The Chinese University of Hong Kong
Computer Science and Engineering Department

Fall Semester Report of

Final Year Project **LYU9903**

QoS Schemes in Wireless Networks

Written by **Ho Pun Mo Matchman** (97678721) & **Ng Maggie** (97746133)
Supervised by Prof. Lyu Rung Tsong Michael

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Contents

Chapter 1

Introduction

In this project, we have two aspects to be concerned about, namely Quality of Service (QoS) and Wireless Networks.

Quality of Service becomes a very hot topic for telecommunications systems. It provides guarantee on various services for telecommunications networks. These services include video on demand, traffic control on congested networks, and maintain required network bandwidths while wireless communications today span a wide range of different technologies, including cellular, Personal Communications Service (PCS), satellite, infrared, wireless data WANs, specialized mobile radio, and wireless LANs.

Maybe someone would consider achieving QoS is as easy as raising a hand, what you should do is just getting enough bandwidths. However, this is definitely wrong. As an analogy, imagine there is a road reserved for buses to travel. If the drivers are not punctual, the road is not utilized at all, and the passengers would be annoyed. Therefore, good controls on the bus schedules are also important, that is to say, good packet scheduling algorithms are essential in order to achieve QoS in computer networks. But, bandwidth reserving and packet scheduling are not the only components needed in order to provide quarantee services, there are more. We will discuss this throughout the report.

In our project, we choose Linux as our development and experiments environment. The reasons are that Linux is an open source operating system, we can control the kernel fully comparing to other platforms such as Microsoft Windows, and LYU9802 project team has developed a QoS system which runs on Linux. Moreover, Linux is evolving to support QoS at the mean time.

In this report, we focus on QoS on both wireless LANs and traditional wired networks at most of the time. And the networks and network protocol we concern most are IP-based and TCP respectively.

Chapter 2

Introduction to Wireless Networks

2.1 Introduction

In this section, we will talk about wireless LANs and wireless WANs followed by a comparison between wired and wireless networks.

2.1.1 Wireless LANs

According to [10], a wireless local area network (LAN) is a flexible data communications system implemented as an extension to, or as an alternative for, a wired LAN. Using radio frequency (RF) technology, wireless LANs transmit and receive data over the air, minimizing the need for wired connections. Thus, wireless LANs combine data connectivity with user mobility.

That is to say, wireless LAN can stand alone as a communication system or be used as an extension to an existing wired LAN. The interoperability between wired LANs and wireless LANs makes it become a flexible way to establish a communications network. More advantages will be given later in this report, and disadvantages as well.

According to [12], wireless LAN technology today is relatively mature, it has been adopted in many applications such as health care, trading floors, supermarkets, transportation and warehousing and are increasingly being used in office environments. And the coming of IEEE 802.11 makes wireless LAN towards standardized, increasing the interoperability between different wireless devices between different vendors. Real life examples will be given later in this report.

Types of Wireless LANs

Most likely, a wireless LAN is connected to an existing wired LAN, this is called an infrastructure network. The scenario is shown in figure 2.1. In order to connect a wireless LAN with a wired LAN, a bridge called access point is needed. An access point effectively bridges wireless LAN traffic onto the wired LAN. It can also act as a repeater for wireless nodes, effectively doubling the maximum possible distance between nodes. Difference wireless devices will be introduced later in this report.

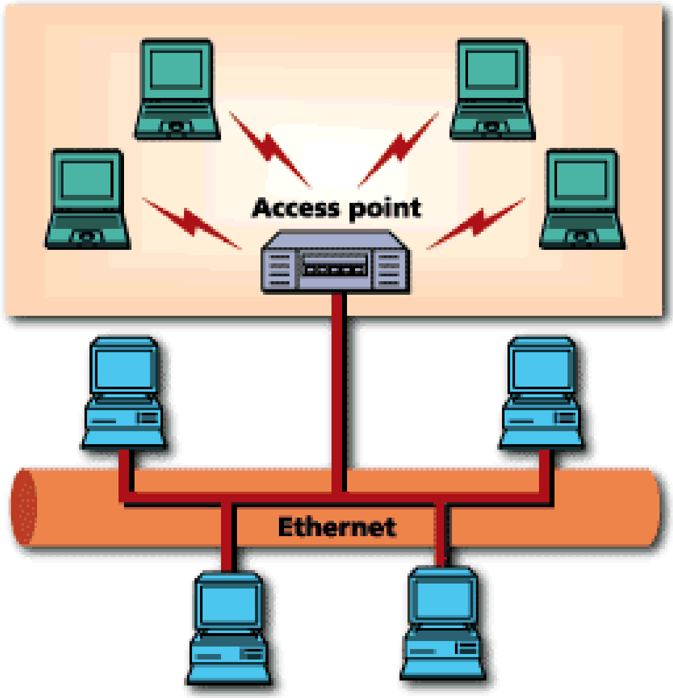

Figure 2.1: Infrastructure Network

There exists different types of wireless LANs, some of them are spread spectrum, low-power narrowband, HiperLAN, infrared LANs, and Infrared Data Association (IRDA).

Spread Spectrum Most wireless LANs today use spread spectrum technology, operating in a number of radio bands, including 902 to 928 MHz, 2.400 to 2.483 GHz and 5.725 to 5.85 GHz. The 900 MHz band best serves consumer products, while the 2.4 GHz band best serves midrange performing wireless LANs (1 to 3 Mbps) and the 5.7 GHz band best serves higher-performance wireless LANs (5 to 10 Mbps). For coverage, spread spectrum usually operates over a typical range of about 100 meters and coverage areas ranging from 5,000 to 25,000 square meters (50,000 to 250,000 sqaure feet).

Low-Power Narrowband An alternative approach to spread spectrum is to transmit narrowband signals at low-power levels, which have the ability to operate at higher data rates. Commercial company such as RadioLAN has product that uses this approach and operates at 10 Mbps in the 5.8 GHz band with 500 milliwatts of peak transmission power. The tradeoff for this higher performance is a reduction in transmission range of about 30 meters (100 feet) in an office environment.

HiperLAN Higher Performance Radio LAN, abbreviated as HiperLAN, is a wireless technology standard developed by the European Telecommunications Standards Institute. It has a data rate of about 24 Mbps using a channel width of 23.5 MHz. This type of throughput readily supports multimedia applications. However, no commercial products are yet available.

Infrared LANs An alternative approach to radio-based wireless LANs is infrared communications. Infrared networking uses electromagnetic radiation with wavelengths of 820 to 890 nanometers, corresponding to a frequency of about 350,000 GHz. The advantages of IR include no need for licenses, no safety issues, huge potential capacity and good control of interference. IR does not penetrate walls, so infrared LANs must be contained in a room. Note that IR LANs generally do not operate in outdoor areas where there is sunlight. IR transmitters and receivers can be designed either for directional use or for diffuse use, where signals bounce off walls and other objects to reach the receiver. In fact, IR is specified as one of the physical layer options in the new IEEE 802.11 standard.

Infrared Data Association (IRDA) The Infrared Data Association is a consortium of vendors that has defined low-cost IR communications characterized by:

- Directional point-to-point communications of up to one meter
- 115-Kbps and 4-Mbps connectivity
- Walk-up ad hoc connectivity for LAN access, printer access, and portable computer to portable computer communications

The products using in our department are both (RangeLAN2 and WaveLAN) using the spread spectrum technology. We have been using RangeLAN2 at most of time in this semester, and are using WaveLAN now, and most possibly, in the next semester.

Roaming

A special feature of wireless LANs that wired LANs do not have is roaming.

As the coverage of one access point is limited, as depicted in figure 2.2, and most possibly, users will be always going from the coverage of one access point to that of another one. In order to let the user maintain continuous connection, the hand-over between access point must be provided. Achieving this lets the users roam from one physical area to another without losing the connection.

Something should be mentioned is that, if one access point is on one subnet and another access point is on another subnet, traffic will have to cross a router, and most wireless LAN vendors do not support this currently. One of solutions for this situation is to use mobile IP.

Mobile IP

According to [4], mobile IP was suggested as a means to attain wireless networking. It focuses its attention at the Network Layer, working with the current version of the Internet Protocol (IP version 4). In this protocol, the IP address of the mobile machine does not change when it moves from a home network to a foreign network. In order to maintain connections between the mobile node and the rest of the network, a forwarding routine is implemented.

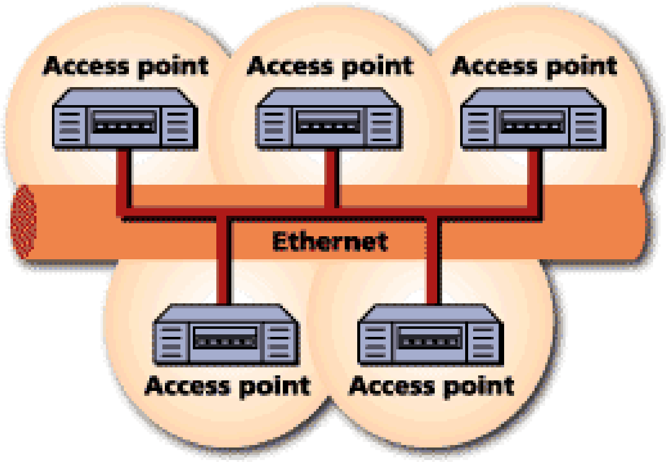

Figure 2.2: Roaming

The operation of the Mobile IP is that, when the mobile agent moves from its home network to a foreign (visited) network, the mobile agent tells a home agent on the home network to which foreign agent their packets should be forwarded. In addition, the mobile agent registers itself with that foreign agent on the foreign network. Thus, all packets intended for the mobile agent are forwarded by the home agent to the foreign agent which sends them to the mobile agent on the foreign network. When the mobile agent returns to its original network, it informs both agents (home and foreign) that the original configuration has been restored. No one on the outside networks need to know that the mobile agent moved.

This configuration works, but it has some drawbacks. Depending on how far the mobile agent moves, there may need to be some store and forwarding of packets while the mobile agent is on neither the home nor the foreign network. In addition, Mobile IP works only for IPv4 and does not take advantage of the features of the newer IPv6.

IEEE 802.11

Finally released in 1997 after nearly seven years of development, the IEEE 802.11 standard specifies physical layer and medium access control (MAC) protocols. The MAC constitutes the lower half of the datalink layer in the OSI network model. 802.11 was designed so that to upper levels the network behaves like a standard wired network. To accomplish this the link layer engages in error correcting functions that are not usually employed at the link layer in wired LANs.

In IEEE 802.11, there are two different ways to configure a network: ad-hoc and infrastructure. In the ad-hoc network, computers are brought together to form a network on the fly. There is no structure to the network; there are no fixed points; and usually every node is able to communicate with every other node. This is suitable for temporary purpose. Infrastructure network has been introduced before (figure 2.1), it consists of wired LANs, access points and mobile nodes.

2.1.2 Wireless WANs

Since we focus on wireless LANs in our project, so details will not be given for wireless WANs. However, sake of completeness, a brief introduction will be given instead.

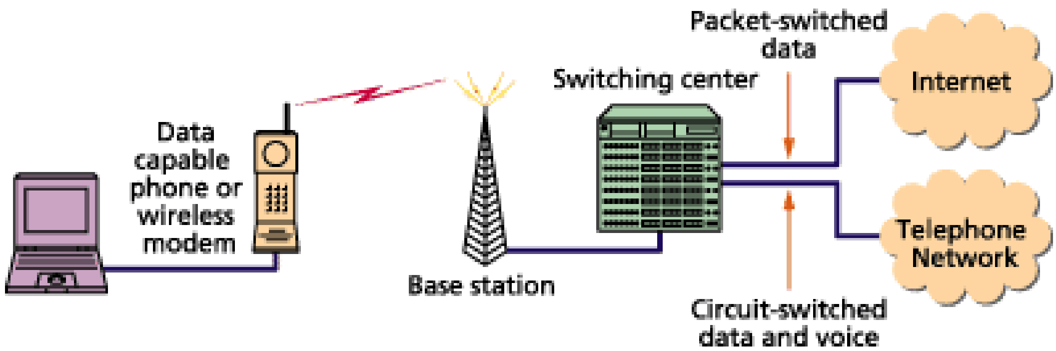

Figure 2.3: Mobile Connection

Figure 2.3 shows a scenario of computer using wireless WAN. A computer connects to a data capable phone or wireless modem can communicate with the Internet or the well established telephone network using packet-switching techniques and circuit-switching techiques respectively.

There exist some types of wireless WANs, such as cellular-based systems, paging networks and dedicated wireless WANs, like CDPD, Metricom's Ricochet, ARDIS and RAM Mobile Data. In Hong Kong, we also have a wireless communication system that allows us to phone or to be phoned, to page or to be paged, with a broad coverage.

Communications are not wireless from end-to-end, actually, wireless networks are complex networks involving wire-line infrastructure, and they connect to other complex networks – value-added networks, corporate intranets and the Internet, as shown in figure 2.4.

