ADAPTIVE QoS MANAGEMENT FRAMEWORK FOR COLLABORATIVE MULTIMEDIA APPLICATIONS ON WIRED AND WIRELESS NETWORKS

by

RANGINI CHOWDHURY

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ABSTRACT OF THE THESIS

Adaptive QoS Management framework for Collaborative Multimedia Applications in Wired and Wireless Networks

by RANGINI CHOWDHURY

Thesis Director:
Professor Manish Parashar

Guaranteeing quality of service to the heterogeneous media formats, for streaming and non-streaming multimedia applications, is a challenge that is being addressed individually at the different system layers. However for multimedia applications that aim to collaborate with users connecting via a wireless gateway to a fixed network or collaborating between all wireless users, poses new issues that need to be resolved. New generation multimedia conferencing applications require a new solution framework for handling data that would take into consideration network and data heterogeneity. The domain of focus in this thesis can be stated in two parts –

- Managing QoS while collaborating multimedia data in wired-cum-wireless scenarios
- Defining a new interaction and forwarding mechanism for adaptive QoS framework at wireless gateway

In this thesis we propose a adaptation algorithm that considers both the user preference of data formats for information exchange and the current channel condition estimated by packet losses incurred in a transmission cycle. This helps to decide the service level of the collaboration and the data format to be processed at the application layer. The middleware implementation at the wireless access point of a heterogeneous network, include the QoS management functions aiding a collaborative session inclusive of wireless users.

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Table Of Contents

List of Tables and Figures

Chapter 1

Introduction

1.1 Objective

The objective of this thesis is to develop a framework where wireless users form collaborative networks with wired network users using interactive multimedia applications. The objective is to exchange information such that enhanced utility is achieved based on user preferences and wireless network conditions. We propose a modality transformation algorithm whose parameters are the user preference of data formats for information exchange and the current channel condition estimated by packet losses incurred in a transmission period. The algorithm decides the service level (data rate, multimedia type) of the collaboration and the resultant data type that is to be processed at the application layer. The utility of the shared information and the overall satisfaction gained are considered to be the metrics in the collaboration.

1.2 Background and Motivation

Information technology is taking long strides towards providing multimedia (voice, video, data) communications to the wireless user on handheld, lightweight devices, at reasonable prices and in making the services comparable if not the same as that achieved on wired networks. Inherent technical challenges are faced by wireless systems in the aspects of hardware, communication link design, different access technologies, resource allocation, networking and application issues. Providing QoS – particularly means meeting data rate and packet delay constraints, and permissible BER [1][2][3]. The restrictions of throughput, bounded delay, and bounded BER values of multimedia data besides the complex traffic profiles (continuous or bursty) are well known and various mechanisms to handle them by the multimedia applications have been suggested and established [4][5][6]. The challenge is in handling the unpredictable losses and delays over the wireless links and preventing severe degradation in the application performance.

However the focus of this thesis is creating a collaborating overlay network between the heterogeneous networking methods and making adaptations to data to suit the system condition and preferences of the users. Since the collaboration itself introduces parameters and guidelines that lead to successful information sharing, hence it is realized that there is a requirement in data control modules for these additional parameters to be abstracted to the upper layers of the application framework. Furthermore for wireless networks, this middleware layer can be utilized to introduce the first level of control for data transmission and other parameters like power control. With wireless communication systems projecting higher bandwidth capabilities, varied network architectures and routing techniques are being suggested to provide solutions to QoS requirements over the wireless interface. The challenge is to realize the end-to-end QoS parameters required by a multimedia application, incorporate user preferences, decide the suitable location for QoS management. Finally sustain a collaboration session over heterogeneous networks (wired and wireless) while overcoming the complications in view of the remarkably diverse methods of service provision.

1.3 Overview of Thesis

1.3.1 Collaboration and Information Management

The focus of this work is to define an innovative interaction mechanism to provide adaptive QoS management over the wireless interface. The QoS management framework uses the packet loss achieved at the receiver, updates the user profile for the wireless client at the gateway. Thus the data type specifications most suited to current system condition will be stated in the user profile and forwarded to the collaboration. The information interaction mechanism was mainly based on the Semantic Information Management (SIM) model for collaborative multimedia applications wherein data is adapted and forwarded selectively based on matching the description of the data and a profile generated from the user preference and the current network conditions [7] [8]. The preference-weight for data types combined with device capabilities form the user-profile locally for each user running the application and collaborating with other users in a particular session.

1.3.2 Estimation of Wireless Link Condition

Managing wireless networks is a significantly harder task than managing wired networks for many reasons. One of the main problems is the unpredictable behavior of the wireless channel, due to fading, jamming and atmospheric conditions. Signal quality can vary quite dramatically, which might suddenly reduce the efficiency of the management operation. The wired implementation of the collaboration application uses input from SNMP agents to determine network conditions. For the wireless networks, the performance of previous transmission is used to make an estimate for the link condition. This gives a good estimate during medium to high activity sessions and also reduces dependency on mobile agents like those SNMP for wireless, or physical layer agents to provide link condition information. Also since there is no requirement for special buffering, does not introduce complexity at the Base station nodes.

1.3.3 Adapting Multimedia Data for Enhanced Performance over Wireless Link

Adaptations implemented include gradual degradation of media quality and media transformation.

- Gradual degradation: The application gradually degrades its service level such as reducing resolution of image to match current preferences and network/system state and capabilities. The SIM collaboration application used in the first set of experiments in the thesis, uses a progressive image encoding (based on an algorithm developed by P. Meer et. al., CAIP, Rutgers University) each client can view image at different resolutions (and compression ratios), based on current system/network state.

- Information Transformation: Transforming or adapting the application media type based on local client preference and capabilities. For example, in the shared image viewing application, if a particular client is visually impaired or is unable to view the image due to excessive packet loss or system resource limitations, the image can be transformed in an alternative medium, e.g. text or speech in this case, and can be presented to the client.

Hence the adaptations helped smooth out the degradations in service. Since the net utility or gain out of the transaction is the actual useful data at the receiver, the QoS metric used is a utility metric. It is defined as ratio of total useful information gained to total energy is used to measure the success of adaptation. This utility metric is also taken into consideration when measuring the overall satisfaction of the collaboration.

Simulation experiments conducted were in two sets –

a) First set of experiments on a simulation test-bed created extending a Java-based multimedia application called SIM Collaboration Application. Wired users on different subnets used the application to successfully collaborate and were provided with chat, image sharing and whiteboard areas. The communication backbone was using a multicast channel, with the multimedia data handled using standard RTP and RTCP based real-time transport and feedback mechanism for streaming multimedia applications. The simulated base-station and wireless user interactions captured conditions where profile maintained at base station were updated, and data was transferred and decoded according to user profile.

b) Simulation of wired-cum-wireless scenario with dynamic changing number of wireless users on NS-2. Analyzing performance of adaptation implementation for a collaboration group, exchanging data with users on wired networks.

The experimental evaluation demonstrated that orchestrating data interaction or information flow based modality transformation policy and the link condition, the framework was able to achieve a balance between collaboration satisfaction and expense of effort.

1.4 Contributions

The main contributions of this thesis are:

- Presenting an adaptive QoS management solution for wireless users communicating with wired users in a collaborative session, with session and QoS management functionalities performed at the gateway access point to the wireless users.

- Using a Utility metric for performance measure and Satisfaction metric for collaboration success measure. The two metrics highlight the framework behavior to the policy-based adaptations of data shared in a session.

1.1 Outline of Thesis

Chapter 2 presents related work that discusses various approaches adopted by the research community, and identifies different issues being addressed by various research groups to provide Quality of Service for distributed multimedia applications over heterogeneous networks.

Chapter 3 identifies Adaptive QoS Management for effective collaboration, the main collaboration elements and content adaptation methods.

Chapter 4 defines the Utility and Satisfaction metrics for QoS and collaboration measure. The adaptation (modality transformation) algorithm is also detailed here

Chapter 5 describes the general AQM implementation architecture and the modifications for wireless implementation. It then discusses the experimental setup for the SIM application-based wireless extension and discussion of the results.

Chapter 6 presents the setup and simulated results for the AQM implementation on NS

Chapter 7 summarizes with the conclusion and discusses future work.

Chapter 2

Related Work

Research on provision of QoS over the varied networks is proceeding in parallel with the work on integrated access services, wireless-IP and other internet concepts like streaming media, ecommerce, distributed application hosting. Currently wireless users intending to interact with multimedia data register for services like SMS and MMS[9]. These services are also provided for fixed wireless networks using broadband communication systems like LMDS that provide digital two-way voice, data, Internet and video services for Wide Area Networks. MMS goes beyond text and voice messaging to encompass picture and image, voice and video messaging between 3G mobile users. Also since it is based on standards and open interfaces, the MMS fulfills the need for cross-network messaging between 3G, 2.5G and 2G cellular networks, IP, CATV and even PSTN networks. The MMS core service is inherently messaging of multimedia content between users, including creation, addressing and delivery.

2.1 Fixed Network QoS Schemes

The basic idea of the Integrated Service (IntServ) [10] model is that the flow-specific states are kept in every IntServ-enabled router. A flow is an application session between a pair of end users. A flow-specific state should include the information about bandwidth requirement, delay bound, and cost etc. of the flow. IntServ proposes two service classes in addition to Best Effort Service. One is Guaranteed Service and the other is Controlled Load Service. The Guaranteed Service is provided for applications requiring fixed delay bound. The Controlled Load Service is for applications requiring reliable and enhanced best effort service. Because every router keeps the flow state information, the quantitative QoS provided by IntServ is for every individual flow. In an IntServ-enabled router, IntServ is implemented with four main components the signaling protocol, the admission control routine, the classifier, and the packet scheduler. Other components, such as the routing agent and management agent, are the original mechanisms of the routers and can be kept unchanged.

The Resource Reservation Protocol (RSVP) [11] is used as the signaling protocol to reserve resources in IntServ. Applications with Guaranteed Service or Controlled-Load Service requirements use RSVP to reserve resources before transmission. Admission control is used to decide whether to accept the resource requirement. It is invoked at each router to make a local accept/reject decision at the time that a host requests a real-time service along some paths through the Internet. Admission control notifies the application through RSVP if the QoS requirement can be granted or not. The application can transmit its data packets only after the QoS requirements are accepted.

IntServ/RSVP model is not suitable for wireless networks due to the resource limitation: 1) Amount of state information increases proportionally with the number of flows - the scalability problem. Keeping flow state information will cost a huge storage and processing overhead for the mobile host whose storage and computing resources are scarce. 2) RSVP signaling packets will contend for bandwidth with the data packets and consume a substantial percentage of bandwidth in wireless networks 3) Every mobile host must perform the processing of admission control, classification and scheduling. This is a heavy burden for the resource-limited mobile hosts.

Differentiated Service [12] is designed to overcome the difficulty of implementing and deploying IntServ and RSVP in the Internet backbone. Diffserv defines the layout of the Type Of Service (TOS) bits in the IP header, called the DS field, and a base set of packet forwarding rules, called Per-Hop-Behavior (PHB). At the boundary of a network, the boundary routers control the traffic entering the network with classification, marking, policing, and shaping mechanisms. Diffserv may be a possible solution to the Wireless QoS model because it is lightweight in interior routers. However, since Diffserv is designed for fixed wire networks, we still face some challenges to implement Diffserv in wireless links. First, it is ambiguous as to what are the boundary routers in. In the Internet, a customer must have a Service Level Agreement (SLA) with its Internet Service Provider (ISP) in order to receive Diffserv Services. The SLA is indispensable because it includes the whole or partial traffic conditioning rules which are used to re-mark traffic streams, discard or shape packets according to the traffic characteristics such as rate and burst size.

