Knowledge Oriented Network Fault Resolution Method Based on Active Information Resource

Yusuke Takahashi [1] Daisuke Misugi [1] Akira Sakatoku [1] Akihiro Satoh [1]
Akiko Takahashi [2] Kazuto Sasai [3] Gen Kitagata [3] Toru Abe [4] Tetsuo Kinoshita [4]

[1] *Graduate School of Information Sciences, Tohoku University, Japan*
[2] *Department of Computer Science, Sendai National College of Technology, Japan*
[3] *Research Institute of Electrical Communication, Tohoku University, Japan*
[4] *Cyberscience Center, Tohoku University, Japan*

***Abstract*—To reduce the loads imposed on network administrators, we have proposed AIR-NMS, which is a network management support system (NMS) based on Active Information Resource (AIR). In AIR-NMS, various information resources (e.g., state information of a network, practical knowledge of network management) are combined with software agents which have the knowledge and functions for supporting the utilization of the resources, and thus individual resources are given activities as AIRs. Through the organization and cooperation of AIRs, AIR-NMS provides the administrators with practical measures against a wide range of network faults. To make AIR-NMS fit for practical use, this paper proposes a method for achieving the effective installation and utilization of the network management knowledge needed in AIR-NMS.**

***Keywords*-network management support system, network state information, network management knowledge, active information resource, knowledge organizing.**

I. Introduction

Currently, with the advance of network technology, the scale and complexity of the intranet facility in most of organization (e.g., universities, institutes, corporations, etc.) are growing correspondingly. As a result, the intellectual and time-consuming loads imposed on the network administrators are markedly increasing. Focusing on network fault resolution, the administrator's tasks can be classified into five tasks: 1) observing symptoms / detecting faults, 2) gathering network state information, 3) assuming the conceivable causes of the faults, 4) diagnosing the exact causes of the faults, 5) planning the measures against the identified causes, and 6) taking the planned measures. The functions in most of the traditional network management support systems (NMSs) correspond to the operations 1) and 2), e.g. amount of traffic, utilization rate of system resource, and activity of application process. However, the other operations 3) $\sim$ 6) still require comprehensive network management knowledge (NMK) and highly skills to the administrators, and intellectual and time-consuming heavy loads are imposed on them.

To solve the problems of the traditional NMSs, we have proposed AIR-NMS, which is a NMS based on Active Information Resource (AIR) [1]. AIR is a concept to enhance usability of distributed information resources [2]. Each AIR consists of its information resource and two type features: Knowledge of Utilization Supporting (KUS) and Function of Utilization Supporting (FUS). By using KUS and FUS, each AIR can actively process its own information resource and cooperate with other AIRs. Figure 1 presents an overview of AIR-NMS. AIR-NMS is composed of two type AIRs: network state Information AIR (I-AIR) and network management Knowledge AIR (K-AIR). I-AIRs have the state information of network equipments as their information resources, and K-AIRs have the practical knowledge of network management. Through the organization and cooperation of I-AIRs and K-AIRs, AIR-NMS can fully support the administrators in the operations 1) $\sim$ 5). However, to support the administrators adequately, a large variety of NMK needs to be installed and utilized as K-AIRs in AIR-NMS, then this is a problem to be solved in making AIR-NMS practicable.

