

NGN: Provisioning QoS for an MPLS Core Network

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Abstract— Next Generation Networks (NGNs) require convergence of various access technologies. The best way to interwork all these access networks is via a standardized core network. This paper proposes a design of a core network and several entities in the access networks to allow interworking in NGNs as well as provide adequate Quality of Service (QoS). The core network implements MPLS combined with DiffServ for QoS. Furthermore, a Bandwidth Broker (BB) is included to perform admission control and policy based QoS. The proposed design decouples QoS signaling from session establishment. Therefore a session can only be established after QoS requirements have been guaranteed. In our proposed core network, the QoS signaling is considered out-of-band since it passes from one access network to another via the BBs and not the MPLS routers.

Index Terms— Bandwidth Broker, DiffServ, IntServ, QoS.

I. INTRODUCTION

THE evolution of communication networks to NGN leads to the convergence of voice, data and video. In addition, NGNs converge fixed and mobile networks. The migration to NGN has been started by a number of companies and research institutions in France, Europe and other continents. However, it is still a long way before NGN becomes a reality due to various issues in the end-to-end interoperability.

The convergence of various services and access network traffic passing through the core network causes a problem in terms of QoS provisioning. The diverse traffic has different requirements that must be met for efficient interworking. The best effort internet QoS mechanism is not good enough to satisfy the requirements of NGN traffic.

Voice and video traffic is sensitive to jitter. Jitter is affected by the Peak Information Rate (PIR) guaranteed by the network. The design of the core network with MPLS should have granularity in terms of PIR which the access networks may demand. This granularity is addressed in this paper and a verification of the effect of PIR in terms of jitter is performed.

The core network for NGN is evolving to MPLS based networks. What is needed to provide end-to-end quality of service guarantees for traffic originating from one access network through the core network to another different access network? A session must be established between the different networks, and the applicable QoS strategy should work with the session establishment protocol. The work presented in this paper proposes an effective design that allows session establishment and a QoS strategy to interwork various access networks through a NGN core network.

The structure of the paper is as follows: Section II starts with an introduction to NGN, the need for migration to NGN, and how QoS can be provided in an NGN architecture. Section III discusses the Session Initiation Protocol (SIP) together with work on combining QoS mechanisms and SIP. Section IV analyses the various QoS mechanisms and the role of the Bandwidth Broker. The subsequent two sections discuss the design and results from the simulations performed using ns2. The last section concludes with a summary of the important aspects of the design proposed.

II. NEXT GENERATION NETWORKS AND QOS

A. Migration to NGN

According to ITU-T, “a Next Generation Network (NGN) is a packet-based network able to provide services including Telecommunication Services and able to make use of multiple broadband, QoS-enabled transport technologies and in which service-related functions are independent from underlying transport-related technologies. It offers unrestricted access by users to different service providers. It supports generalized mobility which will allow consistent and ubiquitous provision of services to users” [1]. The main objective for NGN is to have a single network that can provide all services.

The Telecommunications industry is very competitive. In order for service providers to retain their subscribers, they must be able to quickly create and deploy new and unique services. The migration to NGN makes this a reality [2], [3].

B. Entities Required for QoS in NGN

To guarantee end-to-end QoS in heterogeneous networks, an administrative domain needs to perform certain functions and include various entities [4]. The functions that are necessary include:

QoS Control: This controls resources to guarantee QoS requirements to traffic flows.

Resource Management: This involves efficient use of network resources to allow requested QoS.

Policy Management: Policies exist between network providers and network users on the QoS requirements for traffic belonging to a certain user. In case of congestion, policies exist to drop traffic from lower priority users.

Network Resource Measurements: For the three functions mentioned, they all require information on the state of the network.

Fig. 1 shows the entities of a NGN core network responsible for the various tasks stated above.

