Chapter - 4

CROSS LAYER OPTIMIZATION

CHAPTER-4
CROSS LAYER OPTIMIZATION

This chapter describes the concept of Cross layer design vs layered design approach. Various parameters of IEEE 802.11 standard are optimized for performance enhancement of Smart grid network. Optimization of HAN and NAN using PAMVOTIS and Riverbed-OPNET simulation softwares is illustrated in this chapter. Graphical results are also shown for comparative analysis of effect of various parameters on network performance.

4.1. INTRODUCTION TO LAYERED VS CROSS LAYER DESIGN

Communication network protocols are engineered, developed and established based on the layered approach. Each layer is designed to serve a specific functionality in collaboration with other layers. Thus, various functionalities such as transmission characteristics, error control, flow control, synchronization, routing of information, framing, sequencing of packets, congestion control, application specific services etc. are combined together by some degree of interfacing between various layers for implementation of protocols. Protocol layers are designed and organized in a vertical hierarchical manner. They are designed to ''pass on'' the particular message. Communication is possible only between adjacent layers for the purpose of responding as a part of passing on the information [61].

In TCP-IP and OSI models, each layer provides services to its upper layer. Layered optimization and design has been a well-established approach for communication network design and development. In layered approach, protocols are designed with independent functionalities of layers. The specific layer uses the services of lower layers irrespective of the process and parameters of the service provided.

A specific layer is concerned about a layer located above or below it and that too only for the sake of limited responses and communications. This kind of approach restrict the performance enhancement approaches.

Layered approach for wired communication can be modified with cross layer approach for wireless communication for performance enhancement [61]. For example, cognitive radio technology is meant to provide unused spectrum of primary users to secondary users for enhancing spectrum efficiency. This approach requires continuous monitoring of channel conditions, interference, traffic scenarios etc.

The primitive layered approach is not suitable for cognitive radio technology in which a reliable coordination between layers and adaptation is inevitable for successful operation and management of spectrum. In the context of Smart grid technology, cognitive radio technology is an inevitable approach for gigantic communication network and enormous amount of data communication. Furthermore, Smart grid technology comprises of hierarchical and heterogeneous network with diverse set of communication protocols. This demands a divergence from primitive approach and adaptation of an innovative approach. The cross layer approach can be defined in various ways depending upon its design and functional aspects as described below.

- A design approach to explore the synergy and collaboration between various network layers.
- A combined design and optimization approach by considering more than one layer.
- A collaborative approach between different layers by sharing of information between them.
- In the context of multimedia transmission, a cross layer optimization is a process of collective source and channel coding.
- A design and optimization approach by considering the connection between various layers.
- An approach to explore dependence between network layers in contrast to independent layered approach.
- A combined parameter optimization for different layers.

A cross layer approach is a desecration of traditional layered design approach through ''Collaborative Optimization". For Smart grid technology, this approach is a very essence of optimization of communication network protocols. The transmission and reception characteristics are taken into consideration at higher layers and the data communication is considered at lower layer is one of the aspect of cross layer approach. Non adjacent layers are collaboratively designed and optimized for performance enhancement. Cross layer optimization can be achieved for performance enhancement through either combined optimization of parameters pertaining to various network layers or by exchange of information between various network protocol layers [62] [. Fig.4.1. shows the conceptual diagram of cross layer approach.

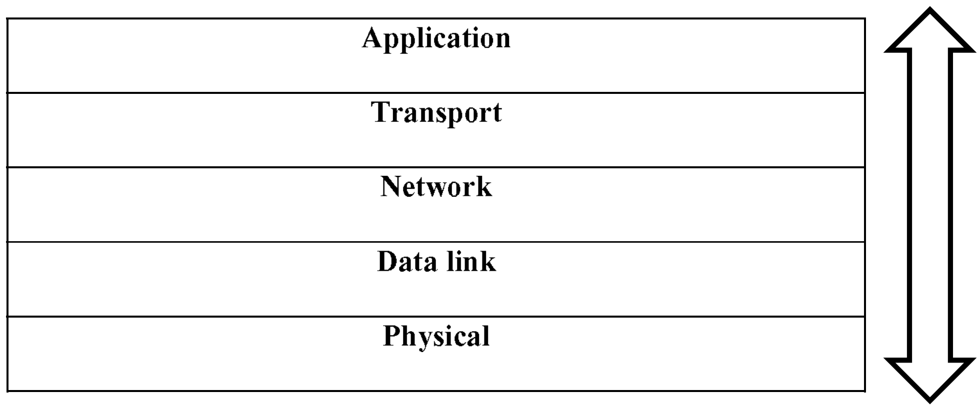


Fig.4.1. Conceptual diagram of cross layer design

Adhoc wireless networks play a crucial role in Smart grid communication architecture especially in home automation applications. Adhoc wireless networks work on the basis of decentralized or distributed control. This feature impose difficulty and challenges to serve and support high data throughput and delay constrained applications which are inevitable in Smart grid. The traditional layering methodology used in wired as well as wireless approach in which each layer is unmindful about operation of rest of the layers cannot provide optimum performance under rigorous performance and reliability requirements. The protocol layer optimization of isolated layers may have adverse influence on performance and operation of other layers. The austere performance and operation demands of Smart grid heterogeneous network can only be realized through cross layer optimization. Cross layer design approach explores interdependencies between diverse network layers through parameter characterization and optimization to optimize an entire network performance. Cross layer design can be used for wired as well as wireless networks. For wireless networks, this approach becomes inevitable to address the challenges such as connectivity, data throughput, QoS and interference. Adaptive power control, signaling, modulation and encryption can address performance challenges. Performance optimization of physical layer parameters can be explored by higher layers to optimize the network performance. Fading and congestion at physical layer can be circumvented by higher layers with the help of adaptive routing for delay minimization. The bottlenecks resulted due to one layer can be avoided if the joint optimization is performed and the operational characteristics of one layer is shared to rest of the layers. If an information regarding data throughput and delay is known to application layer then the solutions such as changing the rate of compression and/or multiple routing can be optimized.

Cross layer optimization approach imposes many design challenges as adaptation or deviations at a specific layer must be compensated at that layer in terms of time scale. The variations in the Signal to Interference Ratio (SINR) are faster in terms of microseconds. Variation in the traffic is in terms of few seconds and topology of a network takes considerable time to change. Cross layer optimization must be performed by adaptations or optimization of parameters pertaining to a specific layer. If it is ineffective then the information must be exchanged with higher layer for better response and resolution. For example, if SINR is changing at a very fast rate as a result of fading and the physical layer shares this information to upper layers for the solution of this issue then during that time, SINR will mostly change to some other value or the fading might have reduced to optimum level. So, the problem must be first addressed at that specific layer before exchanging it with other layers.

Optimization at other layer must resolve or alleviate the effect of performance degradation. If SINR is decreasing due to fading then a physical layer may resolve this problem by increasing the transmitter power. But if this problem is a result of mobility or change in the location where the signal power is weak (for example a mobile station enters into the tunnel) then it's a momentary fading which will be resolved as soon as the mobile station is out of it. This type of fading can be resolved by procrastinating the packet transmission at higher layers. For extremely itinerant nodes, the solution can be adaptations in link characteristics, change in network topology or adaptations in routing methodology. WSN has challenging energy and delay constraints which can be solved through joint optimization at network and MAC layer.

In joint or adaptive cross layer optimization method, each layer must be tuned to the variations done for performance optimization. Cross layer design is a challenging task as it is complex and requires multidisciplinary expertise. The successive part of this chapter describes various case studies of cross layer optimization.

4.2. CASE STUDIES OF CROSS LAYER (JOINT) OPTIMIZATION

This section describes case studies of joint optimization using various simulation results. Smart grid consist of diverse set of communication standards with different network topologies. Parameter optimization of various communication standards is inevitable for reliable and adaptive network performance.

4.2.1. Joint optimization of IEEE 802.11 parameters using PAMVOTIS software

This section describes joint optimization of physical and MAC layer parameters for performance enhancement. Simulation is performed using PAMVOTIS simulator to investigate an effect of RTS/CTS mechanism as well as adaptation of EDCA parameters.

As mentioned in the preceding chapter, IEEE 802.11 standard is meant for WLAN. The protocol stack of IEEE 802.11 standard and its variants are also described in the previous chapter.

In physical layer, parameters such as modulation scheme, data rates etc. are optimized. IEEE 802.11 standard offers three choices namely FHSS, DSSS and infrared. FHSS operates in ISM band using GFSK modulation technique and provides the data throughput of either 1 Mbps or 2 Mbps. DSSS operates in 2.4 GHz ISM band using DBPSK technique for 1 Mbps data throughput and DQPSK for 2 Mbps data throughput.

Physical layer of IEEE 802.11 standard is conceptually divided into two sub-layers namely PLCP and PMD sub-layer. PMD is associated with modulation and coding. PLCP deals with the services which are offered to MAC layer by physical layer. PLCP handles Clear Channel Assessment (CCA) and service access point. CCA is used for CSMA/CA mechanism used by MAC layer. Infrared option works using pulse position modulation scheme. In wired network such as Ethernet, carrier sensing is quite simple as the peak voltage at the cable is compared with threshold value. Carrier sense is a complex task in wireless network. In IEEE 802.11, the PHY layer sensing is through CCA provided by PLCP. The assessment is performed either by measuring the received signal strength and comparing it with threshold value or by detection of bits. The process of measuring received signal strength is faster but it is not as reliable as bit detection as the interference may cause false sensing.

The function of MAC layer is an arbitration and multiplexing of various transmission requests of a specific area. It also takes care of roaming, energy consumption and authentication. Distributed coordination function is based on CCA and CSMA/CA. It is inevitable for accessing IEEE 802.11 standard. CSMA-CA/CD is the well-practiced technique applied for wired networks. This technique cannot be used for wireless network as the error rate is much higher in WLAN.

Detection of collision will drastically reduce the throughput in WLAN. Thus, the technique of collision avoidance is applied for WLAN.

EDCA mechanism is proposed for Quality of Service enhancements in WLAN in the standard IEEE 802.11e. This mechanism is an extension of basic Distributed Coordinated Function. It classifies the traffic into four access categories such as voice, video, best effort, and background. Higher priority is assigned to the traffic with higher QoS requirements.

Inter Frame Spacing is the time span between two successive frames in WLAN. In WLAN, Arbitration Inter Frame Spacing (AIFS) is a methodology to prioritize one access category over other. It works by widening or shortening the time period during which a node has to wait before transmitting the next frame. A small value of AIFS means higher probability of the message to be transmitted.

The size of contention window must be carefully chosen as the too small size may result into packet collisions and larger size may result into unnecessary delay. Wireless network are prone to the ''Hidden terminal'' problem. In this problem, one node receives information from two nodes which are unable to see each other. This situation gives rise to collisions and therefore reduced throughput. The transmitter nodes are unaware of this situation and in an impression that the communication process is successful. RTS/CTS mechanism is used to alleviate the hidden terminal issue. The transmitter sends Request To Send packet to receiver which contains the address of the receiver of next data packets and the expected duration. The stations which receives this RTS, set a network allocation vector. The receiver sends Clear To Send message to transmitter to indicate that it is ready to receive the packet from transmitter. Once this RTS as well as CTS exchange process in completed, all the neighboring stations are informed that the medium is exclusively busy for one sender. After the transmission process is over, the network allocation factor marks the channel as available. The chances of detectable collision are only possible when the RTS/CTS are being sent. Once the network allocation vector is set, collision will not exist. This process adds overhead bits. To determine the necessity of

RTS/CTS, a specific value of RTS threshold should be selected. RTS/CTS mechanism is activated only if the frame size is more than RTS threshold. The sequence will be RTS-CTS-DATA-ACK which is called as four way handshake method. If the frame size is less than the value of RTS threshold, then the two way handshake DATA-ACK is followed.

The effect of RTS/CTS threshold is analyzed for different RTS threshold values. Media access delay will increase as a result of RTS/CTS mechanism as the process of exchanging this commands will procure some time duration.

The probability of using RTS/CTS mechanism is inversely proportional to the threshold value. The higher the value of RTS threshold, the lower the probability of sending RTS frame. The effect of RTS threshold is depicted using graphical representation. The representations show mean value of results. Total hundred values are derived per single node. It is evident from the results that media access delay as well as total packet delay is the lowest in the IEEE 802.11 standard without enabling this mechanism as the communication process is faster. For lowest RTS threshold, the probability of RTS/CTS is highest and therefore the delay is the highest. Total ten nodes are considered and hundred readings are taken for each node. Fig.4.2. to Fig.4.5. shows the outputs for individual nodes. Fig.4.6. shows the mean values for different RTS thresholds.

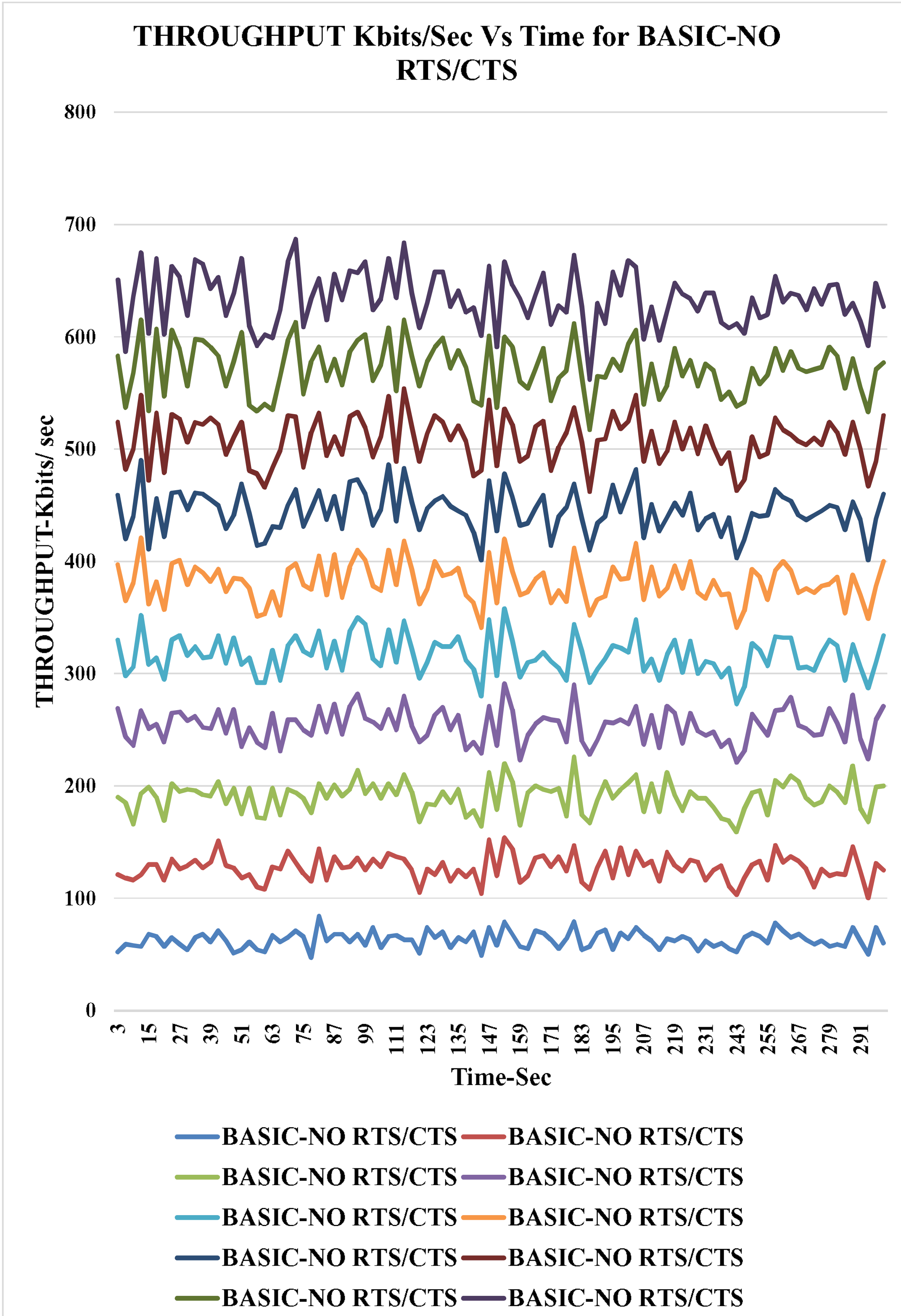


Fig.4.2. Throughput of nodes for no RTS mechanism

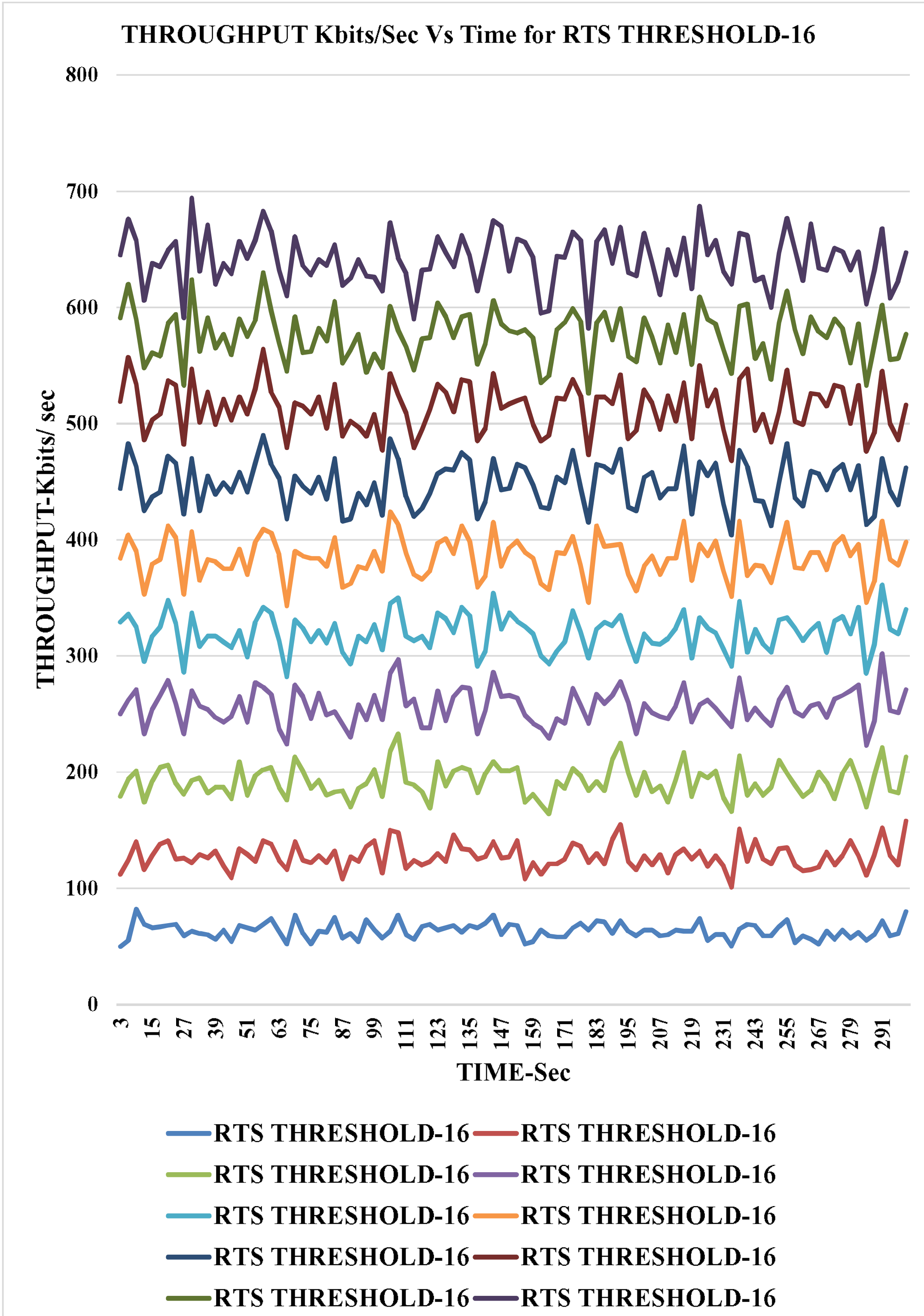


Fig.4.3. Throughput of nodes for RTS threshold-16

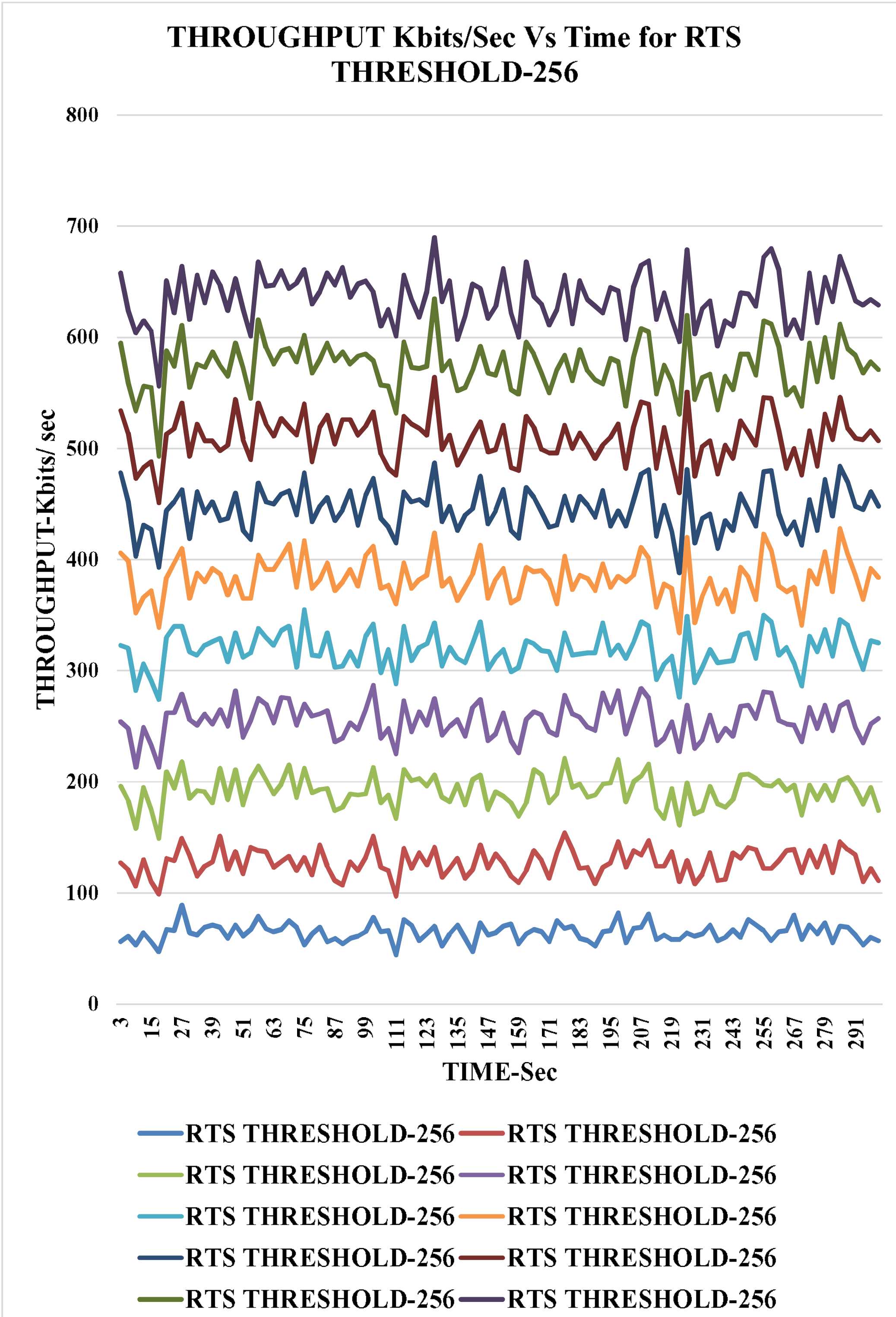


Fig.4.4. Throughput of nodes for RTS threshold-256

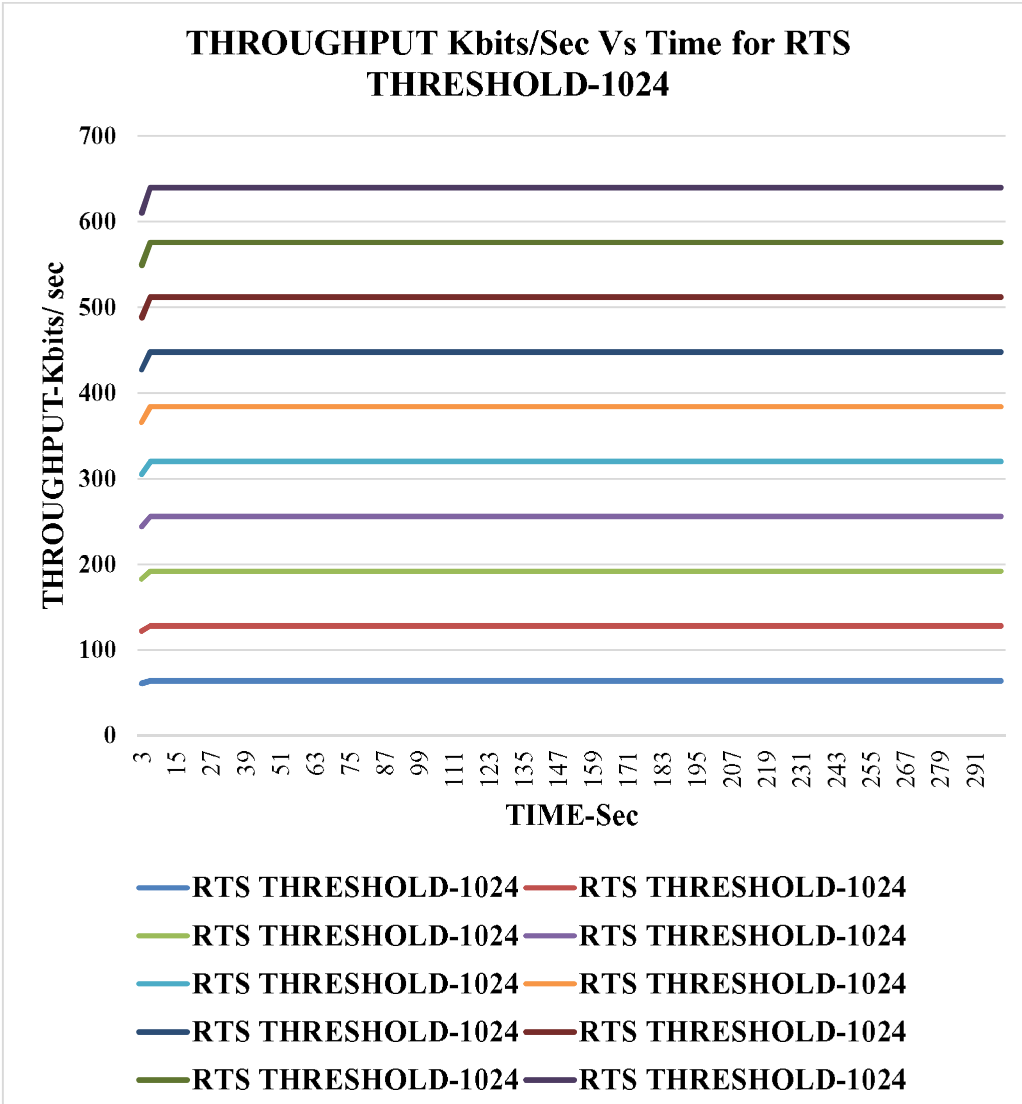


Fig.4.5. Throughput of nodes for RTS threshold-1024

Fig. 4.3, 4.4 and 4.5 show the throughputs of nodes for RTS threshold values 16, 256 and 1024 respectively. IEEE 802.11 standard uses carrier sense multiple access with collision avoidance to initialize RTS/CTS. IEEE 802.11 protocol defines RTS/CTS as an optional mechanism by imposing threshold values. If the length of frame is longer than RTS threshold, then RTS mechanism will be applicable to limit the overhead. The RTS/CTS mechanism reserves the channel for transmissions having larger data frames, with the anticipated result that less bandwidth would be wasted during collision occurrence. Collisions and retransmission of data packets consumes more bandwidth and hence the throughput is reduced. RTS/CTS mechanism avoids the collision. The threshold value is a manageable parameter and must be dynamically implemented. For larger frames, RTS mechanism is beneficial. Graphical results as well as the mean values of results illustrate that there is a minor difference in throughput for different RTS value and least RTS value has maximum throughput value. Lower value of RTS has highest probability of RTS operation.

Fig. 4.6 shows the graphical results of data throughput for different values of RTS thresholds.

Results depicts that mean value of throughput is highest for lower value of RTS threshold as the lower value of RTS threshold ensures highest chances of sending RTS frame. Graphical results show that the throughput and media access delay are higher in case of RTS threshold=16. This is because the probability of sending RTS frame is the highest in this case compared to threshold values of 256 and 1024. Table 4.1 shows the results for mean values of throughput for all 10 nodes.

Node	**MEAN VALUES-BASIC-NO RTS/CTS Throughput (Kbits/s)**	**MEAN VALUES-RTS=16 Throughput (Kbits/s)**	**MEAN VALUES-RTS=256 Throughput (Kbits/s)**	**MEAN VALUES-RTS=1024 Throughput (Kbits/s)**
1	63	64	65	64
2	65	65	63	64
3	64	65	65	64
4	64	65	64	64
5	63	64	64	64
6	65	65	65	64
7	64	64	63	64
8	64	66	65	64
9	64	63	65	64
10	63	66	62	64
Average	63.9	64.6	64	64

Table 4.1. Mean values of results

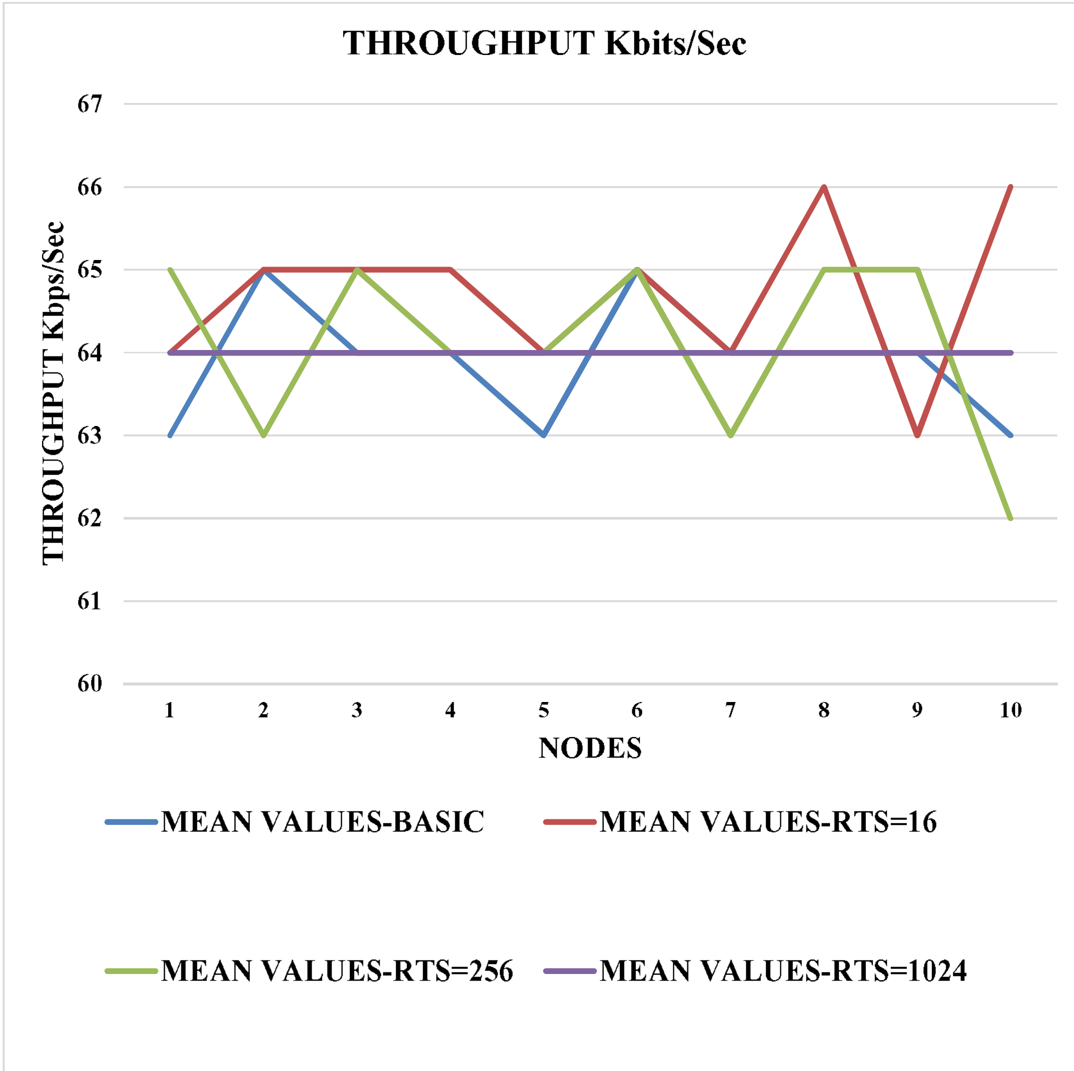


Fig.4.6. Mean values of results

Fig. 4.7. to Fig.4.10. show the graphical results of Media access delay for various values of RTS thresholds.

