Implementation of End-to-End QoS Mapping Scheme on SCIS WiFi Network

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Abstract

For developing countries, wireless networks seem to be the available alternative for providing affordable telecommunications services. In Iraq, the main governmental wireless Internet service provider is SCIS Company. It adopts WiMAX and WiFi wireless networks. Considering Quality of Service (QoS) as an indicator of network performance, it is a challenge for the Wireless Internet Services Provider (WISP) to build an infrastructure network that can provide end-to-end QoS for applications with variety of QoS needs, such in the case of SCIS WiFi network. In this paper, the wireless network of one of the main Internet Service Providers in Iraq is adopted to be modeled and analysed. This paper presents the modeling and analysis of SCIS WiFi network by using OPNET Modeler. End-to-End QoS Mapping (E2EQM) scheme is implemented on SCIS WiFi network to improve its performance. Good performance improvements are obtained by applying E2EQM scheme to the modeled network. Comprehensive analyses and comparisons are performed in terms of evaluating criteria by using delay sensitive applications and delay insensitive applications. The simulation results show that the E2EQM scheme increased the network throughput by 5 % and decreased the delay by 44 %.

Keywords: *Quality of Service (QoS); End-to-End QoS Mapping scheme; IEEE 802.11e; DiffServ; WiFi*

1. Introduction

In many developing countries, where the penetration of mobile phones is considerably higher than that of land lines, they trend to wireless networks as a cheaper alternative. On the other hand, the increasing wireless Internet usage and the limited wireless resources require a careful network management and optimization from the Wireless Internet Service Providers (WISPs). Unfortunately, the WISPs often focus on statistics of the overall usage and have limited care about QoS requirements for delay sensitive applications.

State Company for Internet Services (SCIS) is a main governmental WISP company [1]. SCIS uses WiFi and WiMAX technologies as a last mile solution to deliver Internet services to their subscribers. Modeling and analysis of SCIS WiMAX network is presented in [2]. This paper concentrates on SCIS WiFi network. WiFi is a technology based on IEEE Wireless Local Area Network (WLAN) families [3]. SCIS Customer Premises Equipment (CPE) which consists of outdoor Access Point (AP) uses IEEE 802.11a as a WLAN standard. IEEE 802.11a PHY is based on Orthogonal Frequency Division Multiplexing (OFDM). While MAC layer is based on Distributed Coordination Function (DCF) protocol. The DCF uses CSMA/CA algorithm as channel access mechanism [4]. The IEEE 802.11 standard is designed for the 5-GHz band, where more bandwidth is available, and less interference is present. However, the IEEE 802.11a PHY achieves higher data rates (up to 54 Mbps) but its MAC does not support QoS. The legacy 802.11 MAC (DCF) does not possess any effective service differentiation capability, because it treats all the upper-layer traffic in the same fashion. In 2005, the IEEE 802.11e working group enhanced DCF by the Enhanced Distributed Channel Access (EDCA). EDCA is built on different priorities. EDCA supports up to eight priorities in a station, which are mapped into four different access categories at the MAC layer. The mapping is done by evaluating either the Differentiated Service Code point (DSCP) field, the former type of service field from the IPv4 header or the flow label in an IPv6 header [5-7].

Many researches have addressed the end-to-end QoS mechanism, architecture, and framework that ensure end-to-end QoS through interworking between the layer three QoS techniques and the air interface QoS (WLAN QoS). The first mapping scheme between Differentiated Service (DiffServ) and 802.11e is proposed by S. Park, et. al. [8]. They proposed a mapping methodology to translate the DiffServ Per Hop Behavior (PHB) to the appropriate 802.11e Access Category and to 802.1D. M. Frikha, et. al in [9], analyzed the essential basis for DiffServ in order to ensure an optimal differentiation and defined a mapping solution between DiffServ and QoS mechanisms for IEEE 802.11e wireless networks. A. Bai, et. al. in [10], investigated the rate configuration of the Expedited Forwarding (EF) class of

