Platform Virtualization in Set-top Box for QoS Management in Multi-Provider Environment

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Abstract

IMS is a recent initiative, designed by 3GPP and TISPAN partnership, which outlines a service delivery platform (SDP) framework. A flexible and robust QoS management system for IMS is essential to encertain the achievability of service quality on these converged networks. For end-to-end QoS in IMS, our STB is designed to support virtual platforms such that a service provider is able to manage its own multimedia streams using feedback mechanism and ensure the desired QoS. The STB also works as a Home Gateway and provide QoS support to client nodes.

1. Introduction

IMS was defined by 3GPP [1] as an standard architecture which provides a horizontal, cross-functional layer of intelligence on top of IP, enabling the creation, control and execution of new and rich user-to-user services (video streaming), user-to-server offerings (IPTV) and multi-user media services (game-playing on the move and at home via PC).[1]

To enable this, IMS architecture must be made compatible with existing service delivery environment such as Service Delivery Platform (SDP). The next generation solutions are designed to provide converged services such as Triple Play [3] and Quadruple Play [4] services, which are going to become the most celebrated services in the near future. This demands a need of end-to-end QoS between the consumer and the service provider.

A Set-top Box (STB) [5] is used as the end device to provide multimedia services to the consumers. As this set-top box is a service providers' owned equipment, it can be used to ensure end-to-end QoS. With a single access point that connects the home network to the internet (i.e. the home gateway); many service providers are able to deploy their services. Fig 1 shows the different parties involved in the IMS based service provisioning network.

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In this paper, we present a Set-Top Box; designed to provide both of the above mentioned functionalities. Next section provides a brief background and related knowledge in the field of STB, Home Gateway and end-to-end QoS delivery. Section 3 shows the design of our set-top box, and in Section 4, we present the mechanism of the proposed STB. Finally, we conclude our work in Section 5.

2. Related Work

In this section the existing QoS solutions using Set-top Box or Regional Gateway are reviewed and their limitations are identified for end-to-end QoS provision in multimedia service delivery scenarios. Some of the work in virtualization of service gateway is also discussed. IMS research focus had been concentrated on the particular topic of enabling consumer satisfaction and to contend with the competitors

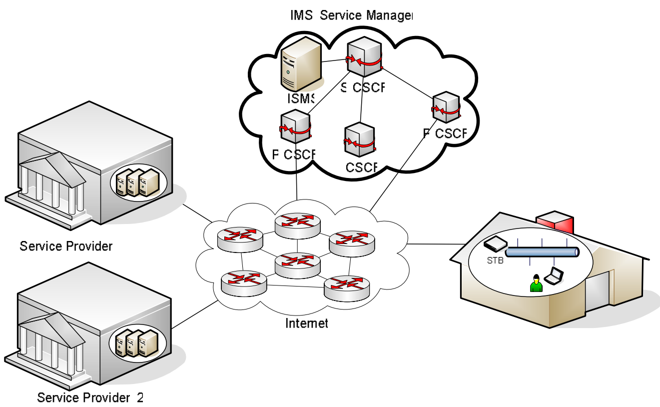

Figure 1. IMS/ SDP Service provisioning environment with major player.

(service providers). Many solutions are proposed to ensure end-to-end QoS in IMS architecture, such as [7] and [8]. These solutions make use of network performance monitoring and ensure end-to-end QoS in the network.

For single service provider, managing the stream is easy if the STB is collaborating with the service provider. But with multiple providers, we need a different approach. One option is to enable the management of QoS using a centralized entity such a management server as shown in [6], while the other solution is to provide virtual or logical STB to each provider. Some of the research papers provide nice solutions for this approach, as in [9] and [10] but they are not efficient enough to provide a comprehensive solution.

For Digital video broadcasting, STBs have been used for quite a while now. They provide audio and video decoding at the user's end. Some intelligent STBs have been designed to provide better QoS in the network, such as [5], [11].

With the concept of digital home, home network gateways are being used to provide centralized network control within a home network. With STB as the end device from the service provider, it can be used to perform the functionalities of the home gateway to extend the internet connection as discussed in [5], [11].

3. Set-Top Box Architecture

In digital video streaming, system and services are not yet robust and in poor QoS conditions, a customer may experience static interference, delayed images and/or non-synchronized audio video phenomenon [11]. We have designed a STB with focus on ensuring QoS in the IMS architecture. As the STB is the end user device on which the service provider has some control. The STB provides a virtual manager to each service provider so that it can manage its own flows and multimedia streams. STB also provides network performance parameters as a feedback to the QoS session enabler in IMS network. The STB uses simple SIP signaling to communicate with the management server, which monitors the network and ensures the optimal QoS.

STB monitors network parameters (such as round-trip latency, jitter, throughput and packet loss etc) and signals them back to the management server and the service provider. The server (at the service provider) & ISMS fine-tunes the network by prioritizing the flows, and service parameters accordingly, making it possible to create an end-to-end solution by integrating cooperative application (based on SIP) from different vendors.