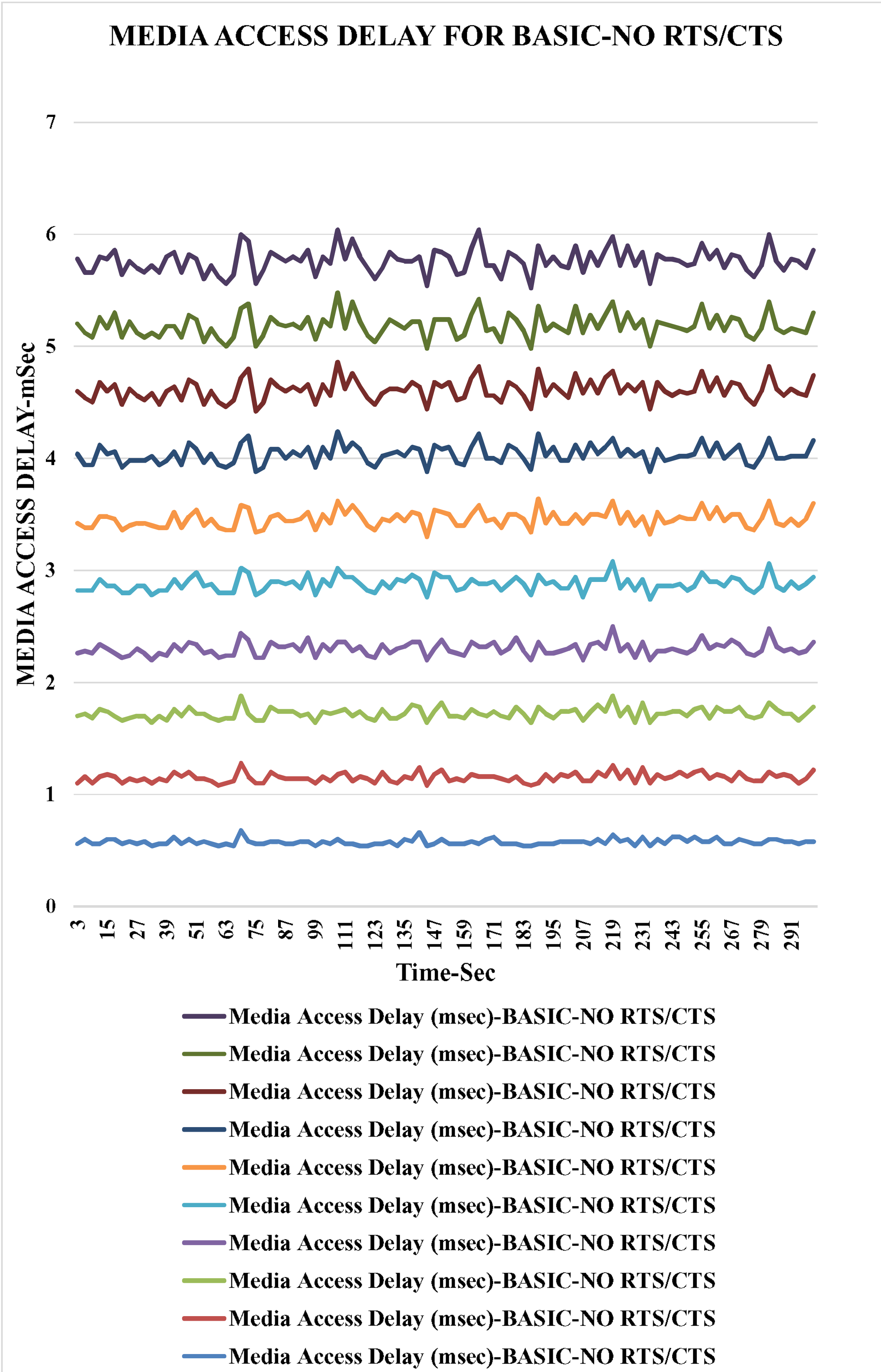


Fig.4.7. Media access delay of nodes for NO RTS

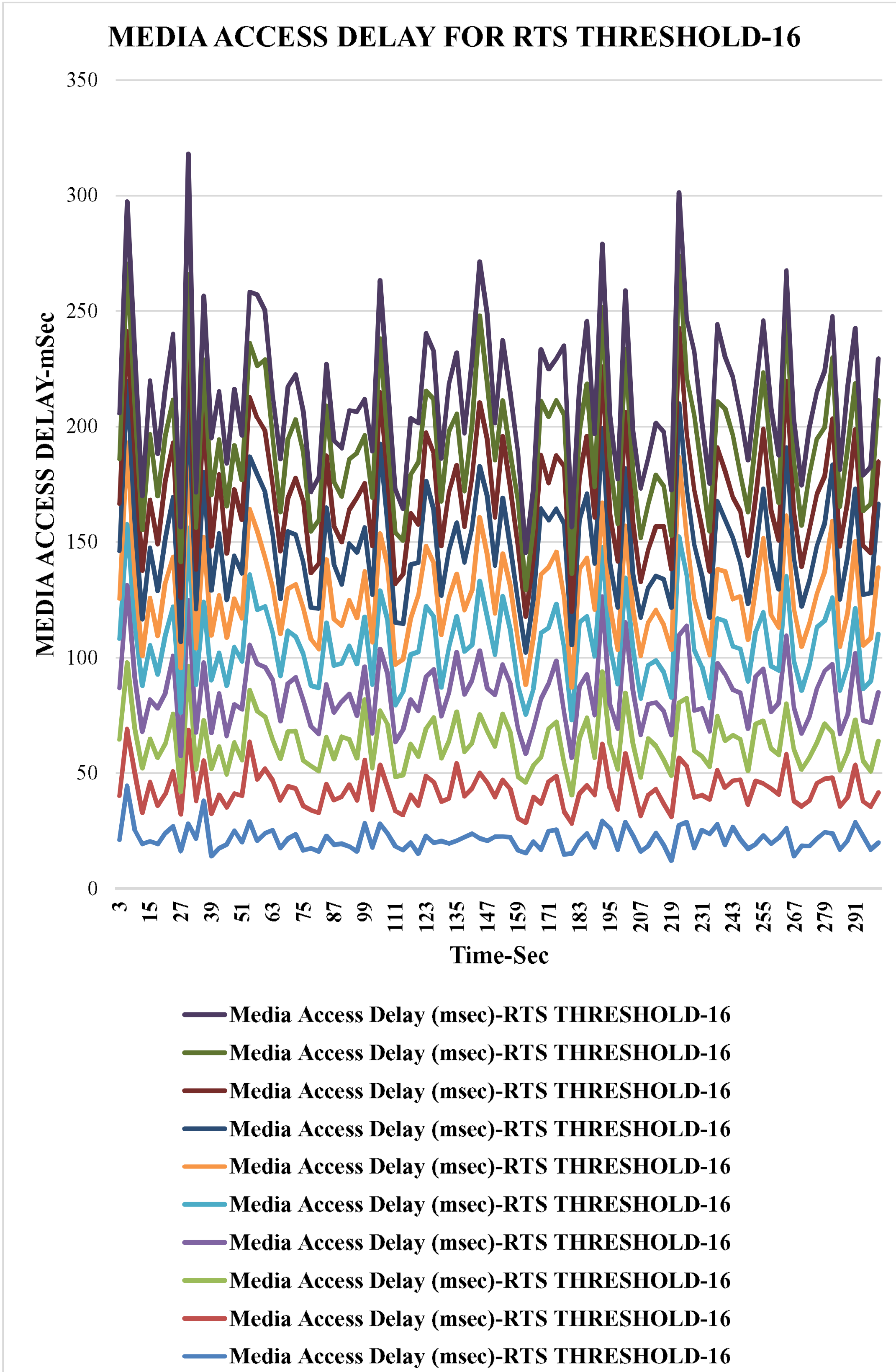


Fig.4.8. Media access delay of nodes for RTS threshold-16

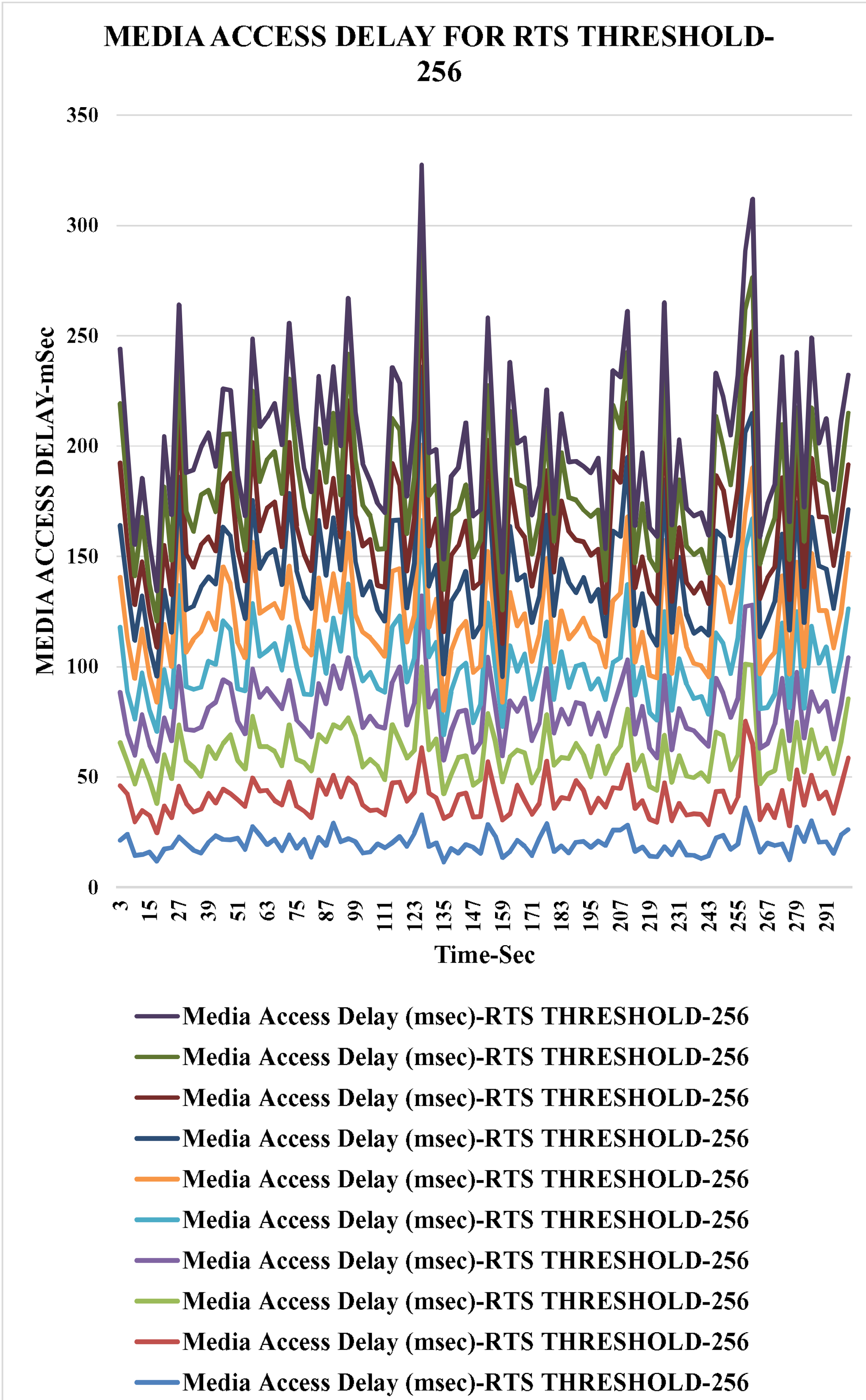


Fig.4.9. Media access delay of nodes for RTS threshold-256

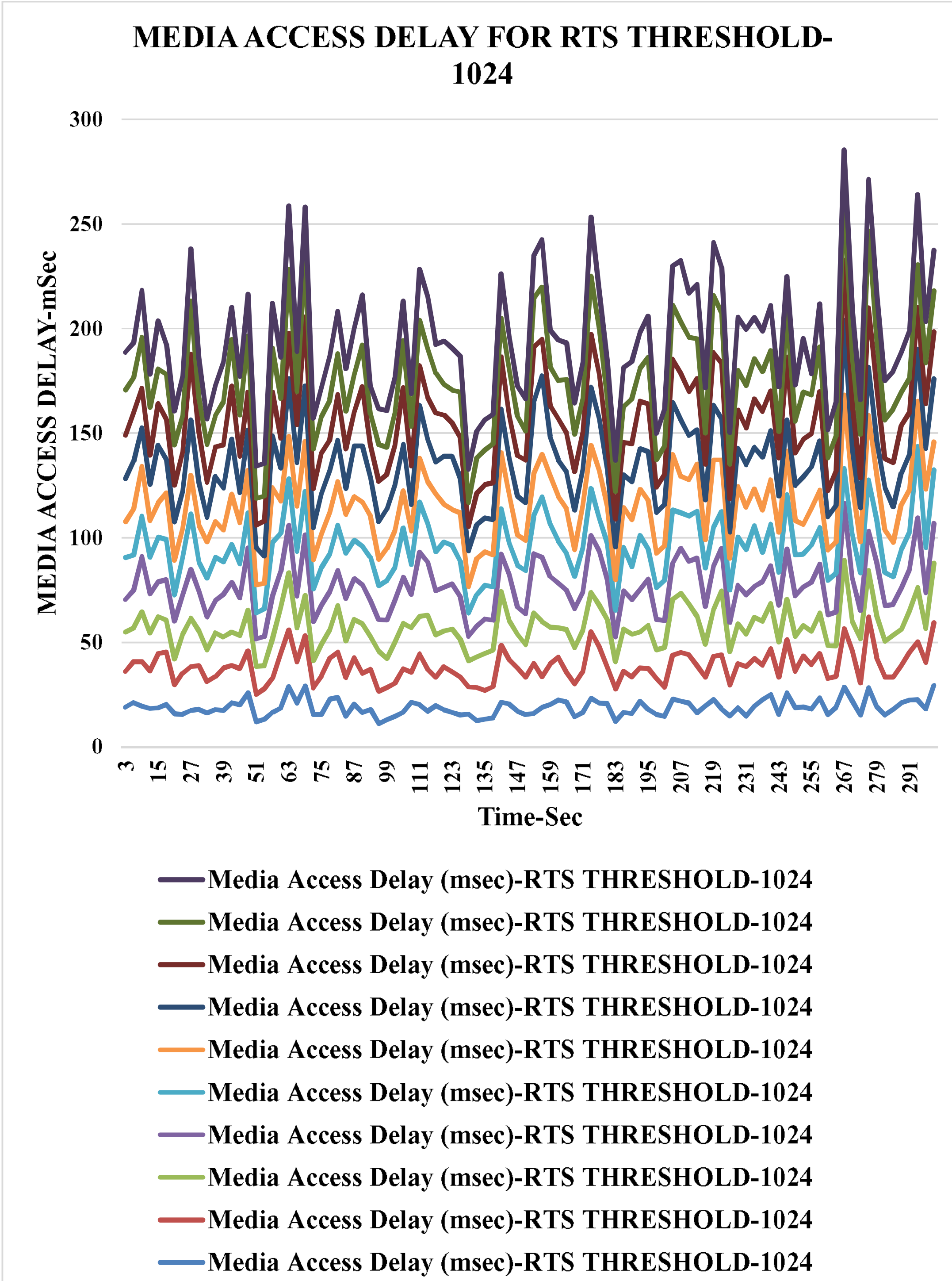


Fig.4.10. Media access delay of nodes for RTS threshold-1024

As shown in above graphs, media access delay is calculated for different nodes for various threshold values using simulations. Apart from distinct results, mean values are also calculated using simulations as illustrated in Table 4.2. Fig. 4.11 shows the graphical results. It shows that media access delay is highest for RTS threshold value of 16.

Node	MEAN VALUES-BASIC Media Access Delay (msec)	MEAN VALUES-RTS=16 Media Access Delay (msec)	MEAN VALUES-RTS=256 Media Access Delay (msec)	MEAN VALUES-RTS=1024 Media Access Delay (msec)
1	0.59	21.56	19.99	18.92
2	0.59	21.35	20.66	19.74
3	0.58	20.74	20.35	19.11
4	0.59	21.03	20.16	19.54
5	0.59	21.65	20.51	19.11
6	0.59	21.39	20.52	19.43
7	0.59	21.33	20.53	20.2
8	0.59	21.74	20.42	19.78
9	0.58	21.39	19.97	19.83
10	0.59	21.9	20.24	19.24

Table 4.2. Mean values of results

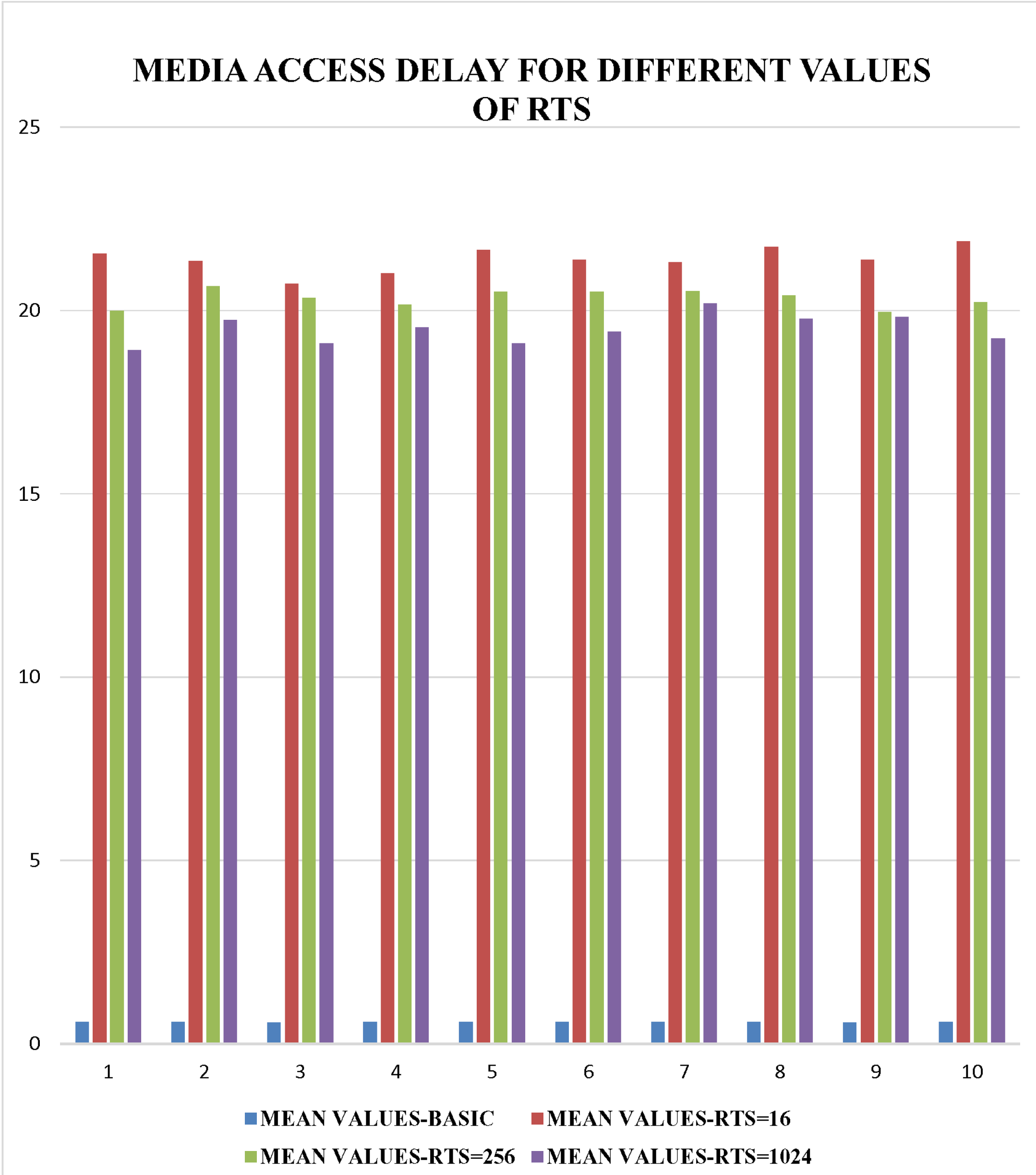


Fig.4.11. Mean values of results

The above results show that RTS mechanism increases media access delay. The highest delay is resulted for lowest value of RTS as it has the highest probability of sending RTS frame. Fig. 4.12. to Fig.4.15. show the graphical results of total packet delay for various values of RTS thresholds. Fig.4.16. show the mean values of results.

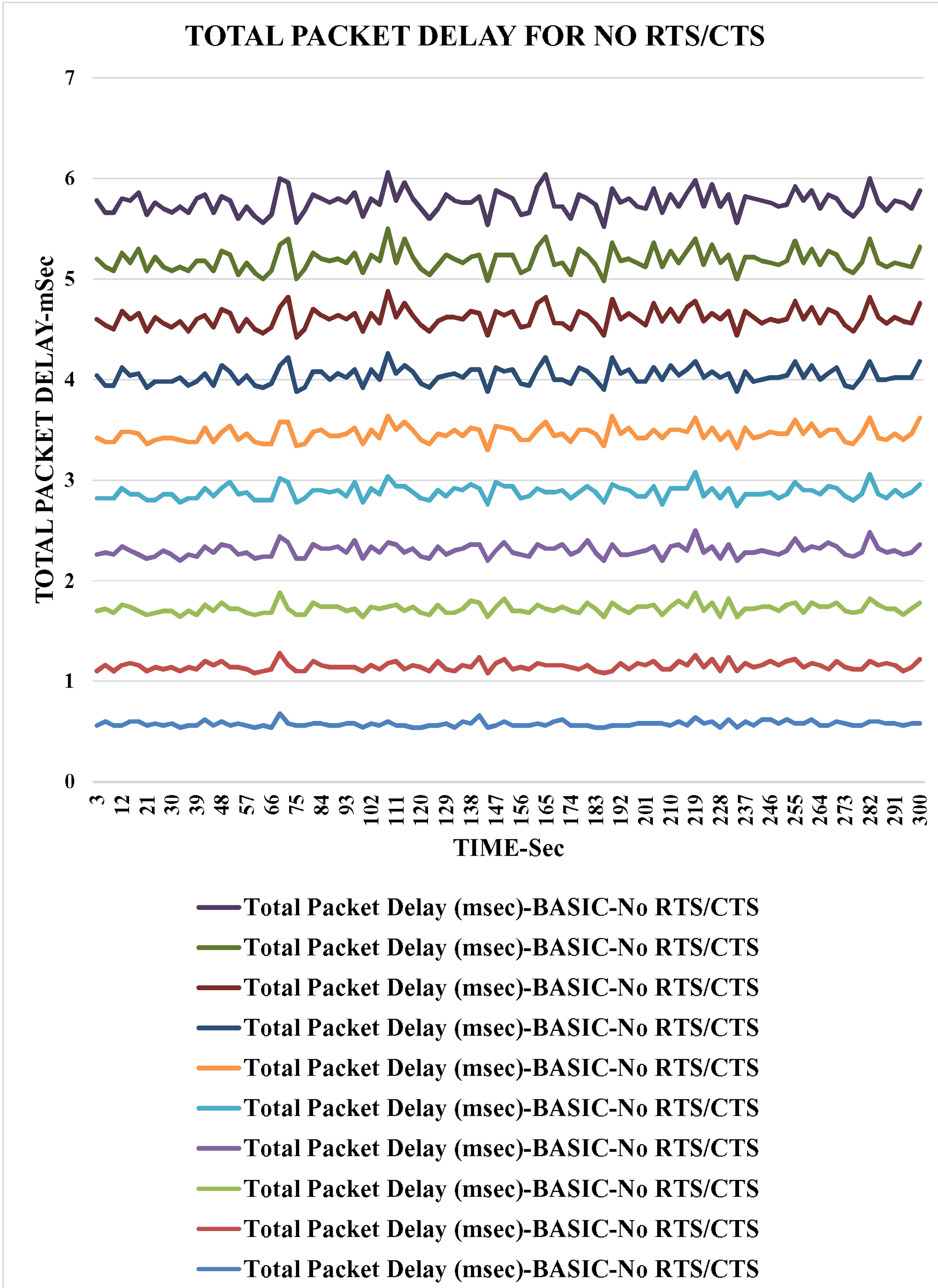


Fig.4.12. Total packet delay of nodes for No RTS/CTS

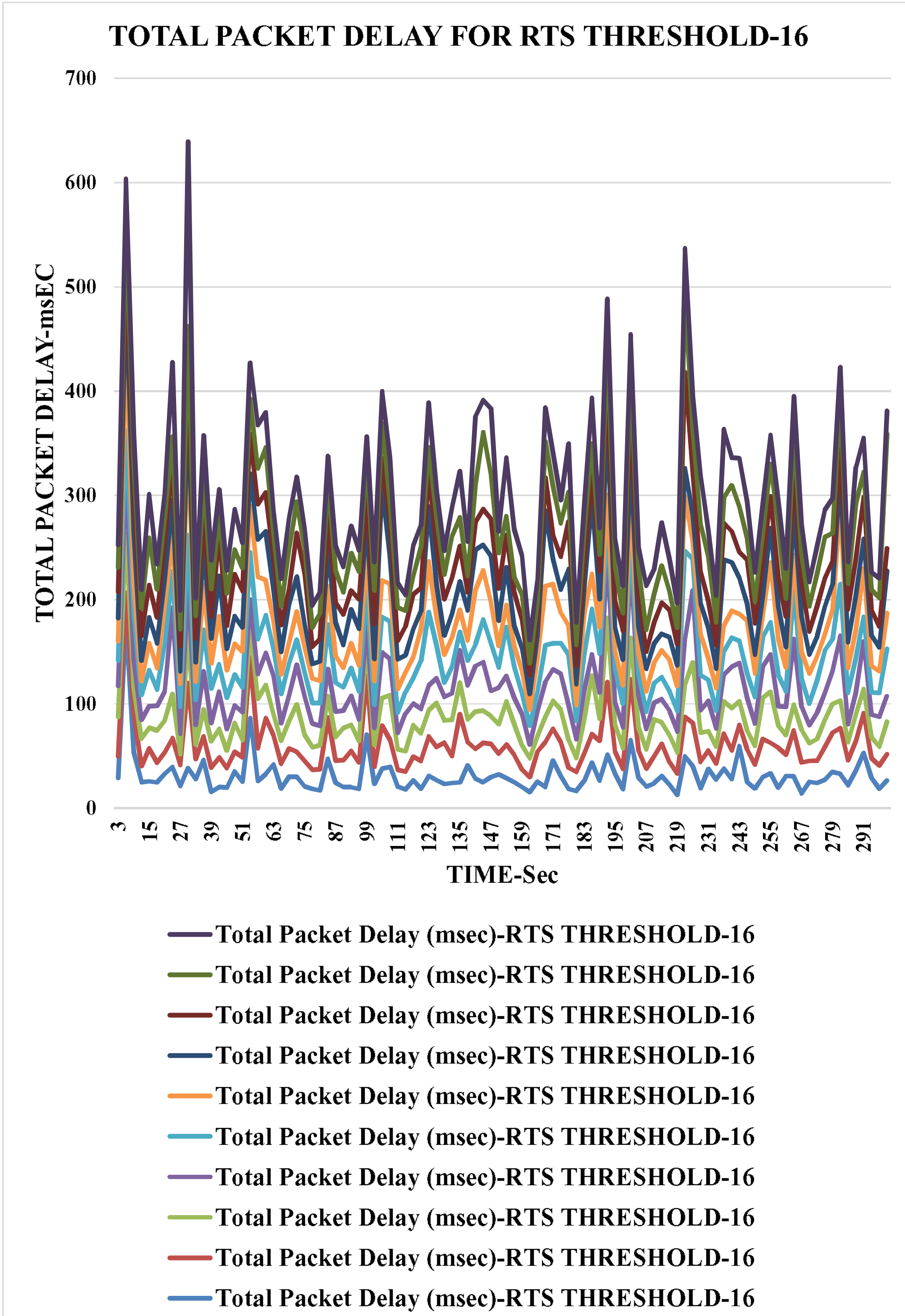


Fig.4.13. Total packet delay of nodes for RTS threshold-16

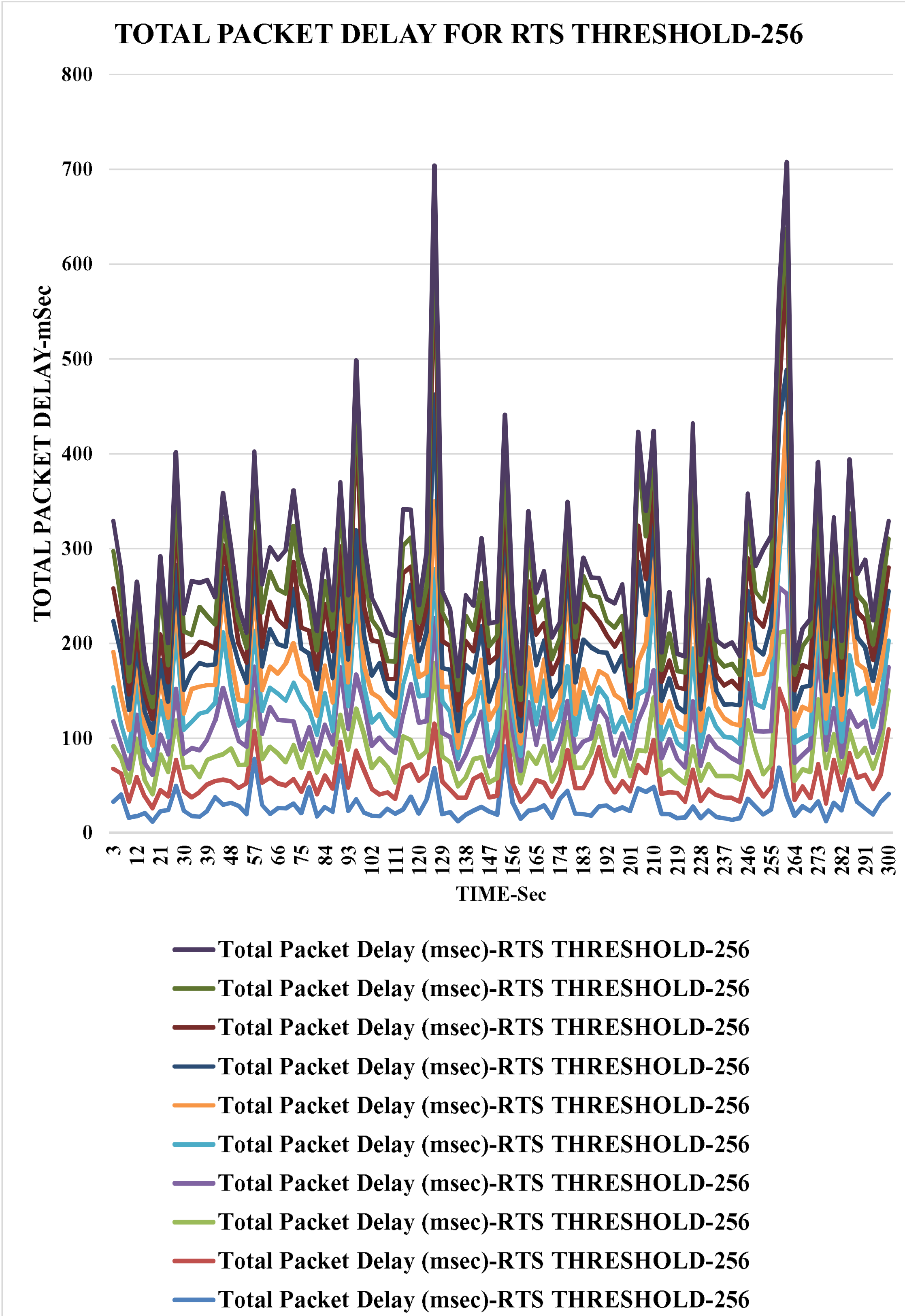


Fig.4.14. Total packet delay of nodes for RTS threshold-256

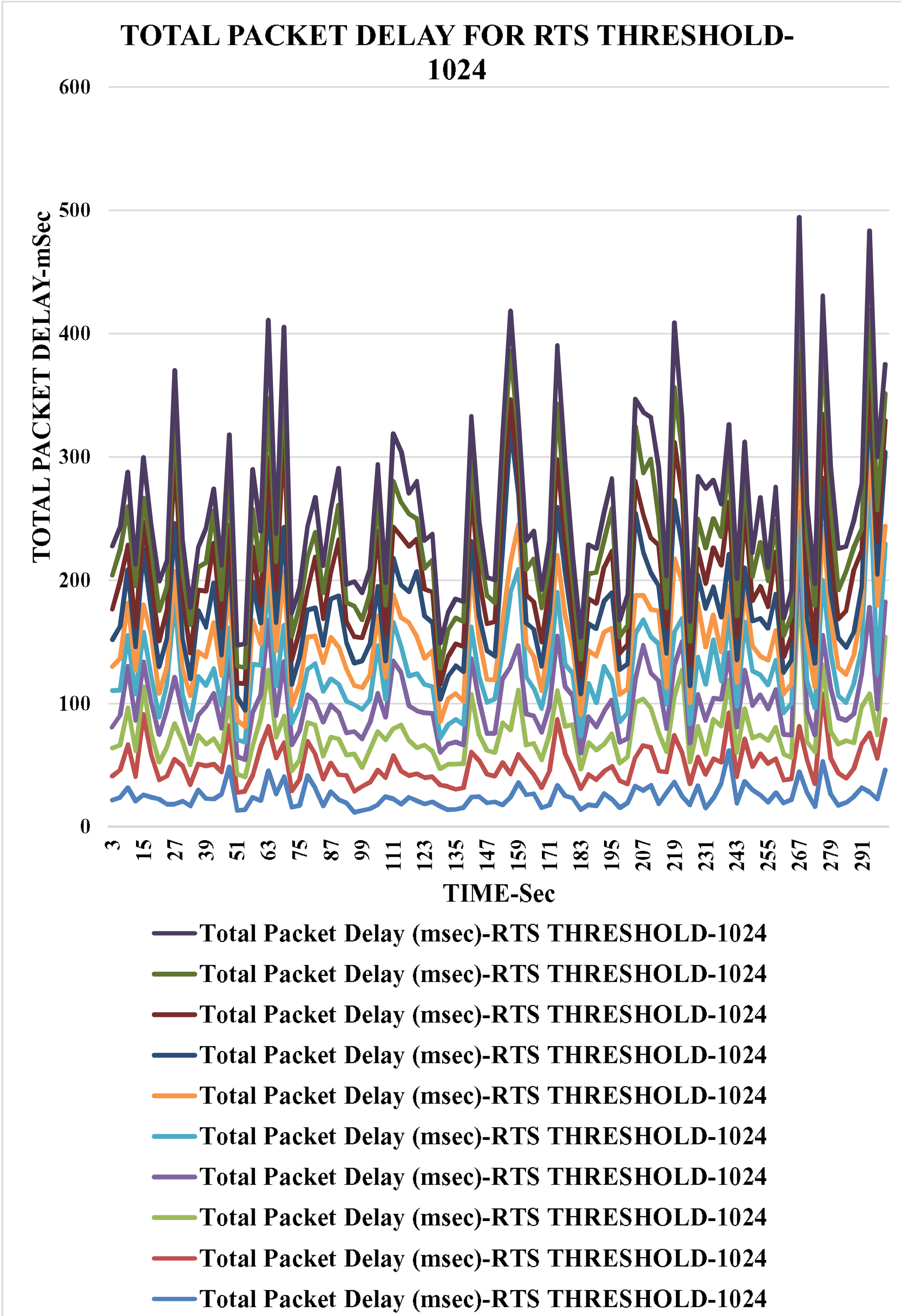


Fig.4.15. Total packet delay of nodes for RTS threshold-1024

Fig.4.15. shows the total packet delay of nodes for RTS threshold of 1024. The total packet delay is reduced for highest value of RTS threshold of 1024 as probability of RTS/CTS is the lowest for higher threshold value. Threshold value 16 has the highest probability of RTS/CTS operation. IEEE 802.11 MAC protocol activates RTS mechanism only when the data frame size is larger than RTS threshold. RTS /CTS mechanism enhances packet delay as a result of handshake operation to combat collision occurrence. Table 4.3. shows the results of mean values of total packet delay. Packet delay is highest for RTS threshold value of 16 due to higher probability of RTS/CTS operation. Fig. 4.16. shows the graphical representation of results.

Node	**MEAN VALUES-BASIC Total Packet Delay** (msec)	**MEAN VALUES-RTS=16 Total Packet Delay** (msec)	**MEAN VALUES-RTS=256 Total Packet Delay** (msec)	**MEAN VALUES-RTS=1024 Total Packet Delay** (msec)
1	0.59	31.56	28.64	24.71
2	0.59	29.41	28.33	26.08
3	0.58	28.13	28.32	26.16
4	0.59	29.69	28.04	25.77
5	0.59	29.93	29.73	26.06
6	0.59	30.88	28.46	25.79
7	0.59	30.11	29.86	27.09
8	0.59	30.36	29.26	27.21
9	0.59	30.54	26.94	26.94
10	0.59	32.26	27.53	26.42

Table 4.3. Mean values of results

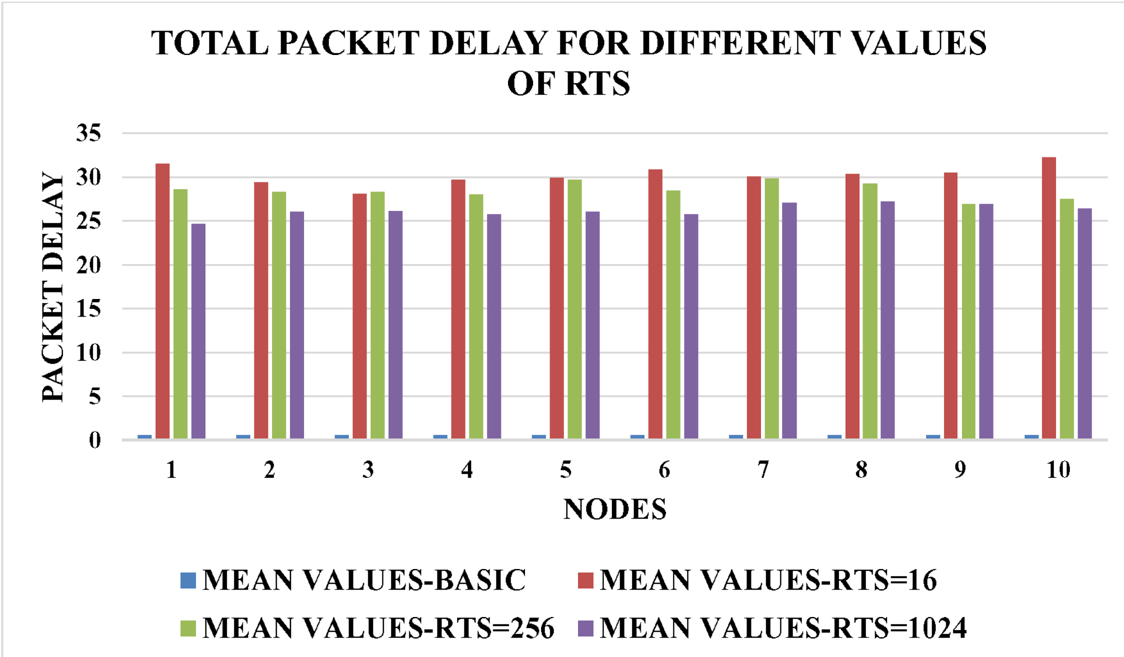


Fig.4.16. Mean values of results

The above results show that RTS mechanism increases total packet delay. The highest delay is resulted for lowest value of RTS as it has the highest probability of sending RTS frame.

EDCA Parameter Optimization

The standard as well as adapted values of AIFS are depicted in the table. Highest priority is assigned to the access category with smallest AIFS. Media access delay and total packet delays are also depicted using tabular and graphical representations. Table 4.4 shows the default values of EDCA parameters. Table 4.5. shows the diverse set of adapted values of EDCA parameters.

