Differentiated Services

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Abstract

Due to the increasing number of users of the Internet, the need for Quality of Service for the internet has increased. This has lead to the development of Integrated (or IntServ) and Differentiated (or DiffServ) Services as possible replacements to the Best Effort Service that is currently used in the Internet. The lack of scalability in the IntServ model has given rise to the popularity of the DiffServ model. Moreover, the initial performance results and ease of introduction into the current Internet scenario have favored the DiffServ model. Despite the advancement of research into DiffServ, they had been limited to the wired network. However, with the increase in mobile users, researchers are looking at ways of extending the wired DiffServ model to include mobile, wireless networks. This paper looks into the current research to expand the architecture and experimental framework to support DiffServ for wired as well as for mobile, wireless networks.

Keywords: wired networks, wireless networks, mobile networks, Quality of Service, differentiated services, signaling protocol

1. Introduction

The importance of Quality of Service (QoS) research in the wired network has grown increasingly over the years. With the advent of mobile and wireless applications, the need for QoS has increased especially with various classes of real-time applications such as voice and video. The expected growth of the Internet, especially with the wireless aspect of the web, has intensified the effort in the research of QoS in the mobile and wireless networks.

The Integrated Services or Intserv model [1, 2] for wired networks was developed before the creation of the Differentiated Services or DiffServ model for wired networks [3]. The signaling protocol for the IntServ Model was developed and came to be known as Resource Reservation Protocol or simply RSVP [5, 6]. This enabled the Intserv researchers to develop applications with signal per-flow requirements and create several scheduling algorithms to support both these applications and requirements. With the coming of mobile and wireless networks, RSVP had been adapted to fit these networks [7, 8]. An architecture that used a form of modified RSVP and Class Based Queuing had been described in [7]. However, there had been reservations about using RSVP in both wired and wireless networks. They were the lack of [1]:

- scalability due to over-reliance on per-flow state and processing. This is especially true in large networks which have several simultaneous flows.
- applications capable of generating RSVP signaling and thus their inability of meeting the minimum requirements using the IntServ model.

The lack of scalability in the IntServ model had given rise to the popularity of the DiffServ framework [9, 10, 11]. Moreover, the initial performance results and ease of introduction into the current Internet scenario had favored the DiffServ model over the IntServ model.

In recent years, the research into DiffServ for mobile and wireless networks had been very active. In [6], Barry et al investigated differentiated services in wireless packet networks using a fully distributed approach that supports service differentiation, radio monitoring and admission control. In [20], Ahn et al proposed SWAN, a stateless network model which used distributed control algorithms to deliver service differentiation in mobile wireless ad hoc networks in a simple, scalable and robust manner. In [3, 5], the authors suggested an enhanced version of DiffServ to tackle the issues faced by users and applications of mobile and wireless networks. They had studied whether DiffServ, for wired networks [2] could be used for mobile and wireless networks. They proposed a new DiffServ framework that worked for mobile, wireless network, taking into consideration factors that differentiated wired networks from that of mobile, wireless network. These factors included signaling requirements, mobility, lower wireless bandwidth and battery power constraints. The framework was implemented and tested over at Washington State University over a mobile and wireless network and experimental results showed the effectiveness of the proposed DiffServ framework. The authors suggested that mobile and wireless network algorithms and mechanisms could be implemented using this new mobile and wireless DiffServ framework.

This paper gives an overview of DiffServ model in section 2 and in section 3, provides information on how it could be extended to include mobile wireless networks. In section 4, it discusses the experimental results and, discusses and concludes in section 5.

2. Overview of Differentiated Services [3, 5, 12, 13]

DiffServ provides differentiated classes of service for the data that flows through the Internet. It is currently in draft stages by the IEEE's Internet Engineering Task Force (IETF). It follows the Class of Service [CoS] mechanism which simplifies the flow complexity of data through the internet by implementing mapping mechanisms to reduce multiple flows of data into a few number of service levels. Diffserv is an improved architecture of Type of Service (ToS) [14].