2.2 Wireless link QoS schemes

The COMET group at Columbia University [13][14][15] have put considerable effort in understanding the concept of QoS for multi-service networks carrying multimedia traffic while addressing the network programming for QoS provision in heterogeneous networks. An extension of this involves providing networking solutions to support end-to-end QoS, bandwidth and other resource management, scalability issues, etc. Specific research work regarding wireless and mobile networking issues that should be mentioned are Daedalus/BARWAN project, UC Berkeley where the objective was to combine intelligent, adaptive applications with smart networking software that can multiplex connections over a wide variety of different networking technologies [16][17] and the Monarch Project, Carnegie Melon University where they developed-protocols for adaptive mobile and wireless networking [18].

2.2.1 UMTS QoS architecture

UMTS [19] has proposed a layered service architecture describing the following key elements –

- Mapping of end-to-end service provided by User Equipment (UE) , wideband CDMA RAN (UTRAN), core network and external IP networks
- Traffic classes and associated QoS parameters
- Location of QoS functions

- QoS negotiation
- Multiplexing of flows onto network resources
- An end-to-end data delivery model

2.2.2 Low power and error control strategies

Two effective methods of supporting QoS for robust video transmission are error control and power control protocols [20][21]. Error control is performed from a single user approach by introducing redundancy. Error control schemes such as FEC (Forward error correction) and ARQ(Automatic Retransmission Request) minimize distortion [22] The Microsoft group for wireless research propose a network adaptive Application-level error control scheme using hybrid UEP (Uniform error protection) and delay constrained ARQ for scalable video delivery. Current round trip and estimated round trip are used at sender side to maximum number of retransmission based on delay constraint.

Scheduled access and transmission power control are MAC layer techniques that help eliminate collisions and minimize transmission power. Power control is also effective in multi-user scenario such that decreasing transmission power helps increase net SNR at receiver and improves utility [23]. Also results show that decreasing transmission power in favor of increased number of transmissions can be a more efficient strategy than maximizing throughput per slot (Throughput is dependent on BER achieved which in turn depends on transmission power).

2.2.3 QoS Routing

QoS Routing explores all the paths available between source and destination with enough resources but does not reserve resources. QoS signaling can then be used to reserve along the best-determined path. Chen and Nahrstedt proposed a ticket based QoS routing protocol for MANETs [24][25] where the number of tickets is determined by current state of network. Each ticket is used to send a probe and ticket limits the number of route queries. Other work include CEDAR[28] , QoS routing based on bandwidth calculation [29]and a more recent work by C. Xhu [30] in which a on-demand routing protocol is suggested based on AODV for mobile TDMA-based ad-hoc networks. A bandwidth calculation algorithm is integrated into the AODV protocol to search for routes with satisfactory bandwidth requirements.

2.3 End-to-end QoS schemes for heterogeneous networks

Some of the key related projects include the MIT project Oxygen [31] in which networks connect dynamically changing configurations of self-identifying mobile and stationary devices to form collaborative regions. This involves developing computational fabrics, which will increase performances for streaming computations while making more efficient use of power. There are a number of research projects trying to address QoS for distributed multimedia systems. Primary areas of research include specification of QoS parameters, level of service based on contracts between user and network, soft state versus hard state, and QoS mapping at the various layers of software to manage heterogeneous demands.

More closely related to this thesis is the quality event mechanism developed by West and Schwan to guarantee QoS to users [32]. Quality Event is a software mechanism by which application or system can be extended to enable runtime QoS Management. As a part of quality event mechanism, Service managers(SM) perform application-specific monitor and handler functions and use adaptation strategies at CPU and network layers.

Wu and Havinga [33] in their recent work have proposed the MIRAI Architecture for heterogeneous wireless networks, which is an overlay architecture with a common platform and common access. This would mean the overlay network would be the basic access separated from other wireless network is used as a means for wireless system discovery, signaling, and paging. This is expected to be adopted in Japan after their adopting the IMT-2000.

DISCIPLE is another ongoing project at Center for Advanced Information Processing, Rutgers University, to achieve adaptive collaboration for wired and wireless platforms using XML as the focus of a data-centric architecture to dynamically adapt data, shared between the devices. The simulation workspace is semi-completed and end-users complete their applications at runtime by selecting and importing task-specific JavaBeans into the Disciple workspace [34].

2.4 QoS Schemes for Multimedia traffic

Some of the works for guaranteeing QoS for multimedia traffic in wireless cellular networks are discussed in this section. Based on the minimum resource requirement criteria provided by the users, Oliveira, Kim and Suda [35] proposed a bandwidth reservation algorithm for guaranteeing QoS to multimedia traffic. For real-time traffic, the call is admitted only if the requested bandwidth can be reserved in the call originating cell and all its neighbors. For a non-real-time call, the requested bandwidth is reserved only in the originating cell. Although this scheme guarantees QoS, the main drawbacks are: (i) bandwidth is reserved redundantly since the user moves only to one of the six neighboring cells (assuming hexagonal cell geometry), and (ii) the stringent call admission procedure might not admit many real-time requests in a highly overloaded system.

Seal and Singh [36] identified two QoS parameters namely, graceful degradation of service and guarantee of seamless service. The carried traffic in a wireless network can be increased by the graceful degradation of on some or all of the existing services in the system. With the help of user supplied loss profiles, bandwidth usage of applications that can sustain loss is degraded in situations where user demands exceed the network's capacity to satisfy them. A new transport sub layer is proposed to implement loss profiles by selectively discarding data from special applications like a compressed video stream [37].

2.5 Discussion

Projects focus on end-to-end aspects of application implementation required in real-time multimedia applications like Video-on-Demand and Distance learning, and others on more general network policy decisions like bandwidth management and congestion control. The AQM framework for collaboration in this thesis builds on application-level awareness of the current client profile and network parameters. A significant feature of the framework is the consideration of the channel characteristics for the wireless clients that determine the capacity and information processing capability for wireless devices. Research work concentrating on a combination of the two factors, i.e. transparent QoS guarantees for heterogeneous networks during collaboration. Heterogeneity concerned here is in terms of collaboration between devices in both wired as well as wireless networks overcoming the challenges and differences in protocols and channel conditions.

Chapter 3

Adaptive QoS Management for Collaboration

The main focus is an adaptive QoS management framework that enables effective collaboration between users distributed in a wired-cum-wireless sharing environment. In this section, a conceptual collaboration model is described recognizing the key elements required for a successful sharing session. Also the functions and suitable locations for the QoS manager are outlined keeping in consideration collaboration requirements. Chapter 4 will then discuss the elements for effective collaboration implemented by the Adaptive QoS framework. The next section discusses adaptation or modality transformation techniques utilized by the QoS manager. Also in this chapter, the Semantic Information Management model is briefly discussed that semantically enhances the multimedia data and is integrated into the messaging mechanism used by the Java-based collaboration application.

3.1 Conceptual Collaboration Elements

A typical sharing session involves interaction and information interchange between people working at physically disparate locations. Collaborating users working in dynamic heterogeneous environments use devices of varied types and capabilities with the purpose of accomplishing mutually beneficial activity [44]. User Data Profile describes the state of a user involved in collaboration, capturing the preferences, capabilities and system state of user environment. Enabling seamless multimedia collaboration in such a distributed and heterogeneous environment presents many challenges. An essential requirement is providing each client with the ability to have direct and immediate access to all information defined by the client's needs, interests, resources and capabilities. User profiles being based on their interests can be dynamically changing. Furthermore, user and network dynamism require the ability to locally transform information on-the-fly so that it matches the client's local capabilities and resources. For example, consider a client participating in a collaboration session involving shared images. The client's device capability or current network connectivity may require reducing the resolution of the image or transforming the image to text or speech to allow the client to be an effective participant in the session.

The domain of collaboration comprises of the range of client and network types interested in the sharing-session. Success in collaboration will depend on meeting the requirements and capabilities of high as well as low processing members.

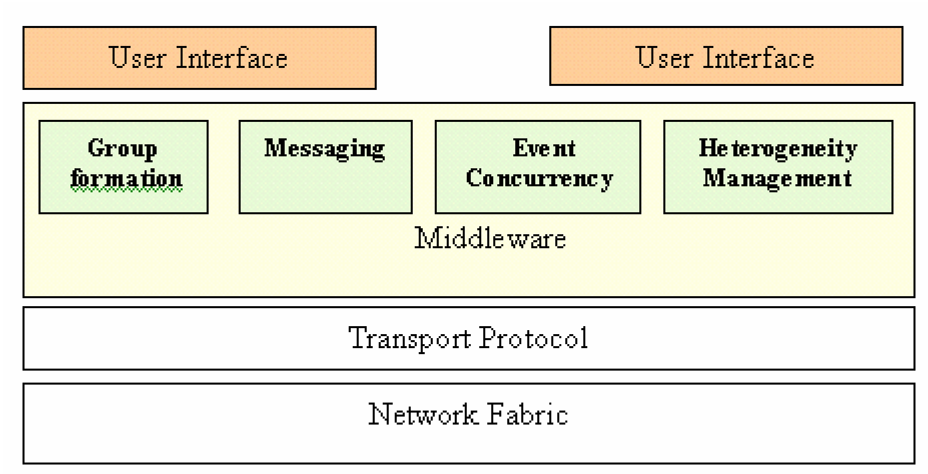


Figure 3.1 Collaboration Framework

Figure 3.1 illustrates collaboration framework. Building blocks for efficient collaboration in a heterogeneous environment are as follows:

- Group formation - Based on the final objective and required results a member joins the appropriate collaborating session. For the entire duration that a user is connected to the sharing session, all information shared by any group member should reach the rest of the group. For effective collaboration, depending on user capability, the data should be adapted or modified, so that a member does not drop any relevant information due to its incapability of processing the data.

- Messaging - Messaging is the process of efficiently and transparently transmitting events generated by one client's action to all other clients in the collaboration session, and reproducing the original action on the remote clients.
- Concurrency Control - Concurrency Control is the process of arbitration and consistency maintenance when multiple clients concurrently manipulate the same set of shared objects in the collaboration session.
- Heterogeneity Management - To enable heterogeneity management it is essential to monitor the state of the network and adapt applications to varying network conditions.

3.2 Modality Adaptation of Multimedia Data

A single multimedia data object can be a temporal composition of different data-type objects. Also each data type such as voice or video has different system requirements like bandwidth and tolerance to delay. The Table 3.1 shows the QoS requirements of different data types-

Table 3.1 Multimedia Data Requirements

	Voice	**Data**	**Video**
Delay	<100ms	-	<100ms
Packet	Loss <1%	0	<5%
BER	10^-3	10^-6	10^-6
Data Rate	8-32 Kbps	1-100 Mbps	10 Mbps
Traffic	Continuous	Bursty	Continuous

One way of handling the multimedia data in low system capabilities is to send to application the data types with low system requirements. Another way is to locally adapt the content or transform the data to suit the system state. Some examples of content adaptation are given in the Table 3.2. For example transforming the video mpeg file to sets of jpeg files or to text or audio description files.

Table 3.2 Content Adaptation Techniques

HTML	Image	Audio	Video
Text Summary Text to audio Format Conversion Table to List Font size reduction	Format Conversion Image reduction Image removal Size reduction Color-to-grayscale	Audio-to-text encoding Format conversion Stereo to mono Audio removal	Frame rate reduction Resolution reduction Video to Image Video to audio Video to Text

For example, MP3 files allow for a small file size while still maintaining a CD-like quality sound. The way an MP3 achieves this is by removing all frequencies that are inaudible to the human ear. While a standard .WAV file may take up 10 megabytes, the same audio file converted to MP3 will take up just a little more than 1 megabyte.

