A Novel Architecture to Enhance Quality of Service in IP Networks.

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***Abstract*—The purpose of this research is to address the issue of enhancing the Quality of Service(QoS) in IP networks, to make it more optimal in a given network of networks using a novel approach. In this approach, QoS is provided to the packet even when the packet crosses its access network into the backbone. It proposes a new design or set of features in the routers which maps and translates the QoS provisioning from one network to the other. This paper targets at making the quality of service more dynamic by attempting to provide QoS not just at ingress or egress routers but also in the backbone network. In addition, it discusses the economic aspects for upgraded network infrastructure and also comments on the scenarios in which the proposed schema would be helpful along with the placement of dynamic QoS aware routers in the network of networks.**

Keywords : Quality of Service(QoS), Backbone Networks, DiffServ Router.

I. Introduction

In the current day internet, the demand for quality of service(QoS) is increasing rapidly, the provisioning of QoS has been made dynamic and granular in order to make it more scalable for deployment. QoS provisioning within the network, or at the ingress/egress routers is explored to a large extent. But there is still a demand for better QoS services with the growth of real time applications, hence this paper explores about the possibility of extension of similar provisions in the backbone network.

Backbone network is an interconnection of networks in the computer network infrastructure over wide areas. These sub-networks can be diverse in terms of the protocols used in the network, topology and Quality of Service(QoS) provisions. The backbone network allows exchange of information among the various subnetworks which can be used to extend the QoS provisioning. Backbone network is also termed as core networks in the context of service providers.

As the backbone network is an interconnection of various sub-networks, its topology is usually a mesh or a star of meshes. Most of the computation is generally restricted to the edge devices, in order to keep the backbone network fast. In our approach we cross this restriction and allow computation in the backbone network.

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A. Current implementation of QoS

With the emerging multimedia services (such as Voice over IP and videoconferencing), the applications might be sensitive to timely delivery and could have significant bandwidth demands. Quality of services (QoS) features in general address this issue. The QoS can also be used for commercial reasons, such as providing different services depending on the payment made by the user. To ensure such a QoS, there are two main architectures currently, Integrated Services (IntServ) and Differentiated Services (DiffServ)[1]. Integ Serv reserves resources and bandwidth per flow on an end to end basis using signalling protocols and hence is not scalable, as this would delay packets at the routers. DiffServ was designed to increase the scalability and usability of QoS in large networks. DiffServ is designed to provide different treatment to different type of data from various services. Traffic is divided into different classes majorly based on criticality, packet size, burstiness, elasticity, bandwidth consumption, and flow duration. It assigns differentiate service code point(DSCP) values to the packets according to which the packets are classified in the network [3].

Implementation of QoS in a network majorly involves following processes.

- **Classification of traffic:** Packets are classified in different classes based on parameters like latency, delay, jitter tolerance and loss tolerance. Real time and mission critical services like voice packets are assigned higher class to provide premium services while low priority data packets is assigned lower class to provide best effort services.
- **Traffic engineering and Protection:** Traffic engineering is an important tool for optimizing the performance of a network for better delivery of QoS. It tackles with issues like uneven load distribution, high link utilization and congestion in a network which can be caused due to an unexpected topology change, bursty traffic or traffic demand shift. Traffic protection provides protection to high priority packets from facing unnecessary delay or loss in a network under emergency conditions like link failure or high congestion by implementing schemes for quick recovery and retransmission of packets.

- **Class based queueing and scheduling:** There are various network scheduling schemes which helps network scheduler to manage queues at various nodes. On bases of assigned classes, the higher priority packets are scheduled to leave the queue or queues ahead of lower priority data.
- **Other traffic management schemes:** Policing, shaping and buffer management are few of the other management schemes which can be implemented for provisioning QoS in the network

The proposed approach uses a similar architecture in the backbone network, where there are dynamic QoS aware routers similar to DiffServ Routers, which classify packets entering the backbone network, and provides a particular QoS feature based on the mapping design discussed.