2.1.3 Wireless Networks vs Wired Networks

Wired and wireless networks seem to be similar from the user's view, Indeed, they differ from different aspects. We are going to compare them in some of these aspects. Basically, according to the Claude Shannon Model, wired and wireless networks differ from the transmission medium they use. Wireless networks are unguided while wired networks are usually guided.
Wired networks and wireless networks have some fundamental differences:

1. While wireless LANs use the same networking protocols as wired LANs, they use specialized physical and datalink protocols. At the physical layer, the wireless network interface card takes frames of data from the link layer, gathers the data, and then uses the modified data stream to modulate a radio carrier signal. At the link layer, a key function is to control access to the medium. Unlike Ethernet networks, which are

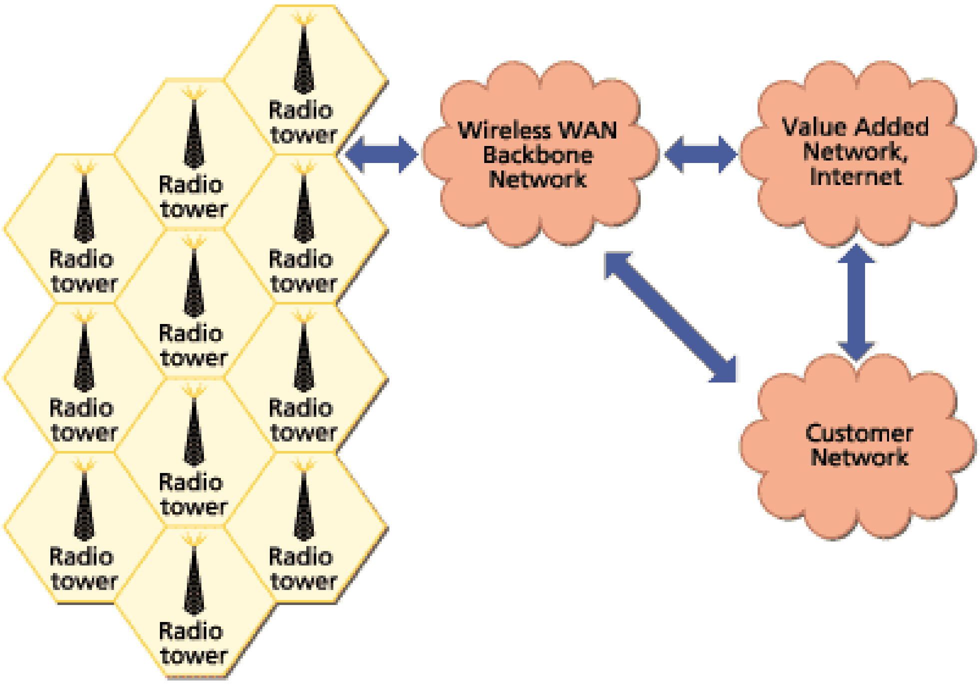

Figure 2.4: Wireless Networks are not wireless from end to end.

carrier-sense-multiple-access with collision detect (CSMA/CD), most wireless LANs are carriers-sense-multiple-access with collision avoidance (CSMA/CA). Figure 2.5 is a typical wireless LAN protocal stack diagram.

2. They let you stay connected as you roam from one coverage area to another. This is the roaming effect of wireless LANs.

3. Distances between nodes vary as mobile users are always moving with their computers equipped with wireless devices.

4. They have unique security considerations. According to [10], because wireless technology has roots in military applications, security has long been a design criterion for wireless devices. Security provisions are typically built into wireless LANs, making them more secure than most wired LANs. It is extremely difficult for unintended receivers (eavesdroppers) to listen in on wireless LAN traffic. Complex encryption techniques make it impossible for all but the most sophisticated to gain unauthorized access to network traffic. In general, individual nodes must be security-enabled before they are allowed to participate in network traffic.

5. They require different hardware. For example, they needed PC cards, handheld terminals with integrated radios and access points.

6. They offer performance that differs from wired LANs. In general, the throughputs of wireless LANs are relatively narrorwer than those of wired LANs, which varies from serveral Kbps to Gbps. Throughputs of some types of wireless LANs are given in table 2.1.

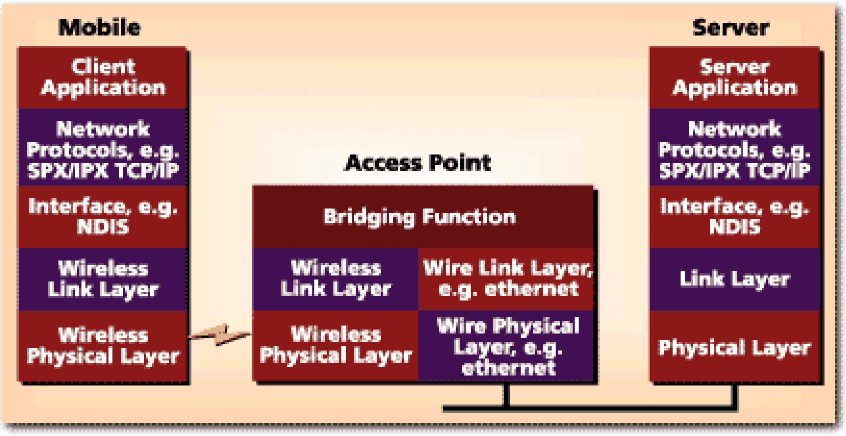

Figure 2.5: Wireless Protocols

Types of Wireless LAN	**Throughput**
IEEE 802.11	1Mbps or 2Mbps
WaveLAN	2Mbps to 6Mbps
RadioLAN	10Mbps
HiperLAN standard	24 Mbps

Table 2.1: Throughputs of some wireless LANs

2.2 Why Wireless?

2.2.1 Importance of Wireless Networking

In a world of increasing mobility, there is a growing need for people to communicate with each other and have timely access to information regardless of the location of the individuals or the information. With the help of wireless LANs, users can access shared information without looking for a place to plug in, and network managers can set up networks without installing or moving cables. And wireless communications may be the future trend of comuputing, why? Imagine a world that anybody can uses cordless or cellular phones, TV remote controls, keyless car entry, or garage door openers. According to Rysavy, while computer networking have vastly increased our options on how and what we communicate, they have physically constrained us by leashing us with a physical wire to the network. But wireless communications brings us back to a form of communications that is inherently natural to us. Actually, the following features of wireless network are the main elements to make wireless networks become popular:

Mobility

Wireless LAN systems can let user access to real-time information anywhere in their organizations.

Installation Flexibility

Wireless technology allows the network to go where wire cannot go.

Installation Speed and Simplicity

Installation a wireless LAN system can be fast and easy as it can eliminate the need to pull cable through the walls. It is much more convenient than installing wired networks.

Scalability

Wireless LAN systems can be configured and changed in different topologies to meet the needs of users.

2.2.2 Trend of Wireless LANs

As the usage of wireless LANs becomes more and more popular, we can note that in future, the development of wireless LANs will become faster. According to Rysavy, there are number of notable trends in next five years. One is that the performance of wireless LANs technology will keep increasing while the costs will decrease. Another is that as wireless data usage grows, increasing amounts of spectrum will become available.

1. Higher Performance At Lower Cost

   In late 1980s, while in the age of early wireless LANs development, the throughputs of wireless LANs was about 250Kbps. In early 1990s, the throughputs increased to 1Mbps. In today technology, we can have a stardard of 1Mbps to 2Mbps standard throughput, even we can now have some device which have 10Mbps throughput. In the next generation, as the technology becomes mature, 10Mbps throughput of wireless LANs may become the standard. Also, 24Mbps throughput of HiperLAN products will be expected.

   On the other hand, we will expect the prices of wireless LANs device dropping. In the near future, the wireless LANs could start competing with wired LANs for typical worker connectivity, and could start propelling wireless LANs into horizontal markets.

2. New Spectrum Options

   As the improvements in technology have allowed radio communications to take advantage of higher frequencies. Wireless LANs that originally operated at 900 MHz have migrated to 2.4 GHz band. And now an increasing number of products are using the even higher 5.7 GHz ISM band. Some new band, like UNII (Unlicensed National Information Infrastructure) is now developing. The UNII band, which spans from 5.15 to 5.35 GHz and 5.725 to 5.825 MHz, will provide home for HiperLAN and the new wireless LAN technologies. In the near future, developments like UNII will be the overall trends. It is expected to see wireless LANs keep moving up in frequency and licensing bodies keep allocating additional spectrums at higher frequencies as market demand increases.

From the above development trends, we will expect the usage of wireless LANs will be keep growing. Even in nowadays, wireless LANs do not subsitute the traditional wired

LANs, but wireless LANs can be used will wired LANs as the backbone. And this usage of wireless LANs will be increased in markets.

2.2.3 Real Life Applications of Wireless LANs

Wireless LANs can be used in many applications. For example, the following situations are suitable to used with wireless LANs.

- Employees that are moblie and have the need fornetworked information can use wireless LANs to stay connected.
- Network managers can use wireless LANs to extend the wired LANs beyond the reach of the cabling infrastructure..
- Network managers can also use wireless LANs as the substitution of wired network, if the environment is too expensive, difficult or impossible to install wire, or the environment is frequently changing.
- As wireless LAN is fast, easy and less costly to set up. It is suitable for use of temporary LANs, such as in the peak times of retail stores.

Actually, in many real-life cases, the wireless LANs are used with the backbone of wired networks. Here are some real-life examples:

- Doctors and nurses in hospitals use notebook computers with wireless LAN to deliver patient information instantly and conveniently.
- Students in the campus use wireless LANs to have mobile classrooms, Internet access for schools or connection to teachers in a more flexible ways.
- Retail stores and restaurants use wireless LANs to have order entry, point-of-sale terminals, and to manage the restaurant seating.
- Warehouse workers use wireless LANs to exchange information with central database, so to increase productivity.
- Network managers use wireless LANs to install networked computers in older buildings that are hard to install cables.

As the growth of using wireless LANs is increasing significantly, there will be more and more use of wireless LANs in real life.

2.2.4 Advantages and Disadvantages of Wireless LANs

Wireless LANs have many advantages so that the use of it is growing so fast. But in today technologies, the wireless LANs still suffer some disadvantages so that it cannot substitue wired LANs.

Advantages:

- The most attractive features of the wireless LAN is it mobility. As the wireless LANs do well with roaming, they allow users to move within the offices while maintaining a network connection.

- The 2 Mpbs bandwidth of wireless LAN is enough to handle most easy office tasks like e-mail and database queries.

- Wireless LANs on spread spectrum radio technology are very secure. Since wireless LANs provide a number of effective security measures, it is difficult to attack without knowing the exact hopping sequences of the users. And wireless LANs also offer some optional encryption mechanisms to users.

- Inexpensive cost is also one of the advantages. The cost is saving from not needing to remove and install and test the cable.

- Since there is no need to construct the wireless network, it is more flexible to build the wireless network as the users need. Especially when the building is not allowed or difficult to install wired network, wireless networks will be very useful at that time.

- Wireless network is also easier to install than wired network. Users only need to plub in the access points and plub the PC cards into notebooks. The configuration for wireless LANs is also easy.

- By taking the benefit of using wireless network, users can take the oppotunity to get basic business tasks done while traveling.

Disadvantages:

- Wireless LANs have standard bandwidth of only about 1-2 Mbps. It is not enough for mulitimedia access and even not very enough for image transfer. For example, video need about 1.5 Mbps bandwidth for MPEG-1, with the overhead on wireless LANs, 2 Mbps is cannot used to play the video smoothly on wireless LANs.

- All wireless devices have limited range of coverage. For example, Proxim and wave-LAN have range of about 150 metres to 300 metres. It reduces the advantage of "mobility" of wireless LANs.

- Wireless LAN cards can cut the life of a PC battery by 20% or more, it also reduces the advanatage of "mobility" of wireless LANs.

- For infrared spread spectrum, line-of-sight may be needed to maintain connection. This limitation restricts the usefulness of wireless LANs in many situations, such as in hard-walled offices and multi-story buildings.

- Due to the unlicensed nature of radio-based wireless LANs, users may have to deal with the unwanted interference from other devices working in their frequency bands.

- Wireless LANs experience higher error rates and delay than wired LANs, resulting in retransmission of frames.

- The collision avoidance mechanism is not as efficient as collision detection used in Ethernet, especially with a large number of users competing for the same frequencies. Since most wireless LANs use carrier-sencse- multiple-access with collision detect(CSMA/CA), once a node starts sending data, it cannot detect whether another station is also transmitting and so senders rely on a positive acknowledgement from the receiver to indicate that no interferenc occurred during the transmission. This makes wireless LANs less efficient than wired LANs under heavy loading. Therefore, actual throughputs of wireless LANs usually only half of the best case throughputs (2Mbps).

You can see that although wireless LANs experience some advantages such as mobility, flexibility and etc, the main problems of wireless LANs are their high error rate and delay which reduce their throughputs. Therefore, it is our job to aware of this weaknesses of wireless LANs and to maintain good performance of wireless LANs under these weaknesses.

In the following sections, we would like to introduce some wireless devices and their "quoted" performance to you.

2.3 How to Perform Wireless?

2.3.1 Wireless Devices

To use wireless LANs, we must have some wireless LANs devices, included access points, and PC cards. There are many wireless LANs devices available in the market. The following subsections introduce some of the devices which have already installed in CSE Department.