3.1. Architecture

Fig. 2 shows the modular architecture of our proposed STB. Along with the usual subsystems of a conventional STB, our STB includes a QoS enabler, a UPnP server, a SIP module, and a Virtual Platform Manager (VPM). A QoS enabler is responsible for providing end-to-end QoS between the end user nodes and the service provider.

The UPnP server provides the centralized management for the home network. The UPnP architecture with plug and play functionality maintains the information of all the devices connected in home network. By using a simple interface at the STB, devices attached in the network can be managed providing simple functionalities such as turn on, turn off and set timer etc.

The SIP module, consisted of SIP Client and SIP server module, is responsible for two functions:
Behave as a client to the SIP server in IMS (such as the P-CSCF) and
Behave as a server to the SIP clients in Home network.

Session Repository is used by the SIP module to store

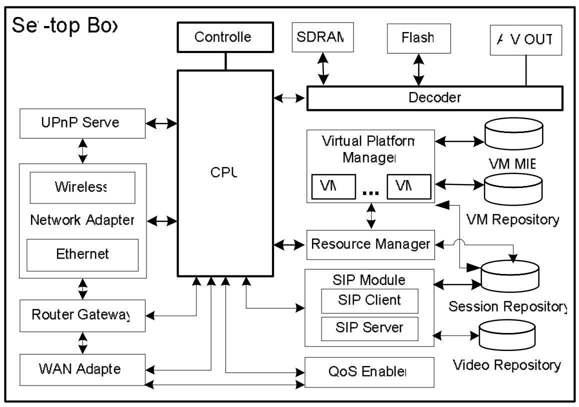

Figure 2. Modular design of the proposed Set-top box.

and manage the multimedia sessions. On the other hand Video Repository is used to provide the functionality for audio/video trick functions such as rewind, forward, fast forward and pause etc.

VPM is responsible for providing virtual managers (or management platforms) to each provider for managing its own media flows. Using virtualization it makes sure that all service providers are isolated from one another. With each provider having its own separate management platform (logical STB), it can access the parameters related to its flows and can guarantee the promised QoS. VPM uses a Virtual manager (VM) repository and management information base (MIB) repository. VM repository maintains information about the VMs running on the STB, while MIB repository maintains the performance parameters related to the service flows.

3.2. Protocols

Fig. 3 shows the protocol stack of the proposed STB. The simple control messages in between the network nodes are delivered using the ICMP protocol. The STB provides both IPv4 (with NAT) and IPv6 functionalities for the network access for the home network nodes. SNMP is used to gather the management information from the different nodes in the network to enable the functionality of the QoS enabler. UPnP protocol stack (includes HTTP, HTTPU, HTTMU and SOAP) provides the plug and play networking for the home network.

3.3. Virtual Platform Manager

The basic idea of providing virtual platform is to isolate the different management agents of each service provider. Hence, each Virtual manager (VM) is managed by one service provider. As the STB has many VM, the VPM is responsible for managing these VMs. Platform virtualization is basically creating logical machines at a single (physical) machine. This is enabled at the software layers, more specifically, at operating system level or by a middleware. Detailed discussion of how to design and implement a platform virtualization is provided in [9].

4. Set-top Box Mechanism

Our proposed STB provides three basic functionalities:

- Home networking gateway;
- SIP session management, and
- End-to-end QoS enablement.

Along with these significant functionalities, the STB also works as the SIP server and client for establishing session calls, manager for the home network, and provides decoding for the video and voice channels.

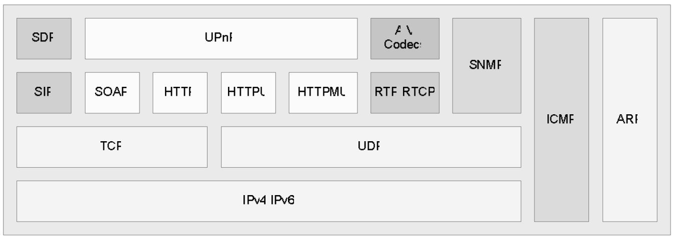

Figure 3. Working protocol stack for the proposed Set-top box.

The major functionalities of the STB are discussed as follows:

4.1. Home Gateway

The STB extends the Internet (broadband) connection to the home network, providing the nodes in the home network access to the external network. The UPnP server makes use of its plug and play architecture and provides a centralized management point for the home network. As the home gateway, the STB can control all the traffic going out and coming in the home network. It classifies the traffic and also work as a firewall for the local network. Our STB is able to support Network Address Translation (NAT) for IPv4 networks and also full support for IPv6 networks.

4.2. Virtual Management

VPM manages all the virtual managers, such as; allowing the initiation of a VM when a new service provider is connected to the STB, registering the services and monitoring them to avoid conflict of resource access. Fig. 4 shows the basic ideology of the mechanism by which each service provider manages its flows.

