Resource Relation Map based Fault Diagnosis and Fault Tolerance Methods for Home Network Environments

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***Abstract*— According to the development of network infrastructure, merging wire or wireless communication technologies into various devices, and the widespread use of mobile devices, various and new services are required. There are many researches about the intelligent home environment or the development of residential space. However, they still have several issues to be resolved. In a situation of interconnecting complex network environment, various devices, and different services, the efficient and accurate revolving of fault is one of important issues that need to be addressed during defect occurs. In this paper, home resource management system is proposed which manages various information from home as resources, provides analyzed relational information between resources. Also, efficient fault diagnosis method is proposed using resource information and relational information from resource relation map and fault tolerance method is proposed with similar functional resource substitution.**

Keywords—fault diagnosis, fault tolerance, resource relationship, home network

I. INTRODUCTION

The development of network infrastructure, merging wire or wireless communication technologies into various devices, and the widespread use of mobile devices require various and new services. Traditional home network technology has developed based on home automation system but many researchers are actively studied for smart home period recently which provides intelligent living space affected by development of the communication environment[1]. In order to develop home environment as intelligent space, there are still many problems to be revolved such as information gathering problems, information heterogeneity problems, complex troubleshooting problems, information disclosure problems for developing various services, and representation of the information intelligent problems[2][3][4].

Those problems are to be resolved and for the purpose of resolving problems, several topics are considered in this paper. Firstly, integration of information is examined. Home contains a variety of information but it is managed separately according to domain or a certain middleware. In these circumstances, it is very difficult to diagnose the accurate cause of fault and to develop home services by using a variety of information. In this paper, we propose a method that manages and delivers in a consistent fashion with collecting information from different domains. Secondly, efficient troubleshooting is examined. Major problem in the field that it is very difficult to find the accurate cause of fault in case of failure, due to complex environment. Also, inefficient diagnosis and shifting responsibility among companies will cause a lot of money. In order to improve efficiency and accuracy of diagnose, this paper introduce a diagnose method that catches problems which has higher potential probability and high relevance by utilizing the relational information between resources. Lastly, openness of information is considered. Traditional home information depends upon certain middle wares or devices and it cannot be utilized in diverse home services. Therefore to minimize the dependency, we implement a base system (platform) in this paper which collects information from integrated protocol and provides the collected information through web services.

The outline of this paper is as follows: we describe the proposed system architecture in Section 2, followed by the proposed fault diagnosis and tolerance methods in Section 3. Implementation is presented in Section 4, and, finally we conclude in Section 5 with justifications and ideas for future work.

II. HOME RESOURCE MANAGEMENT SYSTEM

We designed this home resource management system that consists of 4 level layers(Fig.1). The lower layer is home agent server layer. It aggregates each home information and complex information from home agent. The information is delivered to core layer, and then it is build detail properties depending on their domain. The core layer abstracts the information to resource which is the managing model of this system, analyzes relationship between resources, and builds resource relation map based on the analyzing result. The layer above the core layer is the framework layer, which is based on the core layer and provides specific functions depending on service purpose.

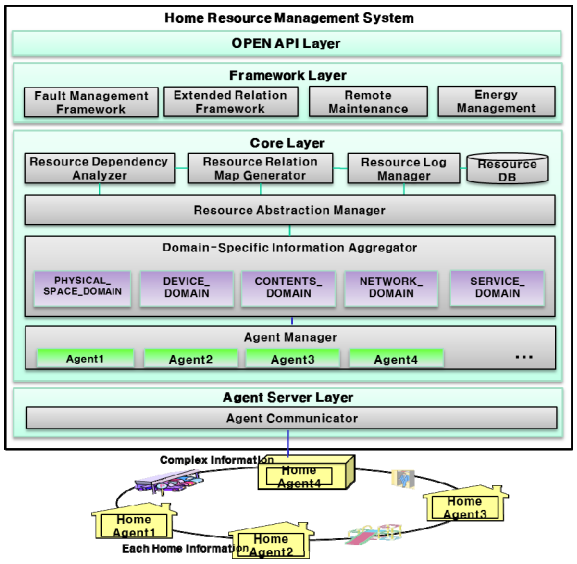

Fig. 1. The proposed Home Management System Architecture

This paper designed and implemented the fault management framework and extended relation framework for fault diagnosis and tolerance service. Finally, we designed the OpenAPI layer on the top of system. It provides how outside users access the resource information, the relation information, and the framework functions.