3.3 Adaptive QoS Framework

This paper presents an adaptive QoS management framework that addresses this challenge. In [8], it has been shown that distributed multimedia applications with QoS policies can perform to a reasonable degree of satisfaction by allowing tradeoffs with certain service requirements. The framework leverage on this ability of multimedia applications to work with flexible and reduced QoS guarantees during low network capacity conditions. This could involve application-level adaptations or centralized adaptation of the information transferred based on processing policies derived from the system state. The framework consists of two key components: (1) Messaging substrate that captures interests, capabilities, state and resources of the system, and (2) Mechanisms and polices for adaptive QoS management for effective collaboration in heterogeneous environments. The messaging substrate implements the publisher-subscriber paradigm using semantic headers - i.e. all messaging is based on profiles rather than names and clients an locally define their profiles to direct access to all information based on the interests and capability. The framework support both wired and wireless (thin) clients. While wired clients directly join a collaboration session as peers, wireless clients join through a base-station with a wireless gateway as the access point as shown in Figure 3.2.

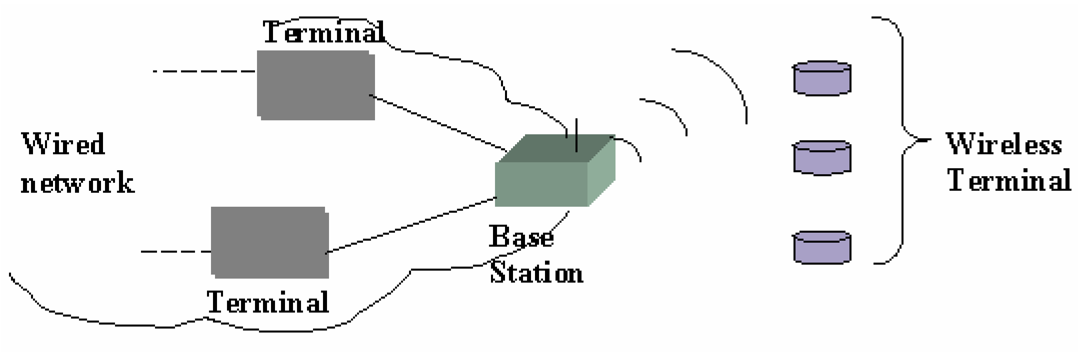


Figure 3.2 Network Overview

Hence the QoS architecture is distributed for wired clients but centralized for wireless users. In the centralized QoS manager, session management is performed at the central access point, which provide tightly controlled interactions, which results if less overhead. In this architecture, it is easier to manage event concurrency and maintain events ordering. The distributed peer based collaboration architectures have loosely coupled interactions, and are more scalable, but need special synchronization management, concurrency management, and event ordering. To illustrate an example, consider a LAN-based member A and a user B using the wireless interface initiating a collaboration session with the same image-viewing application interface. This exemplifies the network heterogeneity. The network capability may change rapidly due to link congestion or path updates of the wireless user. User B is running low on power and decides to go into text-mode to receive information, thus indicating a change in preference. When User A views an image in share-mode with other members of the collaboration, this event along with information data is to be carried on to user B, where the application interface interprets this event, but instead of regenerating the image, reads the text description of the image which is included in the image meta-data. If two users select information for sharing at the same time, concurrency control comes into play and ensures that no information is lost and transmitted in a random order.

3.4 QoS Manager – Features and Functionalities

In the proposed framework for adaptive QoS, the gateway, which is the access point for the wireless users into the session performs the QoS management functions. This is illustrated in Figure 3.3. Gateway is a device that sits at the intersection of two networks and manages the flow of information between them. It provides a variety of services to the networks between which it mediates:

- Translation - Changing messages from one network format, or protocol, to another
- Routing - Making sure each packet of information gets to the correct destination
- Aggregation - Combining the traffic from several devices so that they can all use one internet connection
- Security - Protecting the users and data on one network against improper access from the other

A wireless gateway is a device that connects broadband (ISDN, Cable, or DSL) access to a local wireless network. It also serves the wireless network as a hub, linking all internal devices to each other and to the external network. Wireless networks connect computers, peripherals, and entertainment systems using radio waves instead of cables. Radio signals provide great capacity, flexibility, and ease of use, and have the ability to link devices without clear line-of-sight transmission paths. Radio-based networks require a low-power transceiver in each connecting client device as well as in the gateway/hub. The client radios are commonly built into familiar form factors like PC Cards, NICs, PCI cards, and USB adapters. Multiple radio-based wireless networks can overlap in space without interference, so long as they operate at different frequencies. Notebook and desktop PCs, printers, scanners, television set-top boxes and other devices connect to the wireless gateway using one of several interface devices, each of which includes a compact radio that operates on the same frequency, though at lower power and sensitivity levels, as the access point.

The QoS manager agent at the gateway is similar to the snoop agent for TCP in terms of location and needs to maintain state for all the wireless clients who use the particular gateway as the access point to the rest of the collaboration The SNOOP protocol for reliable TCP transmission over wireless link requires caching history of packets previously forwarded by wired-to-wireless gateway but have not been acked [45]. QoS Manager maintains the profiles of all the wireless clients connect to it and manages QoS on their behalf. This centralized control for wireless clients provides overall improved information sharing under adverse channel conditions and low device capabilities.

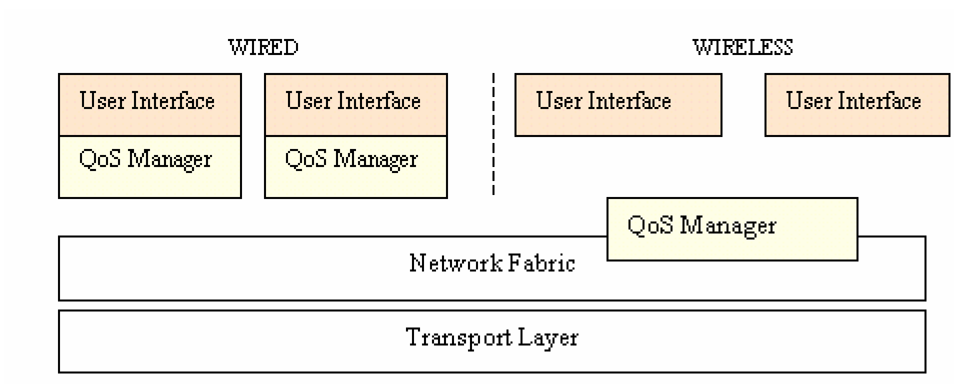


Figure 3.3 QoS Manager in Heterogeneous Collaboration Framework

As shown in Figure 3.4, QoS manager performs the following functions –

1. Create and maintain alterations of user profile.
2. Filter data to application
   a. Depending on user preferences taken from user profile, and possible modality transformation that can be done on each type of data - make a policy table for incoming data.
   b. If incoming data matches client profile, forward to application.

c. If not matching profile, perform modality transformations if possible and forward to application.

d. If changing modality does not locally adapt the data to user state, drop the data.

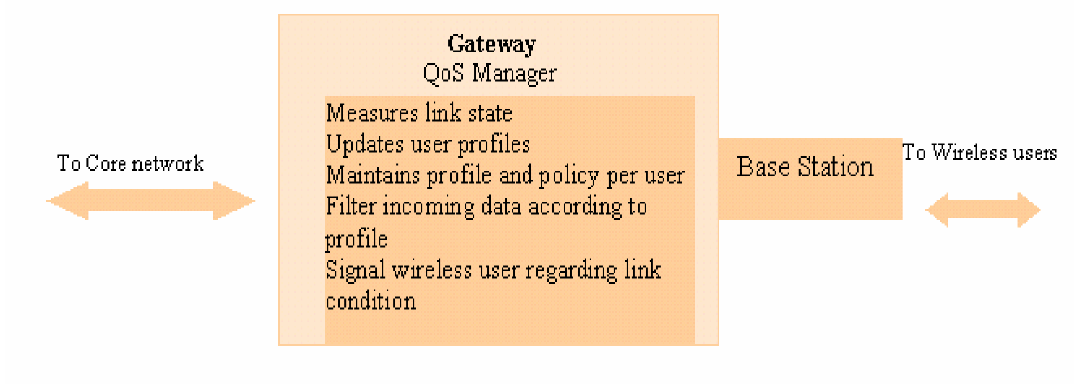


Figure 3.4 Wireless gateway QoS Manager Functions

As a QoS Manager, gateway measures the packet loss percentage to update the user profiles. The packet loss rate is measured for a particular transmission cycle or if continuous transmission then calculated over a period of time. High packet loss cause the profile to be updated. Also a control signal from the wireless user indicates if any user-directed change of profile is required. This occurs when a client changes preference of data type – for example user changes preference from video information to audio, only due to a low power indication by wireless device. The user could indicate change of preference for any reason at his discretion.

3.5 Messaging Model and Semantic Interaction

Conceptually, we can consider the messaging mechanism to be based on the Publisher-Subscriber Paradigm [46]. In this interaction model, publishers are entities that produce information and subscriber(s) are clients that interested in this information. Publishers and subscribers can be decoupled in space (i.e. distributed) and in time. In our messaging substrate, clients can be both publishers and subscribers. Furthermore, as collaboration is real-time, we do not support time decoupling and store and forward mechanisms. Note that sessions can be archived to provide late clients with session history.

Our implementation of the publisher-subscriber messaging substrate is based on semantic interactions. Traditional distributed information management approaches are based on global naming services, where all communications use unique names assigned to clients. In such a system, every application client that enters a session must register itself with the naming server, explicitly stating its interests. The server then assigns capabilities to the entering clients and informs existing clients about the new client's interests. Existing clients can now forward relevant information from the existing collaboration session to the entering client. Clearly, the dynamics of such a collaborative framework is limited by the rate at which the network can synchronize distributing names, interests and capabilities. The semantic interaction approach implements the 'pull' distributed interaction model using semantically enhanced events and state-based communication techniques [47]. In this scheme, each client locally maintains a profile that defines its current state, its interests and its capabilities. All interactions in this scheme are then addressed to profiles rather than explicit names**.** Consequently, the group of interacting clients is determined only at run-time. A client's profile may also encapsulate network/system state. Communications between the collaborating clients are now defined as state-based multicast messages where a message is semantically enhanced to include a sender-specified 'semantic-selector' in addition to the message body. The semantic-selector is a prepositional expression over all possible attributes and specifies the profile(s) of clients that are to receive the message. Thus the conventional notion of a static client or client group name is subsumed by the selector, which descriptively names dynamic sets of clients of arbitrary cardinality (conventional names of clients or clients groups are non-descriptive and statically bound.). State-based messages are received by semantically interpreting message selectors in terms of the client profiles. In the case of wireless clients, the base-station maintains the profiles of all its clients and participates in the semantic interactions. It then appropriately forwards information to wireless clients. Figure 3.5 illustrates the semantic interpretation process, let us look at the following example-

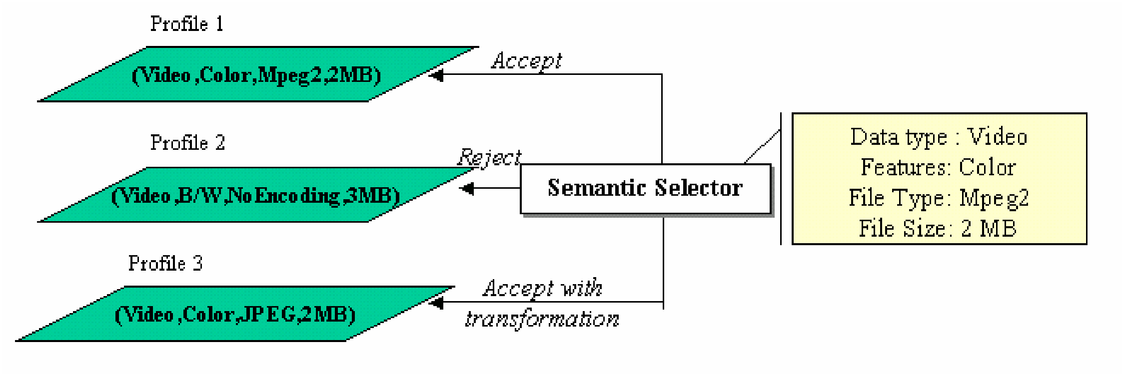


Figure 3.5 Semantic Interpretation Process

The semantic selector describes the attributes of the incoming stream as color video, with MPEG2 compression and 1 MB data.