The TOS or DS byte is made up of two parts. One part, which occupies 6 bits, is called the Differentiated Services Code Point (DSCP). The other 2 bits is currently unused and is simply known as CU. Unlike the other CoS mechanisms, the DiffServ is based on the possible forwarding behaviors of packets, known as Per Hop Behaviors (PHBs). The PHB is selected based on the DSCP.

In DiffServ, the different kinds of traffic are marked for different kinds of forwarding. Markings and policies are used to differentiate the allocation of resources in terms of importance. Packets belonging to mission-critical packets can be encoded with a DSCP that provides high bandwidth allocation and zero-frame-loss routing path. Other important packets such as Interactive video conferencing data and all data from the CEO's computer can be aggregated with the mission-critical packets. Lesser important packets such as Email and web browsing data can be sent by encoding its DSCP that indicates routine traffic handling with minimal packet drops. Route selection is then made by DiffServ-compliant boundary router which forwards these packages using defined network policy and the PHPs supported by the network. The mission-critical packets, which are the highest class packet, will be given the higher precedence over the other classes of packets in terms of queue scheduling and bandwidth allocation. Slower service will be given to the other classes of packets. The DSCP allows coding up to 64 different forwarding behaviors since it is 6 bits wide. Moreover, ToS-enabled will not cause problems with the DSCP mapping since DSCP is backward compatibility with the three precedence bits.

A DiffServ domain is defined as a set of contiguous networks that are DiffServ-compliant containing nodes that are also DiffServ- compliant. Service level commitments, traffic flow constraints, and inter-network DSCP marking rules are defined according to service agreements between networks. The inbound and outbound packets are marked by the ingress and egress routers at the different network boundaries in the domain. These routers ensure that Service Level Agreements and Traffic Conditioning Agreements (TCA) are also met. In Diffserv networks, forwarding is done by DSCP prioritization rules. Lower class packets may be delayed or dropped by routers and switches in preference to higher-class packets. Boundary routers may choose faster, higher quality routes for these higher-class packets. As packets leave or enter the network, the packet’s DSCP can be changed by the marking entities whose rules are defined in the SLA and the TCA to ensure the integrity of packet marking within the network.

In order to ensure that the traffic rules follows the policies outlined in the TCA, the DiffServ architecture uses a Traffic Conditioner mechanism which is situated at the network boundary.

The DiffServ components include

- packet classifiers or traffic classifier: Used in selecting packets based on packet header information
- traffic profiles: Used in specifying the temporal properties of a traffic stream selected by a classifier
- traffic conditioners: Used to contain
    1) meter to measure temporal properties
    2) marker to set the DS field
    3) shaper to bring packets in compliance with the stream
    4) droppers to drop packets to fit traffic profile

At the network boundaries, accounting mechanisms can also be triggered for quality level monitoring and billing purposes.

3. Differentiated Services in Mobile and Wireless Networks [3, 5, 12, 13]

The network considered by the authors [3, 5] is that of a campus network. It is shown in figure 1. The campus network is connected to the internet. It is made up of several departmental subnets. Each department subnet is considered a domain. Hence the campus network is made up of several domains. Each domain is further divided into several regions. A base station (BS) is associated with each region, serving all the mobile applications within its coverage regions. Each BS is then connected to the wired network. Handoff occurs whenever a mobile application moves from region to another. The subsections highlight the extension of the wired Diffesrv model to include mobile, wireless networks.

3.1. Traffic classifier and conditioner

Here, the authors had used the Class Based Queuing (CBQ) [15] mechanism to implement a controlled sharing of the wireless link. It consisted of the following mechanisms:

- Classifier: It was used to classify packets into predefined classes. For example, if there were two classes: Default (DEF) and My_CLS. The former was allocated to 40% of the bandwidth while the latter got 60%. The My_CLS class was then divided into classes A and B with an allocation of 20% and 30% respectively. 10% of the total bandwidth was unallocated from My_CLS class. Thus, packets allocated to certain class would get the bandwidth allocated to that class. Here, the authors modified the component to use the TOS header to classify the header. Originally, packets were classified based on the source and destination addresses and ports. Moreover, the scheduler made it possible for a child class to borrow bandwidth from its parent. This characteristic of the scheduler made it an attractive choice for the authors to use it with wireless networks.