Proxim RangeLAN2

Our department uses Proxim RangeLAN2 7400 PC cards and RangeLAN2 Ethernet and Token Ring Access Points. Here is the specification of rl2 7400 PC card:

Radio Data Rate	1.6 Mbps per channel
Frequency Band	2.4 GHz
Radio Type	Frequency hopping spread spectrum (FHSS)
Channels	Support 15 independent, non-interfering channels
Range **(Indoor)** **(Outdoor)**	 About 152 meters About 305 meters
Platforms Supported	Windows 95/98/NT, WinCE, Linux

Nowadays, Proxim provides another higher speed wireless LAN products which can support 24 Mbps bit rate. It is RangeLAN5 series. It operates in the 5 GHz band, which guarantees seamless coexistence with existing 2 Mbps 2.4 GHz wireless LANs. It also

Figure 2.6: RangeLAN2 Access Point and PC Card.

gurantees the Quality of Service (QoS) for multimedia applications. Unfortunlately, our department have not installed these products.

To set up wireless LANs using Proxim RangeLAN2, we need the well configured devices and also a driver program for Proxim installed in the notebook. After installing the driver program, the PC can then plug in and wireless LANs can be used. The next section will describe how to install the driver program.

WaveLAN

WaveLAN is another company providing wireless LANs devices which are compliant with IEEE802.11 standard. CSE department has also installed some WaveLAN wireless devices, which are WaveLAN IEEE Turbo (Bronze) PC cards and WavePOINT-II access points. Here is the specification of IEEE Turbo (Bronze) PC card:

Data Rate	2-6Mbps with 4 speed options
Frequency Band	2400MHz - 2483.5MHz
Radio Type	Direct Sequence Spread Spectrum
Channel	11 for United States, 13 for other countries
Range **(Indoor)**	 40-115 meters, higher range for lower speed
(Outdoor)	120-540 meters, higher range for lower speed
Delay Spread	55-500ns
Bit Error Rate	Better than 10^{-5}
Platform	Windows 95/98/NT, WinCE, Win2000, Apple, IEEE802.11 (e.g. Linux)

WaveLAN also provides other higher speed wireless devices. The latest product for WaveLAN is IEEE Turbo PC Card (Silver/Gold) which supports 11 Mbps data rate and still operates at 2.4 GHz frequency band.

To use wireless LANs with WaveLAN devices, the well configured access points are needed. Moreover, driver program must be installed in the users' notebooks in order to access wireless LANs. After installing the driver program, the PC card can be plug into the notebook and wireless LANs can be used.

Figure 2.7: WaveLAN Access Point and PC Card.

Other Wireless Equipment

Other than Proxim and WaveLAN, there are many other companies providing wireless equipment, one of the example is Apple company. Apple company provide an iBook Airport cards and stations which run in MacOS 8.6 platform. The products have 11 Mbps data rate and range of about 150 metres indoor. These products is similar to WaveLAN and Proxim products which described above, except that the notebook (station) is also provided in Apple company.

Another example is Motorola Bluetooth which is a personal area wireless networking device with low-power, short-range. It is designed for local area voice and data communications. The system operates in 2.4 GHz frequency band. The system supports 64 Kbps synchronous voice channels and 721 Kbps asynchronous data channel. The range of the system is about 10cm to 10m, and can be extended to 100m. The Bluetooth products are mainly for personal use, such as automatic synchrnoization of a mobile phone with a notebook or PDA. Since the functions of Bluetooth are a bit different from the devices described above, we do not spend much time to explain this device.

From the above examples, we can see that many wireless devices now can support at least 11 Mbps. The rate of increasing bit rate is very fast. But it should be bewared that the bit rates stated above are usually the best case throughputs, due to the high error rate of wireless network, the actual throughputs are only about half of the quoted bit rates.

2.3.2 Setup RangeLAN2 and WaveLAN drivers in Linux

In the following, a guides on how to configure the RangeLAN2 and WaveLAN drivers in Linux in notebook (Toshiba Portégé 3110CT) are given. Driver programs must be installed in order to use wireless LANs. Note that all of the items would be specific but not general. The Linux used is RedHat 6.0+CLE0.8.

Setup RangeLAN2 Driver

A guide on setting up the driver:

1. Get *rl2-1.5.1.tgz* from *ftp://ftp.komacke.com/pub/rl2isa-driver*

2. Switch yourself to be root ("su -")

3. Go to the directory */usr/local/src* and make a new directory called *rl2*
4. "cd rl2"
5. Copy the file *rl2-1.5.1.tgz* to here
6. "gtar xvfz rl2-1.5.1.tgz"
7. "vi /etc/pcmcia/config"
8. Add the following to the file:

   device "rlmod"
   class "network" module "pcmcia/rlmod"
   card "Proxim RangeLAN2 7400 PC Card"
   version "PROXIM", "LAN PC CARD", "RANGELAN2"
   bind "rlmod"
   card "Proxim Symphony PC Card"
   version "PROXIM", "LAN PC CARD", "SYMPHONY"
   bind "rlmod"
   card "Proxim RangeLAN2 7200 PC Card"
   version "PROXIM", "LAN CARD", "RANGELAN2"
   bind "rlmod"

9. Restart the pcmcia system by "/etc/rc.d/init.d/pcmcia restart"
10. "make install"
11. Set the module location to be */lib/modules/2.2.5-15CLE/pcmcia*
12. Answer(executables): */usr/local/bin*
13. Answer(man pages): */usr/local/man*
14. Answer(system header files): */usr/include*
15. Answer(cardtype): *3*
16. Answer(pc card support): *y*
17. Answer(pcmcia header files): */usr/src/pcmcia/include*
18. "make modules modules_install"
19. "vi /etc/pcmcia/network.opts" (backup the file first if necessary)
20. Type in the network information (ip address, netmask and etc)
21. Inside the function *start_fn()*, add */usr/local/bin/rl2cfg dev eth0 sta domain 1;* (before *return;*)
22. Save the file (":wq")
23. Now, plugin the card. If you can hear two high pitch beeps, the Proxim should be working now. However, if the second beep's pitch is low, there is error.

Setup WaveLAN Driver

A guide on setting up the driver:

1. Get *wvlan_cs-1.0.1.tar.gz* from *http://www.fasta.fh-dortmund.de/users/andy/wvlan/*
2. Get *pcmcia-cs-3.0.14.tar.gz* from *http://hyper.stanford.edu/HyperNews/get/pcmcia/home.html*
3. Switch yourself to be root ("su -")
4. Go to the directory */usr/local/src* and make the new directores *wvlan* and *pcmcia*
5. Copy *wvlan_cs-1.0.1.tar.gz* to the directory *wvlan*
   Copy *pcmcia-cs-3.0.14.tar.gz* to the directory *pcmcia*
6. "cd pcmcia"
7. "gtar xvfz pcmcia-cs-3.0.14.tar.gz"
8. "cd pcmcia-cs-3.0.14"
9. "gtar xvfz ../../wvlan/wvlan_cs-1.0.1.tar.gz"
10. "patch -p0 ¡ wvlan.patch"
11. "make config"
12. Answer(linux source directory): */usr/src/linux*
13. Answer(alternate target install directory): (nothing, just press enter)
14. Answer(module install directory): */lib/modules/2.2.5-15CLE*
15. Answer(c compiler name): *gcc*
16. Answer(linker name): *ld*
17. Answer(compiler flags for debugging): (nothing, just press enter)
18. Answer(build 'trusting' versions of card utilities): *n*
19. Answer(include 32-bit (cardbus) card support): *n*
20. Answer(kernel-specific options): *1*
21. "make all"
22. "make install"
23. Restart the pcmcia system by "/etc/rc.d/init.d/pcmcia restart"
24. Now, plugin the card. If you can hear two high pitch beeps, the Proxim should be working now. However, if the second beep's pitch is low, there is error.

Note: Since during the configuration of the RangeLAN2 driver, some information of the pcmcia system are needed to be modified, the modification may be covered by the re-installaton of the pcmcia system during installing the WaveLAN driver, therefore, in order to let the two drivers co-exist, it is better to install the WaveLAN driver first.

Chapter 3

Quality of Service

3.1 What is QoS?

There are many QoS, for instances Disk QoS [13], and as [5] says that QoS means different things to different people such as average case versus worst case, high robustness, high availability and the predictable performance for application in presence of statistical sharing. Now, in our project, we would like to narrow it down just to concern computer networks. Here, we just quote some of them, they are:

- QoS is the collective effect of service performances which determine the degree of satisfaction of a user of the service.
- QoS is the guarantee a network makes to an application in terms of providing a certain contracted level of service through out the application session.
- QoS represents quantities like how fast can data be transferred, how much does the receiver have to wait, how correct is the received data likely to be, how much data is likely to be lost, etc.
- ATM defines QoS as a collection of rate, latency, jitter loss ratio and error ratio.
- QoS refers to the ability of a network to deliver time-bounded traffic types (e.g., realtime video or voice) with predictable latencies.
- QoS is a way to specify an applications network performance requirements, and it is specified by performance parameters (flowspec).

And what QoS meant to us is as follow:

> QoS is the guarantee of delivering network packages punctually and the guarantee of delivering an acceptable numbers of network packages in an compromised time interval, which would not annoy the receivers.

In order to achieve the QoS talking above, there are many efforts needed. And there are different aspects required to be concerned for wired LANs and wireless LANs, they have common parts though.

3.2 Why QoS?

3.2.1 Importance of QoS

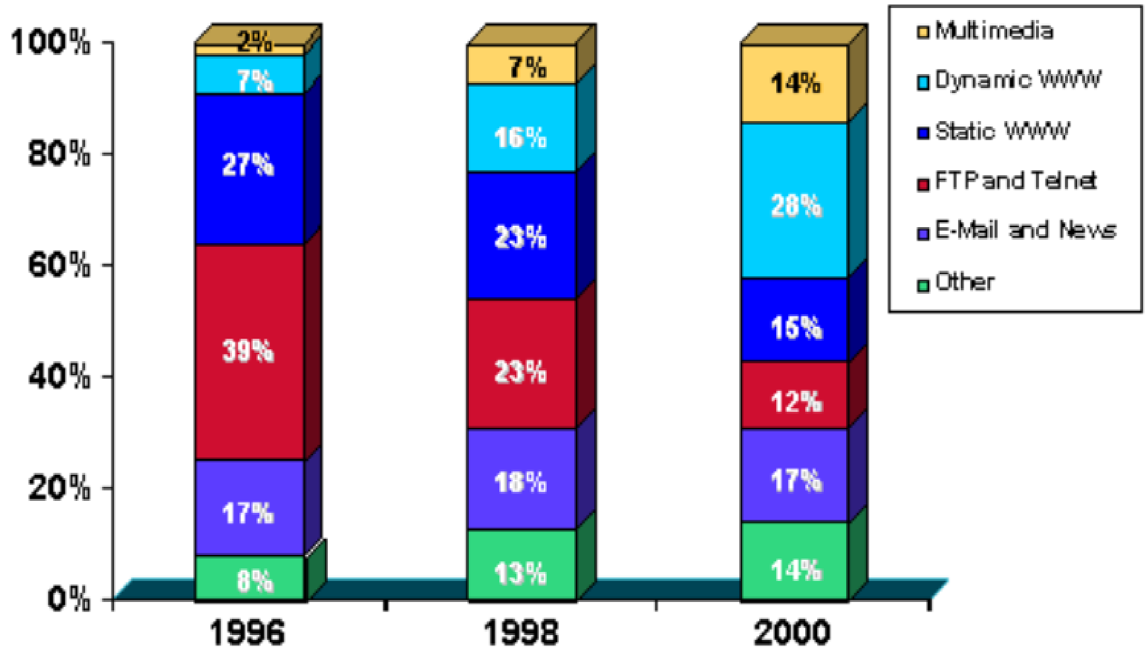

Figure 3.1: Fundamental shift towards bandwidth-intensive applications.

By looking at the recent growth of the need of real-time multimedia applications as well as the higher and higher demand for the quality of the applications, the limited bandwidth problem is obvious, figure 3.1 and figure 3.2 show the relevant statistics given by Cisco. Certainly, expanding the bandwidth is an effective solution. However, it is costly and cannot solve the root of problem. As a result, controlling and managing the use of networking resources is the key point to solve the problem. That is, QoS is needed.

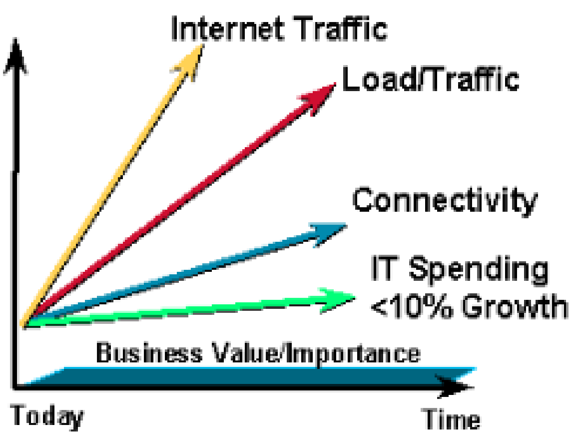

Figure 3.2: IT issues

But, according to [2], there are some problems in the traditional networking management that lower the efficiency of the network. Some of them are:

- IP offers only a best-effort model of service,
- TCP guarantees reliability and sequence, and
- TCP uses reactive congestion control.

Hence, no guarantees can be made to real-time and multimedia traffic.

Then, another question comes out: why do we need QoS in wireless networks? It has been more or less answered by the previous sections. Wireless networking become more and more popular, so it is now a suitable time to concern QoS in wireless networks. However, achieving QoS in wireless networks, or specifically in wireless LANs, is harder than that in wired networks. Some reasons are the limited bandwidths, the high error rates, the varying distance between nodes and access points and etc. More will be discussed in the coming sections.