A. Home agent and agent server layer

We proposed home server-agent architecture and message protocol that supports methods of consistent aggregation for heterogeneous home information. Home agent server transfers request messages from core to home agent, response messages from home agent to core and events of home agent, and manages home agents.

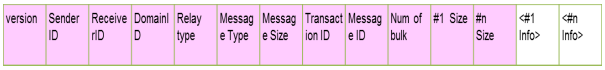

Fig. 2. Home Agent Message Format

Fig.2 shows a message format between agent server and agent. First field means the version of header. Second and Third field mean agent id of sender and receiver. Domain id field means a domain of the information in body. Domain was defined device, network, service, physical space, and content in this system. It can be expanded by necessity. Relay type means a schema type of the information like DMAP(Device control and management protocol)[5], IWF(Interworking Function)[6], and so on. Message type means an opcode of message type. Message types were defined server advertisement, agent register, agent add/delete, resource info, status, control, update, error notification, and event notification. Message size means PDU(protocol data unit) size. Next two field means transaction id and message id. Num of bulk means the number of data in PDU, and next fields show the size of each data. The agent server and agent communicate over RAIB(Reliable Information Bus), which can configures overlay network.

B. Core layer

Core layer mainly performs abstracting from variety of home information to be consistent resource object and analyzing relationship between resource objects. Resource object consist of common part and domain specific part. Before abstracting step, gathered information was extracted to detail properties depending on domain, for example, functions in device domain, parents and child node information in network domain, coordination in physical space domain, and so on. They become to domain specific part in resource object. Common part is generated a resource id, a resource type, and a resource name by abstracting step. You can reference more detailed resource type and specific property from [7]. This paper suggests the home resource management system to provide not only basic resource information but also relationship between resource objects by modeling explicit relation objects. The relation objects are made of implicit knowledge through internal analyzing. We called that methods to RMF(Relation Mapping Function). RMF is divided three categories – based on property, based on user definition, and based on discovering algorithm (Fig.3).

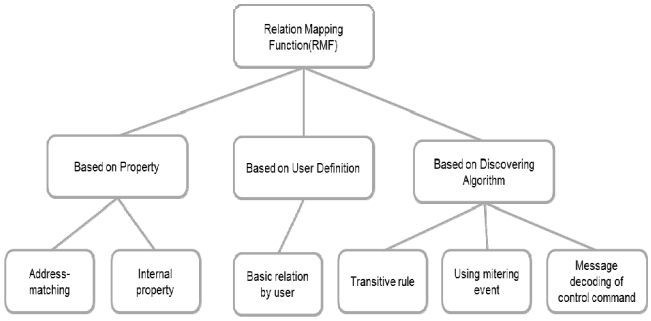

Fig. 3. Relation Mapping Function Classification

The method based on property analyzes using specific part property of resource object. We have RMF using ip address or mac address of device and network resource, and root device id of service and content resource. The method based on user definition analyzes using user's explicit hints. The methods based on discovering algorithm are using mitering device algorithm, transitive rule algorithm, and message decoding algorithm. The structure of relation object consist of source resource, target resources, and relation type, and is similar to triple structure of RDF[8]. The difference between this structure and RDF is that this structure can have multi targets. The relation objects are contained in resource relation map (Fig.4).

Furthermore, core layer has logging functions which are performed periodically or based on events. We defined events including resource addition, resource deletion, error occurrence, changing state, and sending control.

