CHAPTER 4: END-TO-END QUALITY OF SERVICE ARCHITECTURE

The technological growth is supplemented by new user viewpoints. A novel set of applications like VoIP, video on demand, video conferencing and virtual assistance using wireless devices are considered by their highly dynamic nature and their major use for real-time applications and information transfer. These applications are highly time-varying in nature and enormously different. Their service levels change with respect to the key parameters like bandwidth, latency and jitter. The ultimate requirement of the end-user is a guaranteed service for the above said applications. There are various mechanisms to provide the QoS control and guarantees to fulfill the needs of end users [3][48]. The QoS for real-time services such as the streaming video and streaming audios in particular are predictable, configurable and sustainable on end-to-end basis. The end-to-end system considered for QoS control and management as in figure 4.1, includes the number of entities from source to destination such as devices, operating systems in the devices, communication protocols used, transport system and Internetwork.

To fulfill the end-to-end QoS needs, there are different end-to-end QoS schemes and management techniques. These include source-to-destination resource reservation.
and admission control followed by buffer management [16] and process scheduling in the end systems, flow control and packet scheduling in the wireless channel and a dynamic QoS evaluation and maintenance mechanisms.

4.1. EVOLUTION OF QoS FRAMEWORKS

Before 1990’s, the quality of service in communication was not considered seriously by the network service providers. Even though the QoS parameters for different communication standards are issued by the standard agencies such as International Telecommunication Union – Telecommunication Standardization (ITU-TS) and ISO-OSI, the quality of service parameters are not completely reinforced by the network and cellular service providers. In the meantime, the standards agencies of Internet and the Internet service providers adopted the parameters of qualitative QoS to the Internet Protocol (IP) based services such as higher bandwidth, delay, and reliability. These parameters are provided as a part of the service field in the IP header. But still they are not completely accepted and adopted by the basic networks.

The basic architecture of the Internet is considered to provide the BE service and not to support the qualitative QoS requirements imposed by the real-time applications. The reasons for the poor responses are the service delivery architectures are static in nature. That is, in open source interconnection model, the quality of service parameter continued to be constant for the entire service period. The sender and the receiver initially agreed for the QoS parameters cannot re-negotiate for the changing network conditions. It cannot dynamically adjust either disconnecting or re-establishing the connection due to the availability of limited resources.
4.2. NEW QoS INITIATIVES

The Integrated service group of Internet Engineering Task Force (IETF) has proposed the QoS guarantee for streaming applications and a viable QoS framework based on the functionality of the network components like, routers, network elements and operating systems. Every component in the internetwork has to have the required quality of service-responsive and ought to provide the required interfaces by the QoS description. The integration of these components in the entire data path used by the service provides an overall definition of end-to-end QoS. A new set of defined service provides a wide range of new services for the current applications.

The ATM standard and ATM forum, a group of users of telecommunication service providers and vendors, have proposed a provisional ATM standard. It has cleared certain limitations in the previously proposed ITU-TS standard. ISO has proposed two new frameworks. These are;

i. **ISO SC21 QoS Work Group:** - Its contribution is in the field of QoS support for ISO-OSI communication.

ii. **Enhanced Communication Functions and Facilities (ECFF):** - This framework was proposed by the ISO SC6 ECFF working group for addressing the improved communication functionalities and services for the lower layers of OSI reference model.

The main limitations of these contributions and the QoS frameworks are; they are in the context of the individual architectural layers of those specific communication models [59]. There was less contribution towards addressing the end-to-end QoS needs. Some of the proposed enhancements are in terms of queue management, flow control and synchronization, resource reservation as well as admission control. There
are many new frameworks based on the requirements of the service providers to address the required quality of services. But still they fail to provide the guaranteed service quality for a specific application. The important features of the recent state of QoS research can be summarized as below:

i. **Incompleteness in Service**: - The present service interfaces are usually not QoS configurable and deliver only a part of the services required for the real-time applications.

ii. **Absence of the Techniques to Provide QoS guarantee**: - Fresh developments are required in the related QoS in distributed control, monitoring, evaluation and updating the QoS techniques based on end-user requirements.

iii. **Lack of Continuity**: - The existing frameworks about quality of service are mainly network centric and don’t address the suitability of network QoS semantics to meet the real-time applications.

iv. **Lack of Overall Framework**: - A well-intended architectural framework is essential to improve the existing idea of QoS for different network architectures and systems.