3.2.2 Advantages and disadvantages over QoS

Advantages

Motivation for QoS is more or less due to multimedia applications in the Internet. So, while it lets you manage your network resources, the multimedia applications get benefits by the way. The advantages over QoS are discussed all over the world, they are business-oriented though, we just quote some of them as follows [14]:

What are the benefits to enterprises? The Internet is increasingly relied upon for doing business, and the expectations for quality assurances are the same as for a private, controlled network. The Internet is being used to power both intranets within the enterprise and extranets that enable electronic commerce with business partners. As business is increasingly conducted over the web, it becomes more important that IT managers ensure that these networks deliver appropriate levels of quality. Quality of Service (QoS) technologies provide the tools for IT managers to deliver mission critical business over the public network.

What are the benefits to applications? Applications are getting more and more demanding. Mission-critical applications deployed over IP networks increasingly require quality, reliability, and timeliness assurances. In particular, applications that use voice, video streams, or multimedia must be carefully managed within an IP network to preserve their integrity. Managing QoS becomes increasingly difficult because many applications deliver unpredictable bursts of traffic. For example, usage patterns for web, email, and file transfer applications are virtually impossible to predict, yet network managers need to be able to support mission-critical applications even during peak periods. QoS technologies allow IT managers and network managers to:

- Manage jitter sensitive applications, such as audio and video playbacks
- Manage delay-sensitive traffic, such as real time voice
- Control loss in times of inevitable bursty congestion

What are the benefits to service providers? Clearly, enterprises and corporations are becoming more suitable to the requirements of mission-critical business conducted over the public network. Increasingly, they are also outsourcing more and more network services to service providers, which allows them to focus more on the internal business and reduce capital expenses. This means that service providers who can offer quality assurances for end-to-end business traffic will win more enterprise business going forward. QoS technologies will allow service providers to offer more services, such as real-time traffic support, or specific bandwidth allocations. This creates more revenue generation for service providers, while offering more services to enterprises.

Disadvantages

While the advantages over QoS have been talking all over the world, the disadvantages over it are seldom mentioned, so we would like to address some of them here.

RSVP is not scalable For those who adopt RSVP to achieve QoS, there is a problem, as said by [6], "...Providers have plenty to choose from. Some support the resource reservation protocol (RSVP), which was designed to reserve bandwidth within the network. Yet UUNet and some others have rejected RSVP because it doesn't scale...".

Admission Control Here comes the question: who should be granted for QoS? It is the system administrator's task to decide it. However, this is not an easy task, if it is too loosely controlled, bandwidth will be congested before QoS is achieved while if it is too tight, the situation will become back to no QoS is applied.

Current Support Since the traditional networks do not support QoS, many protocols, devices and etc must be updated, or even changed in order to be adaptive for achieving QoS. It is really an immense work!

As an early conclusion, the advantages outweigh the disadvantages over QoS.

3.3 How to Achieve QoS?

3.3.1 Introduction

There are many ways to achieve QoS. In the simplest form, it comes from the bandwidth reservation and packet scheduling. Bandwidth reservation is to ensure there exists enough space for the packets to travel on while packet scheduling is to ensure the packets are delieverd on time.

According to [14], the key QoS mechanisms are:

Admission control Admission Control determines whether a requested "connection" is allowed to be carried by the network. The main considerations behind this decision are current traffic load, current QoS, requested traffic profile, requested QoS, pricing and other policy considerations. For QoS enabled IP networks, Admission Control, for example, could be performed in the setting up of RSVP flows.

Traffic shaping/conditioning In QoS enabled IP networks, it's necessary to specify the traffic profile for a "connection" to decide how to allocate various network resources. Traffic Shaping/Conditioning ensures that traffic entering at an edge or a core node adheres to the profile specified. Typically, this mechanism is used to reduce the burstiness of a traffic stream. This involves a key tradeoff between benefits of shaping (e.g., loss in downstream network) and the shaping delay. Leaky Bucket based traffic shaping is an example of this mechanism.

Packet classification In order to provide the requested QoS, it's critical to classify packets to enable different QoS treatment. This can be done based on various fields in IP headers (e.g., source/destination addresses and protocol type) and higher layer protocol headers (e.g., source/destination port numbers for TCP or UDP). Efficient and consistent Packet Classification is a key problem under active research.

Packet marking Either as a result of a traffic monitoring mechanism or voluntary discrimination, a packet can be annotated for a particular QoS treatment in the network (e.g., high/low loss/delay priority). IP Packet Marking is proposed to be done using the IP header's Type of Service (TOS) byte for IPv4 and Traffic Class byte for IPv6.

Priority and scheduling mechanisms To satisfy the QoS needs of different "connections", nodes need to have Priority and Scheduling Mechanisms. The Priority feature typically refers to the capability of providing different delay treatment, e.g., higher priority packets are always served before the lower priority ones, both in the context of packet processing and transmission on outbound links. Nodes also implement different loss priority treatment, i.e., higher loss priority packets are lost less often than the lower loss priority ones. Nodes also need to have the closely related Scheduling Mechanisms to ensure that different "connections" obtain their promised share of the resources (i.e., processing and link bandwidth). This mechanism also ensures that any spare capacity is distributed in a fair manner. Examples of this mechanism include Generalized Processor Sharing (GPS), Weighted Round Robin (WRR), Weighted Fair Queueing (WFQ), and Class Based Queueing (CBQ). Efficient implementation of these mechanisms, and extending them to include (a) both delay and bandwidth needs simultaneously, and (b) hierarchical scheduling are the areas of active research.

Signalling protocols To obtain the required QoS from a network, end-systems need to signal the network the desired QoS as well as the anticipated offered traffic profile. This has been a fundamental part of various connection-oriented networks (e.g., ATM). However, for connectionless networks (e.g., IP), this is relatively new. Corresponding examples are the signaling associated with Resource ReSerVation Protocol (RSVP) and Label Distribution Protocol (LDP). Implementation scalability and the corresponding capabilities to signal different QoS needs are issues under current examination.

Queuing (WFQ, CFQ, SFQ) Some network elements enable "fair queuing" algorithms so a misbehaving application–one that continues to send during times of congestion–

won't punish other, better-behaved applications (e.g. TCP applications), or so the average of dropped packets is evenly distributed across flows [Queuing]. Basically, they determine how packets are dropped when congestion occurs in a router (i.e. when a queue is full). CFQ (Class-based Fair Queuing), WFQ (Weighted Fair Queuing), SFQ (Stochastic Fair Queuing) are examples of these algorithms.

Congestion Control (RED, ECN) For QoS IP networks to operate in a stable and efficient fashion, it's essential that they have viable and robust Congestion Control capabilities. These capabilities refer to the ability to flow control and shed excessive traffic during the periods of congestion. Random Early Detection (RED) and Explicit Congestion Notification (ECN) are two of the proposed capabilities. RED prescribes discard probability to drop packets in a fair and robust way (i.e., consistent with behavior of higher layer protocols like TCP) based on the measured average queue length. RED (Random Early Detection) attempts to avoid congestion rather than reacting to it (and thereby avoid TCP synchronization problems that can result when hosts decrease or increase TCP traffic simultaneously after congestion occurs). It randomly drops packets before queues fill, to keep them from overflowing. Unlike the queue management algorithms mentioned above, it does not require flow-state in the routers.

The mechanisms given above may be a little bit complex. What we are focusing at our project are bandwidth reservation (RSVP) and packet scheduling (CBQ), which will be discussed in the following sections.

Besides the mechanisms given above, there are still other ways to achieve QoS. Most of what talking above are software level approaches, but for hardware, there are commercial products such as XEDIA Access Point QoS Router. And not just the network traffic would affect the performance, servers like database server always need to touch harddisks, Disk QoS is needed [13]. And for wireless, the context-switch between access points for roaming is also spot needed to be taken into consideration when talking QoS.

3.3.2 Bandwidth Reservation - RSVP

What is RSVP?

RSVP (Resource Reservation Protocol) is a protocol that allows channels or paths on the networks to be reserved for the transmission of video and other high-bandwidth messages. RSVP is part of the Internet Integrated Service (IIS) model, which ensures: best-effort service, real-time service, and controlled link-sharing. RSVP protocol is used by a host to request specific qualities of services from the network for particular application data streams or flows. It is also used by routers to deliver quality of service requests to all nodes along the path(s) of the flows and to establish and maintain state to provide the requested service.

Why RSVP is needed to Achieve QoS?

Today's networks are designed to deliver traditional bursty data very reliably but with acceptable delays. They are not set up to handle streaming real time audio and video data.

To get real time mulitmedia data, quality of service should be imposed on it according to its flow specification (which includes the throughputs and delays of multimedia data). The reason RSVP is needed, is that TCP/IP has no prdicatble level of performance. Networks that support multimedia should provide the following: bandwidth and consistent quality of service. And these can be done by RSVP.

How RSVP works?

Assume you want to see a real time video on the network, you send an RSVP request before the seeing the video to allocate sufficient bandwidth and priority of packet scheduling for the program. This request will go to your nearest network router with an RSVP server. It will determine whether you are eligible to have such a reservation set up and ,if so, whether sufficient bandwidth reamins to be reserved to you without affecting earlier reservations. If you can make an resveration, the router then forwards your reservation to the next router toward the destination. In this manner, your reservation is ensured all the way to the destination. If the reservation cannot be made all the way to destination, all resverations are removed.

In detail, we can see that the RSVP server actually communicates with two local decision modules, admission control and policy control. Admission control determines whether the node has sufficient available resources to supply the requested QoS. Policy control determines whether the user has administrative permission to make the reservation. If either check fails, the RSVP program returns an error to notify the application process that originated the request. If both checks succeed, the RSVP daemon sets parameters in a packet classifier and packet scheduler to obtain the desired QoS. The packet classifier determines the QoS class for each packet and the scheduler orders packet transmission to achieve the promised QoS for each stream.

Here is the flow of the protocol:

1. Senders characterize outgoing traffic in terms of the upper and lower bounds of bandwidth, delay, and jitter. RSVP sends PATH messages from the sender that contains this traffic specification (TSpec) information to the (unicast or multicast receiver(s)) destination address. Each RSVP-enabled router along the downstream route establishes a "path-state" that includes the previous source address of the PATH message(i.e. the next hop "upstream" towards the sender)

2. To make a resource reservation, receivers send a RESV (reservation request) message "upstream" to the source of the PATH message. In addition to the TSpec, the RESV message includes the QoS level required in an RSpec, and characterizes the packets for which the reservation is being made (e.g. the transport protocol and port number), called the "filter spec". Together, the RSpec and filter-spec represent "flow-descriptor" that routers use to identify reservations.

3. When an RSVP router receivers and RESV message, it uses the admission control process to authenticate the request and allocate the necessary resources. If the request accepted, the router sends the RESV upstream to the next router.

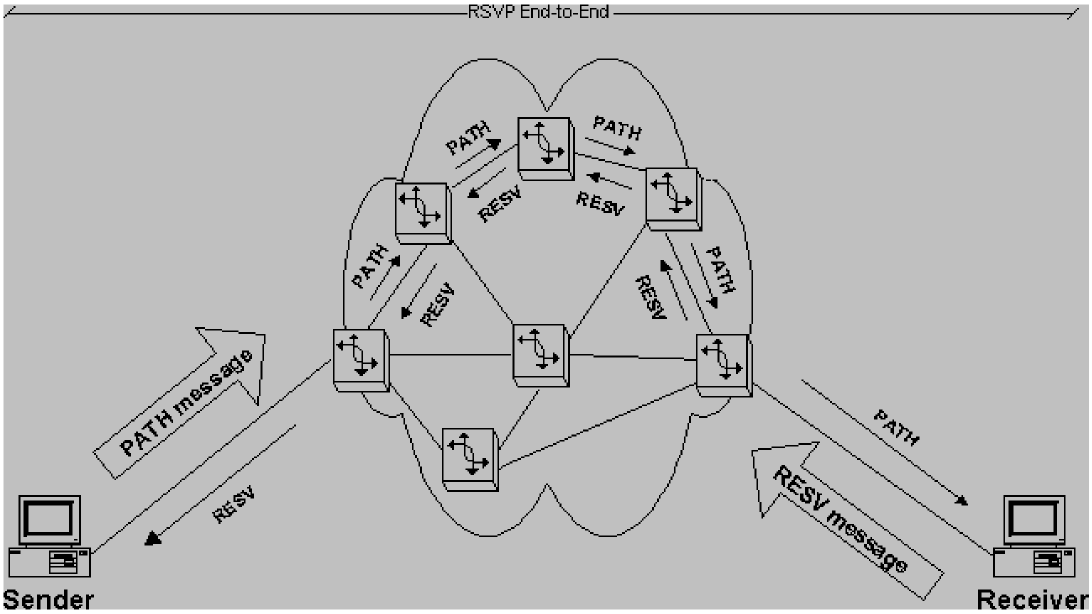

Figure 3.3: RSVP Overview.

4. When the last router receives the RESV and accepts the request, it sends a confirmation message back to the receiver.

5. There is an explicit tear-down process for a reservation when sender or receiver ends an RSVP session.

There are some characteristics that RSVP support:

- Reservations in each router are "soft", which means they need to be refreshed periodically by the receivers.

