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IMPROVEMENT OF PERFORMANCE OF HETEROGENEOUS WIMAX SYSTEMS BY USING RELAY NETWORKS

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HETEROJEN WIMAX SİSTEMLERİNİN RÖLE AĞLAR KULLANILARAK BAŞARIMININ ARTTIRILMASI

IMPROVEMENT OF PERFORMANCE OF HETEROGENEOUS WIMAX SYSTEMS BY USING RELAY NETWORKS

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ÖZ

HETEROJEN WIMAX SİSTEMLERİNİN RÖLE AĞLAR KULLANILARAK BAŞARIMININ ARTTIRILMASI

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Heterojen kablosuz iletişim sistemleri, WIMAX, WiFi, HSPA, 3G gibi farklı kablosuz teknolojileri kullanarak abonelere ses, görüntü, veri iletişimi için kablosuz, kesintisiz, genişbantlı servisler sunar. Kablosuz teknolojilerin her biri farklı sistemler ve ayrı bir iletişim ağı mimarisi ile gerçekleştirilmektedir. Farklı sistemlerin birlikte kullanıldığı heterojen sistemlerde, en düşük bedelle, kapsama alanının ve system kapasitesinin arttırılması, servis kalitesinin iyileştirilmesi büyük önem taşımaktadır.

Bu tezde heterojen sistemlerin röle ağlar kullanılarak, kapsama alanının ve sistem kapasitesinin arttırılması, servis kalitesinin iyileştirilmesi dolayısıyla başarımının arttırılması hedeflenmiştir. Bu hedef doğrultusunda OPNET simülatörü kullanılarak çok atlamalı heterojen sistemlerin başarımın arttırılabilmesi için röle yapıları, kuyruk metodları, yayılma kayıpları, protokoller, hız, trafik, gecikme, modülasyon, kodlama, çoklama gibi çeşitli sistem parametreleri gözönüne alınarak heterojen sistemlerin başarımı analiz edilmiştir.

ANAHTAR SÖZCÜKLER: Heterojen WIMAX sistemleri, WLAN, IEEE 802.16j, çok atlamalı röleli sistemler

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ABSTRACT

IMPROVEMENT OF PERFORMANCE OF HETEROGENEOUS WIMAX SYSTEMS BY USING RELAY NETWORKS

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Heterogeneous wireless communication systems use different wireless technologies such as WIMAX, WiFi, HSPA, 3G, etc… in providing continuous, wireless, wideband voice, video and data communication services to users. Each wireless technology is implemented for different systems with different communication network architectures. In heterogeneous systems, where different systems are used together, increasing the system capacity and coverage, improving the quality of service and the error performance at a minimum cost is of great significance.

The aim of this thesis is to increase the coverage area and system capacity, improve the quality of service and the system's performance by using relay networks in heterogeneous systems. The OPNET simulator is used in order to increase the system performance of multihop, heterogeneous systems, where various system parameters such as relay topology, queuing methods, propagation loss, network protocols, velocity, traffic, delay time, coding, multiplexing and modulation are considered in the error performance analysis of the heterogeneous systems.

KEYWORDS: Heterogeneous WIMAX Systems, WLAN, multihop relay system
Advisor: Asst. Prof. Dr Aysel ŞAFAK, Başkent University, Electrical and Electronics Department.

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LIST OF ABBREVIATIONS

AAS	Adaptive Antenna Systems
AHP	Analytic Hierarchy Process
APA	Adaptive Power Allocation
ARQ	Automatic Repeat Request
BE	Best Effort
BPSK	Binary Phase Shift Keying
CDMA	Code Division Multiple Access
CRC	Cyclic Redundancy Check
DSA	Dynamic Subcarrier Allocations
EDCA	Enhanced Distributed Channel Access
ErtPS	Extended Real Time Polling Services
EVDO	Evolution Data Optimised
FEC	Forward Error Correction
FDD	Frequency Division Duplex
FDM	Frequency Division Multiplexing
FIFO	First in First Out
GPC	Grants Per Connection
GPSS	Grant Per SS
HSPA	High Speed Downlink Packet Access
ITU	International Telecommunication
MAC	Media Access Control
LTE	Long Term Evolution Union
MCNs	Multihop Cellular Networks
MCS	Modulation and Coding Scheme
MIMO	Multiple Input Multiple Output
nrtPS	Nonreal Time Polling Services
OFDMA	Orthogonal Frequency Division Multiple Access
QoS	Quality of Service
QPSK	Quadrature Phase Shift Keying
PDU	Protocol Data Units
PMP	Point to Multipoint

RSSI	Received Signal Strength Indicator
SDU	Service Data Units
SINR	Signal to Interference and Noise Ratio
SISO	Single Input Single Output
SOFDMA	Scalable OFDMA
TDD	Time Division Duplex
TDMA	Time Division Multiple Access
UGS	Unsolicited Grant Service
WFQ	Weighted Fair Queuing
WIMAX	Worldwide Interoperability for Microwave Access

1. INTRODUCTION

The field of wireless communication continues to advance very rapidly with many new technologies, ideas, applications and concepts which will surely have a profound impact on the way we communicate in the future.

One technology that is receiving much interest from both the research community and the marketplace is so called as WIMAX which is a deliberately ambiguous brand name for the set of technologies standardised by the IEEE 802.16 working group [1]. These technologies [2][3] have the potential to deliver high capacity to fixed and mobile wireless terminals.

While WIMAX deployment is increasing in the market, there are still significant issues that must be addressed to make WIMAX more competitive to alternative mobile broadband technologies such as HSPA [4] and 3G LTE [5]. One very important issue which is faced by network operators at initial network roll out is how to provide maximum throughput and coverage at minimum cost. One approach which can be very useful in this context is to employ so called relay network architectures. The essential idea is to use Relay Stations, which are associated with Base Stations to effectively increase the system capacity and the coverage area of the BS at low cost. If the price point of the RSs is sufficiently low, this can result in a lower cost deployment solution than the traditional BS based solution.

1.1 Thesis Outline

The goal of this thesis is to improve the performance of heterogeneous WIMAX systems by using relay networks. So, performance analysis of the wireless systems has been performed using OPNET due to user friendly interface.

This thesis is broken down into six parts. Chapter 1 contains this introduction and chapter 2 consists of heterogenous wireless network systems.

This is followed by chapter 3 which provide a detailed description of standardization of WIMAX anf WLAN technologies necessary to understand the proposed simulation.

Chapter 4 presents modelling of heterogeneous wireless by using relay networks. In particular, propagation, interference and antenna model, routing algorithm, quality of service, traffic, protocols, different relay mode of operation, etc… are described as shown in Figure 1.1 and some related equations are given in this chapter.

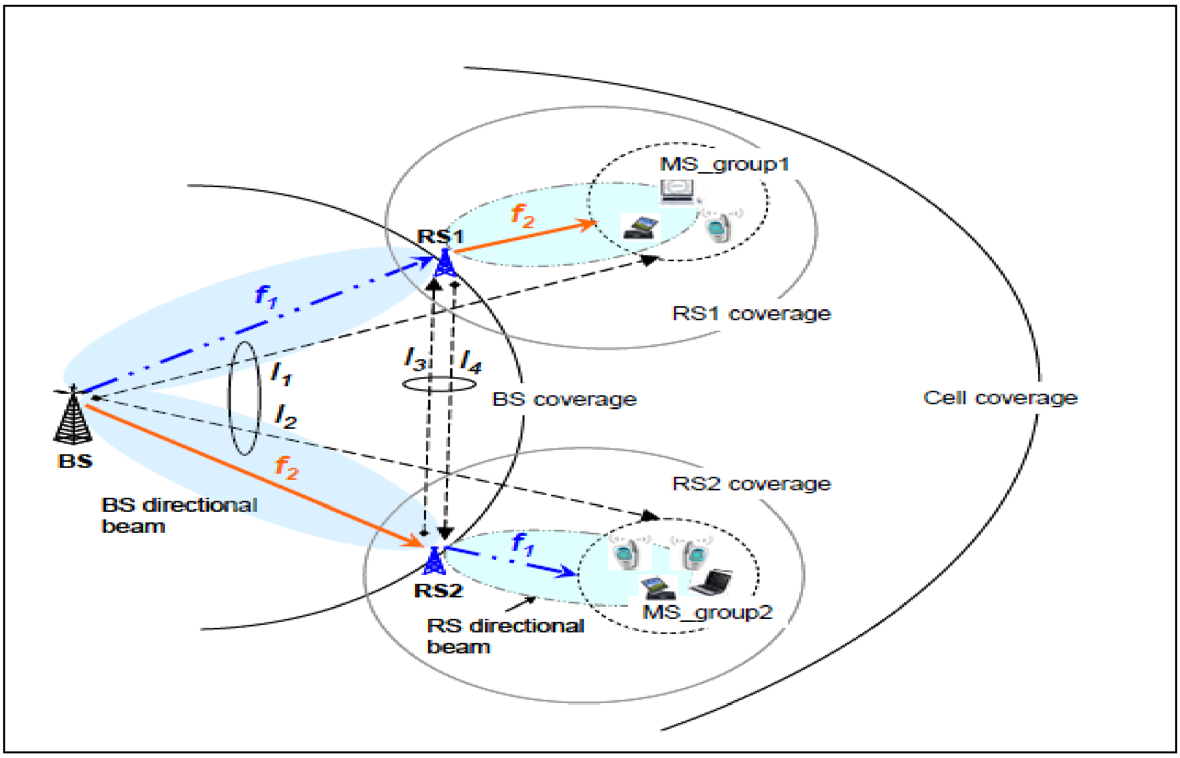


Figure 1.1 Directional distributed relaying with paired radio resource

Chapter 5 focuses on heterogeneous wireless network design by using OPNET simulator and then, this chapter presents the results.

The final part of the thesis is the conclusion and future work which is contained in chapter 6. This chapter concludes the thesis with a summary of the results and a discussion of potential future work.

2. HETEROGENEOUS WIRELESS NETWORK SYSTEMS

A heterogeneous wireless network is used in combining of different access technologies. For example, a wireless network which provides a service through a WiFi and is able to maintain the service when switching to a WIMAX network is called a wireless heterogeneous network.

Higher bit rate data transmission and better coverage range is expected from wireless technology. On these conditions, integration of WLAN with WIMAX has become an inevitable, but integration of these two technologies brings some issue to be investigated**.** Single hop WIMAX system also has its own limitations such as low SNR at the cell edge, coverage holes due to shadowing and the access requirement of nonuniform distributed traffic in densely populated areas, etc…

To make the WIMAX system more competitive and applicable to the future metropolitan area networking scenarios, multihop relay WIMAX has been considered as a promising solution as shown. It overcomes these of the limitations of single hop 802.16 systems.

In this thesis, I therefore extended my analysis from initial scenario of WLAN network to integrated WLAN and multihop relay WIMAX system.

Several proposals are provided to improve performance of heterogeneous WIMAX systems. The author in [6] provides vertical handoff between 802.11 and 802.16 wireless access networks. The proposed vertical handoff scheme aims at reducing handoff signaling overhead on the wireless backbone and providing a lower handoff delay to mobile nodes.

The author in [7] provides spectrum access scheduling among heterogeneous wireless systems. The mechanisms for spectrum sharing in time and two heterogeneous wireless systems coexistence of GPRS and WIMAX and GPRS and WiFi scenarios as use cases are discussed.

3. STANDARDIZATION OF WIMAX AND WLAN

The IEEE 802 is an IEEE project covering several well established standards of wireless networks. This IEEE project specifies MAC and PHY layer of the OSI reference model.

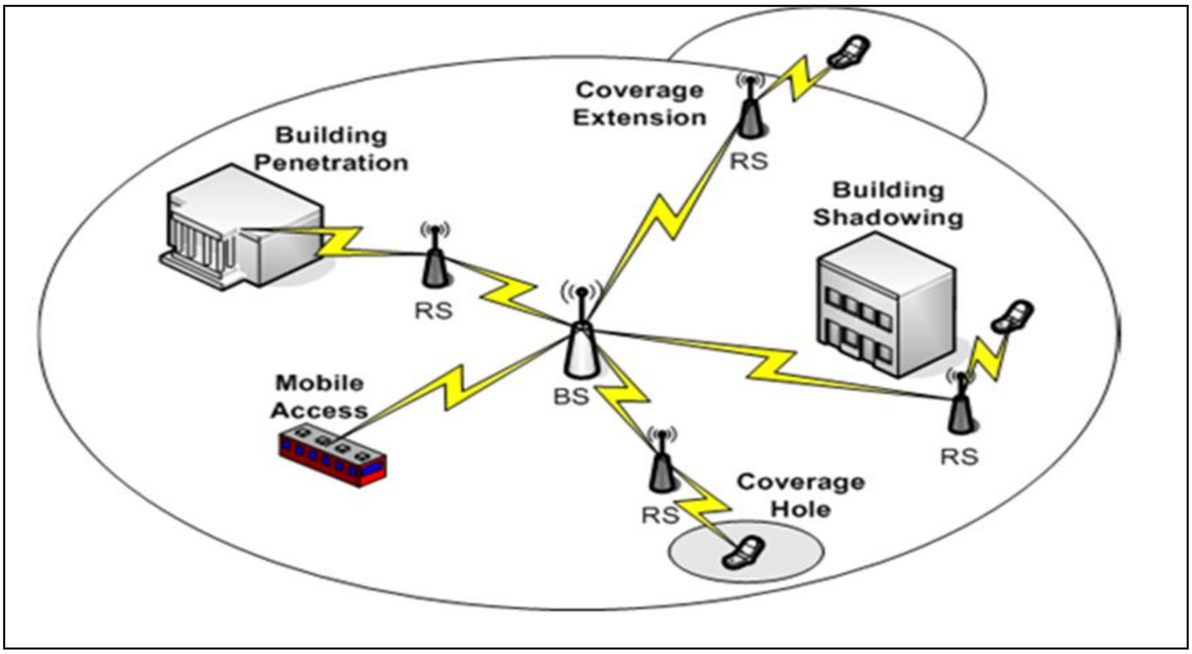


Figure 3.1 Uses cases for 802.16j

WLAN is based on 802.11 standard [8] where as WIMAX is based on 802.16 standard [2]. 802.11a, 802.11b, 802.11g, 802.11n standards, which differ in data rate, range, modulation, frequency, were released by IEEE working group, but 802.11ac and 802.11ad standard has not been ratified. 802.11ac standard provide up to 2.6Gbps throughput for 160 MHz bandwidth. 802.11ac standard supports more MIMO spatial streams (up to 8), and high density modulation (up to 256 QAM). On the other hand, IEEE 802.11ad is a new proposed standard which supports multi-gigabit speed wireless communications technology operating over the unlicensed 60 GHz frequency band.

802.16 standard has been known as WIMAX (Worldwide Interoperability for Microwave Access). To meet the requirements of different types of access, two versions of WIMAX were defined: Fixed WIMAX and Mobile WIMAX based on the 802.16-2004 and 802.16e-2005 standards, respectively. These standards have been replaced by the 802.16-2009 standard ratified recently. This standard includes optimisation on Frequency Division Duplex (FDD) bands, MIMO support and the MAC efficiency to provide better support of VoIP and video traffic. One key modification is the removal of the mesh mode defined in IEEE 802.16-2004 to allow multihop communication among the BS and SSs. Its removal is due to its incomplete specifications, which were unlikely to be completed, and its lack of support for PMP and mobility.

The second major effort within 802.16 is developing an 802.16 based solution for input to the ITUs IMT Advanced initiative. This is the mandate of the 802.16m group that is working on new radio interfaces and system architectures to support highly mobile high data rate communications up to 100 Mb/s mobile and 1 Gb/s fixed. The 802.16m standard was ratified by the 2011.

The remaining important initiative has resulted in the publication of a new standard which specifies a new relay based architecture to support multihop communication: the IEEE 802.16j-2009 standard, which is an amendment of the 802.16-2009 standard, as shown in Figure 3.1.

4. MODELLING OF HETEROGENEOUS WIRELESS SYSTEM

Modelling of heterogeneous wireless system is presented to understand the proposed simulation in detail. So, propagation, antenna, interference, routing, quality of service, protocol and relay mode are discussed in this thesis.

4.1 Propagation Model

A critical component of any model of a wireless system is the radio propagation model. Two basic test environment defined as pedestrian and vehicular. Users located on streets or inside buildings for pedestrian mode while users located on mobile station for vehicular mode.

The channel has three components for propagation model as path loss, shadowing and multipath as shown in Figure 4.1.

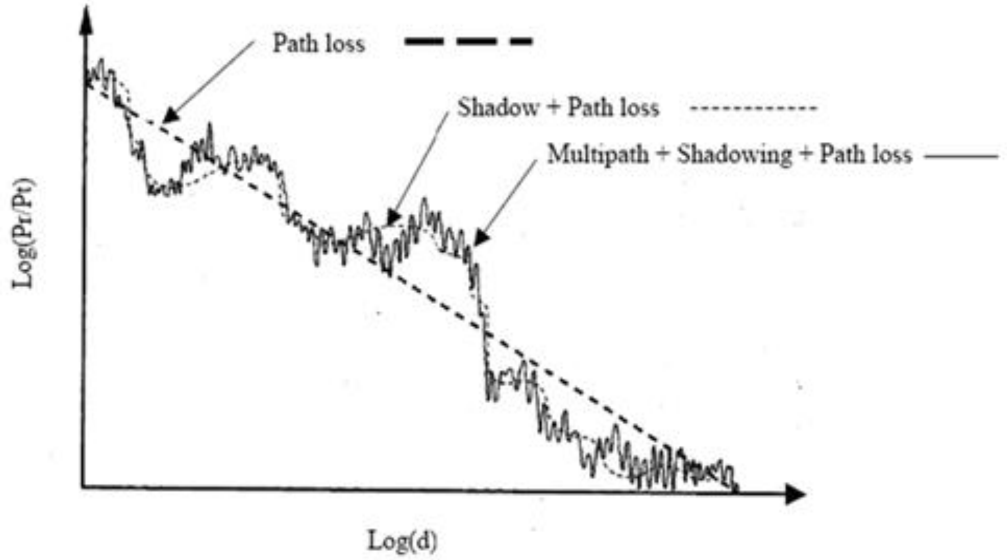


Figure 4.1 Plot showing the three propagation loss: path loss, shadowing and multipath effects

4.1.1 Pathloss

Pathloss is the difference between the transmitted power and received power.

Free space path loss is calculated using:

$$L = 20\log(d) + 20\log(f) + 92.45 \tag{4.1}$$

Where L: path loss (dB),

d : distance from the transmitter (m),

f : signal frequency (GHz),

Pedestrian path loss is calculated using:

$$L = 40\log R + 30\log f + 49 \tag{4.2}$$

Where L: path loss (dB),

R: Tx-Rx distance (m),

f :carrier frequency (MHz),

Vehicular path loss is calculated using:

$$L = 40\left(1 - 4*10^{-3}\Delta h_b\right)\log R - 18\log(\Delta h_b) + 21\log f + 80 \tag{4.3}$$

Where $0 < \Delta h_b < 50m$,

L : path loss (dB),

R : Tx-Rx distance (km),

Δh_b: BS antenna height (m),

4.1.2 Shadowing

Shadowing is the effect that the received signal power fluctuates due to objects obstructing the propagation path between transmitter and receiver.

Experiments reported by Egli in 1957 showed that, for paths longer than a few hundred meters, the received (local mean) power fluctuates with a ‘’log-normal’’ distribution about the area-mean power [9]. Also, Table 4.1 shows some typical values of standard deviation of shadowing [10].

The probability density function (pdf) of the local mean power is thus of the form.

$$f_X\left(x;\mu,\sigma^2\right)=\frac{1}{x\sigma\sqrt{2\pi}}\exp\left(-\frac{\left(\log x-\mu\right)^2}{2\sigma^2}\right) \tag{4.4}$$

Where x: the random variable,

μ,σ^2: mean and variance of the distribution (dB),

The variation of the lognormal shadowing with frequency need to be taken into account. For this expression given by Okumura can be used [11].

$$\sigma=0.65\left[\log\left(f\right)\right]^2-1.3\log\left(f\right)+A \tag{4.5}$$

Where f: frequency (MHz),

A: 5.2 dB (urban) and 6.6 dB (suburban),

Table 4.1 Some typical values of standard deviation of shadowing

Environment	σ **(dB)**
Outdoor	4 to 12
Indoor(Office, hard partition)	7
Indoor(Office, soft partition)	9.6
Indoor(Factory, line-of-sight)	3 to 6
Indoor(Factory, obstructed)	6.8

4.1.3 Multipath

Multipath is a term used to describethe multiple paths a radio wave may follow between transmitter and receiver.

An approach to model multipath propagation with calculation effiency is to calculate two propagation paths, the direct path and one reflected path as shown in Equation 4.6. Rayleigh, Rician, Nakagami model mostly address the channel behavior for multipath receiption.

Rayleigh fading is a statistical model for the effect of a propagation environment on a radio signal. Rayleigh fading is caused by multipath reception. The mobile antenna receives a large number, reflected and scattered waves. Because of wave cancellation effects, the instantaneous received power seen by a moving antenna becomes a random variable, dependent on the location of the antenna.The model behind Rician fading is similar to that for Rayleigh fading, except that Rician fading occurs when one of the paths, typically a line of sight signal, is much stronger than the others. The Nakagami-m model derives the received signal strength from a multipath environment where the different signal components arrive randomly because of the different propagation phenomena.

Multi-path propagation is calculated using:

$$\Pr = Pt * \frac{\left[1+\eta^2+2*\eta\cos\left(\frac{4*\pi*h^2}{d*\lambda}\right)\right]}{4*\pi^2*\left(\frac{d}{\lambda}\right)^\gamma} \tag{4.6}$$

Where η : reflection coefficent of the road,

λ : wavelength,

h : antenna height,

γ : path-loss coefficient,

d : distance between transmitter and receiver,

4.2 Interference Models for Heterogeneous Wireless Networks

The interference introduced by relays should be carefully managed to maximise the overall system capacity. Two types of interference is defined as intercell and intracell interference and they should be minimised.

Intracell interference arises when multiple simultaneous transmissions ocur within a single cell. On the other hand, intercell interference occurs from the closest cells which use the same channel.

Based on the received signal strength indication (RSSI) reported by each RS, the MR-BS can predict the received interference under different MR network topologies and radio resource reuse patterns [12].

Then, RSSI reported by each RS is defined by using matrix as following:

$$\begin{pmatrix} P_{R,0,1} & \cdots & P_{R,0,3} \\ \vdots & \ddots & \vdots \\ P_{R,3,0} & \cdots & P_{R,3,3} \end{pmatrix} \tag{4.7}$$

Where $P_{R,i,j}$ is the RSS of the signal transmitted from node #*i* and received by node #*j*, and $P_{R,j,j}$ is the thermal noise and background interference power received by node #*j*. Relay traffic will be transmitted per below Figure 4.2. The multiple access interference may exist, if the radio resources are reused in different transmission links. In Table 4.2, the possible resource reuse patterns are listed by the notation *Li,j* and {·}, where the *Li,j* indicates the radio link from node #*i* to node #*j*, and {·} indicates the allocation of the individual radio resources to the links inside.

Prediction on received interference level is shown in Table 4.2.

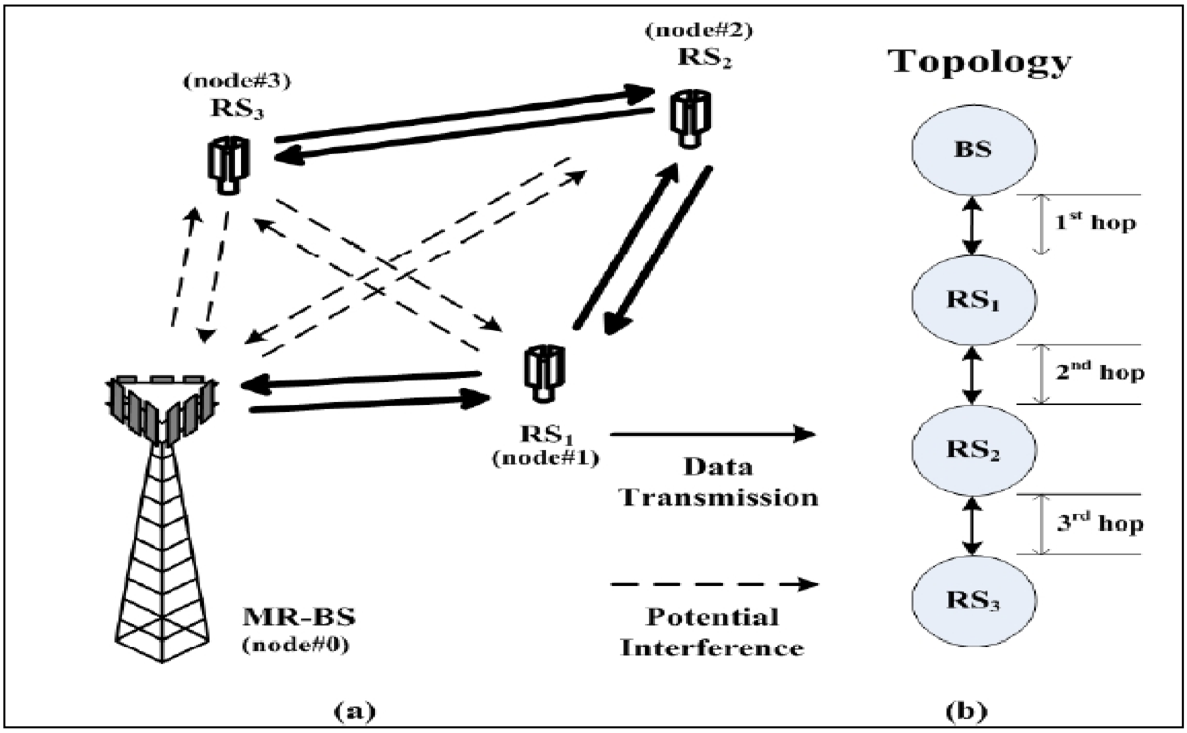


Figure 4.2 An example to illustrate the proposed Interference prediction method

Signal to Interference plus Noise ratio (SINR) is an important factor of wireless communication link. SINR estimates several applications such as handover, adaptive modulation and coding, path selection, etc…

Transmission using a MCS i is considered successful at the receiver r when:

$$SINR_r\left[dB\right]=10\log\left(\frac{P(t,r)}{BN_f N_o+\sum_{t'\neq t}P(t',t)}\right)\geq\alpha_i \tag{4.8}$$

Where t : parent node of the receiver r ,

t': different potential concurrent transmitters in the DL,

The received signal strength, P_{r} , is then calculated using the standard approach:

$$\mathrm{P}_{\mathrm{r}}=\mathrm{P}_t+G_t+G_{\mathrm{r}}-\mathrm{P}_L \tag{4.9}$$

where P_{r} : received power (dBm),

P_t: transmit power (dBm),

G_t : antenna gain at the transmitter (dBi),

G_r : antenna gain at the receiver (dBi),

P_L : path loss based on the SUI model from the transmitter to the receiver (dB),

Table 4.2 Prediction on Received Interference Level

Radio Resources Reuse Pattern		**Prediction on Received Interference Level**			
		Node #0	**Node #1**	**Node #2**	**Node #3**
DL	$\{L_{0,1}\},\{L_{1,2}\},\{L_{2,3}\}$	*Null*	$P_{R,1,1}$	$P_{R,2,2}$	$P_{R,3,3}$
	$\{L_{0,1}, L_{2,3}\},\{L_{1,2}\}$	*Null*	$P_{R,2,1}+P_{R,1,1}$	$P_{R,2,2}$	$P_{R,0,3}+P_{R,3,3}$
UL	$\{L_{3,2}\},\{L_{2,1}\},\{L_{1,0}\}$	$P_{R,0,0}$	$P_{R,1,1}$	$P_{R,2,2}$	*Null*
	$\{L_{1,0}, L_{3,2}\},\{L_{2,1}\}$	$P_{R,3,0}+P_{R,0,0}$	$P_{R,1,1}$	$P_{R,1,2}+P_{R,2,2}$	*Null*

4.3 Antenna Modeling for Wireless Networks

The antenna is a very important element of radio equipment. Omnidirectional, sector and smart antennas are introduced. In [13], the authors investigate resource scheduling in an urban environment with high shadowing. A system with four directional antennas on the base station and relay station is assumed. The simulations show the advantages of directional antennas over omnidirectional antennas in an urban environment. More specifically, the proposed resource scheduling methods with directional antennas show that the system throughput can be increased by 6 or 12 times compared to an omnidirectional system as additionally shown through simulation studies in [14][15].

4.3.1 Omnidirectional antennas

An omnidirectional antenna is an antenna which radiates radio wave power uniformly in all directions in one plane. More specifically, the antenna gain G is set to 0 dBi in all directions for omnidirectional antennas in the system [16]. The number of interfering cells is always 6, regardless of the size of the cell group as shown in Figure 4.3.

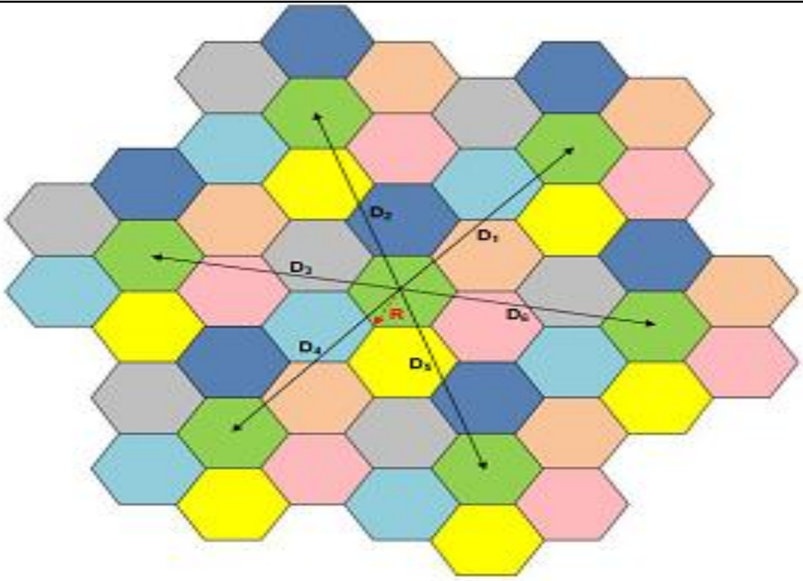


Figure 4.3 omnidirectional antennas (6 interferers)

For 6 interfering cells, signal to co-channel interference (CCI) ratio can be expressed as shown in Equation 4.9.

$$\left[\frac{S}{I}\right]_{omni} = \frac{1}{6}\left(\frac{D}{R}\right)^{v} = \frac{1}{6}\left(3N_c\right)^{v/2} \qquad (4.10)$$

Where v: path loss exponent,

N_c: number of cells in a cluster,

D: from center to center distance between any to co-channel cells,

R: radius,

4.3.2 60 degree sector antennas

Omni base stations are mainly installed in regions with a relatively low number of subscribers. For capacity reasons the communications cell is divided into 6 sectors of 60° in urban areas as shown in Figure 4.4. Cochannel interference is reduced when directional antennas are used to divide a cell into sectors.