ACCESS CATEGORY	Cwmin	Cwmax	AIFSN
AC_BK	15	1023	7
AC_BE	15	1023	3
AC_VI	7	15	2
AC_VO	3	7	2

Table 4.4. Default values of EDCA parameters

Type Of EDCA	Basic-Default	Adapted EDCA-1	Adapted EDCA-2	Adapted EDCA-3	Adapted EDCA-4	Adapted EDCA-5
AIFS (Ac0)	7	2	6	6	8	9
AIFS (Ac1)	3	2	3	6	6	6
AIFS (Ac2)	2	1	2	2	2	2
AIFS (Ac3)	2	1	1	1	1	1

Table 4.5. Default and adapted values of EDCA parameters for simulation

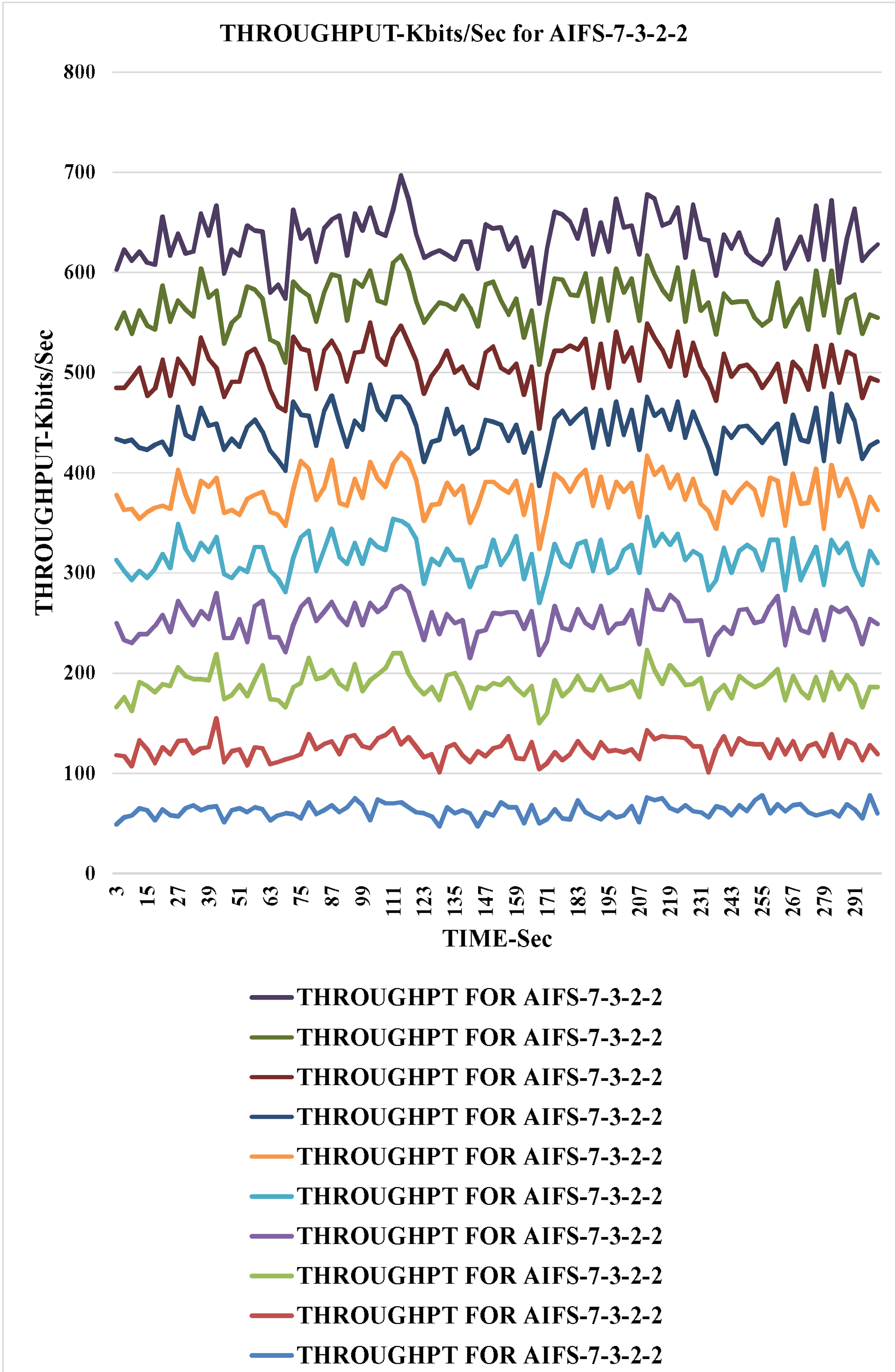


Fig.4.17. Throughput of nodes for default EDCA parameters

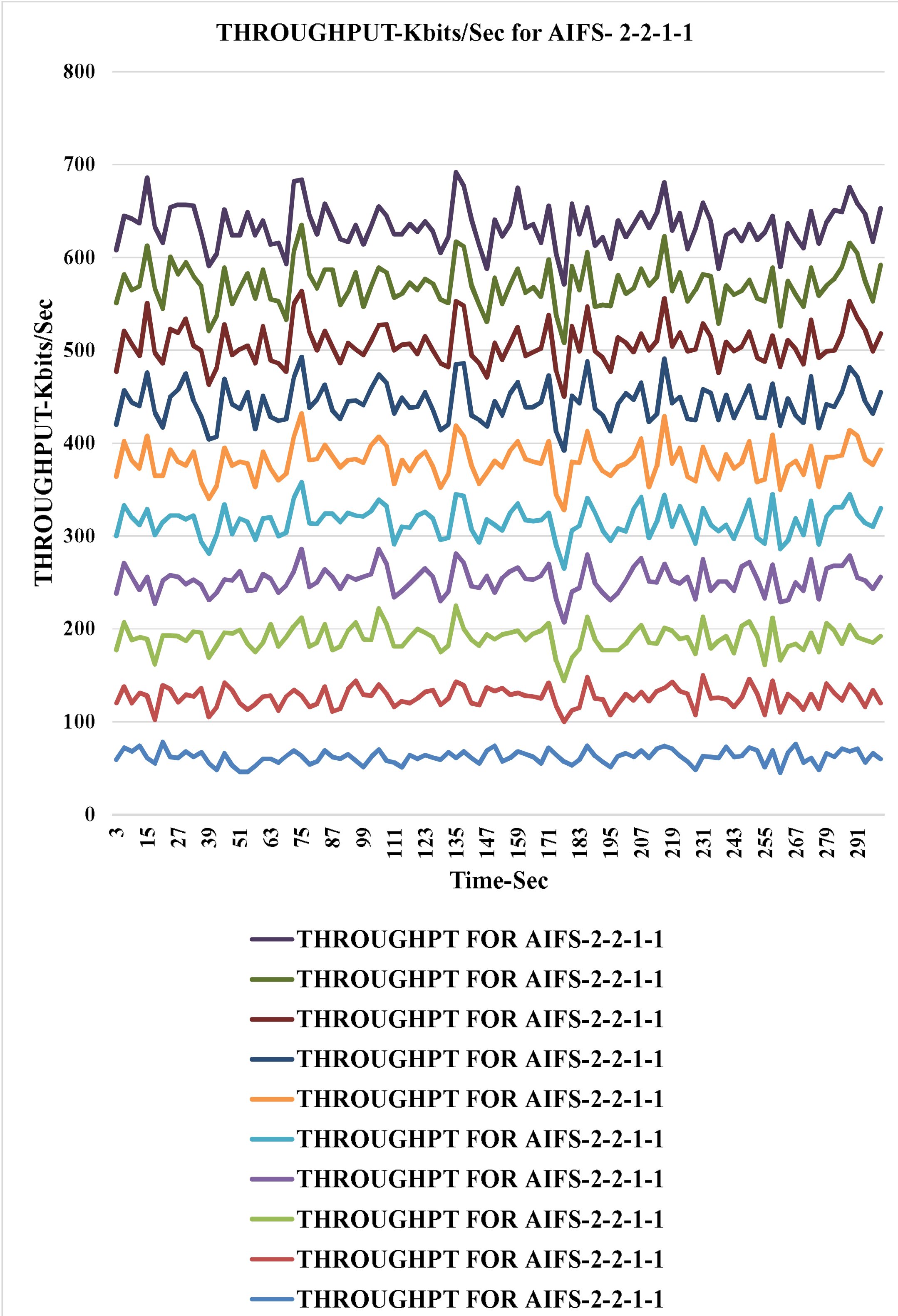


Fig.4.18. Throughput of nodes for adapted EDCA-1

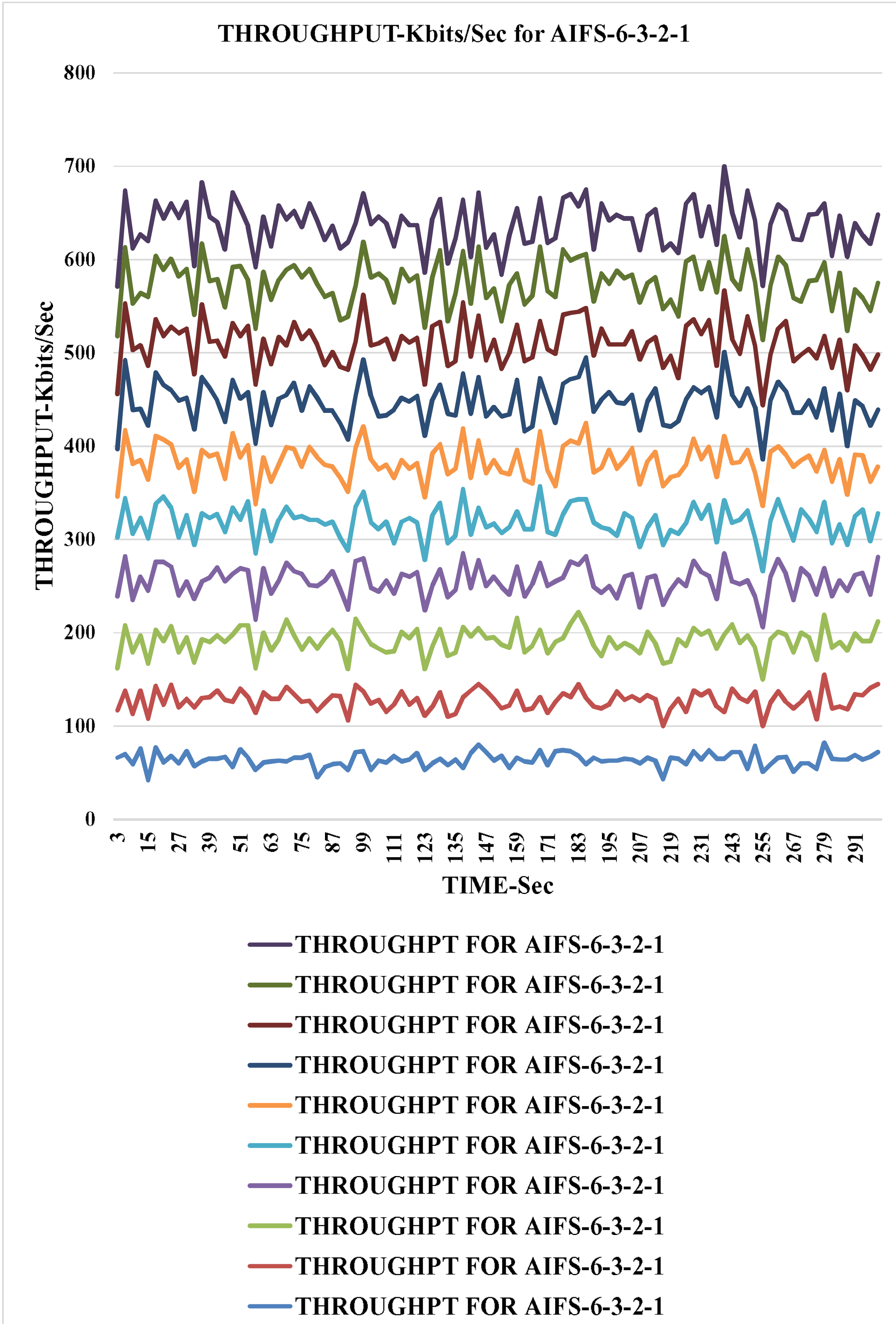


Fig.4.19. Throughput of nodes for adapted EDCA-2

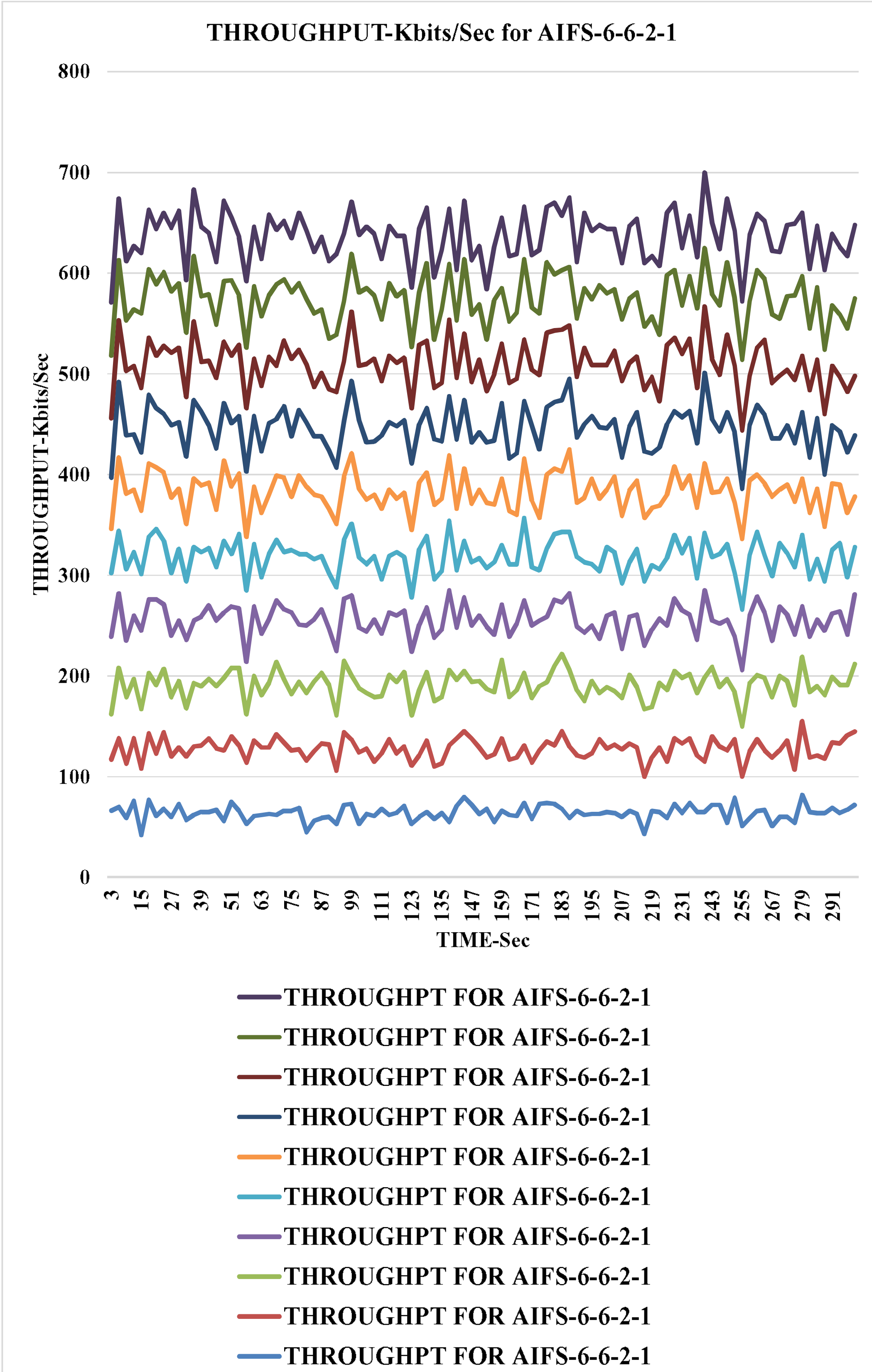


Fig.4.20. Throughput of nodes for adapted EDCA-3

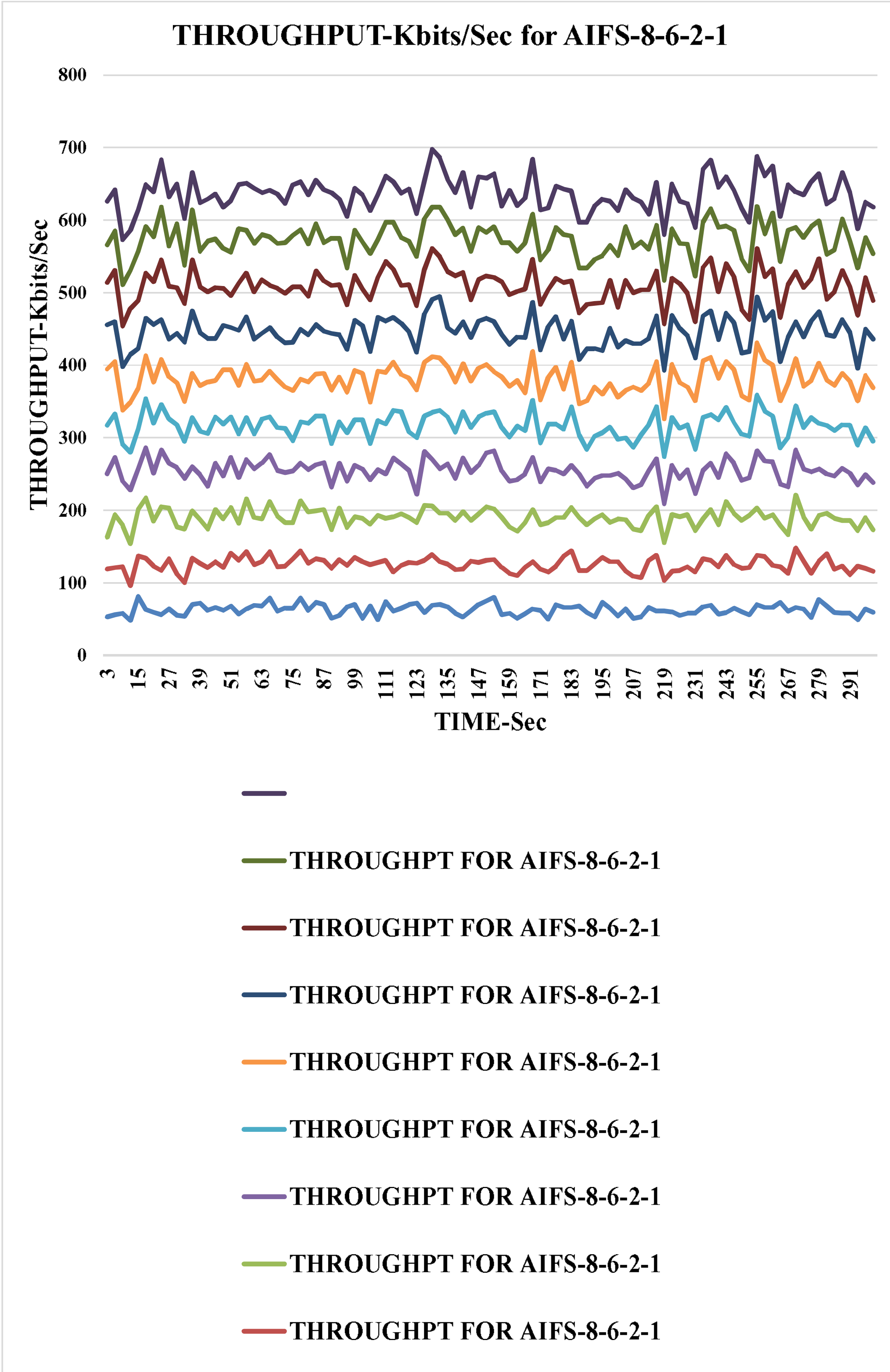


Fig.4.21. Throughput of nodes for adapted EDCA-4

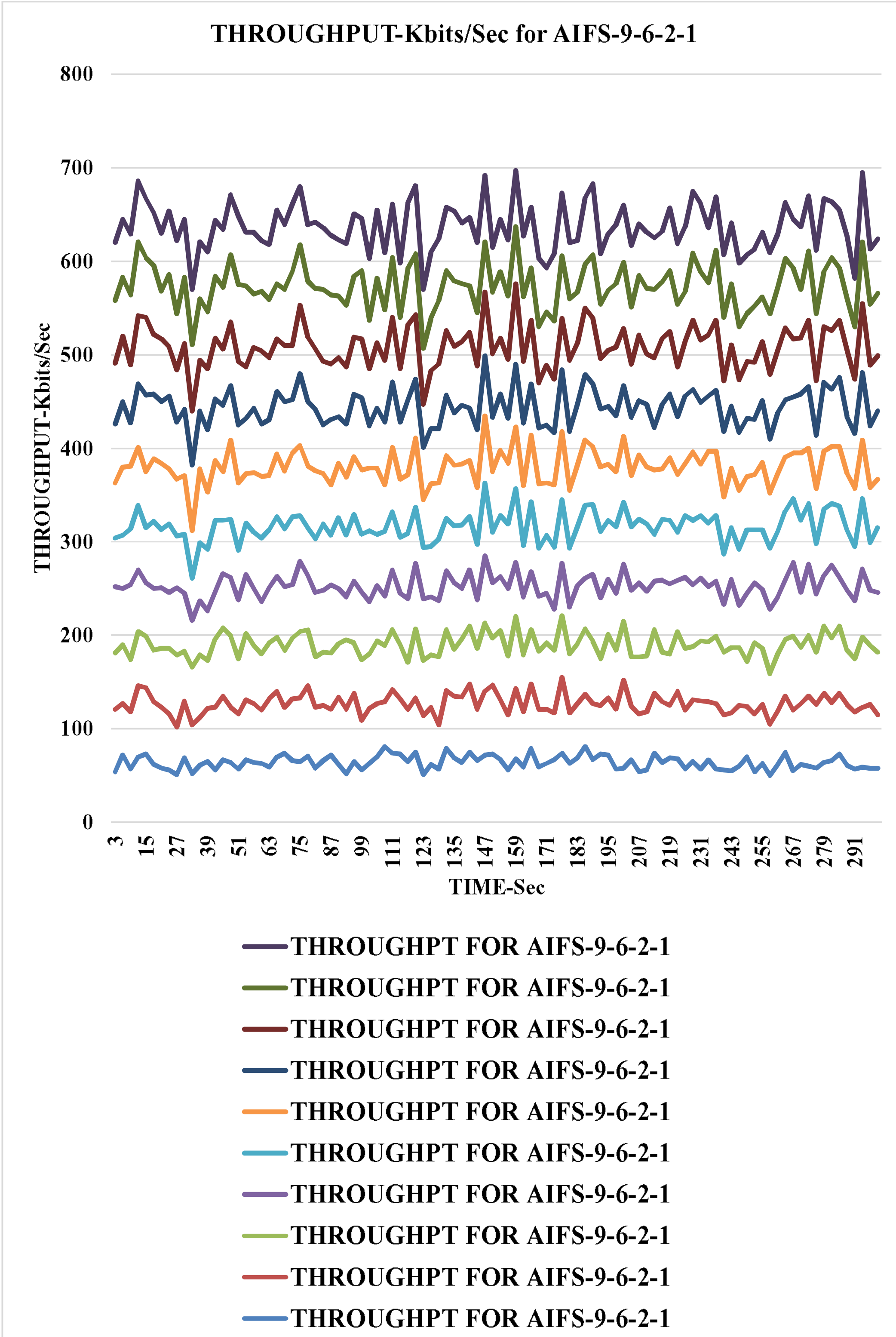


Fig.4.22. Throughput of nodes for adapted EDCA-5

Table 4.6. shows the results for mean values of throughput for basic as well as adapted EDCA parameters. Throughput is maximum for adapted cases 2 and 5.

Node	MEAN VALUES-BASIC-Throughput (Kbits/s)	MEAN VALUES-ADAPTED EDCA-1-Throughput (Kbits/s)	MEAN VALUES-ADAPTED EDCA-2-Throughput (Kbits/s)	MEAN VALUES-ADAPTED EDCA-3-Throughput (Kbits/s)	MEAN VALUES-ADAPTED EDCA-4-Throughput (Kbits/s)	MEAN VALUES-ADAPTED EDCA-5-Throughput (Kbits/s)
1	63	65	65	63	63	65
2	62	63	64	65	63	64
3	65	64	64	64	65	64
4	65	63	65	63	65	65
5	64	64	63	64	63	63
6	64	64	65	65	65	65
7	64	64	64	64	65	64
8	64	65	64	64	64	64
9	64	65	65	64	64	65
10	64	64	63	64	64	63
Average	63.9	64.1	64.2	64	64.1	64.2

Table 4.6. Mean values of results

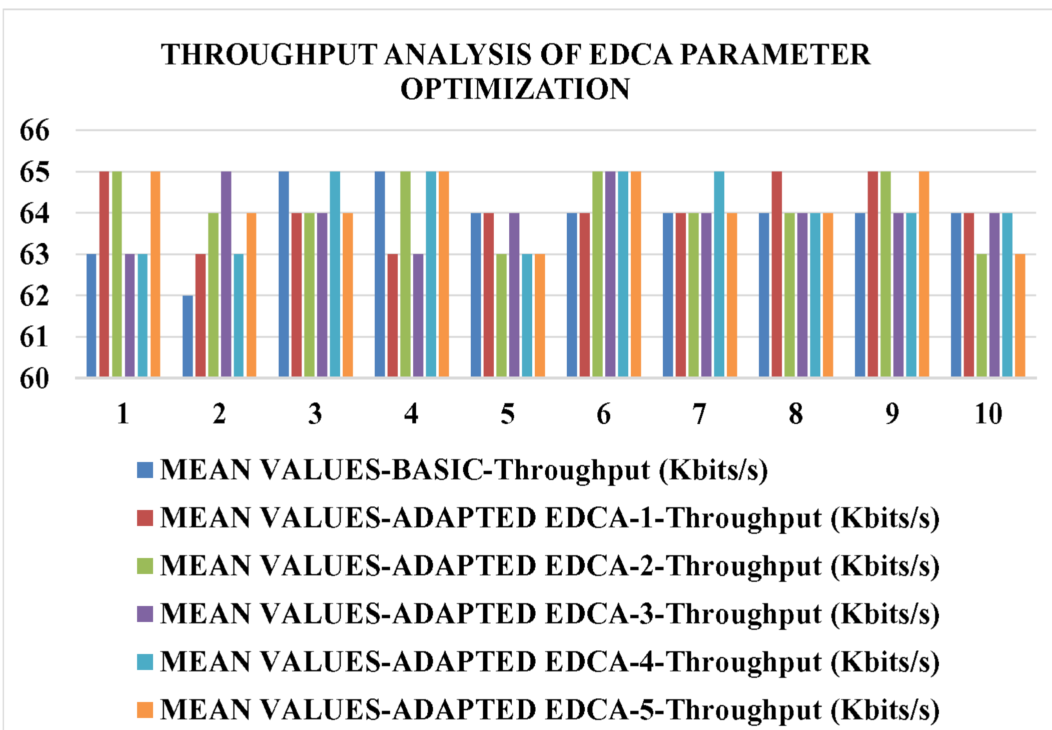


Fig.4.23. Mean values of results

Fig 4.23. illustrates that adaptation of EDCA parameters results into enhanced throughput. The highest throughput is achieved in adapted EDCA-2 and 5. It is the lowest in case of default values. The following graphs show the results of media access delay.

