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Fault Management for Home Networks

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Abstract

The rapid growth of information technology and consumer devices has made it realistic to speculate a home network connecting all the home appliances. Many architectures and communication protocols for home networks are taking shape and in particular, Home Audio Video Interoperability (HAVi) – a standard for Home Entertainment Network has already hit the market. The users of the Home Network are generally naïve to its technology, which brings to attention the requirement of a system that will help them locate and correct faults in such a complex enviornment. In this paper we propose a framework for Fault Management in Home Networks making use of the Home Audio Video Interoperability (HAVi) architecture as an illustration.

1 Introduction

In the past 15 years there has been a tremendous growth in the number of networked devices within home, as well as in the number of networked homes. More and more computing devices like the PCs, printers etc. as well as common place appliances like TVs, heaters, lighting appliances etc. are being connected together, so that they can be easily accessed and configured, both from within any point inside the home or from outside through the Internet.

A number of communication technologies facilitating the interconnection of such devices have come up in the market and many more such specifications are being worked upon. The picture of the emerging home network seems to be the one employing a variety of technologies and protocols for device interconnections.

With the growing complexity and diversity of home networks, the configuration and fault management of these networks become important. The users of the home networks will not have the technical expertise to be able to locate and manage faults and misconfiguration. The user will need to be assisted by user-friendly managing software, which will be able to locate the faults for them and probably even give suggestions for fixing the fault/misconfigurations.

This paper explores the possibilities of home network management from inside/outside the home and tries to outline a fault management system for HAVi Networks.

2 Configuration of home networks

The Home Network is made up of household appliances that provide a range of services. Appliances access the network with data and control ports that connect to a communications bus sharing a common medium. The communications bus might be a wired or a non-wired medium such as powerline carrier (data carried on electric wires), radio, or infrared. These ports would allow appliances to exchange status, control, and data with other appliances or controllers.

The availability of different kinds of communication media and communication protocols allow the Home Network to be configured in many ways. The following section gives two broad classifications of Home Networks – Homogeneous and Heterogeneous Networks.

2.1 Homogeneous home networks

Homogeneous home networks use only one kind of communication protocol e.g.: UPnP, JINI, Bluetooth (for short ranges), X-10 etc. These networks are easy to manage as the managing entity has to interact with only one kind of protocol. However, each protocol has its own constraints and is not suitable for all kinds of home appliances. Furthermore, some protocols are already deployed, networking a few devices in a home. A homogeneous network may require those protocols to be uninstalled, making it costly and inconvenient for the consumer.

2.2 Heterogeneous home networks

These networks use a mix of networking protocols that communicate with each other using bridges e.g.: UPnP bridges, OSGi gateways. The topology of a heterogeneous network contains clusters of devices operating on different protocols. Heterogeneous networks allow devices to be networked using protocols that are most suitable for them but the management of these networks is difficult as the managing entity should be able to interact with different protocols

3 Home Network Management

The growth of Home Networks has brought to picture the necessity of a Home Network Management. An average user of the Home Networks is not equipped with enough technical expertise to handle Home Networks. Such a user requires a Management System that would ensure the efficient and timely working of the Home Network. The Management framework and their requirements are described in the following section.

3.1 Management by an entity internal to Home

In this kind of framework, the Managing entity resides on the Home Network. The Management functionality can be either embedded in the control points of the network, or Management can be done by a separate entity meant for the purpose of management of the network only. This framework allows the managing entity to see all traffic within the home network. The managing entity can be directly connected to the network and does not need to rely on the Gateway to communicate with the devices.

However, the user needs to load the management software on to an end point of home network and has to make sure that that end point is always ON for the proper functioning of the Home Network Management System.

3.2 Management by an entity outside home

An ISP or a third party specializing in home network management can also manage home Networks. Such third parties access the devices on the home network by a Gateway. In this kind of Management framework, the managing entity has an end-to-end view and can correlate faults and performance across multiple homes. It also provides an easier, automated administration to the end user. In this scenario, the home network MUST be connected to such a third party/ Internet through a Gateway to find Management services. A third party overview of a home also brings security issues into consideration. Also, in this framework, the managing entity needs to heavily rely on the functionality of the Gateway that connects it to the Home Network.