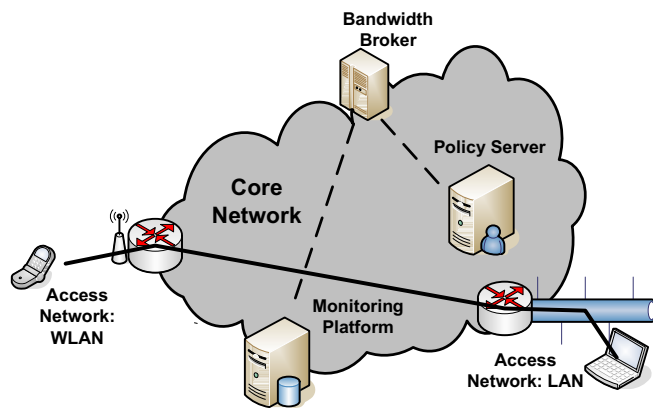


Fig. 1. QoS framework for a heterogeneous inter-domain scenario

These entities (Bandwidth Broker, Policy Server and Monitoring Platform) are currently under research. The signaling interfaces for these three entities have not been defined. The methods these entities use to carry out their functionalities are also under research.

There is a need for QoS to work well with session establishment protocols. The next section analyses the various QoS methods associated with the popular SIP protocol.

III. SESSION ESTABLISHMENT AND QoS

IP Multimedia Subsystem (IMS) is a NGN architecture adopted by telecom operators' providing integration of fixed and mobile services. IMS uses the Internet Protocol, supporting existing packet and circuit switched access networks.

SIP is adopted in the IP Multimedia Subsystems Architecture due to its simplicity. H.323 is another session establishment protocol similar to SIP. However, SIP compared to the H.323 protocol is much more versatile. SIP has a simple horizontal, open architecture suitable for NGN, whereas H.323 has a vertical architecture.

A. Strategies to Provide QoS in SIP Based Networks

In order to ensure minimum session failure for SIP, it is imperative that network resources are reserved [5]. Session

Description Protocol (SDP) can be used to send parameters needed for QoS in a session. This method introduces preconditions [5]. Preconditions are constraints that need to be met which are included in the SIP offer. This method has the shortcoming that delays are introduced in setting up SIP sessions since network resources need to be reserved beforehand.

The enhancement of SIP to include QoS is called Q-SIP (QoS-SIP). In Q-SIP all QoS related functions are implemented in the local SIP servers [6], [7] as shown in Fig. 2. This method removes the need for QoS support in the user terminals allowing backward compatibility with normal SIP protocol.

SIP is the preferred session establishment protocol due its simplicity. The IMS solution for convergence in NGN has problems regarding QoS provisioning. This problem can be solved using Q-SIP proxy servers, but how this will work with the core network is not specified.

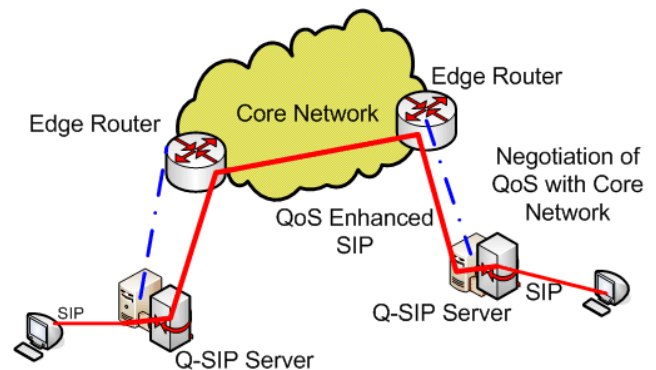


Fig. 2. Operation of Q-SIP.

IV. RELATED WORK

Integrated services (IntServ) for an Internet service model includes best-effort service, real-time service, and controlled link sharing [8]. IntServ identifies the resources required by the traffic and uses end-to-end resource reservations to provide QoS. The Resource Reservation Protocol (RSVP) defined in RFC 2205 [9] is the signaling protocol used to maintain soft states for flows of packets by IntServ.