- RSVP is not a transport, but a network (control) protocol. As such, it does not carry data, but works in parallel with TCP or UDP data flows.

- Applications require APIs (RAPI) to specify the flow requirements, initiate the reservation request, and receiver notification of reservation success or failure after the initial request and trhoughout a session.

- RSVP can scale to very large multicast groups because it uses receiver-oriented reservation requests that merge as they progress up the multicast tree. The reservation for a single receiver does not need to travel to the source of a multicast tree; rather it travels only until it reaches a reserved branch of the tree.

- RSVP is very flexible, it provides opaque transport of traffic control and policy control messages, and provides transparent operation through non-supporting regions. However, this characteristic can create a "weak-link"in the QoS chain where the service falls-back to "best effort" (i.e. there is no resource allocation across these links).

- RSVP runs over IP, both IPv4 and IPv6.

To install RSVP in linux, the package rsvpd_linux_r4_2a3.tgz should be downloaded first. The package includes RAPI, which is the interface for applications.

3.3.3 Packet Scheduling

According to [1, 2, 3], there are many packet scheduling disciplines. They have given some examples:

CBQ Class based queuing, abbreviated as CBQ, is a packet scheduling algorithm proposed by Van Jacobson. It is an approach of hierarchical link-sharing management [7]. It outlines a set of flexible, efficiently implemented gateway mechanisms that can meet a range of service and link-sharing requirements. One requirement for link-sharing is to share bandwidth on a link between multiple organizations, where each organization wants to receive a guaranteed share of the link bandwidth during congestion, but where bandwidth that is not being used by one organization should be available to other organizations sharing the link. Examples range from the multiple agencies that share the Trans-Atlantic FAT pipe and each pay a fixed share of the costs to individuals who share a single ISDN line. Another requirement for link sharing is to share bandwidth on a link between different protocol families (e.g., IP and SNA), where controlled link sharing is desired because the different protocol families have different responses to congestion. A third example for link sharing is to share bandwidth on a link between different traffic types, such as telnet, ftp, or real-time audio and video.

RED Random Early Detection, be precise, is used for congestion avoidance at gateways in packet-switched networks. It is proposed by Sally Floyd and Van Jacobson at 1993. The gateway detects incipient congestion by computing the average queue length. The gateway could notify connections of congestion either by dropping packets arriving at the gateway or by setting a bit in packet headers. When the average queue length exceeds a preset threshold, the gateway drops or marks each arriving packet with a certain probability, where the exact probability is a function of the average queue length.

FIFO First-In-First-Out is a 1-band FIFO pseudo-scheduler, which is a best effort service. The earlier a packet comes, the earlier it is being sent. It is used in the older Linux Kernel as well as many other operating systems to provide best effort service. FIFO guarantees neither the bandwidth consumption nor the delay bound of each connection. Thus, it is not suitable for providing QoS, since an application can dominate all the bandwidth in the link, while others are starving.

SFQ Stochastic Fairness Queuing has been suggested as a technique to address the implementation issues relating to Fair Queuing. The first overhead that is reduced is that of looking up the source-destination address pair in an incoming packet and determining which queue that packet will have to be placed in. SFQ does not require as many memory accesses as Fair Queuing to place the packet in the appropriate queue. SFQ is thus claimed to be more amenable to implementation for high-speed networks. SFQ uses a simple hash function to map from the source-destination address pair to a fixed set of queues. Since the assignment of an address pair to a queue is probabilistic, there is the likelihood of multiple address pairs colliding and mapping to the same queue. This would potentially degrade the additional fairness that is gained with Fairness Queuing. If two or more address pairs collide, they would continue to do so. To deal with the situation when such a collision occurs, SFQ periodically perturbs the hash function so that these address pairs will be unlikely to collide subsequently.

There are others, such as CSZ (Clark-Shenker-Zhang scheduler), TBF (Token Bucket Filter queue), PRIO (3-Band Priority scheduler) and WFQ (Weighted Fair Queueing). As it is impossible for us to learn all of them, we will focus at CBQ only. It is mainly because the system developed by LYU9802 project group is mainly using CBQ.

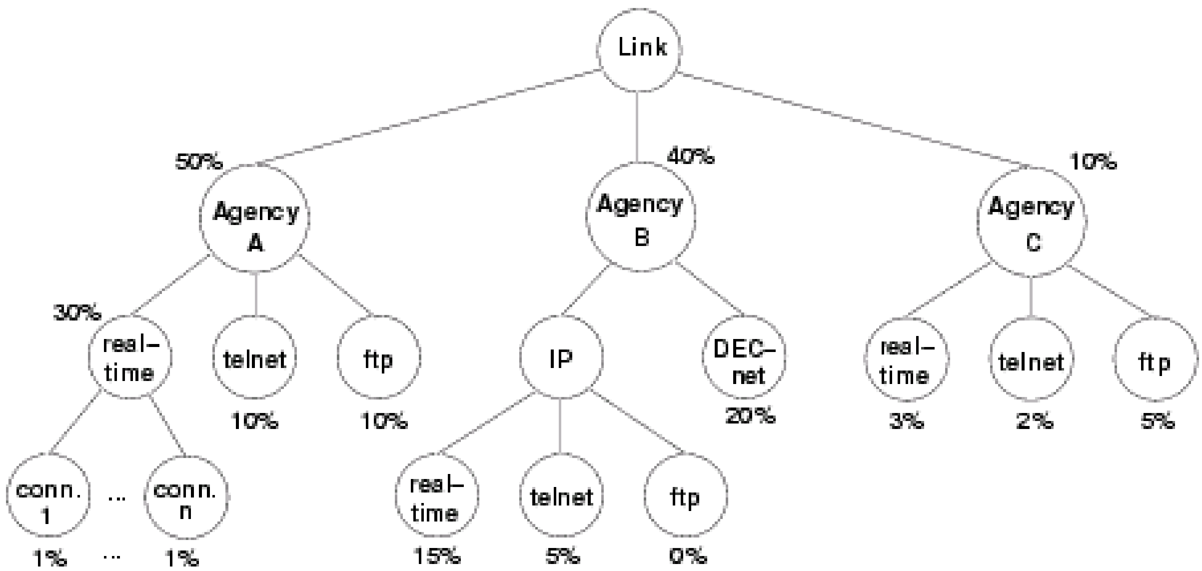

Figure 3.4: A hierarchical link-sharing structure.

CBQ is based on the link-sharing structure, an example is shown at figure 3.4. There are different contraints appeared at different nodes of the structure. When the contraints are violated, the nodes that involved are needed to be regulated. [7] has a detail introduction on this.

3.3.4 LYU9802's Way To Achieve QoS

Last year, LYU9802 project team has implemented a QoS scheme on Linux. The QoS scheme is achieved by using RSVP, Traffic Control in Linux, CBQ (Class based queueing), and a package called iproute2+tc, which controls the packet scheduler, classifier and policy control implemented in Linux kernel 2.2.X. The packet scheduler, classifier and policy in Linux are intended to support QoS (RSVP and CBQ have been introduced in the previous sections).

In their QoS scheme, RSVP is implemented on router level to provide QoS. The admission control in the router determines if there are enough resources, thus accepts or denies the requests. It also ensures that the router will not be congested if every connection is confined in their specifications, resulting in minimizing the packet queueing time in each router, and so reducing the delay jitter. and for host level, The traffic control and packet scheduler in Linux provides service guarantees. Different scheduling disciplines provide different time bounds for one waiting in the queues, as well as different consumptions of bandwidths. Within the kernel, network traffic is controlled by three modules, namely packet classifier, packet scheduler and policy control.

3.3.5 Wireless Version of LYU9802's QoS Scheme

Basically, the wireless version of the QoS scheme is much like the original version. However, we have to do some updates in order to make it works.

First of all, the version of RSVP is needed to be changed in order to keep it updated and consistent with the Linux kernel we use. By re-installing and re-configuring the RSVP, we have to modify their programs and scripts in order to make it adapted to the new version of RSVP. Also, we have changed a little of their controlling scripts in order to make it suitable for using in wireless LANs. Lastly, we have changed the statistics layout of their MP3 player in order to print out the statistics we want and make the layout more tidy.

Performance evaluations we have done on the QoS schemes will be given in the following sections.

Chapter 4

Performance Evaluation of LYU9802's QoS Scheme

We have evaluated the performance of LYU9802's QoS system on both wired network and wireless network. The results will be given in the following sections:

4.1 Preprocessing

In order to measure the statistics, we have changed the codes of both FTP application and the MP3 player.

In the LYU9802's system, the MP3 player already recorded the performance statistics. Our major change is only the layout of its statistics, since the layout done by LYU9802 project team was not so tidy and beared some information which is meaningless at the moment.

The FTP application source code is obtained from the REDHAT 6.0 source code CD. We have changed the source code in order to makethe transfer process becomes automatic, say removing the authentication procedure, hard-coding the file to be transferred and etc. We have also changed the code such that it will print out the statistics, such as packet length, period, total length, total time, current bandwidth and average bandwidth (the same layout as the MP3 player), during transferring the files.

We have also written several small control programs to manipulate the overall experiment. The programs mainly control the start of the FTP applications and MP3 player. One of the programs is listed as follows:

```
#include<stdio.h>
#include<stdlib.h>
#include<unistd.h>
int main() {
printf("noqos 200: Running ftp.../n"); /*noqos at this moment*/
system("~ycwan/lyu9903/lyu9903ftp/ftp/ftp pc90082 &");
```

```
/*Start the FTP applications*/
sleep(30); /*wait for 30 seconds*/
print("Start playing mp3...time=%ld/n", time(NULL));
/*Print out the start time of MP3 player */
system("~ycwan/app/cli pc90082 0 1234 /mp3/rightHereWaiting.mp3 >& rub-
bish &");
/*start the mp3 player. All output to the stderr will be redirected to the file
rubbish.*/
sleep(90); /*wait for 90 seconds*/
printf("qos200/n"); /*qos.200 will be run now (manually) */
return0;
}
```

Although the time measured is not accurate, we believe that is is enough for the experiments.

The quality of service will be applied when the applications are on the fly. There are some files, such as noqos, qos, noqos.200, qos.200 and etc. They are used to set the traffic and tc specify whether the quality of service is applied or not to the applications. We typed in the command by hand at the appropriate time for our experiments.

The general flow of all our experiments is that, we control the traffic first if neccesary and then our control programs will be run. The quality of service will be applied at the proper time. The statistics will be redirected to some predefined files while the applications are running. After the experiments are done, the statistics will be collected and will be plotted as graphs. And several sets of experiments have been performed, and we have chosen the best one.

4.2 Measurement on Wired Network

The following experiments are done on wired network. The scenario is that we have two machines collected through the wired network, one uses as server and one uses as clients. Both FTP applications and MP3 players are run in the client machine, and both applications get the source files from the same server. The quality of service is controlled on the fly.

Note that in order to see the performance by using quality of service, in the experiments, the throughput of the network should be restricted to about 200Kbps - 400Kbps. Since the wired network has throughput of about 10Mbps, but the MP3 player needs only about 150Kbps to play smoothly. It is necessary to restricted the throughput so that it is more easier to jam the traffic and to see the performance under applying quality of service.

Experiment 1: In this experiment, the limit of bandwidth was 200Kbits. QoS was using in first measurement and no QoS was using in second measurement. At the start of experiment, FTP was run, after 30 sec for first measurement, (and 20 sec for second measurement), MP3 player was started to run. For both measurements, the files used for FTP and MP3 player were the same and all gotten from the same server. Figure 4.1 and figure 4.2 show the current received bandwidth by using QoS and no QoS respectively.

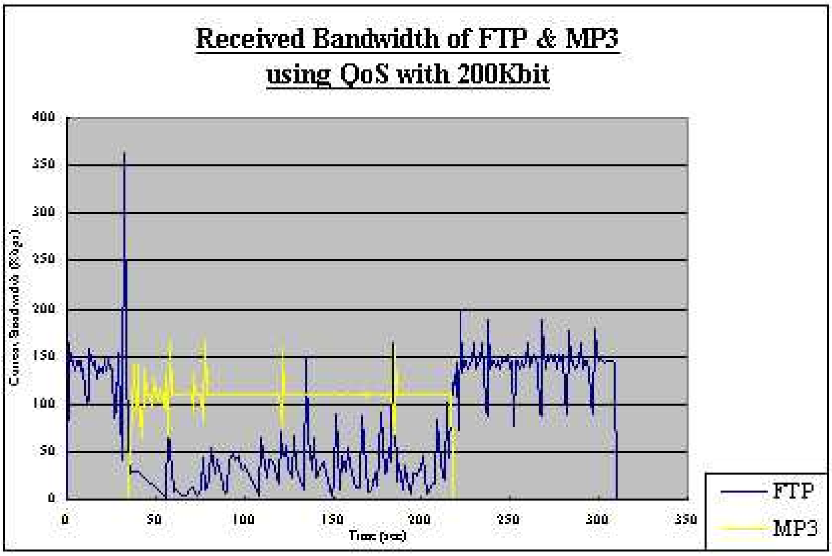

Figure 4.1: Result of experiment 1: with QoS.