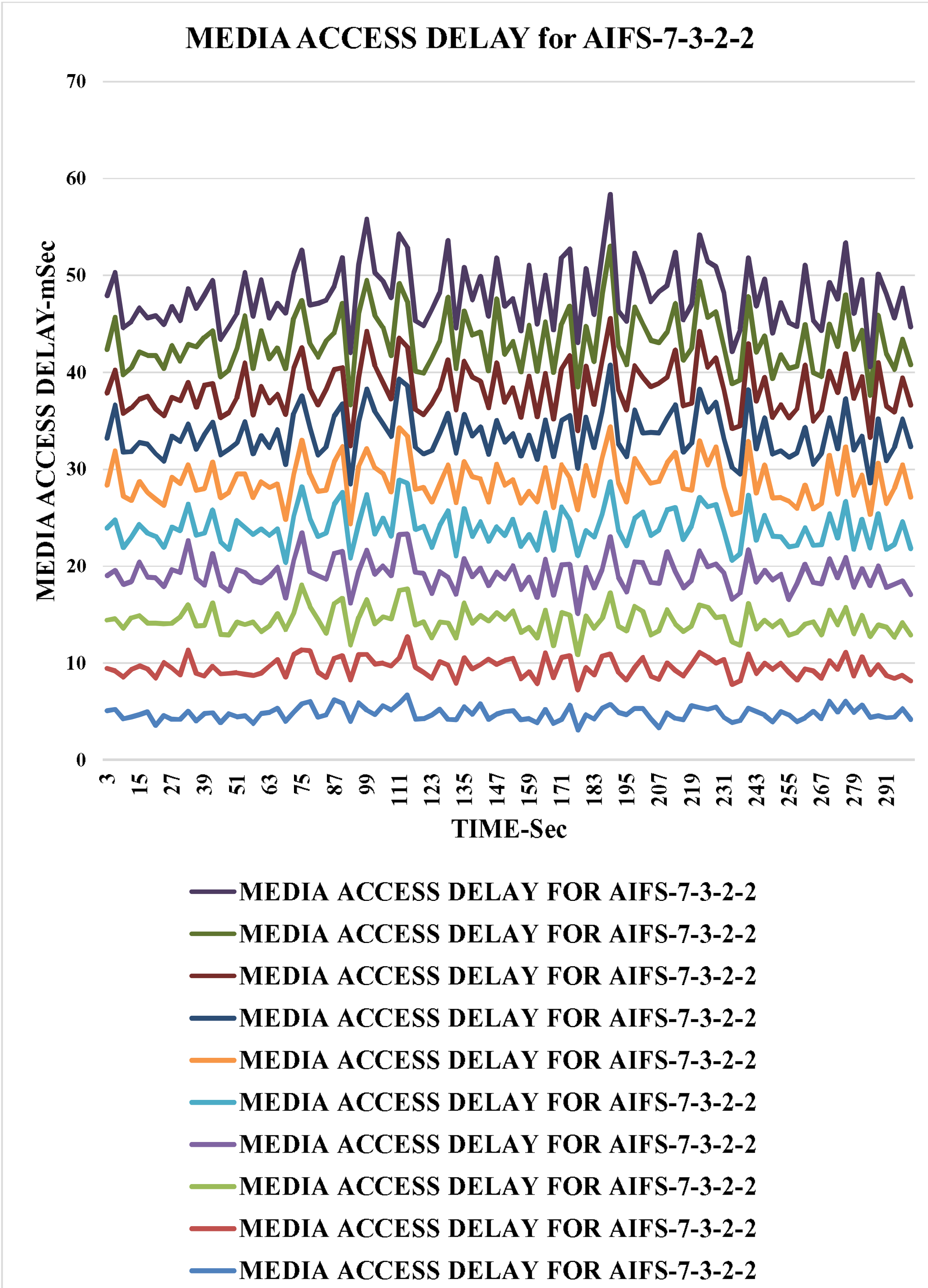


Fig.4.24. Media access delay for default EDCA parameters

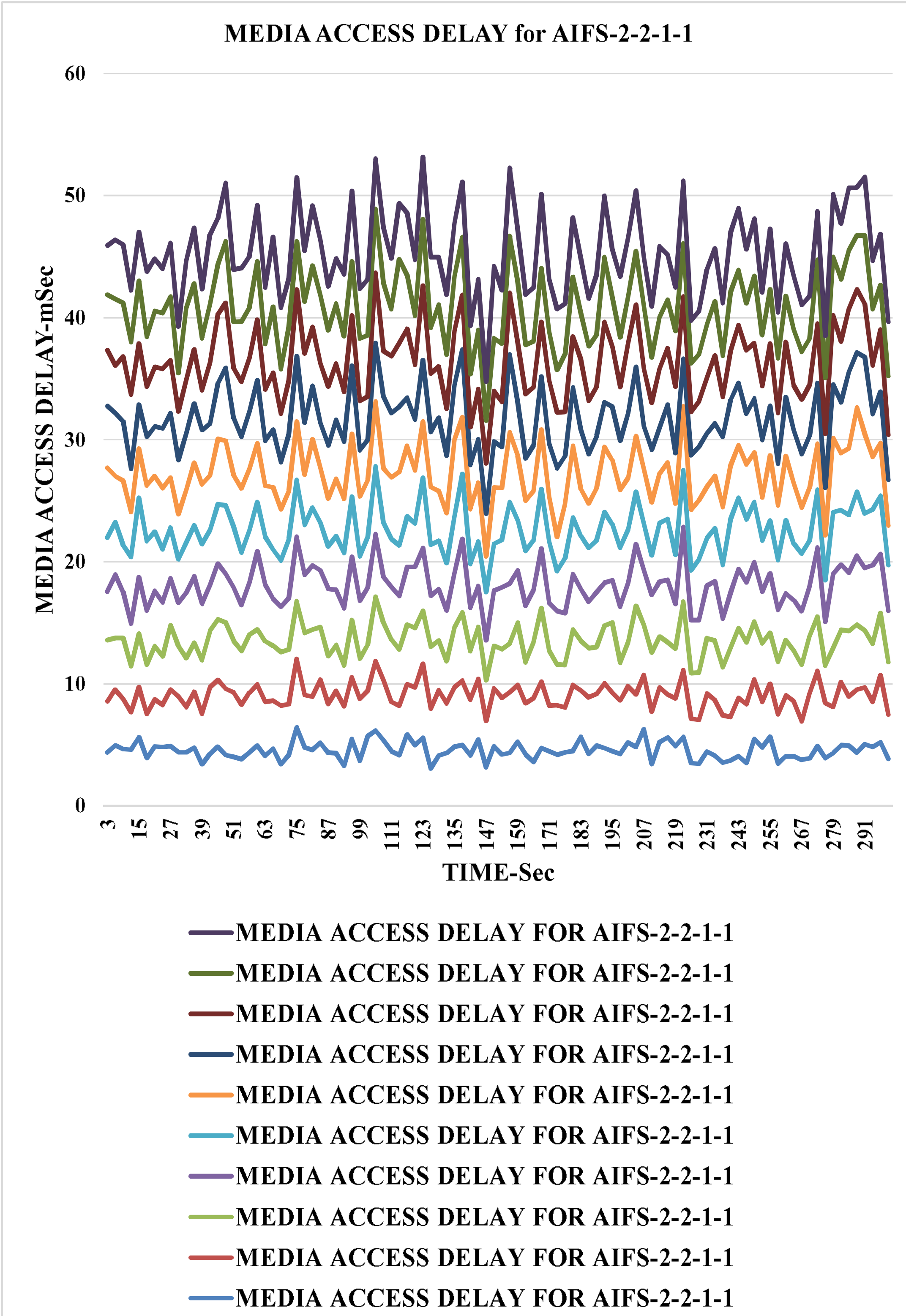


Fig.4.25. Media access delay of nodes for adapted EDCA-1

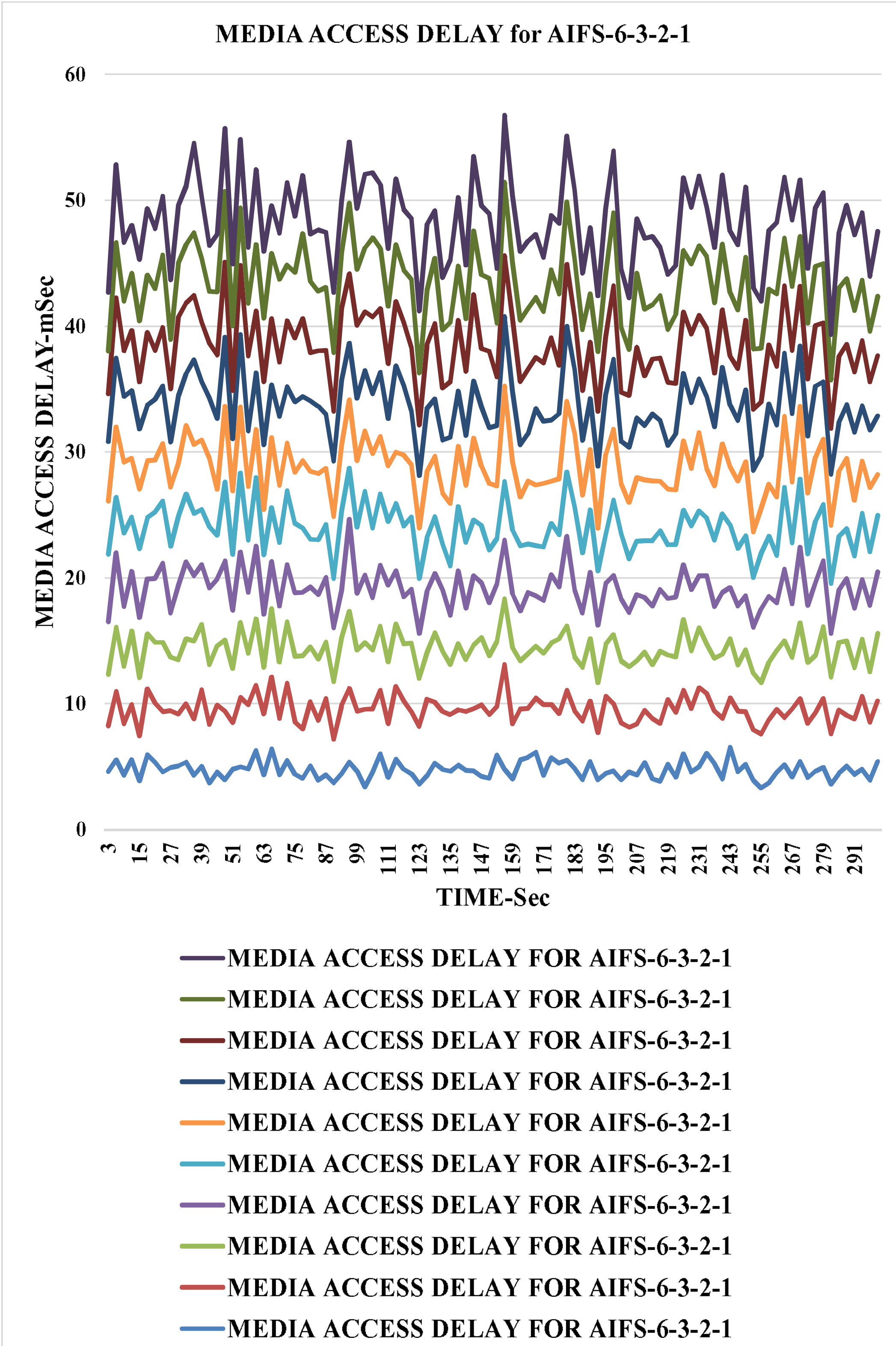


Fig.4.26. Media access delay of nodes for adapted EDCA-2

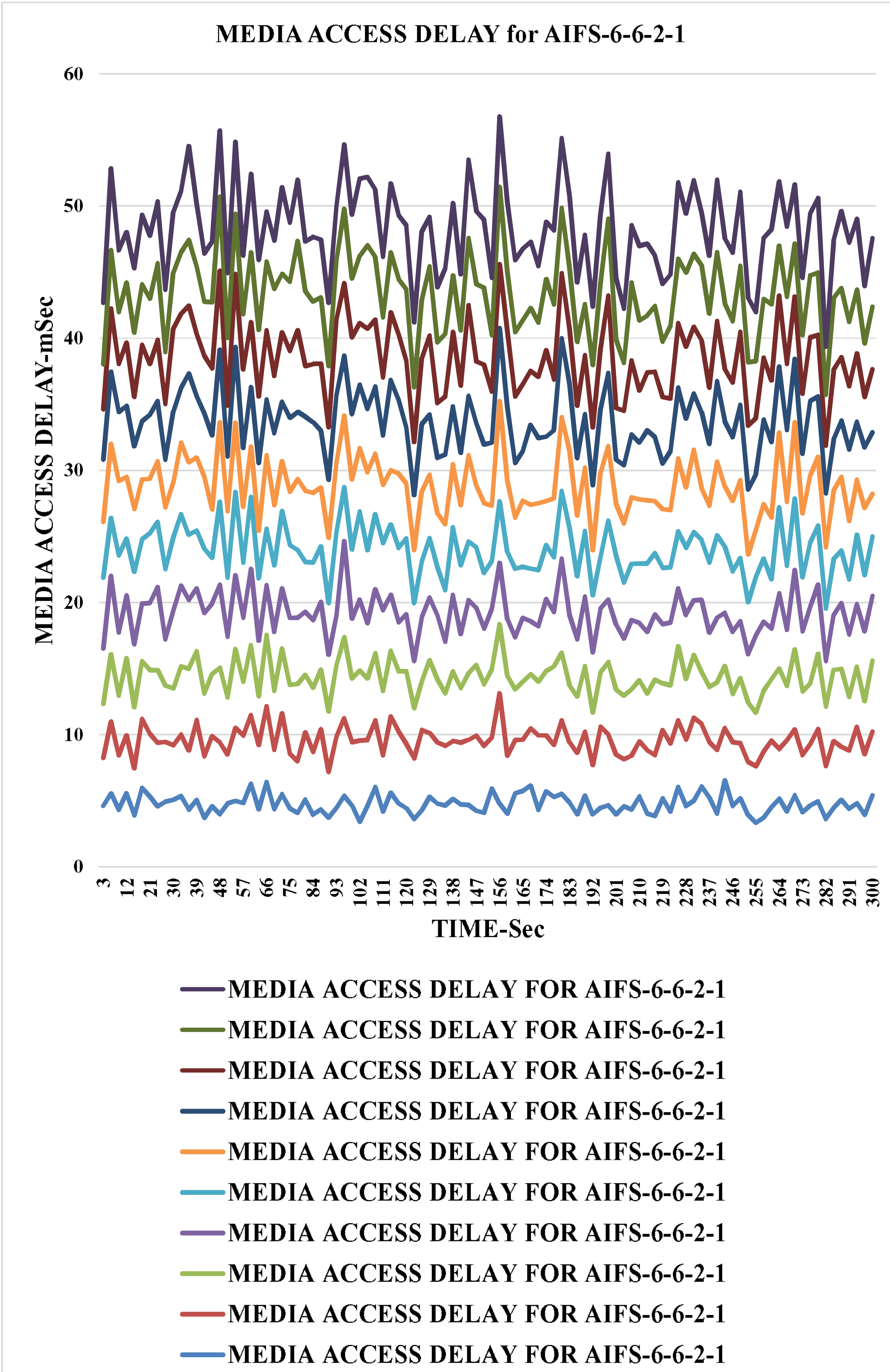


Fig.4.27. Media access delay of nodes for adapted EDCA-3

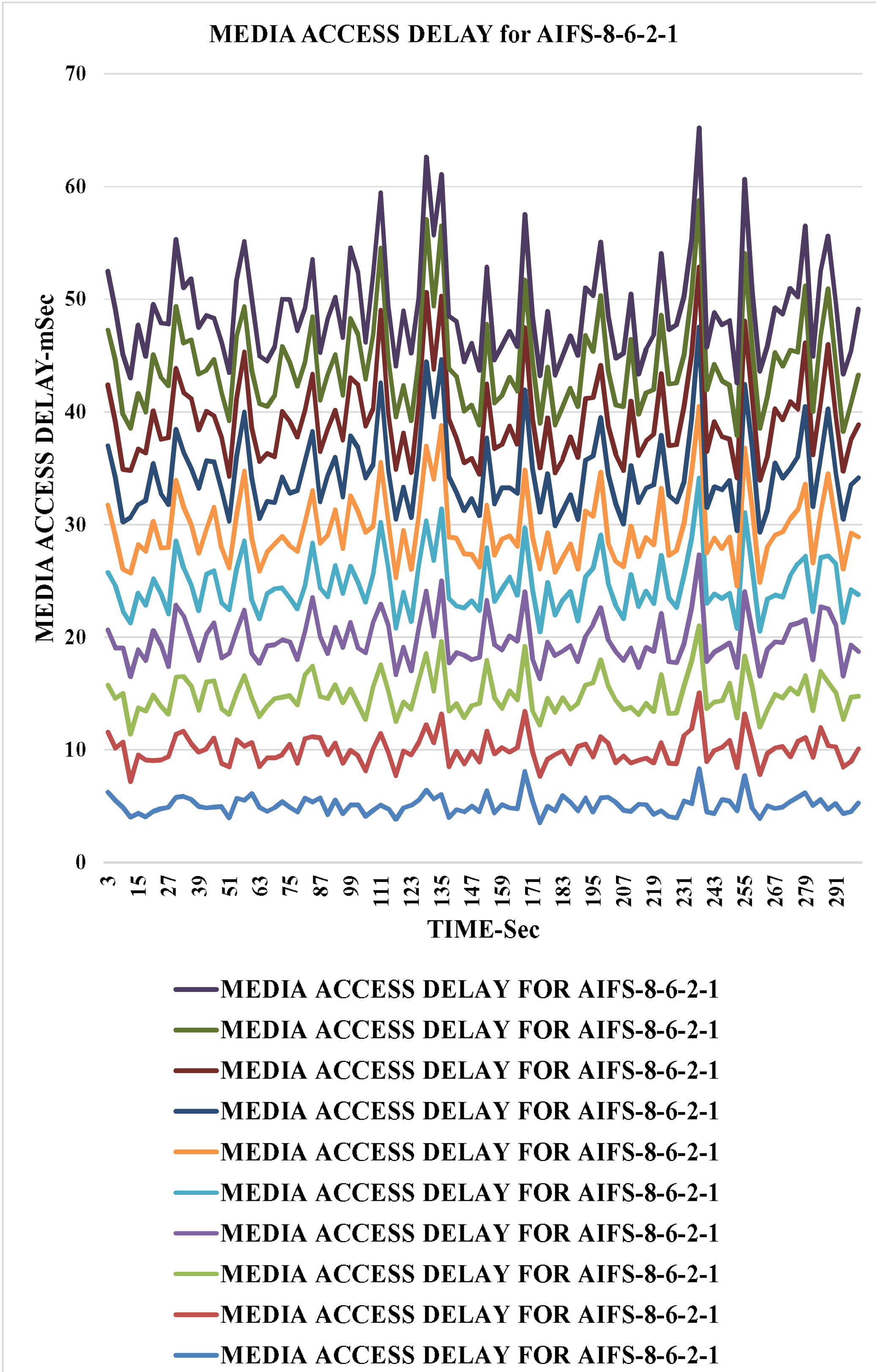


Fig.4.28. Media access delay of nodes for adapted EDCA-4

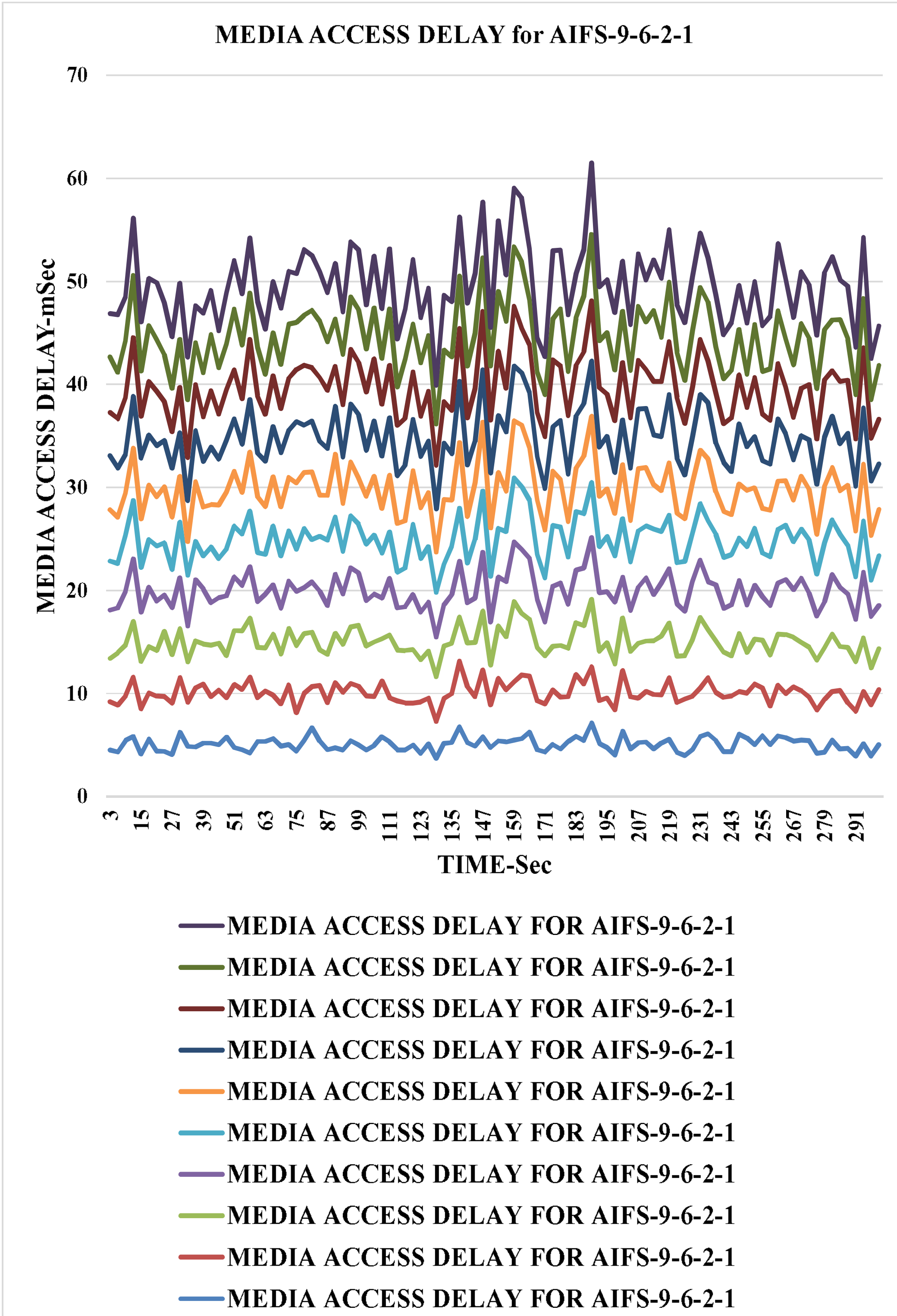


Fig.4.29. Media access delay of nodes for adapted EDCA-5

Table 4.7. shows the mean values of media access delay for default and adapted EDCA parameters. As shown in tabular and graphical results, it is the lowest for adapted EDCA-3.

Node	MEAN VALUES -BASIC- Media Access Delay (msec)	MEAN VALUES- ADAPTED EDCA-1- Media Access Delay	MEAN VALUES- ADAPTED EDCA-2- Media Access Delay (msec)	MEAN VALUES- ADAPTED EDCA-3- Media Access Delay (msec)	MEAN VALUES- ADAPTED EDCA-4- Media Access Delay (msec)	MEAN VALUES- ADAPTED EDCA-5- Media Access Delay (msec)
1	4.79	5.09	4.76	4.55	5.11	4.76
2	4.78	5	4.83	4.54	4.91	4.83
3	4.79	4.98	4.84	4.5	4.89	4.84
4	4.89	4.97	4.82	4.55	4.88	4.82
5	4.78	4.94	4.81	4.5	4.94	4.81
6	4.85	4.95	4.84	4.63	4.91	4.84
7	4.79	4.94	4.87	4.52	4.97	4.87
8	4.73	4.93	4.86	4.61	4.89	4.86
9	4.91	4.93	4.89	4.51	4.82	4.89
10	4.87	5.02	4.88	4.48	4.92	4.88
Average	4.82	4.98	4.84	4.54	4.92	4.84

Table 4.7. Mean values of Media access delay

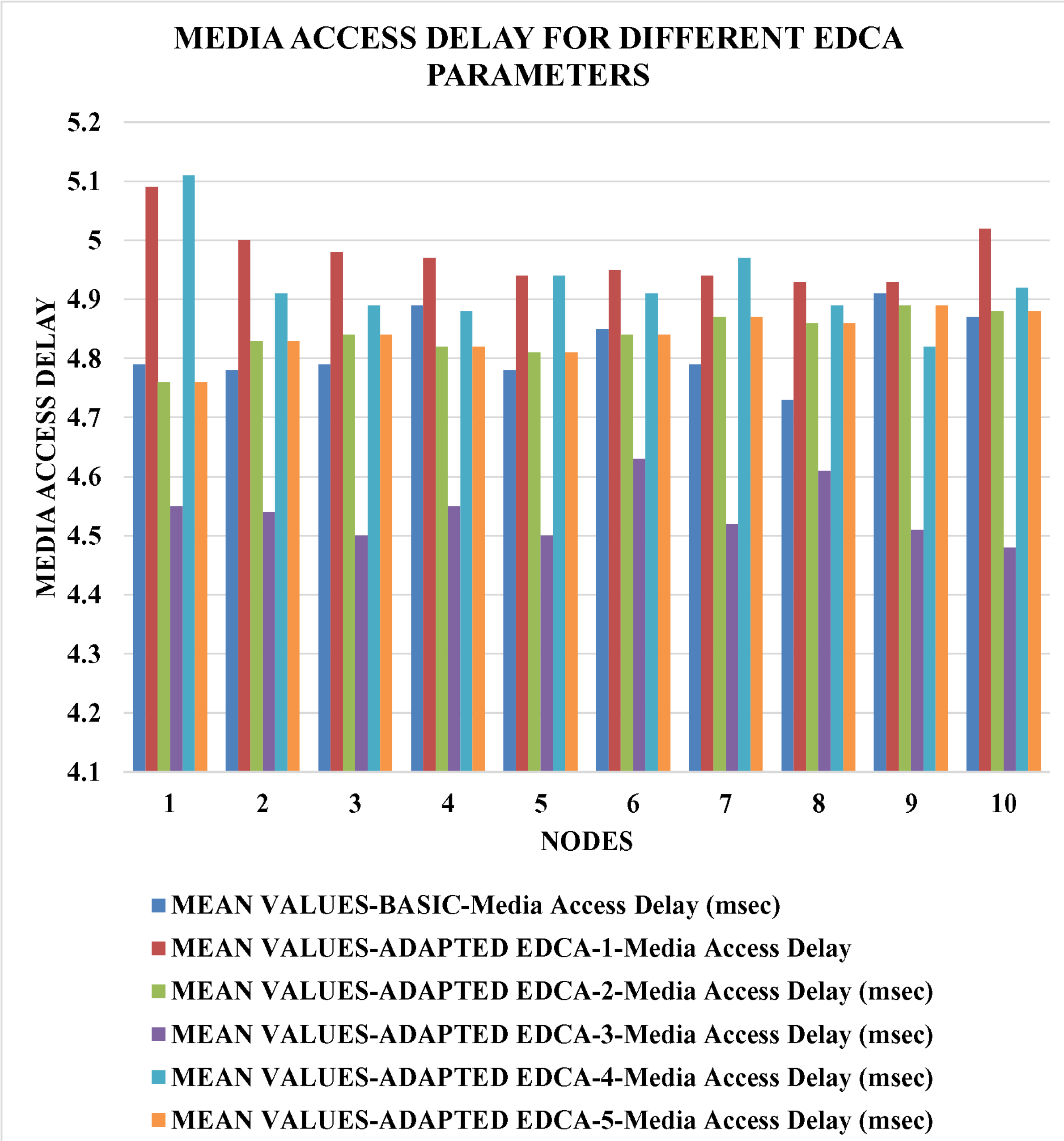


Fig.4.30. Mean values of Media access delay

Results illustrated in Fig.4.30. show that the lowermost value of MAC delay is achieved for adapted EDCA-3. The next section shows the graphical results of total packet delay for various EDCA parameters.

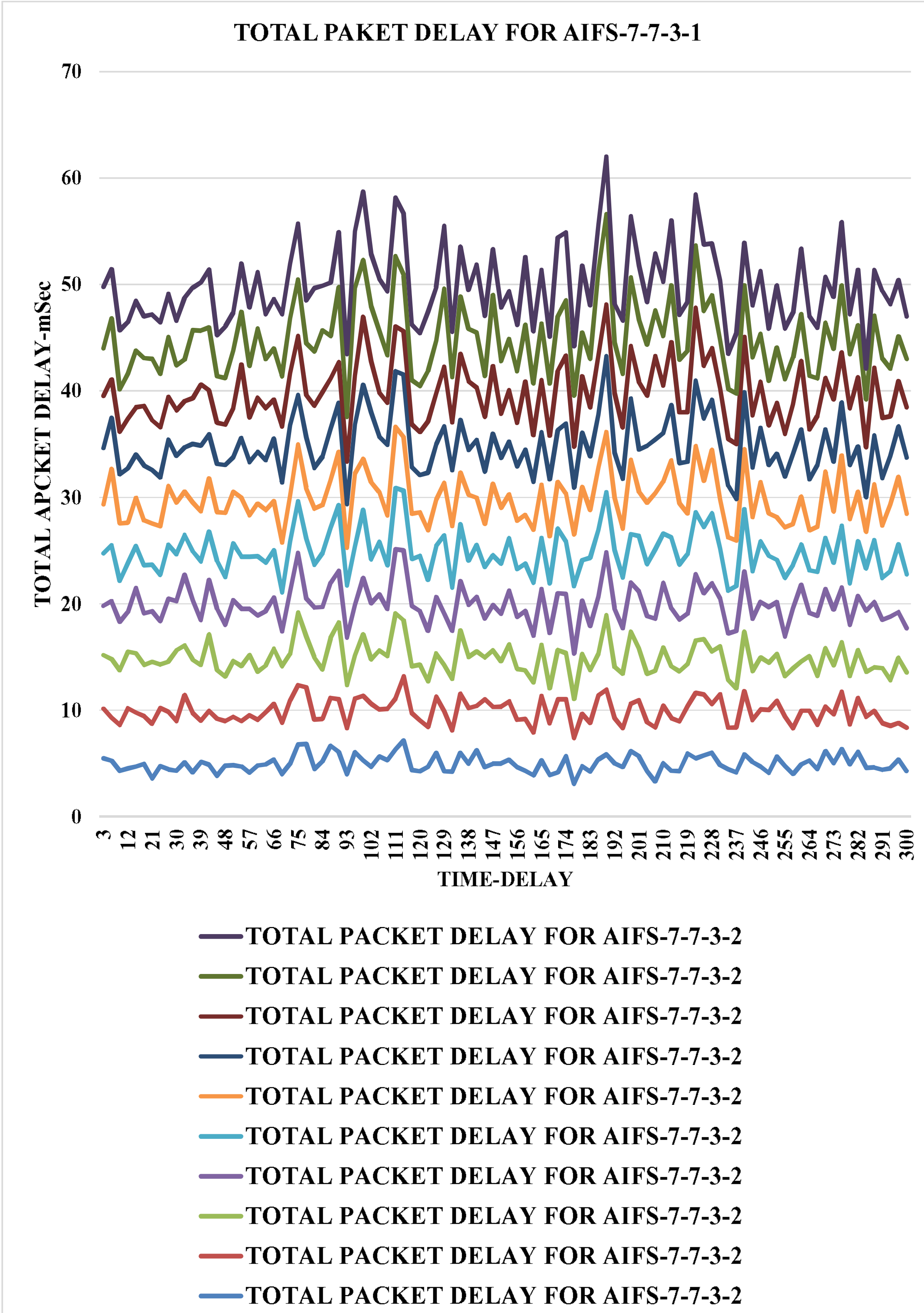


Fig.4.31. Total packet delay for default EDCA parameters

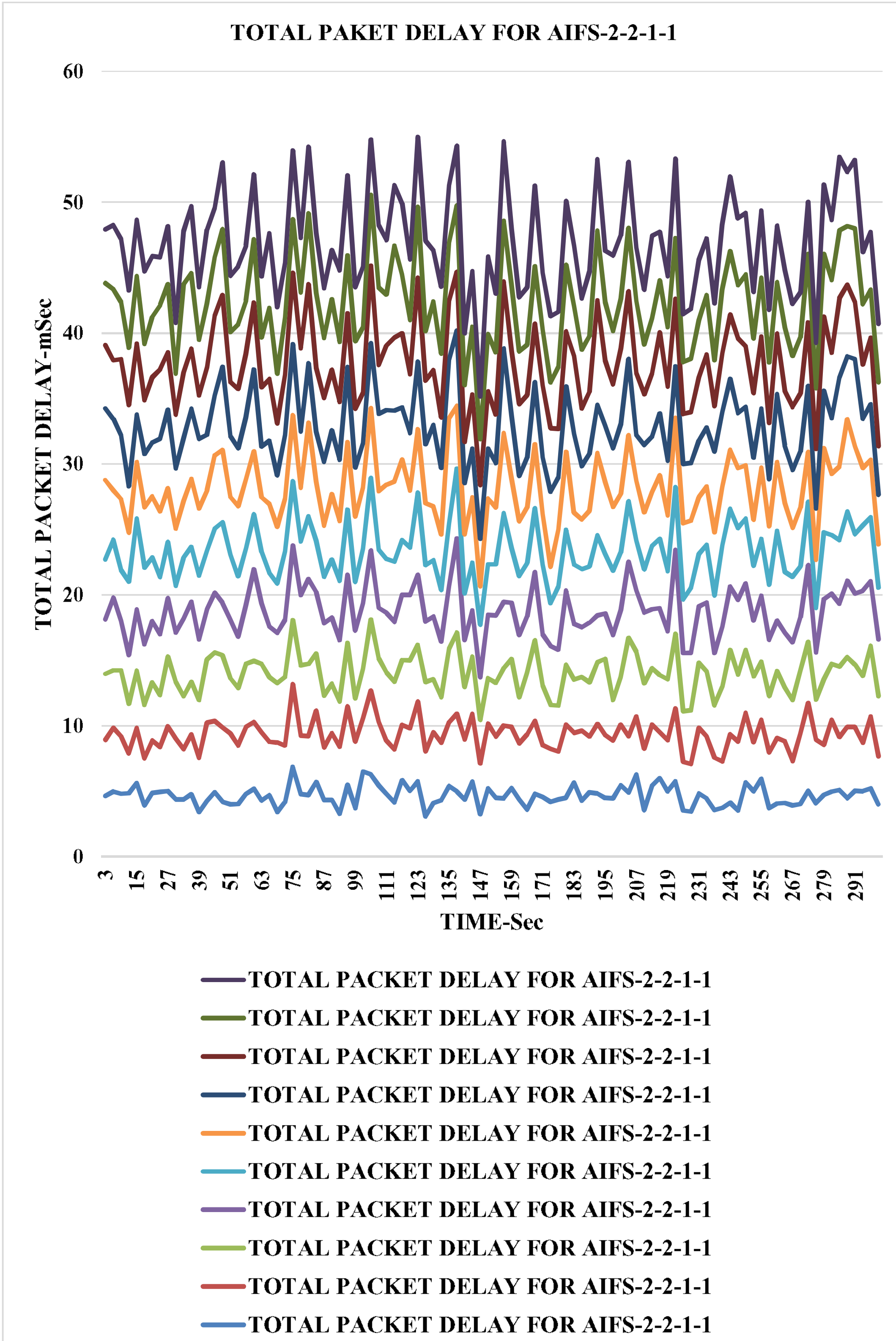


Fig.4.32. Total packet delay of nodes for adapted EDCA-1

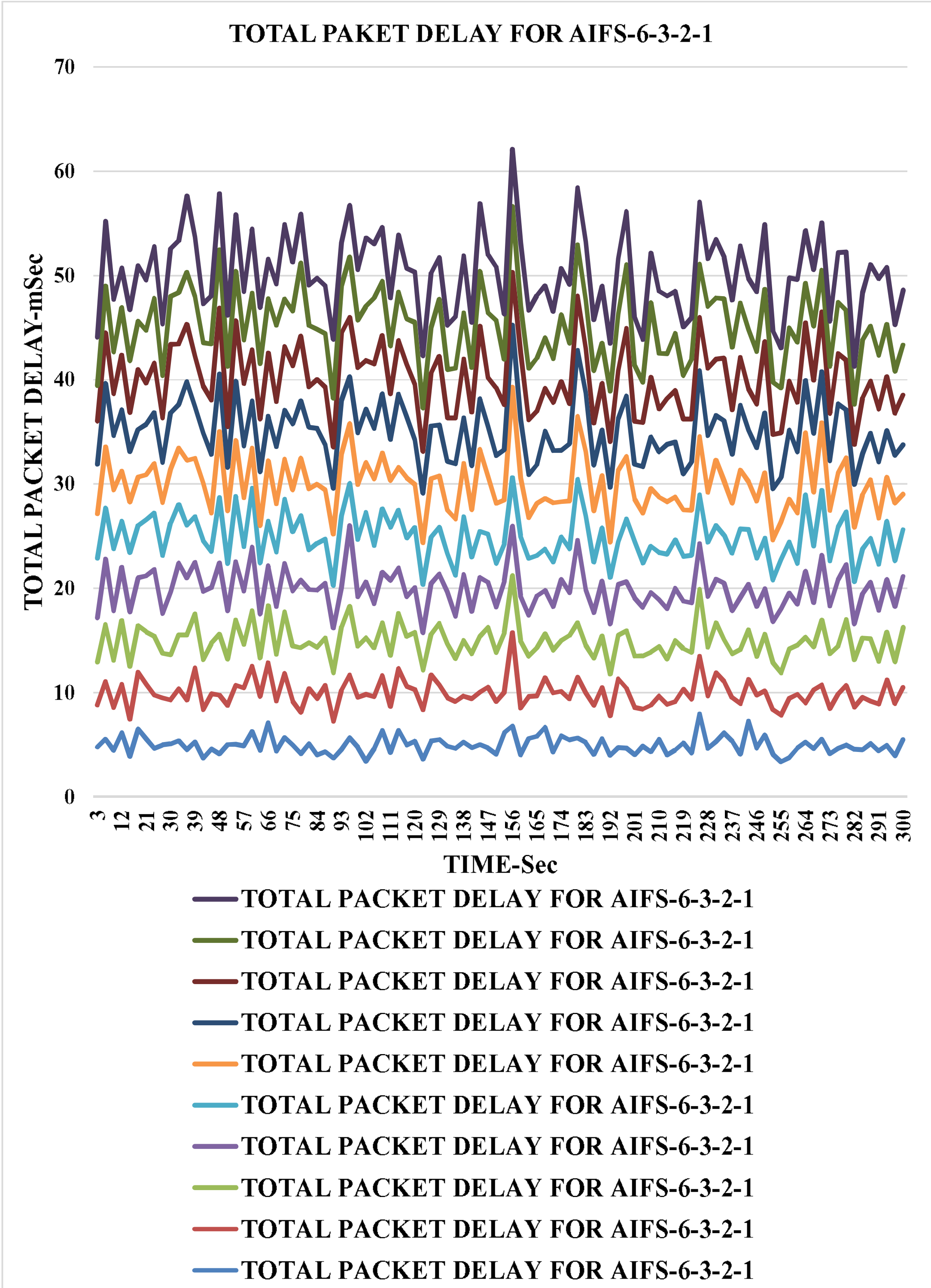


Fig.4.33. Total packet delay of nodes for adapted EDCA-2

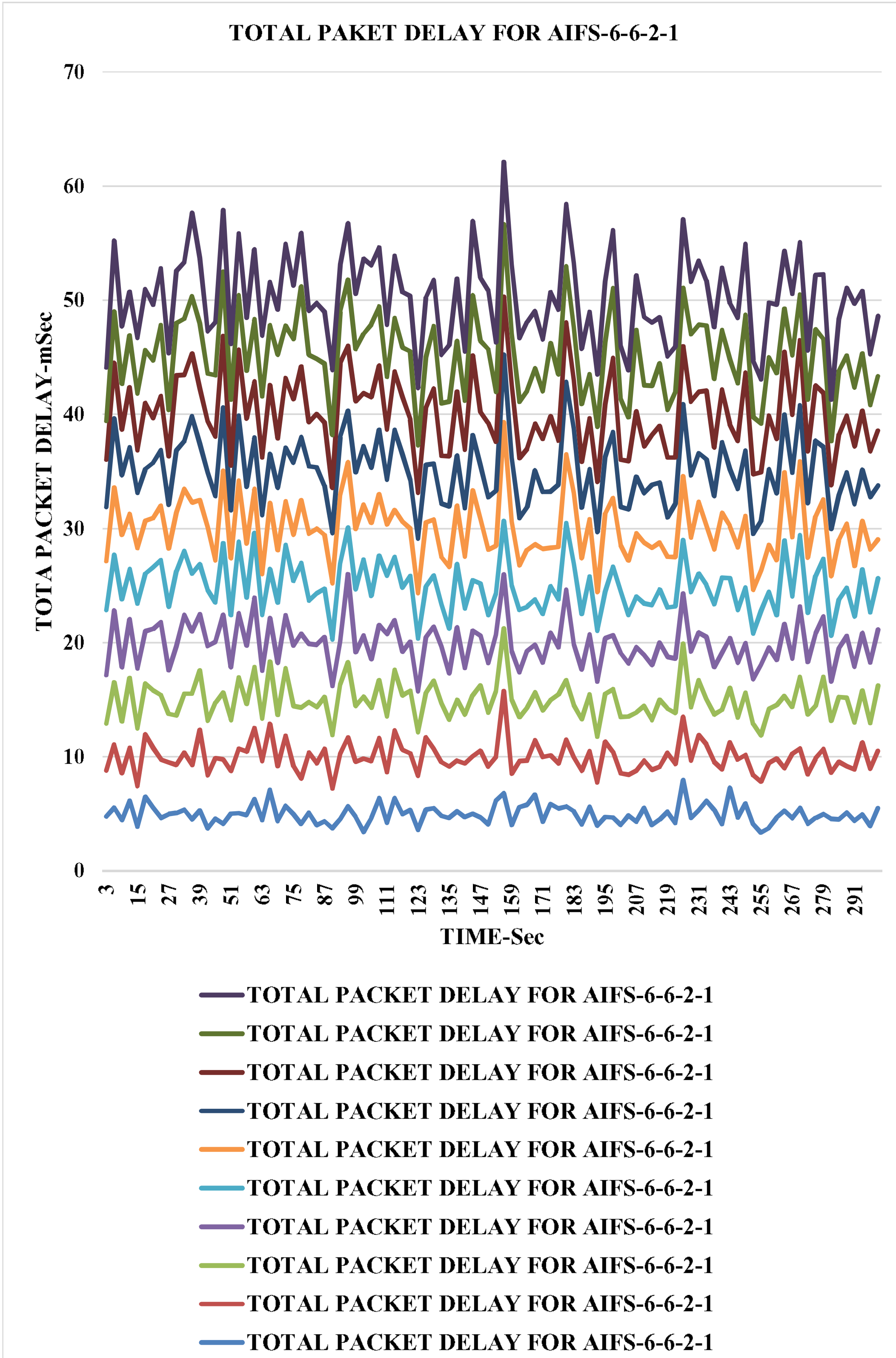


Fig.4.34. Total packet delay of nodes for adapted EDCA-3

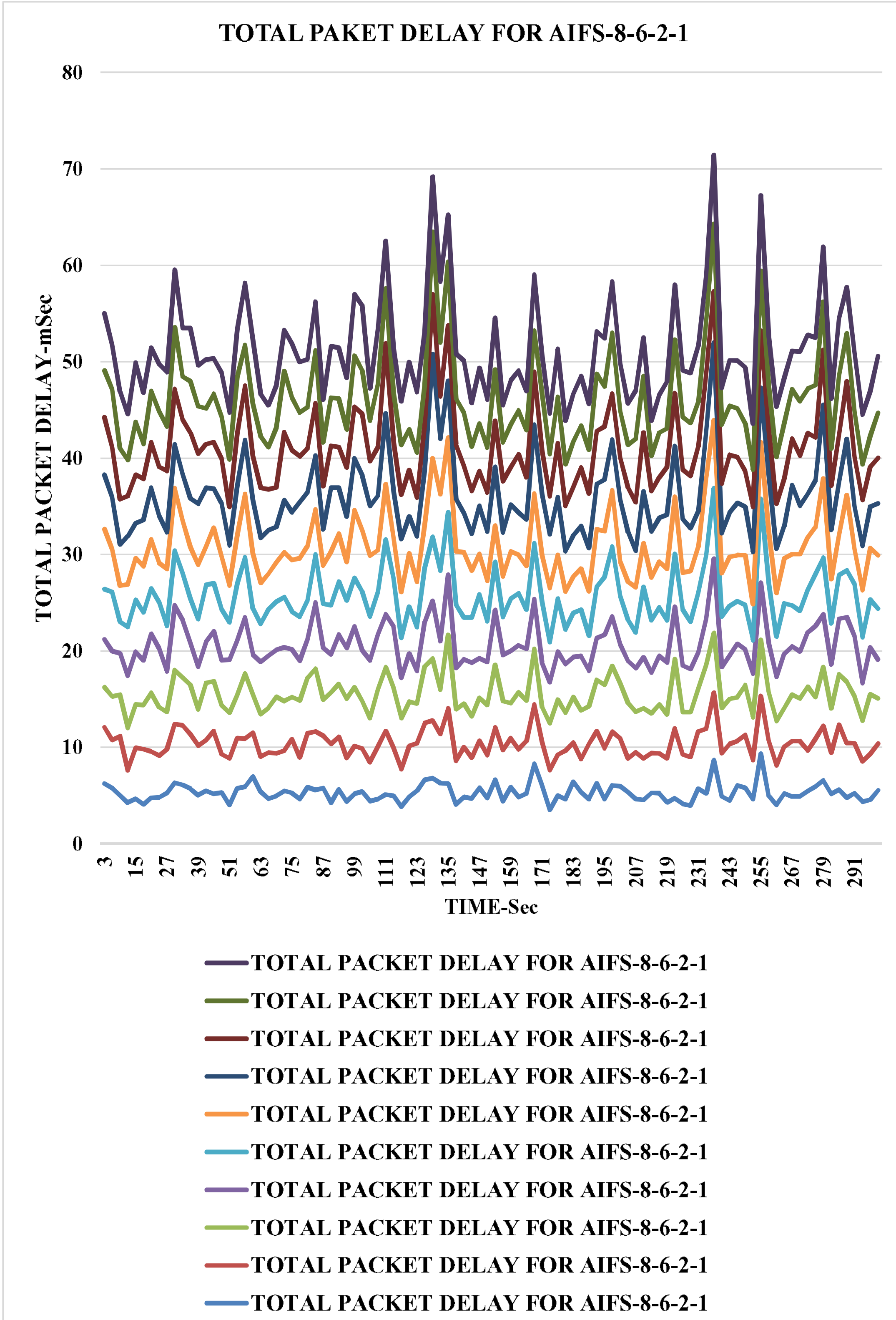


Fig.4.35. Total packet delay of nodes for adapted EDCA-4

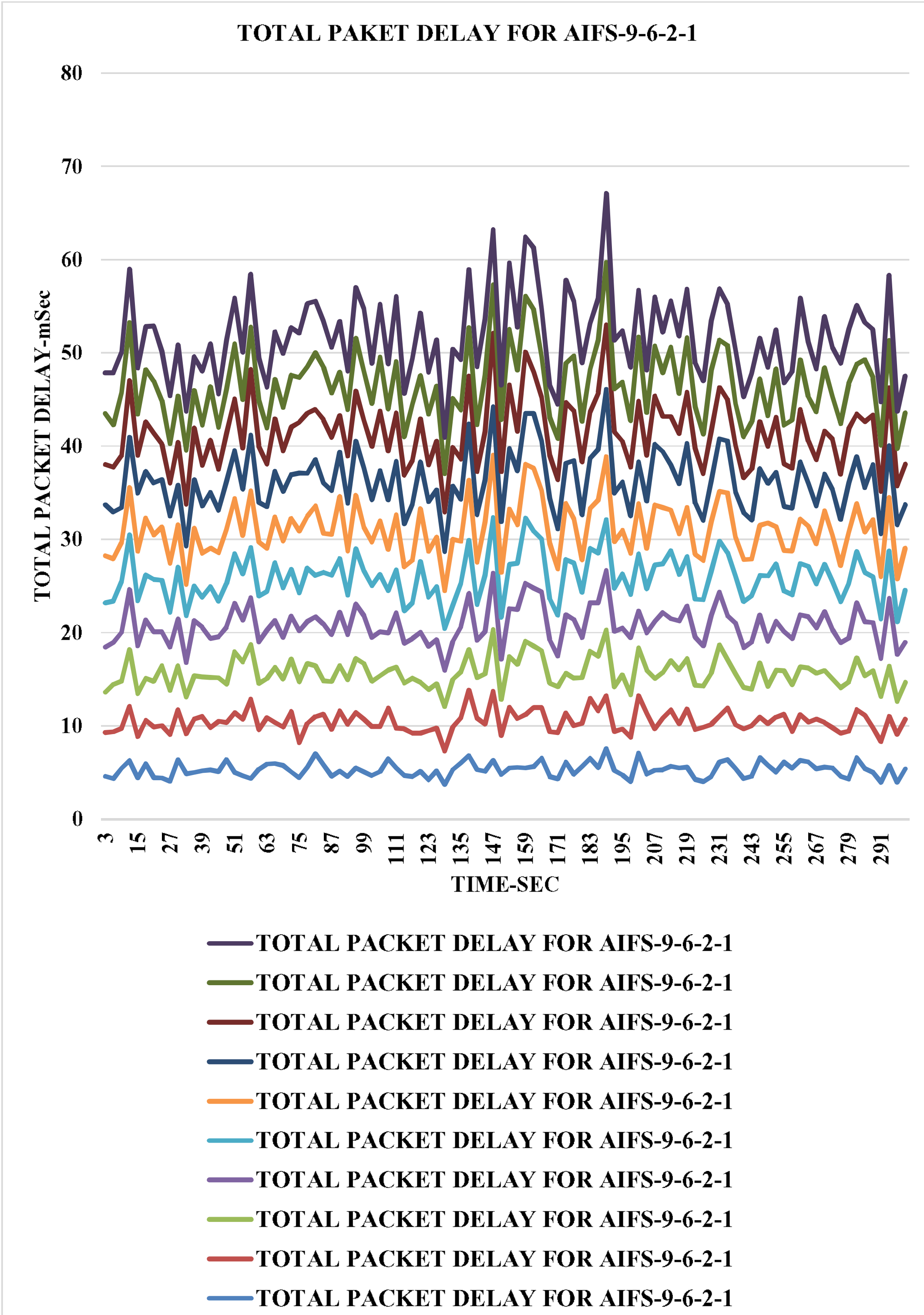


Fig.4.36. Total packet delay of nodes for adapted EDCA-5

Table 4.8. shows the mean values of total packet delay for basic as well as adapted EDCA parameters. Tabular results illustrate that total packet delay is lowest for adapted EDCA-3 and highest for adapted EDCA-1.

