, a notification message is transferred. This process works in constant cycle and the consumer can receive failure information according to the specified threshold.



(Figure 6) Notification State Transition Diagram

5. The result of Implementation

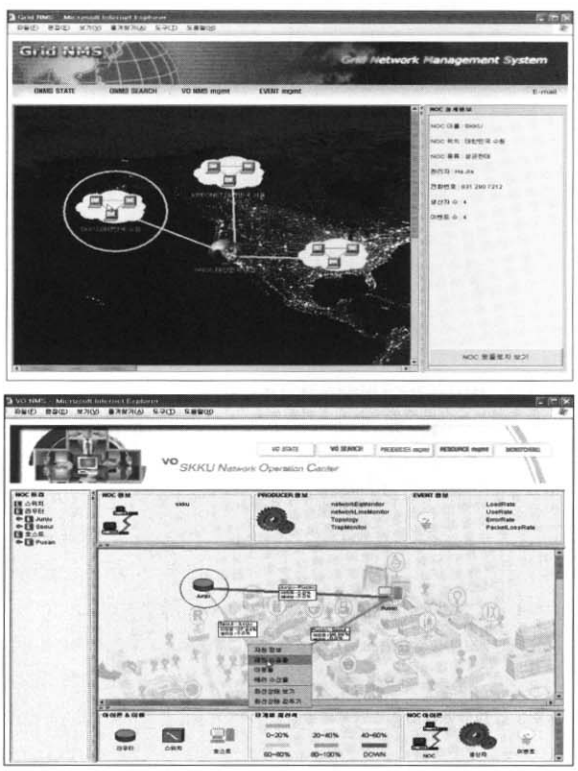
We implemented web-based monitoring system which has architecture and components appropriate to the monitoring of network resources that are scattered over a wide area.

5.1 Overall System

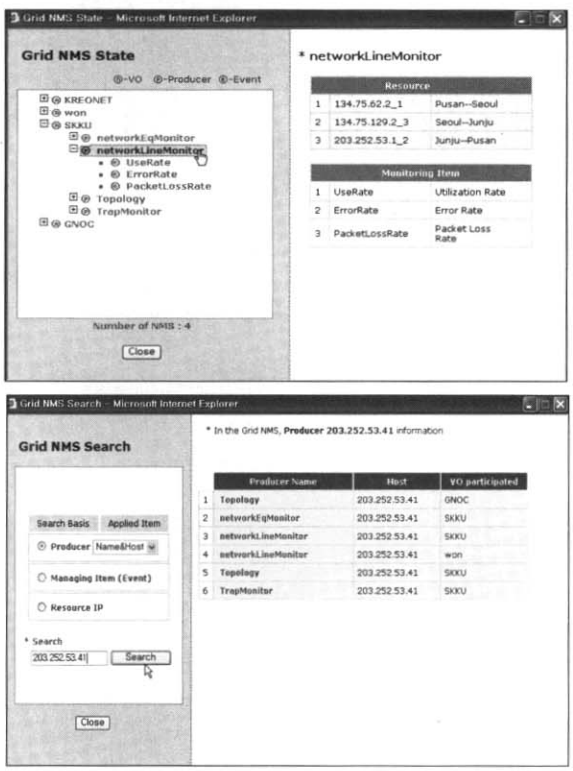
(Figure 7) shows our Grid monitoring system. This system performs the definition of events and the management of the directory for overall monitoring system. This organization manages monitoring systems of VO. It needs the management of producers and events in the directory, shown as in (Figure 7) (b). By clicking each entry, it shows the detailed information in the right frame. As in (Figure 7) (b) (down), producers, events, and resources in Grid environment can be searched. Also, it provides the connection to monitoring system of VO. As in (Figure 7) (a) (down), each VO can operate its monitoring system.