4.3. **QoS ARCHITECTURE OVERVIEW**

By considering the issues discussed in the earlier unit, related to the QoS necessities in specific to the applications, an end-to-end QoS architecture is proposed. It covers both end-systems and the wireless network. The primary objective of QoS architecture is to guarantee QoS for a wide range of applications. This architecture promotes a system approach to end-to-end management. Due to the augmented complexity of quality of service delivery needed by the multimedia and real-time applications [48], it becomes obvious that the required extension to
ensure the quality of service delivery cannot be carried out in a fragmented fashion. Instead a complete quality of service architecture is being encouraged whereby the application requirements can be mapped through all the levels of the system.

4.3.1. QoS Mechanisms

The QoS mechanisms are derived based on the quality of service requirement of the end-users. These are;

- **QoS Specification** - Flow synchronization and flow performance such as; guaranteed throughput, delay, and jitter and data loss.

- **Resource Availability and Resource Management**: - It is classified as static or dynamic resource management. Its main functionality is the formation of traffic flow and end-to-end quality of service re-negotiation (considered as a quality of service condition). Among this, the dynamic resource management [49] mainly deals with the quality of service control mechanisms. The basic difference between them is due to the differences in time state on which they operate and is of direct significance to the asynchronous resource management principle.

4.3.2. QoS Conditions

The principal QoS conditions include three constituents; quality of service mapping, admission testing and resource reservation [49].

**QoS Mapping**: – It is a mechanism to map the QoS requirements in different components or levels of the systems, such as operating systems used, transport layer mechanisms and network layer parameters. This provides the information
about the QoS specification like bandwidth requirements, transmission delay and jitter and data loss.

**Admission Testing:** It is to evaluate the available resource and the request for the resource requirement. This helps to decide whether the new requests from the contending STAs are to be considered or not and also to manage the available resources to provide the services. If a particular service is considered in a QoS module, using admission testing, the available resources are reserved and then allocated, if the test is successful.

**Resource Reservation:** The resource reservation protocol allocates the required resources for the end-system, according to the users QoS specification and requirements. To deliver the resources needed the QoS system selects appropriate QoS mechanism such as admission control, scheduling and queuing [19][49].

### 4.3.3. QoS Control Mechanisms

The quality of service control mechanism provides real-time traffic control of streaming applications according to the demanded quality of service, which is established during the quality of service setup. This is attained by adopting suitable quality of service control mechanisms, traffic scheduling, buffer management, and communication protocol operations. The quality of service control mechanism includes flow scheduling, flow control and flow synchronization. The flow scheduling manages the controlled flow of frames according to the end-systems requirements and the channel bandwidth. The flows are being scheduled based on the priority levels of the frames and the available channel capacity and is not based on the QoS assured and the scheduling scheme adapted. The flow control uses both open loop and closed loop control
mechanisms. In open loop system, the sender lets packets into the channel at the decided levels and the availability of the resource, whereas in closed loop flow control, the flow rate is controlled according to the feedback control systems. The closed loop flow control system can adapt to any variation in the existing QoS.

The applications with time-varying characteristics such as streaming video and audio are expected to be adaptive and can function in such systems. Applications that cannot adapt to these changes are best suited for open loop scheme. The QoS parameters can be deterministically ensured and achieved ignoring separation from other contending stations for the particular transmission period. The flow synchronization is very much mandatory to control the event ordering and exact timing of real-time services. Flow synchronization in dynamic quality of service management can be achieved with the rigidity of synchronization between flows.