The basic provisioning of the quality of service in the network with respect to the applications is given in the Table 1.

B. Related Work

Intensive research is been conducted to satisfy the ever rising demand for better and stringent QoS requirements. Significant work has been done to address the issue of QoS implementation in backbone networks. However most of the research which tackles the issue are not dynamic with respect to flow of the packet into the backbone network i.e the design sets the QoS requirements for a packet at ingress/egress nodes which remain unchanged as packet travels in backbone.

In most cases access networks have their own design of QoS implementation that we need to integrate with the backbone network. There are various designs with levels of detailing and complexity. For example, considering IP/MPLS networks several design alternatives are present that can satisfy the QoS targets. These designs vary with levels of differentiation and optimization they provide. Best effort design is least detailed and complexity increases as we add more constraints on QoS requirements. Introduction of Traffic engineering and diffserv increases degree of optimization but also the complexity.

Research has been also been done on UMTS/GPRS (Universal Mobile Telecommunication System) which is very closely related to our proposal. UMTS mentioned in this paper[4] supports different QoS provisions that might be required by the subscribers and their applications. This approach uses differential service model, as it is a relatively simple but a scalable IP-based technology. A framework for setting a DiffServ based UMTS backbone router and a mapping function to ensure interworking between a UMTS and a DiffServ domain was defined.

This paper[4] proposes a structure of a DiffServ router with the appropriate functionality for forwarding the UMTS aggregate traffic classes, and also presents the mapping function. But it fails to address dynamic resource allocation and admission control mechanism.Our paper works in the similar lines but on an IP based backbone computer network. We categorise a network based on the Bandwidth, Bit error rate and other packet characteristics and hence use them in the mapping function accordingly.

C. A possible issue

The QoS protocols provide different streams of data with priorities and guarantee qualities such as bandwidth, delay or resource allocation based on the QoS label the packet has been assigned. Consider a case where the network does not have enough resources, or an allocated resource for a higher priority packet undergoes failure. In such a case where the access networks has its restriction to provide desired QoS, the resources from the backbone network can be used for the same.

It is possible that few packets which deserve a certain QoS provisioning might not get the services as per the expectation, QoS of such packets can be upgraded or downgraded as required in the backbone network according to our proposed approach.

II. PROPOSED QoS DESIGN IN THE BACKBONE ARCHITECTURES:

The network architecture in general is an interconnection of various subnetworks, which are diverse in terms of the quality of service provisions, protocol it follows etc,. In most cases, a particular subnet doesn't know any information such as resource allocation or the routing information of another network, hence the quality of service provided is usually restricted within the domain of its network.

Therefore our approach proposes a special router (Layer-3 device typically, there can also be a layer-2 device which has the special feature to modify QoS related fields such as type of service, of the particular packet without containing any routing information) which improves the QoS provisioning by extending the services into the backbone network.

This approach is similar to that of service provisioning in the mobile networks, consider a case in which the user moves from one network area to the other, the services provided are modified according to the user profile which is fetched. For example, the roaming charges are incurred when the users moves to another state. Also, services are provided based on the user profile for example, if the user has no balance to make a call, he/she is allowed to make only emergency calls.

In a similar manner, the proposed approach will extend the QoS when a packet moves from the access network into the backbone network, mapping the quality of service of the packet in a particular access network to a value according to which the further services are provided.

This mapping can be designed in various possible ways,
1) A control message is sent to these special routers which change the QoS of the packet according to the requirement of that traffic.
2) The packet itself contains a value according to which the QoS is mapped.The optional fields in the packet can be used to store these values.

The special routers can upgrade or downgrade the priority of the packet accordingly.