In this paper, to make AIR-NMS fit for practical use, we

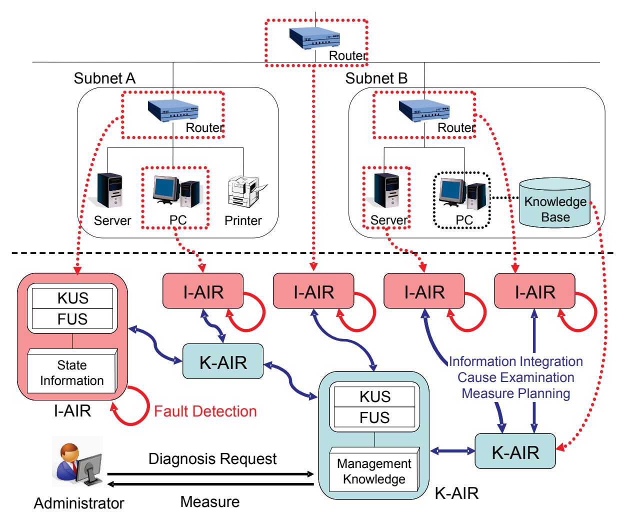

Figure 1. Overview of AIR-NMS

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take up network fault resolution procedures as the NMK, and propose schemes for achieving the effective installation and utilization of the NMK needed in AIR-NMS. The proposed schemes divide and classifie the NMK (a network fault resolution procedure), and structure each classified part as an AIR. Since our approach enables AIR-NMS to reuse the NMK parts, the installation of the knowledge in AIR-NMS can be carried out for each part, and consequently the installation loads would be reduced. In AIR-NMS, the installed NMK parts organize themselves autonomously and compose a complete fault resolution procedure for the network situation, thus the effective utilization of the NMK can be achieved.

II. Proposal

A. Representation Scheme for NMK

1) Division and Classification of NMK: A fault resolution procedure consists of several operations. Among them, the following operations are conducted mainly with the network administrators' knowledge:

1) Cause assuming — assuming the conceivable causes from observed symptoms or detected faults.
2) Cause diagnosing — diagnosing the exact causes of the faults and presenting the diagnosis reports.
3) Measure planning — planing the measures against the identified causes and presenting them.

On these operation bases, the proposed scheme divides the knowledge of a network fault resolution procedure, and classifies the divided knowledge parts into the three operation types. From each type of classified knowledge parts, the following three knowledge elements are extracted: $\mathbf{K}_{\mathrm{SC}}$ **(Symptom, Cause)** extracted from 1) above, $\mathbf{K}_{\mathrm{CD}}$ **(Cause, Diagnosis method, Diagnosis report)** extracted from 2), and $\mathbf{K}_{\mathrm{CM}}$ **(Cause, Measure)** extracted from 3). These three types of knowledge element sets are regarded as information resources, structured as K-AIRs, and added in AIR-NMS individually.

Generally, a single cause may lead to different network faults, and/or one network fault may lead to another network fault. Therefore, one NMK parts may occur in different fault resolution procedures. Although this leads to bloat of knowledge system, the proposed scheme divides and classifies NMKs, and makes it possible to reuse and install the additional NMK parts as composed elements. Consequently, this scheme can avoid redundantly describing and adding the knowledge of the same operation. Furthermore, the proposed scheme does not explicitly specify the relations among the classified NMK parts, and it gives independence to each classified NMK part. As a result, this scheme has no need of considering the already installed one, and it facilitates upgrading if there is a need. Thus, the propose scheme would reduce the loads for installing the NMK in AIR-NMS.

2) Representation of NMK: In the proposed scheme, the five types (**Symptom**, **Cause**, **Diagnosis method**, **Diagnosis report**, and **Measure**) of knowledge elements compose the three types ($\mathbf{K}_{\mathrm{SC}}$, $\mathbf{K}_{\mathrm{CD}}$, and $\mathbf{K}_{\mathrm{CM}}$) of knowledge element sets. We use XML and XPath to make these knowledge element sets into information resources for K-AIRs.

Figure 2 shows examples of the representations of the NMK. In $\mathbf{K}_{\mathrm{SC}}$, **Symptom** is represented as the attribute **'symptom'**. **Cause** is represented as the element <**cause**>. In $\mathbf{K}_{\mathrm{CD}}$, **Cause** is represented as the attribute 'cause'. **Diagnosis method** is represented as the element <**dm**>, which consists of the program calling method to request information to I-AIRs. In $\mathbf{K}_{\mathrm{CM}}$, **Measure** is represented as the measure template <**m**>, which includes the information request destinations (Figure 2 (1)) and conditional statements (Figure 2 (2)).

Using the proposed representation scheme, concrete diagnosis reports and practical measures are appropriately produced from knowledge element sets for individual network situations. Since it improves the reusability of the classified parts of NMK, it leads to the reduction of the loads for installing into AIR-NMS.