DiffServ when used with 802.11e Enhanced Distributed Coordinated Access (EDCA). A. A. Elmangosh, et.al. in [11], also proposed a mapping scheme from the DiffServ Per-Hob Behaviors to the 802.11e EDCA Access Categories (AC). In [12] a hybrid QoS architecture framework for interworking between IP layer QoS and air interface QoS for the next generation wireless networks is proposed. From the above mentioned works, it is concluded that the proposed end-to-end QoS architecture or framework is not implemented on WISP. This paper adopted implementation of End-to-End Quality Mapping (E2EQM) scheme on SCIS WiFi to improve its performance. Four kinds of applications are used to evaluate the impact of E2EQM scheme on the network for different applications. These applications are Voice over Internet Protocol (VoIP), video streaming, File Transfer Protocol (FTP), and Hypertext Transfer Protocol (HTTP).

The rest of paper is organized as follows: in section 2, modeling of SCIS WiFi network architecture is explained. Section 3 presents E2EQM scheme methodology and implementation of E2EQM scheme on SCIS WiFi network. In section 4, simulation results and analyses are discussed. Section 5 concludes the paper.

2. Modeling of SCIS WiFi Network

SCIS WiFi network consists of two types of network connections. These types are Point-to-Point (PtP) and Point-to-MultiPoint (PtMP). In PtP network, the end user uses the outdoor AP as a slave point, to connect with outdoor AP (master point) to get the access to Internet. While in PtMP network, the end user uses the outdoor AP to connect with BS sector to get the access to Internet. Fig. 1 depicts SCIS network architecture. SCIS WiFi network architecture consists of three logical tiers as shown in the Fig.1. These tiers are core tier, distribution tier, and user or access tier. The core tier represents the Network Operation Center (NOC). It consists of core router which is the gateway of the network. The distribution tier consists of network backbone

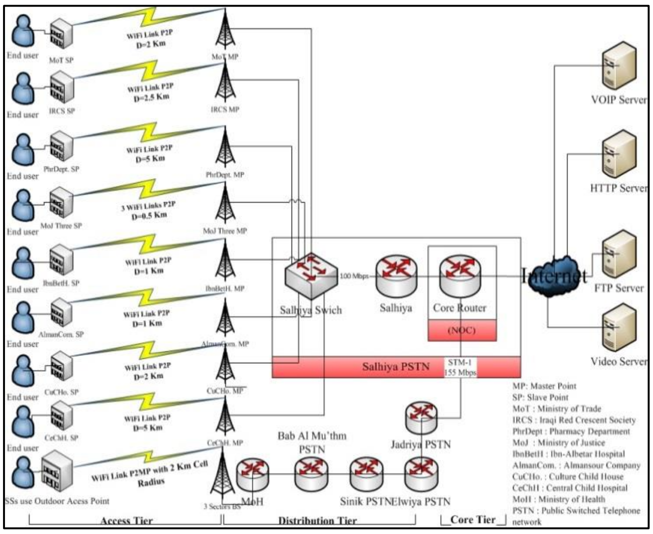

Fig. 1 SCIS WiFi Network Architecture

which is based on Dense Wavelength Division Multiplexing (DWDM) Baghdad rings with 155 Mbps (Synchronous Transport Module level 1 (STM-1)) as links capacity. Finally the access tier consists of end users.

The SCIS WiFi PtP and PtMP modeled networks are shown in Fig.2. In this figure, the locations of each site in Baghdad according to Google earth map are shown. PtMP network consists of three sectors BS with 2 Km radius that are connected to Ministry of Health (MoH) router. The sectors transmit the service to the users. Fig. 3 shows the SCIS WiFi PtMP network.