Client 1's profile (Profile 1) matches this incoming selector and hence the message is accepted.

Client 2 (Profile 2) on the other hand is only interested in B/W video with no encoding and so the message is rejected.

Client 3 (Profile 3) is interested in color video with JPEG encoding and has the capability to transform MPEG2 to JPEG. It thus accepts the message with a transformation.

Chapter 4

QoS Metric Description And Evaluation

4.1 QoS Metric – Requirements

The specification and enforcement of QoS presents interesting challenges in multimedia systems development. Typical application QoS parameters for images and video include image size, frame rate, startup delay, reliability etc. The application QoS profile can also include subjective factors such as the degree of importance of the information to the user and the overall cost-quality metric that the user desires. Network QoS parameters include bandwidth, delay, jitter and loss rate. End-system parameters include CPU load, utilization, buffering mechanisms and storage related parameters. There are several challenges in delivering the specified QoS to video applications. The mapping between different sets of parameters at different levels in the system, the QoS translation process is one of the challenges in meeting end-to-end performance bounds. QoS parameters at the user level must be translated to quantitative parameters at the network and system level. QoS Metric should be measure of user satisfaction and resource consumption factors. User satisfaction factors quantify the QoS guarantees met and factors that affect the delivery of the desired response quality. Application QoS related parameters such as frame rate, frame width, frame height, color resolution, compression ratio, jitter for video and synchronization skew are good measures to determine the achieved quality and the deviation between the actual response and the desired quality.

4.2 Utility - QoS Metric

Since the thesis is focused on a collaboration application, the success of service provided depends on the overall success of collaboration. The effort invested should balance the achieved gain at each user. Hence the requirement is of a metric, which takes into consideration conventional QoS metrics like packet loss, and also incorporates collaboration parameters discussed in chapter 3. We propose the utility of shared data as the QoS metric. Utility is already considered a performance metric in wireless networks by Goodman and Mandayam in their work on power control of wireless networks [23] and it is defined, as ratio of total information bit over energy expended. The utility figure depends on rate and power of data transmission besides the information bits successfully transferred over total data bits transmitted. In the multimedia collaboration, when interacting with a particular data-type, user satisfaction is being measured based on the two factors –

1. Preference weight specified by user for the particular data-type

2. Utility achieved for the data-type

Utility per data type depends on the actual information content and energy expended in transferring the data. This includes encoding bits and also retransmitted bits.

*Utility - (Actual Multimedia bits received)/(Total bits sent * Energy per bit)*

Clients of the collaboration session specify their preferred media. Also utility is an outcome of total effort invested and the net outcome of the investment. Net effort depends on rate of transfer, power of transfer, packet loss incurred and also size of information bits in each multimedia data type. The adaptation profile is created that incorporates the user's preference, specification of data type transmission and transformation. Based on the adaptation profile, the current user profile is created with the most preferred data type specifications. The most interesting and important feature however is maintaining the profile and measuring that collaboration is effective and beneficial.

We now proceed towards an overview of the QoS management process implemented in both the SIM application and the NS-2 simulation environment. In SIM application, the RTP packet header provides the number of actual packets bits from sender including header and coding bits. In the NS implementation too, similar to RTP operation, we use a packet count offset field to calculate total data bytes sent. Amount of data transmitted and received vary only if there are packet losses.

4.3 QoS Management Process Overview

User inputs preference weights for all data types that the application supports. Therefore, ideally packets corresponding to all the highest preferred data types are forwarded to the application interface. If equal weights are assigned for two data modalities, it indicates same preference, in which case the framework will support data type with lower rate of transfer. QoS manager agent calculates the packet loss ratio per object transmission and utility. Packet drops when more than specified for the data type in application based on Table 3.1, results in QoS Manager updating user profile to perform modality transformations. If the performance degradation is very high due to a high packet loss, then QM selects the next index in adaptation profile table maintained by the inference engine, which is typically adjusting to a lower data rate, or to the next preferred data type. This should enable user to access information conforming to his interest but also best meeting current system constraint.

4.4 Packet Loss Ratio - Measure of Network Condition

We discuss here why packet loss is considered as an estimate for wireless network condition and in support of the same present an argument based on BER-SNR relation in the next section (4.5).

For the wired networks, the network management module obtained used SNMP [49] agents to gather information from the network elements. However with the wireless agents, the packet loss is the simplest indication of network condition as it depends on packets dropped due to channel saturation, poor and dynamically changing link conditions. Hence instead of increasing load on gateway, trying to determine the channel conditions periodically, while leveraging effective collaboration, utility provides an impression of the constantly changing wireless link condition. In the work by Seal and Singh [36], in which they used loss profiles to estimate channel condition, using prior link condition in the estimate of what to expect next. The difference in our implementation is that we do not maintain prior information, but compare threshold utility factor (without packet losses) with actual utility factor to perform profile managerial function.

4.5 Argument based on BER-SNR relation

Bit error rate (BER) performance is an important quality in communication systems. QoS requirements include that in order to maintain adequate video quality, requires low BER and low packet loss rate. 802.11 extensions address real-time requirements using priorities and adjustable back-off times in MAC. Table 4.1 enlists the Wireless LAN standards, the claimed and actual expected data rate.

Table 4.1 Different Wireless LAN Standards

Standard	Band (Ghz)	Tx Power (USA)	Prop-rietary/ Open	Data Rate [Claimed] (Expected)	Modulation/ MAC protocol	Indep Users	Avail-ability	Pros/Cons Other comments
802.11b	2.400-2.484	20-30dBm	Open	[1-11], (4)	DSSS-FHSS/ CSMA	3	Now	Pros: Cheap, ubiquitous Cons: Somewhat slow, not robust to interference, in 2.4 GHz band
HomeRF	2.400-2.484	20 dBm	Open	[1-2], (<1)	FHSS/ CSMA	6	Now	Pros: Cheap, supports voice QoS Cons: Low rate, may lose to 802.11b
Wi-LAN	2.400-2.484	15 dBm	Prop.	[30], (???)	DSSS-OFDM/ CSMA	3	Now	25 MHz channels w/ 30Mbps. Developed proprietary W-OFDM Cons: No market momentum
HomeFree	2.400-2.484	13 dBm	Prop.	[1], (<.1)	FHSS/ CSMA	81	Now	Very low data rate, on its way out.
802.11a	5.15-5.35, 5.75-5.85	16-29 dBm	Open	[6-54], (20)	OFDM-FDMA /CSMA	12	End 2001	Pros: High rate, clean spectrum Cons: Behind 802.11b (playing catchup), security, real-time apps
HiperLAN1	5.15-5.35	17-30 dBm	Open	[23.5], (10)	GMSK - FDMA/ HLAN CAC	9	Now	With ECC and EQ, R < 0.5 BW Seems to have really lost steam
HiperLAN2	5.15-5.35	23 dBm	Open	[6-54], (20)	OFDM-FDMA/ TDMA	8	After 802.11a	PHY nearly identical to 802.11a. Optimized for real-time apps. Con: Time to market, Europe

Independent of LAN standard selected, achieved data rate may be scaled based on strength of convolution coding and constellation size. But it is also typically adjusted dynamically based on PER (Packet Error Rate). Based on empirical testing, a reasonable path loss model can be developed. SNR received is a function of system parameters (transmit power Pt, noise power No, coding gain Gc, fading loss FL) and path loss PL.

$$SNR_{eff}\,(dB) = Pt - PL - No + Gc - FL$$

Based on the path-loss model, a reasonable accurate received SNR or Signal to Noise Ratio (SIR) can be estimated. In our extension of SIM application to simulate wireless network, the SIR was calculated as a function of distance, to a varying transmitter power values. The target SIR at the BS from a client varies dynamically when other wireless clients join and leave. The SIR γ_i for a client i is calculated as:

$$\gamma_i = \frac{(P_i * G_i)}{\sum_{k=1, k \neq i}^{N} (P_k * G_k) + \delta_i^2}$$

where P_i, P_k, G_i and G_k are the transmitting power and path gain for clients i and k respectively, and the noise factor, δi , is calculated based on the transmitting power of the client($P/10^{10}$).

BER and PER are functions of system parameters and distance for transmitter. Also "Bottle Neck" is the BER of the wireless link. If error is reasonably high, throughput is limited and even increasing capacity of link does not help. As we see later in experiments, in a link with high BER, even a single user sharing the link suffers high packet drops.

$$BER \approx \frac{4}{\log_2 M}\left(1 - \frac{1}{\sqrt{M}}\right) Q\left(\frac{\sqrt{3SNR_{eff}}}{M-1}\right)$$

$PER \leq 1 - (1-BER)^L$, L – length of data packet (bits)

Hence we see that –

PL $\rightarrow$ SNR $\rightarrow$ BER $\rightarrow$ PER $\rightarrow$ Throughput

- Path loss modeling coupled with information about noise and transmit power determines SNR
- BER is determined directly by SNR
- PER is a function of BER, packet length, data rate/burstiness
- Throughput depends on PER and protocol overhead

Utility being a function of total packets sent, and information received over the entire effort, and in the condition of constant power of transmission and other communication system parameters utility will vary corresponding to the variance of the above parameters. As it is seen that throughput achieved at the receiver at any instant is dependent on BER, which is a function of SNR achieved, hence QoS manager agent approximates link condition into consideration based on utility achieved.

4.6 Adaptation Algorithm

We discuss two cases given below, depicting the adaptive QoS process based on metric variation with respect to the threshold factor. The example is illustrated with file extension used by SIM Java-based collaboration application. In other applications that use regular files such as MPEG files, this represents modifying the files by dropping the intermediate packets. However here, for clarity we refer – Fine image files by extension .res and base image file of same image with .csi.

Example:

Standard: IEEE 802.11b

Maximum Data Rate: 11 Mbps

Step 1 – User inputs preference

Preference Weights –

Image (Fine)	5

Image (2000:1 Base Image)	4
Text	3
Voice	2

Step 2 – Generate Adaptation profile

Set Adaptation order –

Profile Index	File Type	Rate
1	.res file	10 Mbps
2	.res file	5 Mbps
3	.csi file	1 Mbps
4	.csi file	75 Kbps
5	.txt file	50 Kbps

Step 3 – User profile created by selecting Index 1 in adaptation profile –

Step 4 – During file transfer session, calculate packet drop ratio. In both cases 1 and 2 , we select packet drop tolerance for video which is 5% drop tolerance.

Let D_1 be packets dropped and S_1 packets sent-

Case I: ($D_1/S_1 < 0.05$)

No Profile Alterations

Data File Selected: .res file (*No Alterations*)

Case 2: ($D_1/S_1 >= 0.05$)

Profile Alterations

Data File: .res file (*Data rate changed - 5 Mbps*)

If packet drop is within tolerance consecutive transmissions, profile could be upgraded to more preferred data type or increased data rate, as the network condition indicates improvement over previous conditions.