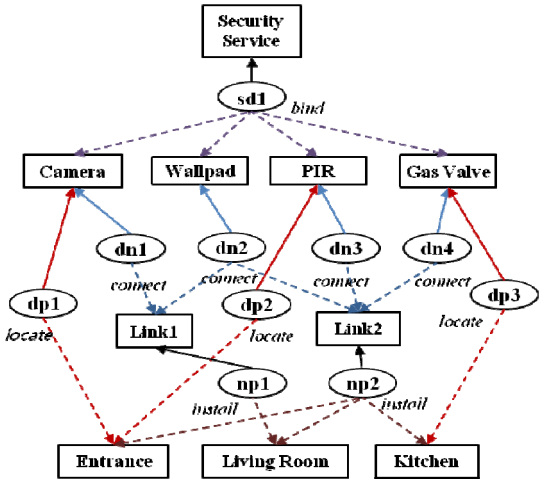

Fig. 4. Resource Relation Map

C. Framework layer

Framework layer based on core layer provides specialized functions for particular services. This paper designed and implemented the fault management framework and extended relation framework for fault diagnosis and tolerance service.

Fault management system commonly has functions which detect error, diagnosis faults, and handle faults. This paper proposed FMF (Fault Management Framework) that uses efficient diagnosis algorithm using characteristics of resource relation map, and substitution method to similar function of other resource for supporting fault tolerance.

ERF (Extended Relation Framework) supports searching information in resource relation map, and building new relationship depended on user requirements. Using this framework, users have not to do complex analysis of resource relation map directly. For ERF, we defined syntax of requirement which helps user's easy requesting. Parameters of syntax are degree of relation, relation type in core layer, target domain id, and detail property. Syntax can apply AND, OR, and NOT operations.

D. OpenAPI layer

The top layer of the system is OpenAPI layer that provides how outside users access the resource information, the relation information, and the framework functions. Our purpose is to support open environment for developing various home services by opening APIs. Table 1. is list of the OpenAPI in this system.

TABLE I. LIST OF THE OPENAPI

Function Category	API
User and Access Management	Login / Logout / UserAdd / UserEdit / UserDel
Search for Resource	getDomainInfo / getAllResourceInfo / getResourceInfobyType / getResourceInfobyID / …
Search for Relation	getAllRelationInfo / getAllRelationInfobyDomain / getRelationSrcIDbyType / getRelationInfobySrcID / …
Control	setAction / reqApply
Fault Diagnosis	FMF_DiagnosisStart / FMF_DiagnosisStop / FMF_DiagnosisStatus / FMF_getResult / …

OpenAPI layer basically manages user authentication and access control by ID and password verification, and applying access role. It provides many search functions about resource, and relation information by address, type, id, name and so on. In addition, user can control resources by OpenAPI. Functions of fault diagnosis are request of diagnosis start, request of diagnosis stop, check of diagnosis status, and check of diagnosis result. The result of fault diagnosis is notified requester and administrator by GCM(Google Cloud Messaging)[9] service and recorded in database. All events from lower layers are also notified by GCM.

III. METHODS OF FAULT DIAGNOSIS AND FAULT TOLERANCE

Fig.5. shows entire procedure of fault diagnosis in FMF.

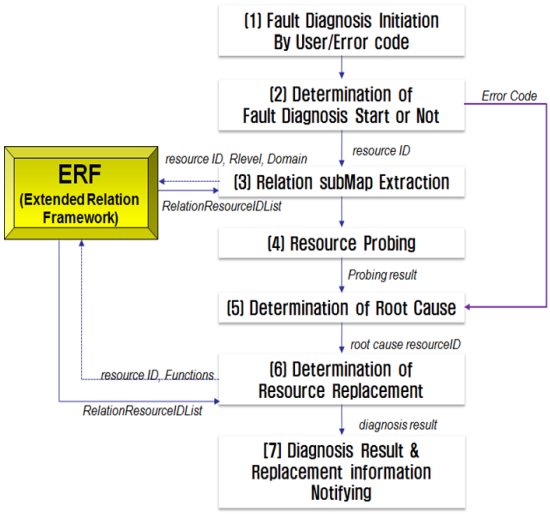

Fig. 5. The Entire Fault Diagnosis Procedure

First step is triggering the diagnosis process. This paper proposed receiving error code from core layer and user request. The fault diagnosis message contained target resource id, source resource id, error type, and user control command. Second step is deciding fault diagnosis method by error type. We proposed fault code mapping method based on error code and root cause tracing method using resource relation map. When the receiving error type contained specific error cause, the system selects fault code mapping method based on error code. It maps fault code to diagnosis result without diagnosis process[10].