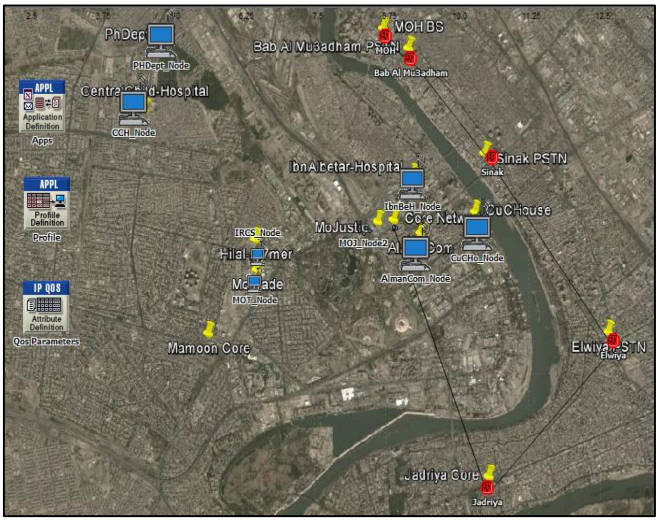

Fig. 2 SCIS WiFi PtP and PtMP modeled networks

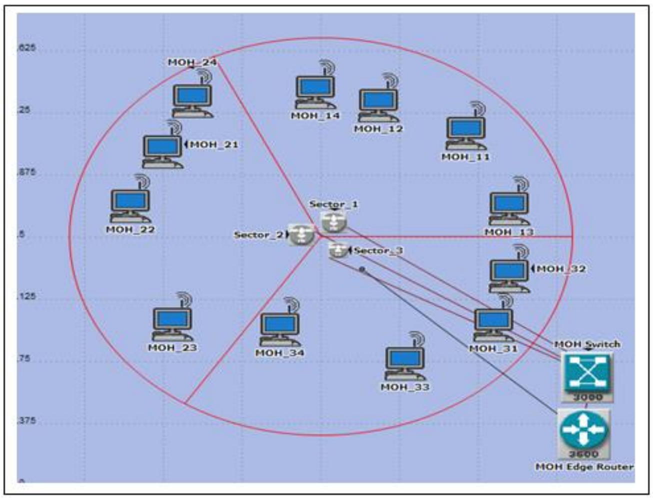

Fig. 3 SCIS WiFi PtMP model

SCIS WiFi network APs use directional antenna with 120 degree of horizontal beamwidth. Because of OPNET Modeler supports only Omni-directional antenna, some modifications have been done on nodes model to support directional antenna. Fig. 4 shows the modifications in outdoor AP either it is master point or slave point or even it is sector in case of PtMP SCIS network to create the directional antenna with 120 degree of horizontal beamwidth. The antenna gain calculation process helps APs to calculate the gain of the transmitted signal.

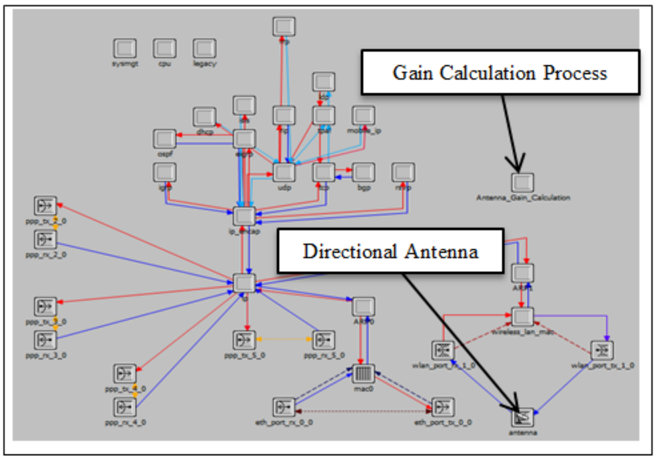

Fig. 4 Modifications in AP to create Directional Antenna

The SCIS WiFi network parameters are summarized in Table 1. Finally, it is important to notify that the backbone utilization used during the simulation is 30 % which makes the model closer to real life network.