When a SIP client at the STB sends an invite message to the service provider (SP), using the SIP INVITE messages, the SP communicate with the VPM at the STB. VPM checks for a VM (in it VM repository) for the concerned SP. If that SP is already provided a VM, the connection to that VP is made. Else new VM is created

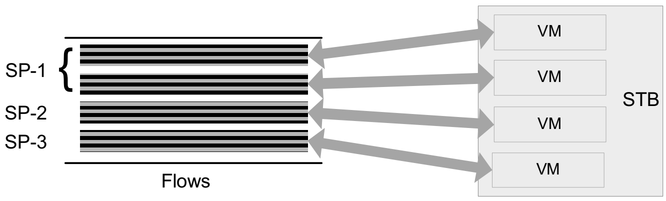

Figure 4. Conceptual diagram showing that each service provider (SP) managing its own flows using virtual managers at the STB.

and the added to the VM repository. For each VM, its sessions are saved in the session repository and the parameters related to each flow are saved in the MIB repository.

Each VM is managed by the SP associated to it. VM provides the services to the SP such as providing the multimedia flow state, the performance it is achieving (calculations are shown in next section) and the resources it is using. VM provides the performance parameters of each flow as the feedback to the SP, so that it can fine tune the resources of the flows and guarantees the QoS according to the SLA.

4.3. SIP Session Management

All the multimedia sessions are managed by the STB, with two-way signaling with the session management enabler (SME) at the management server ISMS. SIP Module within the STB is responsible for:

- Session initiation and negotiation
- Session renegotiation
- Session termination
- Session mobility

The state of each session is stored in the session repository, which helps in session reestablishment, session mobility and performance measurement. Furthermore, it provides all statistical information about active sessions.
SIP client creates, controls, and deletes sessions (e.g. TV sessions). All session related modifications are invoked and monitored here. It furthermore handles the communication with the SIP server. It is also the connection point to the SME.
SIP server is responsible for session establishment and management within the home network.

4.4. End-to-end QoS Enablement

Sometimes, due to a change in network parameters such as degradation of performance, a certain resource may not be provided to each flow according to its SLA. There are various ways (as discussed in Section 2) to avoid such problems, such as, to compromise some flows for certain important flows. This noncompliance of SLA can cost a service provider a loss of customer to its competitors.
The STB includes a QoS enabler, which is responsible of assisting the ISMS and the service provider in managing the overall system. The QoS enabler at the STB and the SME at the ISMS communicate with each other to make sure the multimedia sessions are properly managed and the sessions are served with optimal QoS. The working of the QoS enabler at the STB side is as follows.

The QoS enabler and the SME identify each flow and monitor the flows such that performance measuring parameters of the flows can be calculated on a per flow basis. These parameters are compared to the threshold values defined in the SLA for the customer (available at the ISMS). When for a certain flow, the performance is below the required level, ISMS tries to increase it performance by increasing the resources for it. This is done in two ways.
First, ISMS create dynamic policies according to the required resources and flow performance and these policies are sent to the concerned policy enforcement point to make sure the flow gets more resources.

The second mechanism requires the MPLS mechanism. If the service provider supports the MPLS traffic classification, the QoS enabler contacts the service provider to increase the priority of the concerned flow. This is done by increasing the traffic class for the flow traffic (such as from AF12 to AF11 and so on). Both of the mechanisms are depicted in Fig. 5. The feedback from the STB to the ISMS and the service provider is shown by solid arrows. At ISMS, the new policy is enforced to the network nodes along with the STB itself. While, the SP can change (enhance) the traffic classification for that flow or simply prioritize the flow.

For the traffic feedback there are two solutions available. The first method (as already discussed) is to send the feedback to the ISMS which in turns communicate with the service provider to rectify or improve the link in between the service provider and the user. While the second approach is to send the feedback directly to the service provider, which can

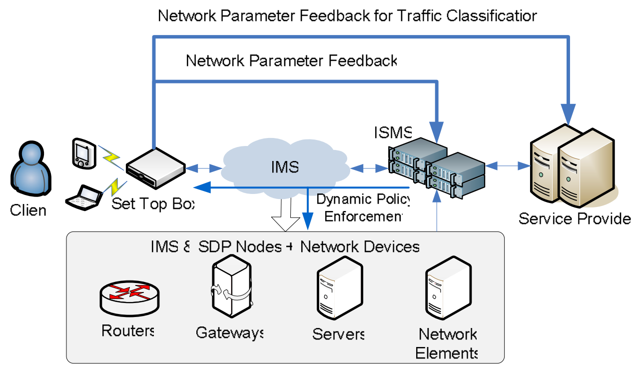

Figure 5. Network feedback and signaling between the STB & ISMS (SME).

take action on its own for increasing the quality of the service it provides. However, for this, the service provider should be able to afford this service. For this the Virtual Managers (VM) at the STB are used. By providing some authority to the SP over the STB, SP can monitor it own service and if some flow is not performing according to the requirement then the traffic classification can be applied (using MPLS) to increase the performance. Next section shows how the SP calculates the network performance parameter at the VM.

5. Conclusion

In this paper, we have presented the design and working of our STB, which works as a home network gateway (regional gateway), as well as enables end-to-end QoS in the IMS architecture. Our STB provides virtual platforms within the STB. With this technology, the STB is able to provide a virtual manager to each service provider (SP), by which SPs are able to manage their own flows. This mechanism assures to assist in the end-to-end QoS provision mechanism by relieving the ISMS server and also reduces the number of messages passed between the SP and the ISMS server in enabling the QoS management.

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