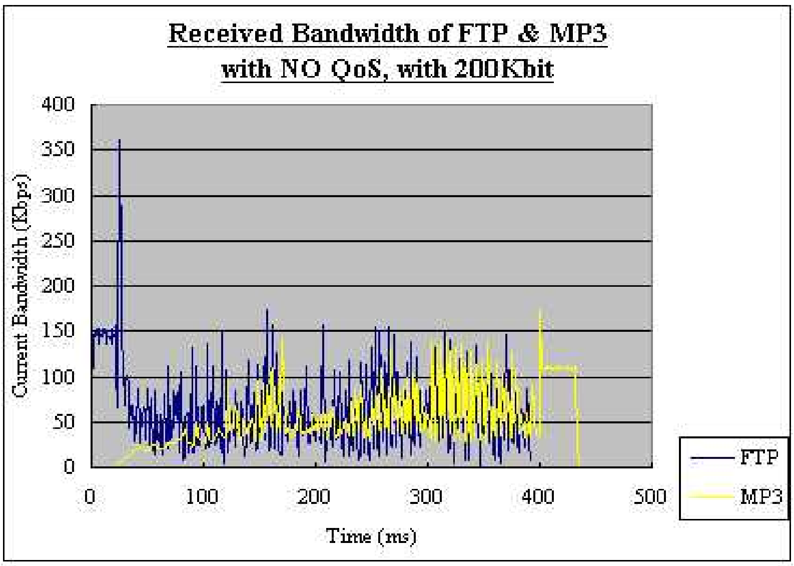

Figure 4.2: Result of experiment 1: without QoS.

From figure 4.1 and figure 4.2, we can see that by using QoS, MP3 played for only 3 minutes, and FTP used up only 5 minutes. But without QoS, MP3 played for about 6.5 minutes and FTP used up 6.5 minutes. And we can see from the graph that the MP3 played smoothly by using QoS, but it was not the case without QoS.

Experiment 2: In this experiment, the limit of bandwidth was 200Kbits. At first no QoS was running, and at time 0, the FTP started to run. After 30 sec., the MP3 player started to run. And at time = 120 sec., QoS was started to used. During the experiment, the current received bandwidth of FTP and MP3 player were measured. All data and files are gotten from the same server. The experiment mainly shows that QoS can be applied whenever you like. And the "power" of using QoS can be shown. Figure 4.3 shows the difference before using QoS and after using QoS for the same program.

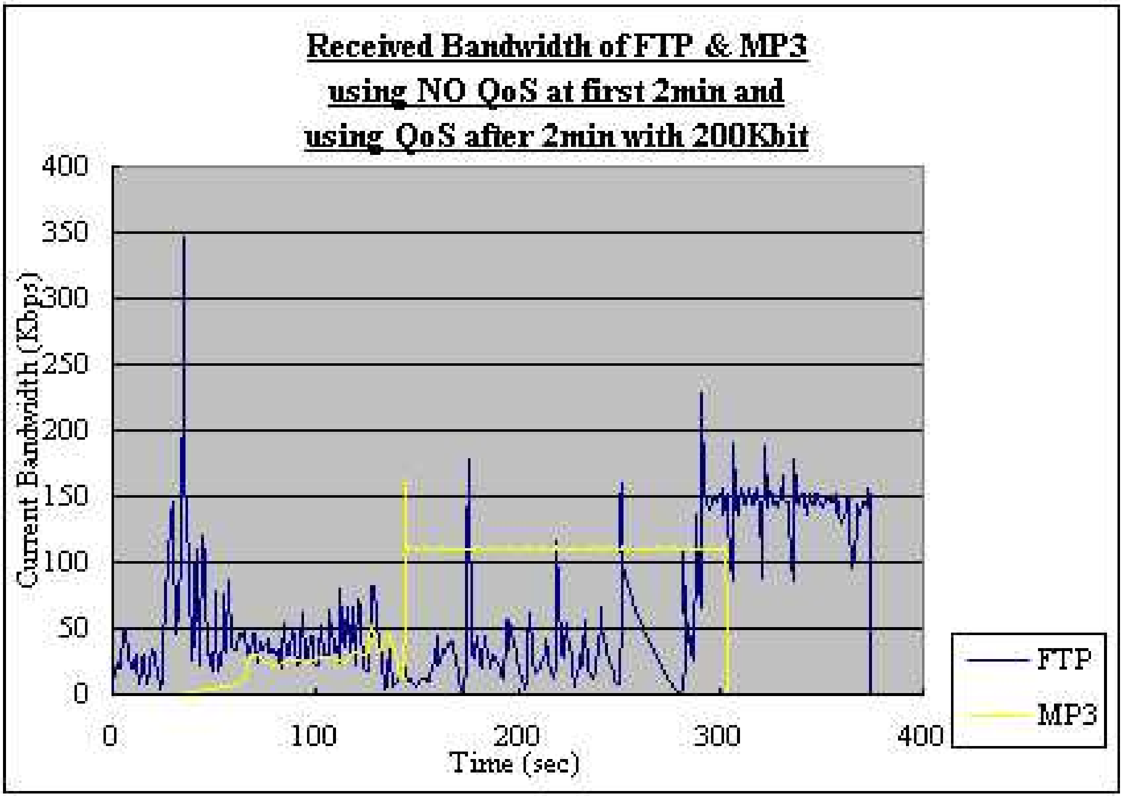

Figure 4.3: Result of experiment 2.

From figure 4.3, we can see that before using QoS, the MP3 did not play smoothly, after using QoS at about 150sec., the received bandwidth of MP3 become steady and the MP3 played smoothly.

Experiment 3: In this experiment, the limit of bandwidth was 400Kbits. The first measurement was done by using QoS, the second measurement was done without using QoS. At the start of experiment, MP3 was run, after 60 sec., FTP was run. At time = 120 sec., another FTP was run. All data and mp3 are gotten from the same server through the wired network.

It is shown from figure 4.4 and 4.5 that with QoS, MP3 played for only 3 minutes and it played smoothly. However, without QoS, MP3 played for about 5 minutes. You can hear the click sound when QoS does not applied.

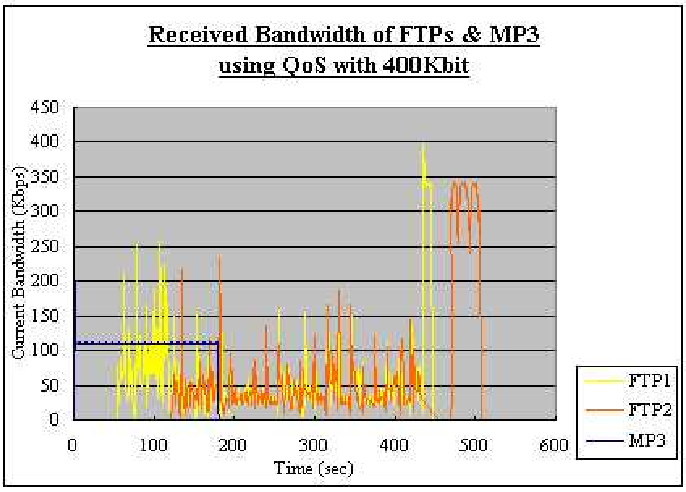

Figure 4.4: Result of experiment 3: with QoS.

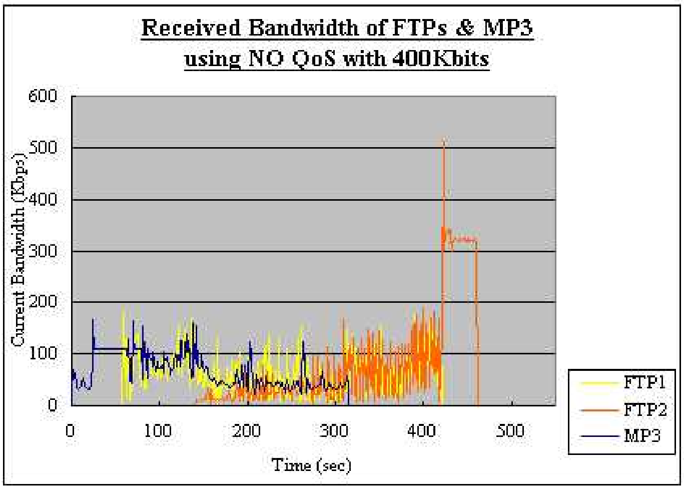

Figure 4.5: Result of experiment 3: without QoS.

4.3 Analysis of the Results of the Experiments

In the above experiments, the effect of using QoS is shown. You can see that during using QoS, the MP3 plays more smoothly, and the it is also shown from the graphs, the received bandwidth of MP3 is quite steady.

On the other hand, although system only ensure that MP3 (which is the real-time multimedia application) has the quality of service, in overall, both MP3 and FTP applications benefit. It is shown in the graphs that both MP3 and FTP applications run in fewer time.

Please note that in the graphs, the curve of FTP received bandwidth are not as smooth as that of MP3 player. This is due to the sampling frequencies of data. For FTP, the data are gotten for every second, but for MP3, the data are gotten for about every 3 seconds.

Chapter 5

Performance Evaluation of Wireless QoS Scheme

We have evaluated the performance of modified LYU9802's QoS system on wireless network. The results will be given in the following sections.

5.1 Preprocessing

In order to measure the statistics, we have changed the codes of both FTP application and the MP3 player, and we have written some control programs for the experiments. The changed are the same for the wired QoS version.

The general flow of all our experiments is that, we control the traffic first if neccesary and then our control programs will be run. The quality of service will be applied at the proper time. The statistics will be redirected to some predefined files while the applications are running. After the experiments are done, the statistics will be collected and will be plotted as graphs. And several sets of experiments have been performed, and we have chosen the best one. (Actually, it is similar to the measurement on the wired network)

5.2 Measurement on Wireless Network

Same as the previous measurements on the QoS system, the same sets of experiments are used to measure the performance of the system in wireless environment. In the experiments below, Proxim RangeLAN2 and WaveLAN wireless devices are used to test their performance. Figure 5.1 shows the scenario of our experiment.

In the following experiments, the bandwidth of the network was also restricted to about 200-400Kbits. This is because, even under wireless networks, the consumption of both MP3 and FTP will not used up 2Mbits (which is the limit throughput for wireless networks), MP3 needs about 150Kbps and there is no bandwidth limit for FTP. Restriction of bandwidth is needed to investigate the performance of the system under network congestion.

Figure 5.1: Scenario of our experiment.

Experiment 1: In this experiment, the limit of bandwidth was 200Kbits. QoS was applied in one measurement while no QoS was applied in other. At the start of experiment, FTP was run, after 30 sec, MP3 player was started to run. For all the experiments, the source of FTP and MP3 player come from the same server in wired network. Figure 5.2 , figure 5.3, figure 5.4 and figure 5.5 show the current received bandwidth by using QoS and no QoS respectively:

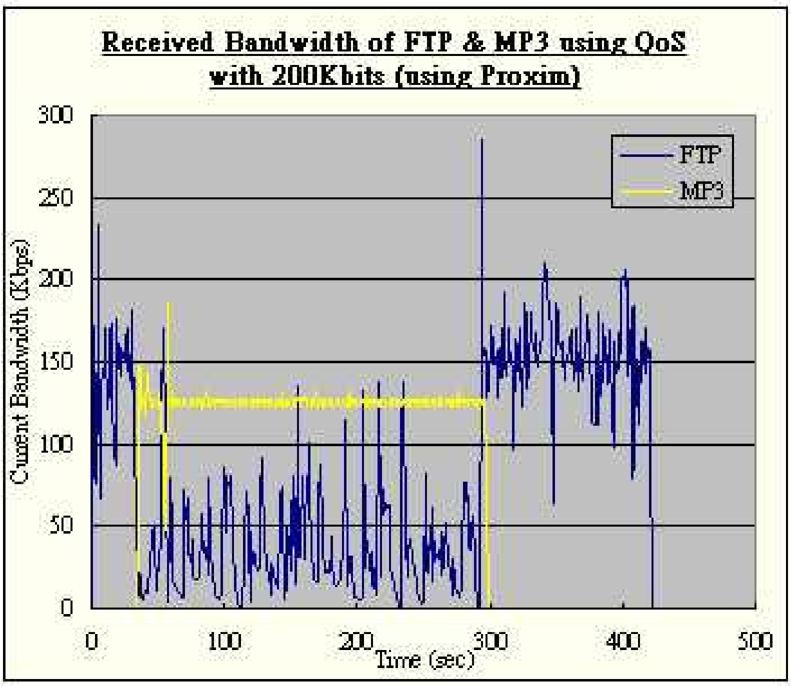

Figure 5.2: Result of experiment 1: with QoS (Proxim).