4.3.4. QoS Management

The quality of service management ensures that the agreed QoS between the end-to-end systems is maintained. QoS management scheme includes;

- **QoS Monitoring**: - It agrees with each level of QoS mechanism to monitor the existing QoS level attained by the lower layer. This is achieved by the help of feedback mechanism with a monitoring algorithm. These algorithms also functions as a scheduler to control the flow and to maintain the contracted QoS.

- **QoS Maintenance Scheme**: - It matches the observed QoS against the estimated performance and then employs modification of resource modules to tolerate the provided QoS.
• **QoS Degradation**: - It provides the existing status to the user when the QoS system fails to provide the contracted QoS. In response to this, the user can re-negotiate the accessible class of service or update the service class.

• **QoS Signaling**: - This lets the user to state the interval over which the quality of service values like bandwidth, delay and jitter, and data loss can be observed and the user is updated with the provided performance in the form of QoS signals. The signaling depends on the users requested quality of service management policy. It can provide single and multiple QoS signals. The performance metrics obtained like this are useful to the adaptive applications, which operate using the best effort network services.

• **QoS Scaling**: - It comprises of QoS filtering and QoS adaptation mechanism. The streaming and real-time applications mainly indicate sturdiness in adjusting to the variation in end-to-end QoS. The QoS adaptation mechanism in the system performs the corrective measures to either adapt to the accessible resources or scale to lower level of the service. This is mainly based on the quality of service management strategy defined by the users.

The QoS filtering mechanism helps to minimize the constraints due to requirements of heterogeneous QoSs, when individual receiver receives different types of flows such as audio and video. The QoS filtering mechanism helps in simultaneously meeting the QoS requirements of individual receivers.

**4.4. QoS ARCHITECTURE**

In the previous section, some initiatives taken by the different organization to improve the QoS of IEEE 802.11 networks have been illustrated. They focused on the data link and the physical layer of the wireless network. These approaches include the mechanisms for managing the resources for accessing the channel and
the QSTA that asks to transmit the frame with the required quality of service. These mechanisms provide services to the nodes if the signals are of constant bit rate (CBR) and best-effort (BE) service. For an accurate network management, the status of the medium is continuously monitored, in order to find the current amount of available resources, number of wireless terminals contending to access the channel and assigning these resources to meet the requirements of these nodes. However if new station with new traffic streams and strict quality of service expectation arrives at the network, it jeopardizes the level of provided service. To accommodate this station, increasing the available amount of resource is necessary. These changes in the number of stations and the mandate to deliver the required QoS by managing the existing resources clearly vouch the usefulness of a suitable architecture [49].

The wireless network involves time varying characteristics compared to the wired networks and are affected by the fast changes in SINR due to the channel impairment phenomenon like signal attenuation, path loss, multipath fading, shadowing, and interference. Also the real-time applications with stringent throughput requirements needs QoS guarantee for CBR and VBR traffic streams. Thus providing the required quality of service is complex process and needs an adaptation of the upgraded techniques along with efficient scheduling and resource management systems. This requirement can be fulfilled by using an adaptive quality of service system with a relative quality of service technique. The relative QoS differentiation can be based on the priority of the traffic streams [53].

There has been a lot of work addressing the quality of service guarantee at each layer such as network layer, operating systems or middleware. Towards that,
multiple end-to-end QoS solutions have also been proposed. There are a few limitations on the QoS architecture as illustrated below.

1. **Lack of cross layer interactions:** - Most of the quality of service techniques relies on individual quality of service mechanism at single layer like the MAC layer. The lack of cross layer interaction usually leads to incompatibilities and inconsistencies.

2. **Lack of end-to-end integration:** - The QoS requires an end-to-end integration. To meet these, the service quality mechanism has to consider all the components in the entire path.

3. **Lack of re-configurability:** - The individual components or the modules of the existing quality of service architectures are tightly coupled. Adding and removal of these modules or substituting new modules are difficult due to such tight coupling.