In Differentiated Services (DiffServ) no flow state is maintained in the routers. DiffServ adds a tag to the IP headers called the DiffServ Service Code Point (DSCP) to classify the packets into different classes.

Expedited Forwarding (EF) DiffServ Class: This service is suited to VoIP. EF provides low latency and a high priority of service. Assured Forwarding (AF) DiffServ Class: This class consists of three different priority classes. The priority classes are further subdivided into four different drop rates. This results in twelve DSCP values. Class Selector (CS) DiffServ Class: This is used for backward compatibility with IP networks and other QoS mappings from other networks. Default DiffServ Class: The Default DiffServ class provides best effort service.

The DiffServ QoS mechanism is scalable unlike IntServ. This scalability is due to the fact that complicated tasks like traffic-flow classification, policing, shaping, and marking are only done at the edge routers.

A. Combining MPLS with DiffServ

For DiffServ to work with MPLS [16] DSCP values need to be mapped to the MPLS Label Switched Paths (LSPs). The DiffServ DSCPs have 64 possibilities and require 8 bits. There are two ways that DSCP can be conveyed in LSP headers [10]. These two methods are:

The network only supports 8 types of Per-Hop Behaviors (PHBs) then the Experimental field can be used to map to PHBs. If the network supports more than 8 PHBs then the three Experimental bits are not sufficient. The label in the MPLS header is then used to convey the DSCP values.

B. Policy Based QoS using a Bandwidth Broker

The policy is a set of rules that govern the Quality of Service received. The policy control uses the policy to determine access of a resource by a specific user. The Policy Decision Point (PDP) is where policy decisions are made. These policy decisions are carried out by the Policy End Points (PEP). Domains providing QoS guarantees may need to incorporate a policy server (PS). The PS has access to policy database as well as accounting and authorizing databases. PDPs enforce policies by sending commands using the Common Open Policy Service (COPS) protocol to the PEPs. There are Service Level Agreements (SLAs) that are enforced by the PDPs.

An SLA is a negotiation between a customer and the network provider on the availability and quality of service offered. The SLA contains IP QoS guarantees and traffic parameters. Service Level Specifications (SLS) are parameters defining the Quality of Service offered in a DiffServ domain. The DiffServ network provides QoS guarantees by specifying different classes. The SLS is used to map a flow of traffic to a specific QoS class in a DiffServ domain. The SLS can contain performance parameters such as jitter, delay and loss.

A Bandwidth Broker (BB) to implement a PDP has been stated in RFC 2638 [11]. The Bandwidth Broker manages the resources of a domain and negotiates with other domains for service levels using SLAs. The Bandwidth Broker consists of the PDP as well as policy databases.

A BB is particularly useful in DiffServ domains. This has been proven by simulations [12], where QoS for real time applications such as Voice over IP has been more effectively provisioned by using a Bandwidth Broker. The study also proves that admission control done by Bandwidth Broker allows more efficient utilization of network resources.

The Globus Architecture for Reservation and Allocation (GARA) is an example of an implementation of Bandwidth Broker architecture. The GARA project tries to solve the problems of discovery of resources and advanced reservations of resources in heterogeneous networks [13].

TUT's (Tampere University of Technology) [14] implementation of Bandwidth Broker allows the application to define source and destination and the peak rates needed using a web interface. The policy database is checked to ensure that the user is allowed to have such a service before the

Bandwidth Broker attempts to reserve resources. In this BB architectural model, a protocol for communication between BBs, and between BB and access networks is required for QoS signaling.