4 Observation

A variety of protocols are coming up in the market for enabling communication amongst devices in home networks. In absence of a monopoly, the topology of the home networks will emerge to be heterogeneous, in which there will be a few clusters of devices communicating through different protocols suitable for them. These clusters will be connected through bridges to form a complete home network.

The home network management software can be either located at control points or at an end point of the network if an internal home management is chosen.

The home network may be connected to the Internet through a Gateway, in which a third party can manage the home network for the users, accessing the network through the gateway.
In today's Consumer Electronic market, Home Audio/Video Interoperability (HAVi) is coming up to be the most popular Standard for Home Entertainment Networking. HAVi is a digital AV networking initiative that provides a home networking software specification for interoperability among home entertainment products.

In the following sections, we present an Overview of the HAVi Architecture and propose a framework for a Fault Manager on HAVi Networks. Currently, the HAVi standard has no provision for a Fault Manager. The Fault Manager architecture for HAVi networks that is proposed here is a major contribution of this paper.

5 Overview of HAVi Architecture

The HAVi Architecture is intended for implementation on Consumer Electronics (CE) devices and computing devices [11]; it provides a set of services which facilitate interoperability and the development of distributed applications on home networks. HAVi is intended for, but not restricted to, CE devices supporting the IEEE Std 1394-1995 [3] (and future extensions) and IEC 61883 [4] interface standards.

The HAVi Architecture is made up of a number of software elements (SEs). These SEs support network management, device abstraction, inter-device communication, and device user interface (UI) management. Figure 1 depicts the arrangement of software elements on an Full Audio Video (FAV) device that supports the complete HAVi Architecture.

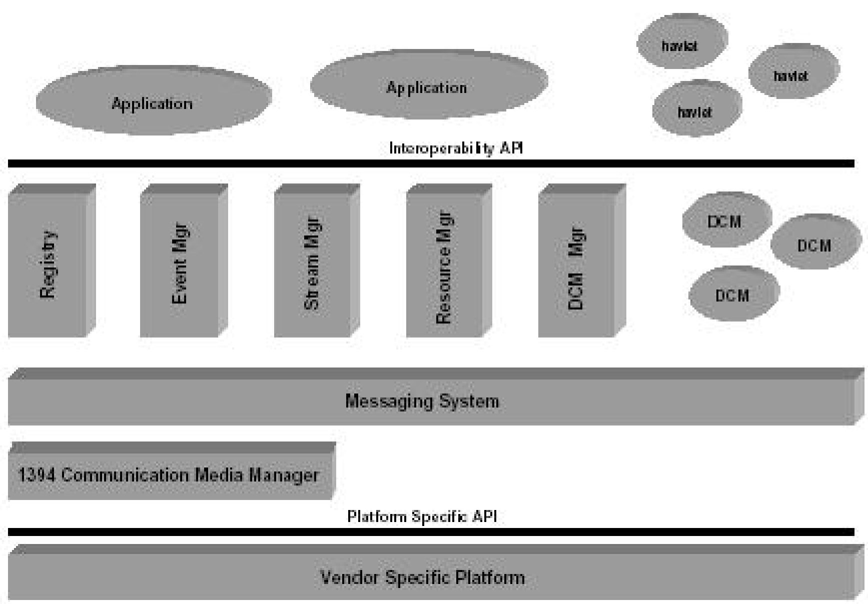

Figure 1: HAVi architecture (from [11])

A brief description of the software elements comprising the HAVi Architecture as defined in the HAVi is given below:

1394 Communication Media Manager – CMM allows other software elements to perform asynchronous and isochronous communication over 1394. CMM is a network dependent entity in the HAVi architecture. It interfaces with the underlying communication media to provide services to other HAVi components or application programs residing on the same device as the CMM. Each physical communication medium has its own CMM to serve the above purpose.

Messaging System – Messaging system is responsible for passing messages between software elements. It is also in charge of allocating identifiers (a GUID, handle pair) for the software elements of that device.

Registry – serves as a directory service, allows any object to locate another object on the home network.