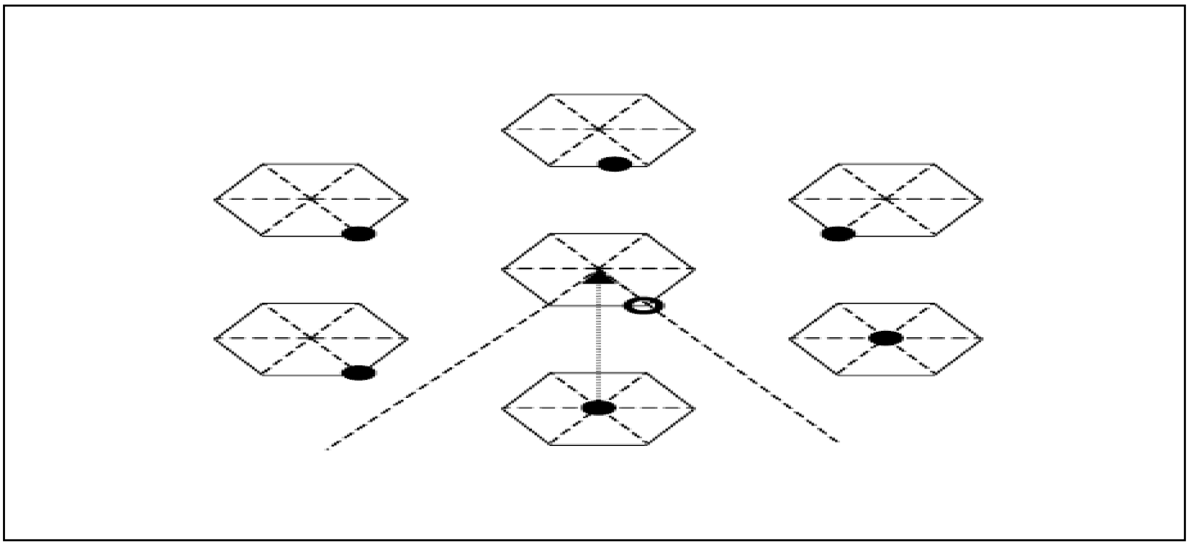


Figure 4.4 60 degree sector antennas (1 interferer)

For the sector antenna, the antenna gain in a specific direction relative to the steering direction of the antenna is computed as follows [16]:

$$G(\theta) = G(0^0) - min[(12(\theta/\theta_{3dB})^2), A_m] \tag{4.11}$$

Where $-180^0 < \theta < 180^o$,

θ: angle between the direction of interest and the steering direction of the antenna,

$G(\theta)$: antenna gain towards a specific direction,

θ_{3dB}: 70^0 is the 3 dB beamwidth,

A_m: 20dB is the maximum attenuation,

For the 60 degree sectors are cochannel interference reduction by a factor of 6, which gives:

$$\left[\frac{S}{I}\right]_{60^o} = \left[\frac{S}{I}\right]_{omni} + 10\log 6 = \left[\frac{S}{I}\right]_{omni} + 7.78dB \tag{4.12}$$

Where S : signal power,

I : co-channel interfering signal power,

4.3.3 120 degree sector antennas

Omni base stations are mainly installed in regions with a relatively low number of subscribers. For capacity reasons the communications cell is divide into three sectors of 120 degree in urban areas as shown in Figure 4.5.

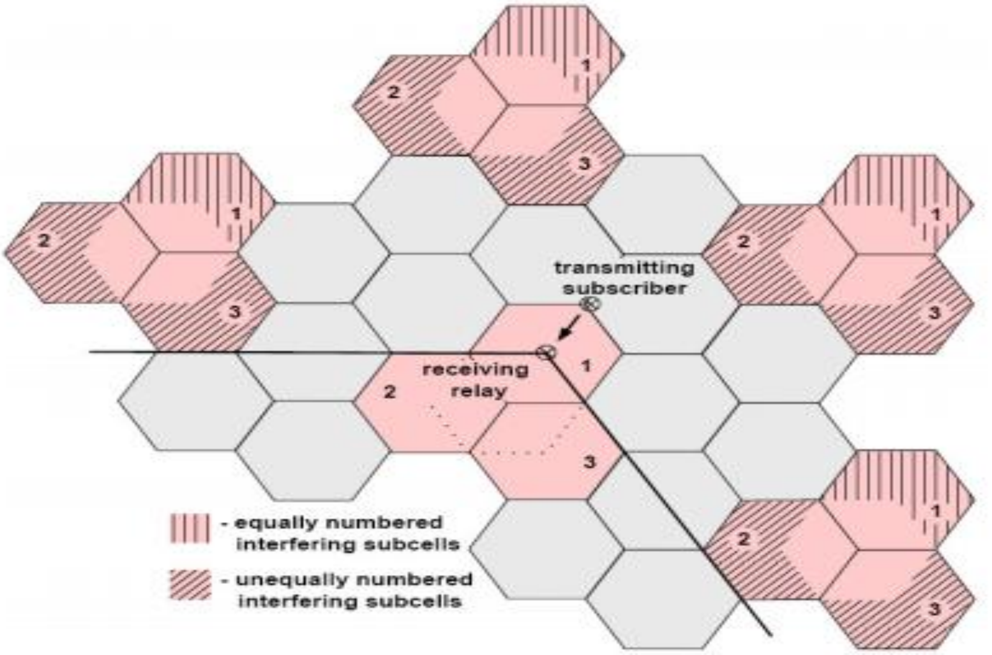


Figure 4.5 120 degree sector antennas (2 interferers)

For the 120 degree sectors are cochannel interference reduction by a factor of 3, which gives:

$$\left[\frac{S}{I}\right]_{120^o} = \left[\frac{S}{I}\right]_{omni} + 10\log 3 = \left[\frac{S}{I}\right]_{omni} + 4.77dB \tag{4.13}$$

Where S : signal power,

I : interfering signal power,

4.3.4 Smart antennas

A smart antenna is a phased or adaptive array that adjusts to the environment as shown in Figure 4.6. That is, for the adaptive array, the beam pattern changes as the desired user and the interference move, and for the phased array, the beam is steered or different beams are selected as the desired user moves.

Smart antennas fall into three major categories: SIMO (single input, multiple output), MISO (multiple input, single output) and MIMO (multiple input, multiple output). Among these different technologies, MIMO is receiving a lot of interest within the research community and is viewed as the best technology solution at present.

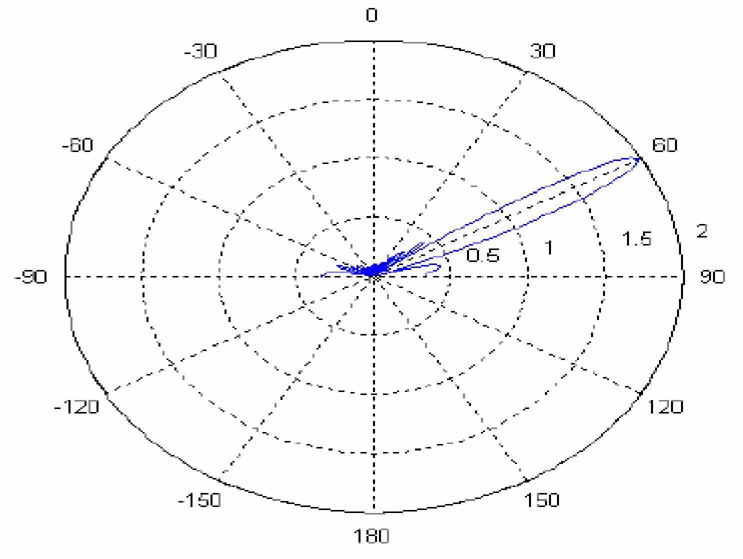


Figure 4.6 Smart antenna simulation beam pattern

4.4 Routing Algorithm

The router uses the routing algorithm to compute the path that would best serve to transport the data from the source to the destination. Routing algorithm use various metrics including some parameters such as distance, bandwidth, cost, multipath,SINR, hop count, etc…

Suitability of path can be calculated for each neighbouring relay station as shown in Equation 4.14.

$$S = \frac{throughput * bandwidth}{hop\_count} \tag{4.14}$$

Then, RS or BS is selected based on maximum value of suitability of path. Routing procedure is started with those RS that is closest to the BS and ends at one that is farthest.

The path decision is based on the following formula:

$$\alpha_{s,r,p} = \frac{W_s}{W_r + W_p} * 100 \qquad (4.15)$$

Where $\alpha_{s,r,p}$: percentage gain on the throughput of using the path $r + p$ instead of the path s,

W_s: weight associated with the BS-SS link,

W_r: weight associated with the BS-RS link,

W_p: weight associated with the RS-SS link,

Each of these weights represents the cost in OFDMA symbols associated to a specific MCS to transmit a bit on the medium. For each SS a specific set of $\alpha_{s,r,p}$ values depending on the number of RSs are associated to it. If no value is greater than zero the SS will be directly associated to the BS. Otherwise the SS will be associated to the RS corresponding to the highest $\alpha_{s,r,p}$ value.

There are many routing protocol in MANETS like Ad Hoc On Demand Distance Vector (AODV), Dynamic Source Routing (DSR), Optimized Link State Routing (OLSR), Temporally Ordered Routing Algorithm (TORA), Geographic Routing Protocol (GRP), etc…as shown in Table 4.3.

Table 4.3 Comparison of routing protocols in MANETS

Characteristics	**DSR**	**AODV**	**OLSR**	**TORA**	**GPR**
Routing Philosophy	Reactive	Reactive	Proactive	Proactive and Reactive	Proactive
Type of Routing	Source Routing	Hop by hop routing	Hop by hop routing	Hop by hop routing	Hop by hop routing
Frequency of Updates	As needed	As needed	Periodically	Based on mode of operation	Periodically
Multiple routes	Yes	No	No	No	No

4.5 Quality of Service

In order to ensure the QoS for various service classes, a QoS architecture including several MAC mechanisms is defined in WIMAX systems. This architecture includes two schedulers which are for DL and one for UL at the BS and one scheduler at the SS for UL as shown in Figure 4.7. At the BS, the BS DL scheduler is defined to handle the packets from the upper layer. Each of these packets is put into different queues corresponding to specific DL connections which are managed, based on their QoS requirements, by the BS-DL scheduler. As the BS controls all the access to the medium, an additional scheduler is required. The UL-BS scheduler allocates resources in the UL based on the bandwidth request received from the SSs.

Finally, as the granted resources are per client despite bandwidth request per connection, a third scheduler is required at the SS. The SS-UL scheduler manages bandwidth requests and data in different queues, i.e. connections, based on the granted resources from the BS and the QoS requirements of each connection. The two main elements then to ensure the QoS in WIMAX systems related to the schedulers and the bandwidth request and grant mechanism.

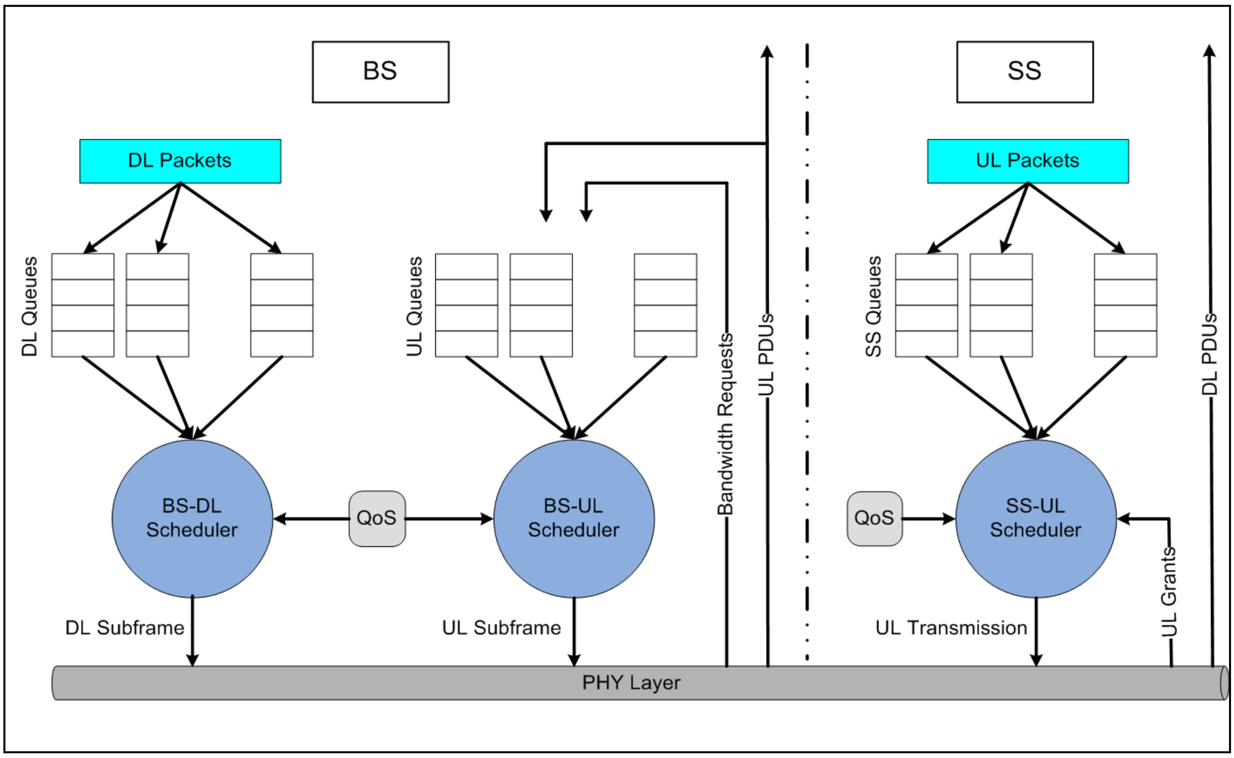


Figure 4.7 QoS architecture at the BS and SSs

Chakchai So-In in [17] provide an extensive survey of the different existing scheduling proposals for WIMAX systems. A scheduler is in charge of distributing the resource among the different SSs and then mapping these allocations into the frame. Hence, a scheduler firrst calculates the number of slots to allocate to each SS and selects on which subchannel and time interval the data will be transmitted.

Askarian and Beigy in [18] provides a survey for load balancing in mobile WIMAX networks. In mobile WIMAX networks, the aim of load balancing process is to control and manage the system in the way that users can achieve guaranteed QoS. In order to satisfy this goal, mobile users should switch from current serving base station (SBS), which is highly loaded, to lightly loaded BSs.

Taheri in [19] gives a comparative analysis of two queuing systems FIFO and WFQ and simulation results in [19] show that WFQ technique has a superior quality than FIFO.

IEEE 802.16j standard defines five scheduling services, unsolicited grand service (UGS), real time polling service (rtPS), nonrealtime polling service (nrtPS), Best-effort service (BE) and extended real time polling service (ertPS). The main QoS parameters are maximum sustained rate, maximum latency, and tolerated jitter. All of them are discussed following subsections.

The prioritization method for 802.11p is the extension of 802.11e EnhancedDistributed Channel Access (EDCA) Quality of Service. Therefore, application messages are categorized into different ACs (Access Categories). There are four available access categories which are BK (Background Traffic), has the lowest priority, VI (Video), the highest priority, BE (Best Effort and VO (Voice) as shown in Table 4.4 [20].

Cwmin and CWmax values are calculated by giving following values:
aCWmin = 15 and aCWmax = 1023

Each AC has to wait at least its AIFS slots, plus additional slots determined by the selected Contention Window (CW) value.

Table 4.4 EDCA parameters

Application	**Access Categories**	**CWmin**	**CWmax**	**AIFS**
HTTP(light)	Background	(aCWmin+1)	aCwmax	9
Remote Login	Best Effort	(aCWmin+1)/2-1	aCWmin	6
VoIP	Voice	(aCWmin+1)/4-1	(aCWmin+1)/2-1	2
Video Conferencing	Video	(aCWmin+1)/4-1	(aCWmin+1)/2-1	3

AIFS time can be determined following Equation 4.16:

$$t_{aifs} = AIFS * t_s \tag{4.16}$$

Contention Window duration is written as:

$$t_{CW} = CW * t_s \tag{4.17}$$

Where t_s : time slot that the MAC utilizes to define the DCF interframe space and to decrement in steps the backoff interval.

4.5.1 Delay

The delay of a packet in a network is the time it takes the packet to reach the destination after it leaves the source. The flow delay per hop traffic is defined as in the following Equation 4.18 and 4.19 [21]:

$$D_{(i,k)} = D_k + D_{q(i,k)} \tag{4.18}$$

$$D_k = d_{proc} + d_{prop} + d_{trans} \tag{4.19}$$

where D_k : constant delay at single hop (k) due to processing delay (d_{proc}), propagation delay (d_{prop}) and transmission delay (d_{trans}).

$D_{q(i,k)}$: represent the queue delay of the (i) packet at (k) hop.

4.5.2 Throughput

A throughput is said to achievable if every mode can send at rate of bits per second to its chosen destination. The cell throughput can be derived as following Equation 4.20 [16]:

$$U_{i,j} = \frac{N_{used}}{T_s \sum_{k=1}^{n} W_k} n \tag{4.20}$$

Where $U_{i,j}$: cell or sector throughput of the sector j of the BS i and in the case of omni antenna,

N_{used}: number of data subcarriers,

T_s: symbol duration,

n: number of SSs in the cell,

W_k: sum of weights of the more efficient transmission path from SS k to the BS: $\min\left(w^r + w^s, w^b\right)$

4.5.3 Bandwidth

B in equation represents the channel bandwidth specifically used for information transmission. This can be determined by the Equation 4.22 in OFDMA system.

4.5.4 SINR

SINR is Signal to Interference plus Noise ratio can be determined following Equation 4.21:

$$SINR_r\left[dB\right] = 10\log\left(\frac{P(t,r)}{BN_f N_o + \sum_{t'\neq t} P(t',t)}\right) \tag{4.21}$$

Where t: parent node of the receiver r,

t': different potential concurrent transmitters in the DL

Ideally, for an n-hop relay, it is necessary to provide n unique radio resource units to avoid interference between each hop. It is clear that the success of relaying is intimately related to the radio resource reuse efficiency. It is possible to produce a comparison of the required relay SNR gain for different MIMO configurations, as shown in Figure 4.8. Figure 4.9 presents the impact of interference on MIMO systems with 2 hop relays. Two thresholds are defined : one is at 100% efficiency (which is required to compute the minimum SIR value), and the other is at 200% efficiency, which implies the relay deployment has doubled the capacity of the direct BS-MS link. It is interesting to note that the high level MIMO configuration is more tolerant to interference. For example, the SISO system requires 4.5dB more SIR than an 8x8 MIMO approach at 200% relay efficiency [22].

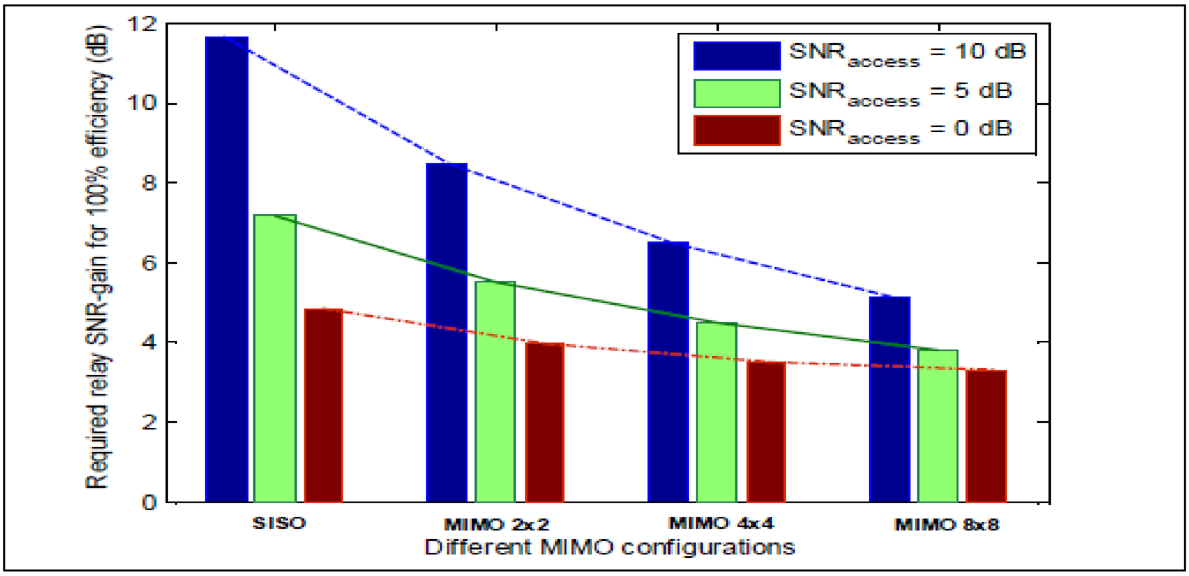


Figure 4.8 Comparison of required relay SNR-gain for different MIMO configurations (2-hop with two radio resource, no resource sharing)

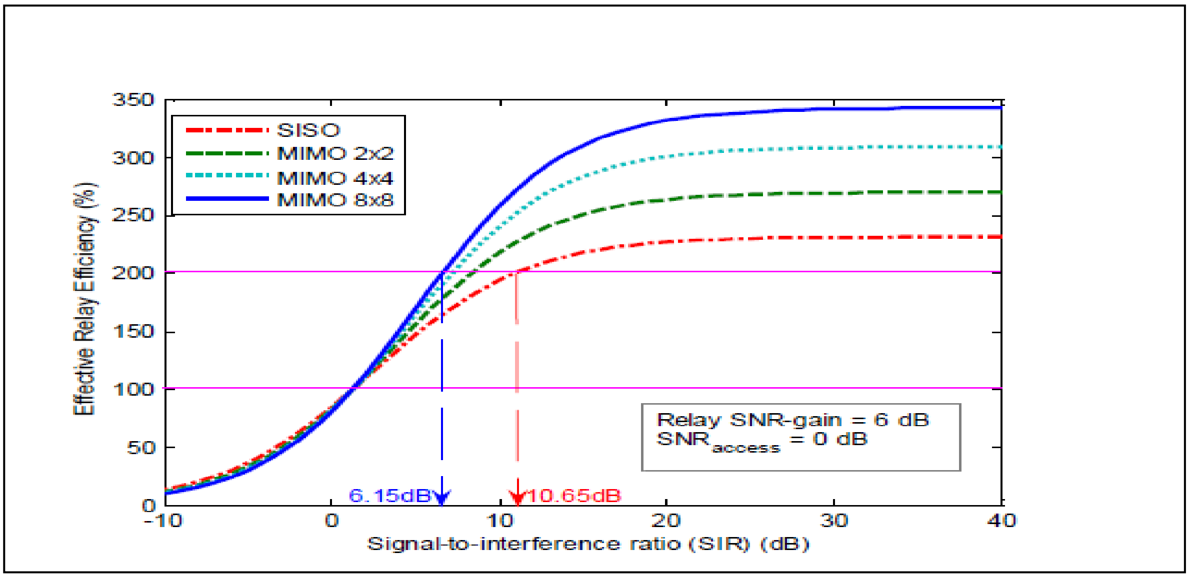


Figure 4.9 Analysis of relay SIR required for high relay efficiency

4.6 Used Techniques of Heterogeneous Wireless Systems

In this thesis, we focus on modulation, coding, multiplexing, access techniques to achieve improvement of performance of heterogeneous networks. All of them are discussed following subsections.

4.6.1 Modulation

Modulation is the process of varying one or more properties of a high frequency periodic waveform, called the carrier signal, with a modulating signal which typically contains information to be transmitted. Multiple techniques have emerged to achieve and improve spectral efficiency such as BPSK, QPSK, QAM, DSSS, etc…

Binary Phase Shift Keying (BPSK) is a form of phase modulation using two different carrier phases to signal 1 and 0, when Quadrature Phase Shift Keying (QPSK) is a form of Phase Shift Keying in which two bits are modulated at once, selecting one of four possible carrier phase shifts. In Quadrature Amplitude Modulation (QAM), the creation of symbols that are some combination of amplitude and phase can carry the concept of transmitting more bits per symbol further. This method is called QAM. For example, 8 QAM uses four carrier phases plus two amplitude levels to transmit 3 bits per symbol. Other popular variations are 16QAM, 64QAM, and 256QAM, which transmit 4, 6, and 8 bits per symbol respectively. Direct Sequence Spread Spectrum (DSSS) is a spread spectrum technique whereby the original data signal is multiplied with a pseudo random noise spreading code. 802.11 standards use DSSS technique.

In the IEEE 802.16-2009 standard, an adaptive modulation and coding mechanism is used, so that WIMAX systems are able to flexibly adjust the modulation and power scheme for individual SSs depending on the radio conditions. Four modulation schemes are defined in burst profiles to suit different SINR situations: Binary Phase Shift Keying (BPSK), Quadrature Phase Shift Keying (QPSK), 16 Quadrature Amplitude Modulation (16QAM) and 64QAM as shown in Figure 4.10. Also, the following Table 4.5 provides mandatory exit and minimum entry threshold in unit dB for each modulation and coding.

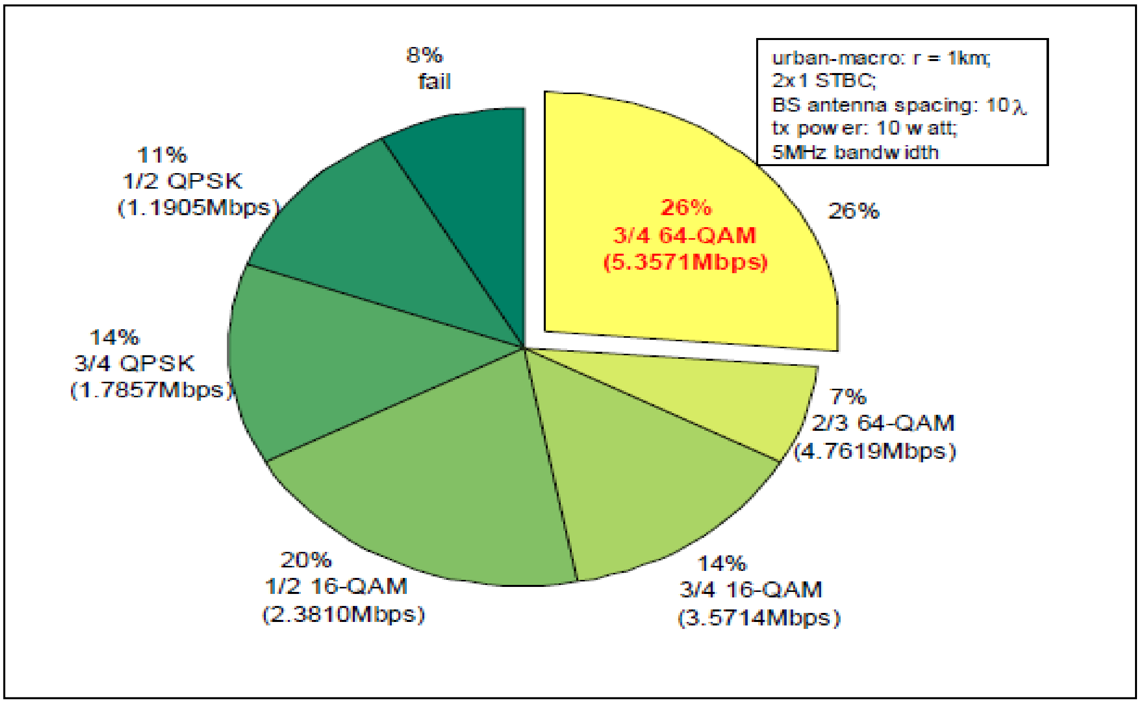


Figure 4.10 Performance for 1 km cell radius (throughput 9.24Mbps)

Table 4.5 MCS/SINR Threshold

Item	Mandatory Exit Threshold (dB)	Minimum EntryThreshold(dB)	Modulation and Coding
0	-20	2.0	$\text{QPSK}_{1/2}$
1	11	11.9	$\text{QPSK}_{3/4}$
2	14	14.9	$\text{16-QAM}_{1/2}$
3	17	17.9	$\text{16-QAM}_{3/4}$
4	20	20.9	$\text{64-QAM}_{1/3}$
5	23	23.9	$\text{64-QAM}_{2/3}$
6	25	25.9	$\text{64-QAM}_{3/4}$

The optimum switching points between the different MCS are strongly depending on the radio channel characteristics. One can see from the comparison of the different schemes that the static approach usually switches to a higher order MCS at a too low SINR as shown in Figure 4.11. This leads to a significantly decreased data rate for some SINR areas. The impact of this effects becomes worse the more fading is observed on the channel [23].

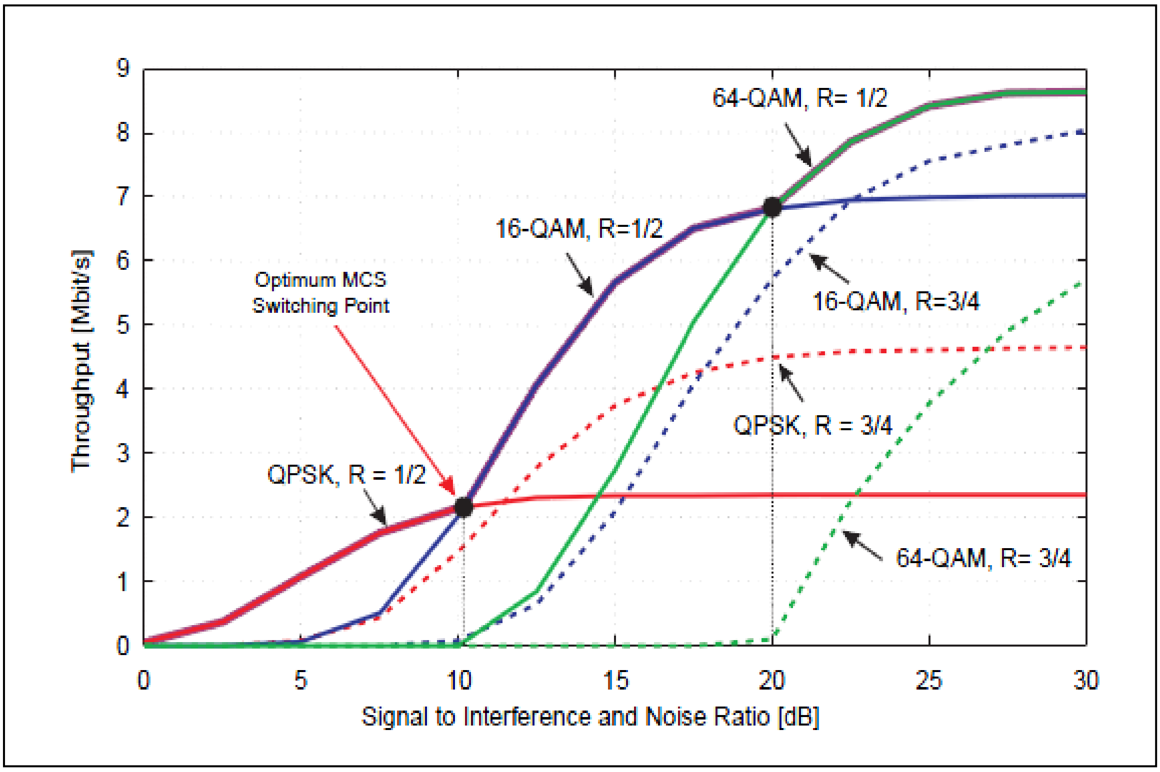


Figure 4.11 Throughput-SINR graph

4.6.2 Coding

802.16 uses Reed–Solomon block code with an inner convolution code or Turbo coding which is one of the difference between 802.11a/g and 802.16. Also, 802.16m consists of advanced coding schemes, including turbo and LDPC.

4.6.3 Multiplexing

Multiplexing is a method by which multiple analog message signals or digital data streams are combined into one signal over a shared medium. The aim is to share an expensive resource.

Multiplexing technologies may be divided into several types, all of which have significant variations: space-division multiplexing (SDM), frequency-division multiplexing (FDM), time-division multiplexing (TDM), and code division multiplexing (CDM).

In wireless communication, space-division multiplexing is achieved by multiple antenna elements forming a phased array antenna. Examples are multiple-input and multiple-output (MIMO), single-input and multiple-output (SIMO) and multiple-input and single-output (MISO) multiplexing.

Frequency division multiplexing (FDM) means that the total bandwidth available to the system is divided into a series of nonoverlapping frequency sub-bands that are then assigned to each communicating source and user pair as shown in Figure 4.12.