The placement of such routers is a key criteria as it involves computation. In general, the backbone network contains

TABLE I
QOS PROVISIONING

Application	Characteristics	D*	J*	L*	DSCP	RFC
Network Control	Variable-size packets, mostly inelastic short messages, but traffic can also burst	L	Y	Y	48	2474
VoIP Telephony	Fixed-size small packets, constant emission rate, inelastic and low rate flows	VL	VL	VL	46	3246
Broadcast Video	Constant and variable rate, inelastic, non bursty flows	M	L	VL	40	2474
Multimedia Conferencing	Variable-size packets,constant send interval,rate adaptive,reacts to loss	VL	L	L-M	34	2597
Real time interacting/Tele Presence	RTP/UDP streams, inelastic, mostly variable rate	VL	L	L	32	2474
Multimedia Streaming	Variable-size packets, elastic with variable rate	M	Y	L-M	26	2597
Call - Signalling	Variable-size packets, somewhat bursty short-lived flows	L	Y	Y	24	2474
0 Low latency/Transactional Data	Variable rate, bursty short-lived elastic flows	L-M	Y	L	18	2597
Operations/Administration/Management	Variable-size packets, elastic and inelastic flows.	M	Y	L	16	2474
High-Throughput/Bulk Data	Variable rate, bursty long-lived elastic flows,	M-H	Y	L	10	2597
Best Effort	A bit of everything	NS	NS	NS	0	2474
Low Priority/Scavenger Data	Non-real time and elastic	H	Y	H	8	3662

TABLE II
TABLE INDEX

D* Latency Tolerance	H-High
J*-Jitter Tolerance	M-Medium
L*-Loss Tolerance	L-Low
DSCP-Domain Service Code Point	VL-Very Low
NS-Not Specified	Y-Yes

switches and the processing involved is very less, in order to keep transmission fast in a backbone network.

Hence few basic backbone architectures are discussed with the placement of such routers.

A. *Proposed placement of special routers in backbone architectures*

Various possible backbone network architectures and the placement of the proposed special routers is discussed below.

1) **Distributed Backbone Network:** Distributed backbone system has a hierarchical network architecture where there are a number of network devices that are connected to a central serial connection of routers, switches or hubs. We propose a layered approach of placement of our special routers to distribute the computation of QoS provisioning. One at the ingress level and the other at a hop away as mentioned in the Figure 1. The special routers map the packets based on a set of parameters such as QoS provisioning in the network, bandwidth allocated within the network and other network parameters. In order to distribute the computation, Level-2 special routers map based on a subset of the parameters, and mark the flag in the optional fields of the packet to indicate that it is already being passed through a special router. In the later stage, Level-1 special router maps the packet to a QoS provisioning based on the remaining parameters.

2) **Collapsed Backbone Network:** For maintenance and to reduce troubleshooting, the routing is centralised in collapsed backbone networks(figure 2). The drawback of such a network is that there is a single point of failure. By the placement of our special routers they can be used to have a redundancy with regards to the routing information in the backbone network.

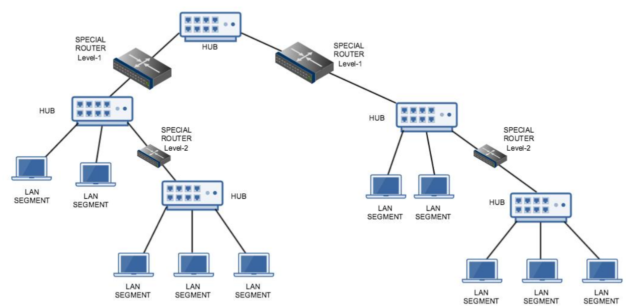

Fig. 1. Distributed Backbone Network

The hierarchy is similar to that of distributed backbone network, hence the layered approach is applicable here too.