Table 1. WiFi Model Parameters

Parameter	Value
No. of users in PtP network	10
No. of users in PtMP network	4 per sector
No. of Sector in PtMP network	3
PHY	IEEE 802.11a
ACWmax	1023
Carrier Frequency in PtP network	5170-5250 MHz
Carrier Frequency in PtMP	5270, 5290, and 5310 MHz
Channel Bandwidth	20 MHz
Modulation and Coding	64-QAM 3/4
(MP) Antenna height	20 m
(MP) Antenna Gain	14 dBi (PtMP), 23 dBi (PtP)
(SP) Antenna height	20 m
(SP) Antenna Gain	14 dBi (PtMP), 23 dBi (PtP)
Transmit Power	400

3. IMPLMENTING OF E2EQM SCHEME ON SCIS WIFI NETWORK

3.1 E2EQM scheme mechanism

For a proper QoS transfer between the DiffServ and 802.11e, an appropriate mapping scheme is required between traffic classes of DiffServ and the access categories of 802.11e. Hence, the appropriated mapping scheme for WiFi network is given in Table 2.

Table 2. Mapping Scheme for SCIS WiFi Network [8]

Traffic Class	DiffServ PHB	802.11e Access Category
VoIP	EF	AC_VO
Video Streaming	AF43	AC_VI
FTP	AF13	AC_BE
HTTP	BE	AC_BK

When implementing E2EQM scheme it works as follows: when implemented on SCIS WiFi network; when the IP packets arrive at the DiffServ engine, which is called Traffic Conditioner (TC) of APs or sector in case of PtMP, they are classified, marked into DSCP values, and shaped in accordance with the priority of the DSCP values. When DiffServ TC completes the traffic shaping, it encapsulates IP packets into 802.11e MAC frames, and forwards them to 802.11e priority queues in accordance with the Access category values [8-12]. Also it is important to mention that the mapping scheme between DiffServ traffic classes and Access categories of 802.11e in Table II can be tuned for specific application requirements by the network administrator to guarantee the QoS requirements for certain type of application. For example, the QoS requirements for VoIP application are to guarantee the maximum tolerable end-to-end packet delay and jitter which are 150 ms, and 40 ms [13] for delay and jitter respectively. While for Video streaming application, the maximum tolerable delay and jitter are 400 ms, and 50 ms [13] respectively.

3.2 Implementation of E2EQM scheme on SCIS WiFi

In order to apply E2EQM scheme on SCIS WiFi model, first the backbone network should be supported with DiffServ architecture. Fig. 5 shows how VoIP application is configured with an appropriate DSCP value according to Table 3. The other applications are configured in same manner.

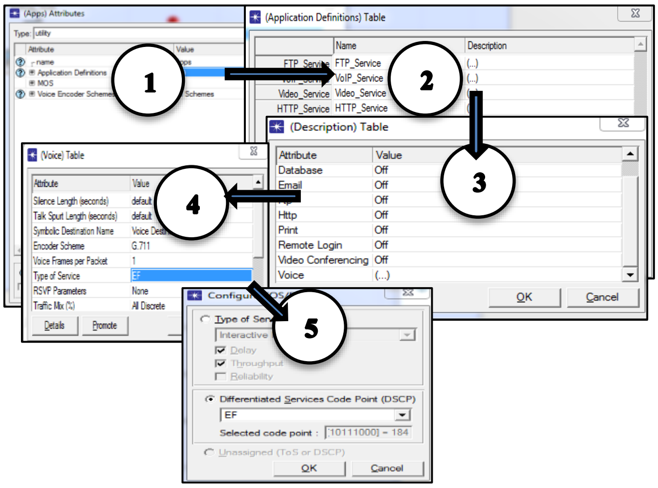

Fig. 5 Configuring VoIP with an appropriate DSCP

Secondly, the APs need to be supported with IEEE 802.11e MAC extension (EDCA) that supports QoS. Fig. 6 shows the configuration of EDCA parameters. Tables III summarize the EDCA parameters. Furthermore, the Priority Queue (PQ) scheduler mechanism is implemented to all routers in the SCIS WiFi network. Fig. 7 shows the configuration of PQ on router interfaces.