In this section, a novel architecture to support the QoS guarantee for real-time applications is proposed. The proposed scheme is expected to deliver a better QoS for real-time services and VBR flow. We show that this architecture is appropriate and can be used by applications demanding guaranteed quality of service, which in turn provides an end-to-end QoS guarantee by managing the available resources and allocating them to the end users. The new architecture proposed to deliver comprehensive QoS requirements of real-time data flow. By considering the above limitations, we have proposed an end-to-end QoS architecture that deviates from the currently proposed QoS techniques and architectures for IEEE 802.11 WLAN. The end-to-end QoS architecture consists of software based reconfigurable quality of service modules corresponding to the different layers, such as application layer, middleware layer, MAC layer, and network layer. The
architecture provides high degree of re-configurability, which supports a wide range of quality of service guarantees ranging from weak quality of service guarantee such as network service differentiation to strong quality of service guarantee such as very fine grained delay sensitive guarantee. The end-to-end integration is achieved by having coordination across different layers and access to end-to-end components such as network components and operating system components. The architecture has strong modularity, which means quality of service components in the architecture can be added, removed or substituted to fulfill various QoS needs. The main components of the proposed end-to-end QoS architecture are; a controller, admission controller, packet scheduler, traffic analyzer, network monitor and packet classifier. The quality of service controller acts as a middleware between the real-time applications. From which it accepts the different QoS needs and the details of the network layers. It translates these requirements in to the specific parameters of each involved medium access protocol.

4.4.1. The End-to-End QoS Architecture

The proposed architecture in figure 4.2 is layered and can be mapped to the OSI model. It is also separated into two planes; control plane and data plane. Control plane comprises of number of a quality of service control strategies that provide the data plane for allocating buffer to the packets, processing and then forwarding. The QoS control scheme in the control plane is also responsible for providing QoS and management. It comprises of the components such as; packet scheduler, flow control, traffic analyzer, packer classifier and admission control. Quality of service management includes QoS monitoring, QoS maintenance and QoS adaptation.
The architecture comprises of the quality of service components for the different layers of the OSI model. In the data plane, the network monitor component essentially keeps track of the wireless channel condition such as perceived bandwidth. The packet scheduler works in the network layer. This schedules the packets from applications according to their quality of service requirements. At the application layer we have packet classifier, which classifies the packets based on the priority class to which it belongs and also the quality of service applications, so that the network scheduler can have appropriate scheduling. The controller acts as the heart of this architecture and also ensures that all quality of service components work together at the QSTA and QAP. The following subsections provide component-wise details of the proposed architecture.

4.4.1.1. Network Monitor

It is a part of the data plane and the main function is ensuring and management of quality of service especially in the context of wireless channel. The wireless medium is shared and open to access the signal. Thus in a wireless network, each
node may perceive very different network conditions depending on its location, the load and the number of stations connected. To accomplish the essential QoS needs, a network monitoring technique is very vital to provide information on the availability of network resources. Depending on the requirements of quality of service metrics, network monitor can collect information on bandwidth or delay of the wireless networks. It monitors the bandwidth related details in the MAC layer of the wireless system. This will assist the bandwidth reservation in case of IEEE 802.11 WLAN. It computes the bandwidth requirement for each traffic flow at a particular time. The resultant bandwidth is equal to the difference between the actual data rate of the network and the data rate lost due to interference. The network monitor constantly compute the total observed bandwidth for each traffic flow. The perceived network capacity is calculated as the size of the packet (in bits) divided by the time difference between the receiving times of two consecutive packets at one node. The network monitor has been used mostly for service differentiation as in [28][20]. It is also useful in resource reservation process.