Node	MEAN VALUES-BASIC-Total Packet Delay (msec)	MEAN VALUES-ADAPTED EDCA-1-Total Packet Delay	MEAN VALUES-ADAPTED EDCA-2-Total Packet Delay (msec)	MEAN VALUES-ADAPTED EDCA-3-Total Packet Delay (msec)	MEAN VALUES-ADAPTED EDCA-4-Total Packet Delay (msec)	MEAN VALUES-ADAPTED EDCA-5-Total Packet Delay (msec)
1	5	5.32	4.99	4.69	5.33	4.99
2	4.96	5.21	5.03	4.73	5.12	5.03
3	4.99	5.2	5.01	4.66	5.14	5.01
4	5.1	5.15	5.02	4.78	5.08	5.02
5	4.97	5.16	5.01	4.63	5.18	5.01
6	5.03	5.16	5.09	4.82	5.16	5.09
7	5.01	5.19	5.07	4.72	5.22	5.07
8	4.95	5.19	5.08	4.83	5.1	5.08
9	5.13	5.17	5.1	4.65	5.03	5.1
10	5.05	5.27	5.06	4.63	5.12	5.06
Average	5.02	5.2	5.05	4.71	5.15	5.05

Table 4.8. Mean values of total packet delay

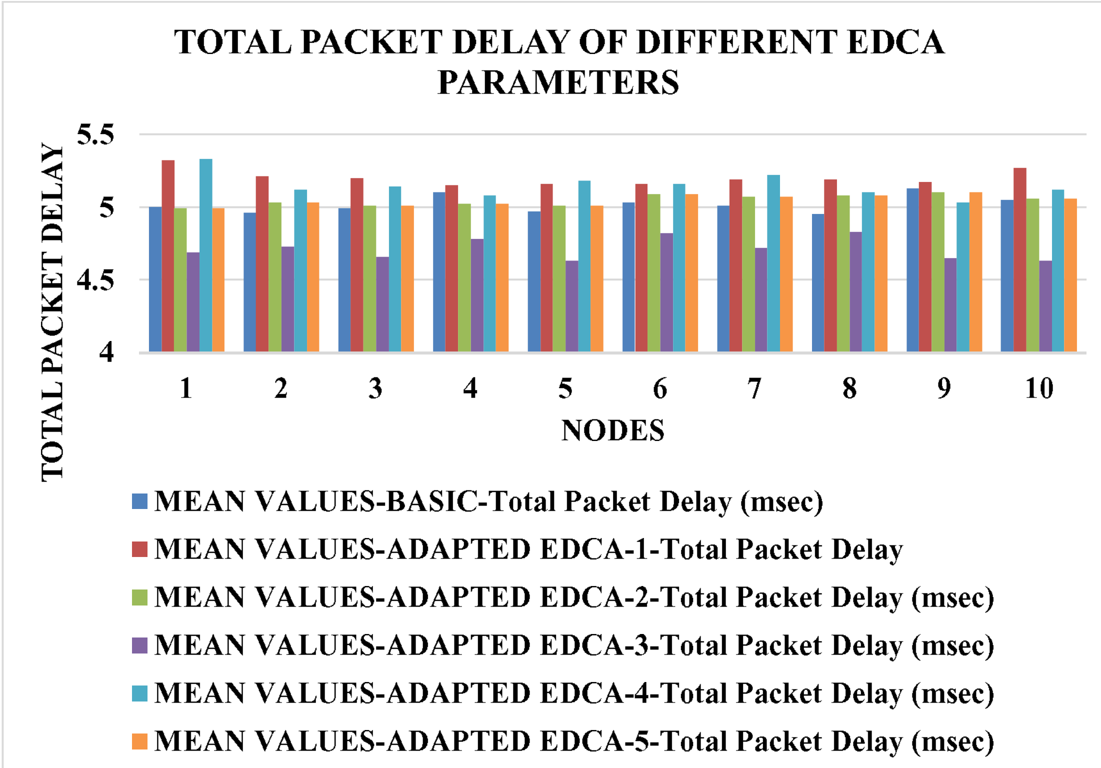


Fig.4.37. Mean values of total packet delay

Fig. 4.37 show the graphical results for mean values of total packet delay for different EDCA parameters. Results show that the lowermost value of total packet delay is achieved for adapted EDCA-3.

From above results, it is evident that a specific value of optimized parameter should be chosen by considering diverse set of results.

4.2.2. CROSS LAYER PARAMETER OPTIMIZATION OF HOME AREA NETWORK

This section depicts the parameter optimization of a building/home area network designed using IEEE 802.11 standard. Various scenarios are implemented and analyzed for performance optimization in riverbed modeler (OPNET).

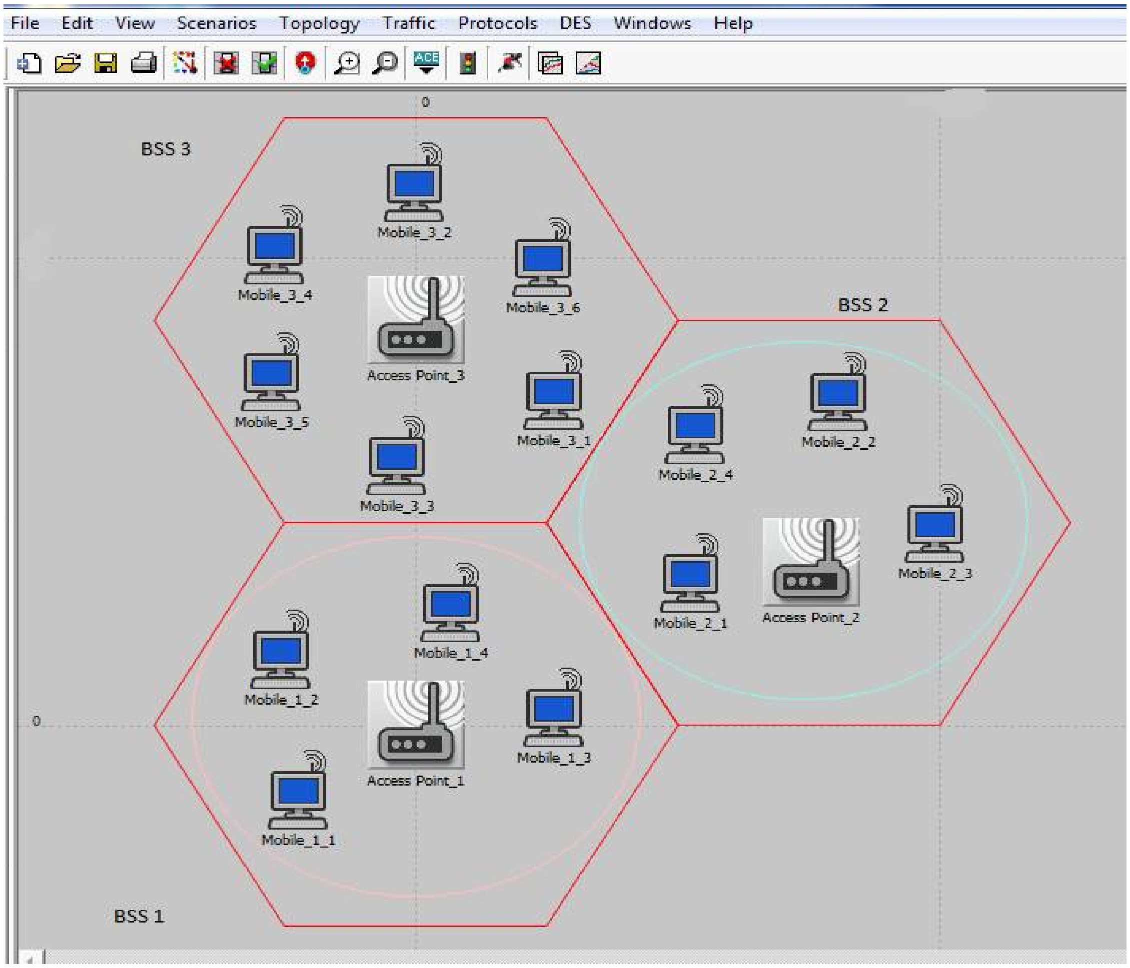


Fig.4.38. Diagram of the network to be optimized

WLAN configuration

Fig.4.38. shows the three WLAN infrastructure networks. Three access points are considered with different parameters for comparative analysis. In access point 1, block acknowledge is disabled and in two other access points, the same is enabled. IEEE 802.11n protocol is used. BSS 1 with access point 1 operates in IEEE 802.11n 20 MHz band with block acknowledge disabled. BSS 2 with access point 2 operates in IEEE 802.11n 20 MHz band with block acknowledge enabled. BSS 3 with access point 3 operates in IEEE 802.11n 40 MHz band with block acknowledge enabled. A short guard band is enabled for all three configurations. The data throughput of 65 Mbps base and 600 Mbps is selected.

Effect of block acknowledge mechanism

The block acknowledge mechanism enhances an efficiency of media access layer. If the block acknowledge functionality is enabled, an entire group of frame is collectively acknowledged rather sending acknowledgement message to each and every frame. This mechanism enhances the throughput and reduces media access delay. An effect of block acknowledgement mechanism is investigated in the above designed network.

The above network configuration can be used for Home or building area network and it can also be expanded for NAN. Graphical results for various parameters pertaining to all BSSs are depicted in figure 4.39 to 4.49.

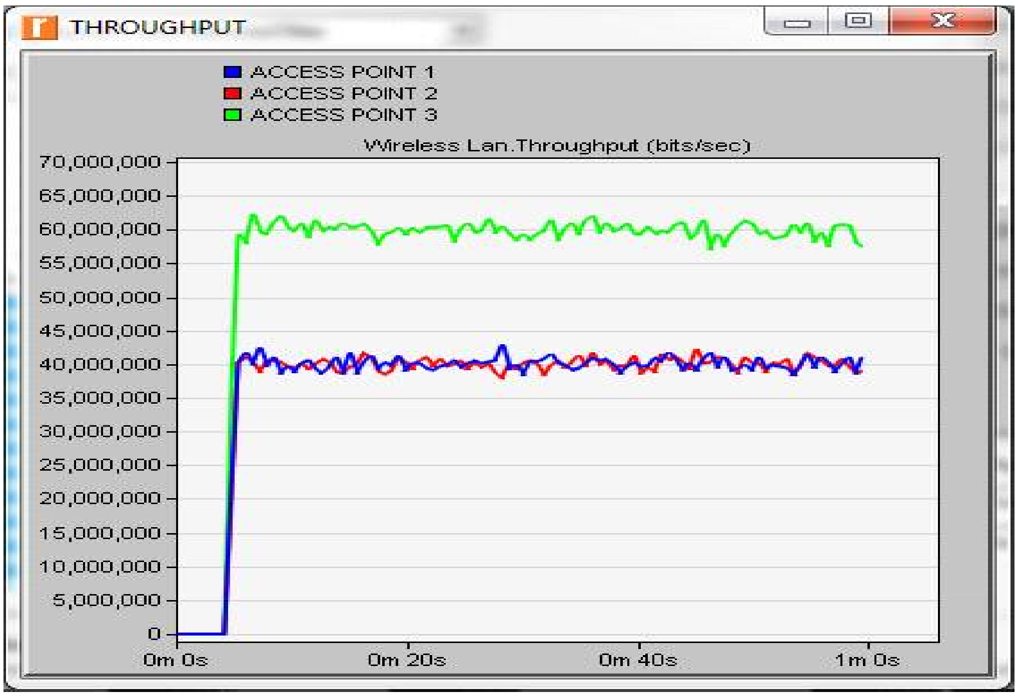


Fig.4.39. WLAN Throughput of different access points

The above graphical results depicts that the data throughput is maximum for BSS 3 with access point 3. The throughput is minimum for BSS 1 with access point 1. It is evident from the results that the use block acknowledge function increases the throughput as the data frame is acknowledged in a single block which reduces overhead.

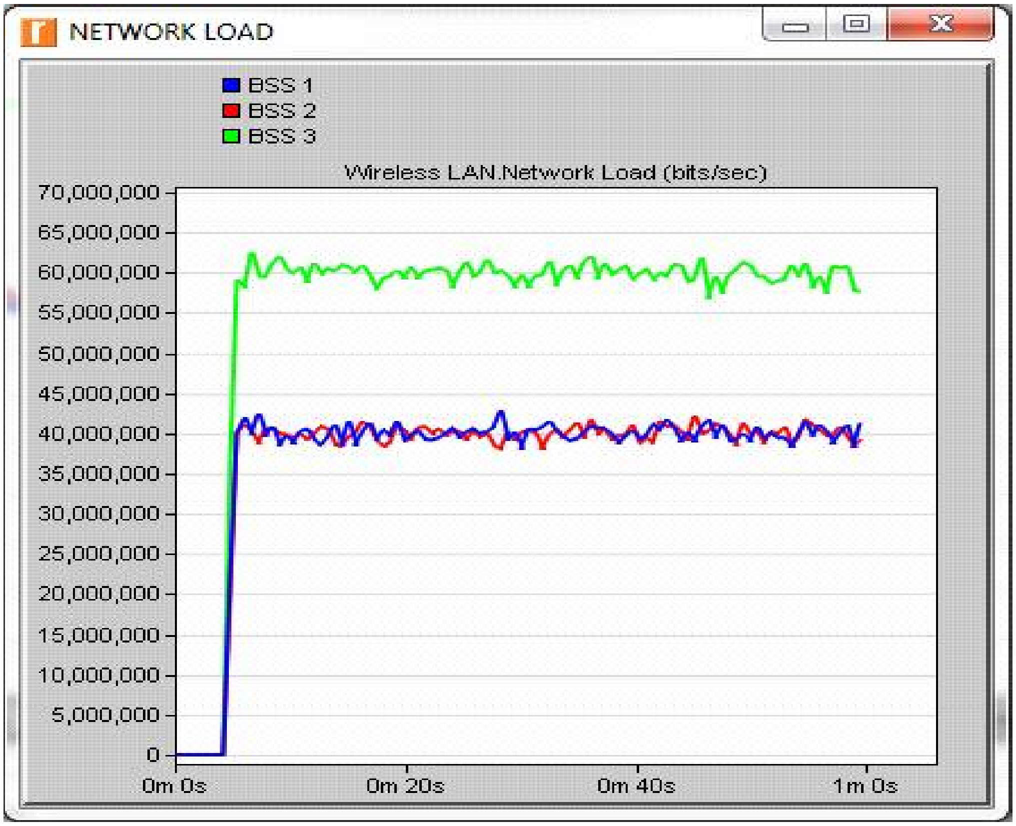


Fig.4.40. Network load of different BSSs

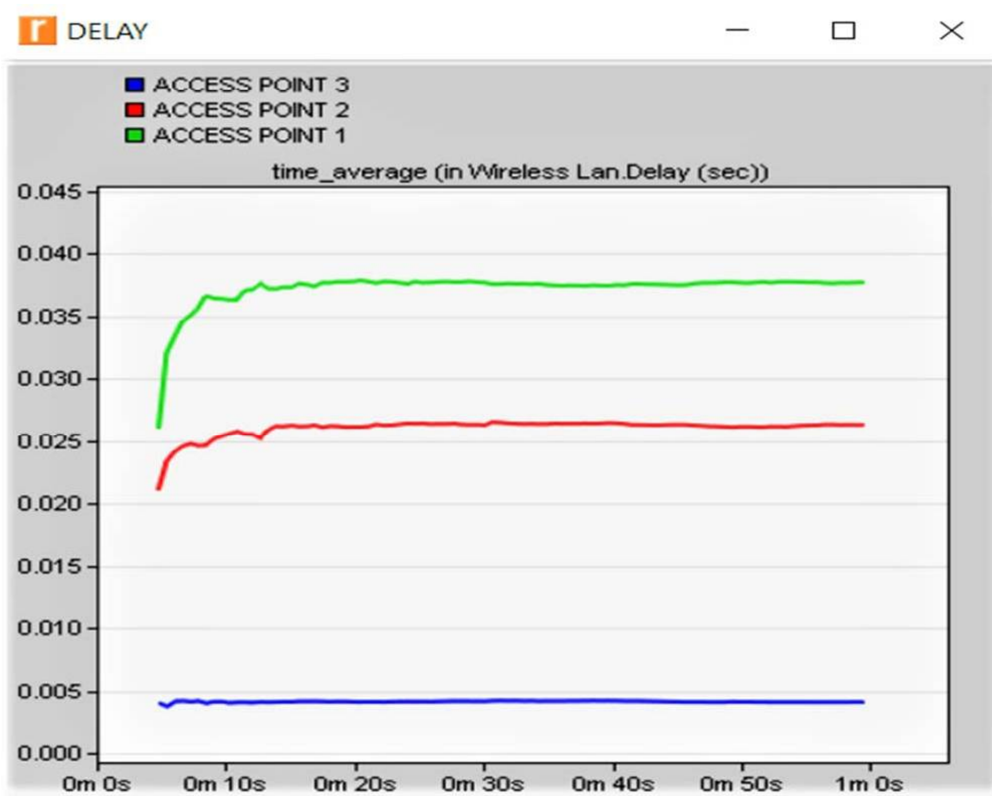


Fig.4.41. WLAN delay of different access points

Figure 4.41. shows the WLAN graphical representation of WLAN delay for different access points. Simulation results shows that the delay is reduced for access point 2 and 3. The delay parameter signifies end to end delay of all packets received by MAC layer of all nodes of wireless local area network and forwarded to upper layers. This delay includes MAC delay at the source MAC, reception of all fragments on individual basis and transfer of frames via access point if AP functionality is enabled. Results show that access point 1 has the highest delay and access point 3 has a lowest delay. Access point 2 also has a lower delay as block acknowledgement mechanism is enabled. In access point 1, block acknowledgement mechanism is disabled. Hence it is apparent that block acknowledge mechanism reduces delay as the frames are collectively acknowledged.

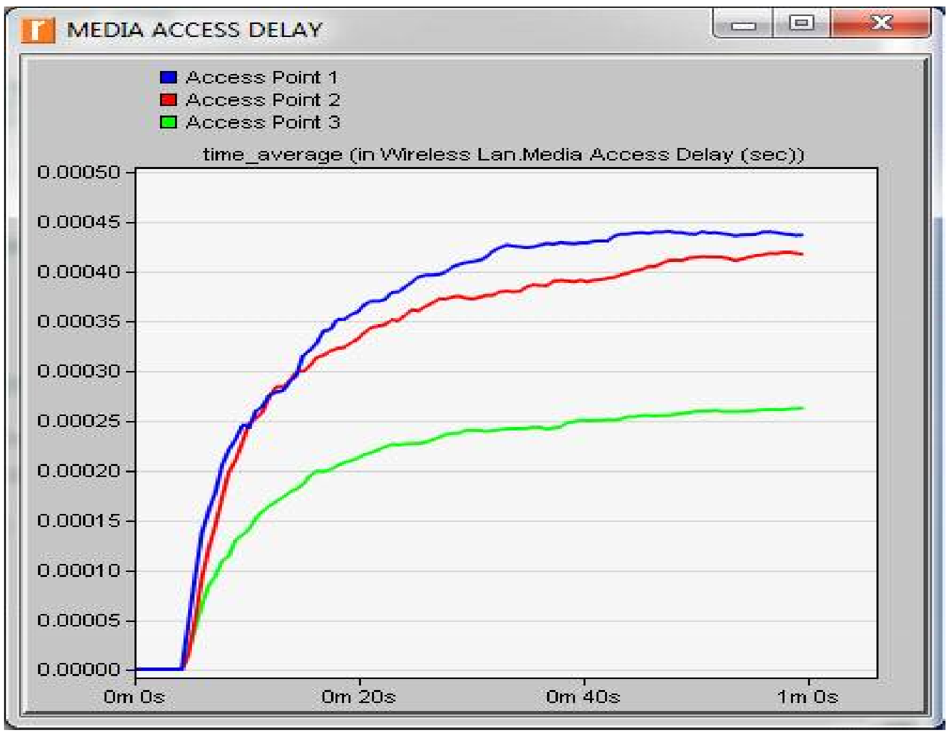


Fig.4.42. WLAN Media access delay of different access points

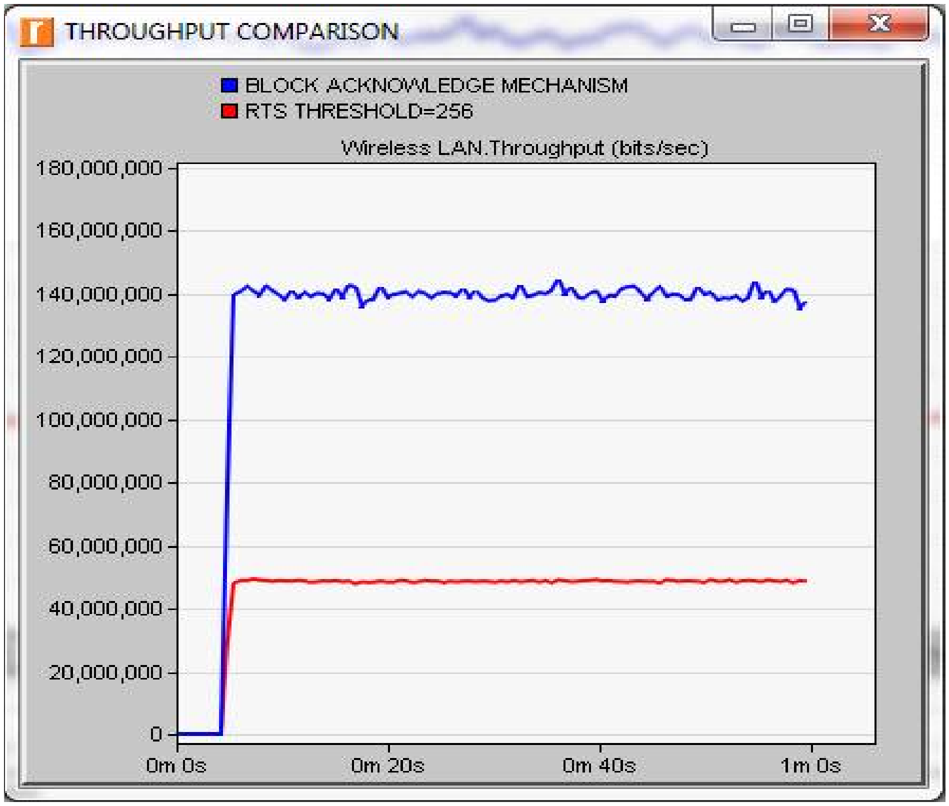


Fig.4.43. WLAN throughput comparison for Block acknowledgement vs RTS mechanism

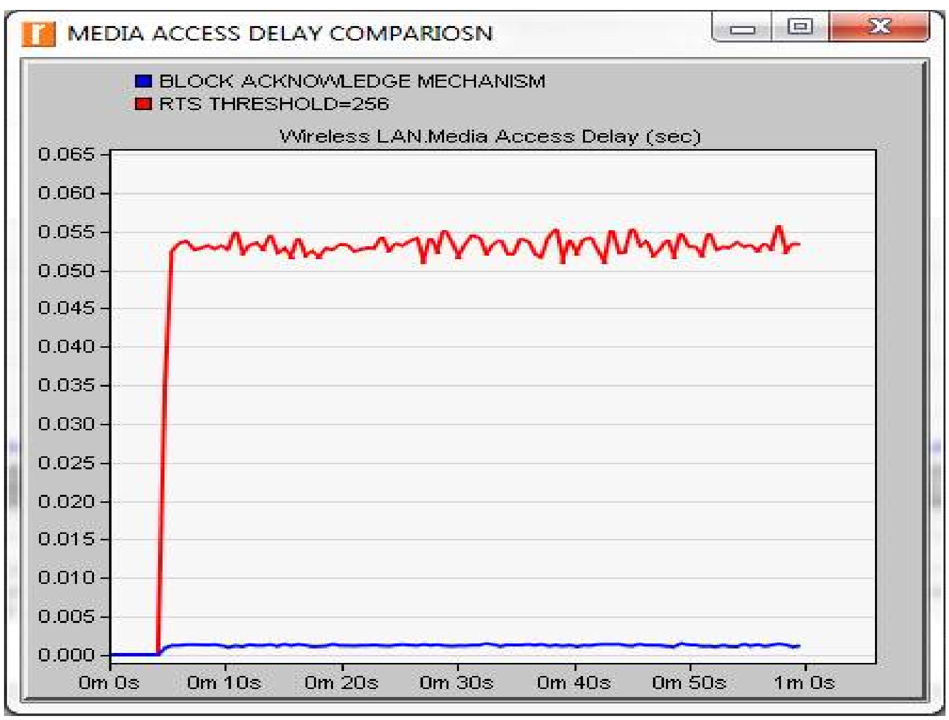


Fig.4.44. WLAN media access delay comparison for Block acknowledgement vs RTS mechanism

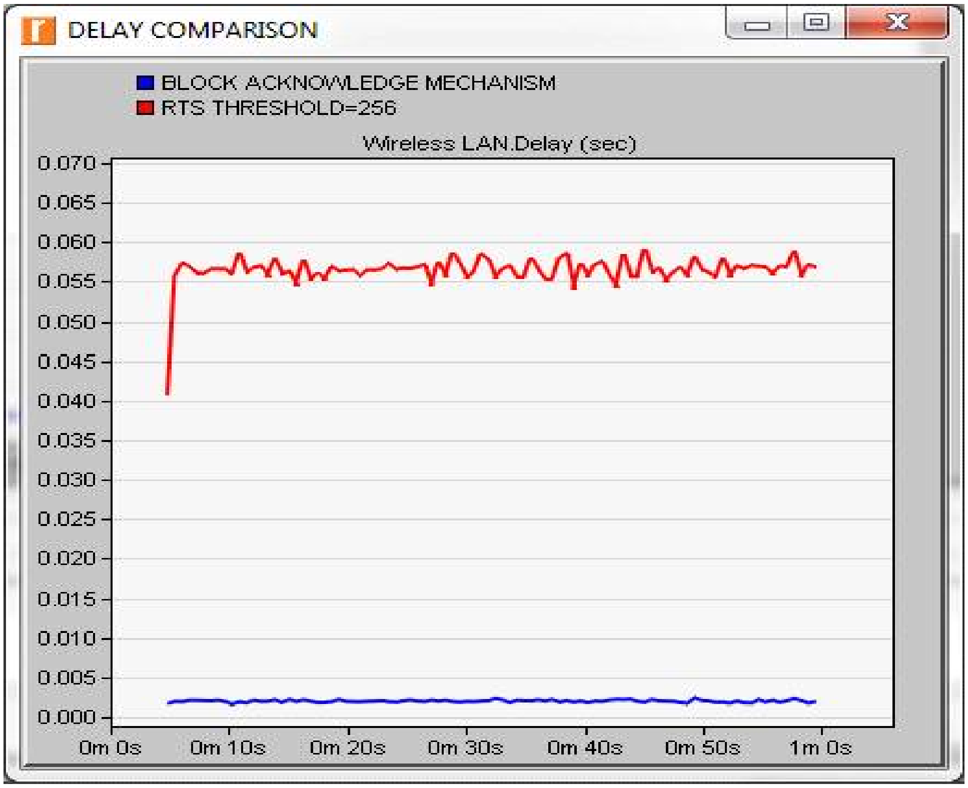


Fig.4.45. WLAN delay comparison for Block acknowledgement vs RTS mechanism

The performance of RTS mechanism and block acknowledge is compared which shows that the delay for RTS is higher with threshold value of 256. RTS mechanism increases delay as shown in above graph. The network delay as well as media access delay with block acknowledgement mechanism enabled is very low.

Effect of fragmentation

Fragmentation is a method to divide the packet into segments. A threshold value from 256 to 2304 can be selected for activation of this functionality. Threshold value signifies the specific value above which the data packet will be fragmented and sent distinctly over the radio path. In other terms, it defines the largest permitted packet without division. If the data packet is too large, it may be fragmented into more than one portions. The value (-1) for none states that the data packet will never be alienated irrespective of its size in bytes.

The results for effect of fragmentation mechanism are shown in the graphs below.

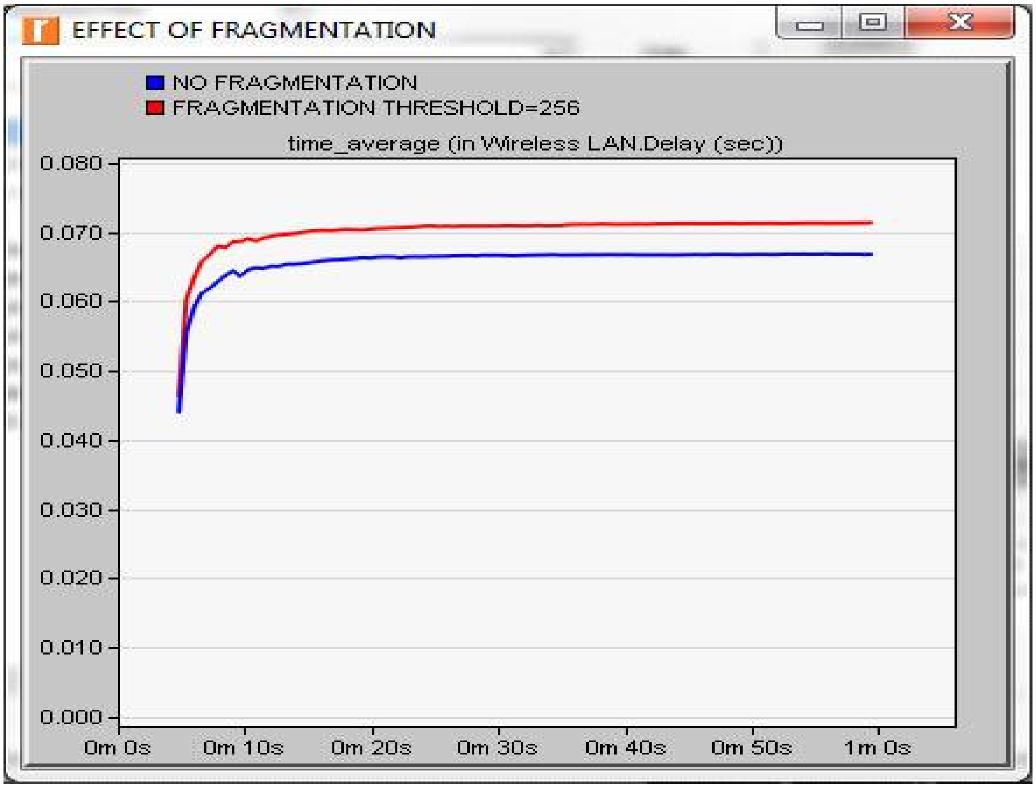


Fig.4.46. WLAN delay with and without fragmentation

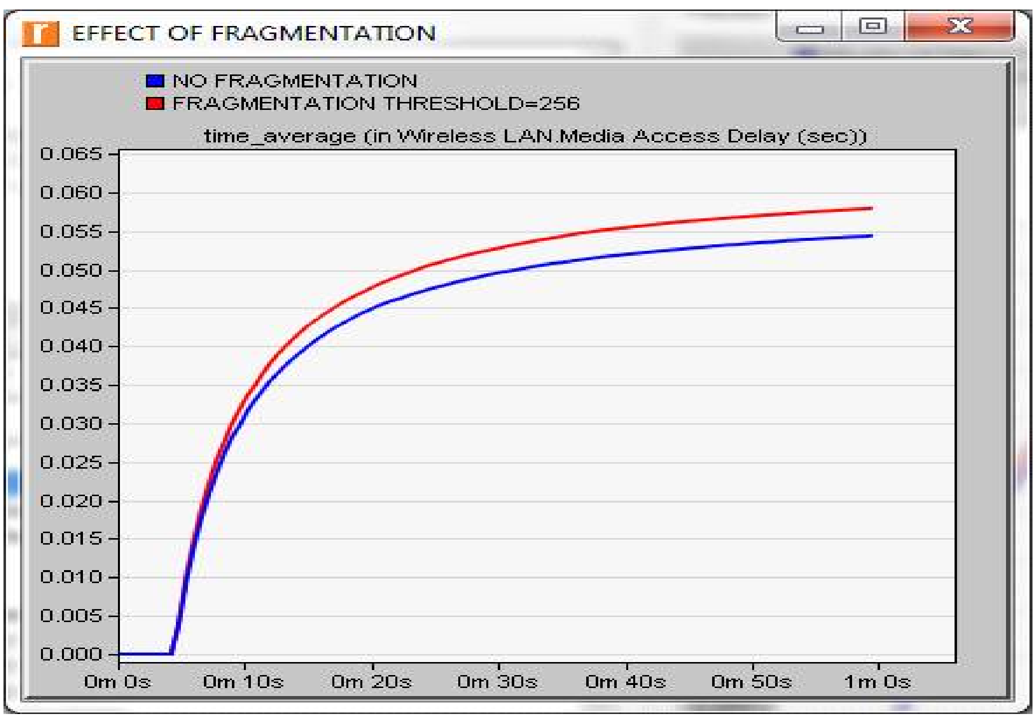


Fig.4.47. WLAN Media access delay with and without fragmentation

Fig.4.46. and 4.47. show that fragmentation mechanism increases total delay as well as media access delay.

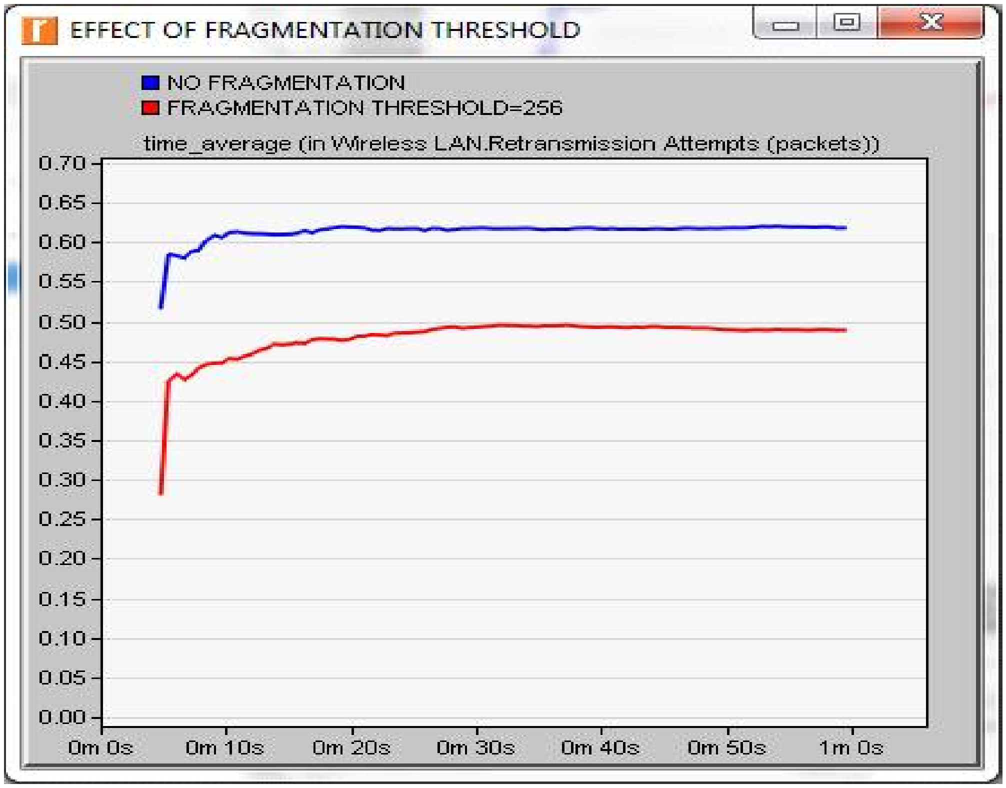


Fig.4.48. WLAN retransmission attempts with and without fragmentation

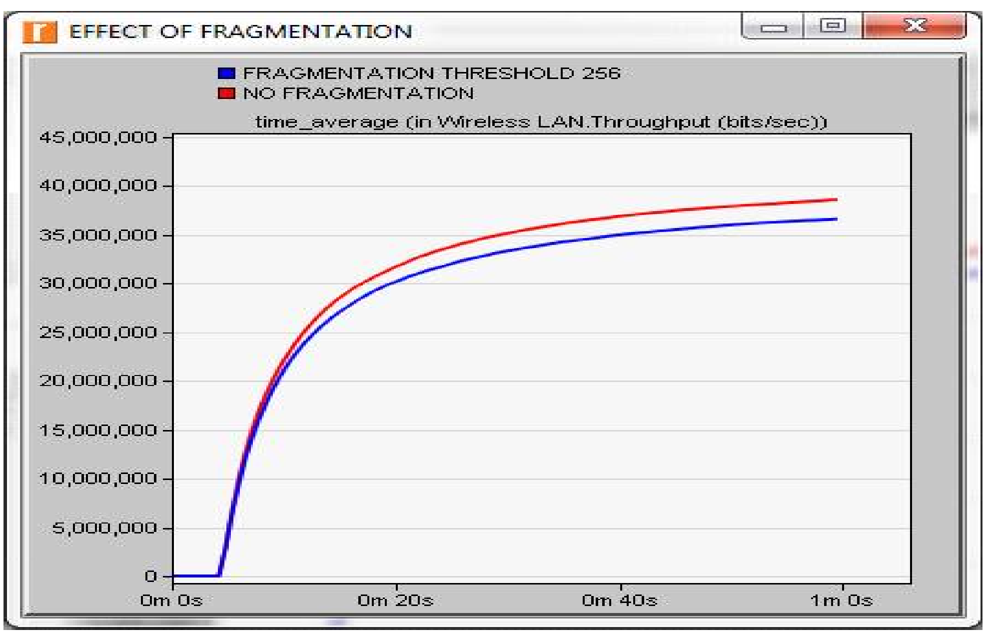


Fig.4.49. WLAN throughput with and without fragmentation

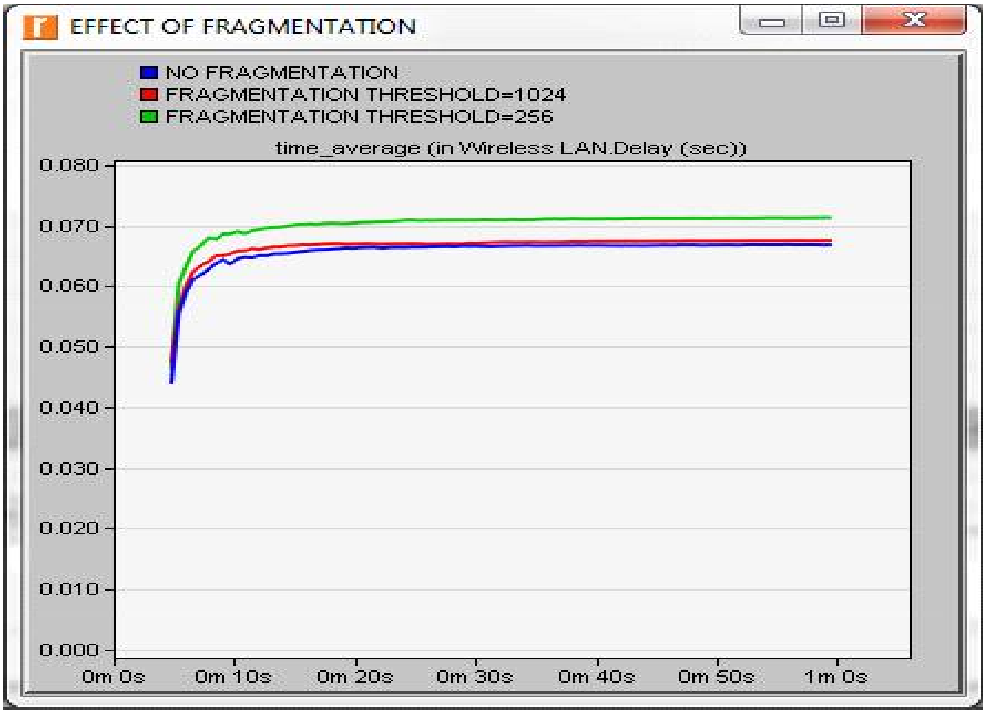


Fig.4.50. WLAN delay for different fragmentation thresholds and without fragmentation

It is evident from the Fig.4.49. and 4.50. that fragmentation increases delay and reduces throughput. The delay is maximum for the lowest value of fragmentation threshold.