Table 3. EDCA Parameters

AC	AIFS (µs)	CWmin	CWmax	TXOP
AC_BK	79	15	1023	One MSDU
AC_BE	43	15	1023	One MSDU
AC_VI	34	7	15	3.008ms
AC_VO	34	3	7	10504ms

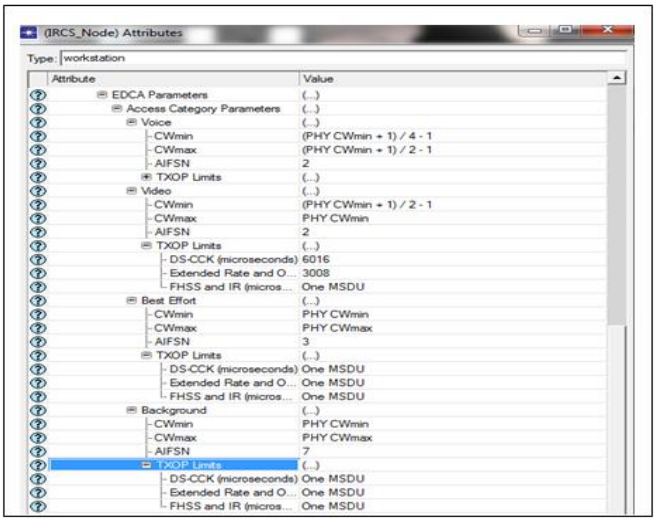

Fig. 6 Configuring EDCA Parameters

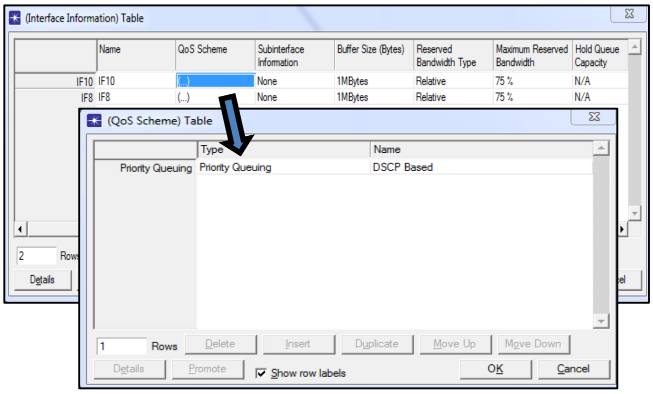

Fig. 7 Configuration of PQ for SCIS WiFi network

There are several scheduling methods are introduced by IETF but in this paper only on Priority Queuing (PQ) is used for routers in SCIS network. The reason for that is PQ outperforms other scheduling methods in term of end-to-end delay and jitter for delay sensitive applications [14].

4. SIMULATION RESULTS AND ANALYSES

In this work, various analyses and comparisons are performed on the real existing SCIS WiFi modeled network. For the real existing modeled networks, no QoS techniques are supported; neither by DiffServ architecture nor by WiFi MAC layer. The performance of modeled networks is compared with and without applying the E2EQM scheme to the network. In order to evaluate E2EQM scheme on SCIS, the essential performance metrics are used for delay sensitive and insensitive applications. The essential parameters are end-to-end delay, and jitter (Packet Delay Variation) for delay sensitive applications. While for delay insensitive applications, the download response time for FTP application and page response time for HTTP application are used. However, the throughput and the delay are used to evaluate the impact of E2EQM scheme on network performance. It is worthy to emphasize that the analyses are performed under the impact of free space propagation model.

4.1 Analyses according to applications

It is worthy to note that throughout all simulation processes the four applications are being used and all applications are working on each individual node. However, the results are investigated to each application individually.

For VoIP application, two essential QoS parameters are used to investigate the impact of E2EQM scheme when VoIP application is being used in WiFi SCIS model. These parameters are packet end-to-end delay and jitter. The improved performance of WiFi network when E2EQM scheme is being applied as shown in Fig. 8 and Fig. 9. In these figures packet end-to-end delay and jitter values, respectively, are compared for case of applying E2EQM scheme and case of not applying it. Fig. 8 shows that when E2EQM scheme is applied, packet end-to-end delay is slightly decreased by almost 1 %. While for Jitter, as shown in Fig. 9, the E2EQM scheme decreases the jitter for VoIP application by almost 90%. The reason for this improvement is when E2EQM scheme is applied, the VoIP packet will be tagged with highest priority (EF) tag when traverses in the backbone network. When the VoIP packet arrives at the intermediate node, it will wait at the highest priority queue. Then when the router has an opportunity to forward a packet, the VoIP packet will be the first to be forwarded. The VoIP packet will arrive at the AP, and it will be mapped to VO_AC queue which in turn will give the VoIP packet the highest priority to access the channel. While in the exist network, the VoIP packet will be treated as a BE traffic flow with other applications traffic flow through the backbone network, and when it arrives to AP, it will be mapped to the DCF queue with other applications packets. Consequently, jitter and end-to-end delay will increase.