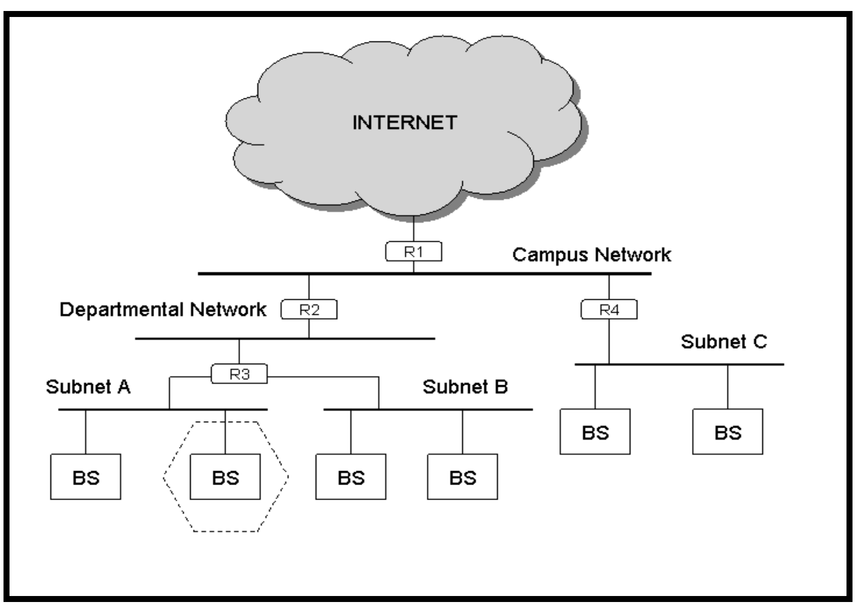

Figure 1: Campus network

- Estimator: This had two functions. They were to
    - estimate the usage of bandwidth for each class and
    - make sure that the specified bandwidth is allocated to each class.
- Packet Scheduler: It was used for the selection of packets for class scheduling. Here the author had used a round-robin scheduler.

The authors had also modified the CBQ mechanism to handle wireless network traffic. The modifications were as follows:

- Packets were classified according to the TOS headers;
- Power profile was used as a basis for packet dropping extensions. The authors had used power profiles that included sending packets based on the differential importance bit in DSCP field and reducing the rate of sending packets;
- Mechanism to be used to allocate bandwidth to a class;
- Mechanism to be used for mapping certain percentage of packets from one class to another.

3.2. Signaling Protocol

As for the Signaling Protocol, the authors had used the Internet Control Message Protocol (ICMP) [16] instead of RSVP [7] and YESSIR [17] as both were deemed as having scalability problems. They used three kinds of ICMP signaling messages. They were

- *Report* messages that were sent from the mobile to convey mobile parameters such as bandwidth requirements, etc.,
- *Reply* messages that were sent from the BS such as to acknowledge the mobile's bandwidth reservation request,
- *Modify* messages that were sent from the mobile such as to convey the request that the bandwidth requirement for a particular session needs to be changed.

Figure 2 shows the flow of signaling messages. In (a), the sender sent the power profile of the application to the BS at the start of the session, before any data was sent. The solid lines represented the mandatory control messages while the dotted lines represented the optional control messages. The BS might sent a modify bandwidth signal that could be sent to the sender depending upon the capabilities of the wireless link and if the bandwidth expectation exceeded the limit of the mobile receiver. On the other hand, the mobile receiver periodically sent its power level messages to its BS. If the mobile receiver moved to another cell controlled by another BS, it would report its bandwidth expectations to its new BS, as seen in (b). The BS would then send a reply message containing the bandwidth that could be allocated to the mobile receiver.

3.3. Mobility

Whenever a new mobile moves into a new cell, the BS of the cell would try to provide the required bandwidth to the mobile. However, there might be situations when the required bandwidth might not be met. The authors proposed two solutions. They were to

- create a new class called *new-mobile* which was then allocated a small percentage of the bandwidth. There had been research done on how to estimate this bandwidth [18]. This class would be used by any new mobile that had entered the cell for a specified period of time until which the BS would modify the priority of the mobile's session based on the availability of bandwidth.

