Virtual Platform Support for QoS Management in IMS based Multiple Provider Networks

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***Abstract*[1]— Design of a Set-top Box (STB) is presented to provide virtual platforms such that it can support multiple service providers. Each service provider is able to manage its own multimedia streams and ensures the desired network performance for each flow and enables QoS in IP Multimedia Subsystem (IMS)-based networks. Simulations are done to assert the correctness of the algorithm.**

Keywords- IP Multimedia Subsystem (IMS); Set-top box; Platform Virtualization; end-to-end QoS

I. INTRODUCTION

A Set-top Box (STB) [1] is used as an end device to provide multimedia services to the consumers. Mostly, a STB is controlled by one service provider (SP). However, a SP can interact with many content providers (CP). We believe that as a STB act as a single access point that connects the home network to the Internet (i.e. the home gateway), it can be used by many service providers to deploy their services. In other words, a STB should be a service independent entity, which can be used by many services. Although the STB is provided by one enterprise however, it enables the consumer to receive services from many SPs. In our previous work [2], we proposed a STB for a single SP. For a single SP environment, our STB provides the network flow performance feedback to the IMS-SDP Management Server (ISMS) [2] which in turn maintains and manages the multimedia flows. The result of this fine-tuning (for a single flow) is discussed in our paper referred as [2] in this manuscript.

In this paper, we extended our previous work and have upgraded the design of our STB to provide virtual management platforms for multiple service providers. With this enhancement each service provider owns its own management platform (a VM) at the STB and easily manages the services it provides. All virtual managers are run and managed by a core Virtual Platform Manager hosted inside the STB, and operated by a centralized service gateway, that is the ISMS node [3].

The rest of the paper is articulated as follows: Next section provides a brief background and related knowledge in the field of STB, Home Gateway, end-to-end QoS provisioning, and Virtual Platforms, and briefly discusses the management in the IMS environment. Section III shows the design of our set-top box and section IV presents the mechanism of the proposed STB. Section V discusses the simulation performed to validate our design and shows the results and analysis. Finally, section VI concludes our work.

II. RELATED WORK

Many solutions are proposed to ensure end-to-end QoS in IMS architecture, such as [4] and [5]. In [4], a Hierarchical QoS Management Framework was proposed that incorporates access independent and policy based network administration to control and monitor resources. However, it does not involve the service provider's side for QoS enablement. In [5], the authors claim to provide a complete end-to-end SIP resource signaling and in-session adaptive QoS control scheme for IMS based networks by using resource availability signaling. However, the details on how the QoS is enhanced or ensured are not provided.

For single service provider, managing a multimedia stream is easy if the STB is collaborating with the service provider. However, with multiple providers, we need a different approach. One option is to enable the management of QoS using a centralized entity such as a management server, as shown in [2]. The other solution is to provide a virtual or logical STB to each provider, like [6] and [7]. With a 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. Reference [1] and [8] are the examples of efficient STBs with home gateway support.

We extend our work in [2] with virtual platform support, by which this STB is able to provide management platform to multiple service providers. Our research has been focused on identifying the key management roles in the IMS/SDP system. Therefore, we designed our management framework around a single management server named IMS SDP Management Server (ISMS), [3]. ISMS is a fundamental part of IMS-SDP system as discussed in [2]. It supervises the vital states of IMS-SDP components. IMS-SDP processes and traffic are constantly monitored, both actively and passively. The captured traffic is collected, correlated and analyzed.

The Serving Call Session & Control Function (S-CSCF) has an agent named Session Management Enabler (SME) of ISMS, which is used to capture traffic for the multimedia

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flows. SME is responsible for the management of the multimedia sessions within the system [3].

III. Proposed Set-Top Box

In poor QoS conditions, a customer may face static interference, delayed images and/or non-synchronized audio video phenomenon [8]. We have designed a STB with focus on ensuring QoS in the IMS architecture (presented in [2]). However, in [2], we discussed the single service provider environment. The motivation of this study is to provide a similar increase in QoS in a multi-provider environment and enable the SP to maintain its own flows. By providing a little control on the STB, a SP can get feedback for its own flows and act accordingly to increase the QoS. This, in comparison to the previous approach, decreases the delay in achieving QoS and also takes off the load from the SME and ISMS.