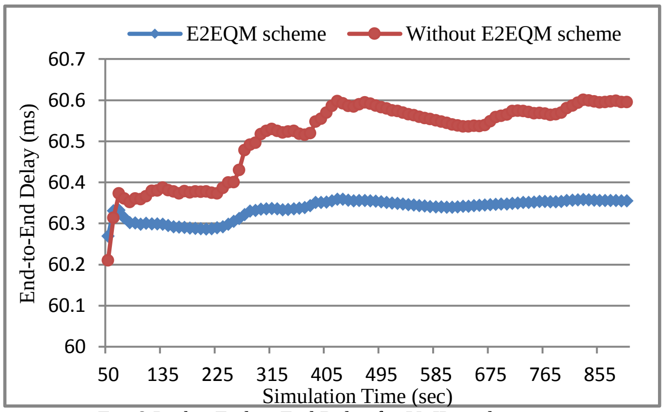

Fig. 8 Packet End-to-End Delay for VoIP application

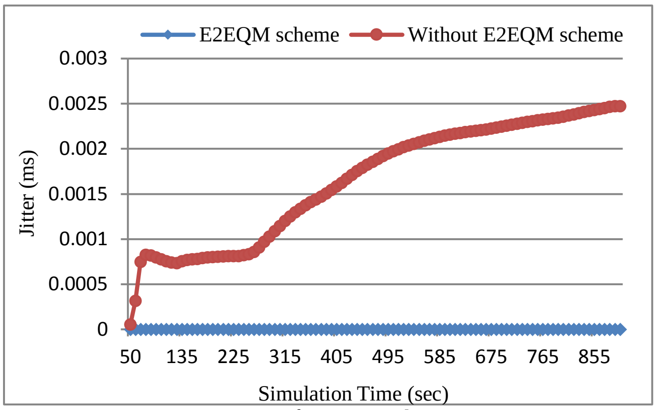

Fig. 9 Jitter for VoIP application

For Video Streaming Application, Fig. 10 and Fig. 11 show the improvement on performance obtained when applying E2EQM scheme to this case. Fig. 10 shows decreasing of 31% of packet end-to-end delay; while jitter decreasing is 89 % as shown in Fig. 11. The reason behind this improvement is that the video streaming packet is tagged with AF43 when it traverses in the backbone network. When it arrives at the AP, it will be mapped to VI_AC queue which in turn gives the video streaming packet the second highest priority to access the channel. While in exist not improved network, the VoIP traffic will be treated as a BE flow with other applications traffic flow through the backbone network. When the VoIP packet arrives to AP, it will be mapped to the DCF queue with other applications packets. Consequently, jitter and packet end-to-end delay will increase.