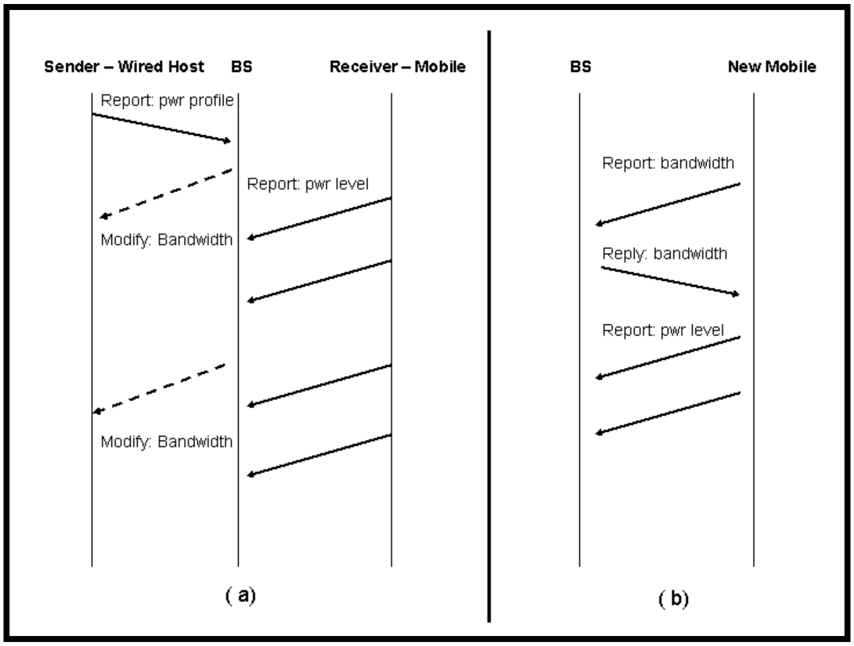

Figure 2: Control signal messages in the system

- take away the bandwidth assigned to low priority applications within the cell and give it to higher priority applications.

The authors had implemented both solutions. Whenever a mobile moved away from a cell, its bandwidth would be reallocated to the default class to be used by other mobiles within the cell.

3.4. Low Bandwidth

Low Bandwidth is always a problem in mobile and wireless networks. Most of the Local Area Networks (LANs) operate at 2 Mbps with migration to 11 Mbps. This is low compared with that of the typical wired LAN network which has a bandwidth of 100 Mbps. Thus, in mobile and wireless networks, there is a need for controlled sharing of the bandwidth. The authors had considered two mechanisms. They were to

- reduce the traffic at the sender which was assumed to be on a wired network. The advantage was that less data would be sent on the wireless link. However, all receivers would be forced to accept data at reduced rate, especially in point-to-multipoint cases.
- require the BS to reduce the traffic. The disadvantage was that there would be wastage of resources in the link between the sender and the BS since the BS need to be aware of the nature of the application.

3.5. Power Constraints handling

The authors had used the current battery power level in scheduling whereby the battery power level would be periodically sent to the BS as part of the *power profile* parameter. The *power profile* parameter identified the following

- the nature of the application and
- how the BS should handle its packets under low power situations.

If the application was a layered video, then the power profile might require that only base level video packets be sent and all others be dropped. In order to handle power constraints, the BS would need to keep a table containing each mobile's power profile and the DSCP code used by its flows.

3.6. Classification of packets within a flow

To classify important packets, the second bit of the DSCP was set to zero for important packets while setting to one represented lesser important packets. The first bit indicated whether there is a power profile or not. The last 4 bits indicated the PHB.

4 Experimental results

Three cells were used. Each cell had a Pentium computer equipped with an Ethernet card and a 2.4 GHz WaveLAN ISA card acting as its BS. The testbed also had two laptops each equipped with 2.4 GHz PCMCIA WaveLAN cards. The applications used for testing were:

- A traffic generator program that used UDP and TCP. H.263 video compression simulation model with an encoder, a decoder, and a few sample video streams.
- Netperf [20], a network performance benchmarking program.
- The Advanced Power Management (apm) [19] tool was used to monitor the power usage in laptops.