Root cause tracing method carried out probing each resource from initial target resource to related resource, then selecting next probing resource using resource relation map.

Before probing target resource, the system checks a home gateway status. That's why the home gateway status has a vital influence on other resources in home. If the home gateway is normal, it starts probing target resource. Now, home network is so complicated, so that checks only error resource can't know exactly root cause. However, to check all resource of home unconditionally is overhead too much. To solve these problems, we proposed an algorithm to extract sub-map from resource relation map. It reduces useless part of resource relation map like physical space resources, and then probes from high relevance resources.

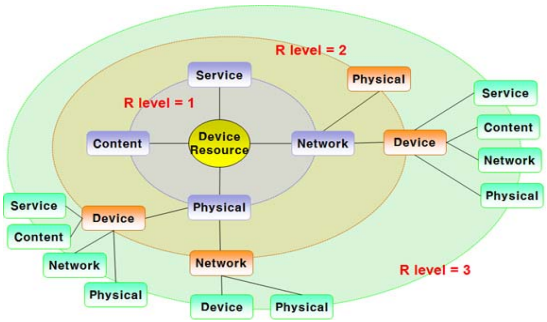

Fig. 6. Sub-map example depending on degree of relation

Fig.6. shows a resource relation map in centered target resource. The target resource has related resources. We make order of probing using degree of relation, domain specification, and other condition rather than all resource probing for efficient and fast diagnosis. Extracting sub-map is used commonly, so that function is provided by ERF.

Root cause tracing step operates three processes repeatedly-probing target resource, selecting next domain, and selecting next resource. After probing target resource, the system should select target domain for next probing. If related domains are more than one, the system selects by domain dependency level[10]. The system repeats these processes until no more resource to choose. Another case, when probing result is fail and the system can't select parent node or uplink resource, then the processes finish. The result of diagnosis includes all of probing resource id and probing results. If root cause is decided, the result also contains it, and the system conducts search process of substitution resource. It can detect the resource, it also contains result of diagnosis, if not, send result of diagnosis without substitution resource.

Fig.7. shows detecting substitution resource example by applying syntax. The left one of Fig.7. shows the resource relation map and error of VPhone Service 1. For discovering replacement resource, the syntax is defined that degree of relation is 0 means target resource can be all of resources. And not contain relation type, target domain is service or device, and has VoiceCall function property. The result is VPhone Service 2 in Smart Pad.

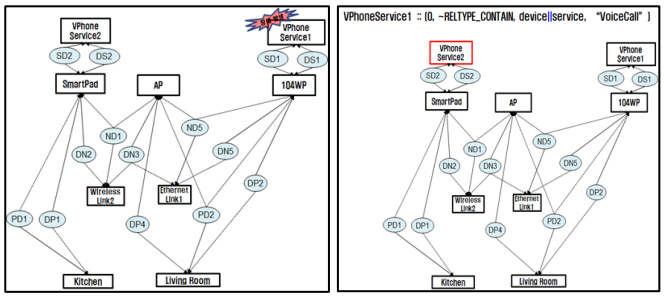

Fig. 7. Substitution resource example by applying syntax

IV. IMPLEMENTAION

In this paper, a prototype of the web service-based home resource management system was created. The test bed consisted of a complex environment of 4 unit households, servers, backbone switch and home gateways in order to collect information on multiple households. Fig.8. shows the system structure that supplies the collected information through OpenAPI. The Web Server, Soap Engine and Database used were Apache, PHP Engine and Oracle DB, respectively. OpenAPI was set to supply through HTTPS. In this paper, three services were developed based on the Android OS: a complex network management service that manages the network state of the complex, a home resource management service that manages and controls the resources of unit households, and a fault diagnosis service.