The STB provides a virtual manager (VM) to each service provider so that it can manage its own flows and multimedia streams. These VMs provide network performance parameters as a feedback to the service provider and the QoS session enabler in IMS network. The STB uses SIP [9] signaling to communicate with the service provider and the management server, which monitors the network and ensures the optimal QoS. A 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. When a flow is observing degraded services, its performance can be increased by: (1) The resource manager at the IMS layer makes sure that the concerned flow is provided with enough resources, such as, bandwidth, high priority queues, etc. (2) In MPLS, flows are classified as different traffic types. The concerned flow is classified as a higher priority traffic class by the SP, thus having less delay, more bandwidth, etc.

A. *Architecture*

The modular architecture of our proposed STB is shown in Fig. 1. In addition to the usual components of a conventional STB, our STB includes a QoS enabler, a UPnP server, a SIP module, and a Virtual Platform Manager (VPM). These entities are discussed in detail in [2].

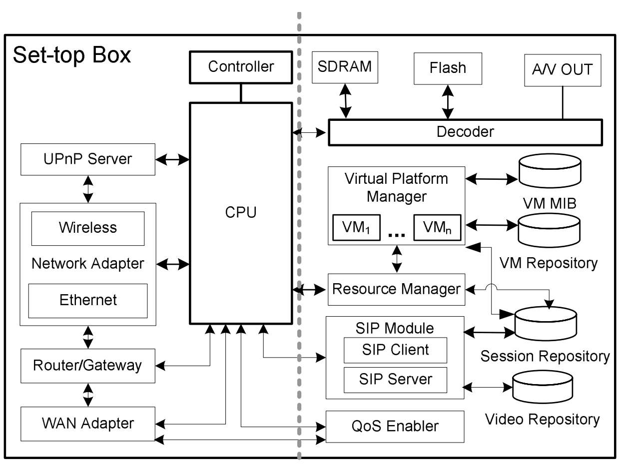

Figure. 1. Modular design of the proposed Set-top box.

A 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 by collaborating with the SP and can guarantee the promised QoS. The 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.

For the internal (STB and Home Network) management the STB uses SNMP protocol. The most of the MIBs for this management are borrowed from SIP protocol and for the virtual platform management, they are custom defined.

B. *Virtual Platform Manager (VPM)*

Virtualization refers to providing a software environment on which programs, including operating systems, can run as if on bare hardware. Such a software environment is called a virtual machine (VM). VM is an efficient, isolated duplicate of the real machine. There are two steps to construct a virtual machine [7]: (1) Mapping of virtual resources or states to real resources in the underlying machine. And; (2) Using the real machine instructions and/or system calls to carry out the actions specified by virtual machine instructions and/or system calls.

Our STB supports process Virtual Machines. Fig. 2 shows the virtualization environment designed within the STB. A Virtual Platform Manager (VPM) works as the overlay layer which provides multiple virtual machines (or platforms). Each of these VMs supports a separate application, which is controlled and managed by a service provider. For the applications, the VPM provides a single operating system environment using a System Abstraction Layer (SAL) such that a single (logical) STB is available for the applications running on each VM.

Fig. 2 also depicts two repositories; one for the Virtual Managers and one for holding the policies. The defined policies are used by the Manager component to manage the VMs. VM_0 is a default machine at the STB, which provides connection to the ISMS server of the IMS. It provides the basic management application for the STB. ISMS remains in contact with every STB using this application, deploying policies and capturing performance and management data. Detailed discussion of how platform virtualization works is provided in the next section and the implementation is discussed in the simulation section.

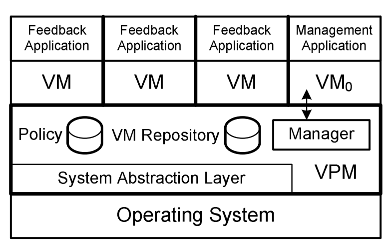

Figure. 2. Virtual Platform design for enabling process VM in the STB

IV. SET-TOP BOX MECHANISM

Along with the basic functionalities of a STB such as decoding the video and voice channels etc., our STB design contributes to many new options. The proposed STB can work as a home network gateway (home network manager), as a SIP Session Manager (SIP server and client for establishing session calls) and, as an end-to-end QoS enabler, as discussed in [2]. But the most outstanding functionality provided by our STB is the support for multiple service providers using Virtual Managers or logical STBs.