4.1. Scenario 1: Reservations under user mobility

In scenario (a), the new mobiles were reserved a certain percentage of bandwidth whereas in scenario (b), the bandwidth requirements for the new application came from a lower priority application. The results for scenario 1(a) and 1(b) were shown in figures 3 and 4. The reservations in both cases were successful.

4.2. Scenario 2: Low bandwidth of wireless networks

Here, the authors studied the mechanism to deal with problems arising from lower link bandwidth. In figure 5 showed the setup and results for the effect of implicit admission control. They tried improvements on the BS side of the network by increasing the buffer size (see figure 6) and allowing the class to borrow from other classes (see figure 7). Both were successful. The former enough to sustain certain flows before packets were dropped. The latter could borrow bandwidth from other classes to a certain extent. Figure 8 showed the effect of the sender getting the signal to reduce the rate of data that is transmitted. Here the signal was received around 30 time units.

4.3. Scenario 3: Power constraints in wireless networks

Here, the authors studied the mechanism to deal with problems due to power constraints in wireless networks. The idea was that the receiver received the power profile message from the sender based on the nature of application it was going to receive from the sender. This information would then be used by the base station or the mobile

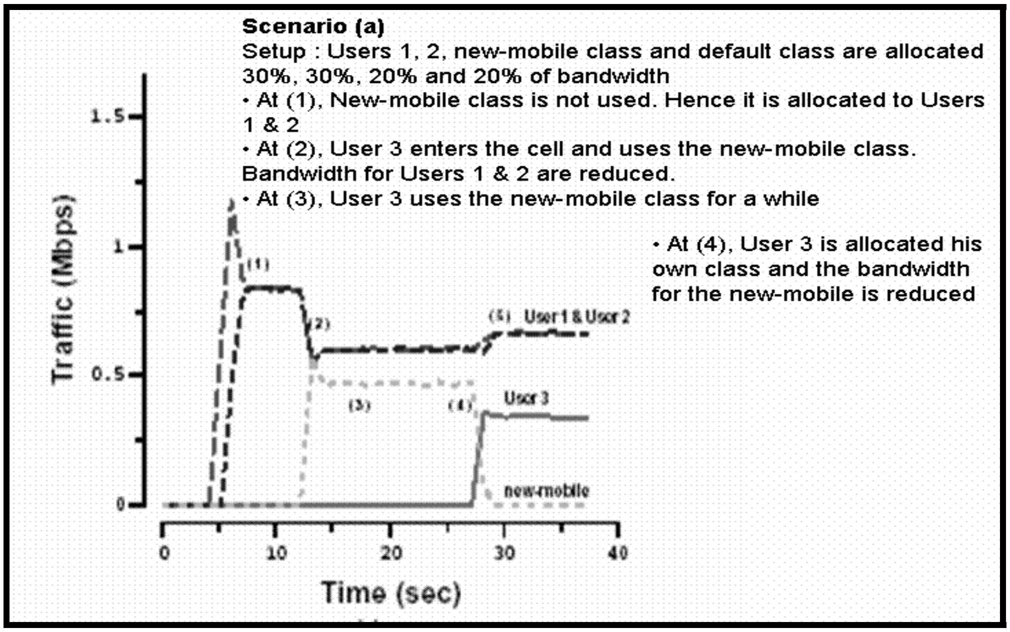

Figure 3: The results for scenario 1(a)