4.7 Multi-user Scenario

This condition arises when more than one wireless user is communicating with the same BaseStation and also participates in the same collaboration session too. However, the data adaptation mechanism can be enhanced to reduce the processing load. When collaborating data is being transferred via the gateway to the wireless extension, then the gateway can adapt the incoming data to the specifications of the wireless user with lowest service level or requirement and do the dynamic adjustments after that. So when there are two users – one with user profile stating image and other with voice – then the gateway has the option of forwarding only the voice, being lower data rate, to both user, at that particular time. This reduces the separate processing and adaptations load at the gateway.

It was required at this stage to modify utility metric, to now form Overall User Satisfaction metric, which is a function of number of users that can be supported at any time, data rates and utility achieved. The satisfaction is greater when data types corresponding to higher user-specified weight are being supported and higher utility achieved, however higher data rates result in poor energy-cost profile. For a particular transmission by a wireless entity-

Data rate $\rightarrow d_1$, weight associated with $d_1 \rightarrow w_1$,utility achieved $\rightarrow u_1$

Collaboration Satisfaction metric = $\frac{w_1}{\sum w_i} * u_1 * \frac{64000}{d_1}$

The data rate factor is normalized using data rate for voice data. Optimum data rate maximizes the overall user satisfaction.

Chapter 5

Adaptive QoS Framework Extension To Wireless Clients in Collaboration Application

5.1 General AQM Implementation Architecture

Figure 5.1 presents the global overview of the Adaptive QoS Management architecture.

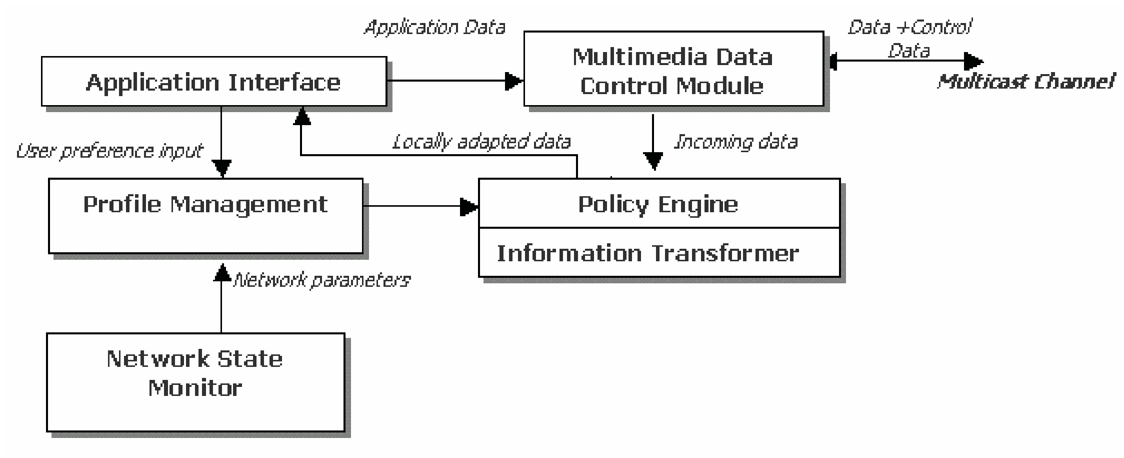


Figure 5.1 AQM Implementation Architecture

The important elements are the Application Interface, Profile Manager, Policy Engine, Information Transformer and Network State Monitor. The general implementation handles messaging between the collaborating users and also more importantly the adaptation of the multimedia data to match each user's profile.

User stores the preference for the data types through the application interface in terms of weights for every data format that are supported by multimedia application. The Policy engine serves as a policy database and encodes policies for information transformations. The *adaptation policy* is then generated in the Profile manager module based on the input user preference values and the processing and adaptation capabilities of user. This policy is then stored in Profile engine. The user profile is dynamic and changes locally to reflect the changes in the client or system state and define the QoS constraints that need to be conformed to. Policy engine interacts with the current user profile to match the data requirements of user with the incoming data. It also prompts the Information transformer to enable the semantic interpretation for the data that has been received. The incoming data has encoded semantic selectors that enable effective interpretation under the current network/system constraints.

5.1.1 Wireless implementation architecture

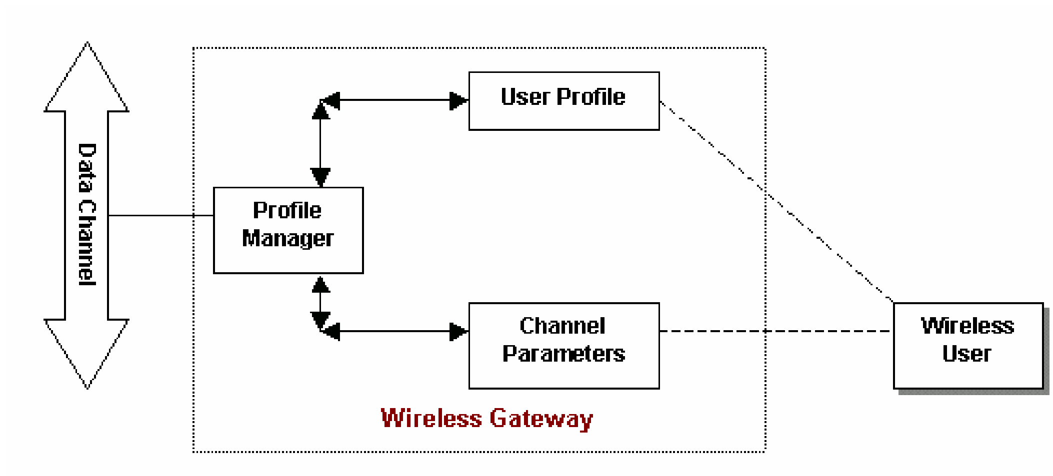


Figure 5.2 Wireless Implementation Overview

The main distinction in extension of the implementation of AQM framework to include wireless clients, is that the application of QoS management functions are at the access point or gateway. The general wireless implementation setup is depicted in Figure 5.2. This centralized implementation is mainly keeping in mind the energy consumption factor, which is an important limitation in wireless devices. The wireless network interface functionalities themselves consume a significant amount of battery power. Hence additional overheads to supplement for other services get significantly restricted. Hence data and profile management functions are implemented at the access point interface, where the Profile manager now maintains profiles and adaptation policies for each wireless user in the collaboration. The

Channel parameters used in the collaboration application are distance, transmitting power for base station and wireless users. The parameters are used to determine the collaboration level in conjunction with the user preferences maintained in the User Profile.

5.2 Experimental Setup On Java Event-Delegation Application Model

Our approach during implementation of the framework was to create a limited distributed client environment, which would form the backbone for a collaboration network. Hence the preliminary phase was developing an application that would function as the interaction interface with chat area, whiteboard and image display space for a complete collaboration session at the client nodes. The different heterogeneity features could then be extended from this version of implementation. The current version of the collaboration application, coined the SIM (Semantic Interaction Management) application, has three basic operational modes – as a wired client, base station or a wireless host and a client when logging into the application selects the mode appropriately.

A wired client joins the multicast network and becomes an active member of the session using the three main entities of the application user interface- the chat-area, whiteboard or image viewer. The user interface is coupled to the adaptive framework using the application interface. This component is responsible for locally orchestrating an application client’s collaboration session. It monitors all local objects of interest to the client and encodes their state as entries in the client's state repository. Similarly, when a remote instance of the object changes state, the change is received by the communication module and forwarded to the application interface, which in turn updates the client's session. Wireless client in order to join the collaborative session establish connection via the base station, which monitors the network parameters for the wireless extension. Base station functions as the control coordinator while maintaining the wireless client state, number of users connecting to it and while a wireless client is in collaborative session, maintains a profile depending on distance, signal strength at base station, transmitting rate and capability of the client. The interaction diagram is shown in Figure 5.3. After the initial link establishment, our implementation uses the same user interface for a wireless client. Base station links the wireless network to the rest of the distributed collaborative session by joining the multicast session and is the gateway to the contributions of the wireless clients. Hence all the wireless clients connecting to the base station are by default a part of the collaborative-networked system. The parameters exchanged between Client and base station interface include the distance and transmitting power.

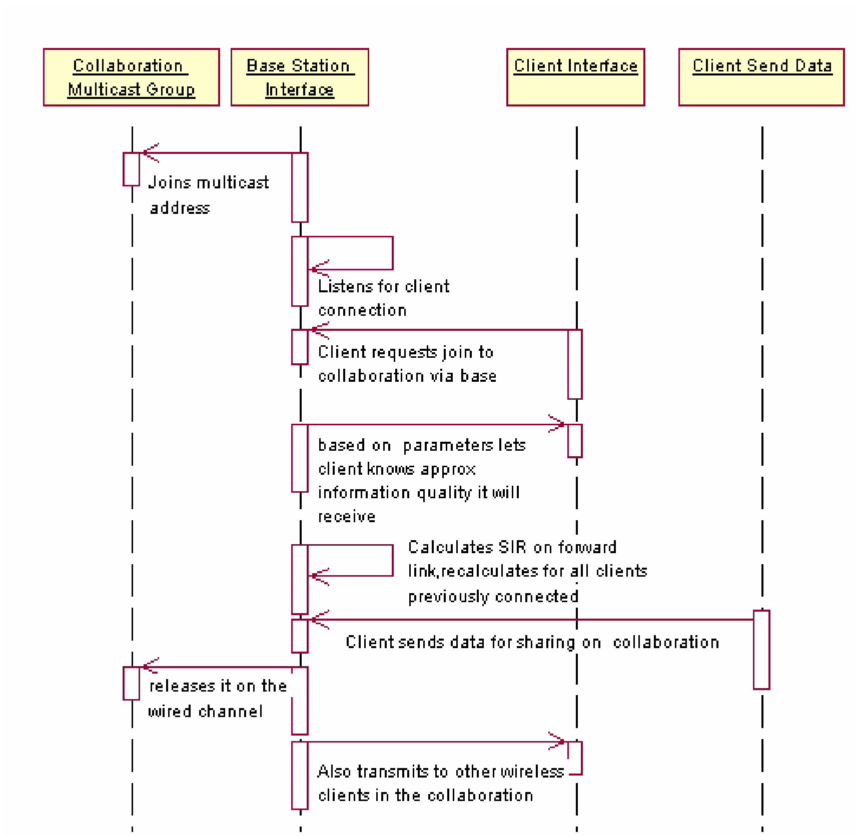


Figure 5.3 Interaction diagram in SIM Application

5.3 Experiments conducted on SIM Collaboration Application

The first part of experiments is implementation of SIM application framework to respond to wireless client. Image Viewer application encodes images using compression algorithm and decode images with lesser number of image data packets. It is considered in the experiments that, if the data file is an image file, it comprises of three main parts- (a) Text description of the image (b) Base Image which forms the sketch of the original image (2000 times less data) and (c) the main image file with high resolution data. Figures 5.4, 5.6 and 5.7 depict the interplay of the transmission power of the wireless hosts and the net SIR received at the base station. The set of experiments conducted are based on-

- Varying distance of clients from BS for fixed values of transmitting power
- Varying transmitting power for constant values of distance for clients
- Varying number of wireless clients

According to theory for power control of wireless data, for the case of multiple clients transmitting to a particular BS, if all the clients transmit at a power level reduced by the same factor from the original power, the net utility at the target is increased for all the clients [22]. Extending this theory to the adaptive QoS framework, wireless devices with high transmission power capability could reduce their power in a multiple client scenario with the goal of reducing overall interference. This will enable the base station to receive the information from low power clients with lower error rates. For example, if the SIR threshold for image data is at 4 db at the base station, while the current target SIR achieved is about 7db, then BS requests client to transmit at a lower power, which would also help to conserve battery power of the client. This is the intended spirit behind effective collaboration.