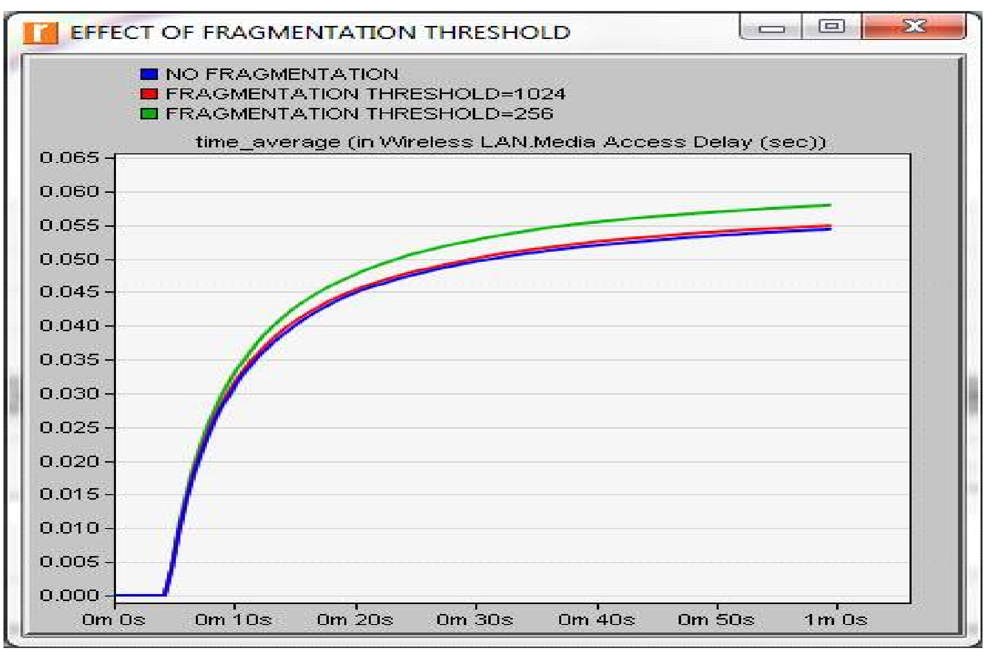


Fig.4.51. WLAN Media access delay for different fragmentation thresholds and without fragmentation

It is apparent from the Fig. 4.51. that fragmentation increases MAC delay. It is maximum for the lowest value of fragmentation threshold.

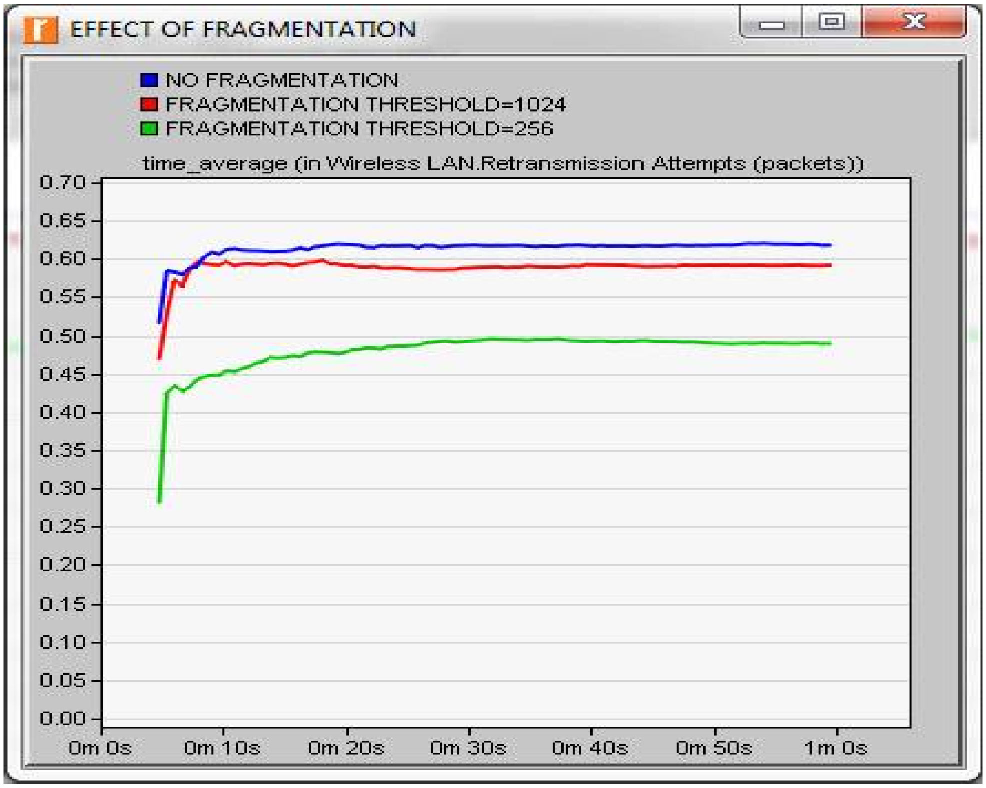


Fig.4.52. WLAN retransmission attempts for different fragmentation thresholds and without fragmentation

Fig. 4.52 illustrates that the fragmentation mechanism reduces retransmission attempts. Figure 4.53 and 4.54 show the WLAN throughput and delay respectively for no fragmentation as well as different values of fragmentation thresholds such as 256 and 1024. Graphical results shown in Fig.4.53 show that throughput is significantly reduced as a result of fragmentation mechanism.

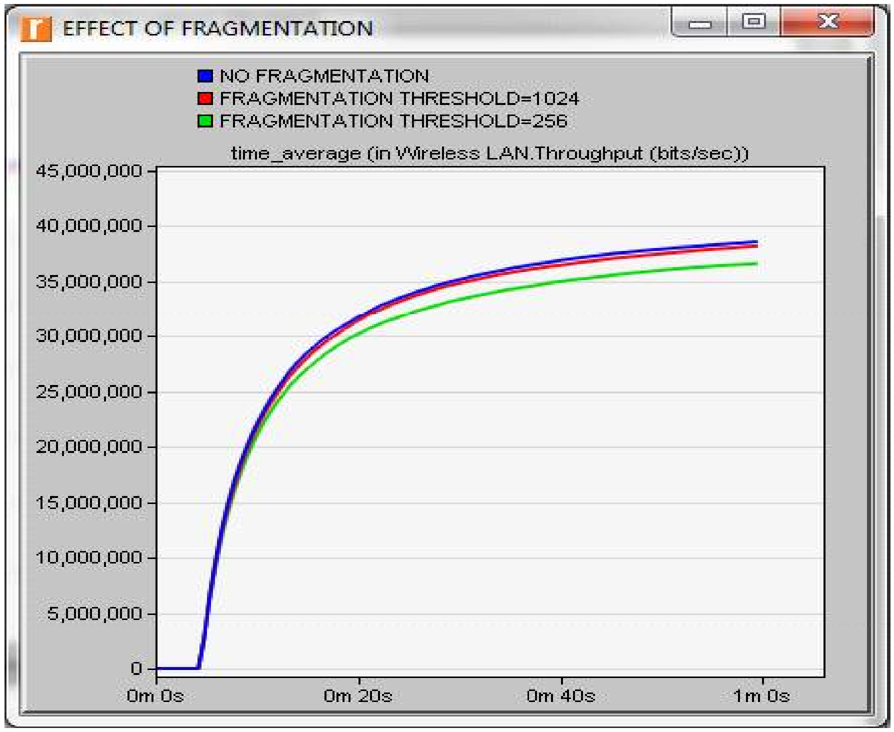


Fig.4.53. WLAN throughput for different fragmentation thresholds and without fragmentation

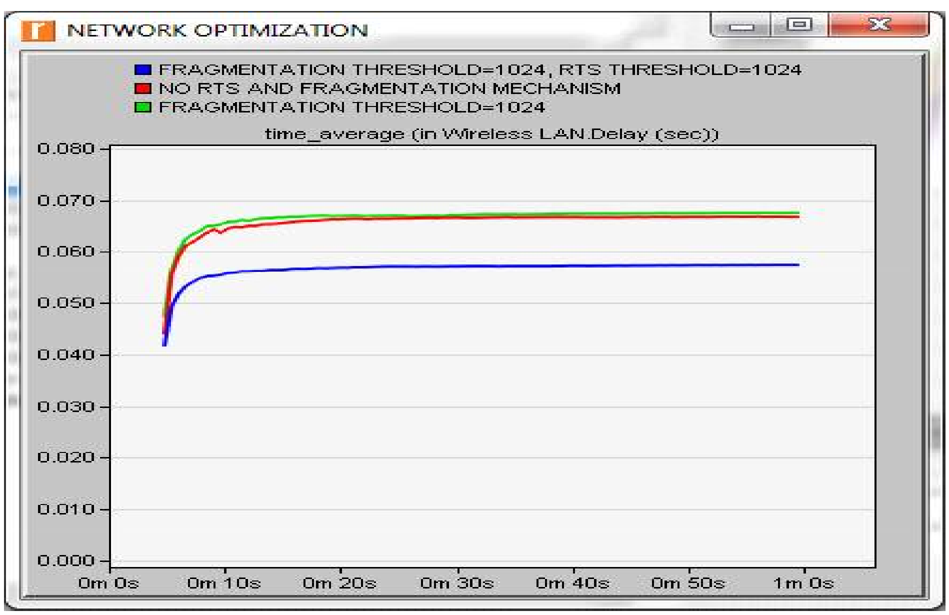


Fig.4.54. WLAN optimization with RTS and fragmentation mechanisms

Fig.4.53. and Fig.4.54 show that fragmentation threshold reduces throughput but when combined with RTS mechanism, the results are significantly improved.

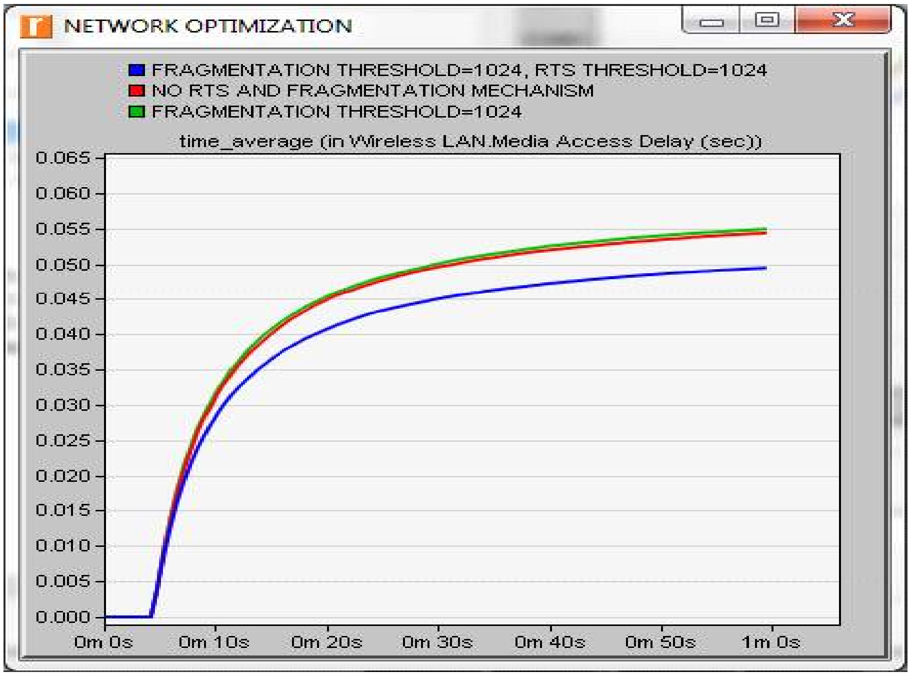


Fig.4.55. WLAN delay optimization with RTS and fragmentation mechanism

Fig.4.55 shows that WLAN delay is almost similar for no fragmentation mechanism and with fragmentation threshold of 1024. The combination of fragmentation and RTS mechanism apparently reduces media access delay. Fig.4.56 and 4.57 show the results of combining RTS and fragmentation mechanisms.

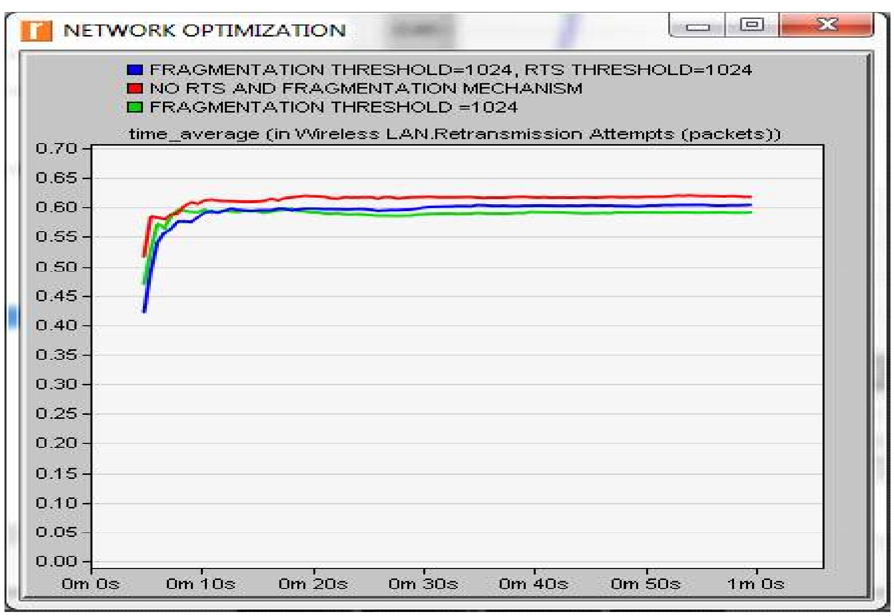


Fig.4.56. WLAN retransmission attempts optimization with RTS and fragmentation mechanisms

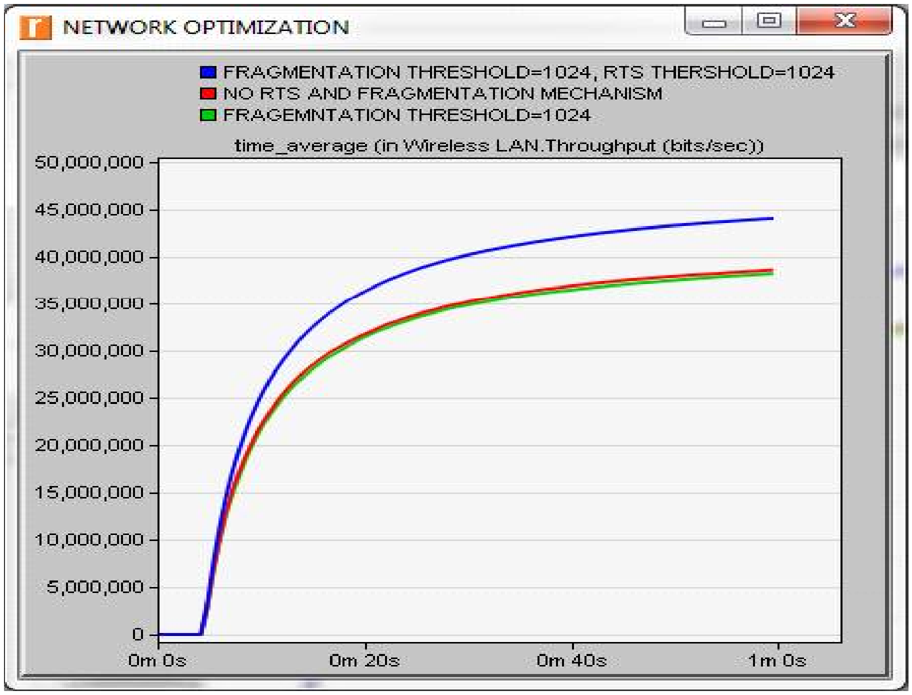


Fig.4.57. WLAN throughput optimization with RTS and fragmentation mechanisms

Fig.4.56. and Fig.4.57. show that a combination of fragmentation and RTS mechanism significantly improves the performance as the number of retransmission attempts are reduced and the throughput is enhanced as a result of this combination.

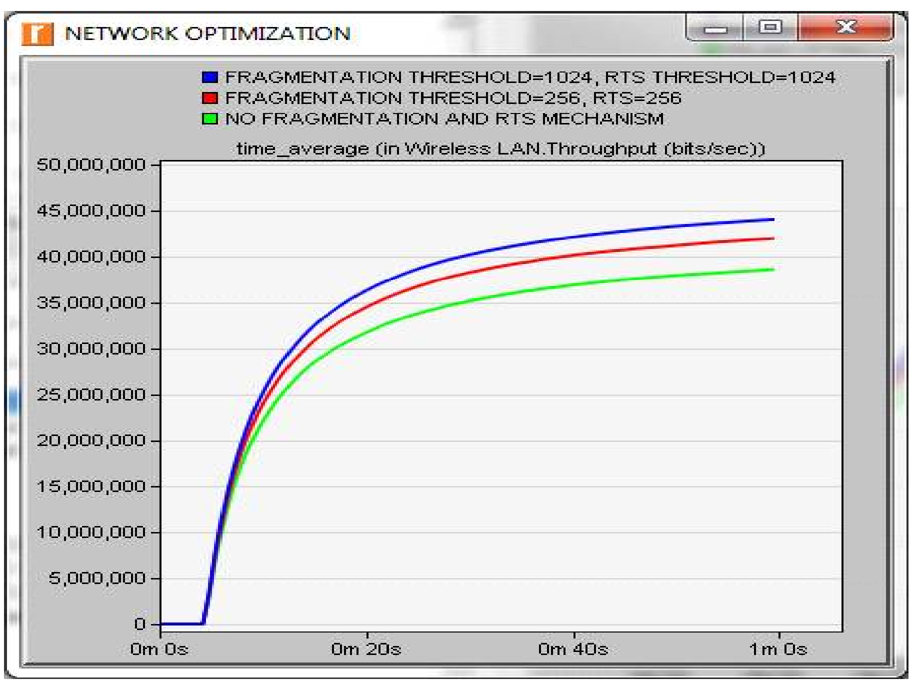


Fig.4.58. WLAN throughput optimization with different values of RTS and fragmentation thresholds

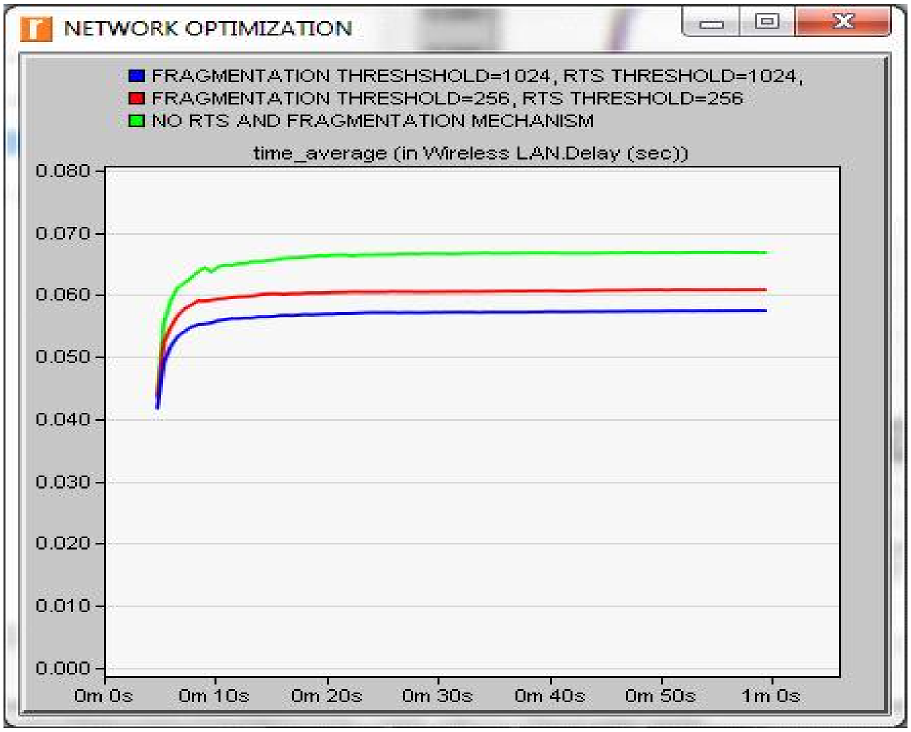


Fig.4.59. WLAN delay optimization with different values of RTS and fragmentation thresholds

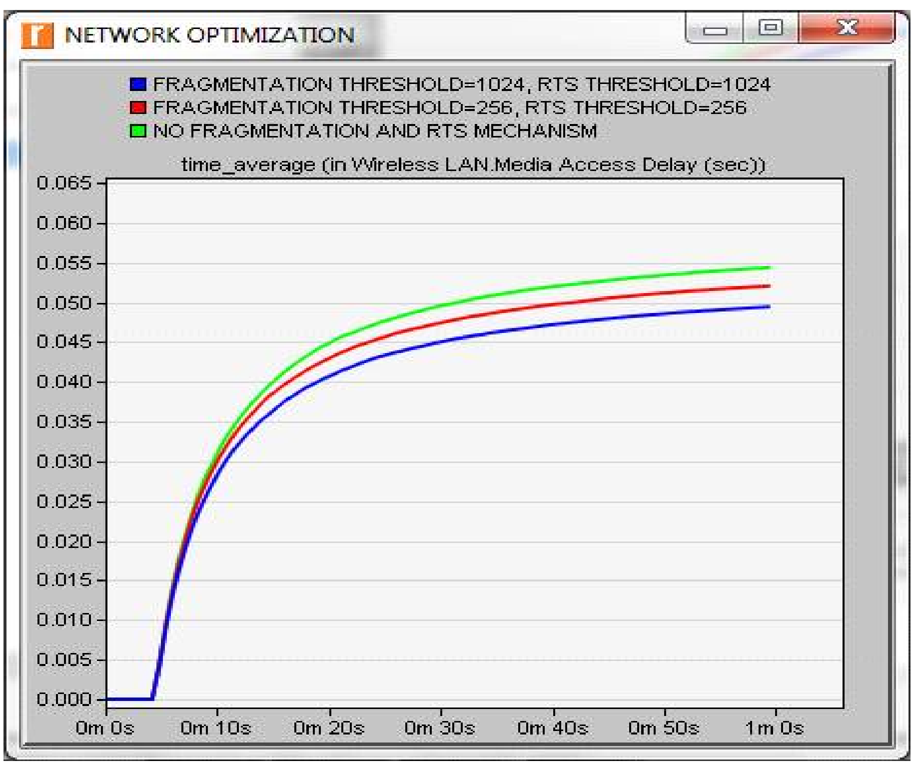


Fig.4.60. WLAN Media access delay optimization with different values of RTS and fragmentation thresholds

Fig.4.58, 4.59 and 4.60 depicts the comparison between no fragmentation and RTS mechanism vs different threshold values of RTS and fragmentation. The simulation is performed and the results indicate that the performance of a network is significantly enhanced for higher threshold values.

Results depicts that the fragmentation increases total delay and media access delay. It reduces retransmission attempts. Throughput is also reduced as an effect of fragmentation process. Higher value of fragmentation threshold reduces delay. Results show that the performance is improved by combination of fragmentation and RTS mechanism. This combination significantly improves the network throughput.

Effect of buffer size

Buffer size defines the maximum value of upper layer buffer in bits. When the new packets arrive and the buffer is full, these packets will be discarded till the buffer is empty enough to accept the new packets.

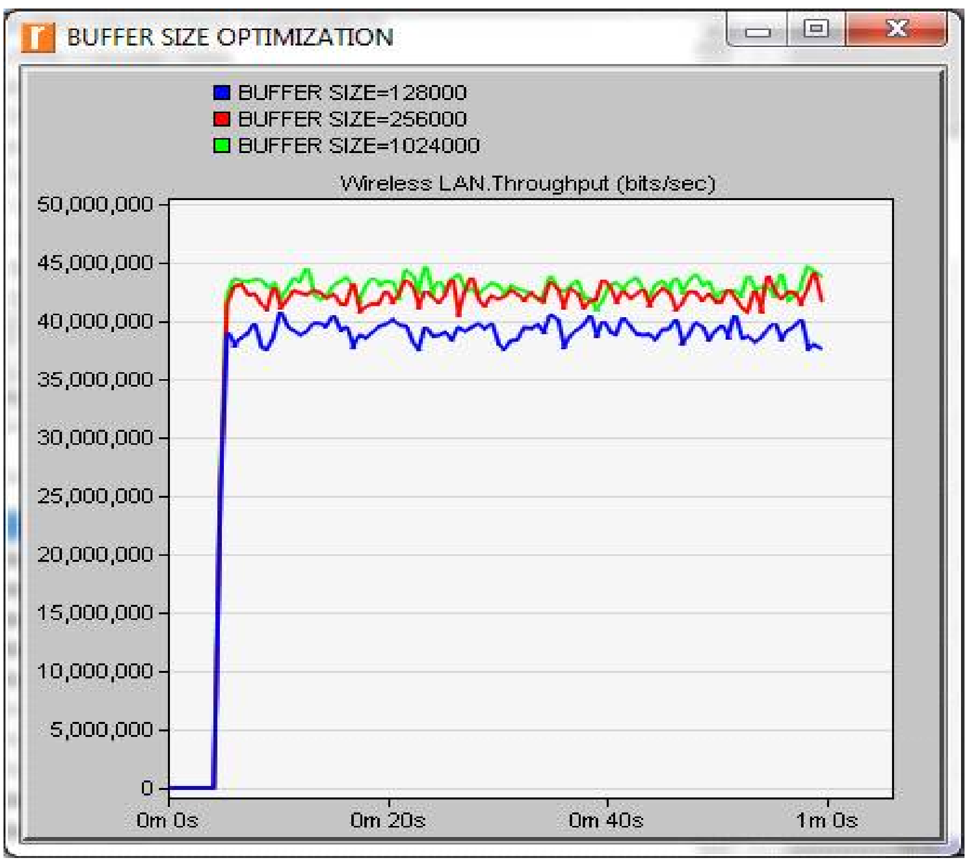


Fig.4.61. WLAN buffer size optimization for higher throughput

Buffer size is an important parameter for network performance and optimization. Lower value of buffer size results in frequent packet loss and thus underutilization of network resources occurs while higher value of buffer size results into excessive delay. Figure 4.61. shows that throughput increases for higher value of buffer size. For smaller buffer size, when the threshold value is reached the new packets will be dropped or discarded as there is no space in buffer to store the packets and thus throughput reduces. This will also reduce queuing and delay. In above figure, simulation results for three values of buffer size such as 128000, 256000 and 1024000 are compared. Simulation results depict that value of buffer size is directly proportional to throughput. Higher value of buffer size increases throughput, delay and queuing. Thus, optimization of buffer size is required due to tradeoff between delay and throughput.

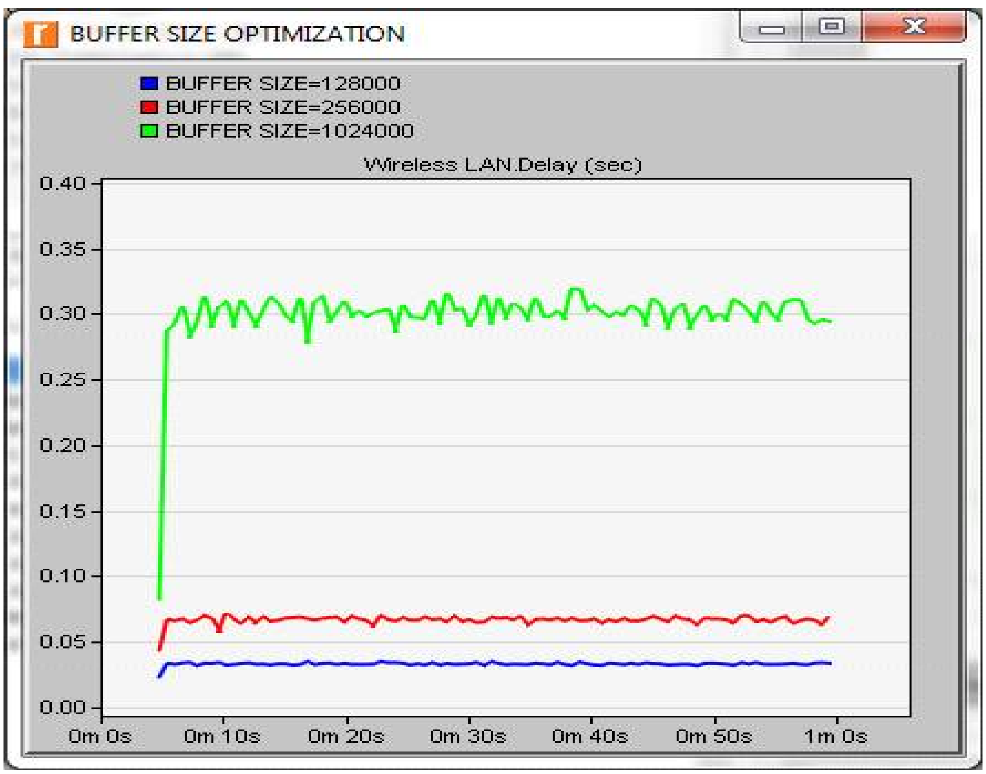


Fig.4.62. WLAN buffer size optimization for lower delay

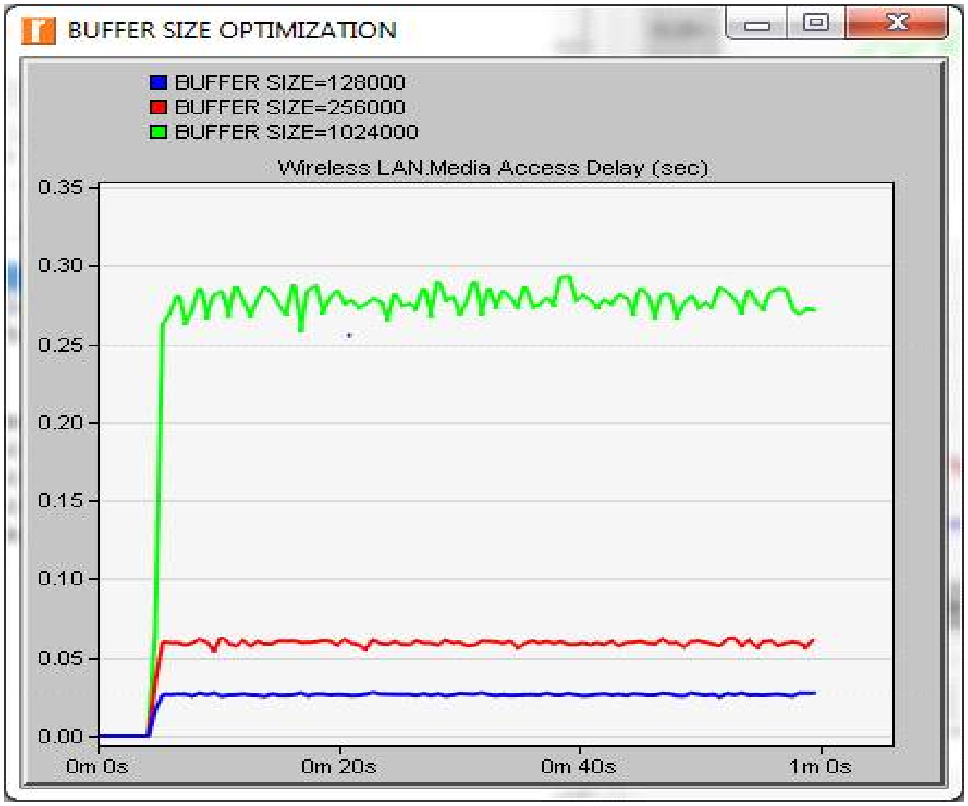


Fig.4.63. WLAN buffer size optimization for lower media access delay

From above simulation results, it is evident that increased buffer size enhances the throughput but also increases the delay. Thus an optimum value of buffer size should be chosen to enhance the network performance.

Effect of Green Field Operation

This attribute enables or disables Greenfield operation in a high throughput station. If the Greenfield operation is enabled, then the high throughput station can use High rate Green Field PLCP header for data frames during communication with another Greenfield capable high throughput station.

The comparative simulation results are obtained for Greenfield operation enabled and disabled. Fig. 4.64 shows that WLAN throughput in bits/sec increases as a result of Greenfield operation.