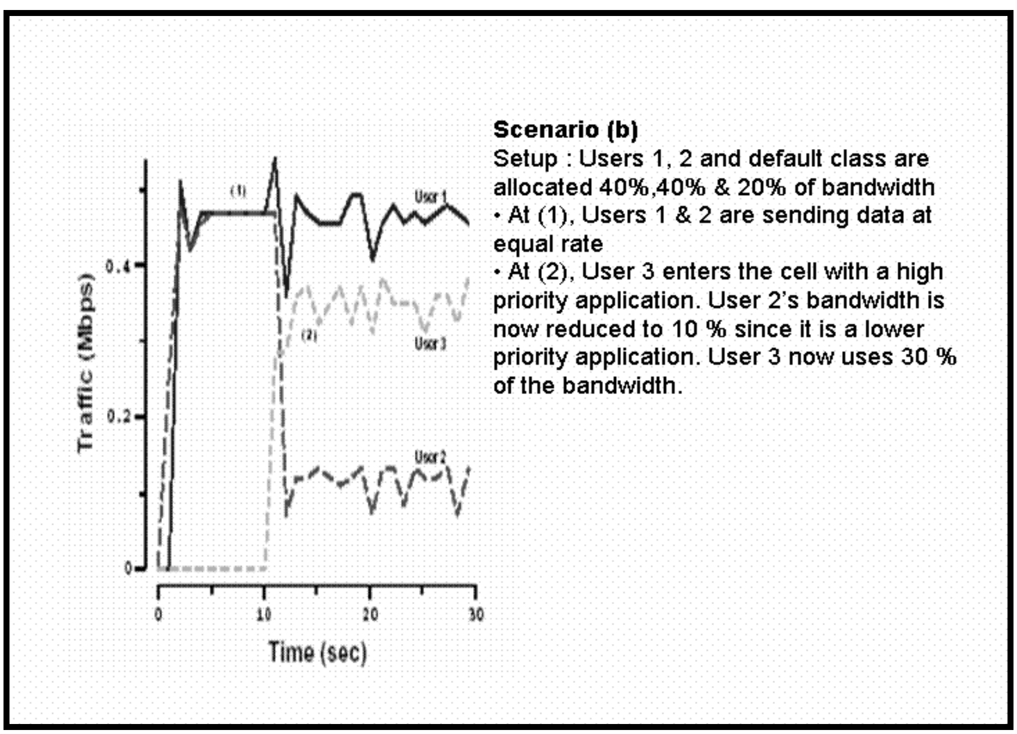

Figure 4: The results for scenario 1(b)

while scheduling in a low power situation. For example, consider an MPEG-1 and MPEG-2 video stream with I (Intra), B (Bidirectional) and P (Predictive) frames. The B frames would be dropped first because this affected only the particular frame and the decoder could extrapolate the rest of the message. If this was not enough, then P frames were discarded. I frames would be discarded last. The experiments here did not produced definitive results as the authors did not have the proper tools to measure the battery power consumption on a per-packet basis.