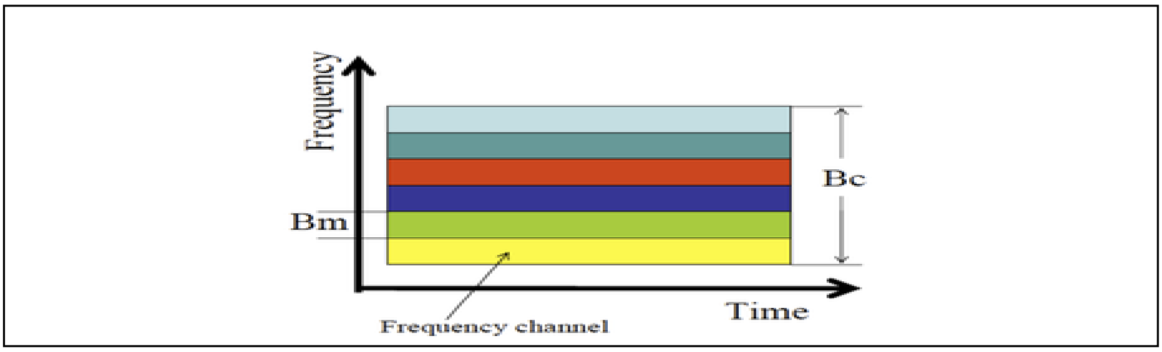


Figure 4.12 Frequency Division Multiplexing

Time division multiplexing is a technique where several signals are combined, transmitted together, and separated again based on different arrival times as shown in Figure 4.13.

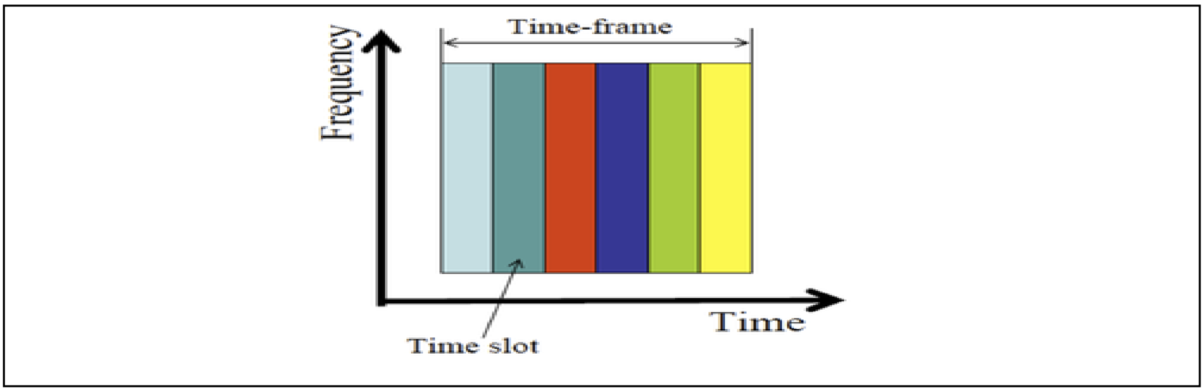


Figure 4.13 Time Division Multiplexing

Code division multiplexing (CDM) makes better use of a frequency band than FDM and TDM. Signals from transmitters are transmitted on the same frequency band at the same time but each has a code to uniquely identify itself.

4.6.4 Access techniques

OFDMA which is a multiple access and multiplexing scheme that provides multiplexing operation of data streams like OFDM as shown in Figure 4.14. In OFDM systems, each user is allocated all subcarriers and hence resource management is limited to which time slots should be allocated to each user. With OFDMA, on the other hand, subcarriers are grouped into subchannels which can be allocated to each user as depicted in Figure 4.14 for the UL. 802.16j supports scalable OFDMA which multiple accesses and also OFDMA parameters are defined as shown in Table 4.6.

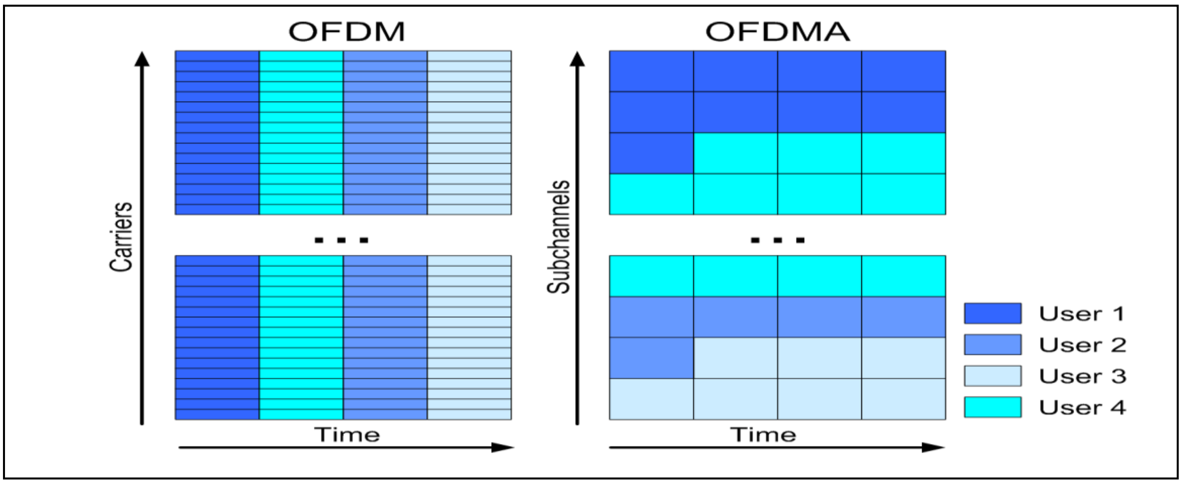


Figure 4.14 Uplink Access in OFDM and OFDMA

SOFDMA supports a wide range of operating bandwidths to flexibly address the need for various spectrum allocation and application requirements. When the operating bandwidth increases, the FFT size is also increased to maintain a fixed subcarrier frequency spacing of 10.94 kHz.

Table 4.6 OFDMA parameters

	OFDMA parameters
FFT size	128,512,1024,2048
Channel bandwidth	1.25, 5,10,20 MHz
Subcarrier frequency spacing	10.94 kHz
Useful symbol period	91.4 microseconds
Grand time	1/32, 1/16, 1/8, 1/4

B in Equation represents the channel bandwidth specifically used for information transmission in an OFDMA system. This can be determined by the following Equation 4.21:

$$B = \frac{F_s N_{used}}{N_{FFT}} \qquad (4.22)$$

Where B: effective channel bandwidth (Hz) ,

N_f : noise Figure (dB),

N_o : thermal noise level (dBm),

On the other hand, CDMA is one of the access technologies and stands for Code Division Multiple Access. It is a wireless communication technology that allows multiple people to use a single radio channel at the same time with little interference and very high security.

4.6.5 Traffic

Controlling and determining the number of user is very crucial in order to maximize the throughput for each individual user requirement of QoS, maintain fairness between users in the networks and guarantee QoS for real time application users. The more users connect to the network, the more traffic congestion toward the MR-BS. For better QoS and resource utilization, Total Traffic (TF) at MR-BS must be less than or equal to the MR-BS capacity. Equation 4.23 used to calculate total traffic at each level (wireless zone) [21]:

$$TF_j \text{ at } Hop_j = \sum_{i=0}^{n_j} U_j i + \sum_{r=0}^{m_j} TF_{j+1_r} \qquad (4.23)$$

Where $j \in \left|0, L\right|$:

L : Layer,

$\left(n_j\right)$: Number of users at level j,

$\left(m_j\right)$: Number of relays at level j,

4.7 Protocols

WLAN is based on 802.11 standard [8] where as WIMAX is based on 802.16 standard [2] and WIMAX multihop relay system is based on 802.16j standard. WIMAX and WLAN are compared each other as shown in Table 4.7..

Table 4.7 Comparison of 802.16 and 80.11a/b/g standards

Feature	WIMAX (802.16)	Wi-Fi (802.11b)	Wi-Fi (802.11a/g)
Primary Application	Broadband Wireless Access	Wireless LAN	Wireless LAN
Frequency Band	2 GHz to 11 GHz NLOS 10 GHz to 66 GHz NLOS	2.4 GHz	2.4GHz 802.11g 5GHz 802.11a
Channel Bandwidth	20 MHz	25 MHz	20 Hz
Max Data Rate	72 Mbit/s	11 Mbit/s	54 Mbit/s
MIMO streams	2x2	1	1
Half/Full Duplex	Full	Half	Half
Radio Technology	OFDM (256-channels)	Direct Sequence Spread Spectrum	OFDM (64-channels)
Bandwidth Efficiency	<=5 bps/Hz	<=0.44 bps/Hz	<=2.7 bps/Hz
Modulation	BPSK, QPSK, 16QAM,64QAM, 256QAM	QPSK	BPSK,QPSK, 16QAM, 64QAM
Forward Error Correction	Convolutional Code, Reed-Solomon	None	Convolutional Code
Outdoor Range	50 km	140 meters	120 meters for 802.11a 140 meters for 802.11g
Access Protocol	Request/Grant	CSMA/CA	CSMA/CA

4.8 Transparent and Nontransparent Relay Mode

The standard defines two different relay modes of operation as transparent mode and nontransparent mode as shown in Table 4.8.

In transparent relay mode, the RSs do not forward framing information, and hence they do not increase the coverage area of the wireless access system; consequently, the main use case for transparent mode relays is to facilitate capacity increases within the BS coverage area. This type of relay is of lower complexity and only operates in a centralised scheduling mode and for topology up to 2 hops.

In nontransparent relay mode, the RSs generate their own framing information or forward those provided by the BS depending on the scheduling approach (i.e. distributed or centralised). They can support larger coverage areas and hence are mainly used to provide increased coverage. On the other hand, the transmission of the framing information can result in high interference between neighbouring RSs and hence the capacity enhancement that can be achieved by using these relays is limited. In this mode, MS recognizes the nontransparent RS as a BS**.**

As transparent relays (T-RS) and nontransparent relays (NT-RS) have different advantages, there can be some scenarios in which it makes sense to associate both with a single BS. Table 4.8 illustrates the difference between both types of relay mode.

4.8 Comparison betweenrelaymodes of operation

	TRANSPARENT RS	**NONTRANSPARENT RS**
Coverage Extension	No	Yes
Number of hops	2	≥2
Scheduling	Centralised	Centralised/distributed

5. ANALYSIS OF PERFORMANCE OF HETEROGENEOUS WIRELESS SYSTEMS USING OPNET SIMULATION TOOL

Analysis of performance of heterogeneous wireless systems systems in this thesis is based on the OPNET simulation tool [24] which provides a good model of the 802.16 standard.

5.1 Simulation of Propagation Model

Pedestrian path loss model, which has the lowest SNR value.

But, pedestrian multipath channel model SNR is almost higher than vehicular multipath channel model SNR (Figure 5.1, item 1).

Free space model SNR is almost higher than vehicular path loss model SNR in vehicular multipath channel model (Figure 5.1, item 2).

Free space model SNR is almost higher than vehicular path loss model SNR in pedestrian multipath channel model (Figure 5.1, item3).

Consequently, pedestrian multipath channel model has more uplink SNR than the others per Figure 5.1 and pedestrian path loss model has the lowest uplink SNR. Also, Table 5.1 makes a comparison for each different scenarios.

In this thesis, we focus only on multipath and path loss, not shadowing.

According to Figure 5.2, while pedestrian pathloss is 150 dB, vehicular pathloss is about 120 dB and free space pathloss is 105 dB in same scenario. Pedestrian pathloss is greater than vehicular and free space pathloss. Free space pathloss is not realistic, but it give opportunity that compare all path loss model in unit dB.

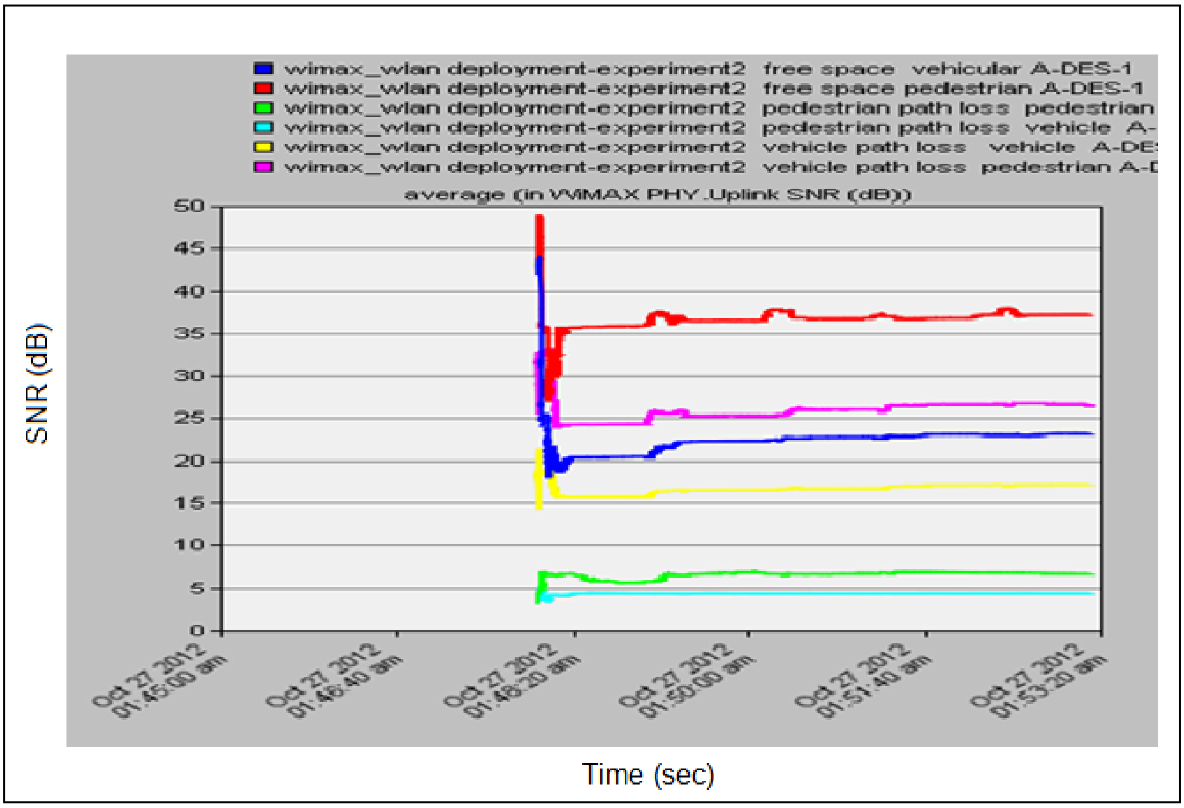


Figure 5.1 Simulation results of uplink SNR of each multipath channel model and each path loss model

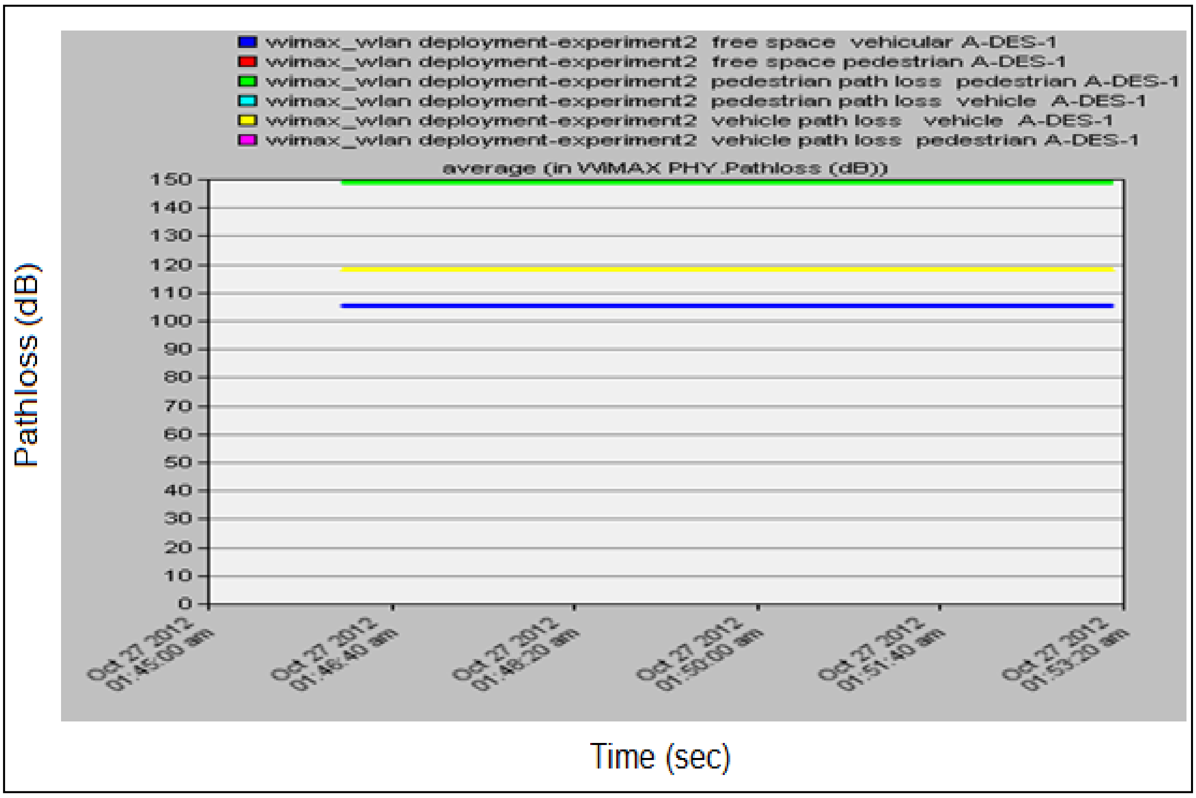


Figure 5.2 Simulation results of pathloss for each multipath channel model and each path loss model.

5.2 Simulation of Quality of Service

During the integration and interaction in vertical handoff between Wi-Fi and WIMAX technology performance compared for FIFO and WFQ. We analyze the graphs and compare the two queuing disciplines and explain their effect on the performance of the three applications as shown in Figure 5.3. In this thesis, comparing these two discipline where considered in the available networks and minimizing delay and try to make the maximum performance is target in service to users.

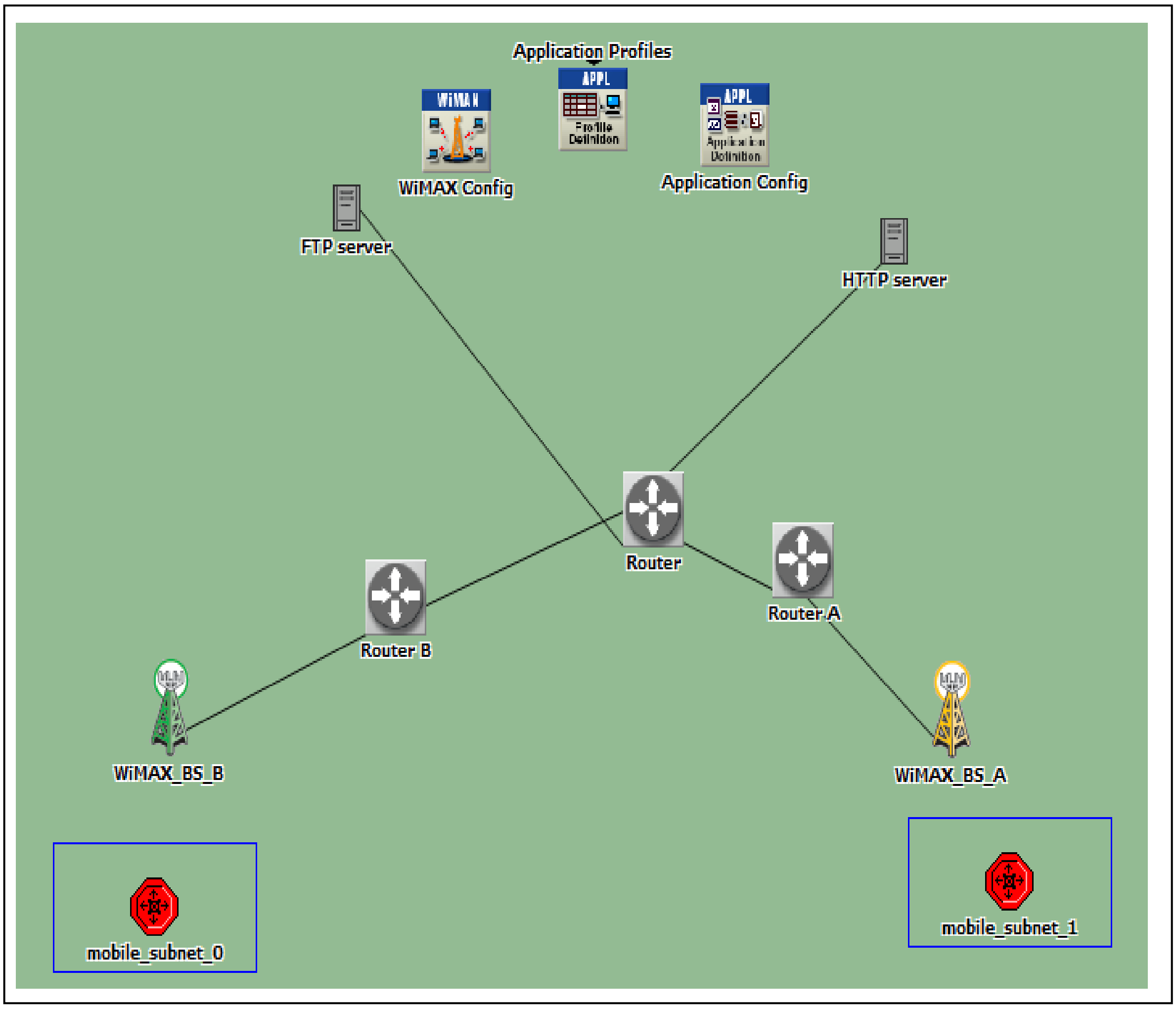


Figure 5.3 Heterogeneous wireless network

Time taken for packets to be transmitted from source to destination. FIFO shows most delay as 3.7 sec and WFQ have lower delay as 0.3 sec as shown in Figure 5.4 extracted from OPNET ‘’packet end to end delay‘’ statistics in voice application. We can see from Figure 5.4 that the delay variation increases up to a certain point when the traffic starts and then stabilizes a little.

Table 5.1 Major settings added and modified under application definitions.

Application	FTP	VoIP	Video Conferencing
Description	High Load	PCM Quality Speech	Low Resolution Video
Type of Service	Best Effort	Interactive Voice	Streaming Multimedia

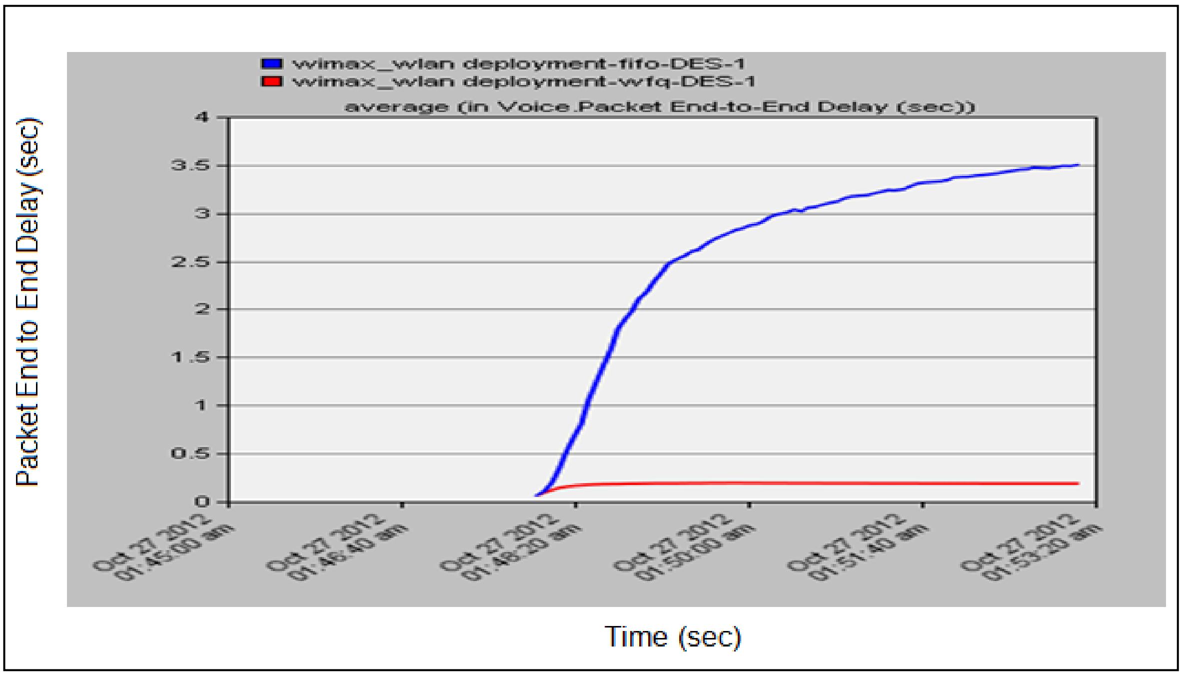


Figure 5.4 Simulation results of end to end delay for voice in for FIFO and WFQ systems

Jitter is the variation in the delay and Jitter should be minimized especially in real time applications. FIFO shows less jitter than WFQ per below extracted OPNET ‘’jitter ‘’ statistics in voice application by the time as shown in Figure 5.5.

Mean Opinion Score defines the perceived voice quality. MOS scale changes from 1 to 5 per voice quality. WFQ shows little more fair perceived audio quality than FIFO as shown in Figure 5.6 extracted from OPNET ‘’MOS ‘’ statistics in voice application.WFQ result in more traffic received than FIFO as shown in Figure 5.7 extracted from OPNET from ‘’ traffic received ‘’ statistics in voice application.

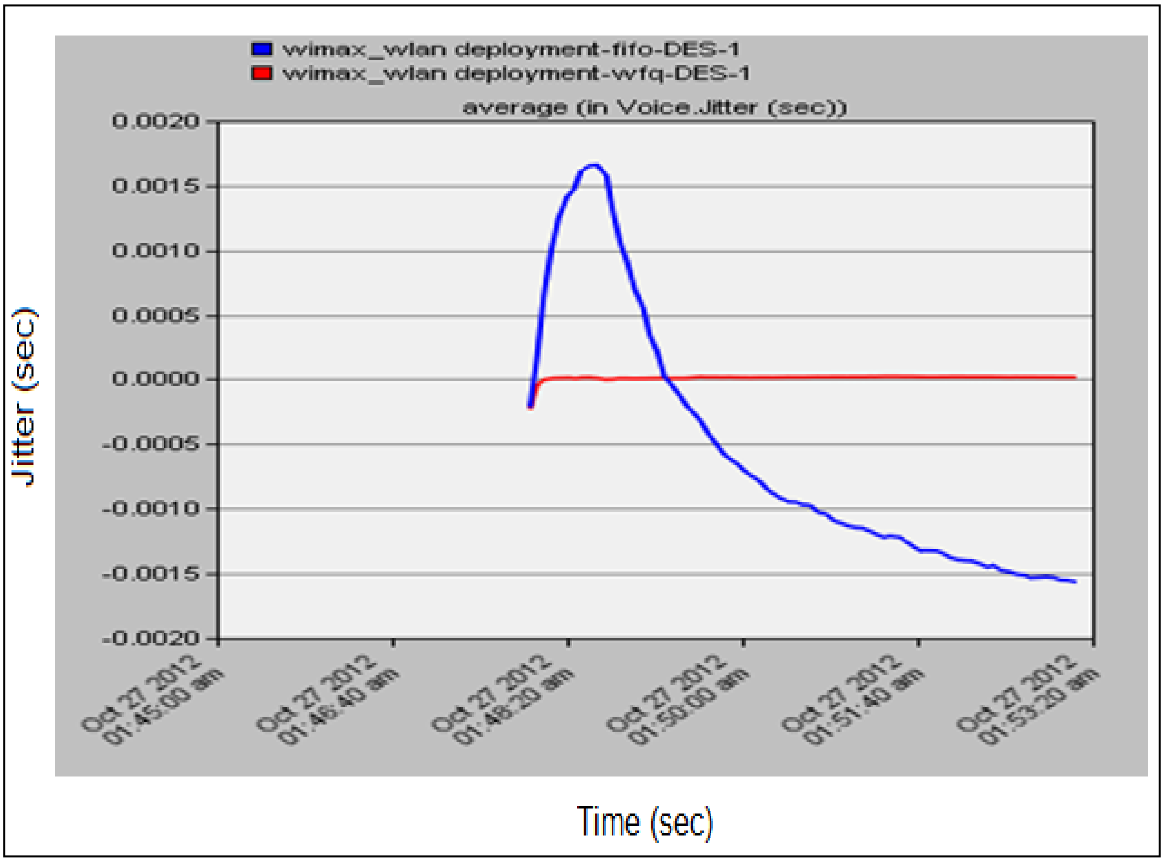


Figure 5.5 Simulation results of jitter noise for voice in FIFO and WFQ systems

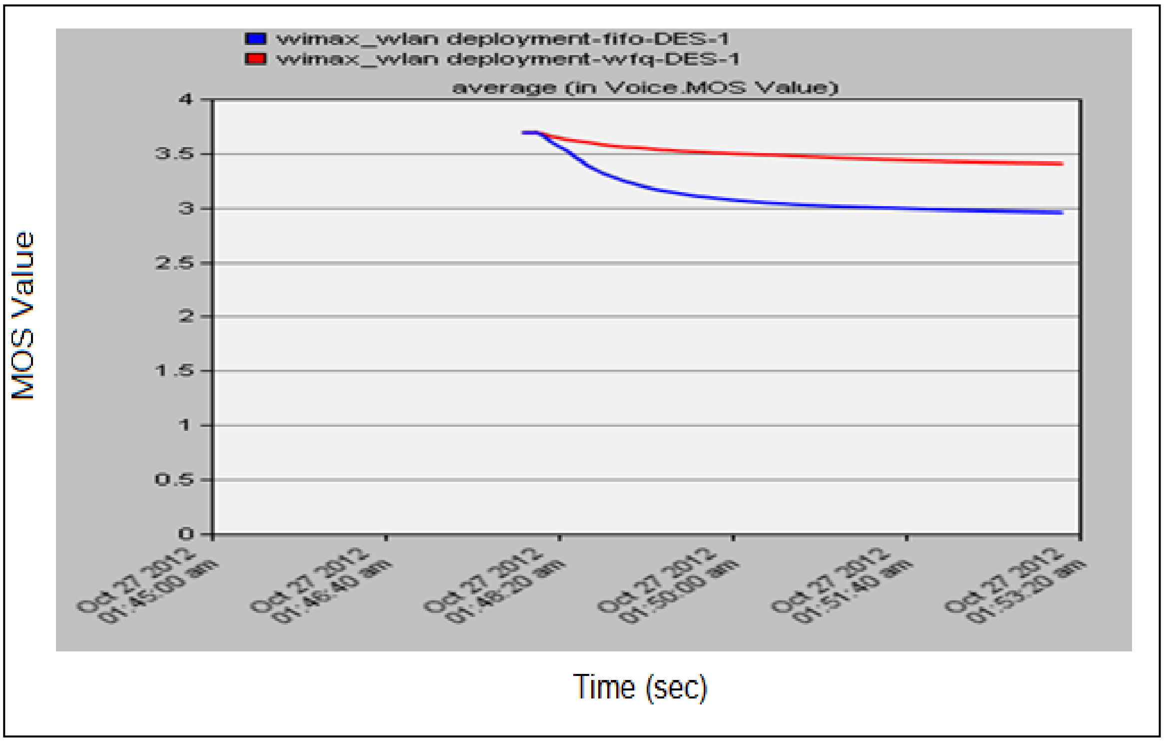


Figure 5.6 Simulation results of MOS value for voice in FIFO and WFQ systems

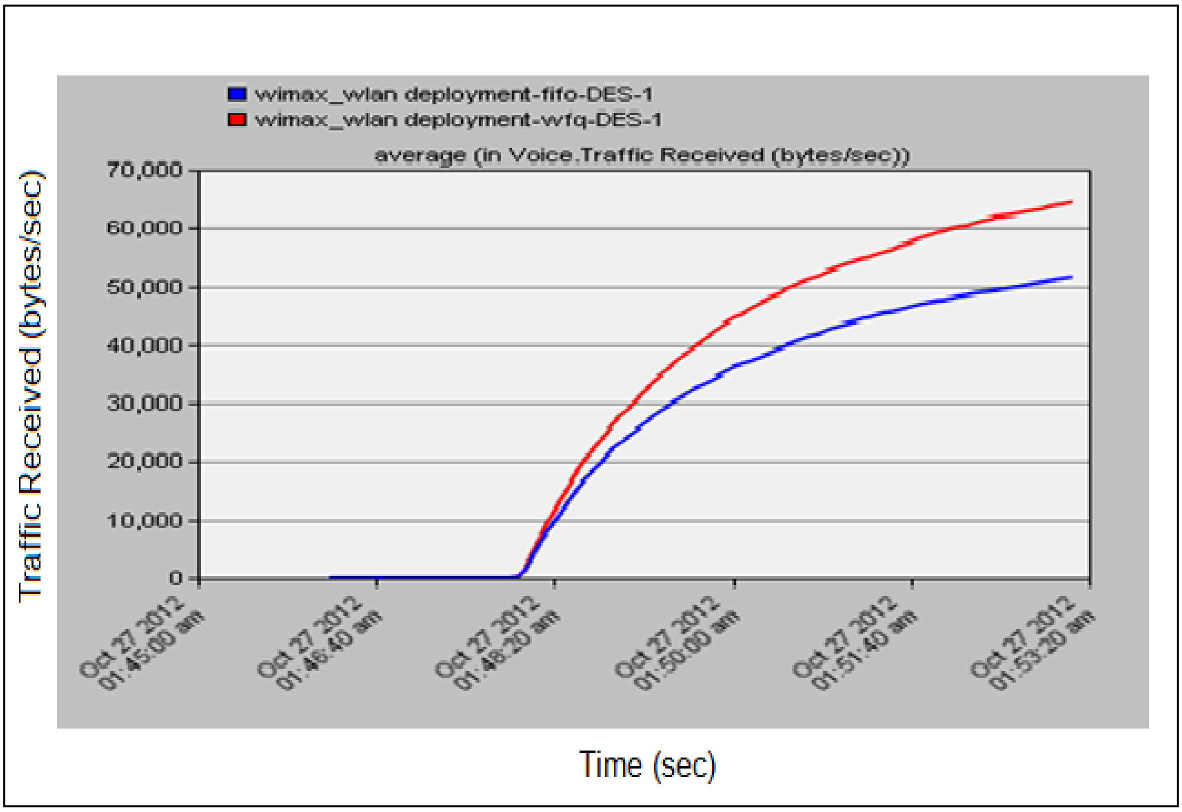


Figure 5.7 Simulation results of received traffic for voice in WFQ and FIFO systems