C. Signaling for QoS

Dynamic Service Negotiation Protocol (DSNP) works using the IP protocol, and is fully defined unlike Simple Inter-Domain Bandwidth Broker Signaling (SIBBS) [16]. It can work with both wireless and wireline networks and is suitable for mobile environments. Both these protocols can be used for QoS signaling between the BBs, and between the access networks and the BBs. However, DSNP is particularly suitable for DiffServ networks [15], however DSNP can work well with any other QoS protocol. DiffServ DSCP values can be incorporated into the DSNP messages. The DSNP negotiation messages are as follows:

SLS_LIST_REQUEST: The DSNP client sends this to the DSNP server to get a list of the SLSs offered by the DSNP server. **SLS_LIST_RESPONSE:** In response to the SLS_LIST_REQUEST the server sends a list of SLS that the DSNP user can use. **SLS_NEGO_REQUEST:** This message is sent to the server from the client indicating the SLS requested with parameters for QoS needed. **SLS_NEGO_RESPONSE:** This message is sent in response to the SLS_NEGO_REQUEST indicating acceptance or rejection of QoS requested. The next section will discuss the proposed QoS design.

V. THE PROPOSED QoS SCHEME FOR NGN

A. Design Considerations

The interworking of different access networks should pass through the core network. This would allow the core network to employ standardized protocols, whereby the access networks just need to consider converting to and from the protocols in the core network.

We propose adding QoS signaling in the core network. This signaling must work well with the session establishment protocol, and the resource management methods that provide the QoS. The QoS signaling should however be flexible to changes in both the session establishment protocol and the resource management methods. In addition, the session establishment method should be flexible enough to be decoupled from the QoS implementation as well as the QoS signaling.

B. Interworking Method

To provide end-to-end Quality of Service, the QoS mechanisms must collaborate with the session establishment protocol and the resource allocation methods. We need to select a suitable session establishment protocol that can be easily decoupled from the QoS signaling portion. This will allow QoS signaling to be established separately. In order to set up data and media traffic, we propose an out of band signaling for QoS and session establishment. This is out of band signaling since QoS and session establishment messages pass from one access network to another through the BBs,

whereas data and media traffic flow through the MPLS routers. SIP is chosen as the session establishment protocol since it can be easily decoupled from transport layer and QoS signaling; in addition to this, H.323 is not suitable as it defines the transport of the data too constrictively. Therefore, all the access networks will employ SIP to interwork through the core network to other access networks.

C. Overview of Design Idea

Session establishment and QoS guarantees must be done before data or media transfer can be done from one network to another, through the core network. The diagram (Fig. 3.) shows that the type of session such as video streaming, telephone call or data transfers require different parameters to be set up in the QoS signaling. Also the QoS signaling allows the resources in the transport layer to be configured in a specific way to provide the Quality of Service required by the type of session. This relationship is shown below in Fig. 3.

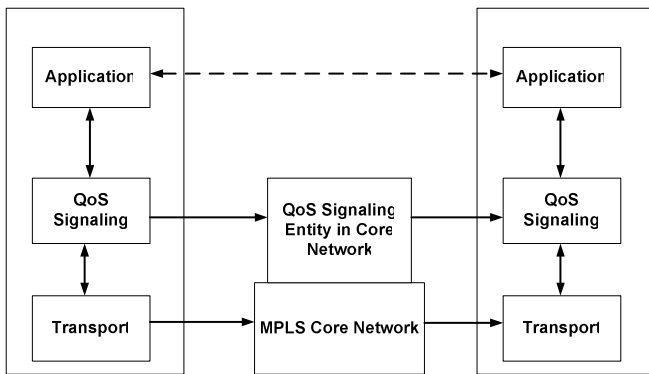


Fig. 3. QoS signaling, session establishment and transport layer relationship in design.

D. Overall Proposed Design

Overview of DiffServ and IntServ is done in Section IV. DiffServ was chosen mainly because it is scalable unlike IntServ. Simulations are performed in the next section in order to prove that DiffServ can work with MPLS to prioritize certain flows. Although MPLS with DiffServ has been implemented before, our implementation uses TS3WCM (Time Sliding Window 3 Color Marker) queues to implement virtual queues for the EF and AF classes. These virtual queues present, only in the edge routers, allow specification of several PIR by the source of traffic.