B. Cooperation Scheme for NMK

To solve the difficulty that the classified parts (i.e., K_{SC}, K_{CD}, and K_{CM}) should be appropriately selected and composed, the knowledge sets with the proposed scheme need to

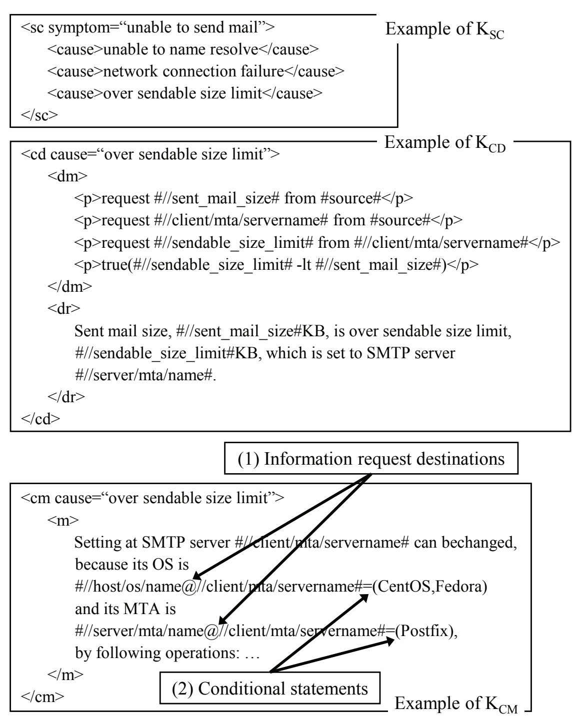

Figure 2. Examples of representations of network management knowledge

organize themselves autonomously to construct a complete fault resolution procedure.

Figure 3 shows the schema of K-AIRs' organization, where $\mathrm{K_{SC}}$, $\mathrm{K_{CD}}$, and $\mathrm{K_{CM}}$ structured as K-AIRs are denoted by $\mathrm{K_{SC}}$-AIR, $\mathrm{K_{CD}}$-AIR, and $\mathrm{K_{CM}}$-AIR, respectively. Each type of K-AIR is activated in the workplace, which is a working environment of AIRs, for its own type. For autonomous organization of K-AIRs , it is needed to design the message expressions and message exchange procedure for cooperation among them.

Figure 4 shows the message expressions among K-AIRs. The details of these expressions are as follows:

Msg-S — this expression is used in diagnosis (for symptoms / faults) request messages, which are broadcast from UI_agent or I-AIRs to $\mathrm{K_{SC}}$-AIRs.

Msg-C — this expression is used in diagnosis (for conceivable causes) request messages, which are broadcast from $\mathrm{K_{SC}}$-AIRs to $\mathrm{K_{CD}}$-AIRs and the other $\mathrm{K_{SC}}$-AIRs. This expression is also used in measure planning (for identified causes) request messages, which are broadcast from $\mathrm{K_{CD}}$-AIRs to $\mathrm{K_{CM}}$-AIRs.

Msg-I — this expression is used in information request messages, which are broadcast from $\mathrm{K_{CD}}$-AIRs or $\mathrm{K_{CM}}$-AIRs to I-AIRs.

As mentioned in II-A1, the proposed representation scheme does not explicitly and statically specify the relations among the K-AIRs ($\mathrm{K_{SC}}$s, $\mathrm{K_{CD}}$s, and $\mathrm{K_{CM}}$s). Nevertheless, by using the proposed cooperation scheme, those K-AIRs organize themselves autonomously and appropriately in AIR-NMS. Consequently, a complete fault resolution procedure is composed and carried out for individual network situations, and it would effectively achieve the exhaustive utilization of a variety of network management knowledge. Furthermore, most of the processes based on the proposed cooperation scheme can be conducted in parallel, and then it is expected that the processing efficiency of network fault resolution will