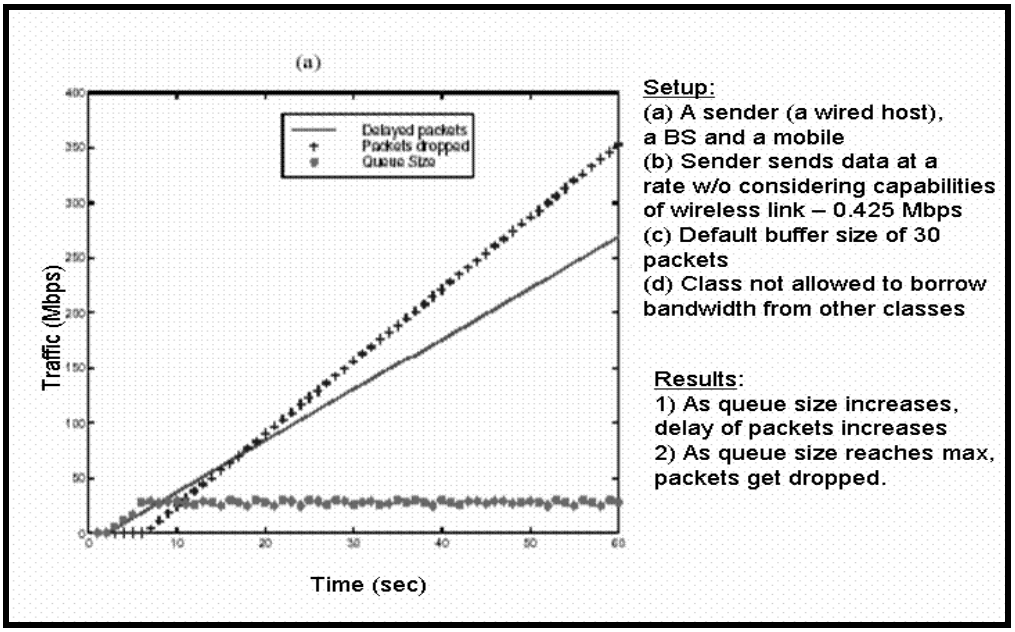

Figure 5: The effect of implicit admission control

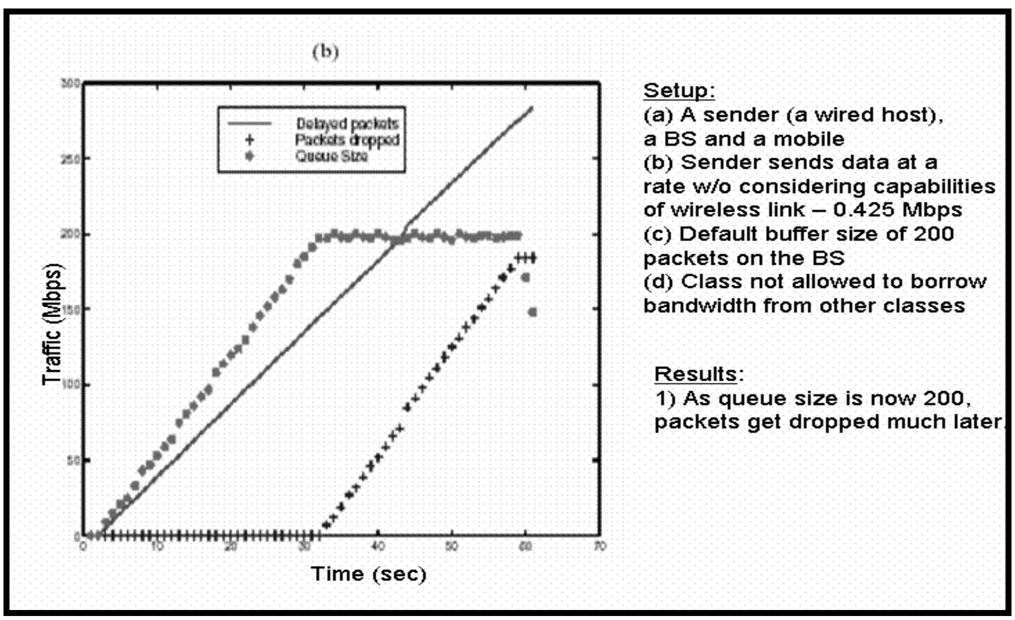

Figure 6: The effect of increasing BS buffer

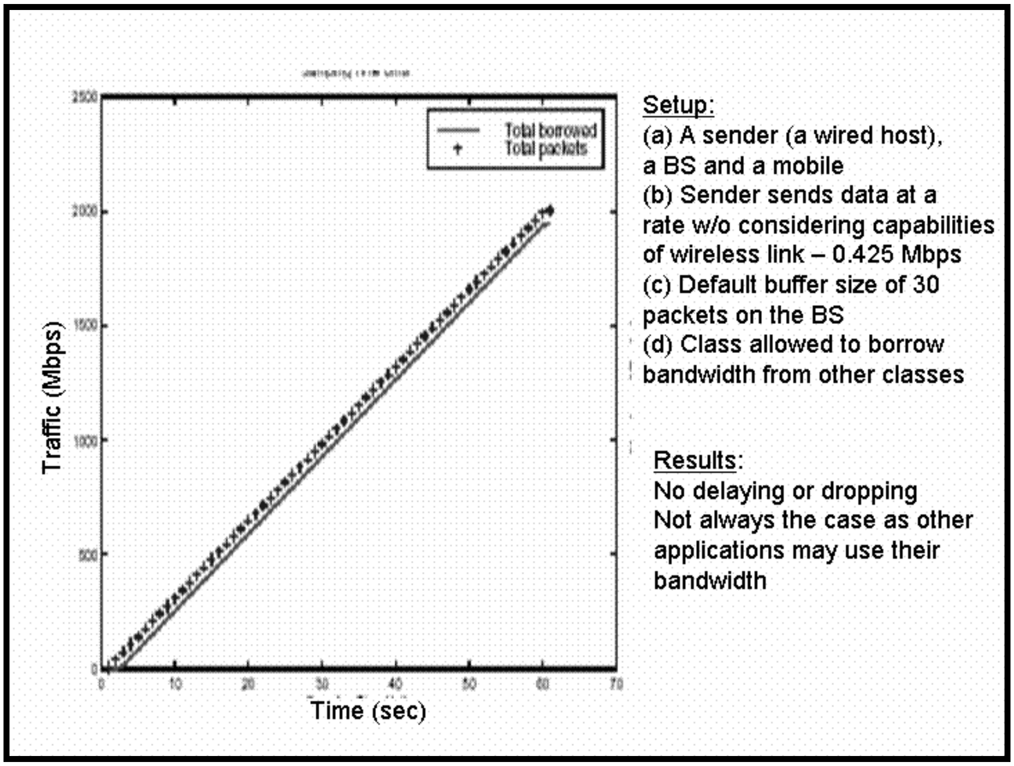

Figure 7: The effect of allowing the class to borrow from other classes

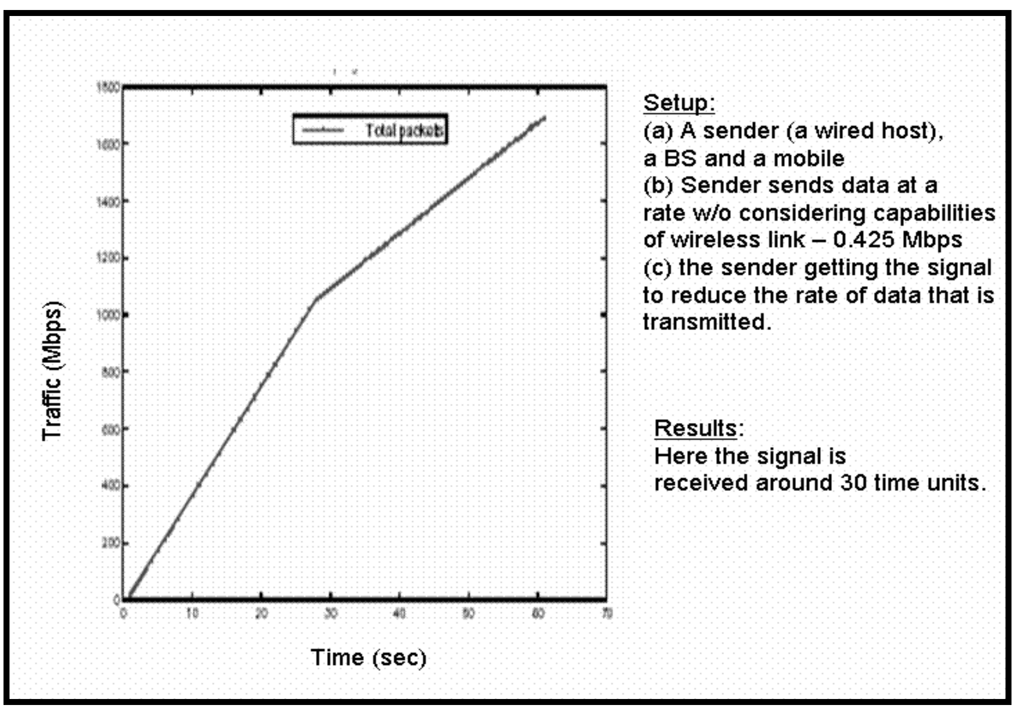

Figure 8: Sender receives a signal to reduce the data rate

5. Discussion and conclusion

The authors had tried to modify the wired DiffServ model to wireless networks by incorporating several enhancements such as

- testing of the CBQ-based scheduling scheme for DiffServ
- mechanism to provide compensation bandwidth in case of high loss in wireless networks,
- use of signaling mechanism for improving performance in low bandwidth situations,
- power level information for power-intelligent scheduling, and
- bandwidth allotment alternatives during mobility.

However, they had not looked into any per-hop behavior (PHB). A research into the various PHB would be useful for the DiffServ community. Moreover, their research into power constraint in wireless networks did not yield any credible results. On the other hand, their ideas on bringing DiffServ into the mobile and wireless regions and their mechanisms that they used to tackle the issues of mobile and wireless seems noteworthy and a step into the right direction.

6. References

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