Event Manager – Event Manager serves as an event delivery service. An event is the change in state of an object or of the home network. A software element registers with the Event Manager using its SEID and the list of events it is interested in. The Event Manager will then use the SEID to send event notification messages to the software element via the Messaging System when the events of interest occur.

Stream Manager – The Stream Manager is responsible for managing real-time transfer of AV and other media between functional components. The Stream Manager provides an easy to use API for configuring end-to-end isochronous ("streaming") connections.

Resource Manager – Resource Manager facilitates sharing of resources and scheduling of actions. Applications in the network will typically use a set of FCMs to perform a task on behalf of one or more users. FCMs are called *device resources* in this context. Usually, also *network resources* are involved in resource management, since these serve to create useful collaborations in audio/video streaming between DCMs and FCMs in a HAVi network. 1394 bandwidth and channel numbers are such network resources. The Resource Manager only deals with device resources.

Device Control Module (DCM) – DCM is a software element used to control a device. The DCM deals with the areas such as connection management, informational and status queries for the device and plugs, etc. DCMs are obtained from *DCM code units*. Within a DCM code unit are code for the DCM itself plus code for *Functional Component Modules* (FCMs) for each functional component within the device. In addition a DCM code unit may include a *havlet* allowing user control of the device and its functional components.

DCM Manager – responsible for installing and removing DCM code units on FAV and IAV devices.

These SEs act as a middleware between the applications and the hardware platform making HAVi framework platform independent. The SEs form the backbone of the HAVi Architecture and are responsible for the proper operation of a device.

6 Fault Manager for a HAVi Network

We observe that the HAVi Fault Manager would need to rely heavily on the various SEs to retrieve the information about the fault and its possible causes. The HAVi Fault Manager would need to interact with these SEs and collect appropriate data from them. We purpose a Fault Management architecture that is shown in Figure 2 also gives an overview of the various updates and information that the Fault Manager would need to get from the HAVi Software Elements, so as to detect and locate faults, deduce the cause of the fault and correct the fault if possible.

As the figure shows, the Communication media manager provides information about the Bus Resets occurring on the network. The Fault Manager would also need to know about the Software Elements (SEs) that have enrolled for indications with the Communication Media Manager, so that it can detect the errors occurring with such SEs that could be a result of an indication failure.

All the SEs are required to be registered with the Registry of their device to make itself known to the other SEs. The Registry maintains a list of all the Software Elements and their respective ids called SEIDs which it makes known to the Fault Manager.

The Messaging System provides information about the number of messages and acknowledgments sent and received, timeouts and the outstanding message limit[1]. The Messaging System is also responsible for the assignment of handles to various Software Elements when they register themselves. Thus, information about any handle that is reused should also be provided to the Fault Manager as it can be a reason for a fault on the network. In addition, Messaging System maintains the list of the elements being supervised which may be required by the Fault Manager in order to deduce the reason of a fault.