Here, a question arises that if more than one SP are supported then who would own the STB. We believe that in the near future although the STB would be provided by one service provider (SP) but it would have the ability to allow the consumer to avail the services from other service and content providers also. As the SP who provides the STB has more control on the STB, hence, its services can have better quality than other 3rd party SPs.

Because of the many functionalities provided by a single STB, the power management at the STB is very important. The dotted line in Fig. 1 shows logical division of the STB in two parts. The left part which is mostly concerned with the network connection and home gateway is always in 'on' mode. While the modules shown on the right side are tuned 'on' when only the multimedia streaming is accessed using the STB. This power management is necessary for the efficiency of the device, however most of the modules shown on the right side are software based. Hence the concerned hardware are storage based (volatile and non volatile), which can be turned of using simple Operating System power management commands for turning off Hard Disk and memory.

A. Virtual Machine Management

A VPM manages all the virtual managers, such as; initiating a VM when a new service provider is connected to the STB, registering the services and monitoring the VMs to avoid conflict of resource access. VM is provided on the basis of a connecting SP, not on the basis of flows. Hence, more than one flows of a SP are managed by a single VM.

When a SIP client at the STB sends an invite message to the service provider (SP), using the SIP INVITE messages [9], the SP communicates with the VPM at the STB. The VPM checks for a VM (in its VM repository) for the concerned SP. If that SP was already provided with a VM, the connection to that VP is made. Otherwise, a new VM is created and added to the VM repository. For each VM, sessions are saved in the session repository and the parameters related to each flow are saved in the MIB repository.

Each VM supports a feedback application, which is controlled by its associated SP using SIP-SSP. This application monitors the state of all multimedia flows associated with the SP, the performance they are achieving (calculations are shown in next section), and the resource they are using. It 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.

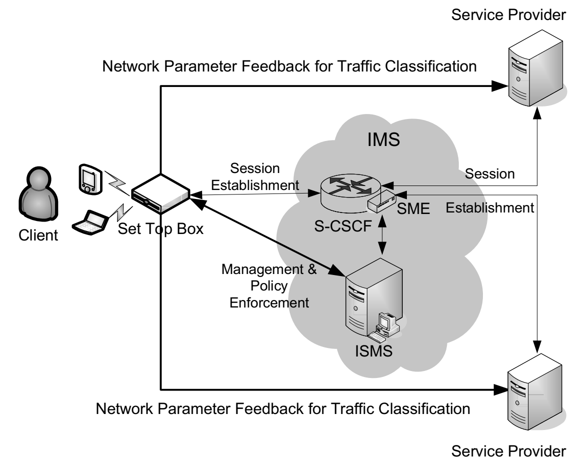

Figure. 3. Feedback and signaling between the STB & ISMS (SME).

The SIP-SSP is used to request, and query VPs at a VPM by the SP. This protocol is not an entirely new protocol but is based on SIP INFO messages. As the session is established using SIP INVITE messages, the SP and the STB are authorized (by each other). As the session is secured so is the protocol used by a VM and a SP.

Now, as there can be more than one SPs providing services so there are as many VMs at the STB. The VPM avoids conflict of interest of all the VMs and separates the logical STBs from each other. For this, the VPM monitors the resource sharing at the STB and optimizes the performance of the VPs. This is enabled by the manager and service abstraction layer (SAL) at the VPM. The SAL (software based) provides an interface for each VM for accessing underlying resources such as operating system, repositories, queues, and other modules; while the manager controls the resource access and provides scheduling and resource sharing. Because the virtualization provided by SAL is software based and relies on authentication rights, therefore, there is no possibility of one VM compromising another VM using direct OS or hardware calls.