4.4.1.2. Packet Scheduler

The packet scheduler is to ensure that the packets in the queue have to meet the required QoS. These schedulers considered here will have two roles such as, intra-node scheduling and inter-node scheduling. The former one refers to the scheduling of traffic within a local node, while the later one is the scheduler responsible for the MAC. If the network system has a quality of service (QoS)-aware MAC mechanisms like 802.11e or 802.11 WLAN with quality of service enhancements, the inter-node scheduling can be easily by-passed. However in the proposed architecture, we had considered 802.11e MAC. The packets are
scheduled based on their priority values and the types of the applications such as, streaming video and audio along with the support of MAC layer of IEEE 802.11e. There are different proposals for quality of service based transmission delay, bandwidth required and bandwidth management processes.

4.4.1.3. Packet Classifier

The function of the packet classifier is to classify the packets arriving from the different applications based on their access categories. It resides in the data plane. The packet classifier supports the function of the packet scheduler. A packet classifier is always coupled with a controller in the control plane, specifically for the resource reservation and service differentiation approaches. It classifies the packets of the applications so that the packet scheduler and admission control unit can obtain associated quality of service information such as deadline. The controller calculates and assigns the quality of service information to the packets. For service differentiation, the packet classifier updates the current priority value of the corresponding applications assigned by the controller. The priority value is dynamically calculated and assigned according to its current quality of service level.

4.4.1.4. Traffic Analyzer

The traffic analyzer permits the QAP to analyze the state of the medium before forwarding the packets. If it perceives that the medium is busy, then the packet has to wait in a queue of the packet scheduler and its flow state is created accordingly. The channel state information is obtained by means of RTS/CTS technique. The operation of the traffic analysis is as follows:
Before the short packet transmission to the wireless channel, an RTS signal is transmitted to the intended receiver. The receiving wireless station replies to this by sending a CTS packet. If QAP receive these packets intact, then the condition of the wireless medium is considered to be good. Correspondingly if it reaches after the time out period, then the wireless medium is considered to be bad. This is because the RTS/CTS packets could have been corrupted or lost, due to the channel impairment. In DCF, the RTS/CTS signals are used to solve the hidden terminal problems. Otherwise it can result a large number of collisions in the wireless medium, which is heavily loaded. The DCF will execute a back-off procedure before transmitting the packet again. Also the AP operating by DCF mode is able to cover the wireless medium before any neighboring stations access the medium in the coverage area. Therefore during this operation it does not require RTS/CTS to avoid the packet collision. In the quality of service architecture proposed, the traffic analysis functions in PCF mode. It checks the state of the wireless medium using RTS/CTS. It is applicable both for uplink and downlink process. The traffic analyzer evaluates the channel state to avoid unwarranted multiple retransmissions of the packets to a receivers. This results in the enhanced channel throughput. The analyzer does not have any suitable compensation technique for the receiver stations that have differed data delivery in the past due to bad condition of the wireless channel.

4.4.1.5. Admission Controller

In order to deliver the QoS in WLAN, it must have some form of admission control. It is a method by which QoS architecture can decide which packets to admit or reject and to make predictions about the future state of the network. The EDCA of IEEE 802.11e will restrict the quantity of data frames considered to a
particular service category, so that the quality of service of the present flow could be assured. However the admission control mechanism in EDCA still cannot guarantee the bandwidth for the real-time traffic. The admission control module of the proposed QoS architecture is implemented in the QAP. It will guarantee the QoS, based on prioritized channel access and service differentiation.

If a traffic stream requires admission control for an access category [19], the QoS station will send a request in the form of an ADDTS to the QAP. This request includes the QoS requirement parameters associated with the traffic and the QoS access policy. The quality of service access point associates the received parameters of the ADDTS request frame, with the suitable access category as per the user priority-to-access category mapping. The QoS parameters in ADDTS are added in the form of traffic specification (TSPEC). It includes the average bandwidth required, minimal MSDU size, and delay bound of the traffic stream. This defines the QoS expectation of the traffic. Once the QAP receive the ADDTS request frame from the QSTA, it evaluates the request to decide whether it can accept or disallowed. If the request is accepted, it then computes the time duration for the requested traffic stream to access the channel. The admission control mechanism avoids huge traffic contending to access the medium [49]. This helps in providing the bandwidth required for the existing real-time traffic.