It is shown in the figures that by using QoS, MP3 played for 4.5 minutes, and FTP used up 7 minutes for Proxim device. And for waveLAN, MP3 played for about 4.46 minutes and FTP used up 7.16 minutes. But without QoS, MP3 played for about 7.7

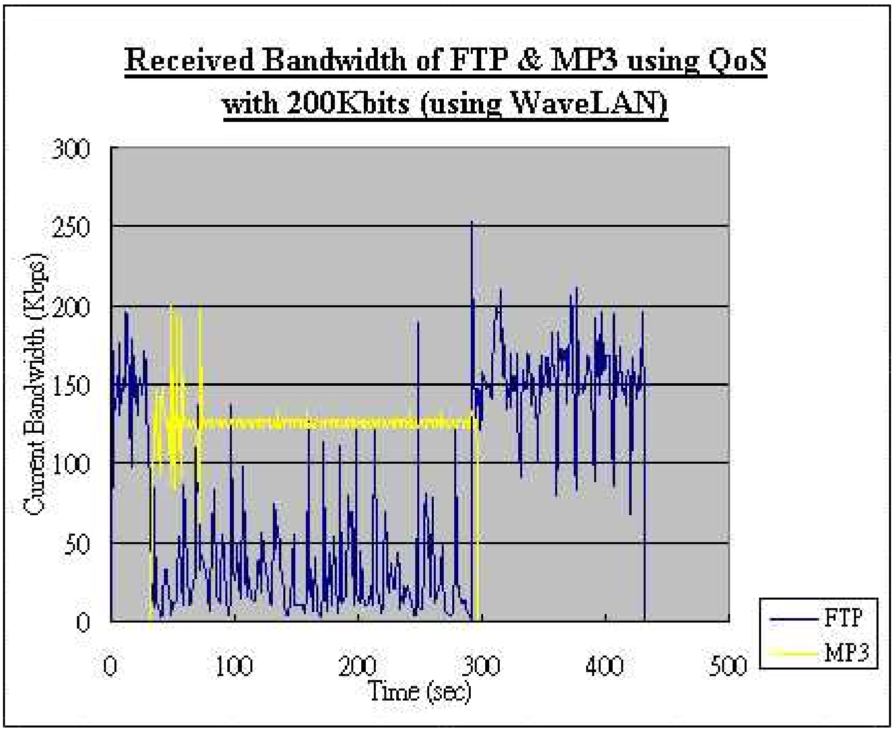

Figure 5.3: Result of experiment 1: with QoS (WaveLAN).

minutes, and FTP used up about 7 minutes for Proxim device, and for WaveLAN, MP3 played for about 9 minutes, and FTP used up about 9.5 minutes. This shows that under QoS, both applications used up less time and the MP3 played more smoothly.

Experiment 2: In this experiment, the limit of bandwidth was 200Kbits. At first, no QoS was using, and at time 0, the FTP started to run. After 30 sec., the MP3 player started to run. And at time = 120 sec., QoS was started to used. This experiment mainly to what is the effect of QoS during applications are running. Again, the experiments measured both on Proxim RangeLAN2 and WaveLAN. Figure 5.6 and figure 5.7 show the current received bandwidth of Proxim RangeLAN2 and waveLAN.

In the figures, we can see that after using QoS, the MP3 played much smoothly than without QoS, and the current received bandwidth of FTP was lower since most portion of bandwidth was given to MP3 during using QoS. And both Proxim and WaveLAN perform similarly in this experiments.

Experiment 3: In experiment 3, the limit of bandwidth was 400Kbits. The first measurement was done by using QoS, the second measurement was done without using QoS. The performance on both Proxim and WaveLAN are measured. At the start of the experiment, MP3 was run, after 60 seconds, FTP was run. At time = 120 seconds, another FTP was run. All data and files are gotten from the same server through the wireless network. The results are shown in figure 5.8, figure 5.9, figure 5.10 and figure 5.11.

It is shown from the graphs that, with QoS, MP3 played for 4.58 minutes (using

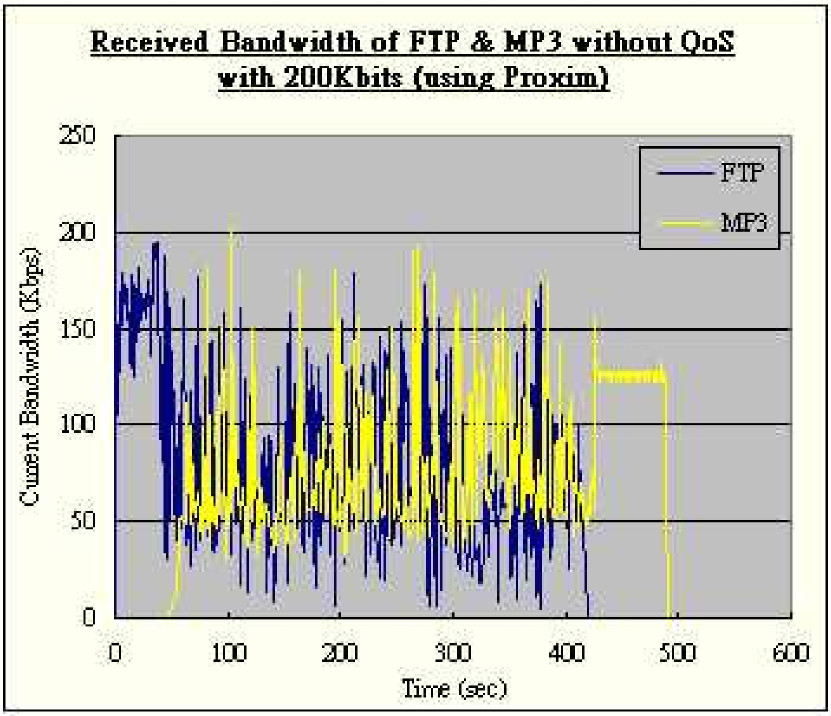

Figure 5.4: Result of experiment 1: without QoS (Proxim).

Proxim rl2) and 4.42 minutes (using WaveLAN). However, without QoS, MP3 played for 5.17 minutes (using Proxim rl2) and 7.33 minutes (using WaveLAN). Without QoS, MP3 played for longer time and much click sound were heard. We can also see from the graphs that if bandwidth is enough for player MP3 and quality of service have been garanteed in the network, the numbers of FTP applications (without garanteed on QoS) would not affect the performance on MP3 player.

5.3 Analysis of the Results of the Experiments

In the above experiments, the effect of using QoS is shown. You can see the during using QoS, the MP3 plays more smoothly, and the it is also shown from the graphs, the received bandwidth of MP3 is quite steady. It is same as wired network.

On the other hand, although system only ensure that MP3 (which is the real-time multimedia application) has the quality of service, in overall, both MP3 and FTP applications benefit. It is shown in the graphs that both MP3 and FTP applications run in fewer time.

Comparing the performance of applications on wired and wireless networks, it is worth to note that MP3 played on wired networks used up less time, no matter QoS is using or not. For example, in Experiment 1, for a song of about 3 minutes, MP3 played for only 3 minutes under QoS on wired network, but on wireless network, MP3 played for about 4.5 minutes and 4.46 minutes for Proxim and WaveLAN respectively. And without QoS,

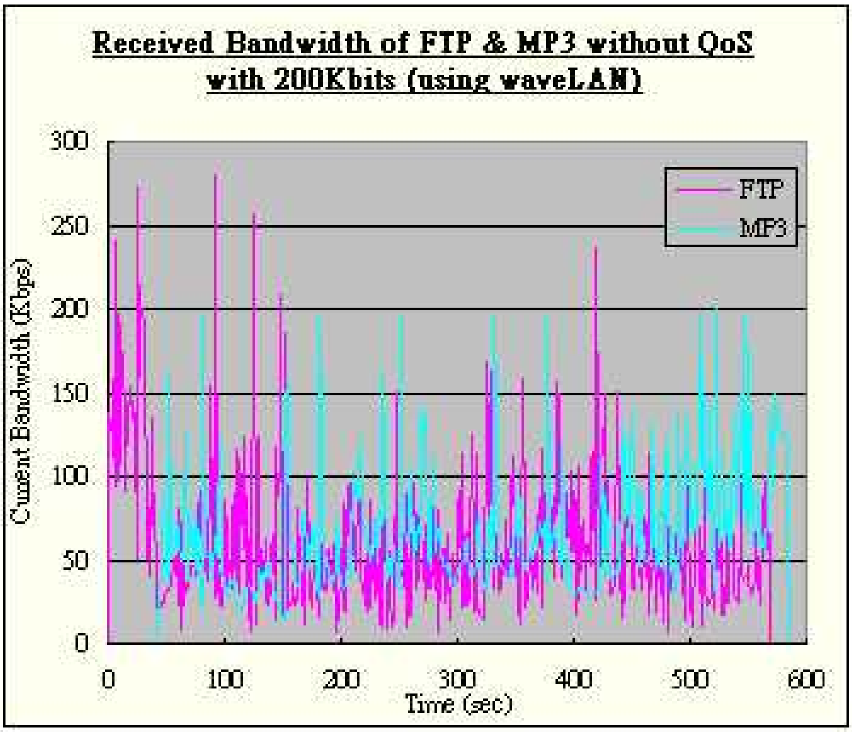

Figure 5.5: Result of experiment 1: without QoS (WaveLAN).

MP3 played on wired network needed 6.5 minutes in Experiment 1, while MP3 played on wireless network needed 7.7 minutes and 9 minutes for Proxim and WaveLAN respectively. The scenario is also found in FTP application, in Experiment 1, during using QoS, FTP used up only 5 minutes on wired network, but it used up 7 minutes (Proxim) and 7.16 minutes (WaveLAN) on wireless networks. And without QoS, FTP used up only 6.5 minutes on wired network, and it used up 7 minutes(Proxim) and 9.5 minutes(WaveLAN) on wireless networks. It is also the case for other experiments. Thus, we can conclude that the delay on wireless network is much more than on wired network. And so the delay are a main factor to affect the performance of wireless applications.

Comparing the performance of applications by using Proxim and WaveLAN wireless devices, we cannot define which one behaves better. But in terms of time needed to run the applications, less time is needed when using Proxim device. However, it cannot conclude that Proxim behaves better than WaveLAN since the testbed of our experiments are not large.

Conclusion can be made from the performance evaluation that QoS is applied to wireless network successfully. However, this is only the case for audio applications. We can not conclude that wireless network can transfer real time multimedia data smoothly using this QoS scheme. More should be done in order to achieve the QoS in wireless network.

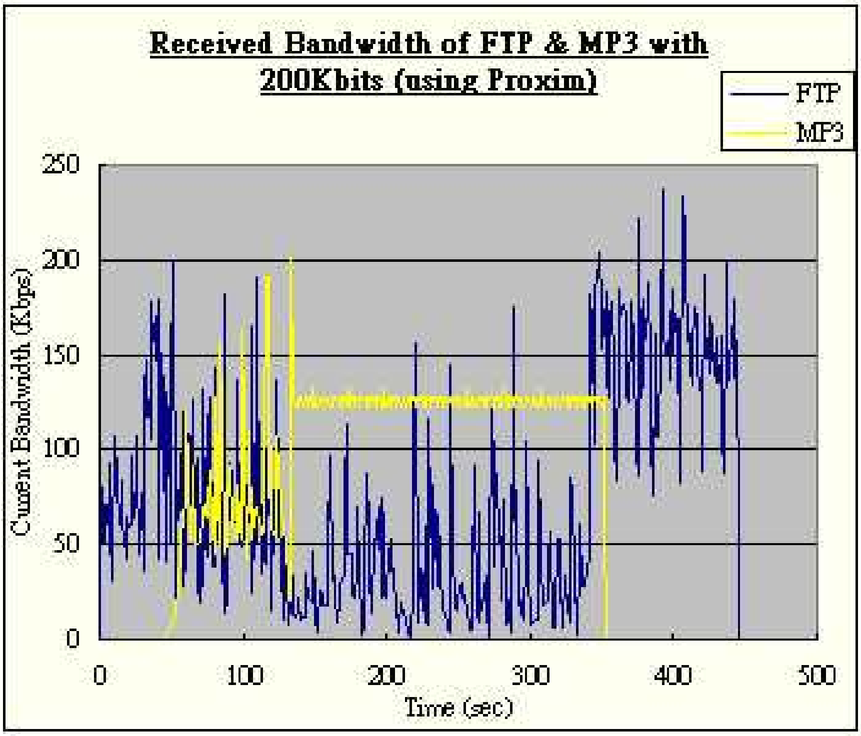

Figure 5.6: Result of experiment 2: without QoS (Proxim).

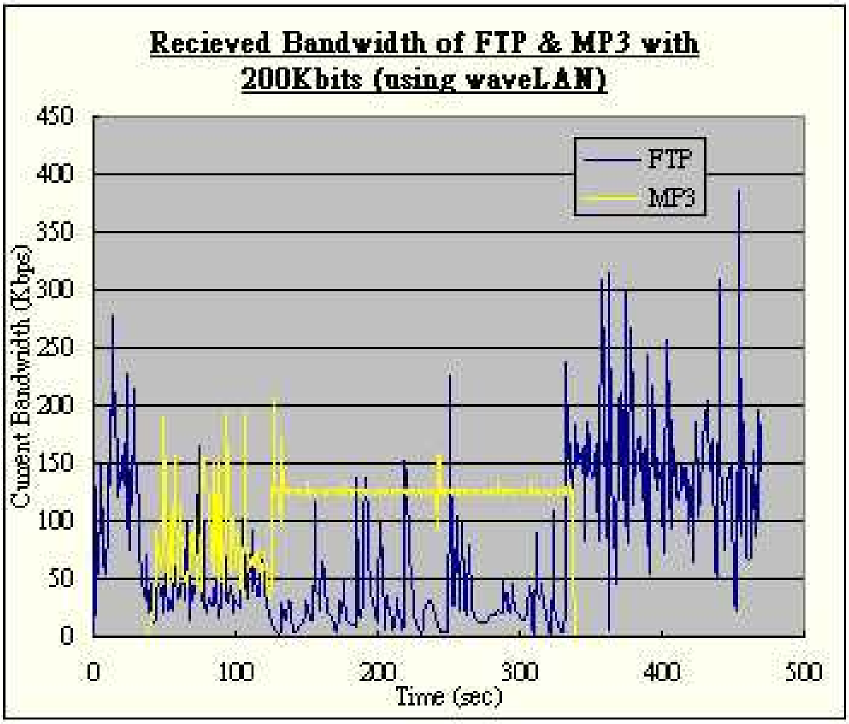

Figure 5.7: Result of experiment 2: without QoS (WaveLAN).