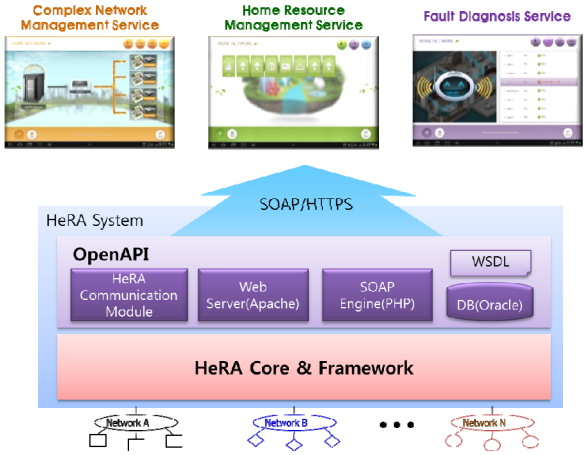

Fig. 8. OpenAPI Structure and Home Services

A scenario for a fault diagnosis is as follows. There is a video call attempt from flat 101 to flat 102, but the call cannot reach the wall-pad in flat 102. The home server detects such a fault state and diagnoses the fault in flat 102, then discovers the network problem at the wall-pad. To overcome this fault state, it looks for a resource that has a similar function to the wall-pad's call function. The search finds a video call service on the smart pad, so it then connects the video call attempt from flat 101 to the video call service on the smart pad in flat 102 to overcome the fault state.

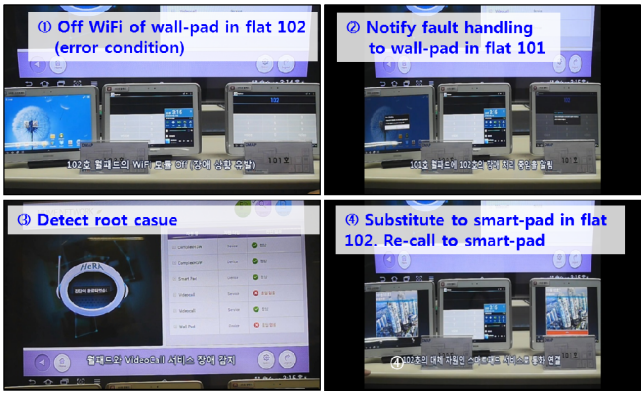

Fig. 9. Demonstration of a Fault Diagnosis Scenario

Fig. 9. illustrates the demonstration scenes of this scenario. First picture shows to make error situation by artificial mean - turning off Wi-Fi of wall-pad in flat 102. After then, if resident in flat 101 gives to flat 102 a call, the service detects fault in flat 102. Next picture shows to notify fault handling to wall-pad in flat 101. The picture of left-bottom shows a diagnosed result to have problem in wall-pad and voice call service of flat 102. Next picture shows the faulty resource substituted an alternative resource, and then the voice call service resumed normal operation. This service has improved on the existing diagnosis method[11] in speed by over 50%, as well as be able to suggest ways to overcome the fault.

V. CONCLUSION

The recent expansion in network environments and the emergence of various network devices demands that the services at home become more diversified and intelligent. To provide for this, however, new measures are required in dealing with faults in complicated environments and in response to the problem of vulnerable information in the homes.

In this paper, a structure to aggregate integrated information in a home has been proposed, and a resource model, in which a home resource management system manages the combined information from various domains, has been proposed. In the paper, a method was suggested not only to combine the collected information, but to analyze the implicit relationship information between resources and supply a resource relationship map. The method to diagnose faults that occur in complicated environments efficiently and accurately was suggested – by diagnosing, based on the home resource management system's resources and resource relationship maps, the resource most closely related to the fault. Further research in fault diagnostics and providing convenient services to the user, through recognizing the user's usage patterns or recognizing the state information from the collected information, is expected.

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