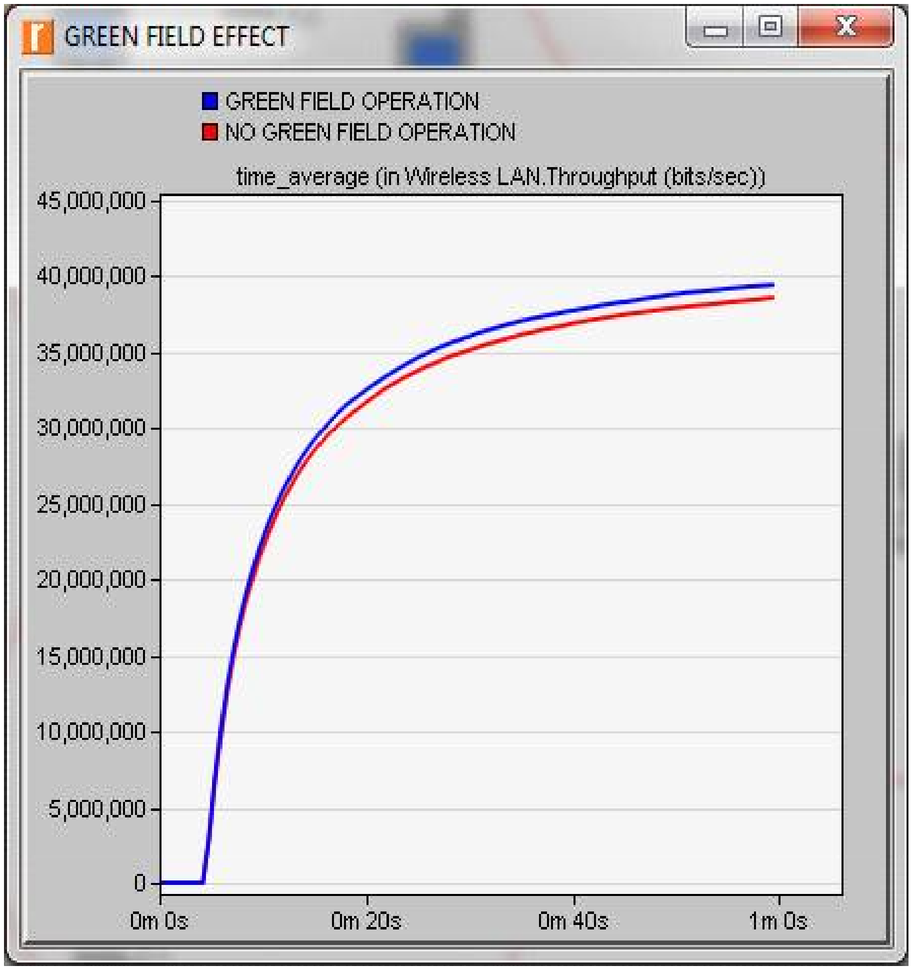


Fig.4.64. WLAN throughput optimization with Greenfield operation

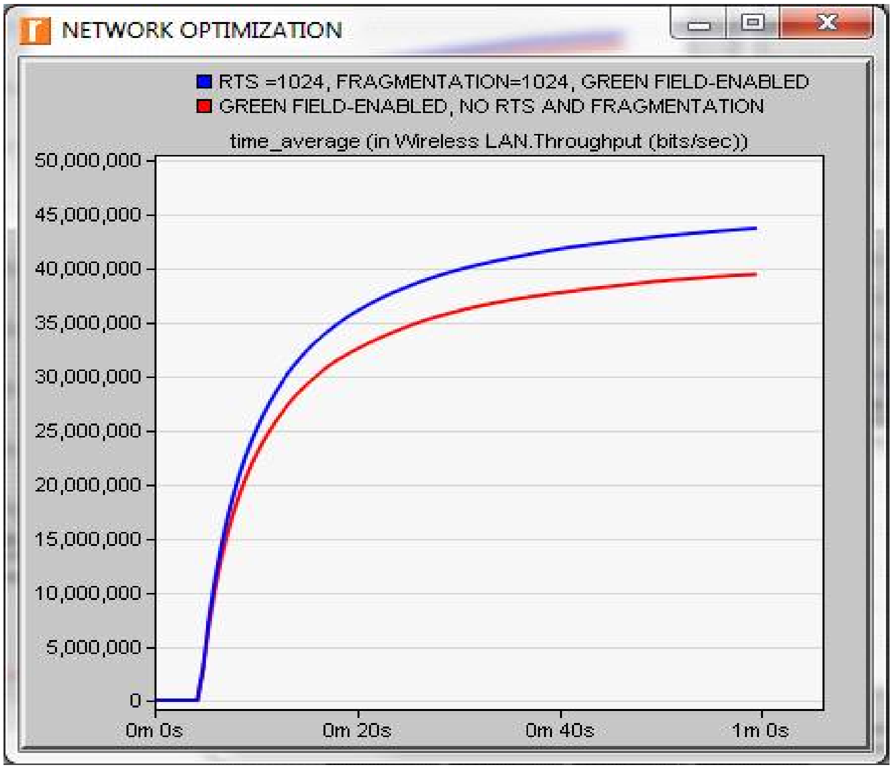


Fig.4.65. WLAN throughput optimization with RTS, Fragmentation and Greenfield operation parameters

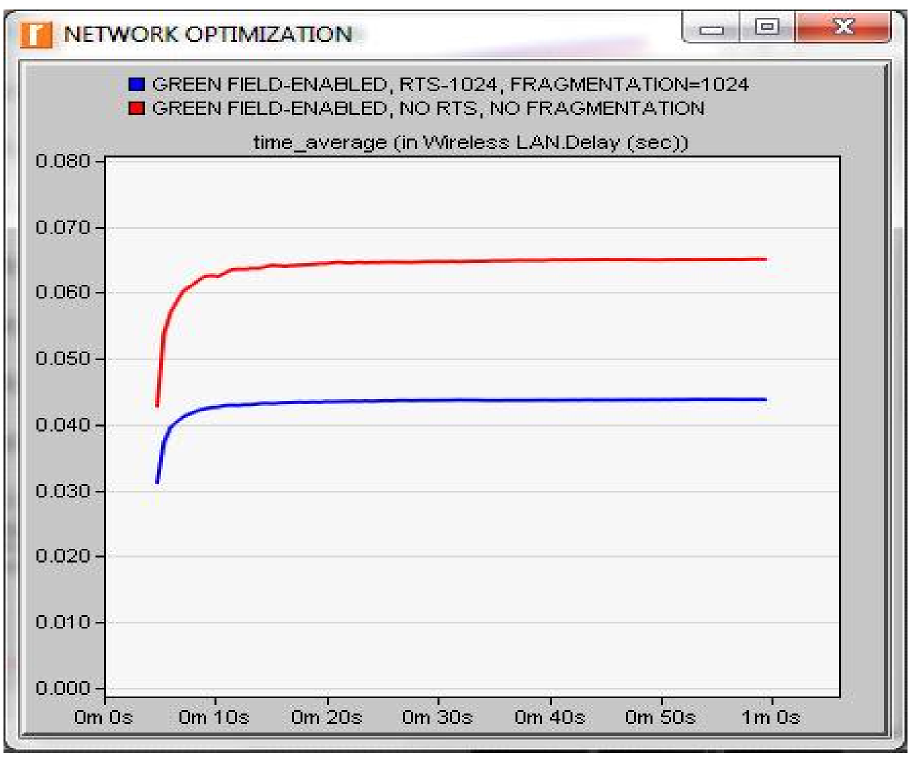


Fig.4.66. WLAN delay optimization with RTS, Fragmentation and Greenfield operation parameters

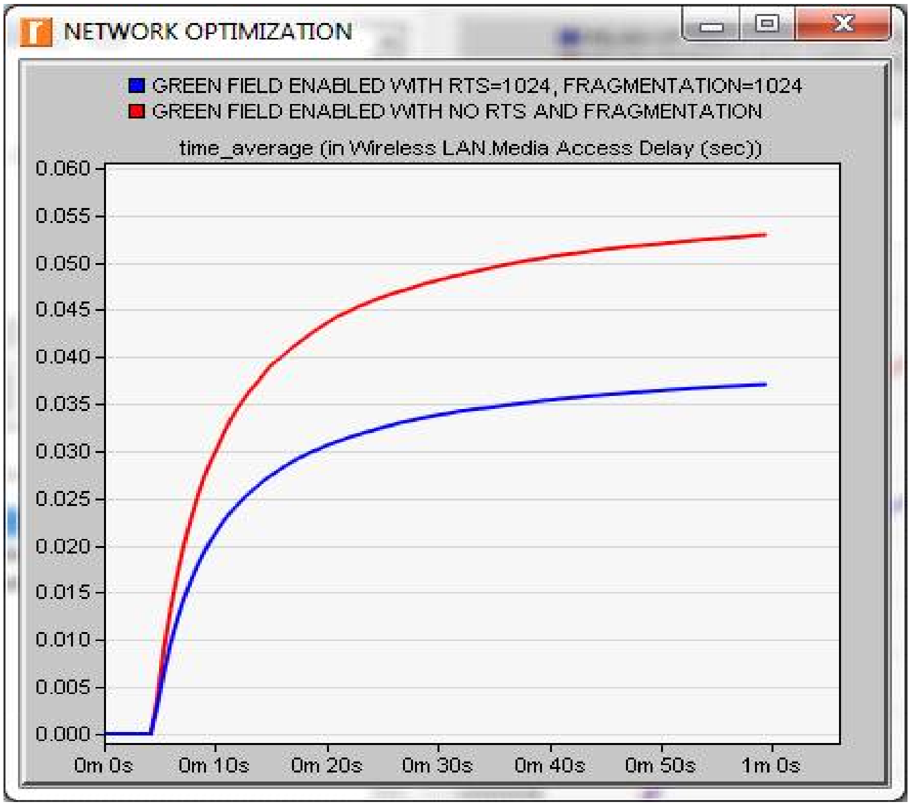


Fig.4.67. WLAN Media access delay for optimized value of RTS, Fragmentation and Greenfield operation parameters

It is observed that the throughput increases when green field operation is enabled. Green field operation combined with RTS and fragmentation mechanism further increases throughput and reduces delay. As shown in the graphical simulation results, Green field operation is combined with higher values of RTS and fragmentation thresholds for performance enhancement.

Effect of Contention Window Optimization

Contention is a media access methodology used for sharing a medium. CWmin indicates the starting size of the "Contention Window" for the Best Effort category. It picks up the arbitrary number of slots for back-off time. CWmax specifies the maximum size of the "Contention Window" for the Best Effort category. Results are drawn for default values of CWmin and CWmax which is (-1) for IEEE 802.11e standard. Results are improved for optimized value of CWmin and CWmax.

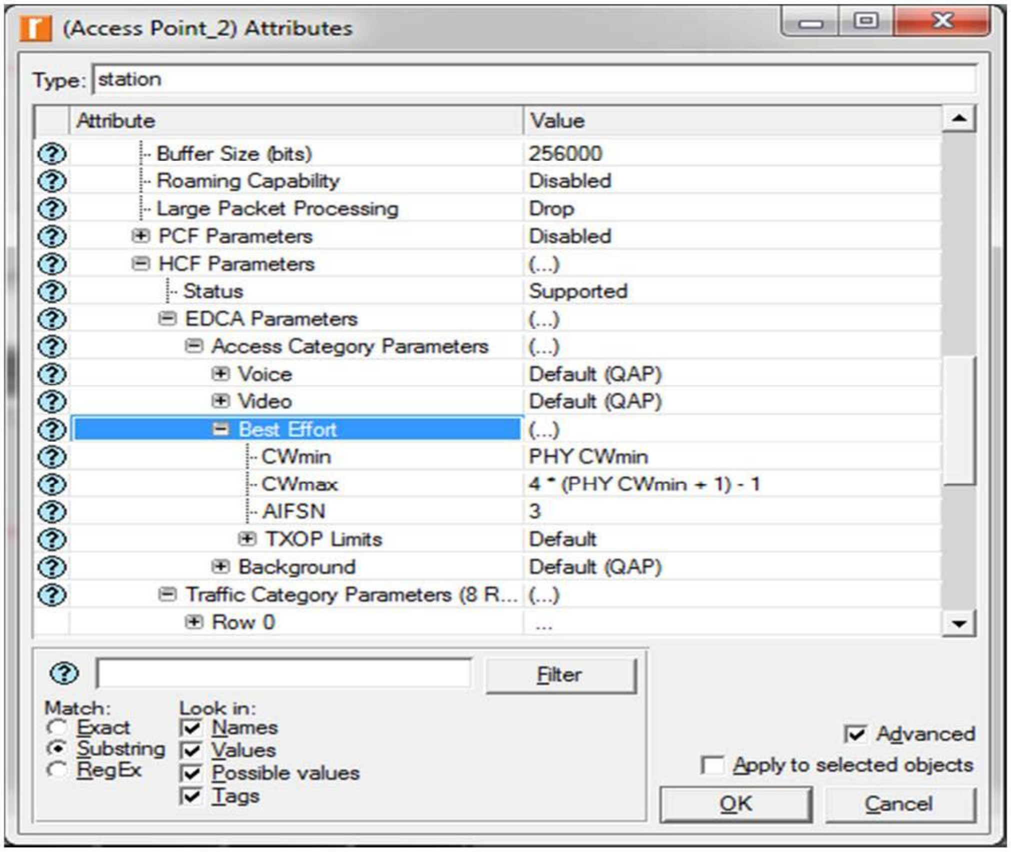


Fig.4.68. Default values of CWmin and CWmax

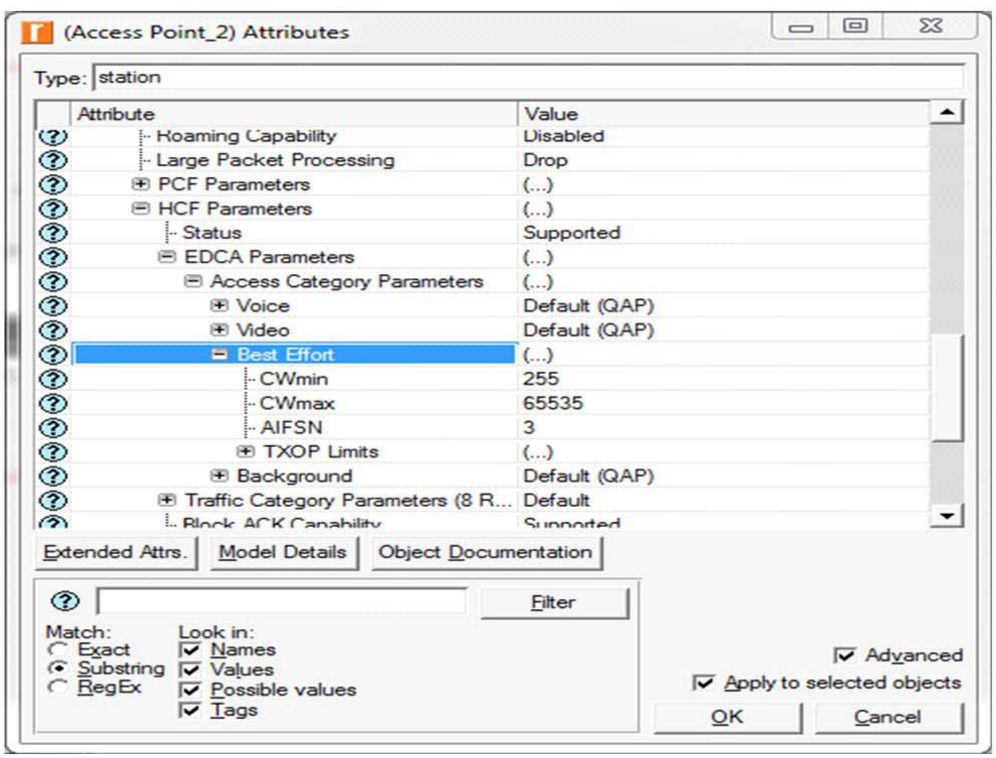


Fig.4.69. Optimized values of CWmin and CWmax

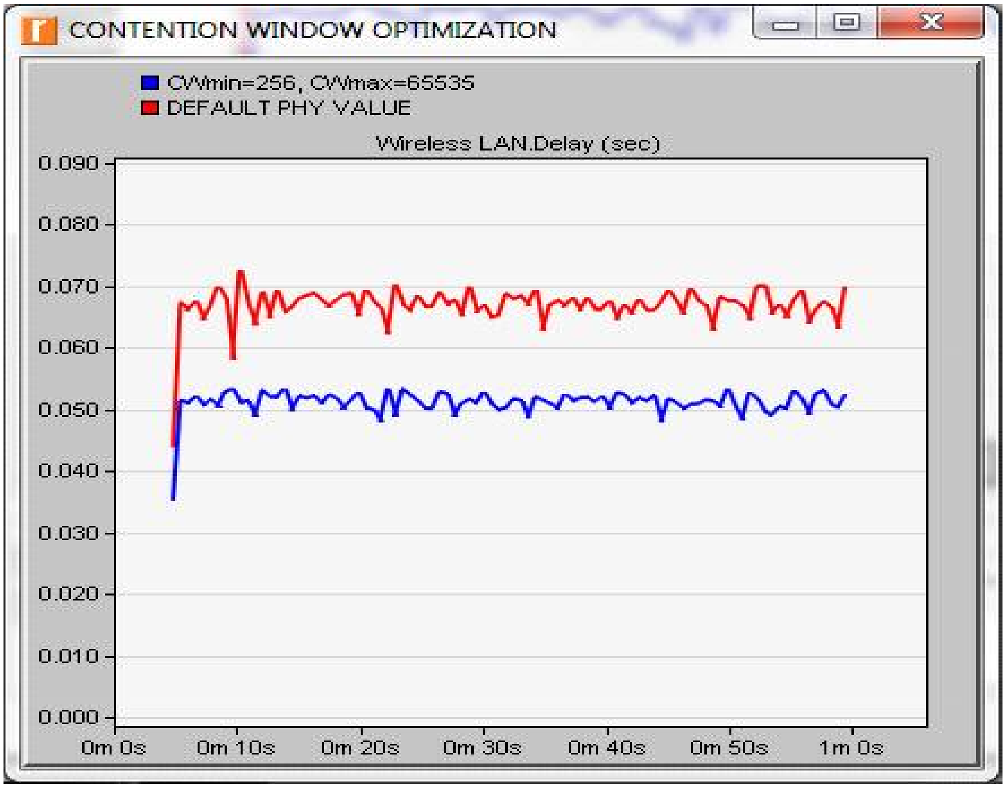


Fig.4.70. WLAN delay with and without Contention window optimization

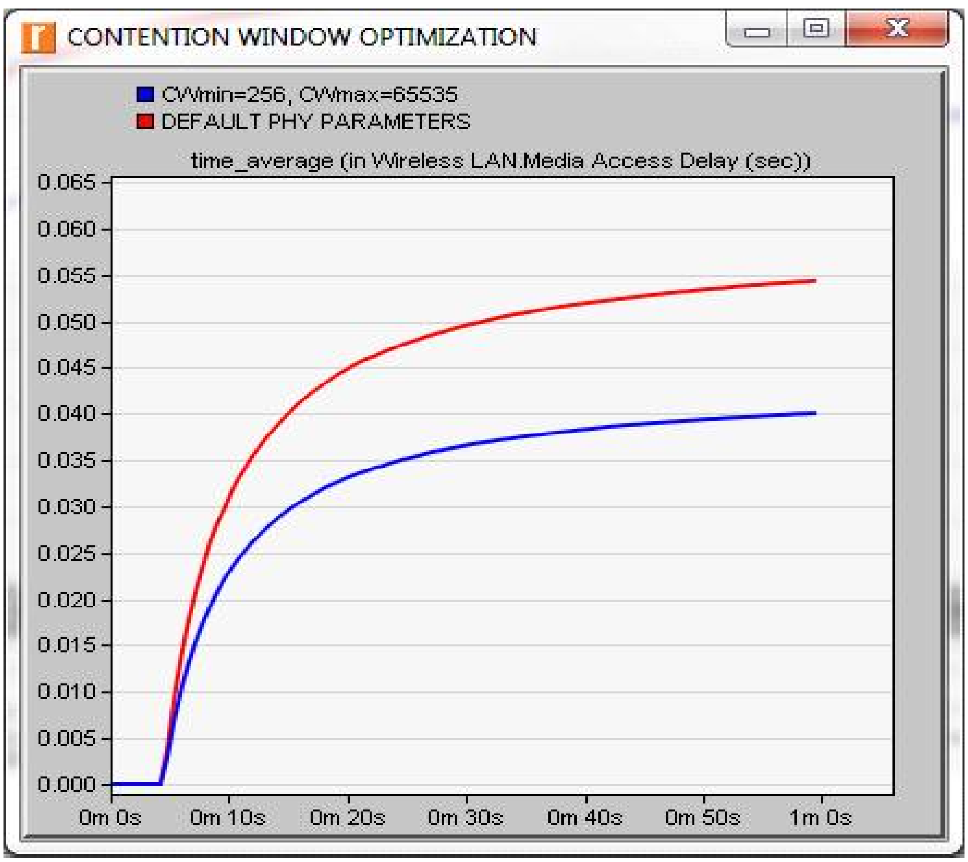


Fig.4.71. WLAN Media access delay with and without Contention window optimization

Fig.4.70. and Fig.4.71. show the comparative results of contention window with default value and with optimized value. Optimized value significantly enhances the performance.

Effect of Frame Aggregation

Frame aggregation is a technique to send two or more frames in a single transmission to enhance the throughput. As the data rates increases, overhead also increases which consumes very high bandwidth.

This issue can be efficiently addressed by using frame aggregation method. Frame aggregation is categorized into two methods namely MSDU and MPDU aggregation. MSDU allows numerous MAC service data units to same receiver contained in single MDPU. MPDU combines multiple sub frames into single header.

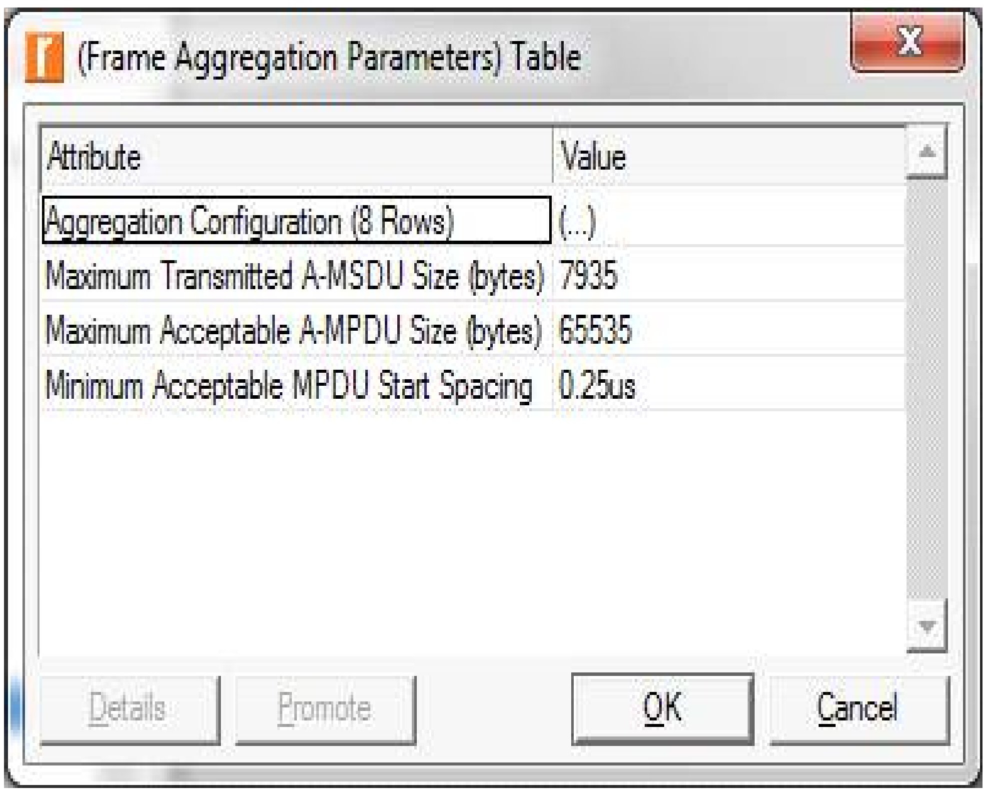


Fig.4.72. Frame aggregation parameters

Fig.4.73 and Fig.4.74 depicts the results for media access delay and throughput with frame aggregation enabled and disabled. Results show that media access delay as well as throughput are reduced by enabling frame aggregation mechanism. To overcome this effect, frame aggregation and RTS mechanisms are combined.

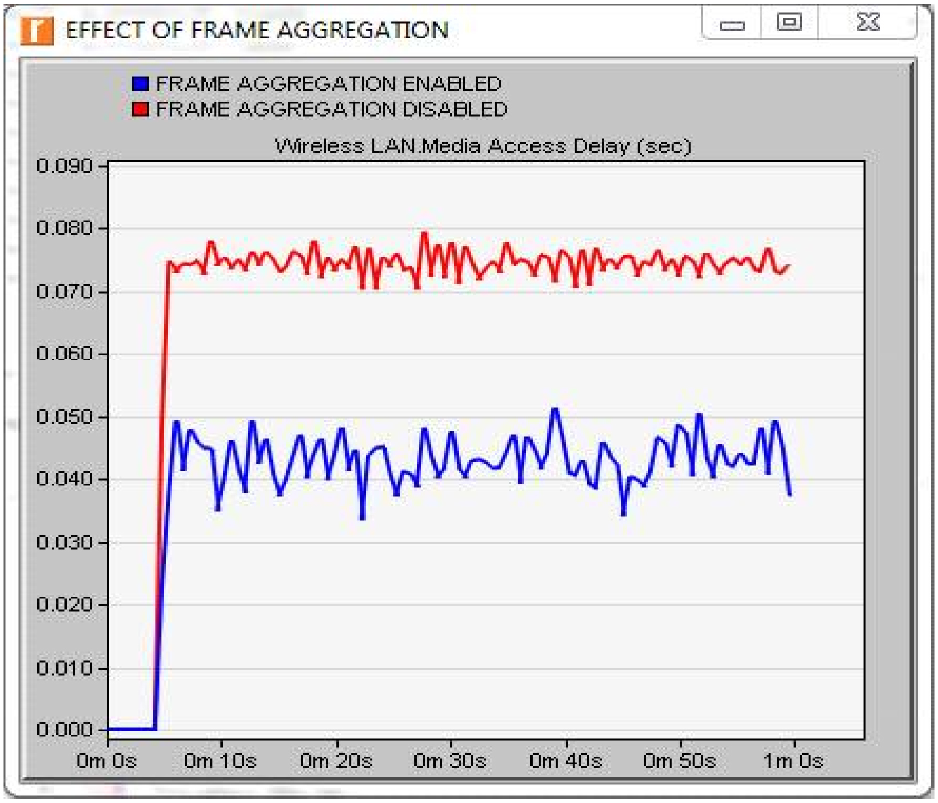


Fig.4.73.WLAN Media access delay with and without frame aggregation

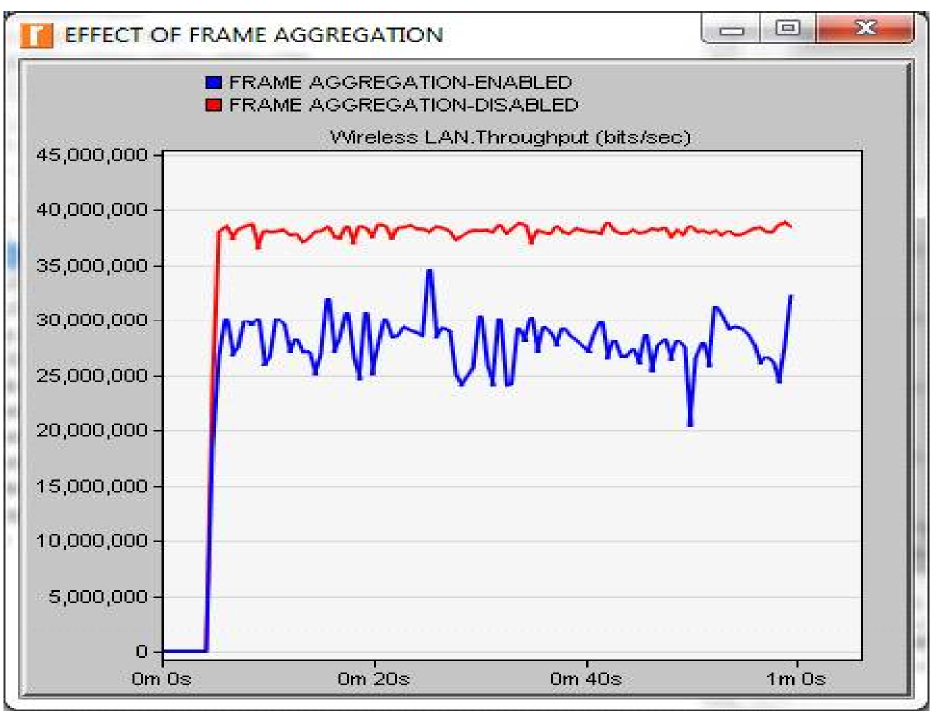


Fig.4.74. WLAN Throughput with and without frame aggregation

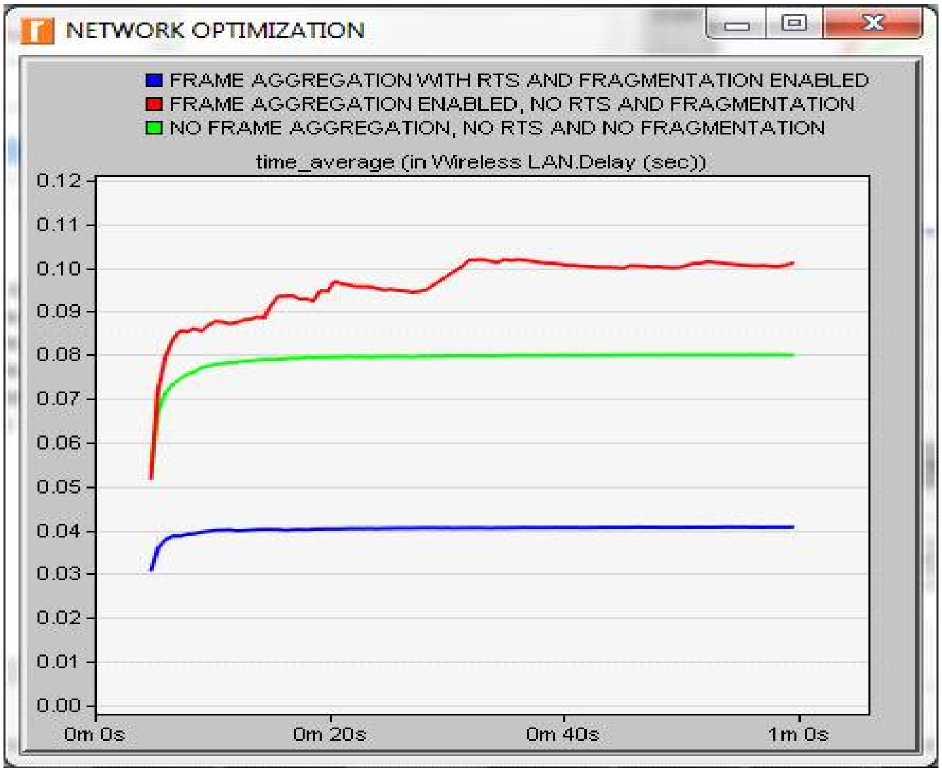


Fig.4.75. WLAN Delay with and without Frame aggregation, RTS and Fragmentation mechanisms

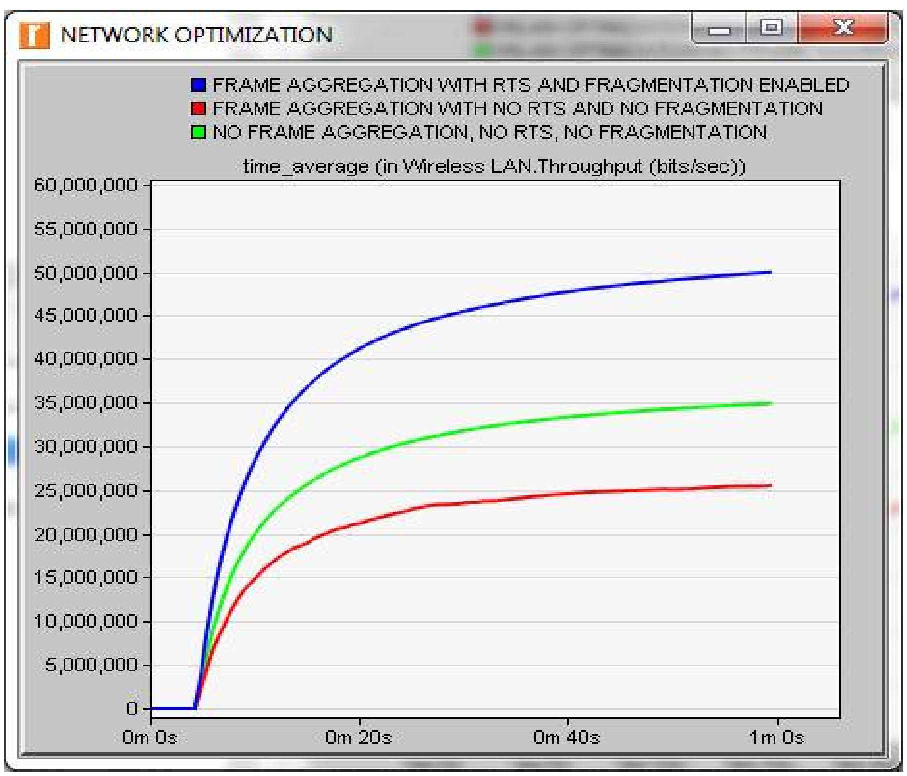


Fig.4.76. WLAN Throughput with and without Frame aggregation, RTS and Fragmentation mechanisms

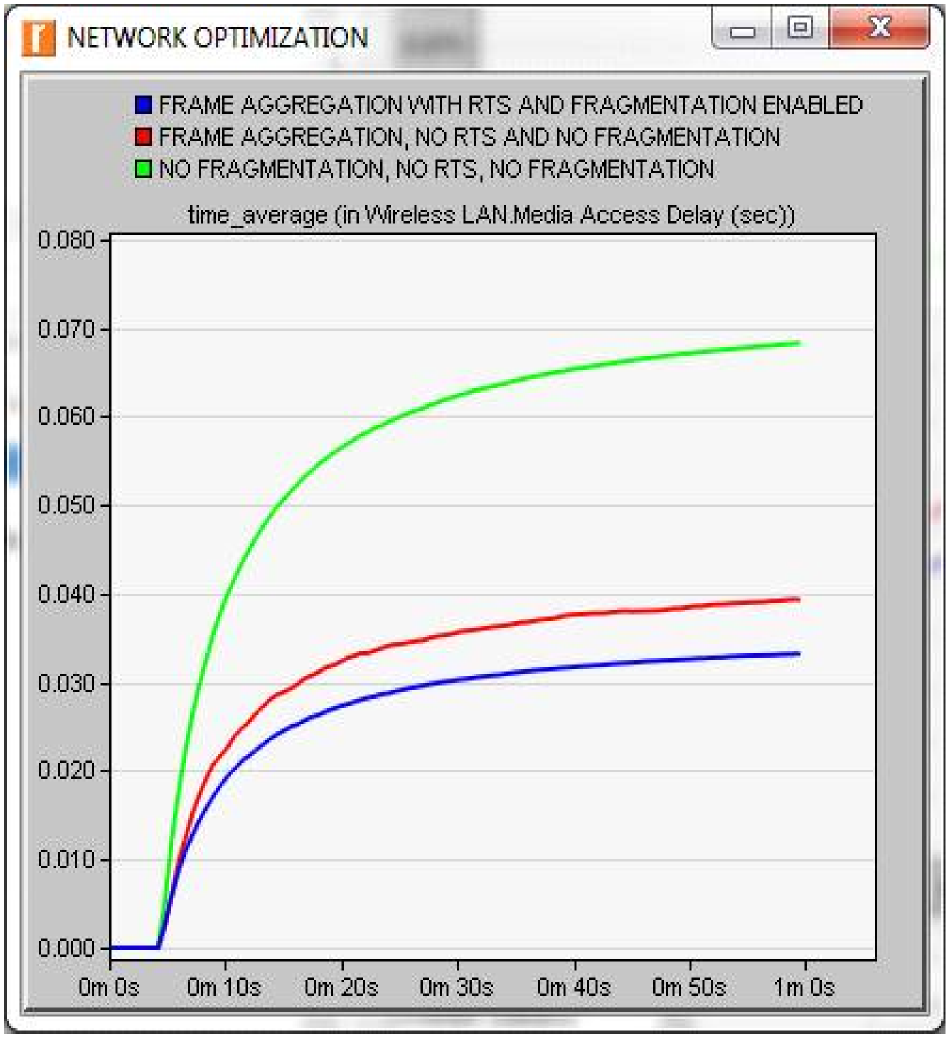


Fig.4.77. WLAN Media access delay with and without Frame aggregation, RTS and Fragmentation mechanisms

Frame aggregation reduces delay but the throughput is also reduced as shown in the graphical representations. To overcome this performance degradation, frame aggregation method is used along with RTS and fragmentation mechanism. For optimization, higher values of RTS and fragmentation threshold (1024) are chosen. As a result of this combination, throughput is significantly improved and delay is also reduced.

Fig.4.78. shows the comparison of individual parameter optimization vs collective optimization of various parameters pertaining to different network layers. The results are depicted with the graphical representation in Fig.4.79.

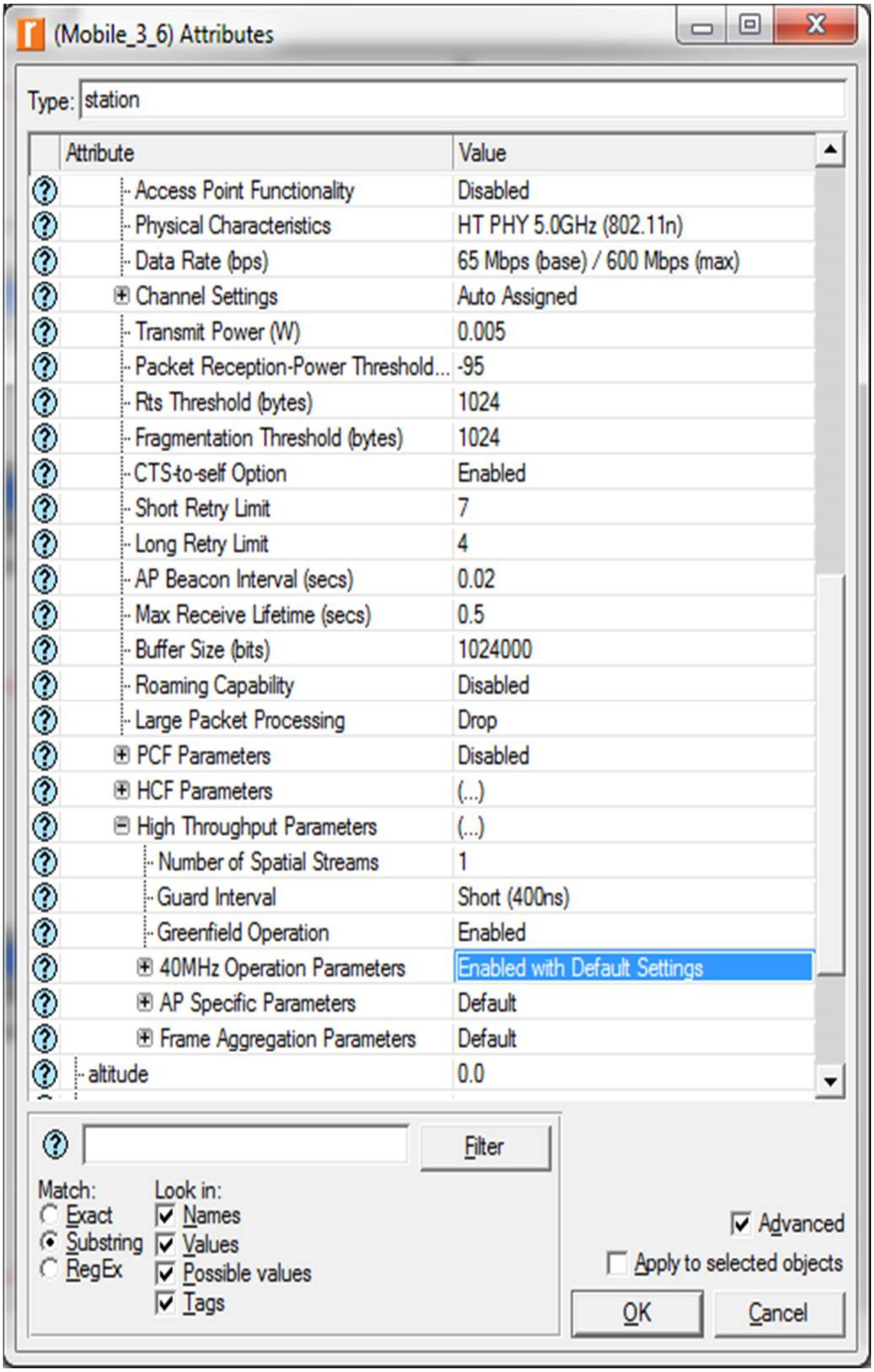


Fig.4.78. Values of various parameters

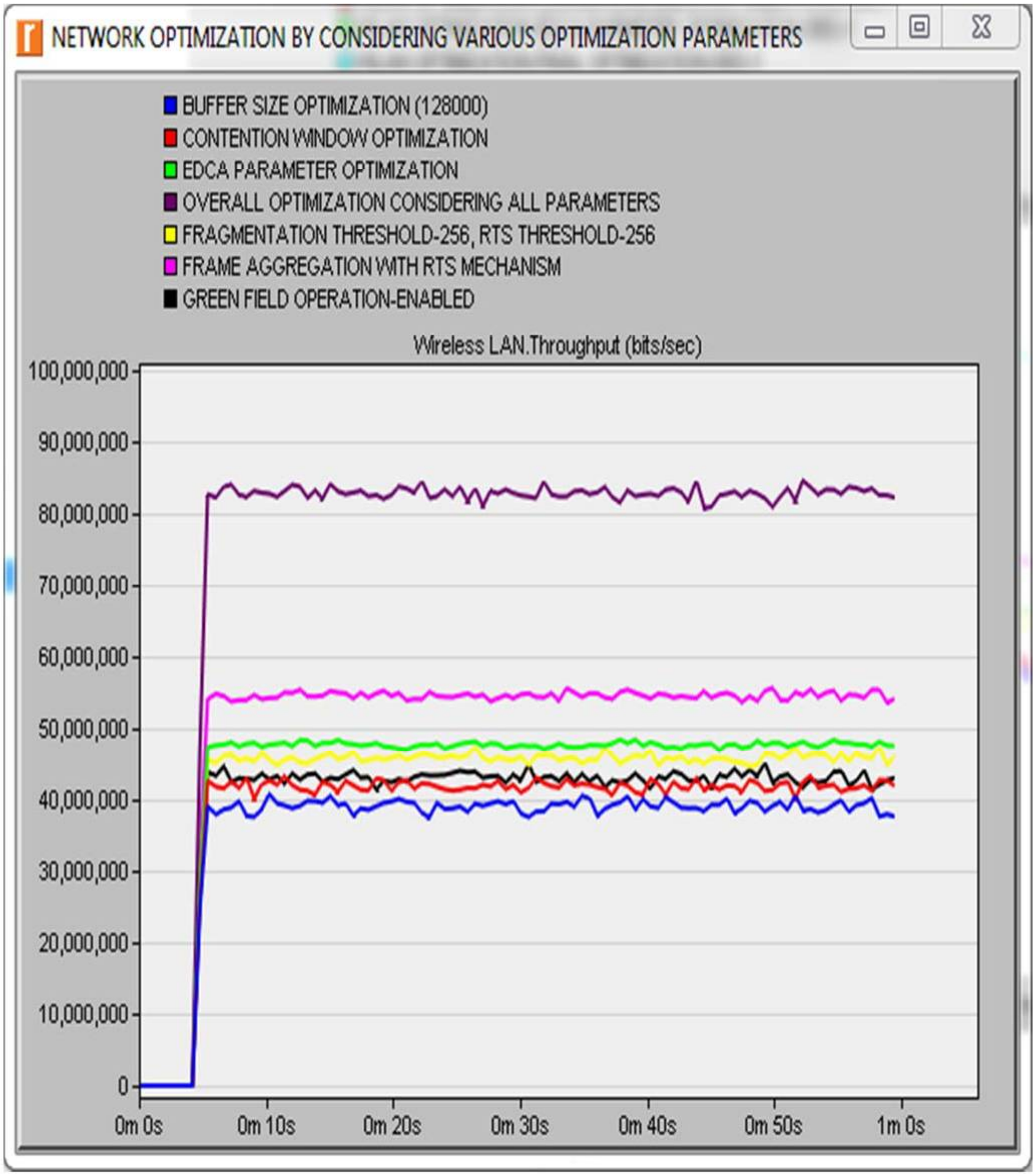


Fig.4.79. Network optimization by considering various parameters

Fig.4.79. shows that by choosing optimum values of different parameters, a network performance can be significantly improved. The throughput is enhanced by proper selection of various parameters.