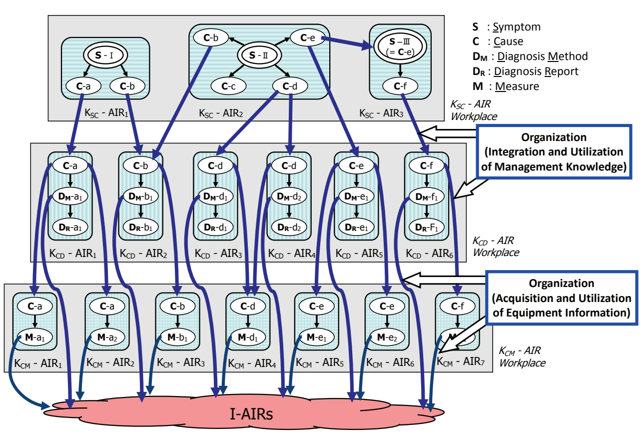

Figure 3. Organization of K-AIRs

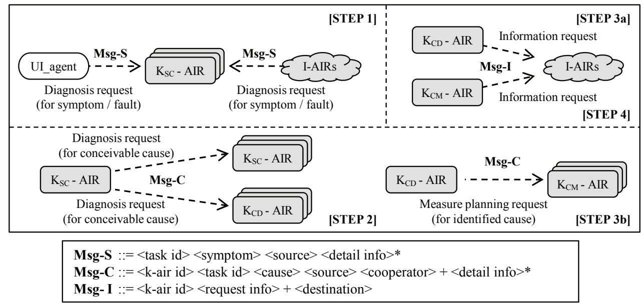

Figure 4. Message expressions among K-AIRs

improve in the distributed environment, such as distributed multiagent systems. Therefore, the propose scheme would achieve the efficient utilization of the network management knowledge in AIR-NMS.

III. Evaluation Experiments

A. Representation Scheme

To demonstrate the effectiveness of the proposed representation scheme for installing the network management knowledge in AIR-NMS, we represent network management knowledge samples with several representation (division and classification) schemes, and evaluate the loads for installing them in AIR-NMS. It is difficult to compare the loads for installing network management knowledge objectively. Therefore, to evaluate the loads, we define a value N_k of knowledge description size. N_k is defined as a number of connections between network management knowledge elements (i.e., **S**ymptom-**C**ause, **C**ause-**D**iagnosis method / report, and **C**ause-**M**easure). For example, the knowledge of a complete network fault resolution procedure usually contains a single S, C, D, and M, therefore, its knowledge description size is defined as $N_k = 3$ (S-C, C-D, C-M). Compared to this, for a classified knowledge part $\mathrm{K_{SC}}$ composed of a symptom and its four causes, a $\mathrm{K_{CD}}$ composed of a cause and its diagnosis method / report, and a $\mathrm{K_{CM}}$ composed of a cause an a measure against it, their sizes are defined as $N_k = 4$ (4×S-C), 1 (C-D), and 1 (C-M), respectively. In the experiments, we used the sample knowledge of 332 network fault resolution procedures. Except duplicates, the numbers of network management knowledge elements extracted from this sample were 7, 33, 40, and 80 for S, C, D, and M, respectively (including duplicates, the total number of extracted knowledge elements was 332 for each S, C, D, and M).

The experimental results (N_k for each classification scheme) are shown in Tale I. To the sample (the knowledge element set {S, C, D, M}), we applied the five classification schemes, where $<\ldots>$ represents a unit of knowledge installation (a divided and classified knowledge part), X-Y denotes a single connection between the knowledge elements X and Y, and X^m means a sequence X_1, X_2, …, X_m

Table I
RESULTS FOR CLASSIFICATION SCHEMES

	Classification scheme	N_k
a.	<S-C>, <C-D>, and <C-M> (proposal)	184
b.	<S-C, C-D, C-M>	996
c.	<S-C> and <C-D, C-M>	298
d.	<S-C, C-D> and <C-M>	250
e.	<S-C, (C-D)^m, (C-M)^m>	341

of finite length knowledge elements. Since our proposed scheme (**scheme a**) can effectively eliminate duplicate installation units, the installation units represented by **scheme a** require the smallest knowledge description size $N_k = 184$. Compared to this, in **scheme b**, the network management knowledge is installed for each complete network fault resolution procedure, and duplicate installation units cannot be eliminated. Therefore, the units represented by **scheme b** require the largest size $N_k = 996$ $(= 332 \times 3)$.