4.5. QoS ARCHITECTURE EVALUATION

The evaluation of the developed QoS architecture is discussed in this section. It is simulated using NS-2 simulator. The wireless stations are loaded with different traffic categories, each having a specific bandwidth requirements such as, VoIP with 64Kbps CBR, Video with 128Kbps CBR, and Data (FTP) applications (best-effort modelled) for simplicity with CBR of 64Kbps. For experiment, a periodic
packet reading and sending of VoIP, video, and data are assumed at an interval of 20ms, 10ms and 12.5ms respectively. The upstream channel bandwidth for the wireless station was 2Mbps; the coverage area of the AP is 40meters. The simulation evaluates the mean up-link traffic delay; which is the time elapsed between the arrivals of the data packets from the wireless STAs and when it is received by the AP. To get a better result, each wireless station is loaded equally and may have more number of real-time applications. The systems are overloaded to such an extent that, the admission control mechanism adopted provides an optimal result in the proposed Architecture. The evaluation ensures that the proposed QoS architecture can yield better performance guarantee for real-time applications than for BE applications.

4.5.1. Evaluation Metrics

The architecture is assessed by comparing IEEE 802.11 (DCF) standard, which delivers BE services and IEEE 802.11e with enhanced QoS, based on the standard scheduling for the traffic streams in the ACs [53]. The architecture is also simulated with the proposed adaptive dynamic admission control mechanism its result analysis is given in the next section. It uses prioritized traffic scheduling with resource reservation. The performance comparison is for:

1. Throughput variations for the traffic load like, VoIP, video and data. It is measured based on the number of bits received per second at the wireless stations

2. The end-to-end delay for transmitting real-time traffic from a specific wireless station to the QAP.
4.6. Performance Evaluation

We simulated a single wireless local area network with 18 active wireless stations to evaluate the throughput. The network topology used for the simulation is shown in figure 4.3, consisting of wireless stations communicating with the AP in a BSS.

4.6.1. Throughput Variation for IEEE 802.11 with BE Services

The IEEE 802.11 protocol delivers only a BE service [55]. It does not guarantee any QoS. Generally the real-time application requires a specific bandwidth and minimum delay. The wireless stations are contending to access the medium with same priority level without any service differentiation technique to ensure the throughput. Each wireless station in this case uses the IEEE802.11g physical transmission mode, and allowed to transmit three different traffic categories viz, VoIP, Video and Data to the QAP. The load on the network is increase from 10% to 95%. Load to the wireless network gets increased by adding as many as 2 to 18 numbers of wireless terminals. From the simulation result for throughput shows that, the mean throughput for the different loads such as, VoIP, video and data is...
about 7.8Kbps, 78Kbps, and 122Kbps respectively for a traffic load less than 65%. This is done by connecting 12 wireless stations. When the numbers of stations are increased and it is more than 12, the throughput decreases. Its value decreases to 35%, when the load reaches to 95% (for number of stations are 18). The throughput performance for DCF packets is as in shown in figure 4.4.

![Figure 4.4 Throughput Performances for IEEE 802.11](image)

**Figure 4.4 Throughput Performances for IEEE 802.11**

### 4.6.2. Throughput Variation for IEEE 802.11e with QoS Mechanism

The simulation result in figure 4.5 for IEEE 802.11e standard with prioritization, based on ACs to enhance the QoS is analyzed in the proposed end-to-end QoS architecture. Each wireless station delivers different types of signals such as VoIP, video and data to the QAP with which they are connected. The physical layer data rate is considered as 2Mbps and other parameters for the three types of signals are as given in the table 4.1. Every simulation lasts for 15 seconds.
Using IEEE 802.11e with EDCA significantly improves the average throughput of the WLAN, when it is loaded. The IEEE 802.11e meet the bandwidth requirements of VoIP, video and data traffic based on the access category parameters. This is because compared to IEEE 802.11; the scheduling mechanism in EDCA minimizes the number of internal collisions and minimized the packet dropping.