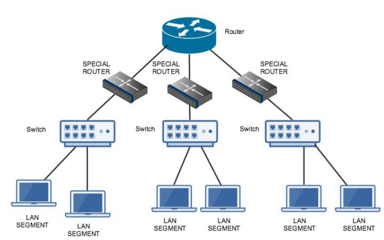

Fig. 2. Collapsed Backbone Network

3) **Parallel Backbone Network:** There can be two different types of special routers which can be placed in parallel backbone networks(Figure 3), as there are generally more than one router in the backbone network, special router

of type A can be placed in between the routers of the backbone network, and those of type B can be placeed between the access network and the backbone.
The type A routers need not have the mapping implementation, but should store the mapping information, can be used to verify the traffic.

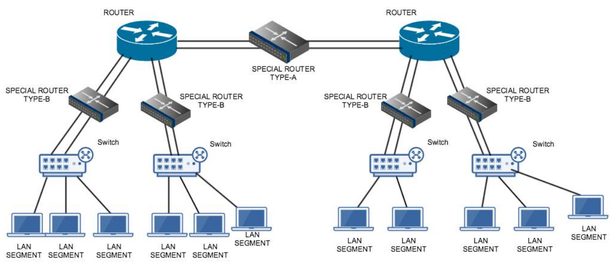

Fig. 3. Parallel Backbone Network

4) **Serial Backbone Network:** In most of the serial backbone networks(Figure 4), the users and the applications are known in prior, hence a dynamic provisioning of quality of service is not necessary, instead based on a fixed use cases, the quality of service particular to those applications can be provided in a static manner.

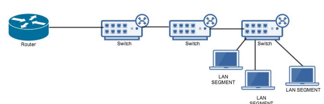

Fig. 4. Serial Backbone Network

B. *Experimentation approach :*

The practical implementation techniques to ensure such a service is defined as below.

Man in the middle approach : The packets need to be passed through a middle machine. The machine can be a router to avoid complexities such as ARP spoofing.

Then on this middle machine either drop relevant packets through firewall (iptables / firewalls) or disable IP forwarding so that OS discards all routing requests. These packets which are being dropped or discarded can be captured using libpcap. The same packet can then be resent from other interface after being modified according to the required mapping. To send packets libnet can be used.

This can also be implemented using NFQueues: The packets can be intercepted by using NFQUEUES in the userspace. Verdict can be given to intercepted packets as NF ACCEPT or NF DROP. So the packets need to be received from NFQUEUE, drop it with verdict NF DROP, modify the packet using libnet or scapy and send it again.

This can also be implemented at kernel level using libnet filter. These kernel modules can be dynamically plugged.

C. *Proposed flow of mapping*

The basis of conversion of QoS from access to backbone may involve various parameters of the packet such as ToS, the protocol which is followed in the network, control flags of the packet etc.

This mapping can be static pre-configured mapping or can be a dynamic function according to which the packet is ranked. The flowchart of the mapping procedure is given in Figure 5.

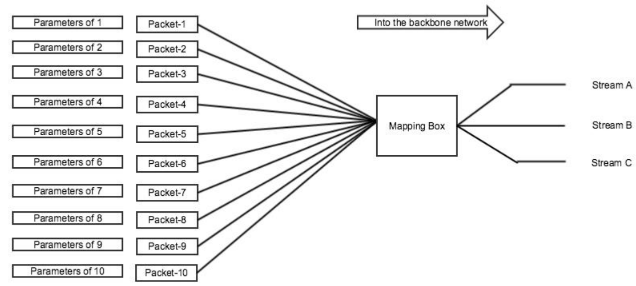

Fig. 5. Flow of mapping

Mapping box is a black box which takes the input as packets from diverse networks which enter the backbone network along with a set of parameters associated with the packet such as QoS provisioning in its network, for example Type of Service (ToS) bits, and maps these packets into streams which are guaranteed a set of QoS provisioning.

In other words, the mapping box rates the packet entering the backbone network and groups them into streams to provide QoS accordingly. The algorithm and the set of parameters which have to be chosen will be part of the future work.