Based on the collaboration network implementation of a simulated wireless network, 3 sets of results are now presented-

(a) Variation of distance

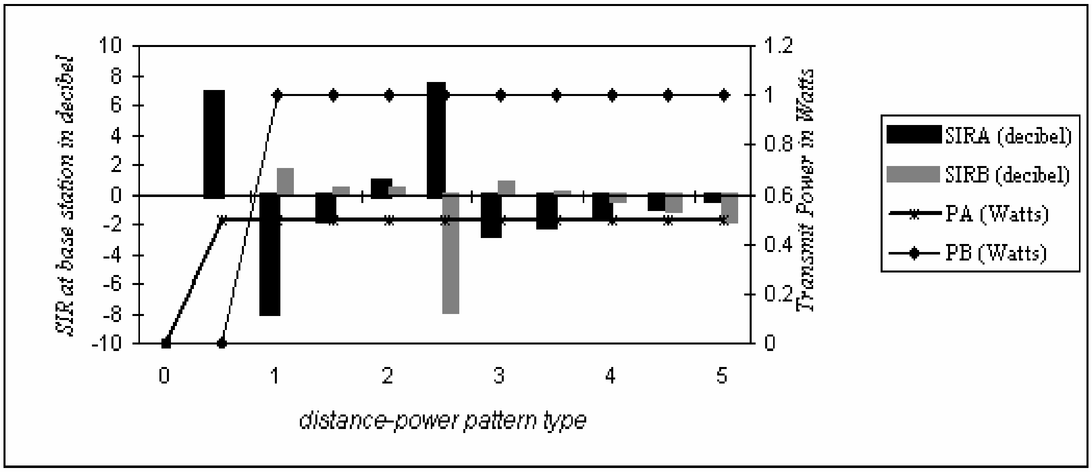


Figure 5.4 Performance of 2 wireless clients with varying distance

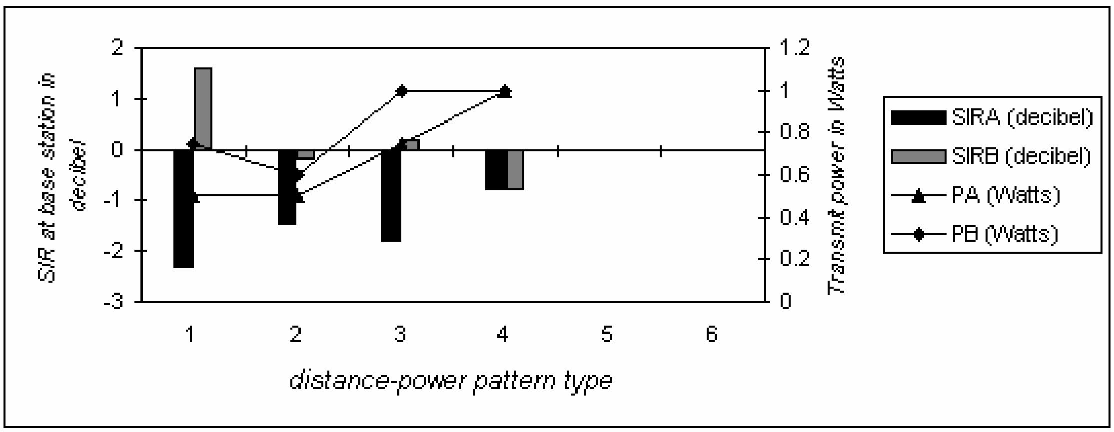


Figure 5.5 Performance of 2 wireless clients with varying power

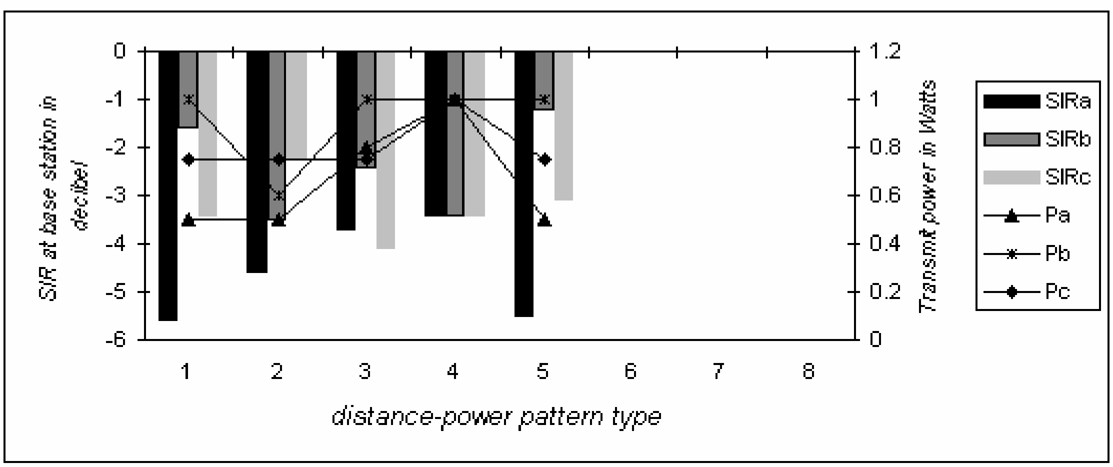


Figure 5.6 Performance of 3 wireless clients with varying distance and power

Figure 5.4 results are with respect to distance (depicting mobility in clients). From points 0 -3 on the x-axis, the distance of client A is reduced from 100m to 50m. At those points when distance is reduces, SIR of client B improves considerably. From point 3 onwards on x- axis, client A distance from base station is increased. When with constant transmitting power the distance is varied, then the base station/gateway periodically calculates SIR and depending on the signal strength selects from the data-type format to forward. If text file is transmitted in a single packet, then BS on reception of that packet will forward it. If it receives the base image packet at SIR above threshold for image, it will send out the image packets too. So even in a low throughput network condition BS is able to send certain level of information from wireless client to the collaboration network.

(b) Variation of power

In Figure 5.5, transmit power of client A is increased in steps for the same distance of client A and B from the base station. If the devices are capable of changing power of transmission then we see that they can improve overall SIR at base station (power control and game theory). However it is seen that changing distance is more effective than change in power.

(c) Limit on number of clients joining the session

We see in Figure that depending on number of clients joining the network via a particular BS, the SIR for all clients deteriorate steadily - for client 2 joining in SIR dropped down by 90% and for client 3 joining SIR of client A went down by another 23%. Hence there is an upper limit to the number of clients that can join in a session, which depends on the range or difference between transmitting power of the clients and the inter-distance between the clients. As the upper limit is approached, no transformation or change with respect to distance, power or modality will improve performance noticeably.

Chapter 6

AQM Framework Experiments On Network Simulator

6.1 Network Simulator (NS) Implementation

The SIM collaboration application experiments showed successful information sharing between distributed users. However in these experiments, wireless users were remote users connecting to an actual collaboration setup using a simulated wireless interaction mechanism. The next set of experiments is conducted on NS-2 [51] to incorporate 'real' wireless network attributes. Wireless users use simulated IEEE 802.11a DSSS interface. The NS-2 implementation of the framework has the following important parts –

i. Generating the wired-cum-wireless environment

ii. Creating a multimedia agent over the UDP agent

iii. Implementing QoS Manager residing at the base-station or the gateway to the wireless network

iv. Implementing Modality Transformation algorithm based on the wireless link features

6.1.1 Generating Wired-Cum-Wireless Scenarios

In network simulator, wired-cum-wireless scenario is created using hierarchical addressing and routing. The entire network is separated into domains – wired and wireless domains and connectivity link is established between the two domains. We have considered every wireless user to be at a distance of one hop from the base station.

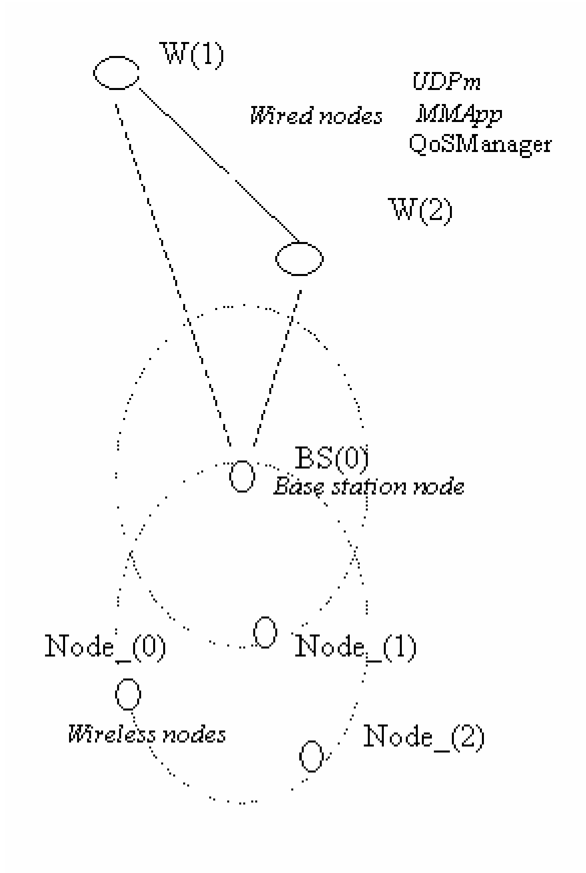


Figure 6.1 Simulation Topology

Experiments on NS-2 were conducted with the objective of capturing collaboration behavior in 'actual' wired-cum-wireless network conditions. The experimental model is as described in Figure 6.1. MobileNode is the basic Node object with added functionalities like movement, ability to transmit and receive on a channel that allows it to be used to create mobile, wireless simulation environments. The class MobileNode is derived from the base class Node. The mobility features including node movement, periodic position updates, maintaining topology boundary, are implemented in C++ while plumbing of network components within MobileNode itself (like classifiers, dmux, LL, Mac, Channel etc) have been implemented in Otcl. The MobileNodes mainly support simulation of multi-hop ad-hoc networks or wireless LANs. The extensions made to the CMU wireless model allows us to simulate a topology of multiple wireless LANs connected through wired nodes. The main problem facing the wired-cum-wireless scenario was the issue of routing. In ns-2, routing information is generated based on the connectivity of the topology, i.e. how nodes are connected to one another through Links. MobileNodes on the other hand have no concept of links. They route packets among themselves, within the wireless topology, using their routing protocol. But the issue is the exchange of packets between the two types of nodes.

So a node called BaseStationNode is created which plays the role of a gateway for the wired and wireless domains. The BaseStationNode is essentially a hybrid between a Hierarchical node and a MobileNode. The BaseStationNode is responsible for delivering packets into and out of the wireless domain. In order to achieve this we need Hierarchical routing. The MobileNodes in wired-cum-wireless scenario are required to support hierarchical addressing/routing. Thus the MobileNode looks exactly like the BaseStationNode. The DSDV agent when forwarding a packet checks to see if the destination is outside its (wireless) subnet. If so, it tries to forward the packet to its base-station node. In case no route to base-station is found the packet is dropped. Otherwise the packet is forwarded to the next-hop towards the base-station. It is then routed towards the wired network by base-station's classifiers.

Each wireless domain along with its base-station would have a unique domain address assigned to them. All packets destined to a wireless node would reach the base-station attached to the domain of that wireless node, which would eventually hand the packet over to the destination (MobileNode). MobileNodes route packets, with destination outside their (wireless) domain, to their base-station node. The base-station knows how to forward these packets towards the (wired) destination.