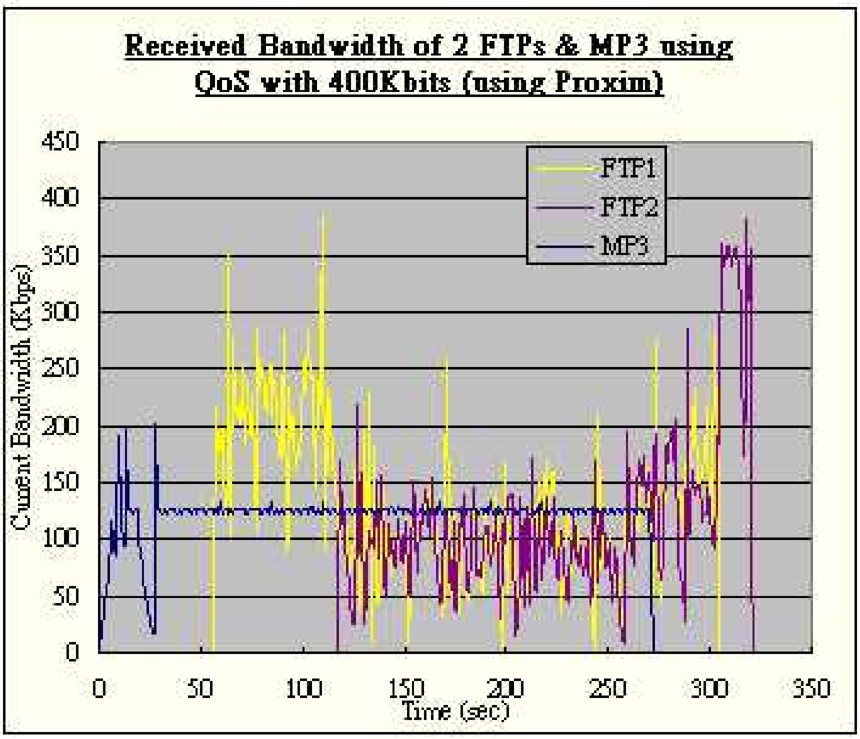

Figure 5.8: Result of experiment 3: with QoS (Proxim).

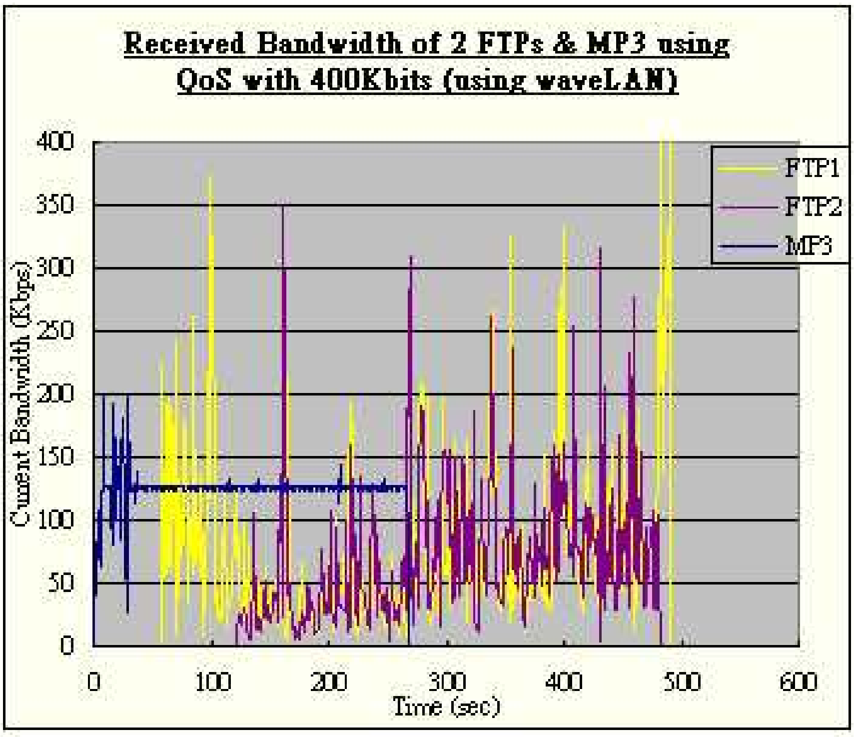

Figure 5.9: Result of experiment 3: with QoS (WaveLAN).

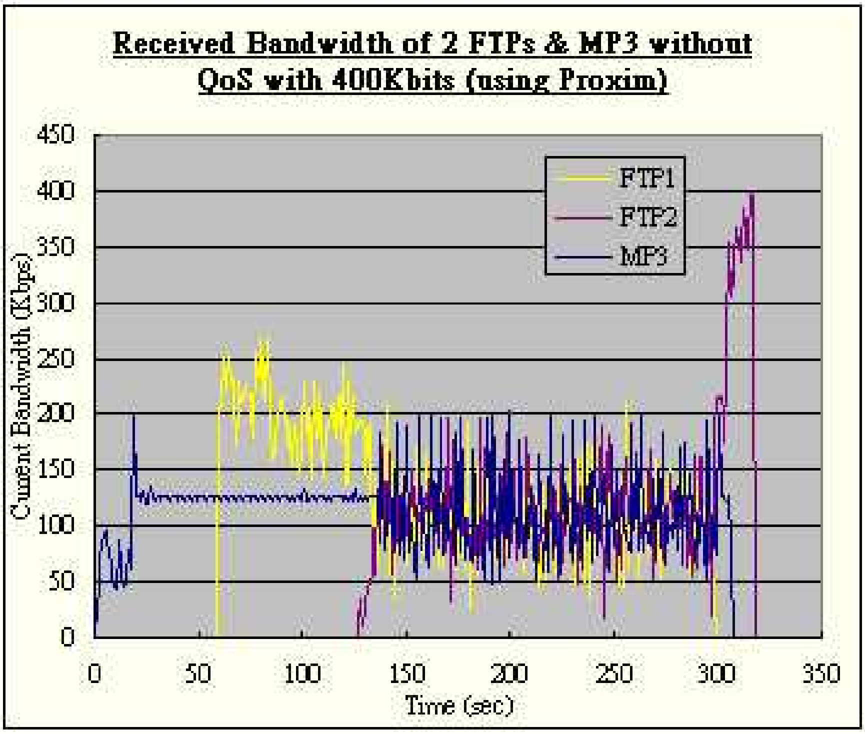

Figure 5.10: Result of experiment 3: without QoS (Proxim).

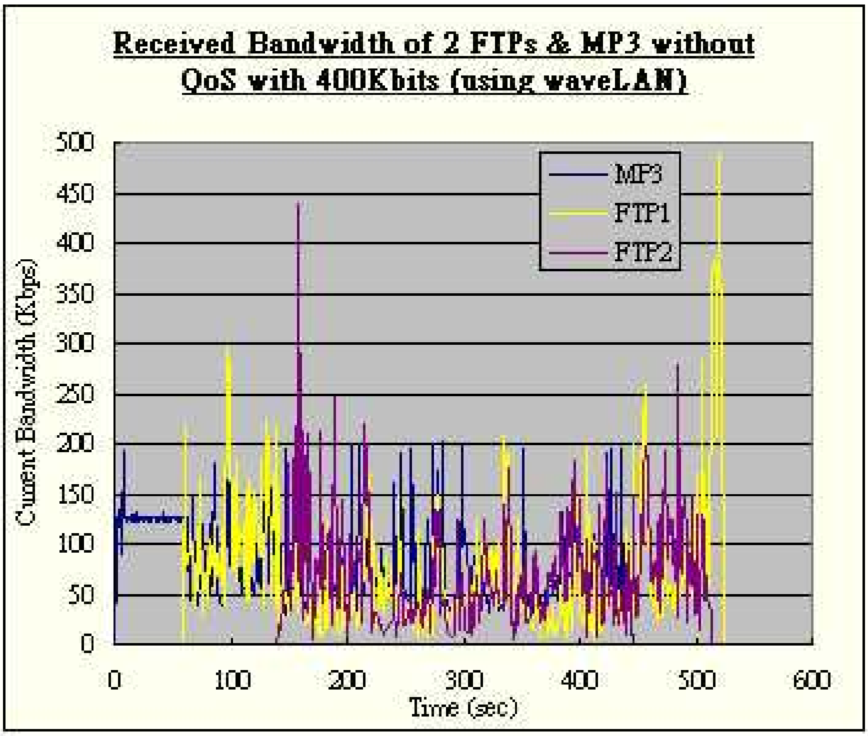

Figure 5.11: Result of experiment 3: without QoS (WaveLAN).

Chapter 6

QoS in Wireless Networks

6.1 Concerns for QoS in Wireless Networks

In addition to concerns for QoS in wired networks, here are some concerns for that in wireless networks.

Variable bandwidth

Actually, the quoted bandwidths of wireless networks mentioned in the previous sections are just the best cases, as said before. The actual bandwidths are possibly half of them. It is due to the high error rates of wireless networks, and the variable distance between the nodes and the access points (delay jitter), so it cannot guarantee a stable bandwidth. For using RSVP to reserve bandwidths, it has the risk that the actual bandwidth one would get is under one would expect, and thus no QoS is achieved. This may lead to chaos of the system.

Roaming

Roaming is a feature of wireless LANs as introduced earlier. This is also an issue needed to be concerned for QoS. As we have tested, when a user moves from the coverage of one access point to another one, the detection time and the "stopping" time of the network is quite long. Roaming should be a kind of transparency to wireless LAN users, however, this long time gap would annoy users, and transparency is not transparent anymore. A good QoS scheme should also aware of this problem.

Low Reliability and Long Delay

Low reliability and the long delay are the main factors affect the throughputs of the wireless LANs. QoS schemes which can applied to wired network may not work in wireless networks. To achieve QoS on wireless LANs, problems about reliability and delay must be solved.

Interference

It has opportunity that the frequency a wireless LAN is using will be interfered by other waves. By the way, it is also a security concern that a blocked frequency will lead to blocked communication. However, if frequency used by the wireless LANs can be changed selectively when the frequency using is "contaminated", not only QoS is achieved, a good reliability is achieved also, it is difficult to do so though.

Harddisk bottleneck

Most likely, services such as database servers would often touch the harddisks, so Disk QoS [13] is needed to be concerned too. Although this is not directly related to network issues, we would like to include this as one of our QoS consideration.

6.2 Proposed Approaches

To Achieve QoS on wireless LANs, here are some proposed approaches:

Renegotiation

Whenever the wireless network can no longer provide requested QoS to an application, due to the decreased in bandwidth or others, the applications can negotiate to reallocate the bandwidth they can get.

Apply QoS in Access Points

To apply QoS in access points can reduce the load for routers and thus smooth the traffic. Actually, some commercial products are going to this direction, example is XEDIA Access Point QoS Router as mentioned before.

Network Collision Control

Addressing a new packet collision algorithm is also a step to achieve QoS in wireless LANs as the packet collision rates of wireless LANs are high.

Chapter 7

Application - Video

We would like to implement a real time video player that can get file through both wired and wireless networks with QoS enabled. One of the reasons of implementing real time video player is that the demand of multimedia access is increasing rapidly, it is mentioned eariler. Another reason is that real time audio needs only about 150 Kbps bandwidth, which is not enough to see the performance of multimedia on wireless LANs with 2 Mbps throughputs. In order to show the effect of performance of multimedia on wireless LANs and show the significance of using QoS, implementing real time video is a good choice. We have choose MPEG-1 video format as our target video format, since MPEG-1 video requires a bandwidth of about 1.5 Mbps, which can be compared to 2 Mbps throughput of wireless LANs.

7.1 Implementation of the Video Player

The source of our video player is from mpeg_play, which is implemented by Berkeley Multimedia Research Center. We have hacked the source code in order to enable real time access of video files through the network. The idea of this implemetation is using RPC, we have provided some services for the client to handle the video files via network. The services are:

fopen Provided for client to open a file.
fclose Provided for client to close an opened file.
fread Provided for client to retrieve data from an opened file.
fseek Provided for client to set the position of the file pointer of an opened file.
ftell Provided for client to get the current position of the file pointer of an opened file.
fgetc Provided for client to get a character from an opened file.
rewind Provided for client to reset the position of the file pointer to the start position.

By setting the environment variable LYU_MPEG_SVR to the address of the server, the modified mpeg_play will automatically retrieve the file from the server specifed. When the environment variable is not set, it will retrieve the file as normal from the local host. At the moment, the modified mpeg_play can work properly in both local and network (wired and wireless) mode. However, QoS is not currently supported. In order to enable QoS in our video application, there are still lots needed to be done, these will be what we will do in the next semester.

Chapter 8

Future Work

- Measure the delay jitter of the QoS systems (both wired and wireless).
- Measure the performance of the QoS systems with router presented.
- Finish our video application with QoS enabled.
- Inspect the source code of WaveLAN drivers in order to make it QoS enabled.
- Measure the performance of our video application.
- Explore and implement new QoS schemes which are suitable for wireless LANs (if time is allowed).

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