In order to address the issue where the desired QoS is not provided to the packet, the parameters which are taken into consideration for mapping also involves a flag which indicates if the desired QoS is delivered and accordingly the mapping is performed to upgrade or downgrade the packets QoS in the backbone network to ensure expected delivery of QoS to that particular packet.

The mapping requires a lot of computation as it operates on packets from diverse networks and various parameters associated with each of the packet. Hence this computation should happen at regular intervals of time.

Another possible approach can include a flag which would be set based on the calculation that indicates if there should be a significant change in provisioning of QoS in the backbone network which means that there would be a variation in the division of packets into the streams above a certain threshold.

Another possible design can have this feature of mapping in every router and can be used as required by the packets based on the desired service.

This implementation can be specific to IPv6 networks, where the streams into which the packets would be classified, will be based on the per-hop behaviours that would be defined at our special router. In this case the functioning of our router would be similar to that of the DiffServ router. The functioning mechanism of DiffServ routers [5][6] is as shown in Figure 6.

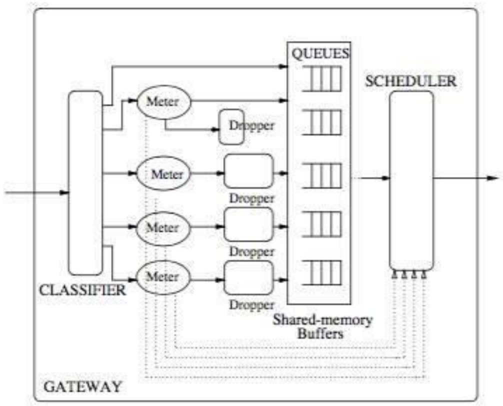

Fig. 6. Functioning of DiffServ routers

DiffServ router consists of packet classification, traffic-conditioning and queuing blocks. Some of the components of DiffServ router are Classifier, Meter, Marker, Dropper, Counter, Multiplexer, Queues, Scheduler. These were embodied into ingress/egress Interfaces.

On arrival of a packet at a particular interface, packet is first classified according to a set of rules, that were predefined using mapping function. Later it is checked by the meter, if the packet is within its allocated rate. Now, the packet is passed along a set of traffic condition blocks(marker,dropper,counter). Here, if the packet is accepted(not dropped), then it is enqueued in the queuing block and then transmitted based on scheduler policy.

Mapping Function: In this function, it translates the QoS parameters of one system, such that it could be understood by another system. This is a necessary function which is usually integrated with classifier into one functioning block.

Classifier: In DiffServ model, classification is done based on the DSCP values or some other implicit information related to that packet and a DSCP value completely identifies the Per-Hop Behaviour associated to that packet. The classifier has a single input and splits the incoming stream into a number of outgoing ports. Classifiers are implemented using filters. The contents of the DSCP is passed through the filter, and according to the matching results, it is grouped into a PHB aggregate.

Meter: A meter is a functional block responsible for measuring the rate characteristics of a packet stream. In a meter, Packet information rate(PIR) and Committed Information rate(CIR) are the two rate characteristics [7][8].

Marker: It uses the statistics gathered by a meter, to decide on the level of a packets conformance to its allocated rate characteristics .It assigns the drop precedence or priority for a packet by using the 3 colors assigned to the packet in the meter (Green-0, Yellow-1, Red-2 & (0,1,2) are drop precedence values used in AF PHB) and assigns a valid DSCP value for a packet [7][8].

Counter: A counter is responsible for updating the packet counter.

Dropper: Absolute dropper and Algorithmic dropper are the two dropper elements. Absolute droppers simply discard the packets whereas the Algorithmic droppers are suggested for avoiding the congestion in the network. Random Early Detection(RED) is a well known algorithmic dropper [9].

Queuing Block: This is the block that stores the packets while they are waiting to receive service by the scheduler and depart to the next hop or DiffServ module.

Scheduler: Scheduler decides on which queue, among a set of queues, to service next.