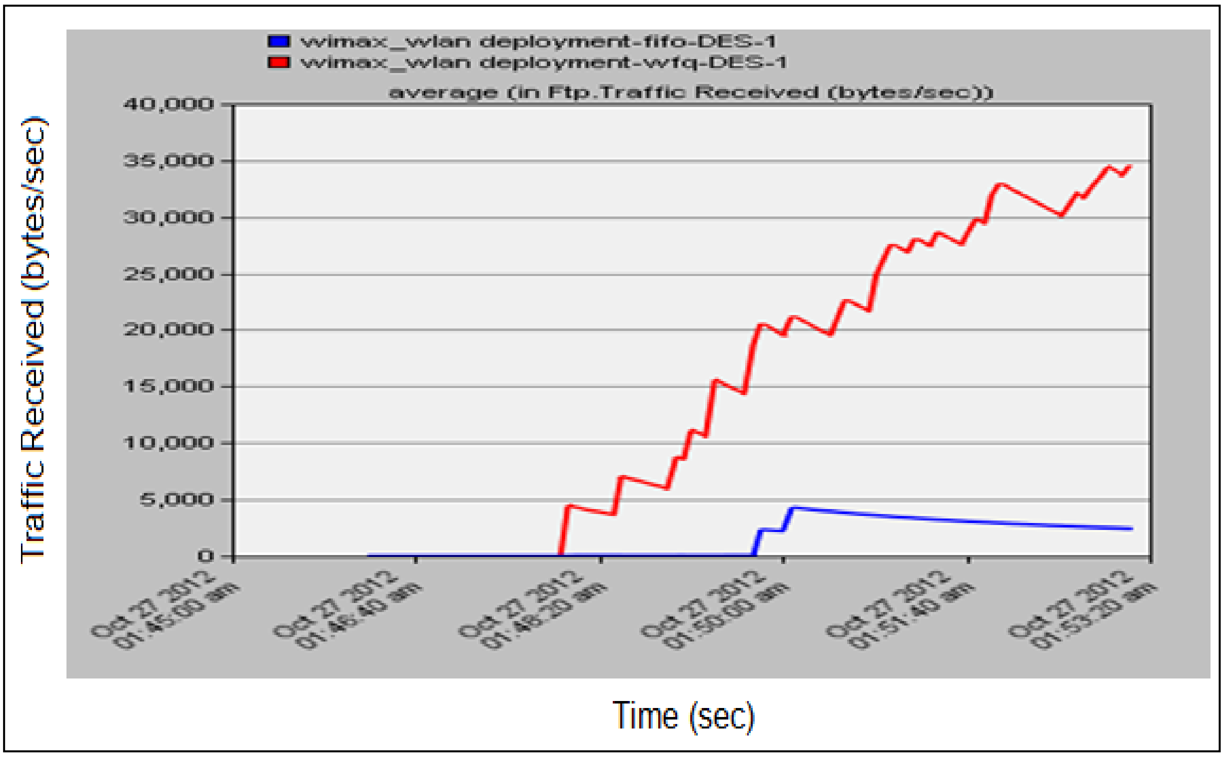


Figure 5.8 Simulation results of received traffic for FTP in FIFO and WFQ systems

FTP packets given lowest priority hence WFQ shows more traffic received than FIFO over the long run per Figure 5.8. FTP traffic not sensitive to jitter, delay.

End to end delay of WFQ packet is less than end to end delay of FIFO packet in video application as shown in Figure 5.9 extracted from OPNET ‘’packet end to end delay‘’ statistics.

We can conclude that end-to-end delay time is decreasing until steady state in video conferencing application. This is done because the utilization of the network gets to a steady state after a while and the data throughput of the routers stabilizes to a certain value dropping the end to end delay.

Received traffic for FIFO is little less than received traffic for WFQ in video conferencing as shown in Figure 5.10. Dropped traffic in WFQ is less than traffic than IP dropped traffic in FIFO for IP as shown in Figure 5.11.

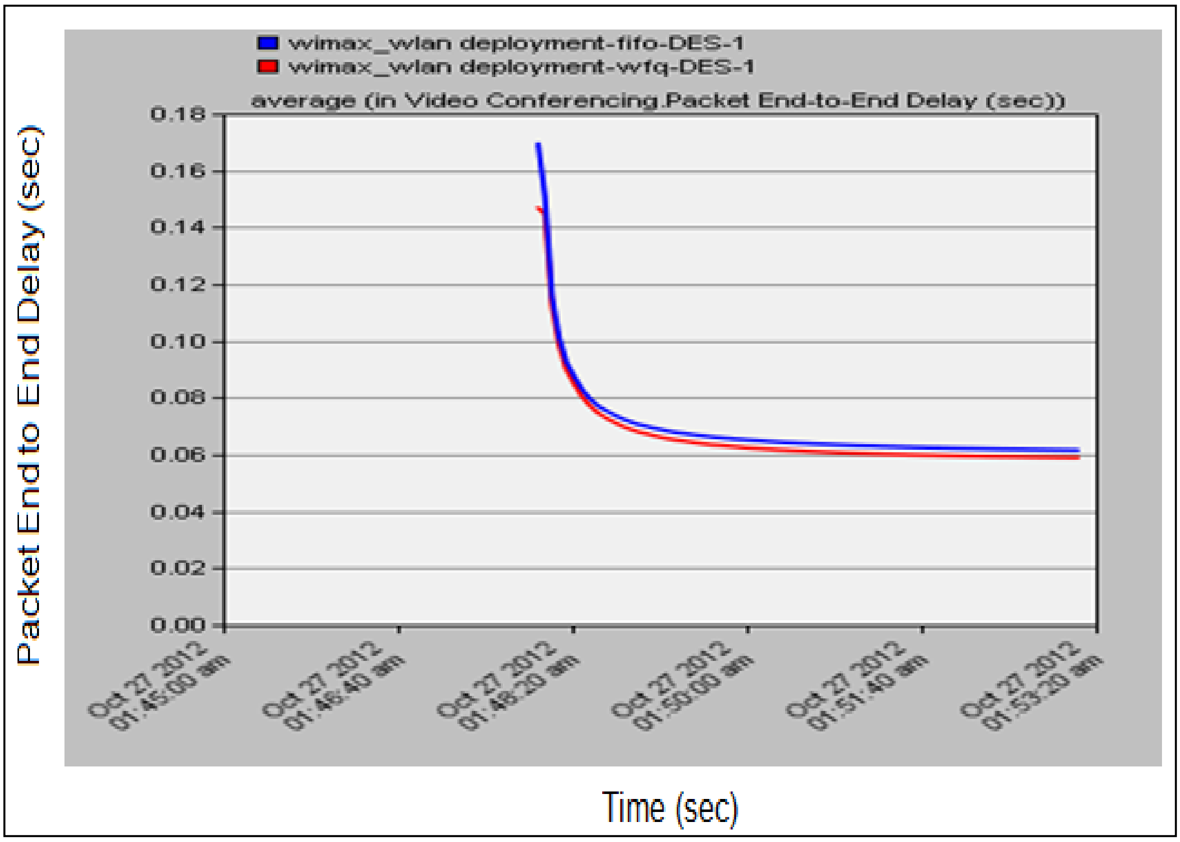


Figure 5.9 Simulation results of end to end delay in video conferencing packet for FIFO and WFQ systems

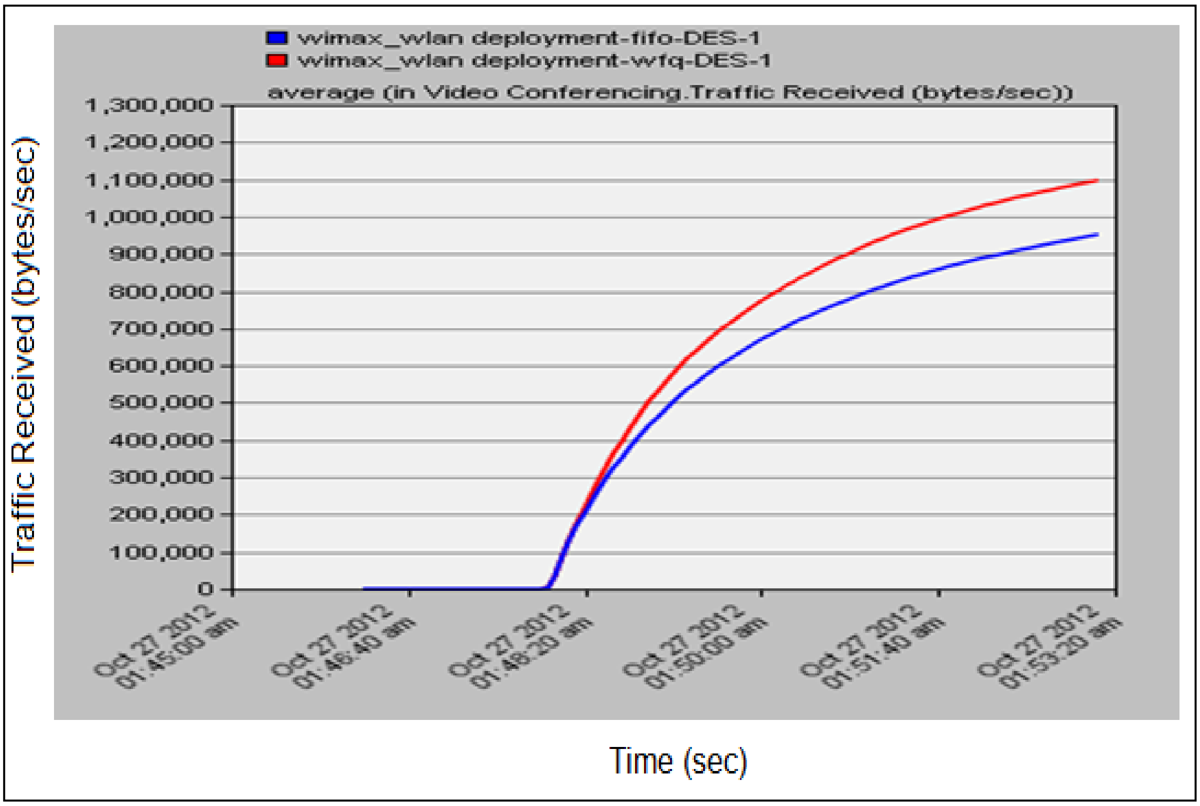


Figure 5.10 Simulation results of received traffic for video inFIFO and WFQ systems

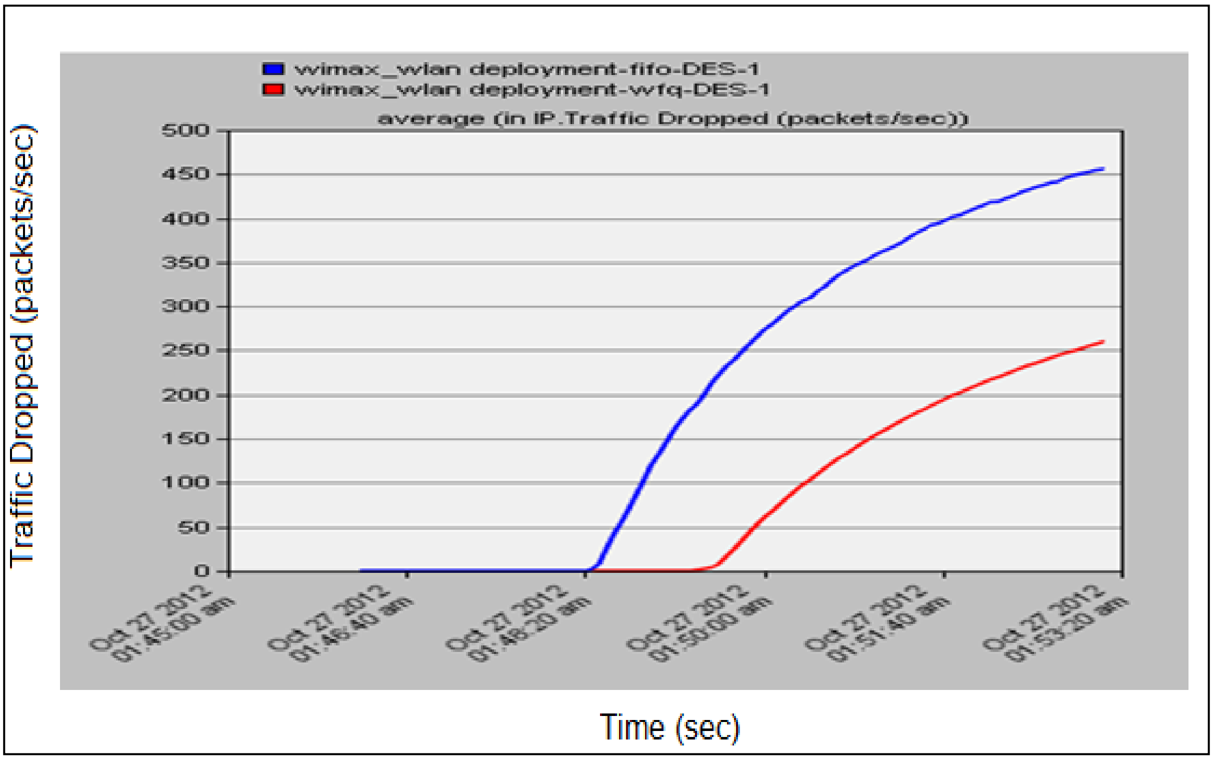


Figure 5.11 Simulation results of dropped traffic in IP for FIFO and WFQ systems

Subsequently, we perform EDCA simulation by using 802.11g., due to lack of 802.11p protocol.To simulate the contention based channel access method called Enhanced Distributed Channel Access(EDCA) , some application configured such as http, remote login, video conferencing, VOIP.

It is observed from Figure 5.12 that throughput of voice is higher than throughput of background and best effort traffic. It means that EDCA provides maximum throughput by providing them more priority over the other services like simple HTTP.

Table 5.2 Simulation setup parameters

Attributes	**Mobile node & destination**
Channel Bandwith	10 MHz
Frequency	5.850-5.925 MHz
Data Rate	5.5 Mbps
CWMin	15
CWMax	1023
Transmission Power	0.76 W
Packet Receiption power threshold	-82.0 dBm
Mobile node speed	50 km/h

It is observed that media access delay for voice is minimum among all access categories. It means that medium is assigned to the application according to the priority. So, EDCA provides less medium access delay for real time applications as shown in Figure 5.13.

Five mobile station added to existing previous scenario to evaluate that how increasing mobile stations effect throughput, media access delay, etc…Priority is given to voice, video, best effort and background respectively as shown in Figure 5.14. If given priority is less, then delay time will increase as shown in Figure 5.15.Media access delay time increases by increasing mobil station for each access categories with same ratio as shown in Figure 5.16.

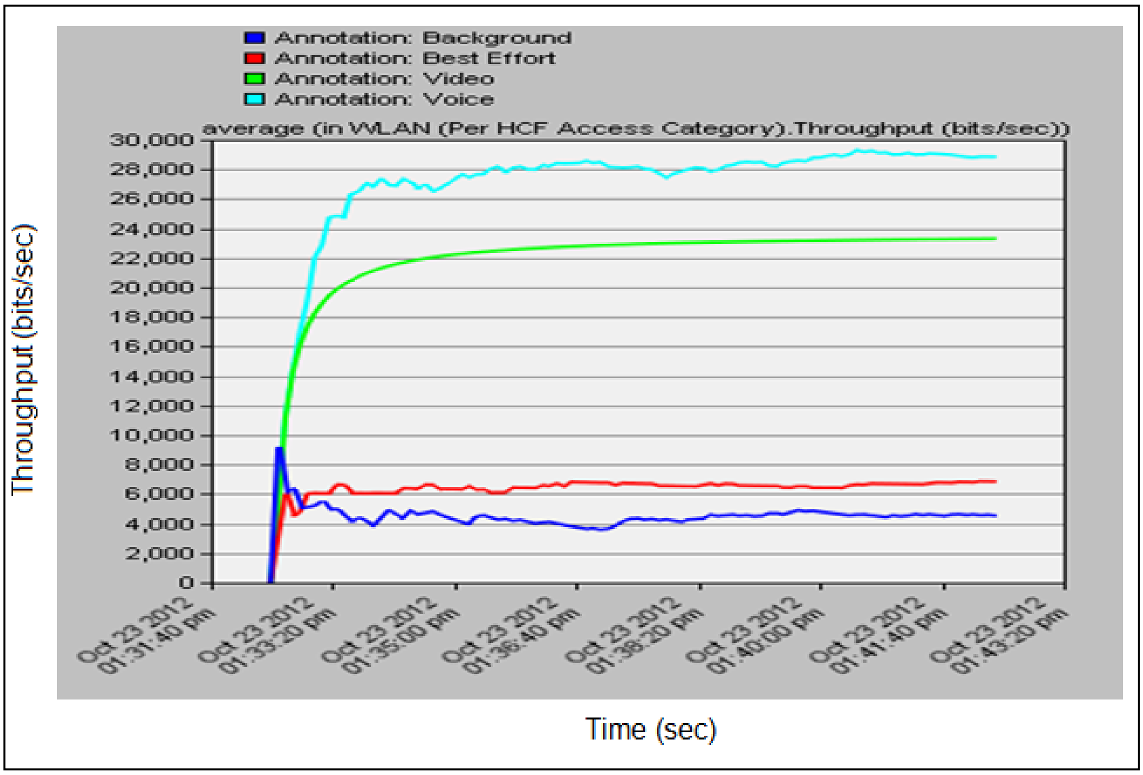


Figure 5.12 Simulation results of throughput for each access category

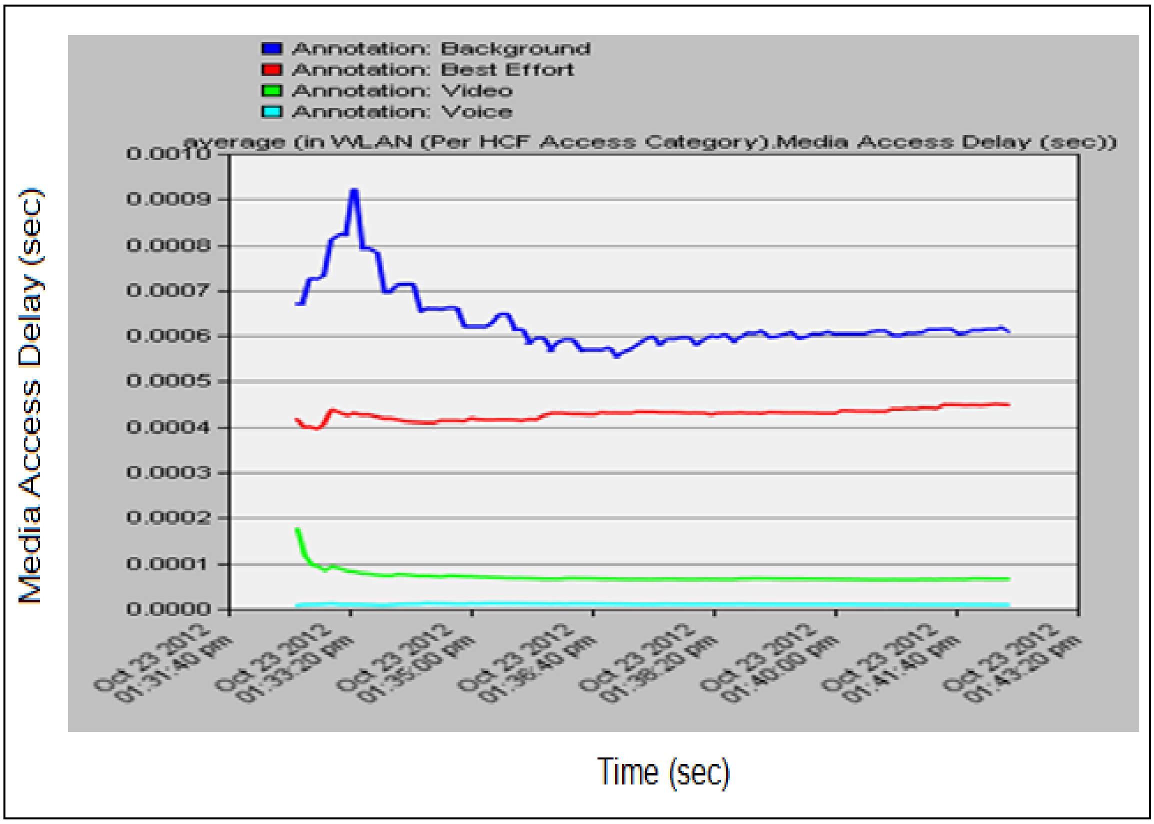


Figure 5.13 Simulation results of media access delay for each access category

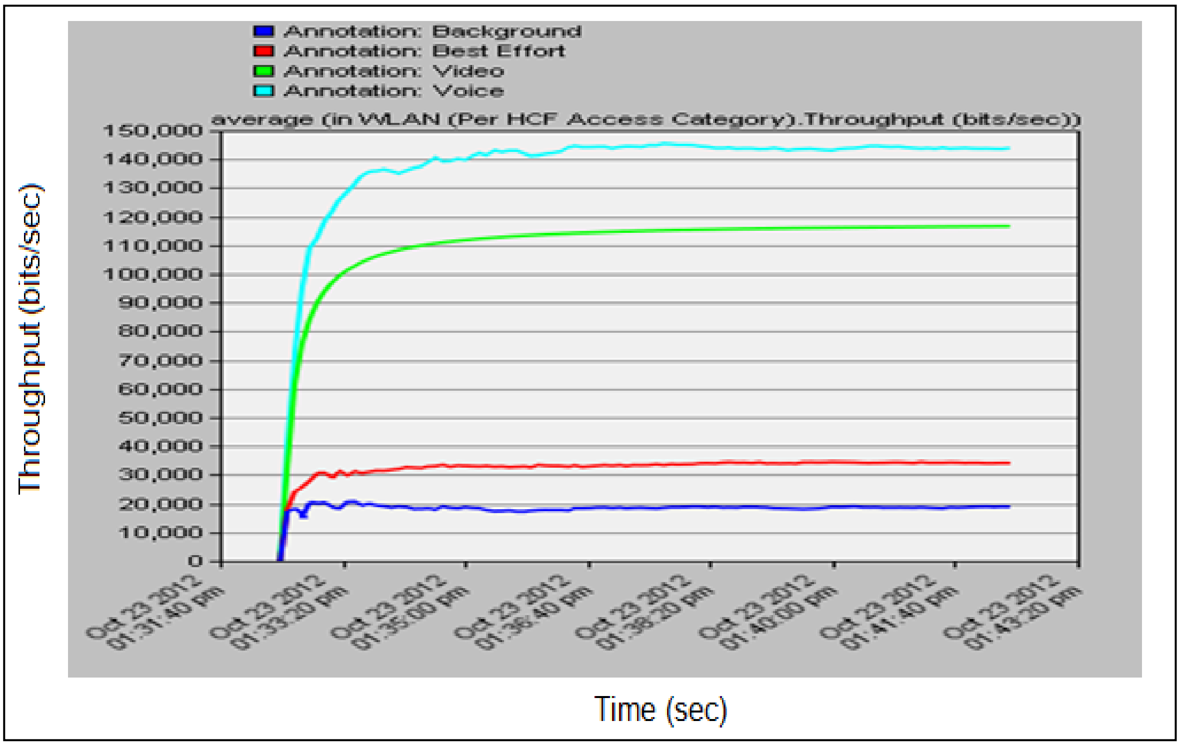


Figure 5.14 Simulation results of throughput for each access category

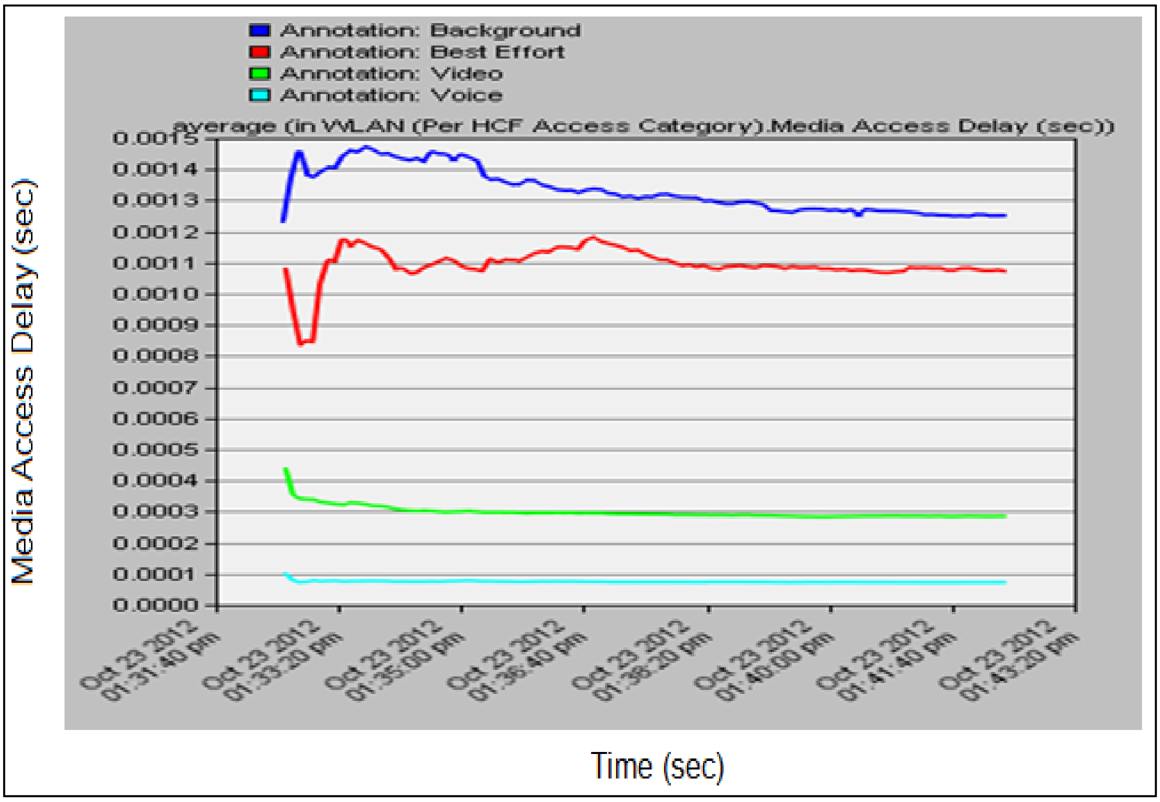


Figure 5.15 Simulation results of media access delay for each access category

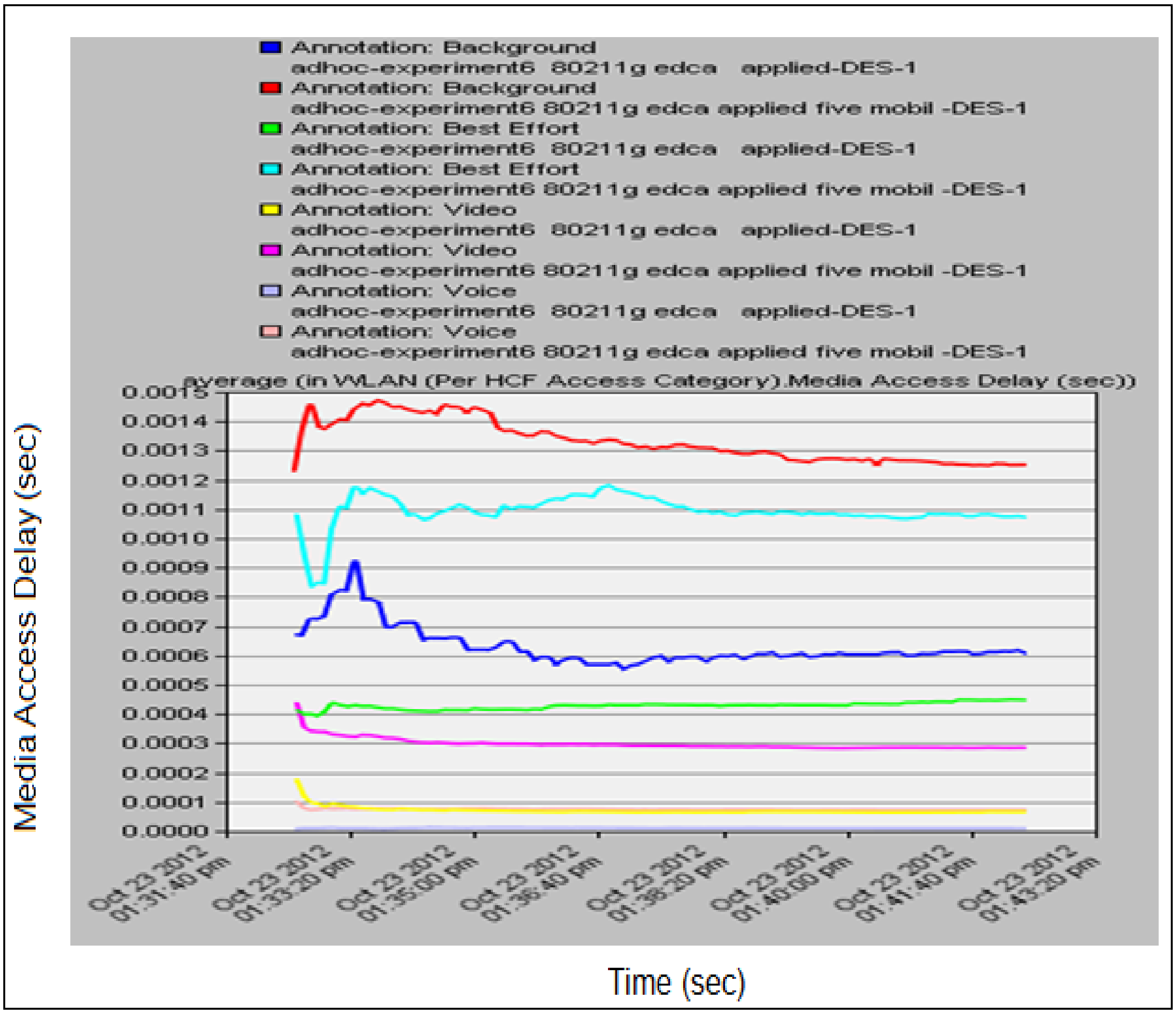


Figure 5.16 Simulation results of media access delay for each access category and number of user

The network throughput decreases when the number of vehicle increases as shown in Figure 5.17 [20].