From these experimental results, we can confirm the effectiveness of the proposed representation scheme for installing the network management knowledge.

B. Cooperation Scheme

In this experiments, the sample knowledge of a network fault resolution procedure, which contained a single S, 20 Cs, 20 Ds, and 20 Ms, was used. This sample was structured as K-AIRs with two approaches: on the one hand, these knowledge elements were made into a single K_{SC}-AIR, 20 K_{CD}-AIRs, and 20 K_{CM}-AIRs; on the other, they were made into a single K-AIR. In the former, 20 diagnosis processes for the symptom were performed in parallel with the proposed cooperation scheme, and in the latter, the processes were performed in sequential. We compared the processing times of these parallel and sequential approaches, because the parallel approach is based on the proposed cooperation scheme and the sequential approaches is similar to an ordinary way in actual network management. Most of the network administrators carries out diagnosis operations in sequential. To measure the processing time of diagnosis processes, we set up a testbed of AIR-NMS implemented on a PC (Intel Core 2 Duo 2.4GHz CPU, 2GB memory, and Windows 7 OS) by ADIPS/DASH multiagent framework.

Let N be a number of diagnosis processes, T_{WAIT} be a limit waiting time for response from I-AIR, T_{PS} be a processing time of each diagnosis process, and P be a probability of failure occurring in request to I-AIR. Analytically, the processing time of the parallel approach is $NT_{\text{PS}} + T_{\text{WAIT}}$ and that of the sequential one is $N(T_{\text{PS}} + PT_{\text{WAIT}})$.

In the experiments, we set that each diagnosis process consisted of three information request processes to I-AIRs and one information confirmation process, and we assumed that a request failure to I-AIR occurred at the third information request process.

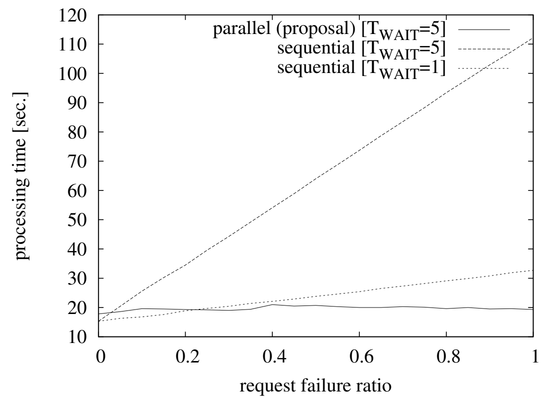

Figure 5. Processing time of diagnosis processes

1) Experimental Results: Figure 5 shows the total processing time of diagnoses by varying the request failure ratio P. The lines in Figure 5 indicate the total processing times of the parallel approach with the limit waiting time $T_{\text{WAIT}} = 5$ [s], the sequential approach with $T_{\text{WAIT}} = 5$ [s], and the sequential approach with $T_{\text{WAIT}} = 1$ [s].

In the sequential approaches, the total processing times are proportional to P. On the other hand, in the parallel approach, the total processing time is not affected by P. These results show that our proposed cooperation scheme can achieve effective utilizing of the network management knowledge and efficient performing of the network diagnosis processes in the presence of request failures to I-AIRs.

IV. CONCLUSION

In this paper, to make AIR-NMS fit for practical use, we have proposed a method for achieving the effective installation and utilization of the network management knowledge in AIR-NMS. The proposed representation scheme divides and classifies the NMK, and the proposed cooperation scheme makes these classified knowledge parts organize themselves autonomously. The experimental results show that the effective installation and utilization of NMK can be achieved by the proposed schemes.

As a future work, we plan to evaluate the effectiveness of the proposed representation and cooperation schemes for network management knowledge on a large scale. In addition to this, we also plan to confirm the effectiveness of AIR-NMS for network management support.

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