Our router would have very similar components, but the criteria of classification would also include network parameters such as Bandwidth and Bit error rate in order to differentiate the network.

III. Economic Implications

Economic aspect of this proposal can be suggested as an agreement between the designated administrator of a backbone network and the users in the access network who want to use this privileged quality of service. Since it is a special service which involves upgradation of the existing infrastructure, few privileged users pay for it and a negotiable share of this amount could be given to the administrator of the backbone network for monitoring and managing the resources.

The investment required in upgrading infrastructure for installing these special routers may be offset by charging the users through various pricing models such as Flat Pricing Scheme or pricing based on usage, priority, tiered usage, congestion of network and Two-part tariff.

Pricing models for ISP's in India [10] discusses about Two-part tariff and price discrimination schemes. Two-part tariff and price discrimination schemes ensure all customer segments are targeted as described below.

1) In a two-part tariff scheme, the first part of the tariff is fixed fee for being connected to the network which would compensate for the basic network infrastructure .The second part is variable fee depending upon bandwidth used, latency, bit error rate and other such parameters that define the quality of service being provided to the user.
2) In a price discrimination scheme, users are divided into segments based on affordability or attributes revealed by user as elucidated below:
   (a) *Affordability*: Charge per user is based on his or her willingness to pay. While this is the most profitable model, implementation could be a challenge due to legal issues
   (b) *Induced user attributes*: Charge per user is based on an induced user attribute. These can be done by segmenting users based on various attibutes such as video streaming, VoIP, email, social networking,, etc. and charging differential prices based on these attributes.
   (c) *Verifiable user attributes*: Charge per user is based on verifiable user attributes. These can be done by segmenting users basis verifiable attributes such as miilitary networks, students, senior citizens, corporates,

entrepreneurs, etc. and charging differential prices basis these attributes.

For such models, a few pointers to determining price are mentioned below.

1) In two-part pricing scheme, unit price is determined through an intersection of demand and marginal cost curves.
2) Users can be segmented on the basis of verifiable attributes or induced attributes. The former is preferred for easier implementation while the latter is preferred is there is a significant affordability difference among various customer segments.

IV. Conclusion

Our paper proposes special routers with mapping features and also comments on placement of those routers in typical backbone architectures. The basic flow design of such a mapping mechanism is also discussed in the paper.

Therefore, the architecture design proposed in the paper improves the QoS provisioning by extending the dynamic nature of QoS services into the backbone network and also ensures the delivery of desired QoS to a particular packet if the access network fails to do so.

V. Future Work

In our paper, we proposed a possible design to provide dynamic QoS in the backbone network, but the algorithm and the parameters needed for the mapping box are not explored yet.

The implementation of the proposal is majorly connected to the computation involved in the mapping box. The algorithm which maps the quality of services from diverse networks is critical and has a scope for exploration. The parameters which have to considered for the mapping process also plays a key role, as these parameters might be different for different networks.

In order to simulate the proposed implementation, we use NS2 simulator and design two networks, one in which the special routers are used in the backbone network to extend the QoS, and the other without this implementation, and compare these two for the performance in various scenarios. For the experimentation purpose, we send packets from access networks to a server placed in the backbone network.

The QoS provisioning which is done at the special routers will be directly proportional to the type of service bit or DSCP code value to maintain the QoS provided in its access network. In order to compare packets from different access networks, the bit error rate and bandwidth of the access networks would also be considered, along with the latency, delay, jitter and loss tolerance and control flags of the packet. A formula should be derived from the dependency on these characteristics and a constant would be introduced based on the simulation result to evaluate the extended QoS stream of a particular packet.

The ideal case would be the one in which every router has the proposed mapping feature. But that involves a lot of computation. The most realistic approach would be to place such special dynamic routers in appropriate positions in the network. The various parameters which affect the placement and the threshold values of these parameters to place a special router has to be defined.

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