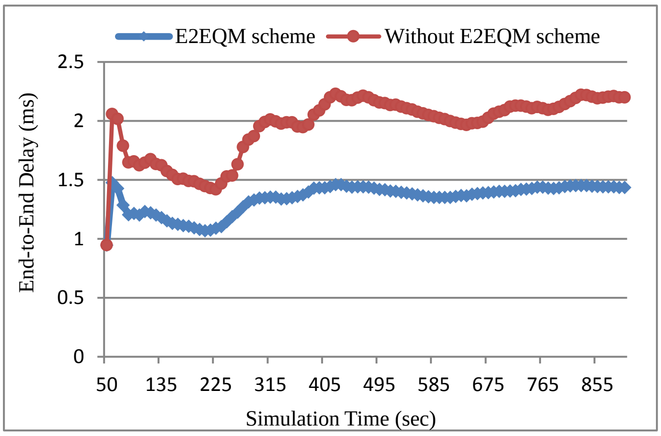

Fig. 10 Packet End-to-End Delay for video streaming

For FTP application, the download response time is used to evaluate the effect of E2EQM scheme when the network is using FTP application. Fig. 12 shows average download response time. The figure indicates when E2EQM scheme is applied, download response time is increased by 2 %. The reason for this is the tradeoff of applying E2EQM scheme. FTP packet opportunity to access the wireless channel is less than video streaming and VoIP packets. It is tagged with AF13 when traversed in the backbone network which enforces the packet to wait for a time more than that for VoIP and video streaming packets in the intermediate node. When FTP packet arrives at AP, it will be mapped to

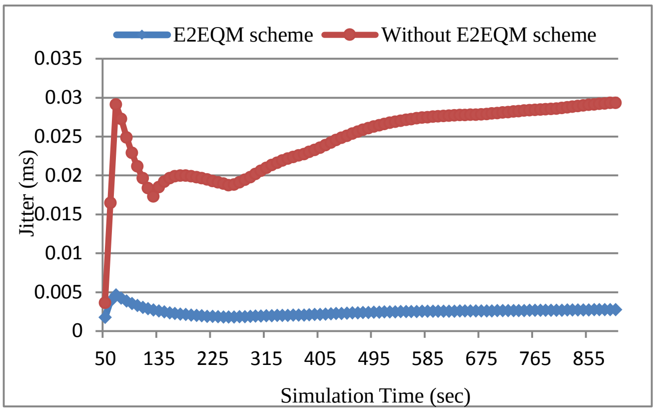

Fig. 11 Jitter for video streaming application

BE_AC queue. This gives additional delay to FTP packet. Consequently, the download response time will increase.

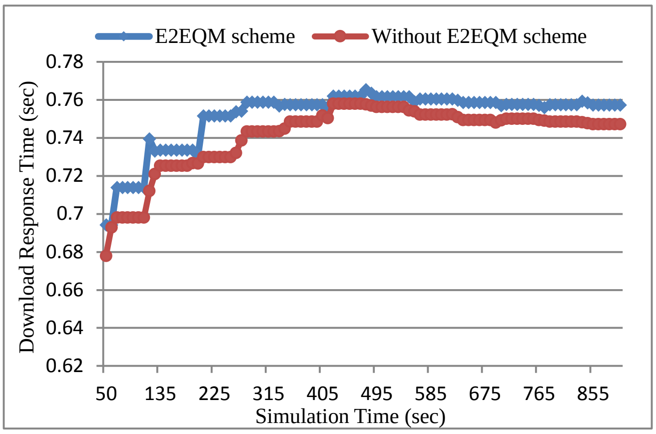

Fig. 12 Download Response Time for FTP application

For HTTP application, the page response time is used to evaluate the impact of E2EQM scheme on HTTP application. Fig.13 shows average page response time for HTTP application. The figure indicates that page response time is increased almost by 14 %. This is expected behavior because of the tradeoff of applying E2EQM scheme. The reason for this increase is the HTTP packet is tagged with BE flow when traversed in the backbone network which makes the packet to wait more than VoIP, video streaming, and FTP packets in the intermediate nodes. Furthermore, HTTP packet is mapped to BK_AC queue when it arrives at AP which is the lowest priority EDCA queue. Consequently, Page response time will increase when implementing E2EQM scheme.

4.2 Overall performance analyses

Here, the overall performance of modeled WiFi SCIS network is analysed and compared in terms of delay and throughput. For delay, Fig. 14 shows the overall delay for all WiFi nodes in SCIS WiFi network. Obviously, when the E2EQM scheme is being applied, the delay is decreased by almost 44 %.