802.11p protocol having problems when the number of vehicles increases,because the packet communication becomes more agressive.So , using EDCA is one of the method which prevent contention [20].

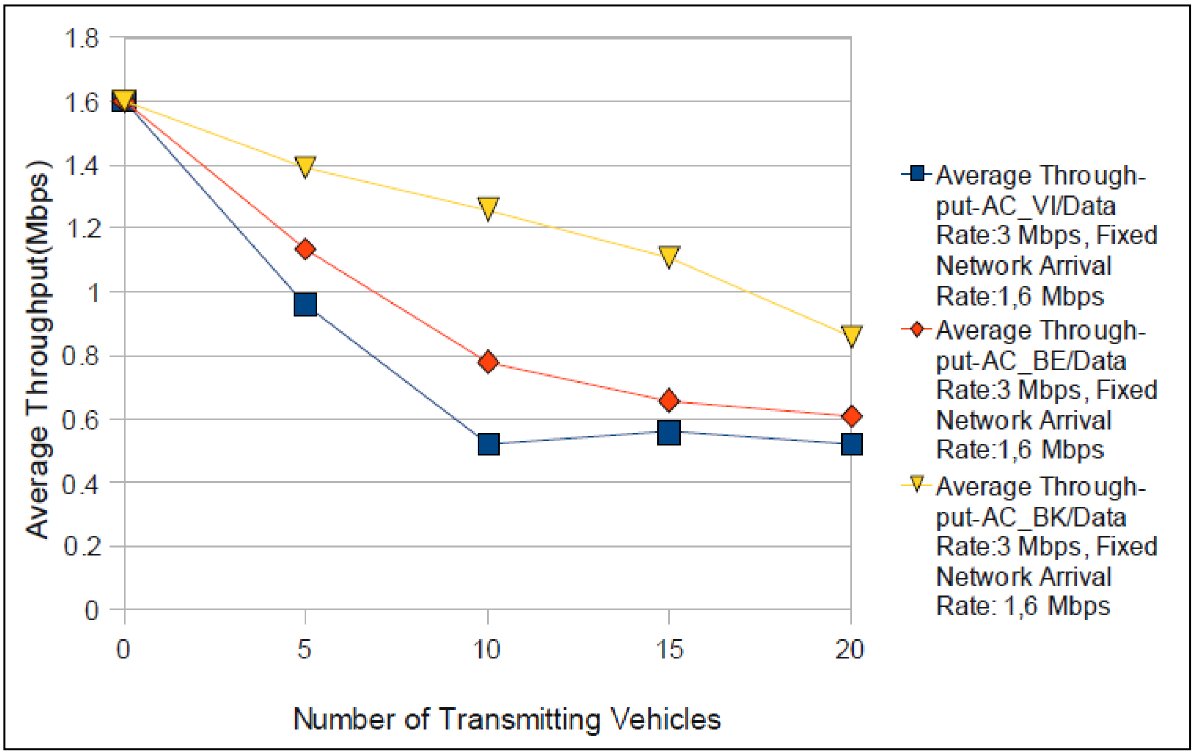


Figure 5.17 Simulation results of throughput on number of transmitting vehicles[20]

This study shows us that EDCA affect traffic flow per given priority. Scheduling priority with EDCA technique is focused by using NCTUNs simulation tool in [20].

In this thesis, we focus on scheduling priority with EDCA technique by using OPNET simulation tool instead of NCTUNs simulation tool.

5.3 Simulation of Used Techniques of Heterogeneous Wireless Systems

The techniques of modulation and traffic are simulated to analyze performance of heterogeneous wireless system with relay stations by using OPNET.

5.3.1 Simulation of modulation techniques

Uplink SINR in QAM modulation techniques is more than QPSK per Figure 5.18. So, that QAM modulation techniques provide more throughput than others. On the other hand, QPSK provide more range than QAM modulation techniques. Due to their different use case, adaptive modulation techniques is the best one. It makes a decision based on SINR.

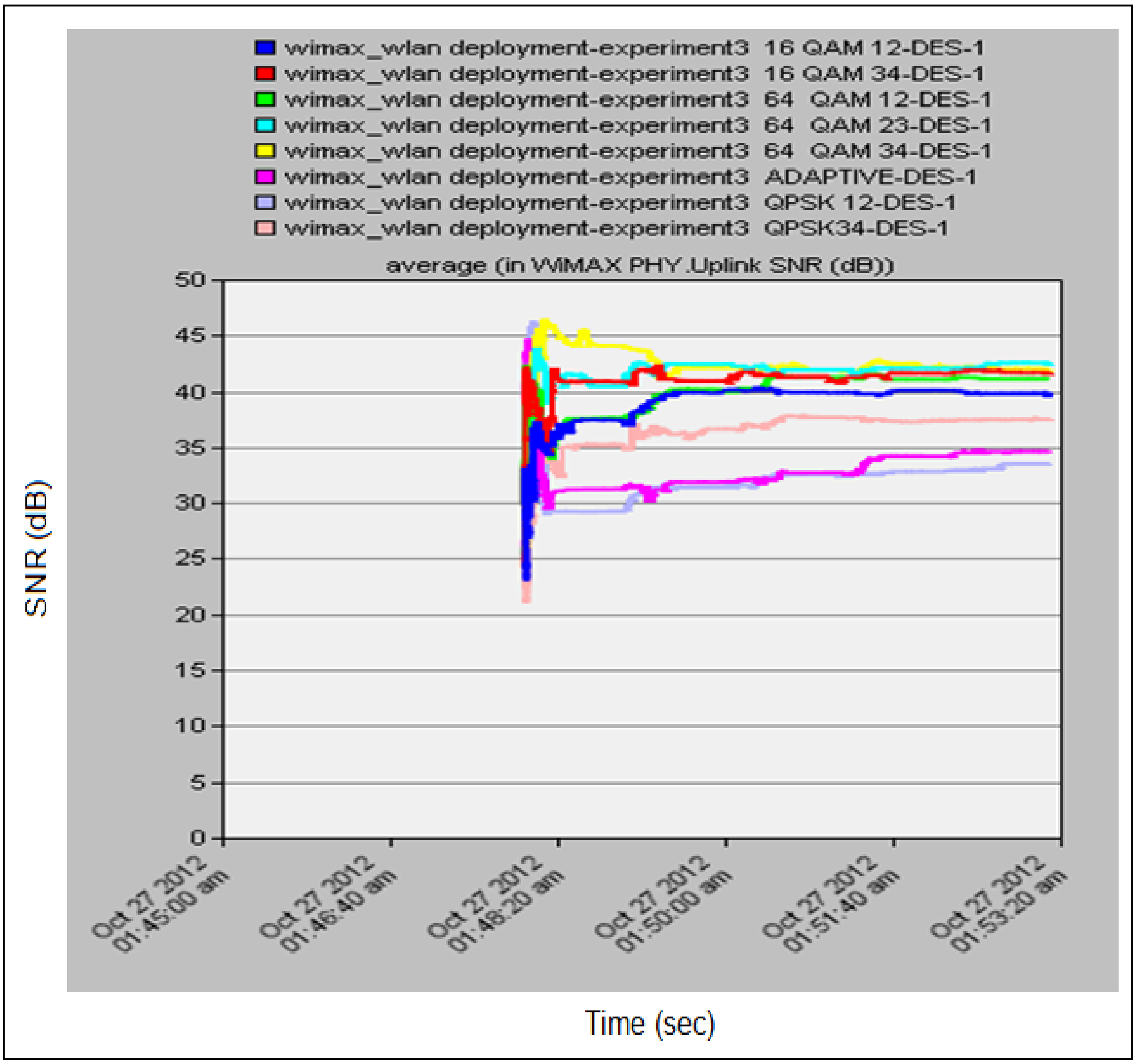


Figure 5.18 Simulation results of SNR for each modulation and coding technique

5.3.2 Simulation of traffic

The performance of having 3 to 8 WiFi user connecting to a single Access Point (AP) is simulated and analyzed. In this case, network traffic is observed by increasing WiFi user. As the number of WiFi users increase from 3 to 8, the traffic sent increases at the same ratio for each HTTP and FTP application case as shown in Figure 5.19 and 5.20, respectively.

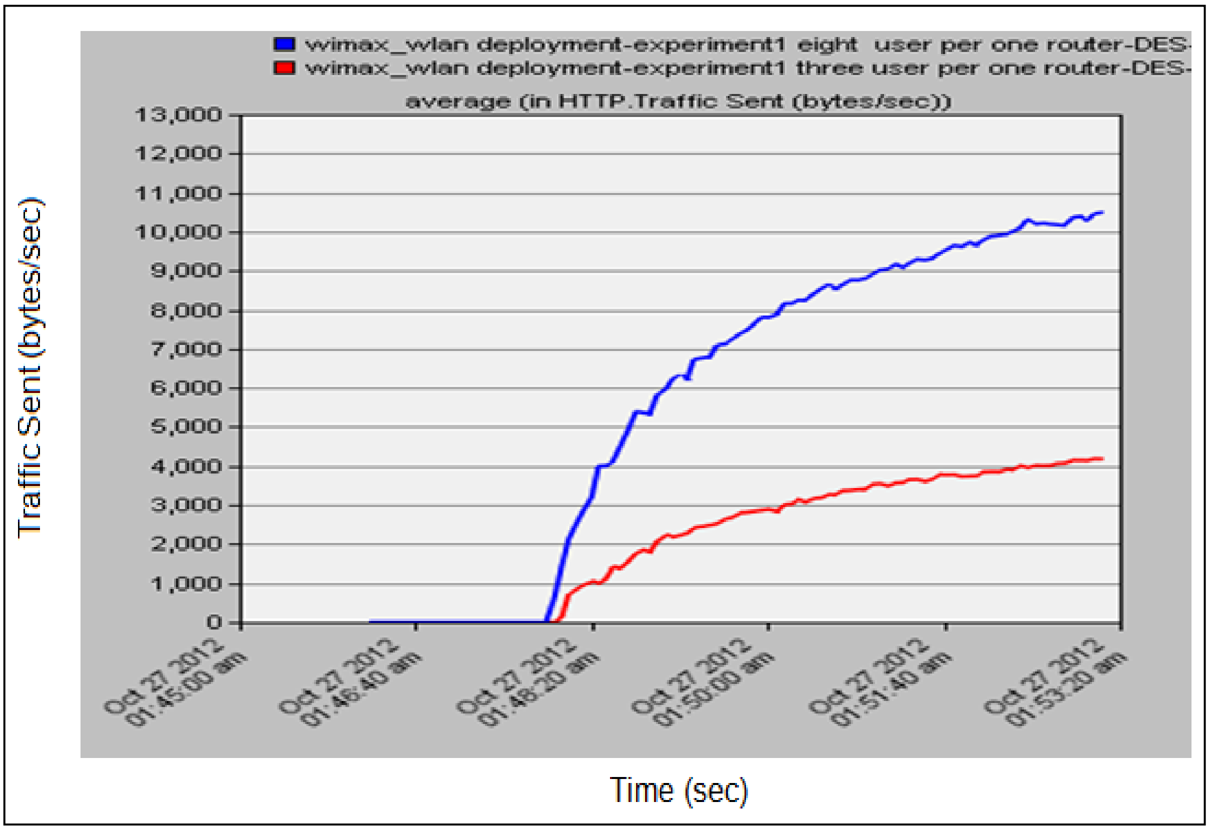


Figure 5.19 Simulation results of sent traffic in HTTP for 3 and 8 users

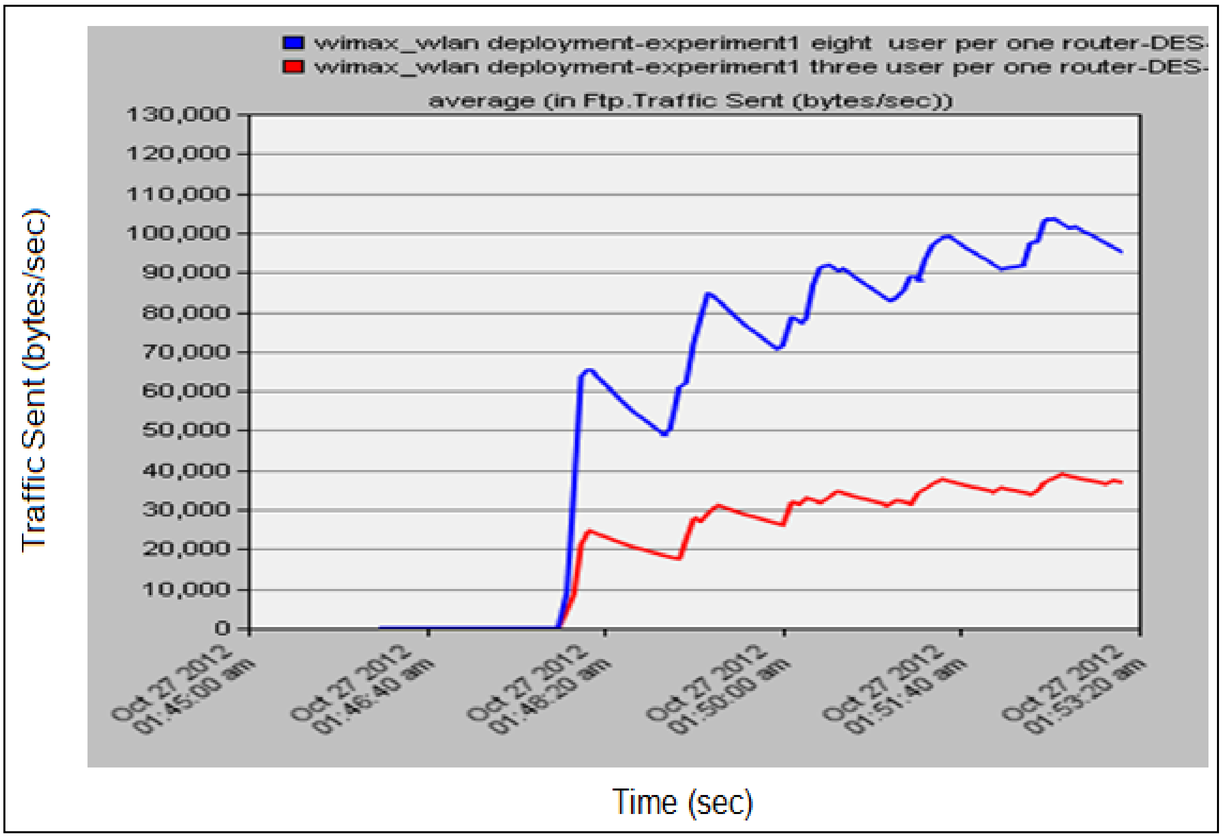


Figure 5.20 Simulation results of sent traffic in FTP for 3 and 8 users

5.4 Simulation of Protocols

Firstly, high resolution video is selected from OPNET application configuration node to create traffic flows as shown in Table 5.3

Table 5.3 Simulation setup parameters

Attributes	**Simulation**
Application	high/low resolution video
Frame interarrival time information	15 frames/sec(high resolutıon video)
Frame size information (bytes)	128 *240 pixels(high resolution video)
Frame interarrival time information	10 frames/sec(low resolutıon video)
Frame size information (bytes)	128 *120 pixel(low resolution video)
Type of service	best effort
Transport protocol	udp
Network scale	campus ,2000 * 2000 meters
Simulation run time	200 seconds

Scenario 1: fixed node

Static scenario is conducted in the campus. Two access point were placed face to face in order to establish line of sight communication with 36 meters as shown in Table 5.4 [25].

Table 5.4 Simulation setup parameters

Attributes	**Mobile Station**
Mobile node Speed	0 km/h
Data rate (bps)	11 Mbps/54 Mbps/54 Mbps, respectively
Distance between access points	36 meters
Wireless Technology	802.11b/802.11g/802.11a,respectively

The 802a and 802.11g throughputs are the same as shown Figure 5.21. Because their data rates are the same as 54Mbps and also delay time is so small enough to be neglected. But, 802.11b througput is less than the others per Figure 5.21.

Unfortunately, delay increment has been observed in this case. Load and throughput are the same for 802.11a and 802.11g as shown in Figure 5.22. It shows us that our parameters are selected correctly.

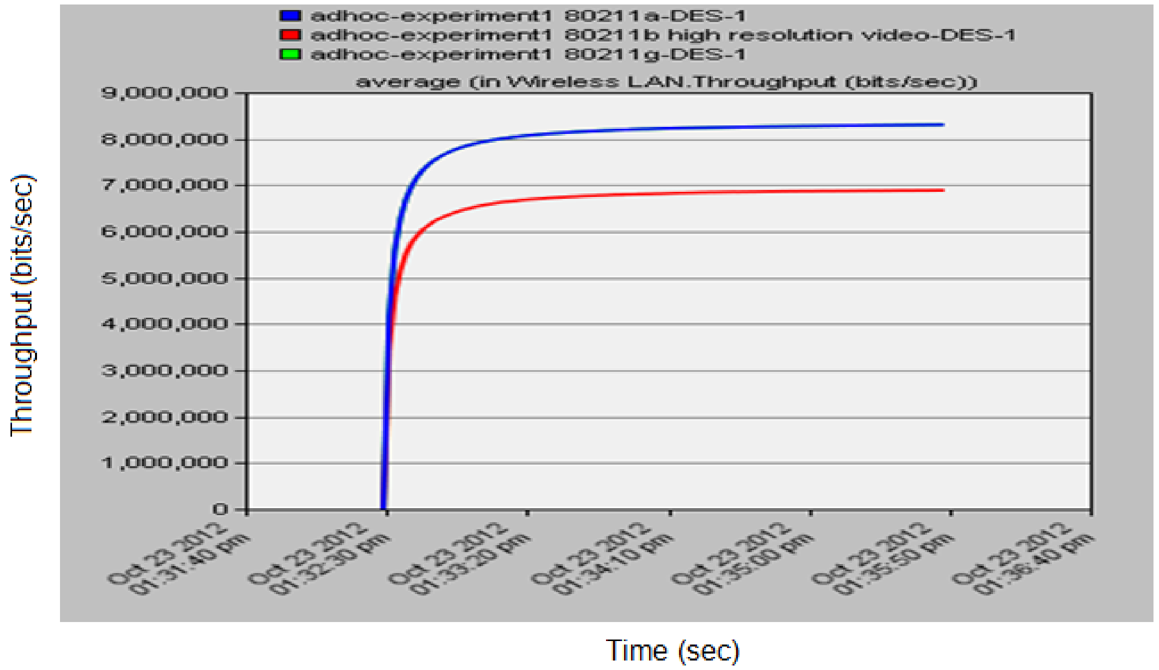


Figure 5.21 Simulation results of throughput in 802.11a/b/g protocols

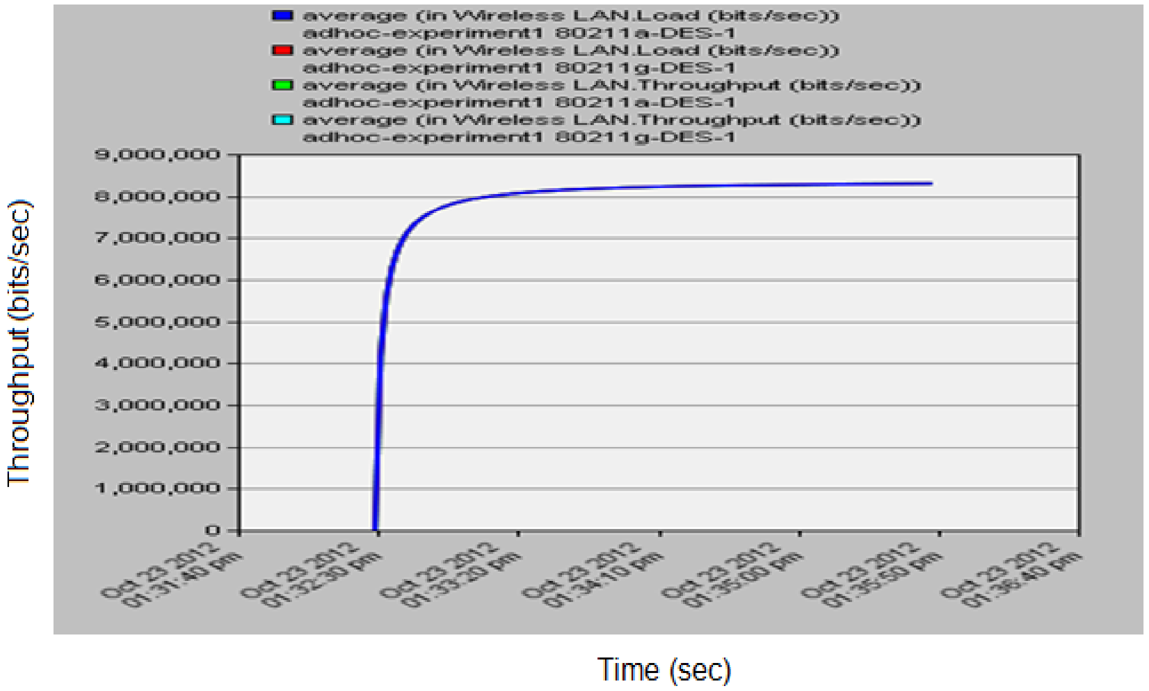


Figure 5.22 Simulation results of load and throughput   in 802.11a/g protocols

But, we couldn’t describe same thing for 802.11b protocol per Figure 5.23. Because, the throughput is lower than the load. This result is only explained by delay.

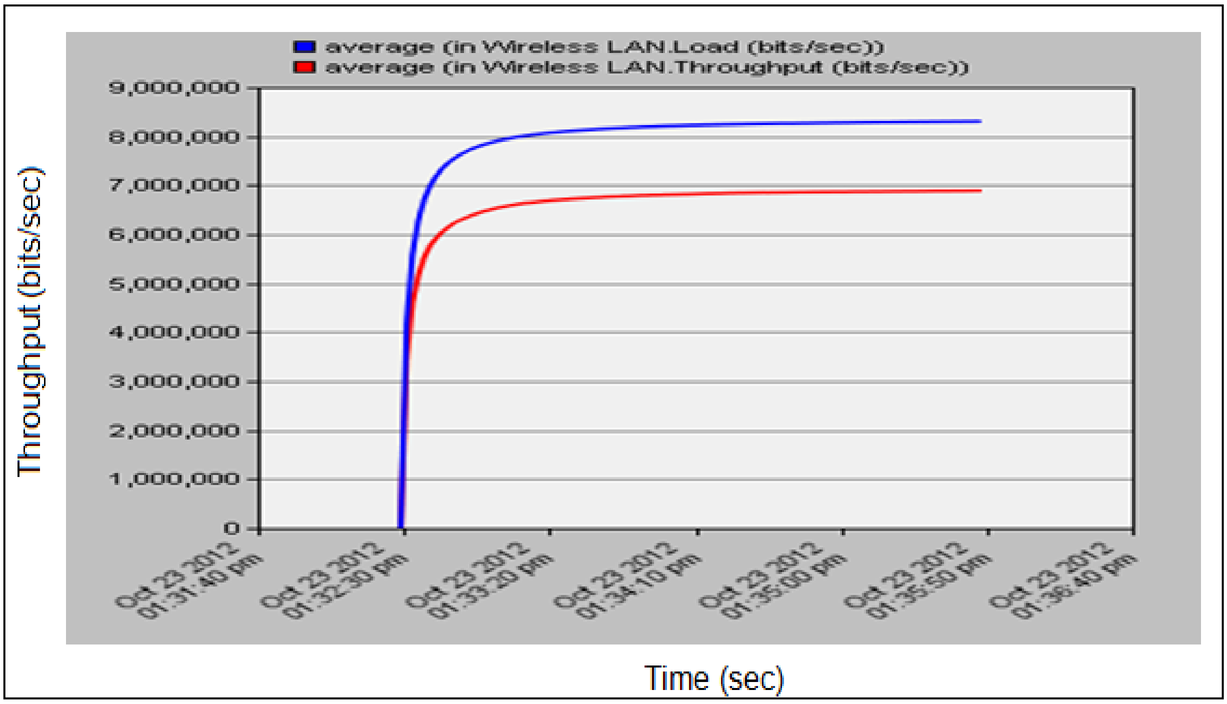


Figure 5.23 Simulation results of load and throughput in 802.11b

Figure 5.24 is based on delay-time axis for 802.11a, 802.11b, 802.11g protocols. Delay increment has been observed for only 802.11b. Because, wireless LAN mac layer discarded some packets due to insufficient buffer capacity. This may lead to application data loss, higher layer packet retransmission.

At this point, remedial actions are that reduce network load, use a higher wireless LAN data rate and increase buffer capacity. So, we will review again network load, data rate and buffer capacity to minimize delay.

There is no buffer capacity suffering per Figure 5.25 for 802a, 802.11b and 802.11g protocols.

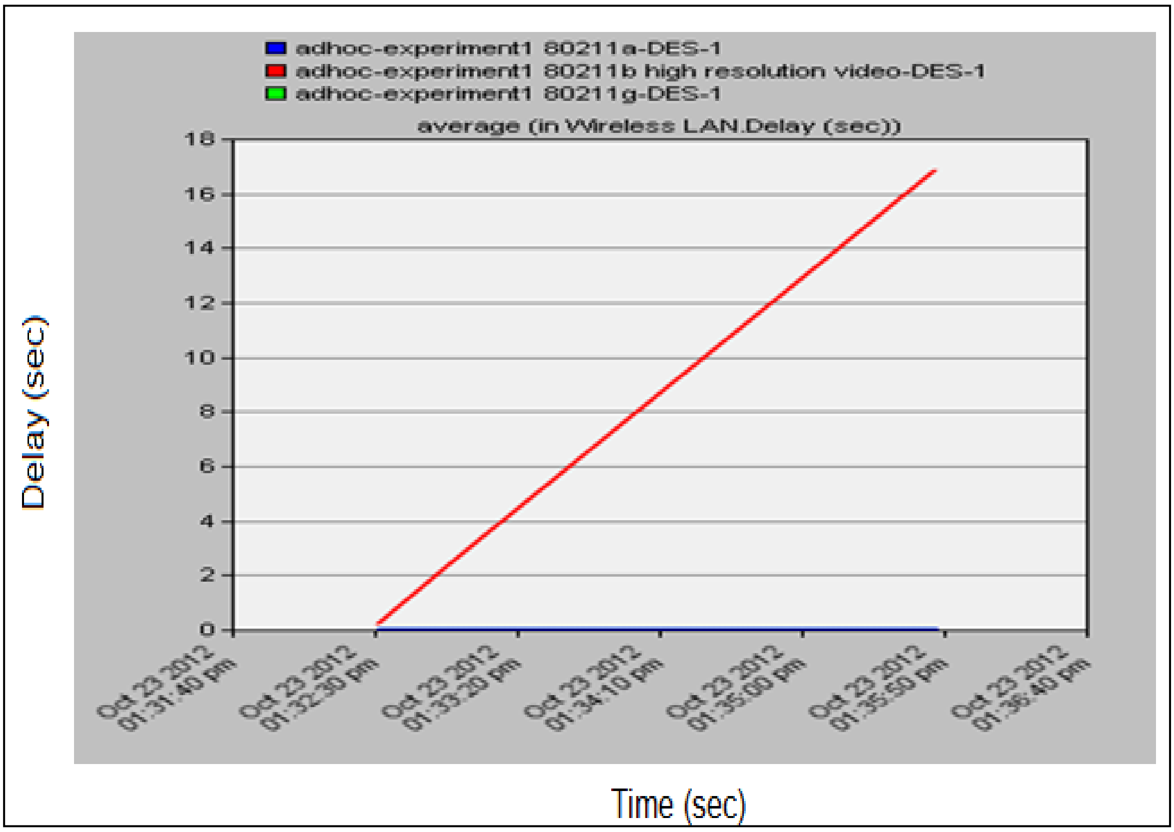


Figure 5.24 Simulation results of delay in 802.11a/b/g

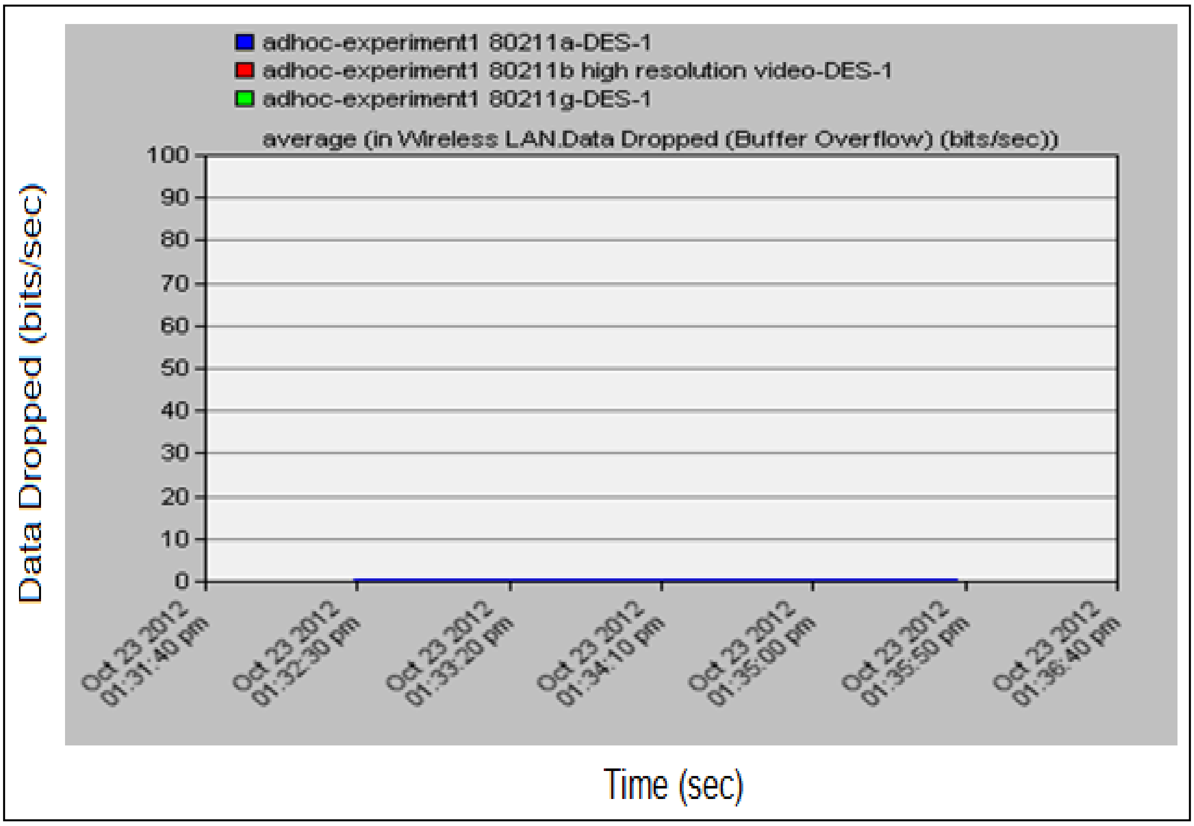


Figure 5.25 Simulation results of dropped data in 802.11a/b/g

Used data rate has been choosen at max value as 11 Mbps for 802.11b. Then, the last choice is that reducing network load. So, video conferencing parameters are updated from high resolution video to low resolution video to reduce network load. After some enhancements, throughput, delay, data dropped (buffer overflow) graphs are extracted again using OPNET. While the peak throughput is 8.482.752 bit/sec for 802.11a, peak throughput 8.464.329 bits/sec for 802.11g and 2.797.440 bits/sec for 802.11b, low resolution video. Also, there is no buffer capacity suffering per Figure 5.27.