5.2 Producer Management

Producer management supports add/adjust/delete of producers. (Figure 8) shows the producer add which registers

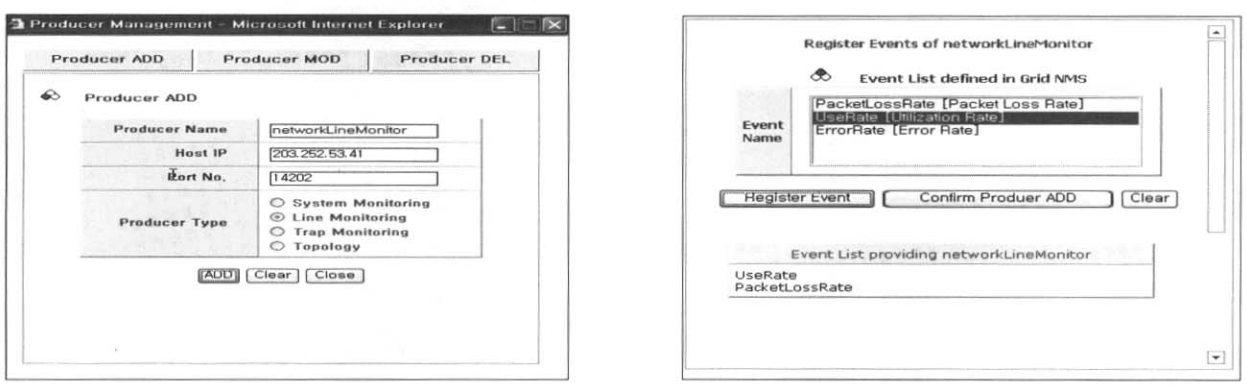


(a) Defining Organization (up), VO's Monitoring System (down)

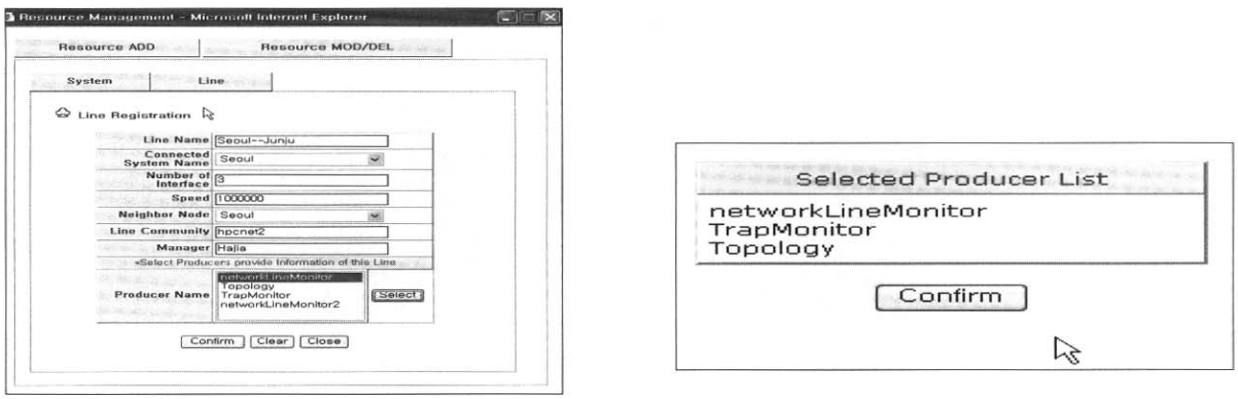


(b) Grid Monitoring System View(up), Search(down)