The MPLS/DiffServ mechanism cannot perform efficient admission control hence the inclusion of a Bandwidth Broker. This Bandwidth Broker keeps an overview of the system and monitors resource utilizations. The provision of resources in a network is closely linked with pricing hence a policy server is included that allows admission only if the policy authorizes the user for such a QoS. The Bandwidth Broker uses LDAP to get policy information from the policy server.

Inter-Domain BBs communicate with each other to negotiate SLAs using a modified DSNP protocol. The modified DSNP however does not include the SLS_LIST_REQUEST or SLS_LIST_RESPONSE messages

in order to improve the speed that QoS is granted. The client asks for a SLS_NEGO_REQUEST with the DiffServ class/DSCP and peak information rate (PIR) specified. The server can accept or reject using the SLS_NEGO_RESPONSE.

The COPS is used by the BB to configure the edge routers in the MPLS/DiffServ domain. The BB can send DSCP code point and PIR to the edge routers to grant a certain level of priority. Simulations are done in the next section to show that PIR can be used to prioritize traffic with the same DSCP in a MPLS/DiffServ system.

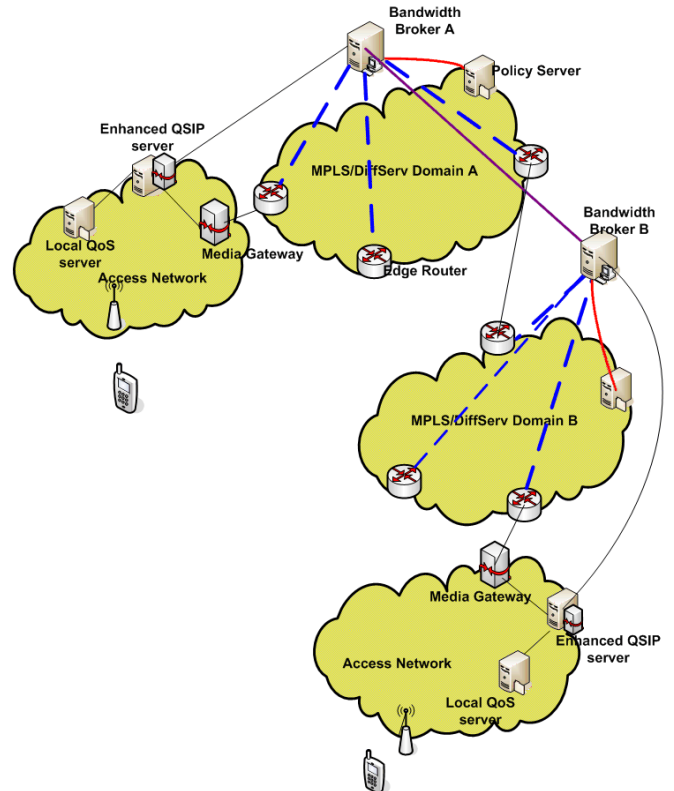


Fig. 4. Components and layout of the overall design.

The Enhanced Q-SIP server maintains the state of the connections. The Q-SIP server obtains QoS information for the service from the Local QoS server. The communication protocol can be different for the exchange of messages between the local QoS server and Q-SIP server. However DSNP can be used, and the compression or codecs used can be negotiated with the Media Gateway by the Q-SIP server. The Q-SIP server sends DSNP messages, SIP invite, and Session Description Protocol (SDP) codec and compression negotiation to another QSIP server through the BBs. The receiving Q-SIP server sends QoS requests to the local QoS server. Media codec and compression information are sent to the Media Gateway. If any of the QoS entities which include the BBs and local QoS servers refuse the QoS requirements then renegotiation of QoS is needed before media or data can be passed through the network.