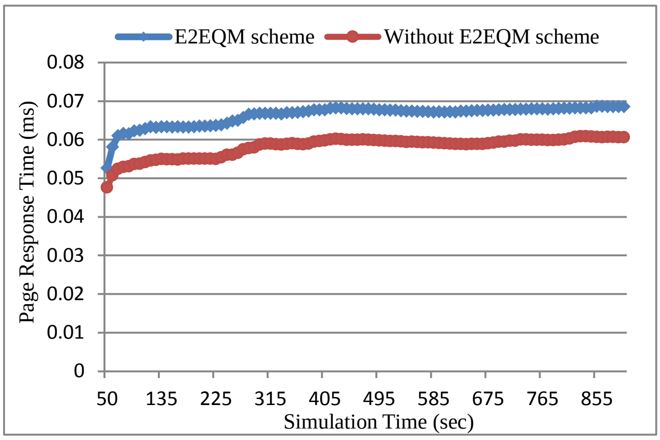

Fig. 13 Page Response Time for HTTP application

While for throughput, Fig. 15 shows the overall throughput for WiFi nodes in SCIS WiFi model. The figure indicates that when E2EQM scheme is applied, throughput is increased by almost 5 %. This improvement is significant and expected. As shown in figure 14, the overall delay in the network is decreased when applying E2EQM scheme, throughput for WiFi nodes is increased consequently. In general, the relationship between delay and throughput is inversely proportional when the product of delay-throughput in the network is fixed.

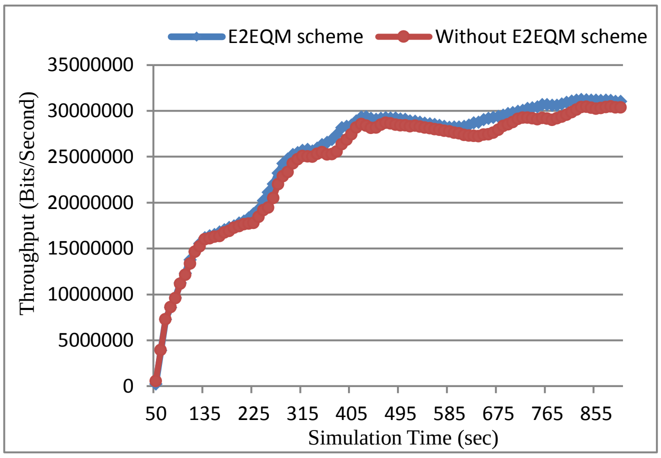

Fig. 14 Overall Delay in SCIS WiFi network

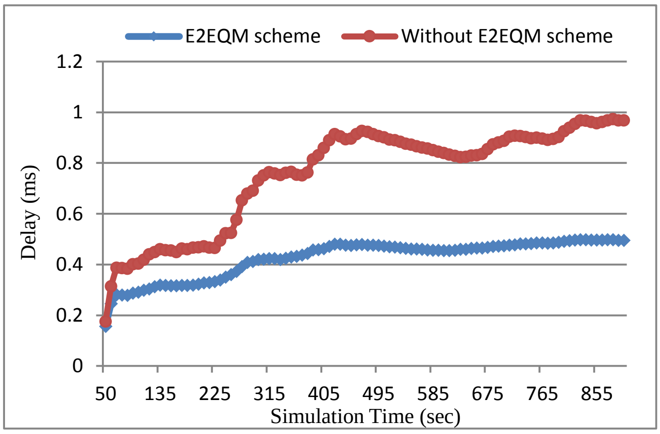

Fig. 15 Throughput in SCIS WiFi model

5. Conclusions

In this paper, Modeling and analysis of SCIS WiFi network has been done. Furthermore, E2EQM scheme is implemented on the modeled network to improve its performance. Highly improved performance has been obtained when E2EQM scheme is applied. The results show that E2EQM scheme improves the SCIS WiFi network performance by decreasing the delay by 44 % and increasing the throughput by 5 %. Also, E2EQM scheme decreases the Packet end-to-end delay and jitter by 1%, and 90 % respectively for VoIP application while decreases Packet end-to-end delay and jitter by 31 %, and 89 % respectively for video streaming application. Finally, there is a tradeoff of applying E2EQM scheme on SCIS WiFi network. E2EQM scheme increases file response time, and page response time for FTP and HTTP applications by 2 %, and 14 % respectively. However, this delay is tolerable and has a little impact on network performance.

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