6.1.2 Multimedia Agent

NS provides Application agents, which generate packets at different rates. CBR application agent generates application data at fixed rate. Other agents such as FTP application agent, generate data at a rate set at initiation of TCL script [48]. Trace files of multimedia application such as Video application are available at NS data pool. Hence using the values of the trace files, the application agent simulates an actual multimedia application generating and sending data packets of different lengths at constant and bursty rates. Figure 6.2 shows the hierarchical connection of agents to the nodes. Each node is attached to Multimedia application (*MMAPP)* agent and *UDP-MM* agent, so that *Sender*-side node now can send data of varying length and varying rates simulating multimedia data.

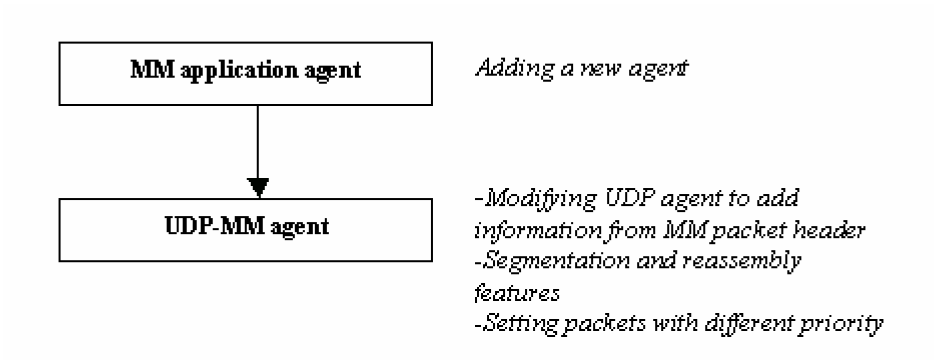


Figure 6.2 Adding MM Application Agent

6.1.3 QoS Manager Agent

The MMAPP agent and UDPMM agent is attached to all the nodes generated in the TCL script. Also the MMAPP agent in wired nodes now link to a QoS Manager, which performs the Profile Management features discussed in Chapter 4. The BaseStation uses the QoS Manager agent to transform packets being transferred by its link layer. The interface used in the experiments is IEEE 802.11 standard for a WaveLAN card, which is the default in NS model. Parameters such as Transmitting power (Pt) are changed at script level.

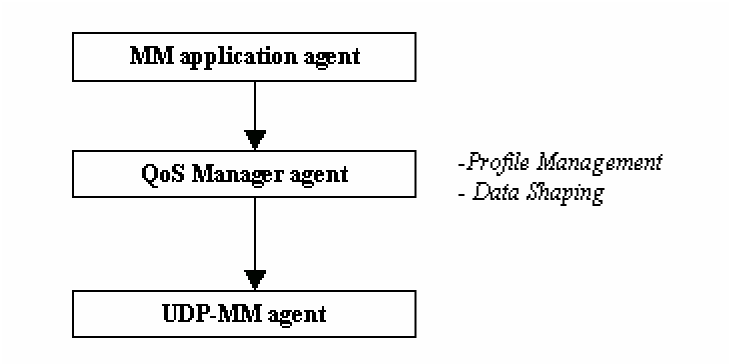


Figure 6.3 Adding QoS Manager Agent

6.1.4 Implementing Modality Transformation algorithm based on the wireless link features

Consider the setup in Figure 6.1 where two users, Node_(0) and Node_(1), join a collaboration group on wireless via a common gateway access point at BS(0). The router function of this gateway will now maintain state for the multicast group address that represents that particular collaboration group. It also maintains a sub-state of the group that comprise of two parts fixed node information of device capability, network interface and variable information based on dynamic inputs of data format preference from user.

The user interface prompts user to enter his preference per data type and user can also change his preference during run-time. Node_(0) and Node_(1) connecting via G will have the fixed and variable parameters as shown in Table 6.1 given below –

Table 6.1 Node Parameters

User Id	Network Interface	Device capability			Preference Weights (1-5)		
		Voice	Text	Video	Voice	Text	Video
Node_(0)	802.11a DSSS	✓	✓	✓	2	4	5
Node_(1)	802.11a DSSS	✓	✓	✓	4	2	5

Following this, the User Profile is developed, based on utility metric. Based on the utility metric and device capability the QoS Manager calibrates adaptation tasks that will be performed on incoming data before forwarding them for actual application processing. The Wireless LAN standards network interfaces in this paper are considered the same for all the experiments.

6.2 Experiments conducted on Network Simulator

The experiments detailed in this section are steps towards building the collaboration environment in NS-2. In experiments of Section 6.2.1 and 6.2.2 experiments QoS Manager does not perform modality transformation algorithm based on utility performance. So there are no profile changes performed as the objective is to show that QoS Manager captures the phases when profile changes can be made to improve utility. For the set of experiments in section 6.2.3 , profile changes are performed and we then show how the satisfaction or utility is improved due to changes in data rate and profile alterations.

6.2.1 Fixed node experiments

Figure 6.4 shows how change of data rates affects packet drop for stationary nodes. The utility calculation based on actual useful information received in bytes over the energy spent, with energy spent per bit estimated at 1.3863 [50]. Also the losses are measured at Node_(0) that is the first node that joins the collaboration. In Figure 6.4, we particularly focus on the fine image data transfer behavior, with more wireless clients joining the BS(0). The bandwidth requirements of each user in the collaboration are also specified. For example, we see that when three nodes are collaborating by BS(0), Node_(0) and Node_(1) with a bandwidth requirement of 1 Mbps, while Node_(2) at 64 Mbps – 63 UDP packets are lost out of 593 packets sent. For the same packets transferred at 1.25 Mbps rate, packets lost count was 17 when only Node_(0) was attached to BS(0) and loss count was 37 when Node_(1) had also joined the collaboration. It is also apparent that the network simulation set-up behaves as expected with increase in number of wireless users.

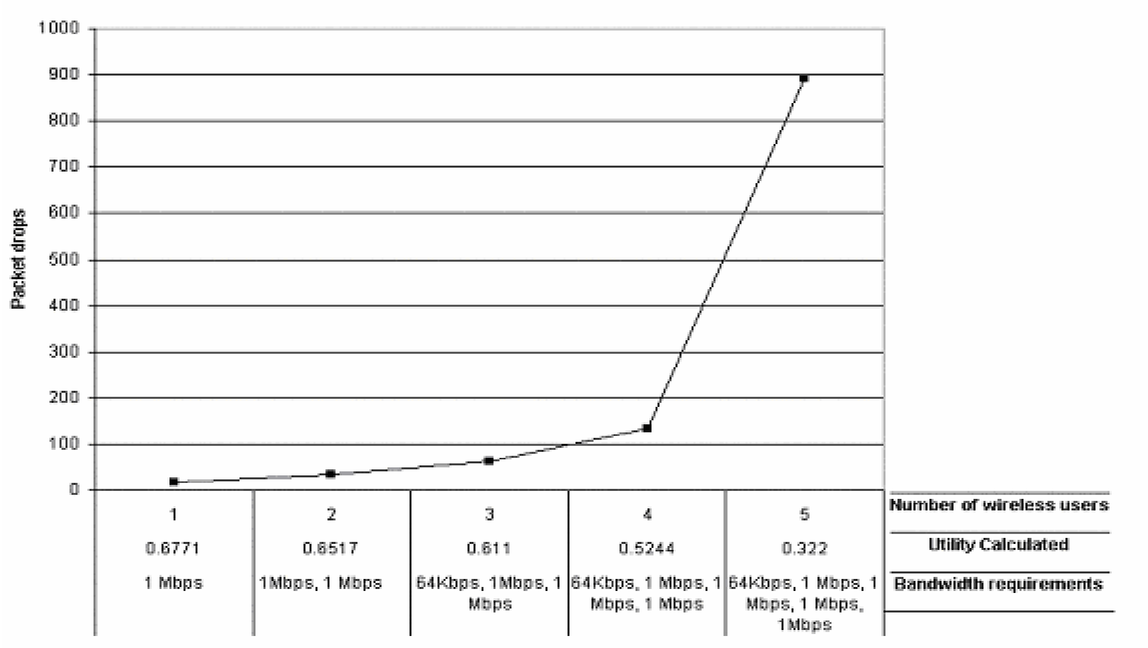


Figure 6.4 Image File Drop Pattern

6.2.2 Mobility Experiments

We see variation in utility with mobile users communicating with a particular base station. Taking the three users - Node_(0), Node_(1) and Node_(2) case, we now attach a mobility pattern script to the original tcl script. The mobility pattern script sets the starting and destination coordinates for all the mobile nodes at the end of specified durations. Also the per hop behavior for packets between nodes now change that result in utility fluctuations due to varying packet losses. We now transmit the same file pattern from Node_(0) with 593 UDP packet transmissions. The same transmission is repeated in each transmission cycle. Each transmission cycle depicts the same number of packets transmitted from Node_(0) to BS(0). As per the mobility pattern script the distance between the nodes is also varying. This experiment is conducted by repeating transmission periodically and looking at the statistics. As shown in Table 6.2, we have set of 4 transmission cycles, at different time intervals where the coordinate positions of each node connected to BS(0) at that time are different as compared to the previous interval. We see that packet losses are affected by the distance of collaborating user to the base station and also the inter-distance between the other users.

Table 6.2 Variation in Utility with Packet Loss

Transmission cycle	UDP Packets sent	UDP Packets Lost	Utility
1	593	67	0.669
2	593	88	0.632
3	593	110	0.575
4	593	97	0.591

In the mobility script the original positions are kept the same. Hence for the first transmission cycle we see nearly the same statistics. However, the distance between the nodes and between BaseStationNode decreases, as the mobile nodes move towards each other and closer to the BaseStation. Hence till transmission count 3 we see the packet losses increase correspondingly, after which the nodes start to move away. The next section describes how adaptation or modality transformation algorithm increases the utility performance for a particular data transfer scenario.

6.2.3 Experimental verification of Adaptation Framework Implementation on NS-2

In this set of experiments, we start transmission of a multimedia object from a wired client, which is forwarded to wireless users who are members of the collaboration. As in the prior experiments, it is assumed that all the wireless users are connecting to the same base station. The QoSManager agent performs data adaptability by controlling data rate and transformation based on user profiles. Simulation setup – MPEG tracer files are provided as miscellaneous additions in NS-2, provides a trace of typical video file as series of images. Adding it to the TCL script gives a set of image file sizes. Simulation script includes mobility pattern for the wireless nodes in action. From the tracer file it reads the time for a transfer trigger and also the number of transmission bits and initiates transfer. For the first transfer, if the packet loss is more than acceptable by the application, then profile management functions of QoS Manager come into play, which selects the most preferred data type based on the modality transformation algorithm. Table 6.3 lists the preference order for Node_(0) based on the node (device) capability and user preference weight in Table 6.1.

Table 6.3 Preference Order with Data Rates

Preference Order			
1	Image	Fine Image	Data rate – 1.25 Mbps
2	Image	Base Image	Data rate – .75 Mbps
3	Text file	.txt	Data Rate – 50 Kbps
4	Voice	.wav	Data Rate – 64 Kbps

Figures 6.5 show that for the series of transmission cycles, varying packet losses suffered at the receiver by the transmission node. The packet drop ratio should be greater than 1% of the total packets sent, to trigger profile alteration. In Figure 6.5 the utility and packet loss plots show how the adaptation of application QoS based on modality transformation algorithm, in accordance with the preference of the user prevented excess loss of packets in deteriorating network condition.