As distance from the access point increases, 802.11 based products provide reduced data rates to maintain connectivity. The 802.11g standard has the same propagation characteristic as 802.11b, because it transmits in the identical 2.4 GHz frequency band. Because 802.11b and 802.11g share the same propagation characteristics, implementations provide roughly the same maximum range at the same data rate.

Because 5 GHz radio signals do not propagate as well as 2.4 GHz radio signals, the 802.11a range is limited compared to the 802.11b or 802.11g range.

So, scenario we will focus on 802.11b and 802.11g protocols.

But, the other topic is that using same frequency band brings interference with each other. The throughput and packet size are illustrated as shown in [25], Figure 5.29 for 802.11b and 802.11 g protocol [25].

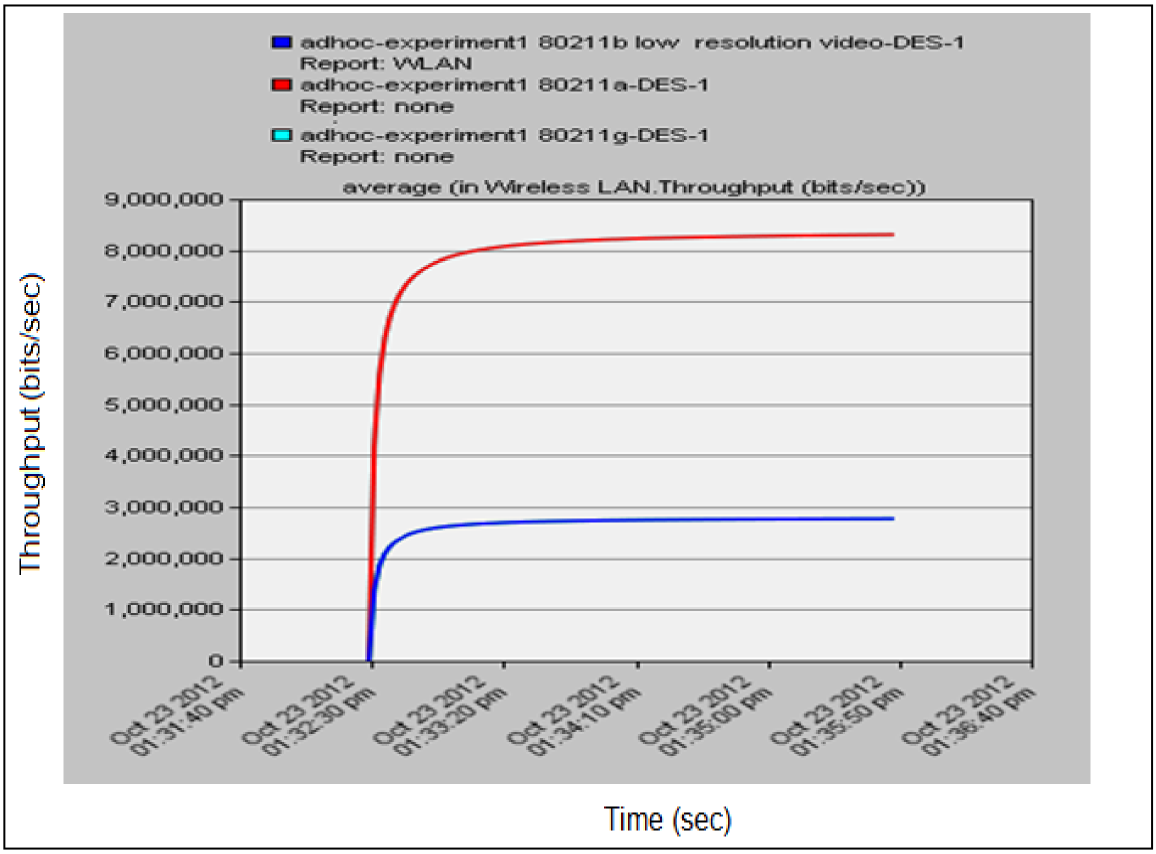


Figure 5.26 Simulation results of throughput in 802.11a/b/g after enhancement

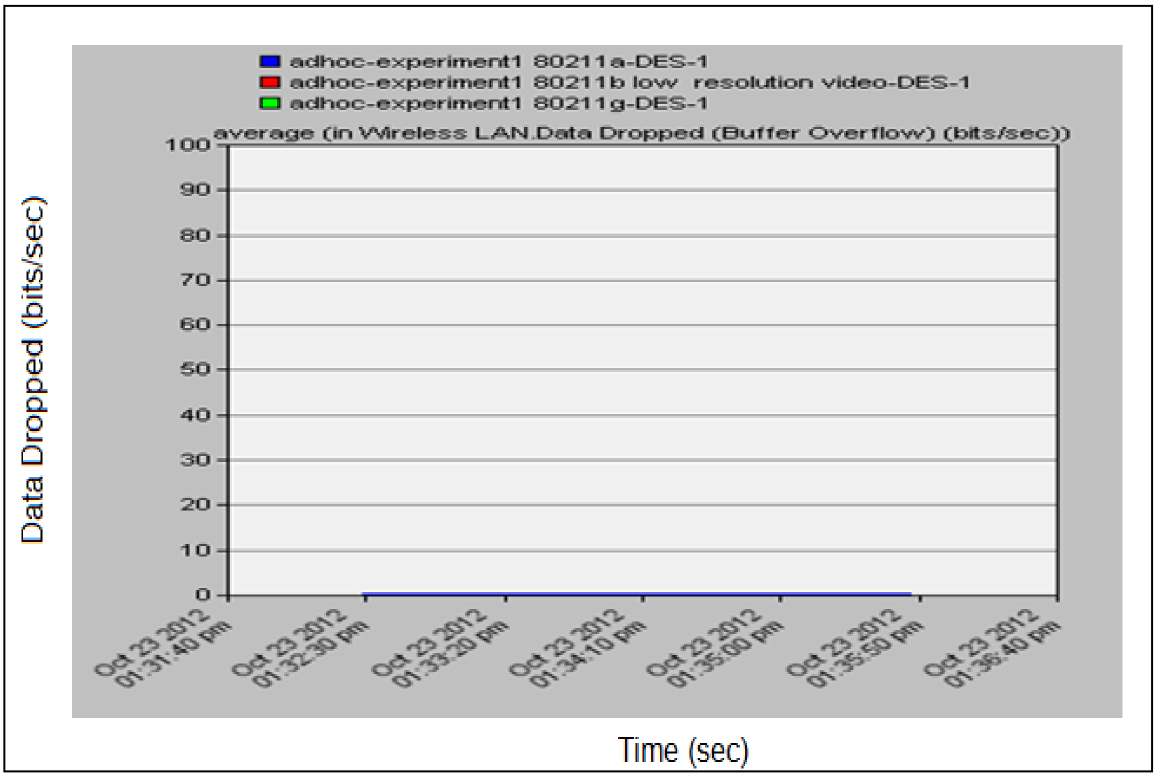


Figure 5.27 Simulation results of dropped data in 802.11a/b/g after enhancemen

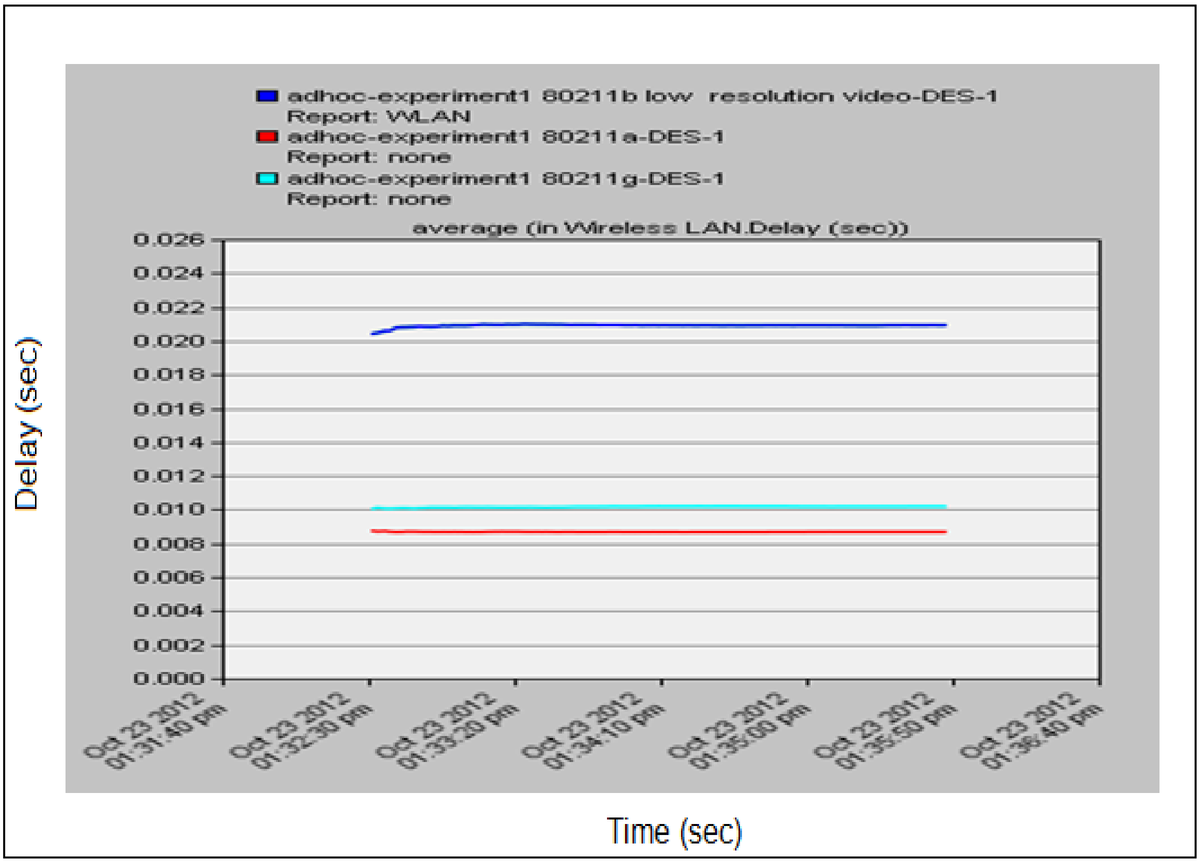


Figure 5.28 Simulation results of delay in 802.11a/b/g after enhancement

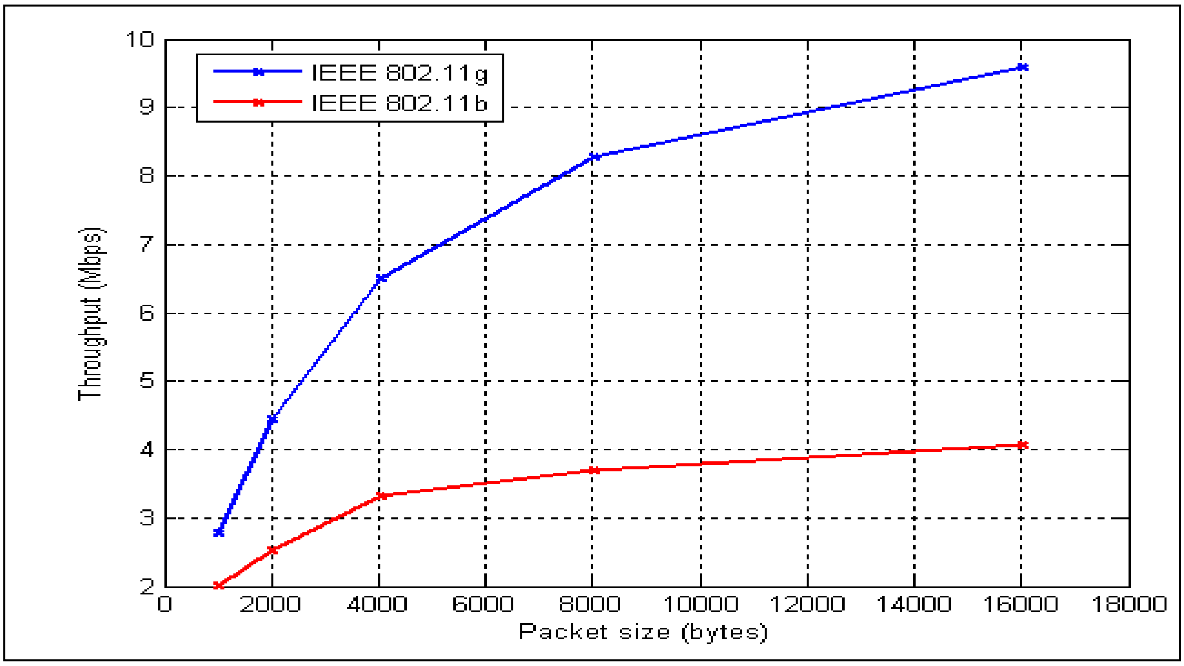


Figure 5.29 Average throughput for Experiment 1 over UDP using IEEE 802.11b/g in terms of package size

Scenario 2: mobile node with low speed 10 km/h

In this scenario, our aim is that establish communication when one access point is fixed, the another one is mobile with low speed 10km/h [25].

Table 5.5 Simulation setup parameters

Attributes	**Parameters**
Mobil node speed	10 km/h
Data rate	11 Mbps
Wireless technology	802.11b (direct sequence)
Simulation time	540 second
Distance	1500 meters

1500 meters distance takes approximately 9 minutes by 10 km/h velocity. This mobility scenario is compared with previous scenario which is fixed 802.11b, low resolution video to observe some changing on graphs. Although max throughput is 2797000 bits/sec to 1111 km, our wlan is experiencing throughput dropping between 1111 and 1194 km and then the throughput is zero between 1194 and 1500 km per below Figure 5.30.

For both standards, throughput is decreasing along the road because of increasing distance, changing in SINR at the receiver due unsuccessful transmission attempts.

Transmission failure is taken from the ‘’data dropped (wlan retry threshold)-time graph’’ extracted from OPNET statistics. The failure occurs when the destination node has moved beyond radio range of the transmitter. So, all packets dropped due to the destination node out of range of the transmitter.

After unsuccessful transmission attempts, such packets are discarded by WLAN and recorded under the data dropped -WLAN Retry Threshold Exceeded statistic.

When the destination node has moved beyond radio range of the transmitter, retransmission attempts and media access delay time increase by the time.

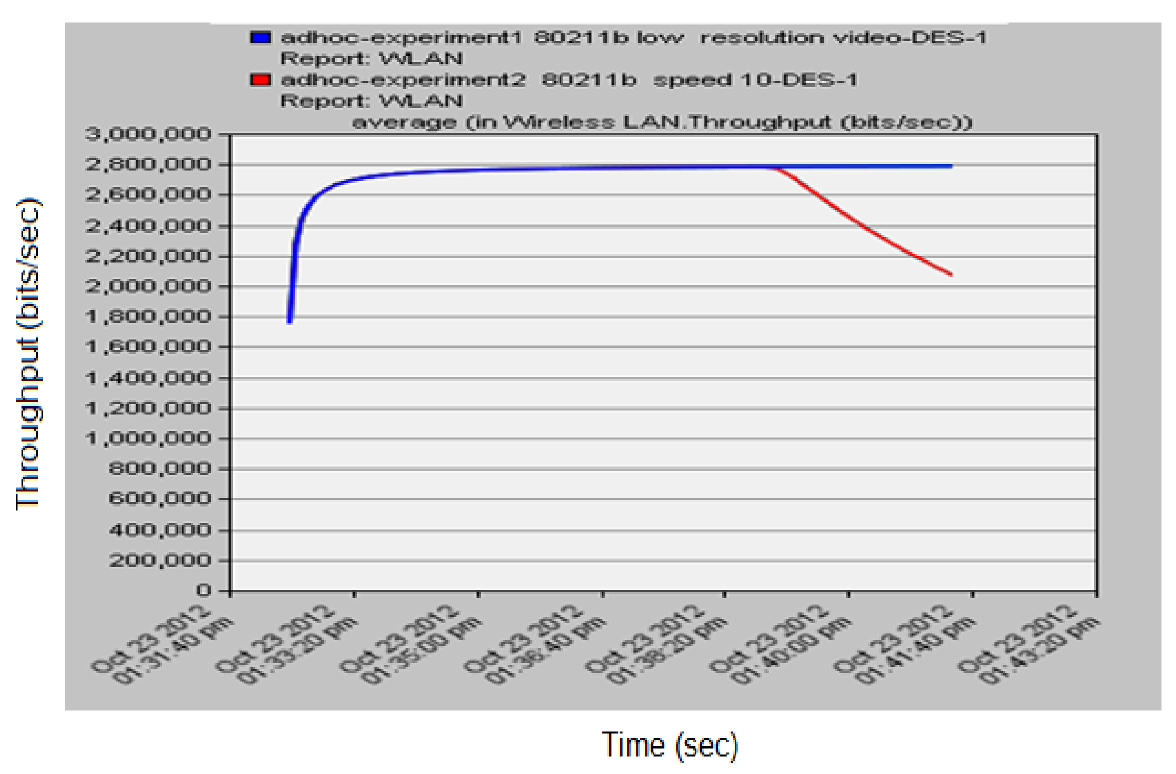


Figure 5.30 Simulation results of throughput in 802.11b fixed and mobile case

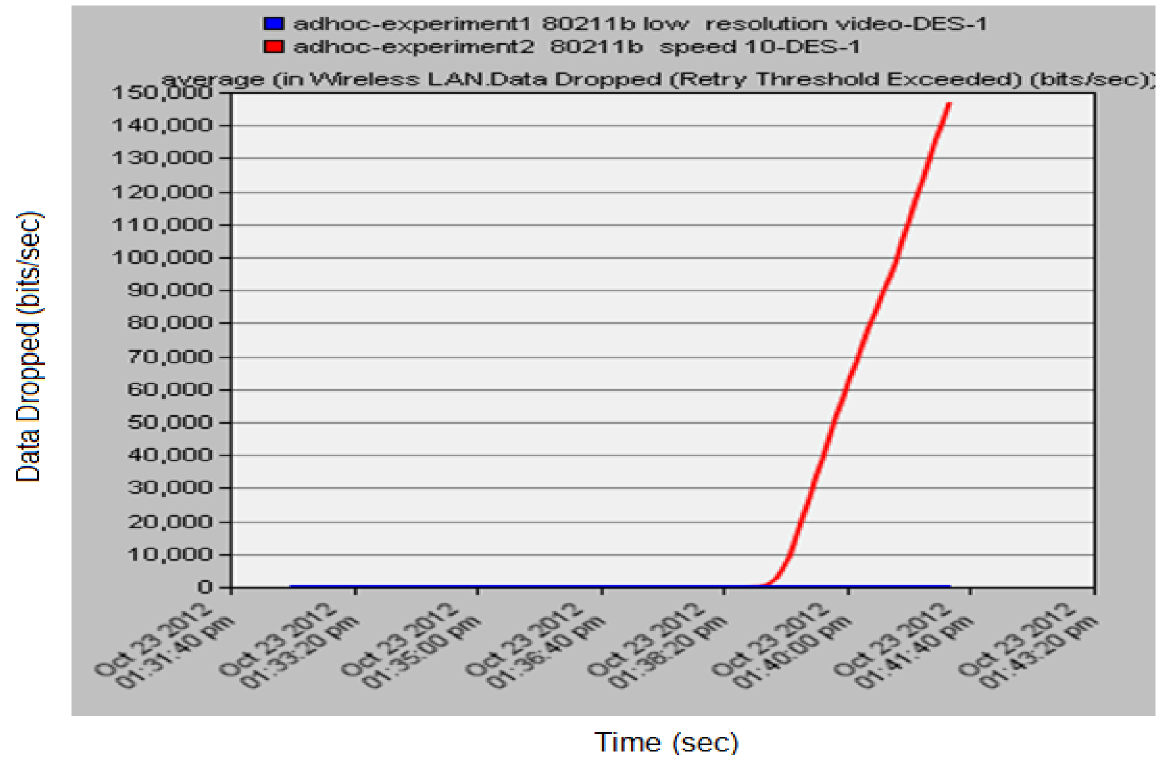


Figure 5.31 Simulation results of dropped data dropped in 802.11bfor fixed and mobile case

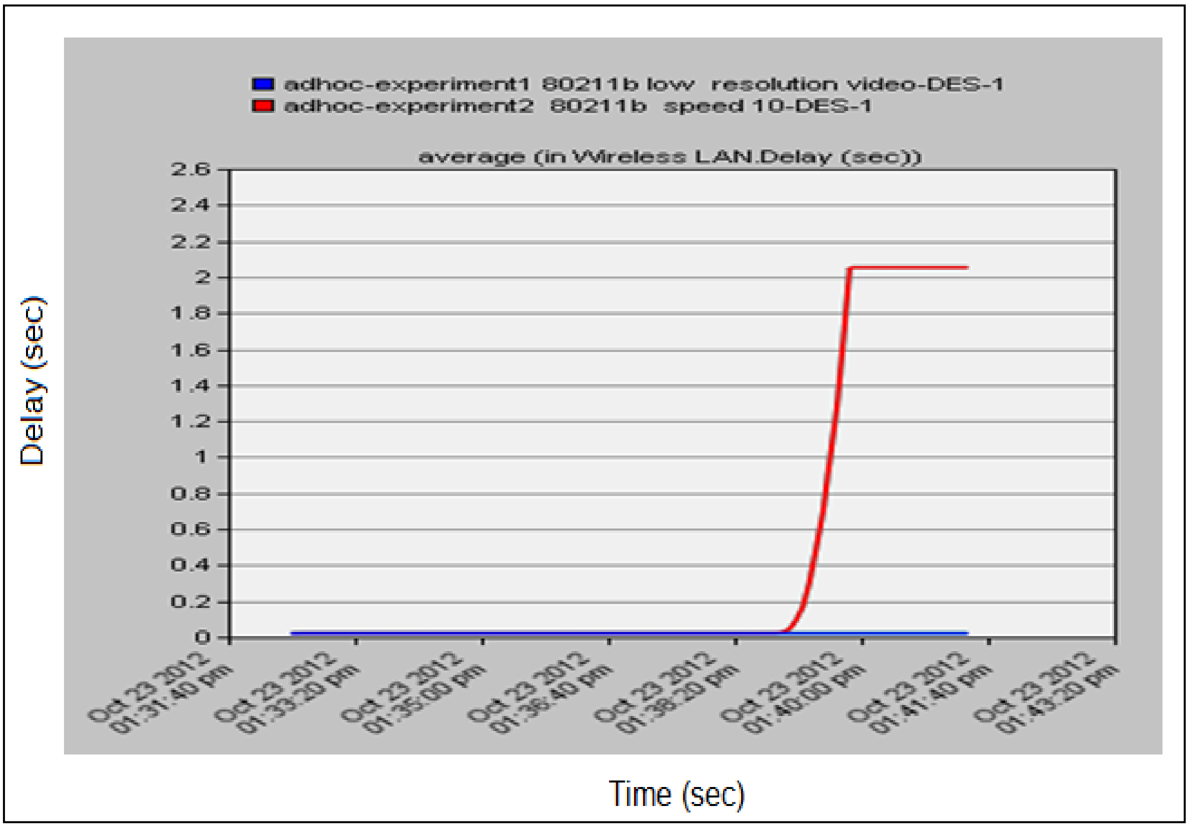


Figure 5.32 Simulation results of delay in 802.11b for fixed and mobile case

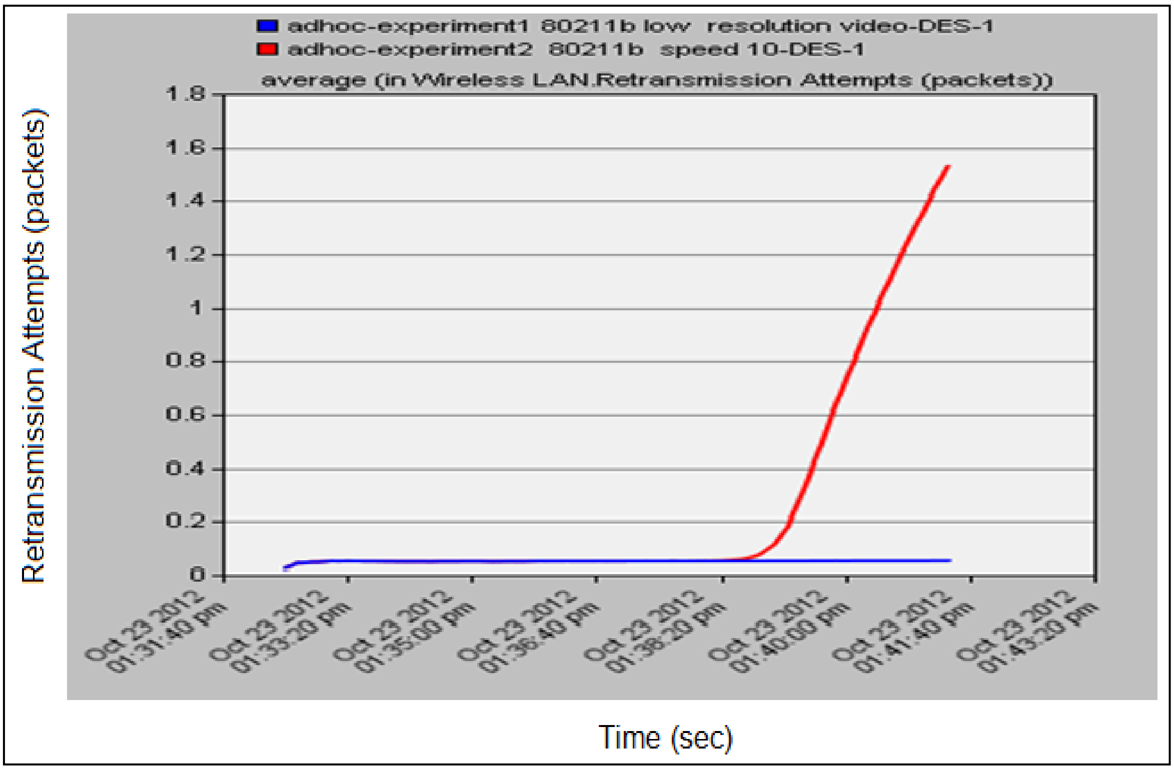


Figure 5.33 Simulation results of retransmission attempts in 802.11b for fixed and mobile case

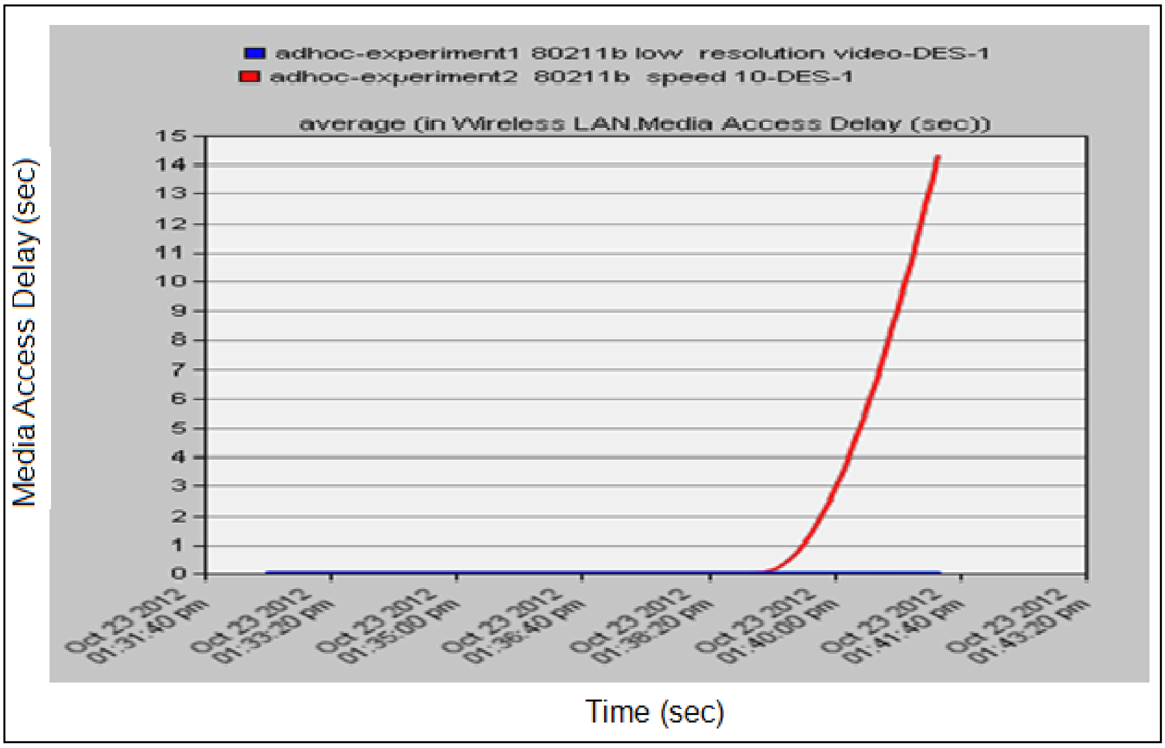


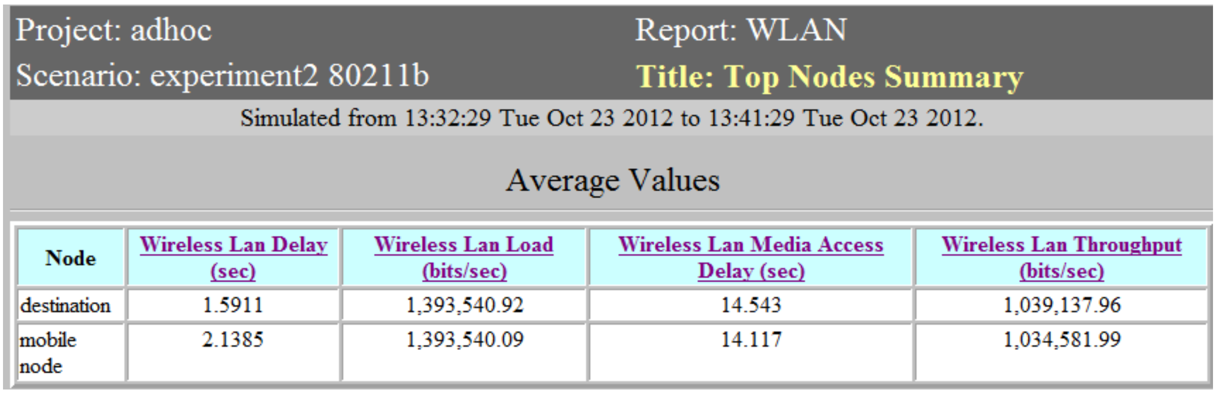
Figure 5.34 Simulation of media access delay in 802.11b for fixed and mobile case

Below statisctics collected in addition to above graphs to compare mobility scenario 2 and fixed scenario 1 statistically. First statistics is for mobility scenario 2, then second statistics is for fixed scenario 1. Network load are the same for both scenarios. Result differs at delay and throughput as shown in Table 5.8 and 5.9 .

In [25], communication without package losses only occured in a short range between 1180-1190m. At that points where line of sight condition communication is satisfied, throughput around 3 Mbps is achieved for 16024 byte packages as shown in Fig. 5.35.

Different from [25] scenario, we assume that line of sight condition communication is satisfied at all points in our scenario.