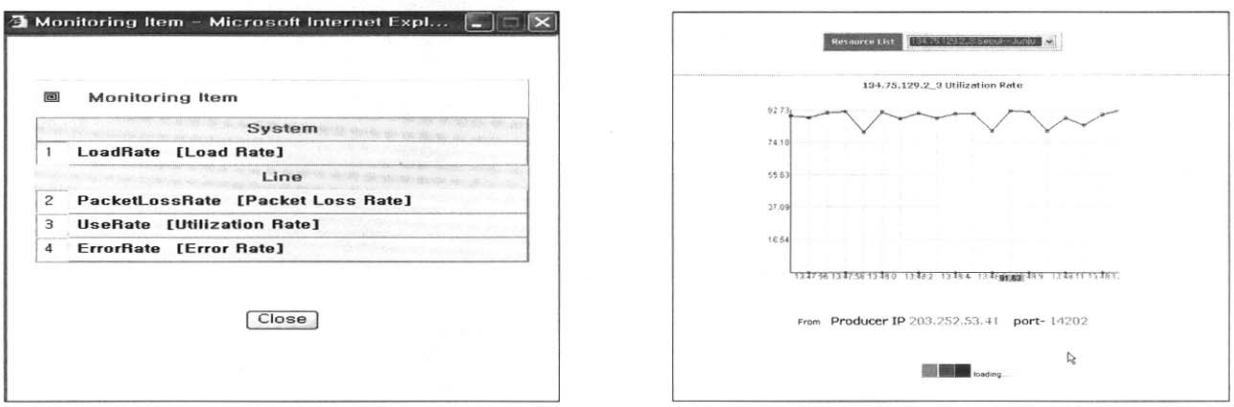
(Figure 7) Defining Organization



(Figure 8) Producer Registration



(Figure 9) Resource Registration



(a) Event List

(b) Receive Monitoring Information

(Figure 10) Monitoring

name, connecting IP, port number and type of a producer. A producer providing event selects its available events from defined events, shown as in the right. It is stored under relevant VO in the directory.

5.3 Resource Management

Also resource management supports the resource's add, adjust, delete. (Figure 9) displays add which selects producers to manage it and then registers them. Resource information is registered to chosen producers of the directory and to database of the topology producer respectively.

5.4 Monitoring

(Figure10) shows a monitoring screen. (Figure 10) (a) displays monitoring items in our Grid monitoring environment. When a monitoring item is selected, resources of producer that provides the item is shown. When resource is selected as in (Figure 10) (b), monitoring data is requested to the producer providing the event of the resource, and thus monitoring information can be attained.

6. Conclusion

The Grid connects resources that are scattered over areas to high-speed network. To perform the applications of Grid, the management to guarantee safety and reliability of network elements is important. Monitoring information can greatly increase depending on the scale of system in the Grid. Therefore monitoring system has to be organized dynamic and flexible.

The GMAWG proposes a monitoring architecture for Grid environment. In this paper, we present the structure for Grid monitoring system based on the GMA, and system of actual use for a manager in web. Since current monitoring system is composed only with arranged system, extension's ability of system was difficult and sharing monitoring service was impossible. When VO is organizing monitoring system, we organizes producers of the metrics defined in the central directory to provide naming and location information. Thus network operating center organizes management system flexibly and scalably. Our monitoring system is expected to be the base of Grid network monitoring system that provides

standardized metrics when standardization is done in the NMWG.

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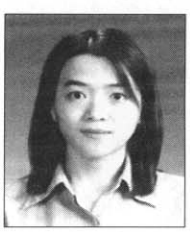

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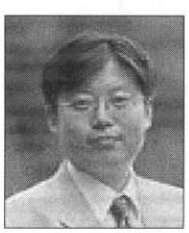

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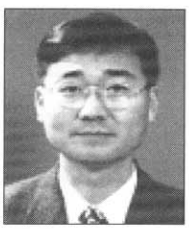

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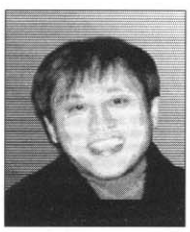

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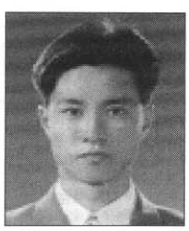

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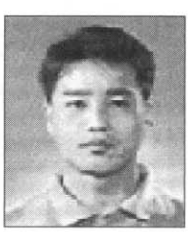

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