**Table 4.1 QSTAs and Traffic Details**

<table>
<thead>
<tr>
<th>QSTAs</th>
<th>Access Categories</th>
<th>Protocol</th>
<th>Traffic</th>
<th>Data Rate in Kbps</th>
<th>Packet Size in Bytes</th>
</tr>
</thead>
<tbody>
<tr>
<td>QSTA 1</td>
<td>AC1</td>
<td>FTP/TCP</td>
<td>Data</td>
<td>---</td>
<td>1040 bytes</td>
</tr>
<tr>
<td>QSTA 2</td>
<td>AC3</td>
<td>CBR/UDP</td>
<td>VoIP</td>
<td>36.8Kbps</td>
<td>92 bytes</td>
</tr>
<tr>
<td>QSTA 3</td>
<td>AC2</td>
<td>CBR/UDP</td>
<td>Video</td>
<td>1400Kbps</td>
<td>1464 bytes</td>
</tr>
<tr>
<td>QSTA 4</td>
<td>AC1</td>
<td>FTP/TCP</td>
<td>Data</td>
<td>---</td>
<td>1040 bytes</td>
</tr>
<tr>
<td>QSTA 5</td>
<td>AC3</td>
<td>CBR/UDP</td>
<td>VoIP</td>
<td>36.8Kbps</td>
<td>92 bytes</td>
</tr>
<tr>
<td>QSTA 6</td>
<td>AC2</td>
<td>CBR/UDP</td>
<td>Video</td>
<td>1400Kbps</td>
<td>1464 bytes</td>
</tr>
</tbody>
</table>
Figure 4.6 and 4.7 shows the end-to-end delay for VoIP, video and data signals. Here the benefit of QoS scheme adopted in IEEE 802.11e is more evident.

4.6.3. End-to-End Delay for IEEE 802.11

The best-effort service cannot deliver QoS for real-time applications because it considers the concept of first-in-first-out (FIFO) for the data delivery. When the number of wireless stations is less, the delay is less than 4 milliseconds. As the contending wireless stations are increased up to 18, delay increases correspondingly as in figure 4.6. Moreover, the mean delay is almost the same for the three different types of signals and is of 422 milliseconds. Because all these signals are accommodated in the same queue, thus the delay experienced by them is same. Without implementing suitable admission control mechanism in a wireless system, it is very difficult to obtain the required QoS for time-sensitive applications.
4.6.4. End-to-End Delay for IEEE 802.11e

The EDCA mode prioritizes the real-time traffic and schedules the traffic streams in the ACs according to their priority values. There is an improvement in the delay performance compared to the wireless networks with legacy IEEE 802.11 protocols. Using the enhanced scheduling mechanism in EDCA and without proper admission control mechanism, the system is able to deliver only about 48% of the VoIP packet with 1.5 milliseconds, 15.9% video packets with 6 milliseconds at 5% of data traffic in 1.7 seconds. This nominal result is due to the contentions by number of similar traffic streams to access the wireless channel. It results in a series of internal collisions. The average end-to-end delay increases as in figure 4.7, by increasing network load.

These results show that the proposed QoS architecture can provide better performance to deliver real-time applications.
4.7. SUMMARY

The proposed architecture includes the main components such as, network monitor, packet scheduler, packet classifier, traffic-analyzer, and admission controller. All these components work together, rather than in isolation to deliver the required QoS. The architecture is highly reconfigurable; end-to-end integrated and has strong modularity. The simulation is performed using the proposed QoS architecture on IEEE protocols viz, 802.11 and 802.11e. Simulation result indicates that, the proposed QoS architecture with the above components is the most effective technique to deliver real-time applications.