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Design of an Adaptive Middleware based on the Universal Middleware Bridge for the Heterogeneous Home Networks

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Abstract—This paper presents an adaptive middleware based on the Universal Middleware Bridge (UMB) that provides adaptive autonomic configuration for the heterogeneous home networks and autonomous fault management including fault diagnostics and recovery about unexpected faults such as device plug-out, network link failure, and service failure.

I. INTRODUCTION

Since home networks are becoming more and more complex due to the increasing numbers of connection of heterogeneous devices and networks, it obviously triggers various types of faults that cause network failures. Therefore, the fault management that ensures robustness of home networks is a vital issue and should be seriously considered to maintain the stability of the heterogeneous home environments. Many researches on the fault management in the network domain are established, but fault management in the home network domain focus on detection and handling of partial faults based on rule-based model. However, problems from cascading or propagated faults will induce a series of wrong actions and force the home networks to be finally paralyzed from critical failure [1].

The Universal Middleware Bridge (UMB) dynamically maps physical devices into virtually abstracted devices in the UMB and so guarantees seamless interoperability of heterogeneous home network devices [2]. The multi-agent-based solutions about a fault diagnosis system for connected home provide distributed and highly autonomous characteristics, but it can be heavy weighted in the home networks with limited resources [3]. The Trust4All project aims to define an open component-based framework for the middleware layer to enable robust and reliable operation [4].

This paper proposes an adaptive middleware based on the UMB that supports adaptive autonomic configuration and autonomous fault management in the middleware layer in order to guarantee seamless interconnection and robustness of the heterogeneous home networks.

II. ADAPTIVE MIDDLEWARE ARCHITECTURE

Fig. 1 shows the proposed adaptive middleware architecture for the heterogeneous home networks. The heterogeneity abstraction layer supports interoperability of the heterogeneous home networks with the UMB and the function to collect network topology and link traffic information.
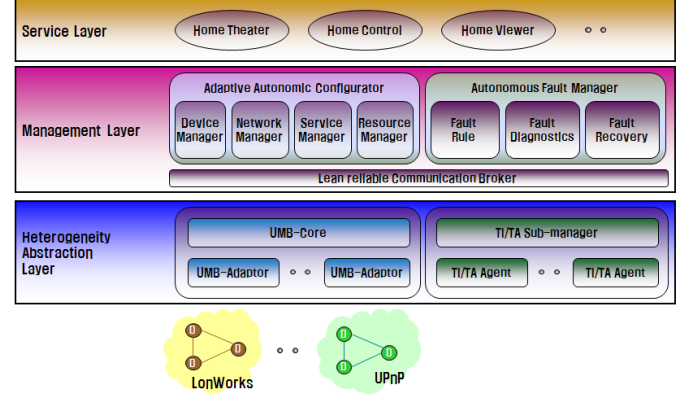

Fig. 1. Adaptive middleware architecture.

As shown in the Management Layer of the proposed architecture, the Adaptive Autonomic Configurator (AAC) module composed of 4 managers; Device Manager (DM), Service Manager (SM), Network Manager (NM) and Resource Manager (RM) in order to provide autonomic auto-configuration and management to reflect the dynamic status changes of the home networks. The Autonomous Fault Manager (AFM) module deals with real-time fault diagnostics, fault evasion and fault recovery.

III. ADAPTIVE AUTONOMIC CONFIGURATION

The Device Manager (DM) manages interconnection of heterogeneous home network devices with the UMB. It controls the UMB components such as the UMB-Core and UMB-Adaptors, which they reports the device plug-in/out to the DM. In addition, the Device Agent (DA) is used to launch UMB components and legacy software for UPnP devices such as UPnP Media Server and UPnP Media Renderer. The DM component reports device faults about unexpected device plug-outs to the AFM. The Service Manager (SM) controls execution and termination of components and services, and maintains components for the adaptive middleware. Besides, it reports component or service failure about the unexpected termination to the AFM. The Network Manager (NM) component consists of the Topology Investigator (TI) and the Traffic Analyzer (TA). The TI composes network topology map using LonTalk protocol and LLTD (Link Layer Topology Discovery) protocol. The TA computes link traffics by means of the Iperf. Lastly, the Resource Manager (RM) not only controls resource reservation, but provides the integrated resource map (IRM), which collects home contexts such as device plug-in/out, status of services and components, network topology and traffic information and resource usage

in the home networks. The IRM is backed up in the persistent storage whenever changed.

In addition, the Lean reliable Communication Broker (LCB) plays an important role of the reliable message transmission among components and is composed of LCB-S (Slave) and LCB-M (Master). Multiple LCB-Ss are connected to an LCB-M. Each component is made using LCB-S APIs and it delivers control messages to another component through LCB-M. The LCB guarantees total ordering for group communication in the message delivery using token, sequence number and queue management. In addition, it supports group management about network partitioning and network merge environment.