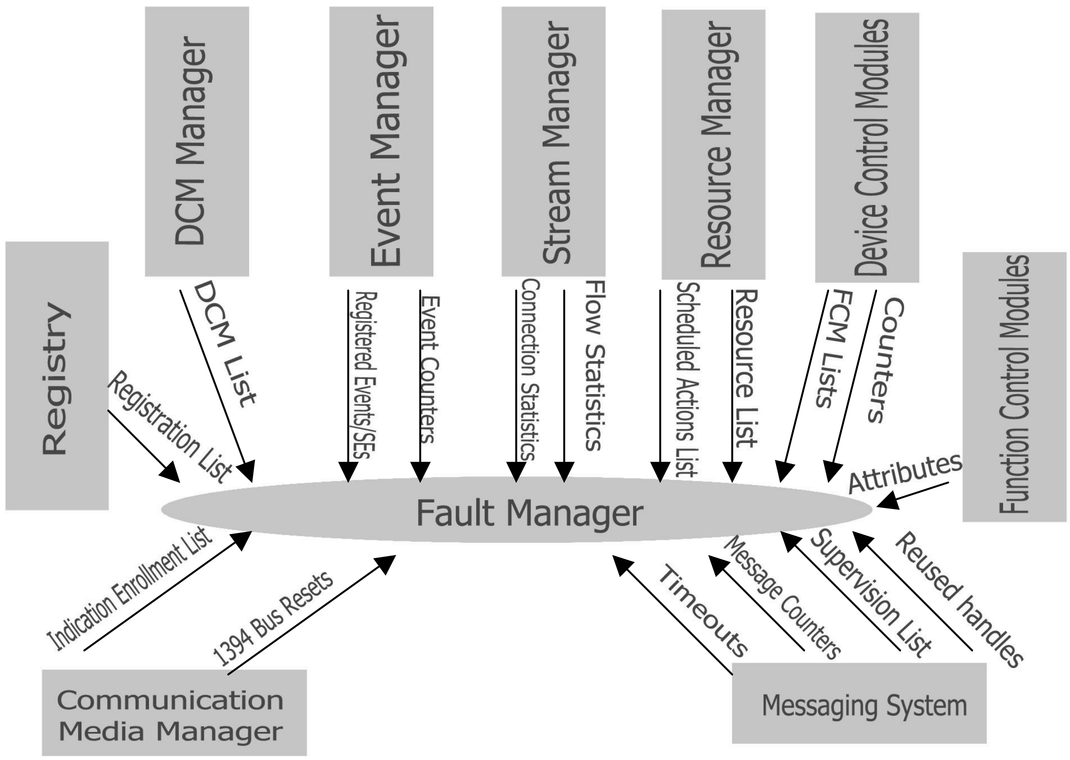

Figure 2: HAVi Software Element updates to Fault Manager

The Event Manager provides Fault Manager with the list of the registered events and the SEs registered for each event. Counters about the number of events posted, forwarded and received along with their types should be maintained. A log for the times when the event manager reached its resource limit should also be kept. The Fault Manager can use this information in detection of faults occurring with the Event Manager or those SEs.

The Device Control Module Manager provides the details of the Controlled Devices to the Fault Manager. The Device Control Modules in turn give the list of all the associated Function Control Modules to the Fault Manager. The Device Control Modules also provide the Fault Manager with a list of all the connections (including broadcast connections) done by the DCM and their attributes, a list of the DCM plugs, their available stream types and their supported transmission formats, a list of the reservations scheduled by the DCM with the Resource Manager, counters for FCMs, havelets, Plugs and Virtual FCMs associated with each DCM and

[1] Outstanding Message limit is the maximum number of messages that can be waiting for an acknowledgement on a device. The device stops sending out messages when this limit is reached.

other information about the Device Class, User Preferred name, Channel Usage, Plug Usage, the DCM Control Capability and Device Power State.

The Function Control Modules also provide the Fault Manager with information about its Power State, HUID, the SEid of its DCM and the Supported Stream Types. Counters for reserved resources and the plugs associated with the FCM are also maintained.

The Fault Manager retrieves information about the various flows from the Stream Manager. Statistics related to the connection failures, connections dropped and changed are also provided by the Stream Manager.

The Resource Manager provides information related to the device resources i.e. resources reserved and resources preempted. In addition, Resource Manager also provides information about the scheduled actions and connections, their requirements and attributes to the Fault Manager.

7 Examples of faults in HAVi Network

This section looks into some possible faults that can occur on a HAVi network. When a fault occurs, the fault manager queries different software elements to find out the reason for the fault as shown in Figure 3. This concept is illustrated by some examples given in this section.