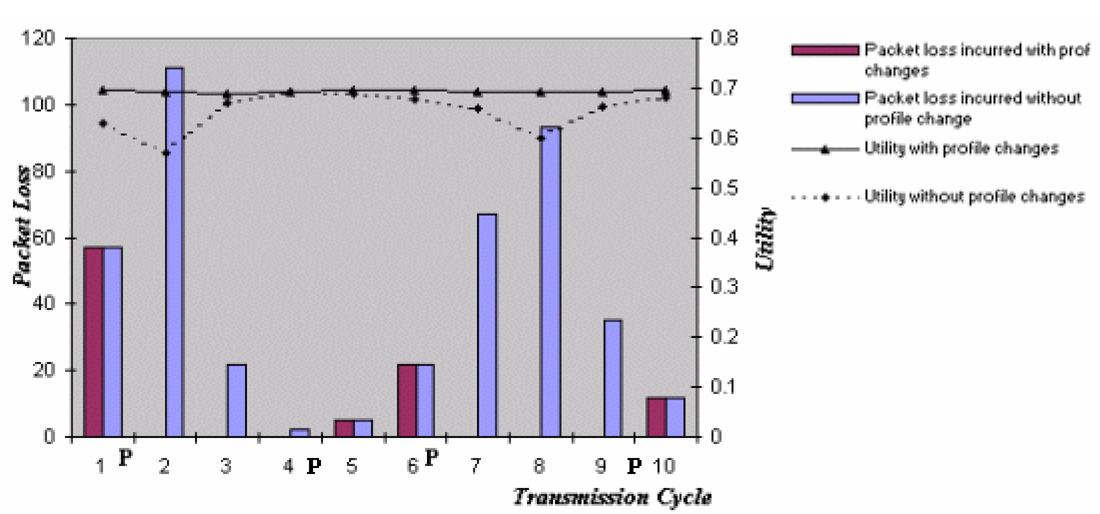
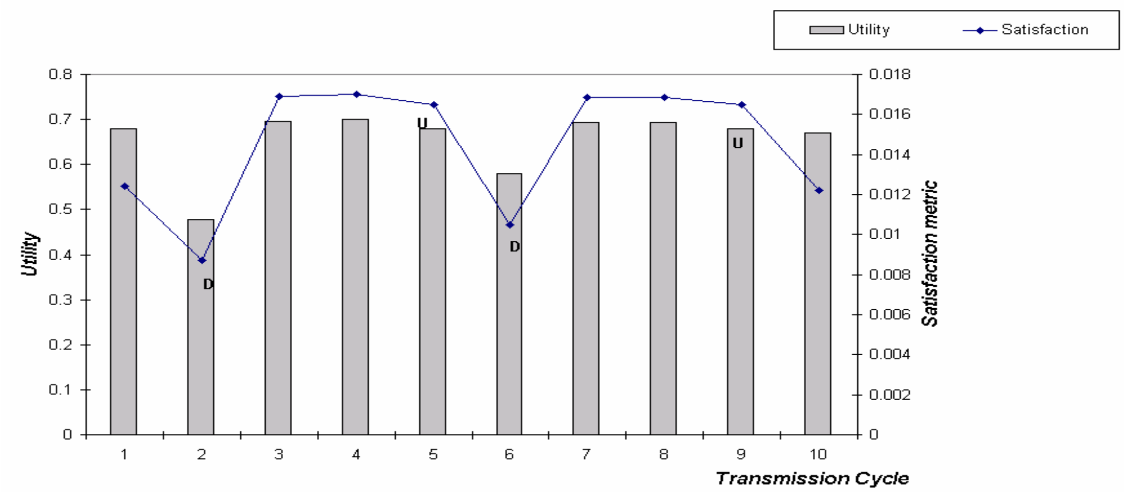


Figure 6.5 Utility Profile with QoS Manager

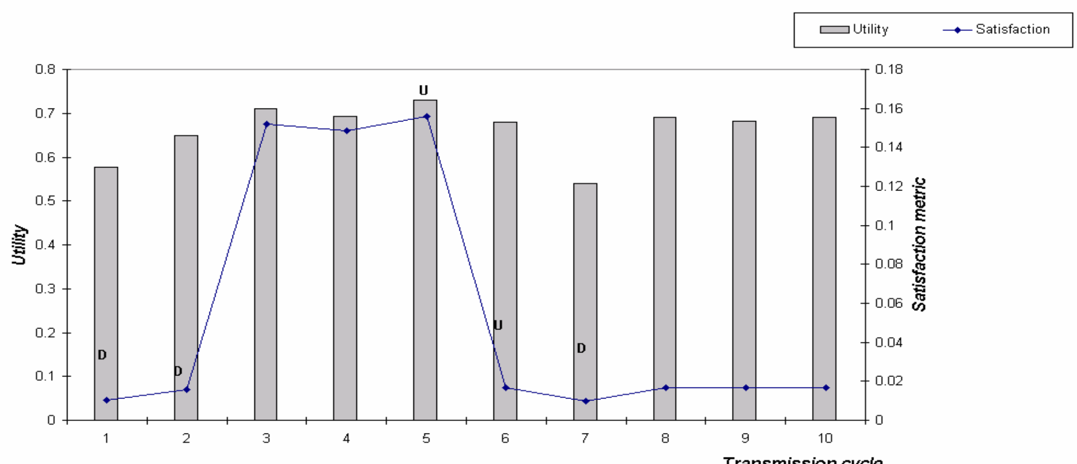
The profile change correspond to the packet loss incurred that are more than the QoS constraints for video and is denoted in the graphs by the pointer P. At the first point of profile alteration, comparing with the non-adapted simulation we see that adapting the data profile to the network, prevented useless energy consumption, in transmitting packets at high packet loss conditions. Low duration of transmission for a single bit, which is the case with high bit rates, involves higher energy required per bit. So overall energy for total image bits is also reduced by a factor of 90. Another factor to be noted is the varying BER constraints for the video, audio and text data. Text data tolerate a higher BER which means a lower transmit power can be set for the wireless hardware system.

However since there is no transmission at higher rate, it is difficult to assess when the service can be upgraded to a higher rate. We here use a TCP-like recovery mechanism and increase the data rate after three successful transmissions at the current data rate. If the packet loss remains high, data rate is further reduced to a lower rate. This mechanism is depicted in Figure 6.5, where after 3 successful, i.e. low packet-drop transmissions, profile is upgraded after transmission cycle 4. This results in a successful transmission of finer image, but with high packet drops again in transmission cycle 6, it again results in profile updating.

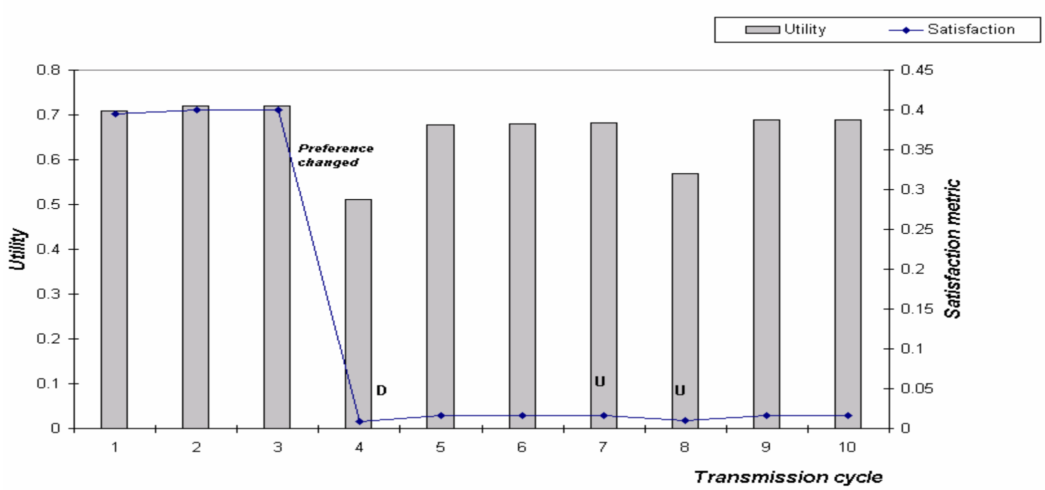
Figure 6.6 illustrates performance in multi-user setup - User 1, 2 and 3 are collaborating users. In these experiments we study the utilities achieved in 10 transmissions for all three users and see the QoS management algorithm help in stabilizing the utilities to a higher value. The transmissions are asynchronous to one another. The three sets of graphs in Figure 6.6 show the utility and satisfaction measure obtained by User 1, User 2 and User 3. User 1 preference order is fine image – base image – voice - text . The maximum satisfaction factor is .017 and it is limited by the high data rate required by application for image data. Pointers 'U' indicate - upgraded profile; pointer 'D' indicate – Degraded profile. Preference change by user is also indicated in the graphs. User 2 follows the same preference as User 1. User 2 sees two consecutive degradations down the preference order. But the collaboration satisfaction is higher due to the high utility maintained and the low data rate. User 3, initiated with text-voice only preference, changes its preference to image data after initial transmission. Hence we see that degradations in service do not indicate reduction in satisfaction value. The degradations in service are performed to maintain effective collaboration and maintain high utility. The satisfaction measure is higher with low data rate. The experiments show that utility is maintained. Also the satisfaction measure of collaboration is in corroboration with the theory that more number of users can achieve effective collaboration with a lower data rate. Packet loss reduction and also possible lower transmission power compensate it.



Utility - Satisfaction For User 1



Utility-Satisfaction for User 2



Utility- Satisfaction for User 3

Figure 6.6 AQM performance in Multiuser Scenario

Chapter 7

Conclusion and Future Work

7.1 Summary and Conclusion

This thesis aims to provide effective adaptation framework for collaborative multimedia data over wired and wireless networks. The main focus is for the wireless networks where the approach is to smooth out degradations in service by realizing the system state by prior performance. It also performs a recovery mechanism, and upgrades when three consecutive transfers in current user data profile are according to the QoS constraints of the application. The data profile is generated based on user preference to data types and an adaptation policy is generated according to the capability of the QoS manager. For the collaboration session over wired-cum-wireless networks, the QoS manager for the wireless extension in the framework resides at the access point to the wireless network or the gateway. The QoS manager maintains profiles and policy for every wireless user collaborating in a session and adapts data as required according to the current profile of each user. Packet drop ratio for a particular transmission is used to estimate channel condition and Utility-Satisfaction metric to measure overall performance of collaboration.

An evaluation of adaptive mechanism showed maintaining utility and stabilizing the overall satisfaction level of collaboration. It is seen that, even though service level was degraded due to poor channel conditions and resultant high packet losses, low data rates and successful transmissions at reduced energy expended and enhanced effectiveness and satisfaction of the collaboration.

7.2 Contributions

The main contributions of this thesis are:

- Presenting an adaptive QoS management solution for wireless users communicating with wired users in a collaborative session, with session and QoS management functionalities performed at the gateway access point to the wireless users.
- Describing Utility metric for performance measure and Satisfaction metric for collaboration success measure. The two metrics highlight the behavior of the adaptation framework to the policy-based adaptations of data shared in a session.

7.3 Future Work

Making the adaptation framework and the associated metrics as the main blocks, future work can involve integrating this framework with other features. Examples include associating with call admission and other radio resource management techniques so that member already in session does not experience sudden degradation due to a new user being admitted. Keeping collaboration in view, introduce a flexibility factor, so that a higher flexibility would mean more users joining collaboration. Also processing and adapting data for multiple users can involve high processing loads at the access point. The adaptation mechanism can move into a single data type mode for all wireless users under a particular gateway, during heavy load conditions for the gateway. Analyzing effect of sharing performance behavior of one wireless user with other wireless users and also describing the area where this information can be considered useful. That means users that are closer in distance can share the channel information between themselves. To analyze if this indeed improves performance of collaboration. Venturing into complete end-to-end collaboration QoS management. Incorporating Bandwidth broker management for the wired collaborators.

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