Table 5.6 Simulation results as statistics in mobility scenario 2



Project: adhoc
Scenario: experiment2 80211b

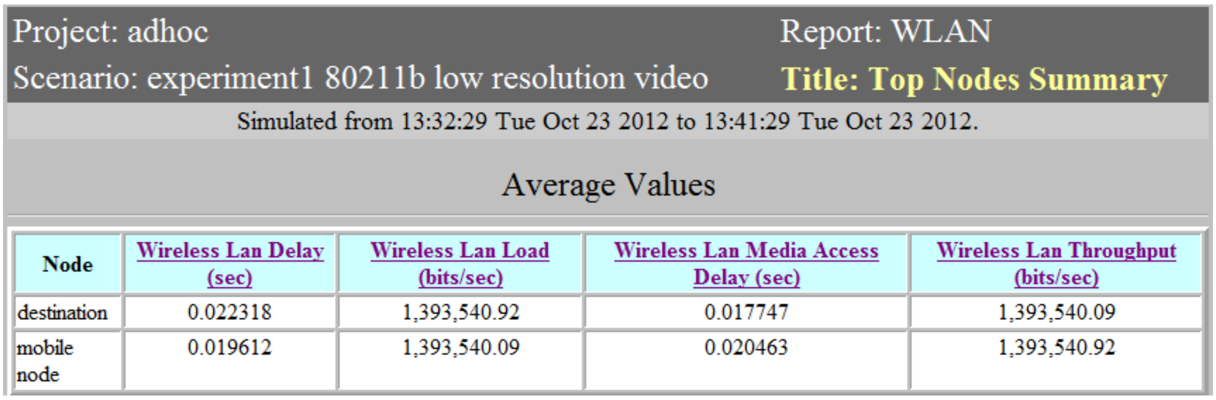
Report: WLAN
Title: Top Nodes Summary

Simulated from 13:32:29 Tue Oct 23 2012 to 13:41:29 Tue Oct 23 2012.

Average Values

Node	Wireless Lan Delay (sec)	Wireless Lan Load (bits/sec)	Wireless Lan Media Access Delay (sec)	Wireless Lan Throughput (bits/sec)
destination	1.5911	1,393,540.92	14.543	1,039,137.96
mobile node	2.1385	1,393,540.09	14.117	1,034,581.99

Table 5.7 Simulation results as statistics in fixed scenario 1



Project: adhoc
Scenario: experiment1 80211b low resolution video

Report: WLAN
Title: Top Nodes Summary

Simulated from 13:32:29 Tue Oct 23 2012 to 13:41:29 Tue Oct 23 2012.

Average Values

Node	Wireless Lan Delay (sec)	Wireless Lan Load (bits/sec)	Wireless Lan Media Access Delay (sec)	Wireless Lan Throughput (bits/sec)
destination	0.022318	1,393,540.92	0.017747	1,393,540.09
mobile node	0.019612	1,393,540.09	0.020463	1,393,540.92

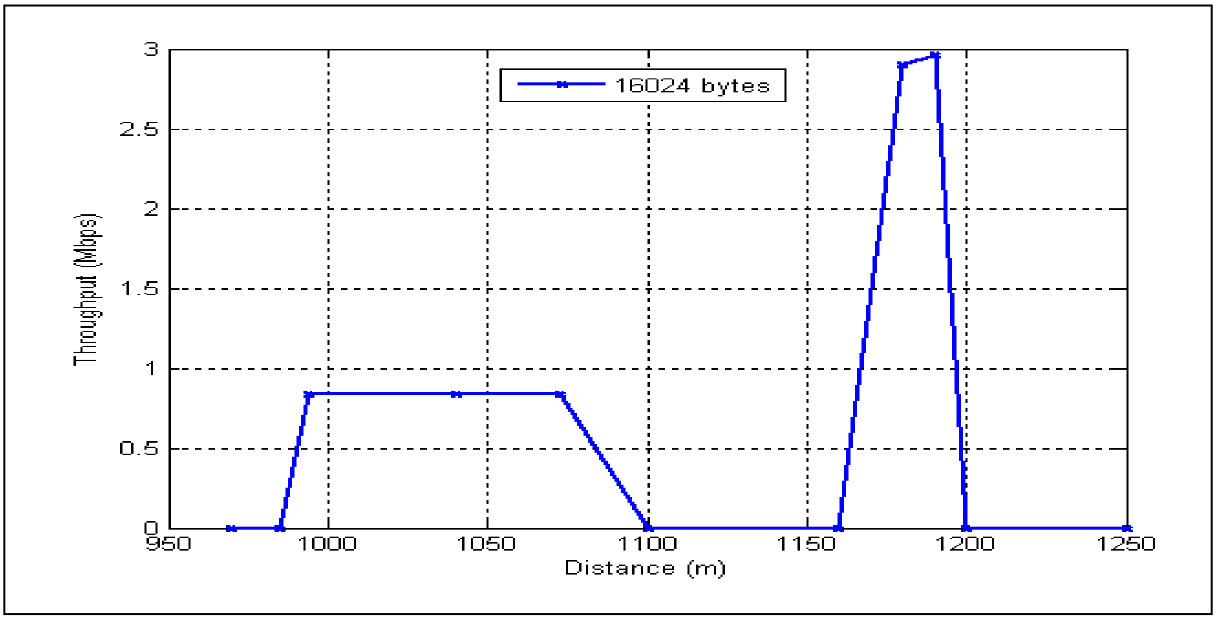


Figure 5.35 Average throughput for Experiment 2 over UDP using IEEE 802.11b while vehicle moving at 10 km/h

Scenario 3: mobile node with low speed 20 km/h

In this scenario, we focus on maximum performance that we can reach in long ranges when one access point is fixed, the another one is mobile with low 20 km/h speed. Different from scenario 2, we will measure long range performance of 802.11g for different data range also with comparing by 802.11b [25]. All parameters are shown in Table 5.8.

Table 5.8: simulation setup parameters

Attributes	Parameters
Mobile node speed	20 km/h
Data rate	11 Mbps / 54 Mbps
Wireless technology	802.11b (direct sequence) 802.11g (11 Mbps and 54 Mbps)
Simulation time	360 seconds
Distance	1986 meters

Although low video conferencing parameters are used for 802.11b, high video conferencing parameters are used for 802.11g. Data dropping has been observed in the same range between 993 and 1155 meters for 802.11b and 802.11 g network with 11Mbps data rate and after 1155 meters, throughput is zero. But, data dropping has been observed between 300 and 385 meters for 802.11g with data rate as 54Mbps and, then after 385 meters, throughput is zero for high data rate. Following Figures illustrate that 802.11b with data rate 11 Mbps is more range than the others. So, The higher data rates supported by 802.11g result in shorter range than the range supported by the maximum 802.11b data rate.

Transmission failure is taken from the ‘’media access delay ‘’and ‘’wlan retry threshold’’ exceeded OPNET statistics for 802.11g protocol with 54 Mbps data rate, the failure occurs when the destination node has moved beyond radio range of the transmitter.Green line shows high data rate 802.11g protocol per Figure 5.37.

In [25], Figure 5.40 which shows that with distance more than 1240 meters where throughput decreased in this scenario

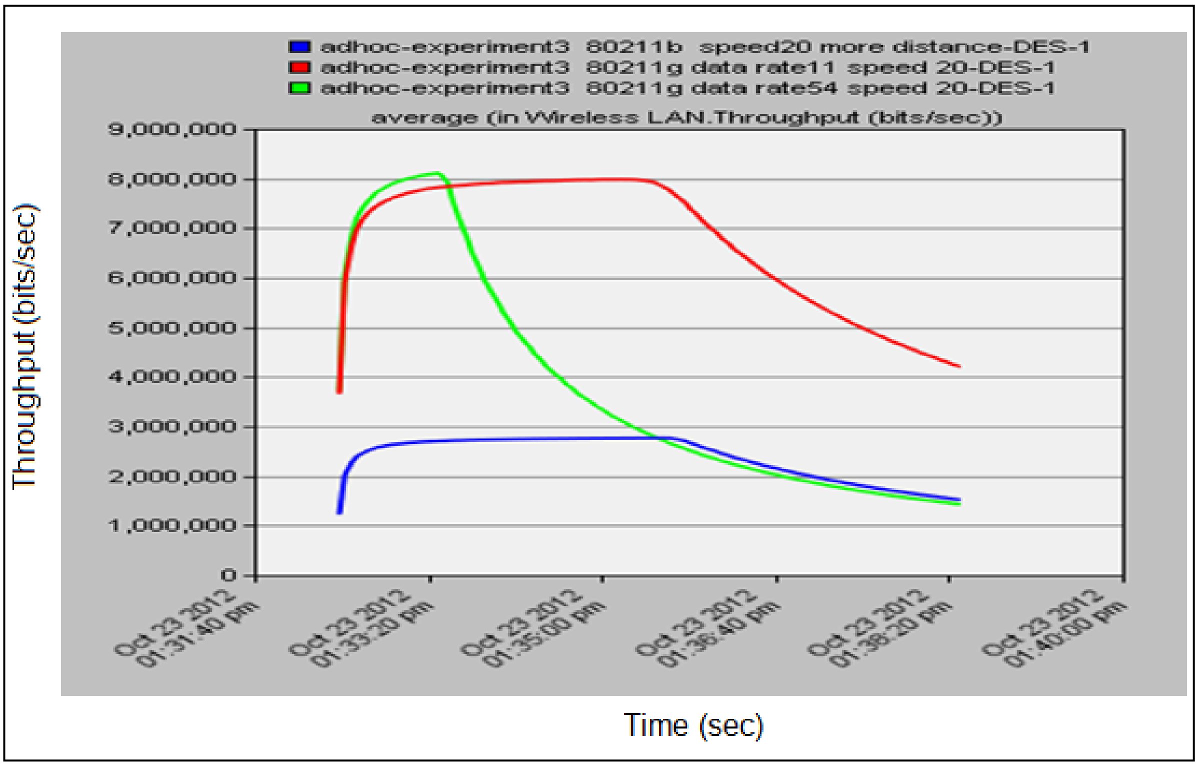


Figure 5.36 Simulation results of throughput in 802.11b(11Mbps) ,802.11g (11Mbps) and 802.11g (54Mbps)

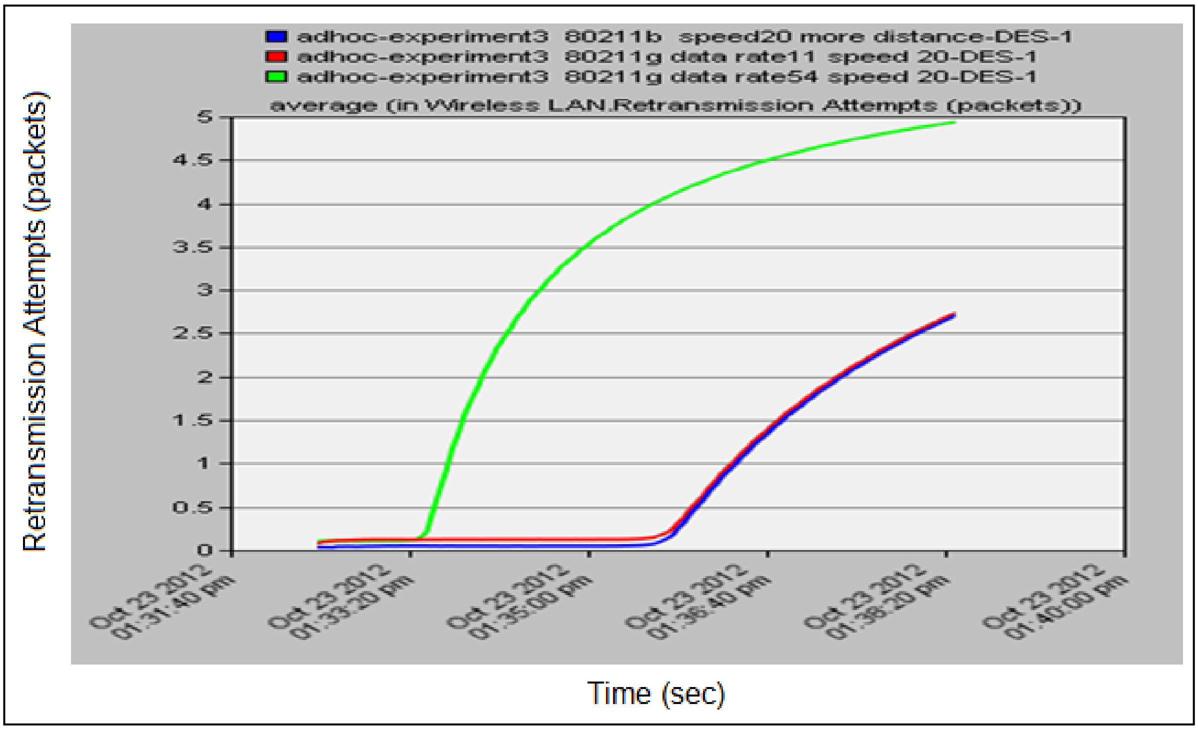


Figure 5.37 Simulation results of retransmission attempts in 802.11b (11Mbps) , 802.11g (11Mbps) and 802.11g (54Mbps)

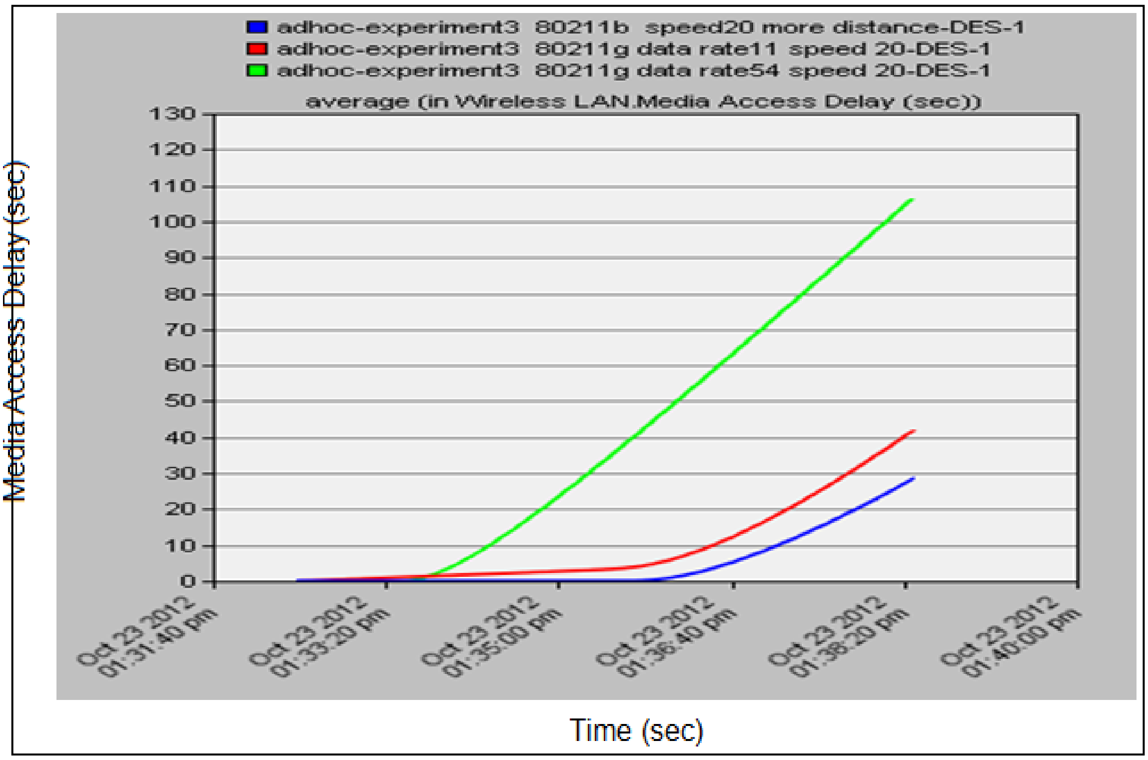


Figure 5.38 Simulation results of media access delay in 802.11b (11Mbps), 802.11g (11Mbps) and 802.11g (54Mbps)

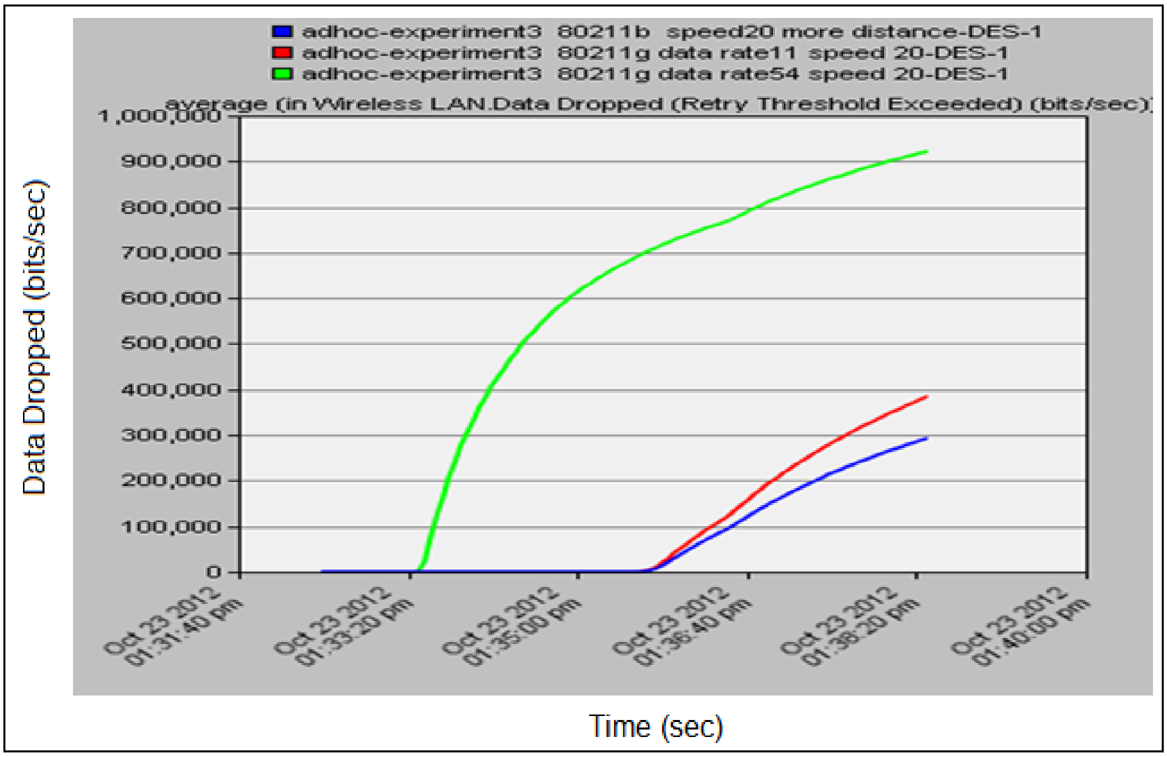


Figure 5.39 Simulation results of dropped data (retry threshold exceeded) in 802.11b(11Mbps) , 802.11g(11Mbps) and 802.11g(54Mbps)

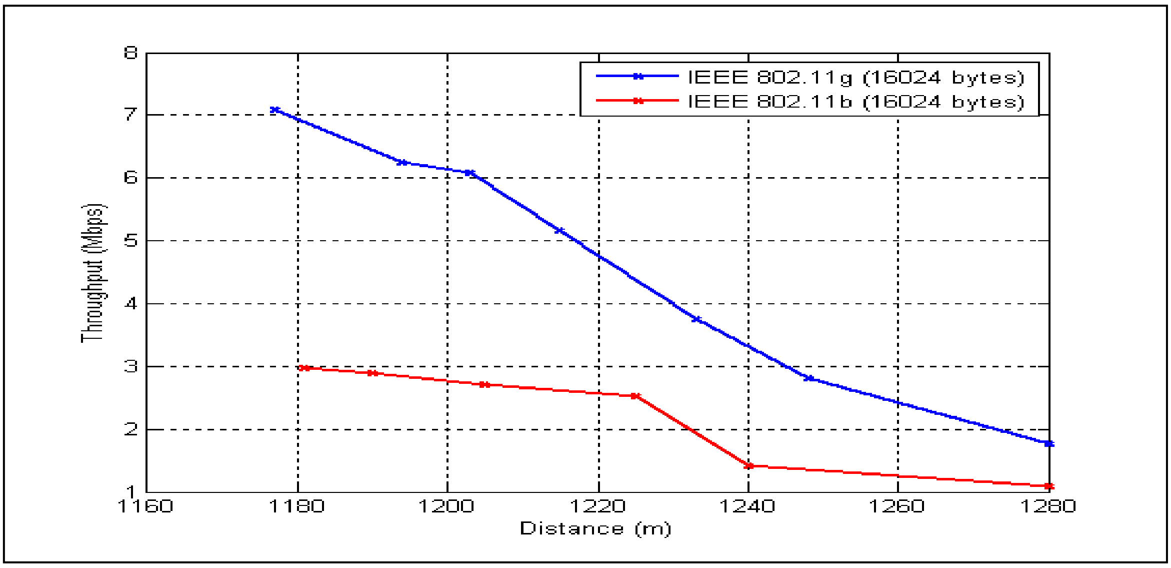


Figure 5.40 Average throughput for Experiment 3 over UDP using IEEE 802.11b/g while vehicle moving at 20 km/h

Scenario 4: Effect of speed in performance analysis

In this scenario, when one access point is fixed ,the another mobile access point is moving with 0 km/h, 40km/h, 80km/h speed respectively. Different from other experiments, we focus on effect of speed in performance analysis [25].

Table 5.9 Simulation setup parameters

Attributes	**Parameters**
Speed	0 km/h, 40km/h,80km/h
Data rate(bps)	11 Mbps / 54 Mbps
Wireless technology	802.11b / 802.11g
Simulation time	360 seconds for speed 0 km/h, 300 seconds for speed 40km/h,150 seconds for speed 80km/h
Distance	1986 meters

Below studies shows that speed does not effect throughput exactly per following five throughput-time graphs and also we observe that data rate increment has negative effect on range. While data rate, traffic load and used protocol are the same, only speed is changed for following each five graphs to compare speed effects on network.

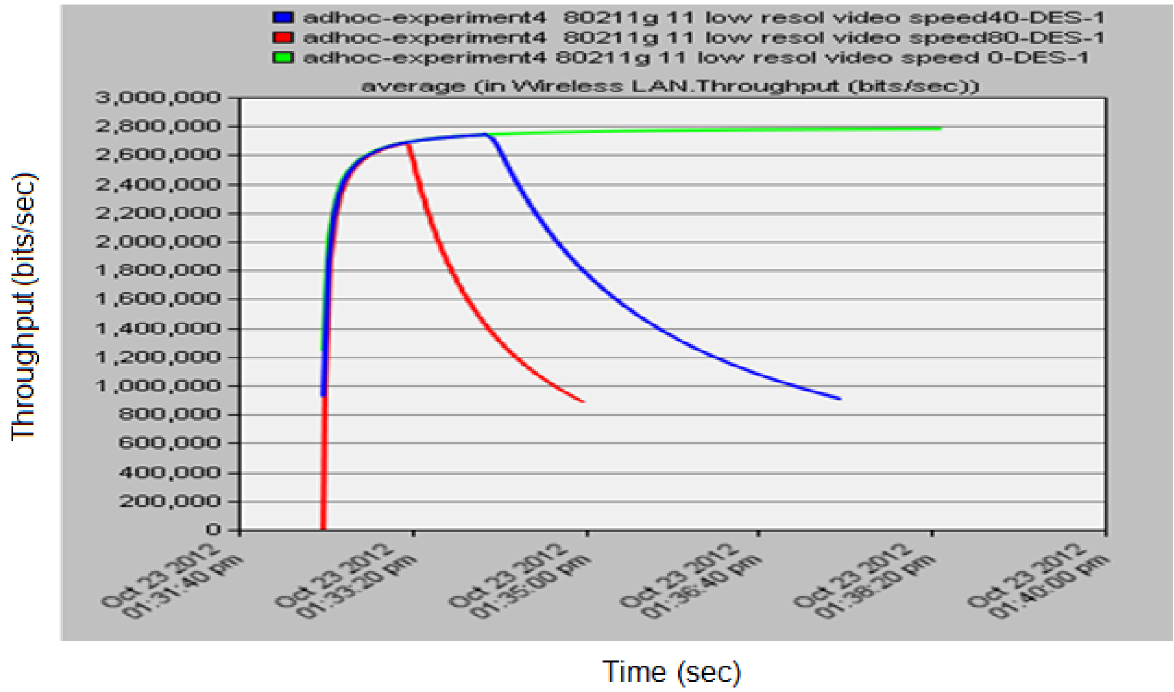


Figure 5.41 Simulation results of throughput in 802.11g protocol, 11Mbps data rate,low resolution video with different speeds

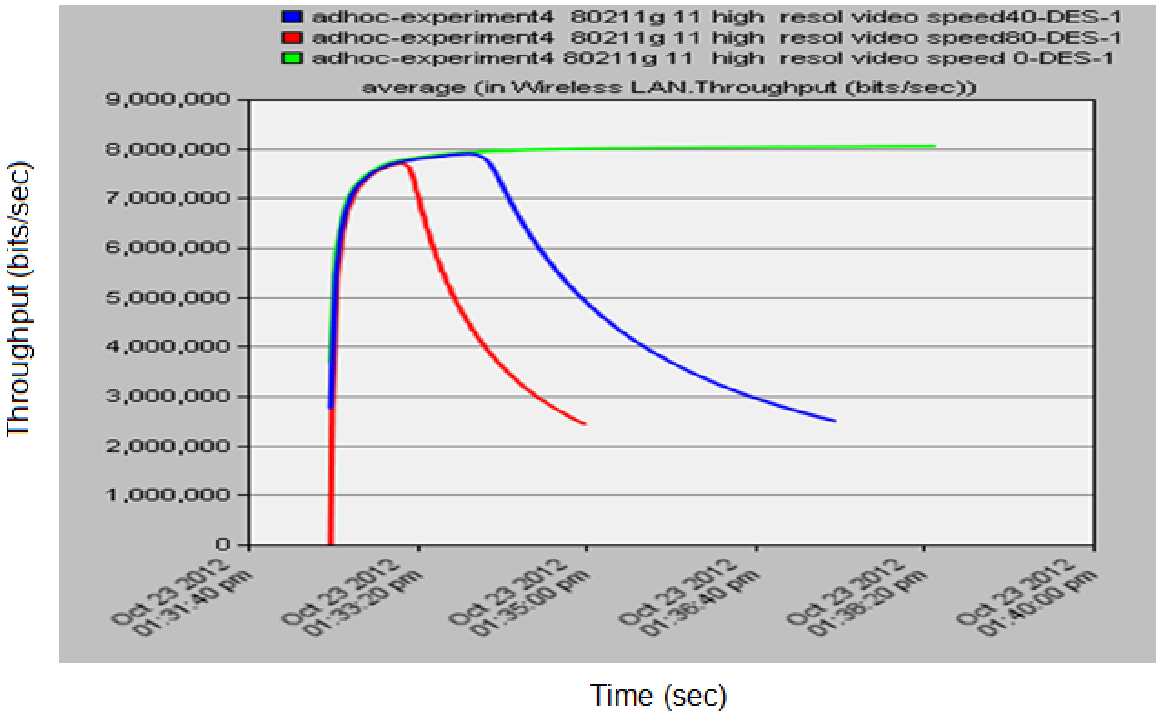


Figure 5.42: Simulation results of throughput in 802.11g protocol , 11Mbps data rate,high resolution video with different speeds

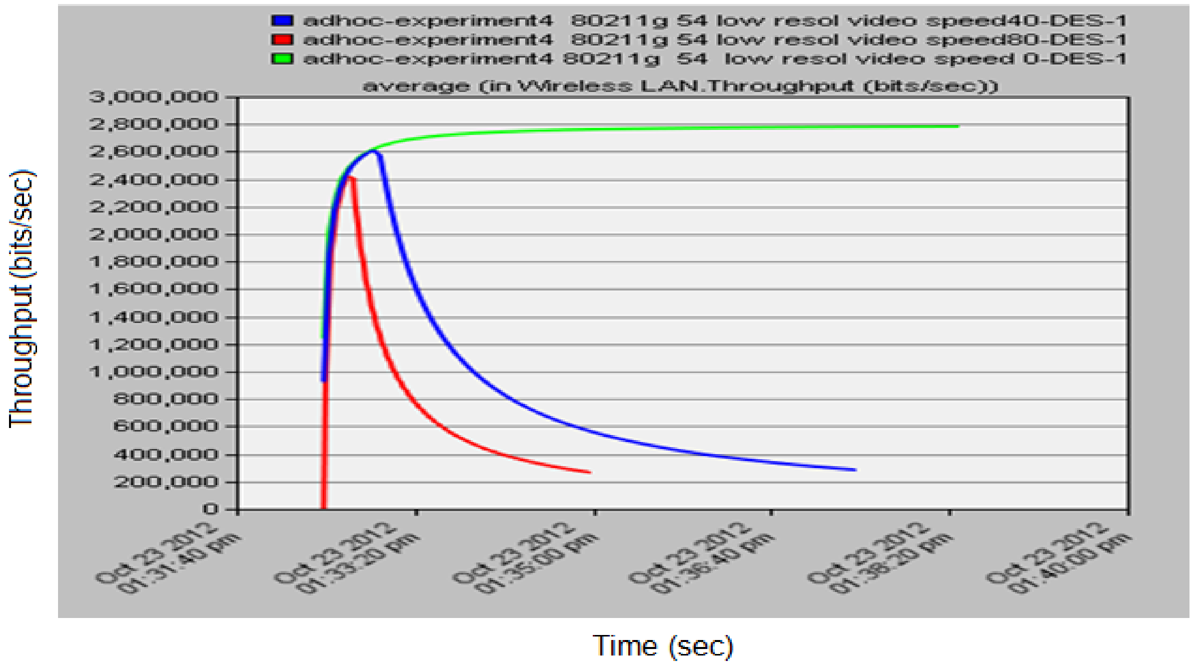


Figure 5.43 Simulation results of throughput in 802.11g , 54Mbps data rate,low resolution video with different speeds

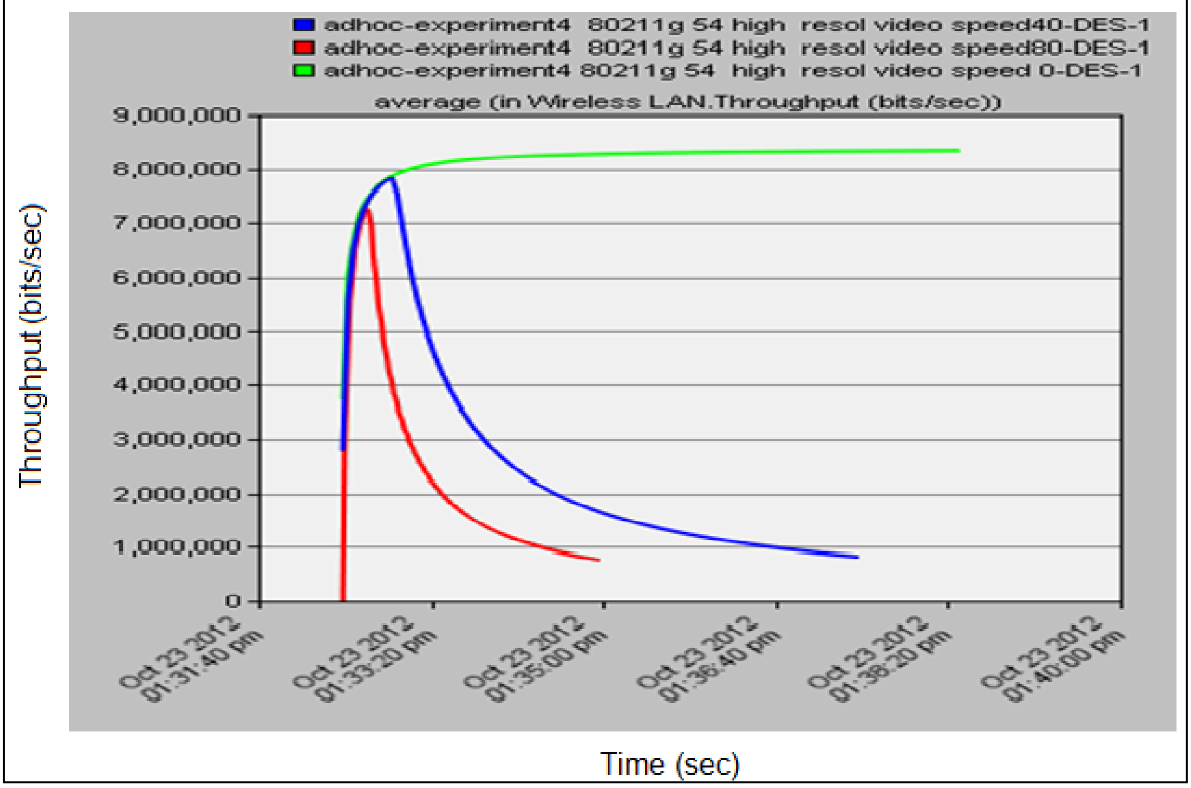


Figure 5.44 Simulation results of throughput in 802.11g protocol , 54Mbps data rate,high resolution video with different speeds.