B. End-to-end QoS Enablement

With the change in design, the mechanism of QoS enhancement is also changed a little bit as compared to [2]. As each Service Provider is responsible for managing its own flows now; the network performance feedback is calculated at the STB and sent to the SP; the SP itself enables the improvement of the flow. The QoS enabler is utilized by the feedback application at the logical STB for monitoring the flows and their enhancements. The threshold values in the SLA are compared with the performance metrics on per flow basis for each SP. When a certain flow experiences degraded services, the concerned SP is notified. The SP takes an action by utilizing MPLS based traffic classification techniques and prioritize the degraded flow as a high priority flow. This is done by increasing the traffic class for the flow traffic (such as from AF12 to AF11 and so on). The mechanism is depicted in Fig. 3. The feedback from the STB to the service provider is shown by bold arrows. Management of the STB

V. SIMULATION & RESULTS

We have implemented the design of our STB as a simulation for the purpose of testing and evaluation of our proposed design. In [7], the authors have provided an efficient way of implementing virtualization using Process VM. They have used OSGi platform in a multiple provider environment using MVM, a multi-platform support based on Java Virtual Machine (JVM). Our STB is simulated on an embedded system emulator running Windows CE.Net, while the rest of the entities in our simulation are built using C#.Net. The whole simulation is running on a Microsoft Windows XP environment. The client is another application connected to the emulator using a socket connection.

We have designed an application which works as the VPM over the OS layer and supports multiple Virtual Manager applications. Each VM application works independently, and uses the service calls provided by the VPM for accessing the STB system. System Abstraction Layer (SAL) is responsible for providing a façade for these system calls. When a Service Provider connects to the STB (the manager in the VPM) a new instance of VM application is created and a connection between the SP and a VM is made using .Net sockets. There is a default management application named VM_0, which is in connection with the ISMS entity for downloading policies and management of the STB itself.

The simulation has been performed with different number of flows with video, voice and the Internet (HTTP & FTP) traffic. Analysis and evaluation are performed on the basis of the simulation results. A client uses a multimedia service, with intermediate nodes having high rate of entropy for network delay and available bandwidth. These delays are generated at each node randomly with simulating different flows. With the help of QoS feedback, our STB, with the help of the SP, is able to reserve better resources for each flow.

For increasing the effectiveness of the performance in our new system, in comparison to [2], we use weighted averages for delay, jitter and packet loss. It helps in studying the overall behavior of the flows and sudden changes in the values are ignored; thus avoiding the useless feedback and traffic classifications.

Fig. 4-a shows the average throughput achieved by a video flow from the service provider to the set-top box. Video flow generates two 1024 kbits packets per second. At the start, the throughput is low as there are small sized packets for session establishment. More packets with small size show less throughput than few packets of larger size (although the rate is same). After session establishment, we see an improvement in the throughput for the video flow. For some time the new flow affects the old flow but after a while the throughput of the first video flow starts to improve again.

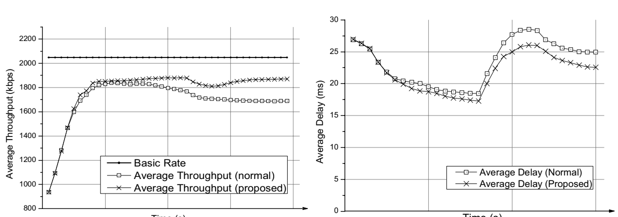

Figure 4. (a) Simulation results for average throughput and (b) simulation results for delay in milli-seconds, calculated at the STB for the data traffic between the service provider and the STB.

Fig. 4-b shows the effect of the proposed mechanism on the weighted average delay of packet delivery for the video flow. As showed by the Fig. 4-b the proposed scheme is able to reduce delay of the delivered packets. This is by prioritizing the flow for high priority queues, thus the packets in the flow bare less delay at intermediate queues.

From the results we got from the simulation, we can see that feedback mechanism shows the potential for improving the QoS in multimedia sessions, especially when more flows are added, the difference increases.

VI. 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 using process virtual machines. With this technology, the STB is able to provide a virtual manager (a logical STB) for each service provider (SP), by which SPs are able to manage their own flows. The results achieved in simulation confirm the effectiveness of the mechanism.

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