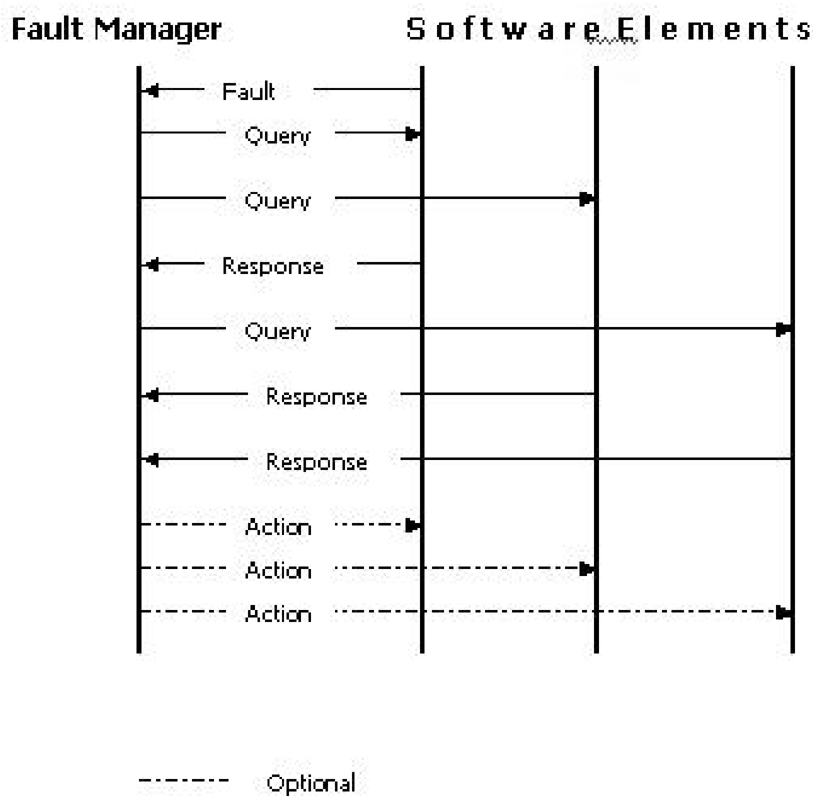

Figure 3 : Sequence of Operations on occurrence of a Fault

7.1 Example 1: Fault with Fcm

The Home Network may contain HAVi and non HAVi complaint devices. The HAVi architecture provides interoperability with non HAVi devices where such devices are controlled using their machine dependent native commands. The native protocols supported by the controlling HAVi device are registered with it. The FCM receives a native command from the application to control one of the native devices on the network.

The prototype

Fcm::NativeCommand Prototype Status Fcm::NativeCommand(in NativeProtocol protocol, in ByteRow command, out ByteRow response)

takes in the protocol that the command is a part of, the command to be sent to the device, and a buffer for the response from the device to which the command is to be sent.

On the occurrence of an error, this prototype as defined in HAVi Standards can return only one error code - Fcm::ENO_PROT which means that the specified native proprietary protocol is not supported. However, the fault can occur because of various other reasons that the Fault Manager would need to find out.

The Fault Manager would need to query the DCM of the device for the native protocols supported by it. This error can also result if the CMM fails to write to the target device, which can be found out by querying the CMM of the controller and the target devices. The messages containing the command and the response can be lost on the network, thus the Fault Manager would also need to query the Messaging System of the two devices.

The Fault Manager thus performs the various queries to find out the appropriate reason of the fault and intimates the user accordingly so that a correct action can be taken.

7.2 Example 2: Faults with VCR Recording

One of the common functions performed on a Home Entertainment Network is recording a tape on VCR. HAVi Architecture provides an FCM API to the application for the same. The prototype

Vcr::Record Prototype Status Vcr::Record()

records data on the loaded tape according to the current recording mode. This API can return many error codes as specified in the Standard according to different error conditions. One of such error codes is WRITE_ERR i.e. there was a error while trying to write to the tape. However, the Fault Manager would still need to query the CMM and Messaging System to determine if the error occurred due to inability of CMM to write the command on the target device or due to loss of messages.

When the error code of NO_CONNECTION is returned, the Fault Manager would need to query the DCM Manager for the Connection list and the Stream Manager for the various connection statistics to determine the reason for which the connection could not be established.

8 Summary and Future Work

The arrival of broadband communication infrastructure and digitization of audio/video appliances has brought to light the necessity of a system that will give simple control over this complex technology. With the advancement of Consumer Electronics and Home Networking, more and more users want easy control and personalization of the entertainment network. We have tried to draw the framework of a system that will make it easy for the users to locate and correct faults in a complex home entertainment network.

This framework can be further generalized to locate and correct faults on other homogeneous and heterogeneous networks and to cover other aspects of Home Network Management.

9 Referances

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