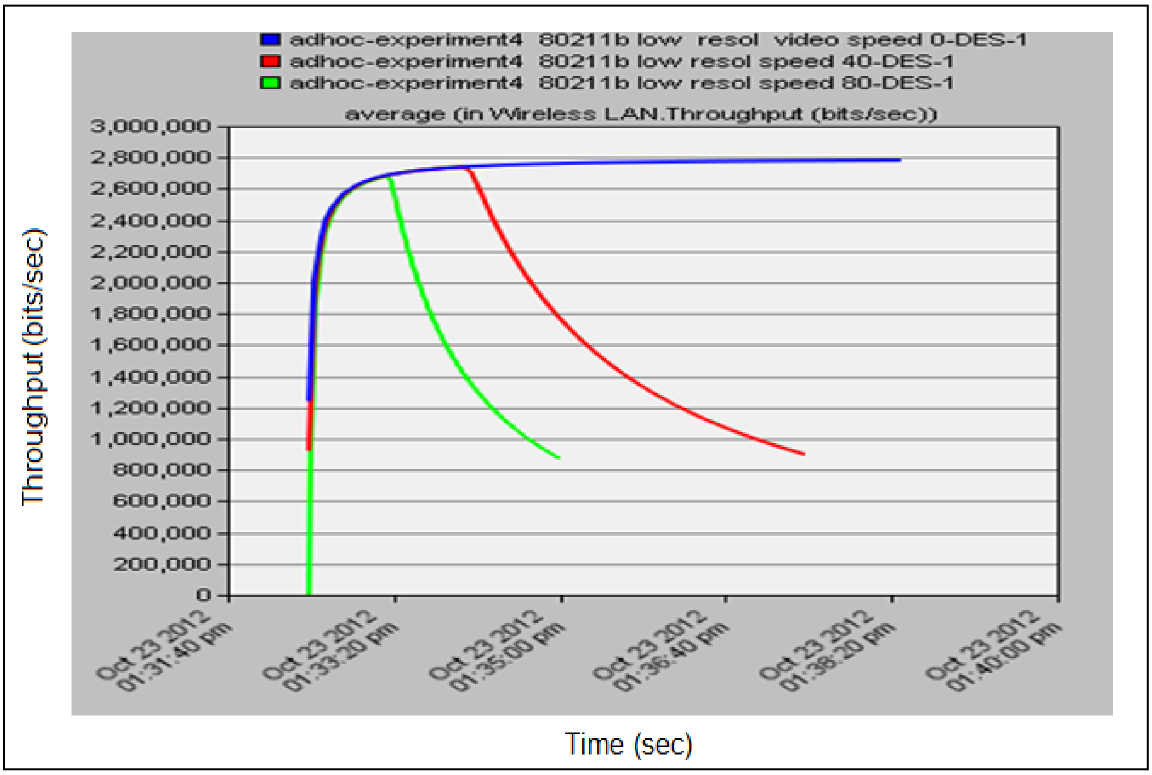


Figure 5.45 Simulation results of throughput in 802.11b protocol , 11Mbps data rate,low resolution video with different speeds

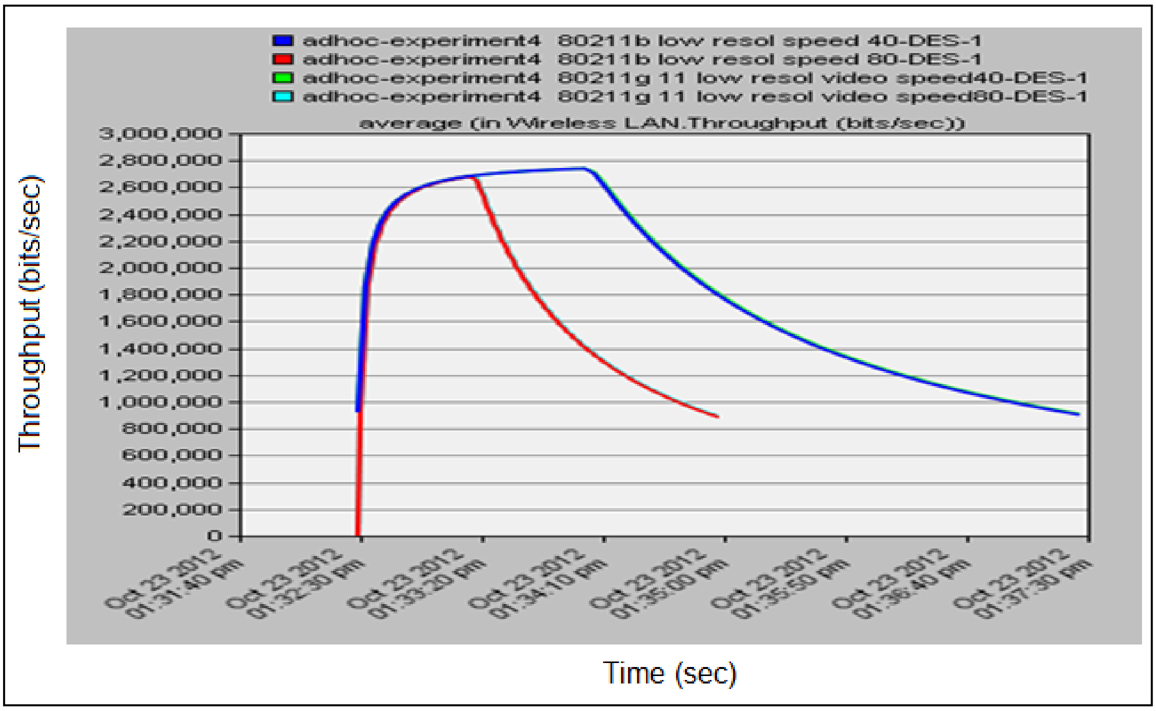


Figure 5.46 Simulation results of throughput in 802.11b/g protocols, 11Mbps data rate, high and low resolution video with different speeds

Please notice that the throughput is almost same when different protocol used for each low resolution video and also high resolution video case.

In [25] ,throughput-distance graph under different speed,different data rate ,and different used protocols are illustrated as shown in Fig. 5.47 and then ,it is observed that vehicle speed decreased throughput slightly compared to stationary condition.

Our simulation throughput-time graphs are nearly same with [25]. But, throughput variation is so small enough tobe neglected due to speed effect under same condition used. Different from his scenario, our scenario is simulated for long distance instead of short distance.

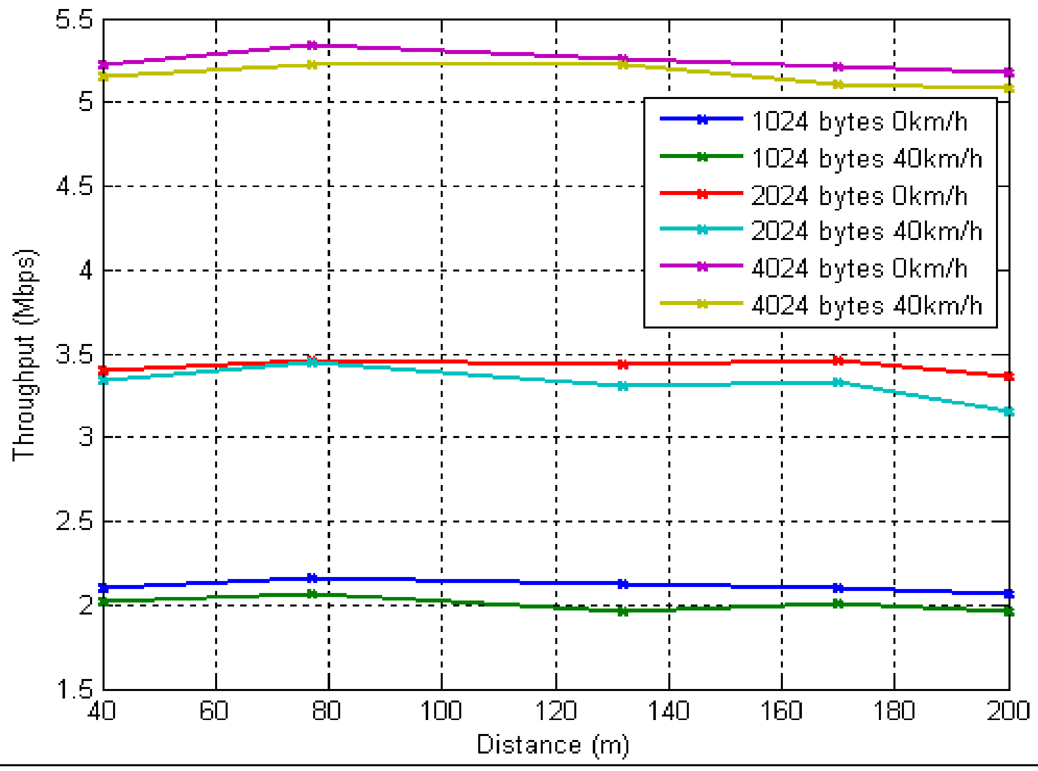


Figure 5.47 Throughput using IEEE 802.11g in terms of speed, package size and distance

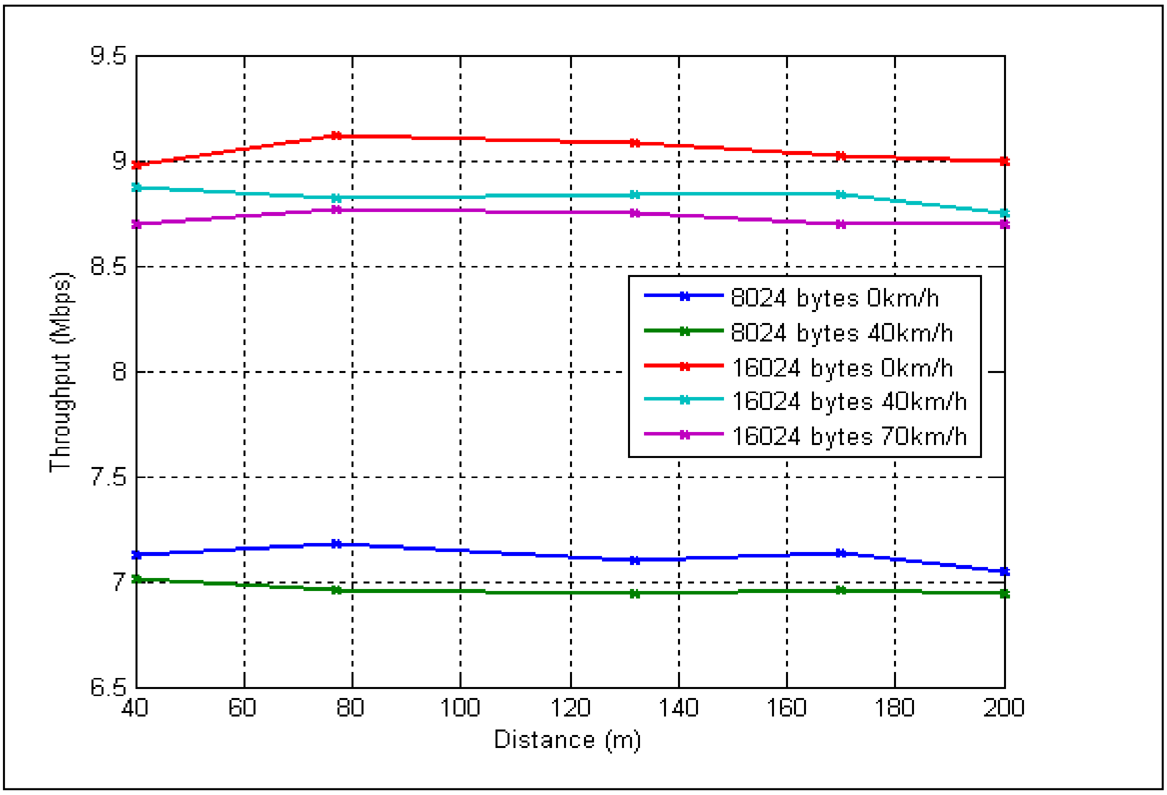


Figure 5.48 Throughput using IEEE 802.11g in terms of speed, package size and distance

Scenario 5: mobile nodes with different speeds

In this experiment, firstly we observe throughput between the two vehicles with short distances,300 meters. Firstly, we maintained speed of first car at 50 km/h and second car at 60 km/h and then second car mobility speed is updated as 80 km/h in this scenario to observe speed effect on mobility. also, distance is fixed between mobile stations to 200 meters at park position and applied low speed and high speed scenarios.

Low video conferencing used for 802.11b and 802.11g protocols in this experiment.

In [25], throughput-distance graph is illustrated as shown in Figure 5.51. Our simulation study show that there is no any clear variation of throughput because of speed effect as low or high speed.

Table 5.10 Simulation setup paramaters

Attributes	**Parameters**
Speed	50 km/h, 60km/h or 80km/h
Data rate	11 Mbps
Wireless technology	802.11b / 802.11g
Simulation time	360 seconds for speed 0, 300 seconds for speed 40,150 seconds for speed 80
Distance	300 meters

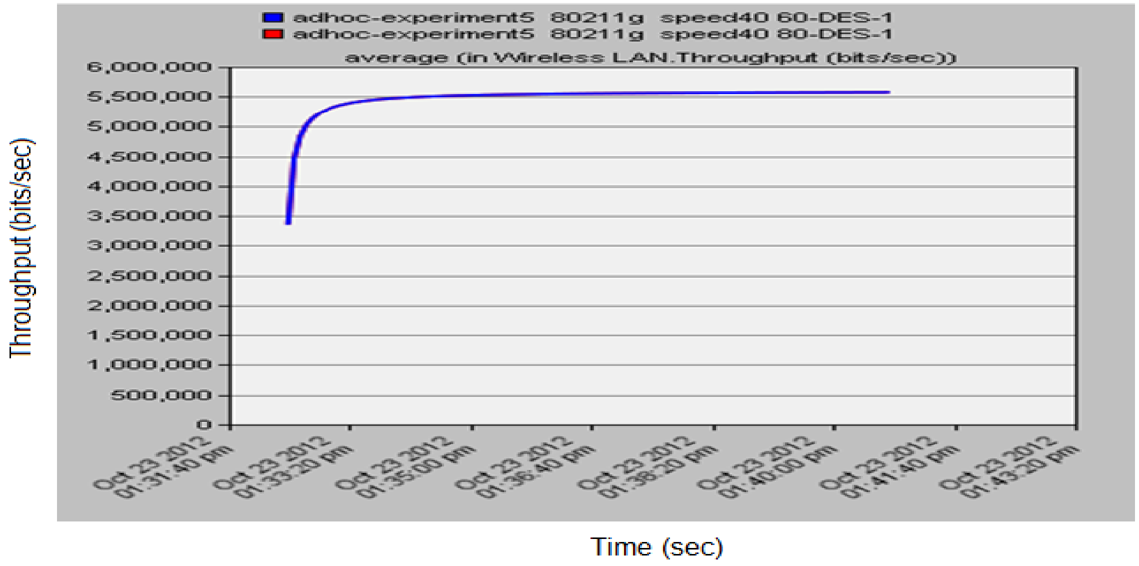


Figure 5.49 Simulation results of throughput in 802.11b/g protocol , 11Mbps data rate with different speed

Additionally, during this test any package loss not occured. In this thesis, 802.11a, 802.11b and 802.11g protocols has been compared with each other for data rate and range. 802.11a protocol is not used any more due to short range, although high data rate capability. Traffic overload, which occured due to data rate, buffer capacity and package size, has been simulated. Long range in mobility is discussed for throughput and delay and speed increment does not effect network at all. GPS scenario case, which provided by [25], is omitted in this thesis.

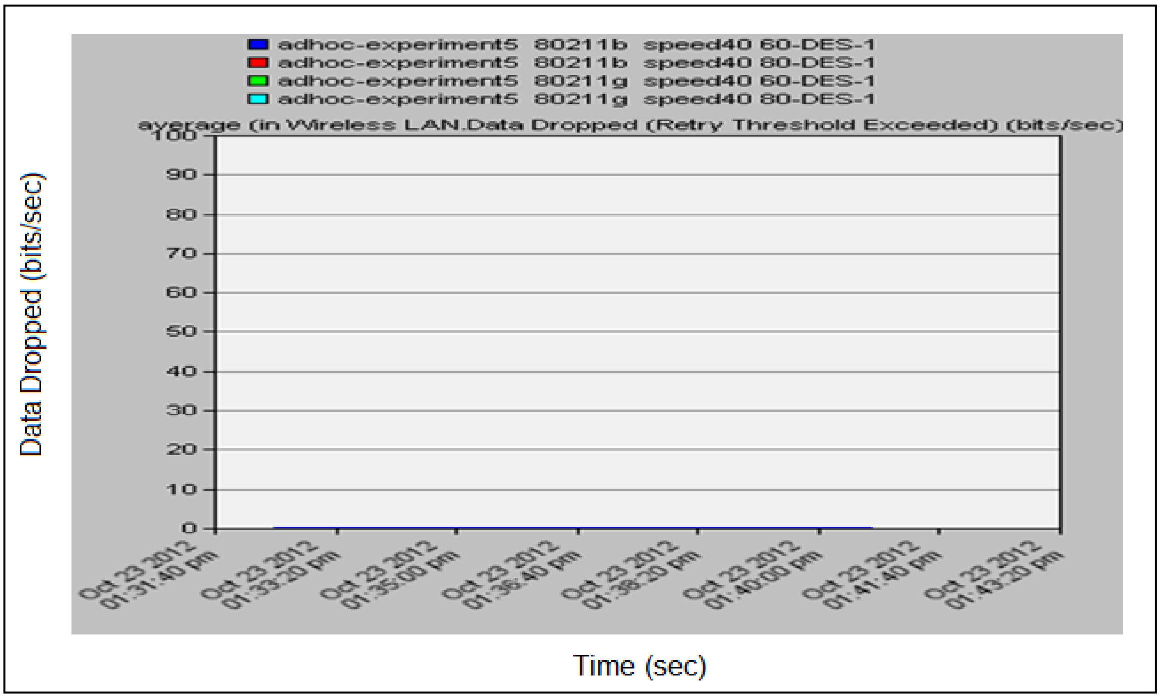


Figure 5.50 Simulation results of dropped data in 802.11b/g, 11Mbps data rate with different speed

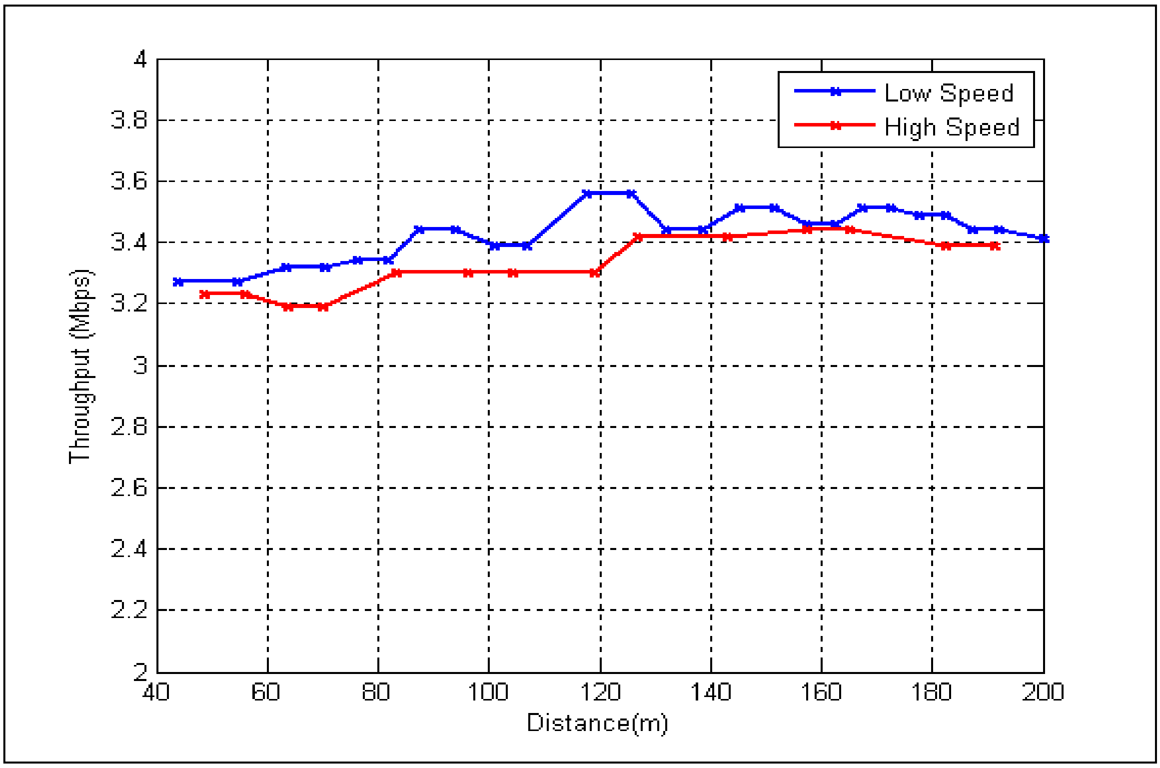


Figure 5.51 Performance comparison on throughput using IEEE802.11g in terms of speed and distance

5.5 Simulation of Transparent and Nontransparent Relay Mode

In this scenario , while frame preambles is one for nontransparent relay mode case , frame preambles is zero for transparent relay mode case. All of the cases are simulated and compared to each other .

Nontransparent relay throughput is greater than transparent relay throughput per Figure 5.52. Transparent relay delay is higher than nontransparent relay delay per below Figure 5.53

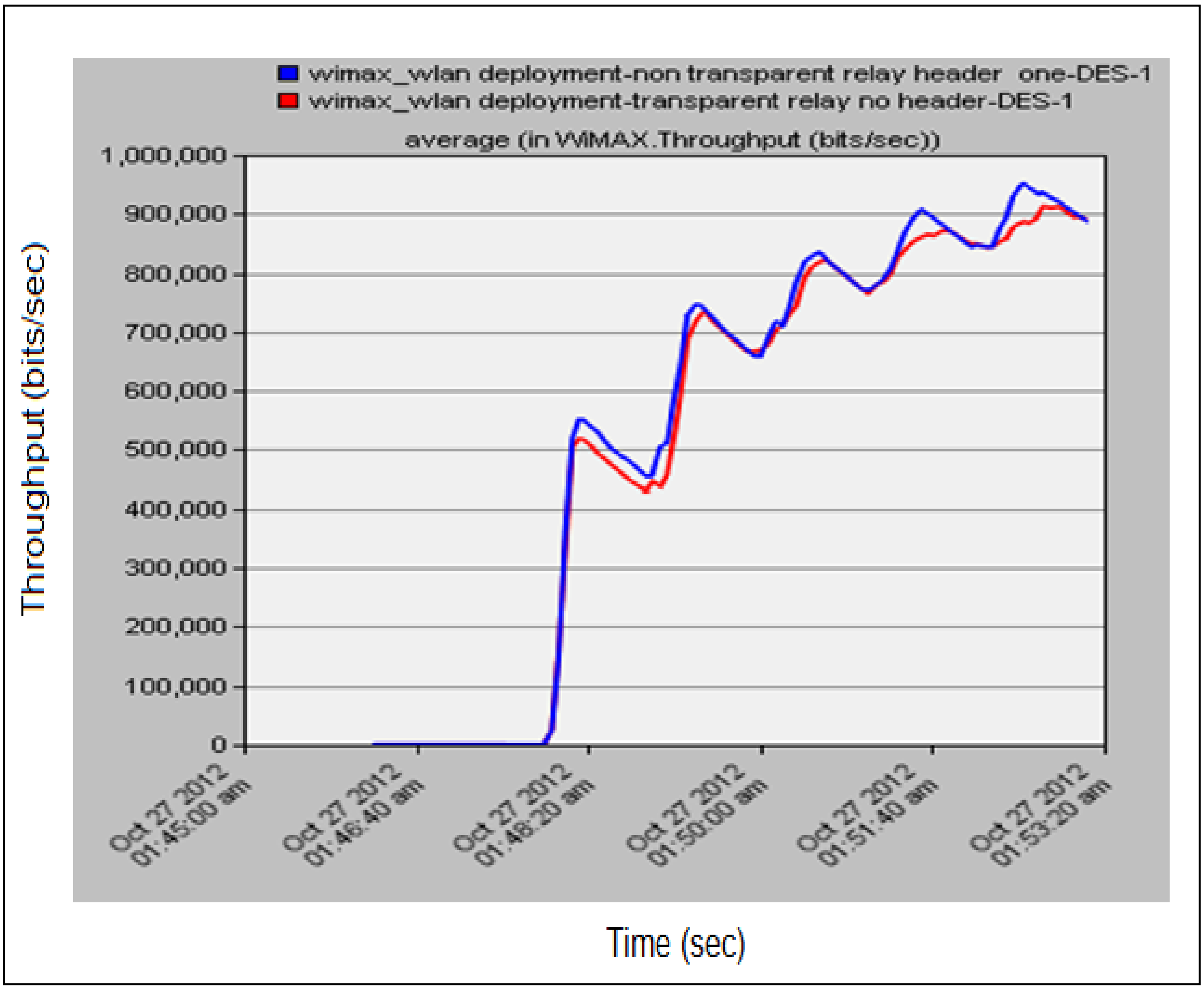


Figure 5.52 WIMAX throughput in bits/sec for nontransparent and transparent relay

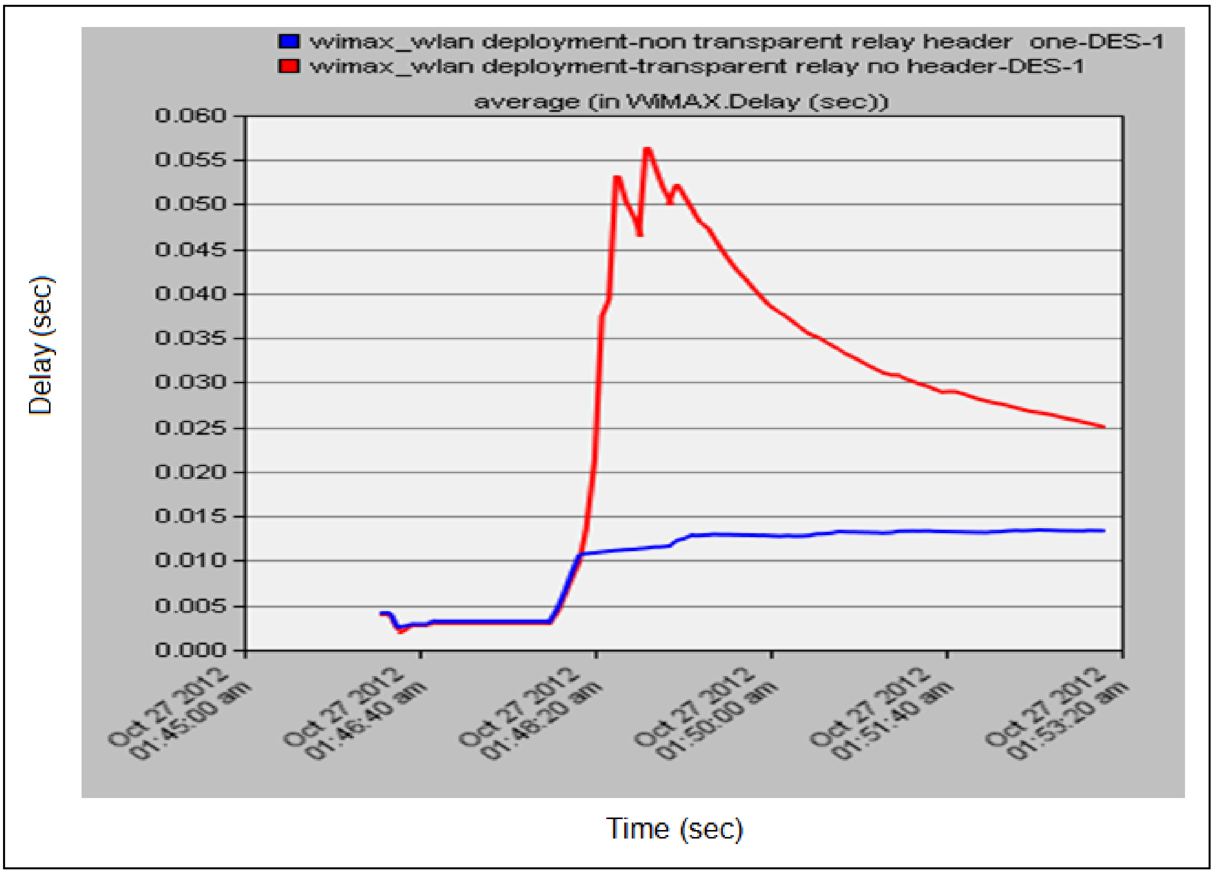


Figure 5.53 WIMAX delay in sec for nontransparent and transparent relay

5.6 Simulation Results

In this thesis, we analyze performance of heterogenous wireless network under different conditions such as number of users, pathloss model and multipath channel model, modulation and coding techniques, relay modes as transparent and nontransparent.

In LOS/NLOS environments, queuing method the results show that significant system capacity gain can be achieved through the use of relays. By simulating different scenarios, we provide enhancement to our network model . This study shows us that increasing number of users, using nontransparent relay,adaptive modulation technique and WFQ method provide much more throughput gain than the others.802.11a, 802.11b and 802.11g protocols has been compared with each other for data rate and range .802.11a protocol is not used any more due to short range, although high data rate capability. We observe that speed increment does not effect network at all.

6. CONCLUSION

Future wireless systems are expected to provide ubiquitous connection, higher data rates and better indoor and outdoor coverage. At present, multiple broadband technologies for mobile services such as HSPA and WIMAX are available on the market. The performance of these technologies, however, is not sufficient to meet the requirements of future 4G systems. Hence, there is much incentive to enhance the performance of these current technologies. One promising solution within this context is the use of relay based architecture.

This architecture is expected to extend the coverage area of BSs and increase the capacity of single hop cellular systems. Typically, it is envisaged that they could be used in the early stages of network roll out to provide coverage to a large area at lower cost than a BS only solution; they can also be used to provide increased capacity in more developed networks as well as coverage to coverage holes such as areas in the shadows of buildings. The 802.16 Work Group has recognised this as an important area of development, and a new standard has been ratified: the IEEE 802.16j-2009 design to enable multihop communications in WIMAX systems.

This thesis focused on (i) the issues that arise within when considering how to design 802.16j relay based WİMAX systems and (ii) the system gain provided with relays. More specifically, this work provides insight on the system design to maximise the throughput of these multihop systems using information pertaining to wireless channel conditions

In order to analyse the performance of 802.16j relay systems, performance analysis of these systems was carried out under different deployment scenarios. Within the different scenarios several aspects of the system design were considered. The system was designed to maximise the gain that can be provided through the deployment of relays.

The results focus on understanding the gain achieved from 802.16j systems with varying number of relays and associated transmit power under a uniform distribution of SSs.

6. 1 Future Work

In this paper, we simulate and analyze the performance of heterogenous wireless network in mobile scenarios to observe network throughput, delay variation under different conditions with 802.16j ,802.11b and 802.11g and results shows that vehicular network brings gain too much to the network. In this study,we focus on much more physical layer than mobility ranging modul. Our future work is combining these techniques that vertical handoff in WLAN-WİMAX-LTE heterogenous network by using OPNET , mobility ranging modul and also mobile scanning interval activity, neighbouring advertisement will be discussed in the future work **.** We will continue using same modeler again due to user –friendly feature.

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