IV. AUTONOMOUS FAULT MANAGEMENT

The AFM obtains home contexts from the IRM necessary for fault diagnosis and composes the real-time topology tree to find the location of faults and determine the propagation range of faults. The topology tree for fault diagnosis is modified according to the change of the IRM. Besides, it makes the fault dependency graph for detecting cascading faults. Following Fig. 2 shows an example of a topology tree and a fault dependency graph being used in fault diagnostics about network partitioning.
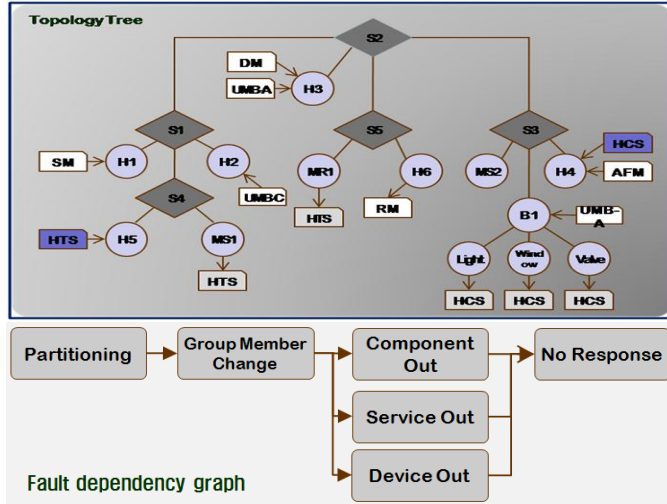

Fig. 2. Topology tree and fault dependency graph for fault diagnosis.

Fig.3 shows message flows for the IRM and faults between components in the AAC and the AFM. The components in the AAC send information about home network status changes to the RM and deliver fault messages to the fault queue to the AFM. The AFM compares fault messages in the fault queue with the topology tree and the fault dependency graph for cascading faults, and so finds the direct cause of faults and the propagation range.

In case of network partitioning, new home network group is organized from the LCB level, and the SM maintains the AAC components and the AFM for adaptive middleware. The AFM fetches the latest backup of the IRM and performs fault diagnostics and fault recovery.
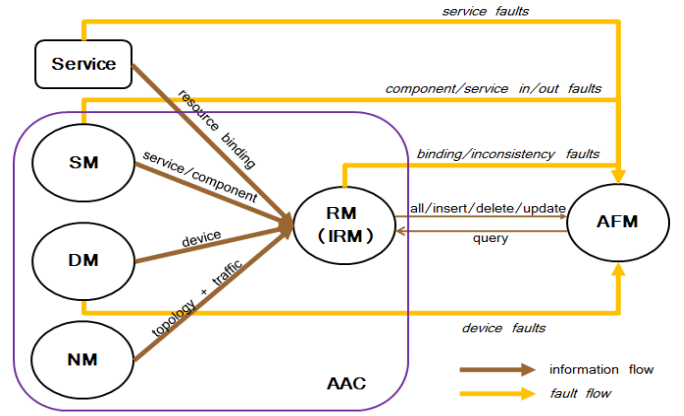

Fig. 3. Message flows between the AAC and the AFM.

The Home Theater Service (HTS) is a streaming service that uses an UPnP Media Server and an UPnP Media Renderer in the home networks. If the DM detects a device plug-out of an UPnP Media Server or an UPnP Media Renderer from the UMB, it delivers a fault message about the device's plug-out to the AFM. The AFM investigates whether it is a localized fault or a cascading fault and whether it can be recovered or not. If the fault is localized in a device and cannot be recovered, the AFM searches another substitute device in the topology tree. If there is any one, the AFM performs the device's surrogate for fault evasion that substitutes the other device for a faulty device and carries out fault recovery that restores the streaming service prior to the fault.

In addition, all operations in the AFM are stored in the persistent log and the Home Viewer provides the timeline-based visual simulation about status changes in the home networks.

V. CONCLUSION

The auto-configuration and fault management are important factors in providing ease-of-use and ease-of-management in the heterogeneous home networks. This paper proposes an adaptive middleware that provides adaptive autonomic configuration and autonomous fault management in the middleware layer appropriate to the heterogeneous home networks with the AAC and the AFM based on the UMB.

REFERENCES

[1] Y. Kitamura, M. Ueda, M. Ikeda, S. Kobori, O. Kakusho, and R. Mizoguchi, "A Model-based Diagnosis with Fault Event Models," Proc. of Pacific Asian Conference on Expert Systems (PACES) 97, pp.275-282, Feb. 1997.

[2] K. D. Moon, Y. H. Lee, C. E. Lee, and Y. S. Son, "Design of a Universal Middleware Bridge for Device Interoperability in Heterogeneous Home Network Middleware," IEEE Transactions on Consumer Electronics, Vol. 51, No. 1, pp.314-318, Feb. 2005.

[3] Peter Utton and Eric Scharf, "A Fault Diagnosis System for the Connected Home," IEEE Communications Magazine, Vol.42, pp.128-134, Nov. 2004.

[4] R. Su, M.R.V. Caudron and J.J. Lukkien, "Adaptive runtime fault management for service instances in component-based software applications," IET Software, Vol.1, No.1, pp.18-28, 2007.