The Q-SIP server can convert session signaling to SIP allowing non-SIP terminals as well SIP terminals to be used.

The Q-SIP approach is backwards compatible to legacy networks. Fig. 5 shows the signaling required in establishing a session. The DSNP requirements must be allowed by every BB and QoS local server before a session is established. Also in case no messages are received, timeouts should be implemented.

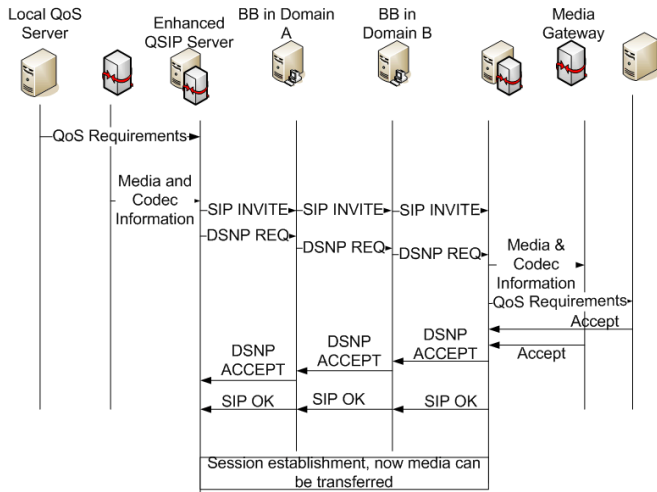


Fig. 5. Signaling before media can be transferred.

VI. SIMULATIONS OF PROPOSED MPLS WITH DIFFSERV QoS MECHANISM

The setup for the simulation is shown in Fig. 6. There is a bottleneck link of 7 Mbps where packets are dropped. MPLS on its own cannot differentiate traffic into priorities. Our scheme combines MPLS with DiffServ with TSW3CM queues which have virtual queues for EF and AF classes.

Fig. 7 and Fig. 8 show traffic prioritization using DiffServ classes and PIR respectively. Fig. 9 proves that PIR is an important factor for jitter hence is important for video and voice transmission. The prioritizing of traffic according to PIR introduces three virtual queues within the AF class.

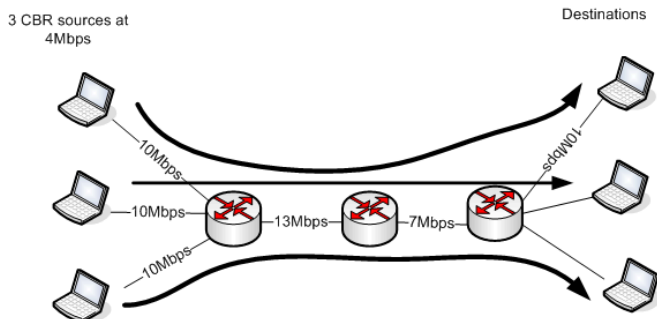


Fig. 6. Nodes and link setup in ns2.

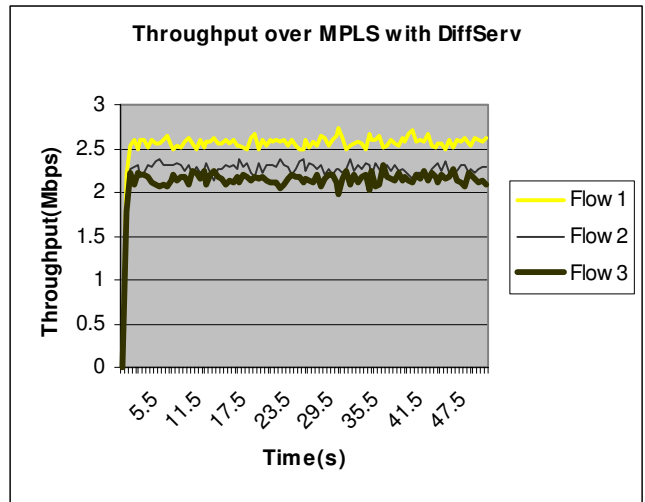


Fig. 7. Prioritization of traffic using different DiffServ classes. Flow 1 has the highest priority and Flow 3 the lowest priority.

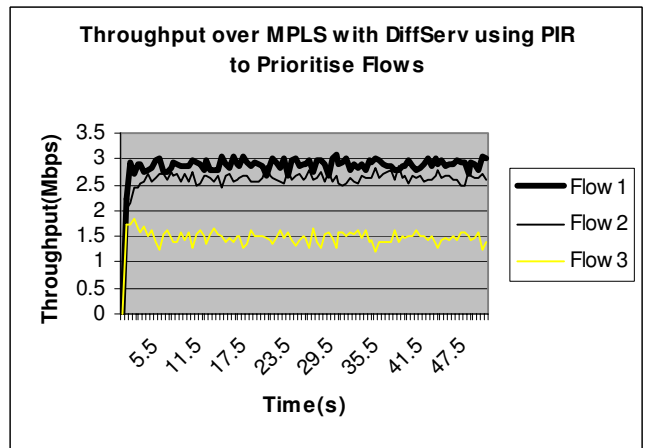


Fig. 8. Throughput prioritization in AF classes using PIR by the source nodes. Flow 1 demands PIR of 3.5 Mbps, Flow 2 demands PIR of 2.5 Mbps and Flow 3 demands PIR of 2 Mbps.

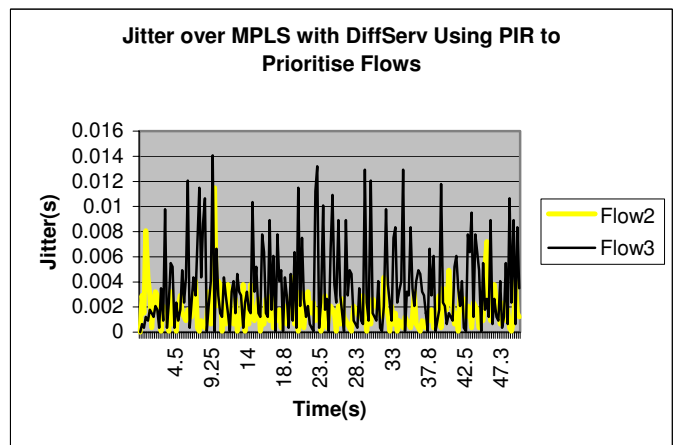


Fig. 9. Dependence of Jitter on PIR. Flow 2 with the higher PIR demand has lower jitter than Flow 3.

VII. CONCLUSIONS

Integrating MPLS with DiffServ allows different classes of service which can be negotiated with the Bandwidth Brokers. Moreover, the PIR can be a parameter that can be negotiated with the Bandwidth Broker. The PIR and class of service can both determine the amount of resources received by a flow in a MPLS/DiffServ network. This is shown in the simulations performed. In addition, the Bandwidth Broker can use the class of service and PIR to configure the edge routers.

The results of the simulations show that a MPLS/DiffServ domain cannot perform admission control. The system allows traffic flows which it has to drop in case of congestion. To avoid the dropping of packets, a Bandwidth Broker is essential to allow only traffic that the core network can support, reducing the number of packets being dropped and congestion situations within the core network.

In order for policy databases to be added separately to the core network, the design included the policy server as a separate entity to the Bandwidth Broker. This also has the advantage that as the number of users increase two or more policy servers can be placed in the core network.

Interworking various access technologies through the core network with standardized QoS signaling and session establishments is economical and allows easy integration of new access networks and services. This strategy is economical since various interworking entities are avoided. To interwork with all other access networks, a new access network only needs to be able to connect to the core network with the standard session establishment protocol and QoS signaling method. Further, a service introduced needs only to be able to establish QoS using the signaling of the core network.

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