4.2.3. CROSS LAYER PARAMETER OPTIMIZATION OF NEIGHBORHOOD AREA NETWORK

Neighborhood Area Network (NAN) is a combination of Home Area Networks in Smart grid hierarchical network. In this section, NAN is formed in 1.5 Km area using IEEE 802.11 standard. Total 50 nodes and one server are considered for optimization as shown in Fig.4.80.

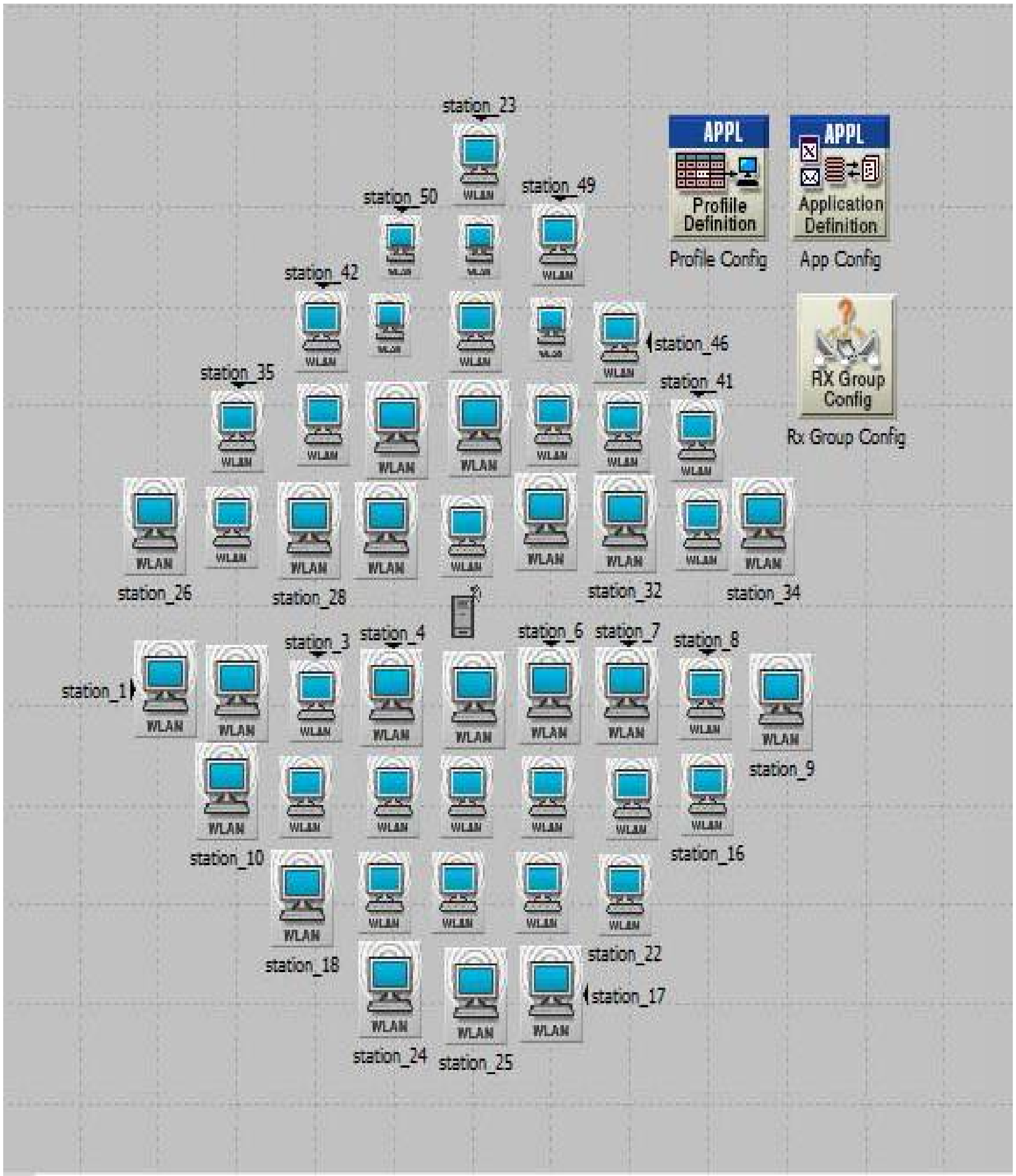


Fig.4.80. Neighborhood area network

Protocol Optimization

AODV routing protocol is considered for optimization. It is a reactive routing protocol. Results depicts that the parameters such as hello interval, allowed hello loss and an active route time out period have significant influence on routing traffic. All these three parameters are increased for reduction in routing traffic. Table 4.9. covers the description of various AODV parameters.

SR NO.	PARAMETER	DESCRIPTION
1.	Active route time out	It indicates the time duration of an initialization of entry of a routing table. The route must be utilized and refreshed during this time period otherwise it is considered as invalid and cannot be used to forward the packet. Invalid route is eliminated from IP table. Small value of Active route time out period is preferred for extremely dynamic networks so that the outmoded routes can be swiftly removed.
2.	Hello Interval	This feature defines an intermission period of transmission of hello message. This message is meant for maintenance of a link. It the node receive neither hello nor any other packet from neighbor node within this interval then it concludes that the connection with the neighbor is lost.
3.	Allowed hello loss	It the node receives neither hello nor any other packet from neighbor node within Allowed hello loss*Hello interval then it concludes the loss of connectivity. This attribute illustrates the amount of lost packets for which a node can sustain before the conclusion of loss of connectivity. The value of this parameter should be high for a network having several collision instances and congestion.
4.	Node traversal time	This parameter is an estimation of an average single hop traversal time of data packets. It includes delay for the queue, processing and transfer periods. The value of this parameter is decided on the basis of the size of a network.
5.	Route error rate limit	This parameter is used to put a restriction on the rate of generation of route error messages.

6.	Time out buffer	This attribute facilitates the buffering period for arrival of route reply.
7.	TTL parameters	These parameters are used during an expansion of ring search while sending the request for finding the destination route as well as during local repair while calculating TTL value used by the node for sending route request.
8.	Packet queue size	This attribute states the number of packets stored by the buffer before path discovery. The default value of this parameter is infinity which states that the packets will be dropped upon non-discovery of a route after specific reattempts.
9.	Local repair	A local repair is initialized by an intermediate node when the active path is broken.
10.	Addressing mode	It specifies the protocol IPV4 or IPV6. The packets unsupported by the set parameter will be dropped.

Table 4.9. Description of various parameters

The standard used for optimization is IEEE 802.11g with 2 Mbps of data rate and 0.005W transmitter power. These are the physical layer parameters. Fig.4.81 shows default AODV parameters while Fig.4.82 shows reduced traffic parameters.

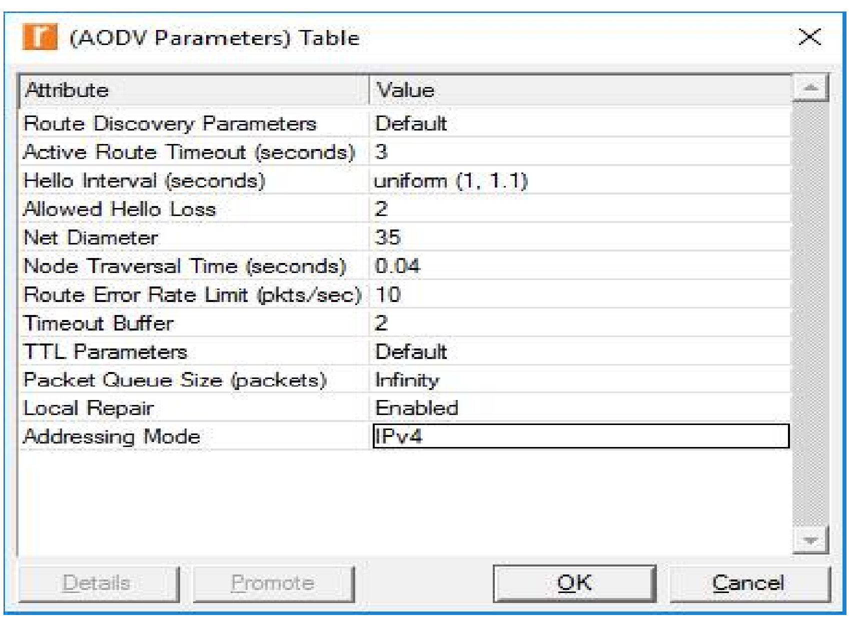


Fig.4.81. Default AODV parameters

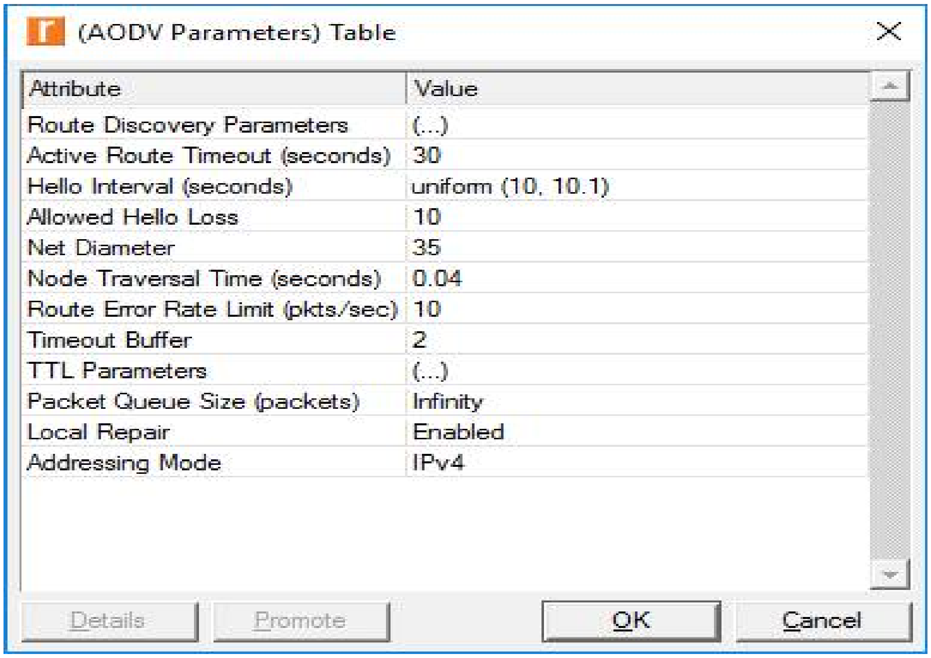


Fig.4.82. Reduced routing traffic parameters

Fig.4.83. shows the reduced routing traffic with gratuitous route reply flag disabled. If this parameter is enabled, a destination node will informed by an intermediate node during reply of RREQ.

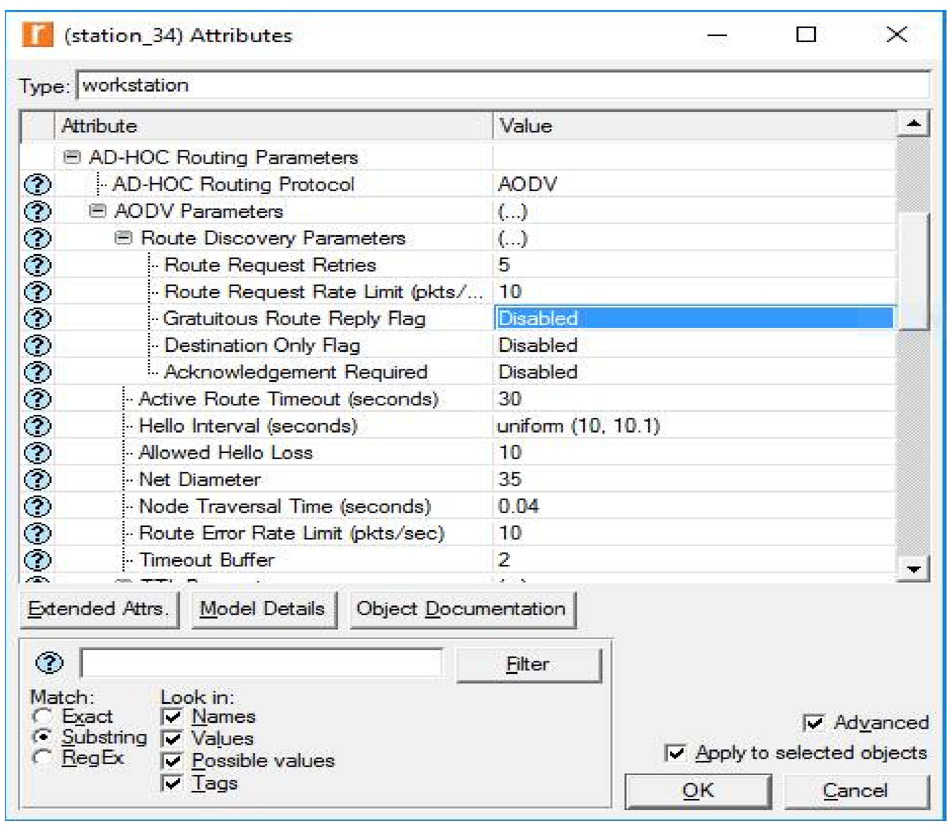


Fig.4.83. Reduced routing traffic parameters with gratuitous route reply flag disabled

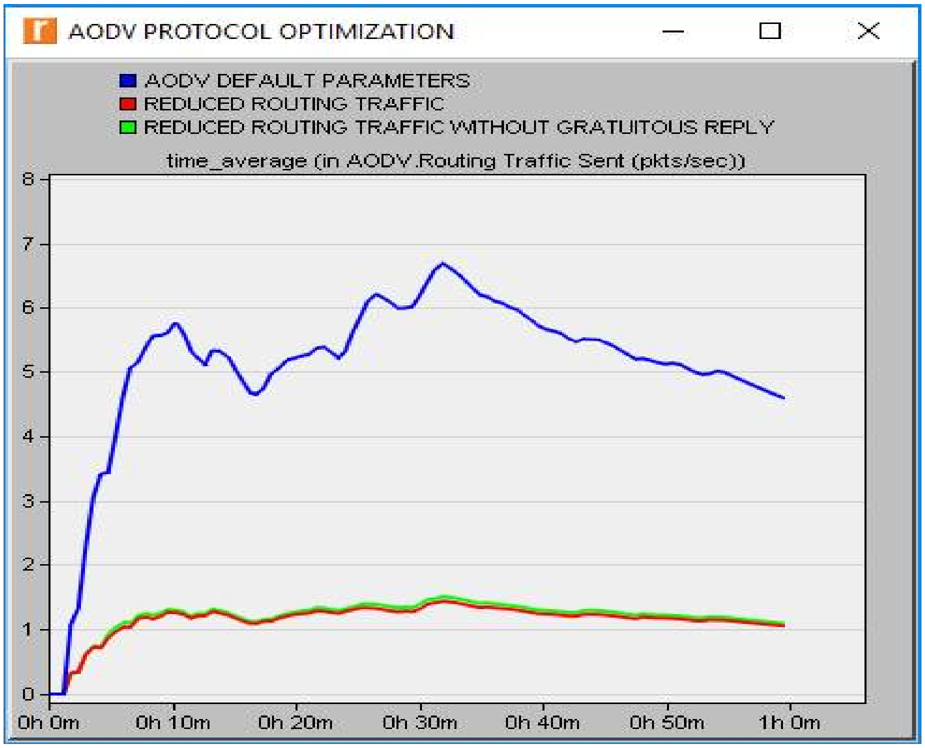


Fig.4.84. AODV protocol optimization-Routing traffic sent

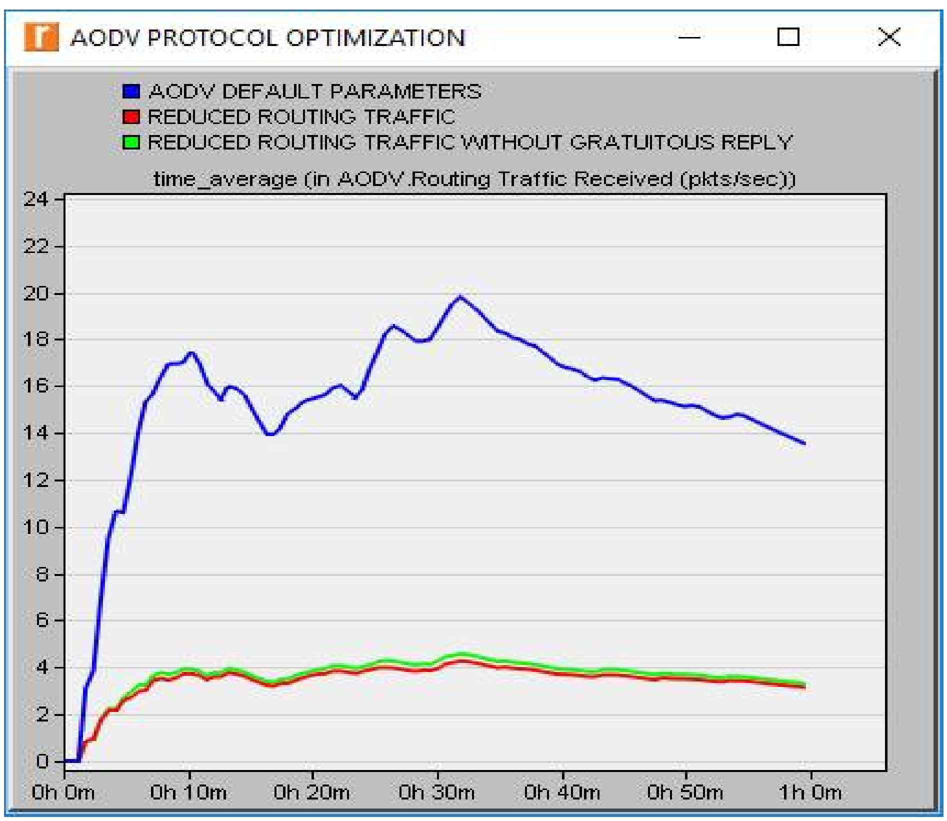


Fig.4.85. AODV protocol optimization-Routing traffic received

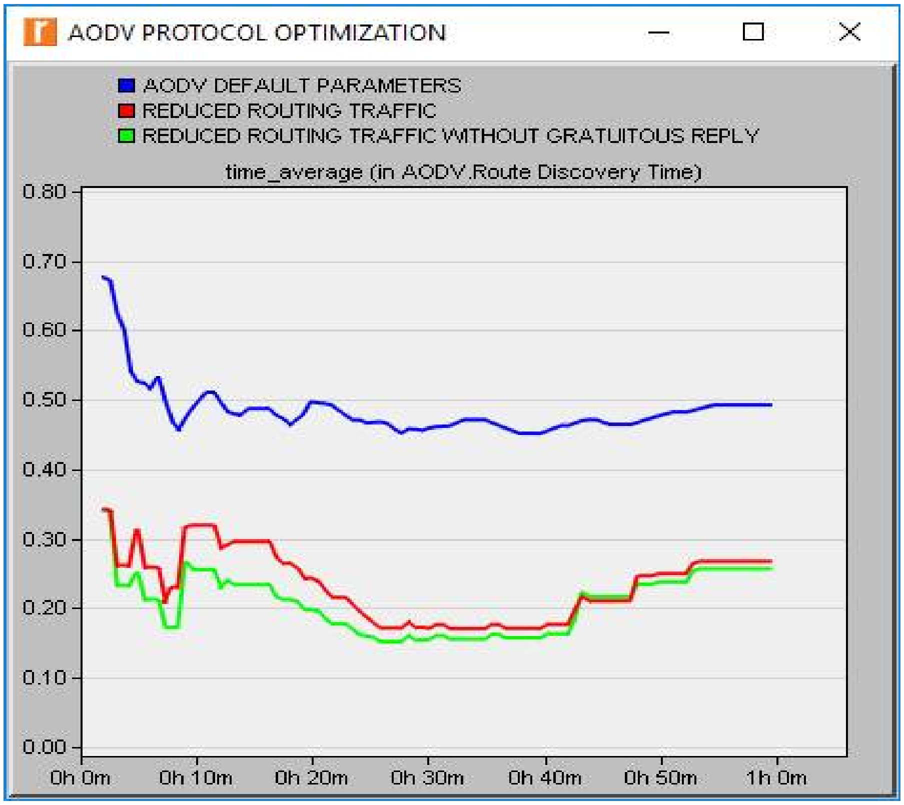


Fig.4.86. AODV protocol optimization-Route discovery time

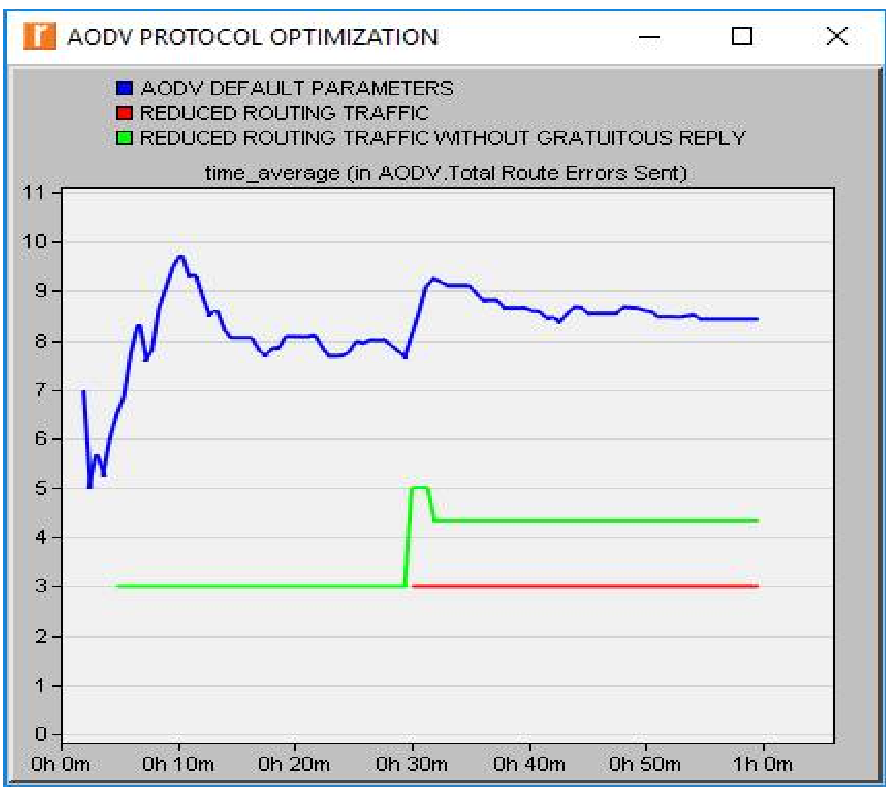


Fig.4.87. AODV protocol optimization-Total route errors sent

The above results show that the routing traffic is significantly reduced through optimization of various route discovery parameters of AODV protocol.

Comparison of WLAN Routing Protocols

In this section, routing protocols are compared for optimization purpose. Default parameters are considered for all the protocols. AODV routing protocol works on the basis of on demand routing, that is, the routing path is settled only when there is a requirement for source node to transfer the packets. The delay caused by set up of connections is lesser in this protocol. Dynamic source routing protocol restricts the bandwidth consumption through elimination of table update messages. It does not use hello packet approach. Temporally Ordered Routing Algorithm protocol uses loop free multipath ways towards destination. It uses a link reversal algorithm for this purpose. It has less overhead as it restricts the control packets for reconfigurations of routes to a small region. OLSR protocol enhances the performance of LSR by decreasing the size of control packets and number of links used to forward the link state packets. OLSR has many advantages such as less overhead, less connection set up time and number of broadcasts. Geographic Routing Protocol is a location based proactive protocol. It uses Global Positioning system for updating flooding information. Graphical representation of simulation results is shown in the figures below.

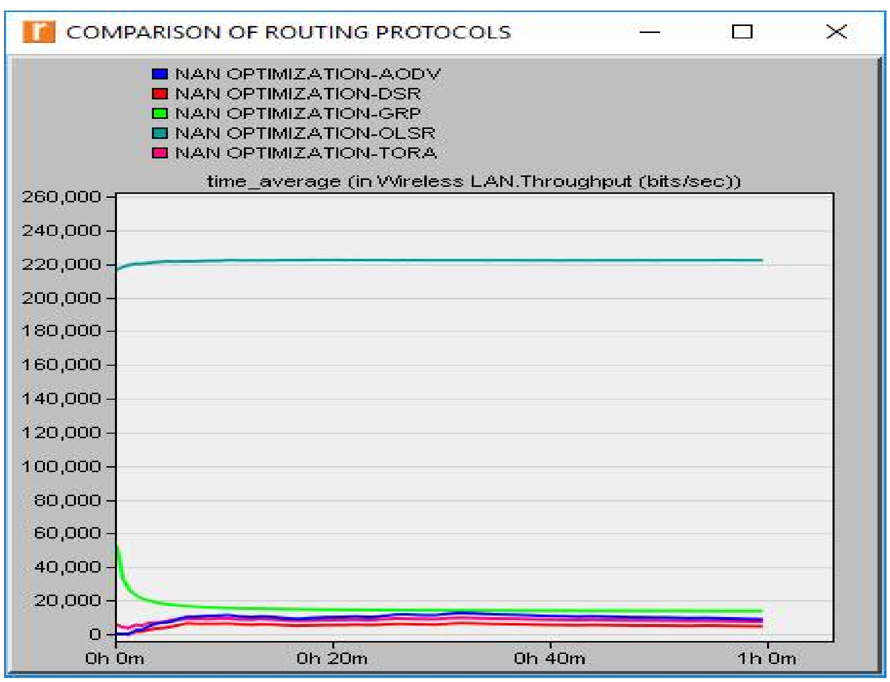


Fig.4.88. Comparison of throughput of different routing protocols for network optimization

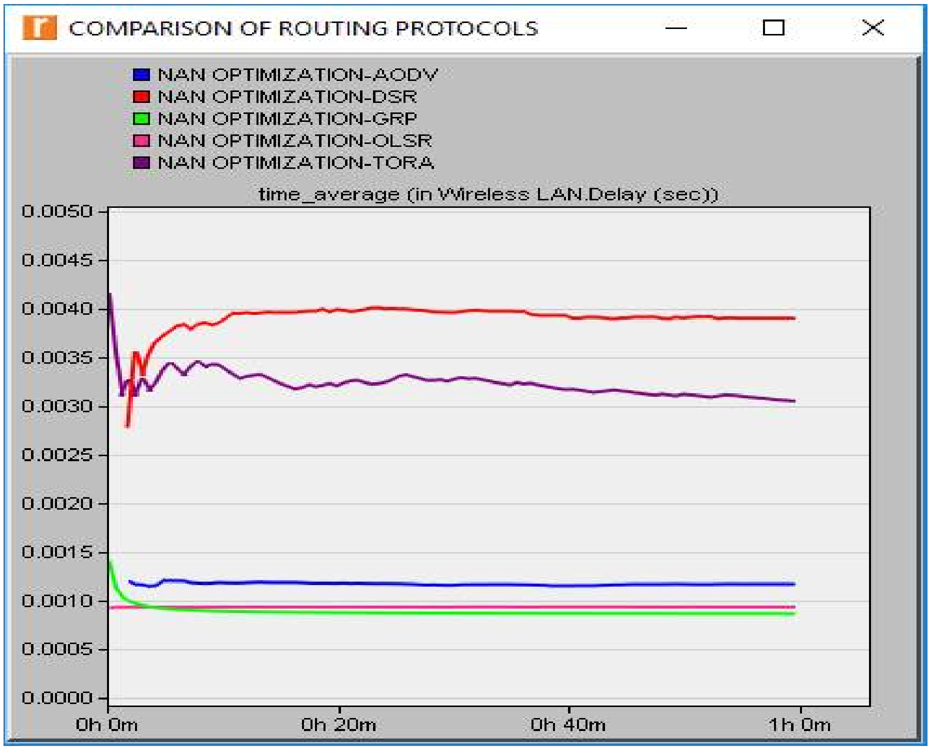


Fig.4.89. Comparison of WLAN delay of different routing protocols for network optimization

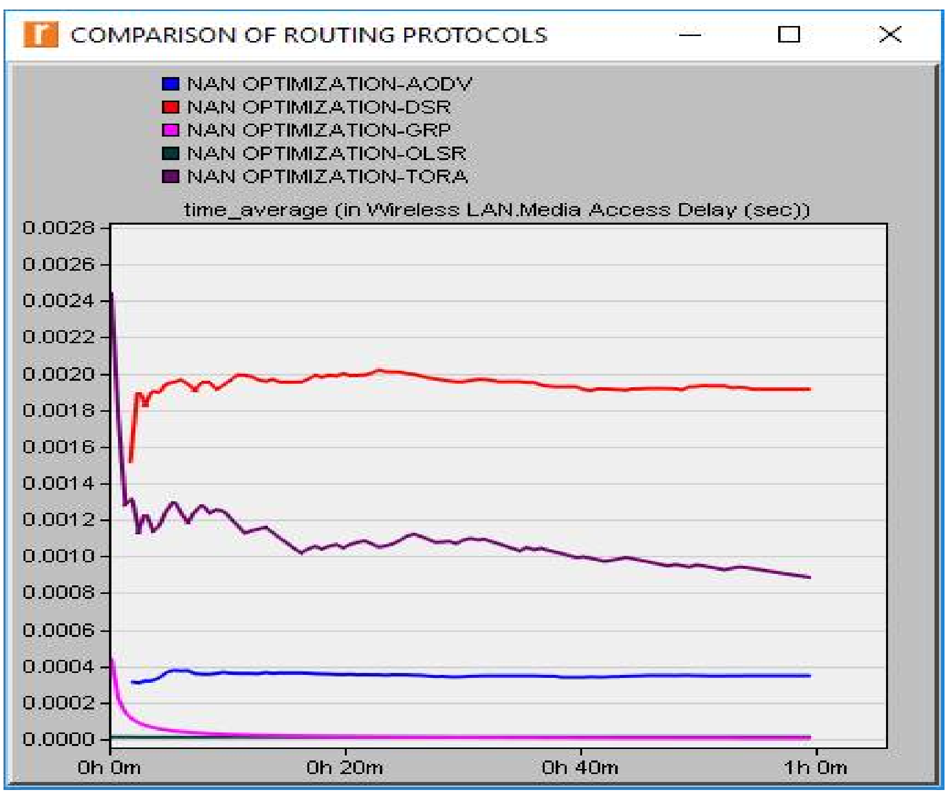


Fig.4.90. Comparison of WLAN Media access delay of different routing protocols for network optimization

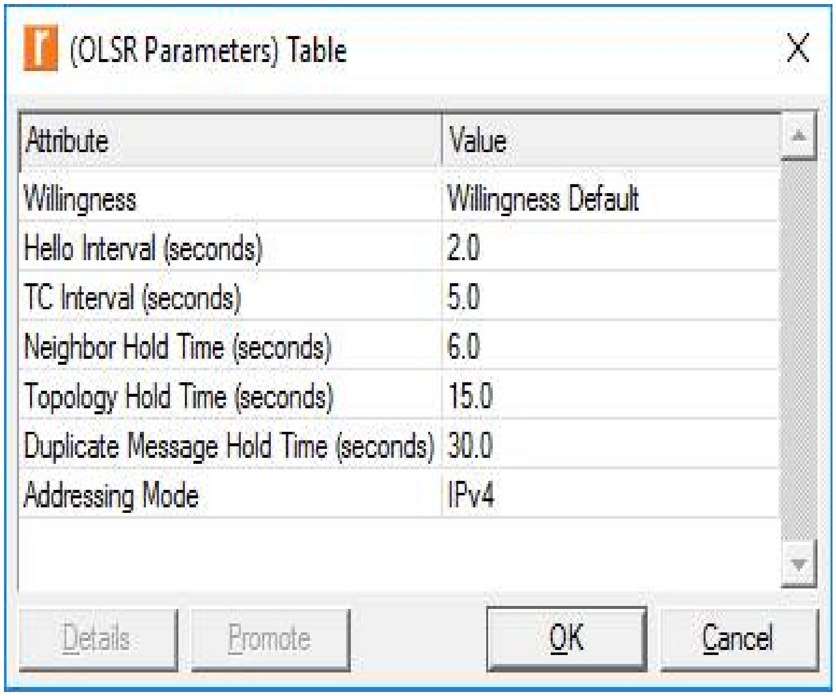
Results show that OLSR protocol outperforms in terms of total delay, MAC delay and throughput compared to all other protocols. It offers higher throughput and lower media access delay as well as overall delay.

Performance Enhancement in OLSR Protocol

As depicted in above results, OLSR protocol performs better than other routing protocols. It can be further improved by increasing Hello interval, Topology hold time as well as Duplicate message hold time. TC interval is decreased. The various parameters are described in Table 4.10.

SR NO.	PARAMETER	DESCRIPTION
1.	Willingness	This attribute defines that whether the node is agree to forward or carry the traffic on behalf of rest of the nodes or not.
2.	Hello Interval	This aspect specifies the time intermission between hello packets. Hello packets are essential to retain adjacencies between various 1 hop or 2 hop adjacent nodes.
3.	TC Interval	This feature states the interlude between TC messages. TC messages are used for routing table calculations and spread the information pertaining to topology of nodes.
4.	Neighbor hold time	This time period defines the duration within which a hello packet should be reached in order to sustain the link with neighbors. It is generally three times the hello interval.
5.	Topology hold time	This characteristic states the termination time for records in topology table. This feature is usually set to 3 times the TC Interval.
6.	Duplicate message hold time	This feature states the finishing time of an entry in the duplicate set table.
7.	Addressing mode	It specifies the protocol IPV4 or IPV6. The packets unsupported by the set parameter will be dropped.

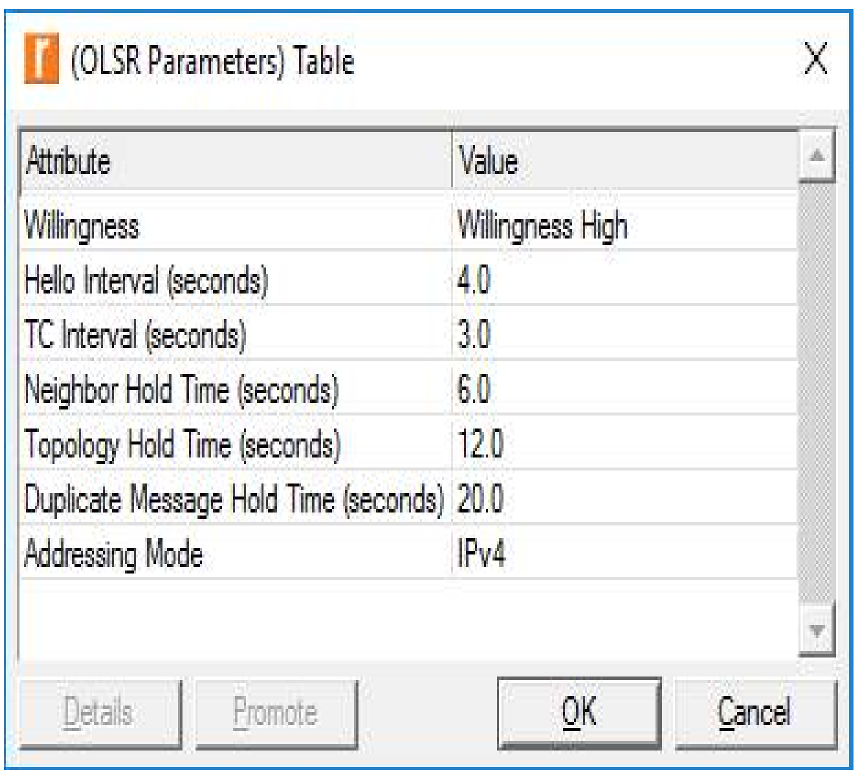
Table 4.10. Description of various OLSR parameters



(OLSR Parameters) Table

Attribute	Value
Willingness	Willingness Default
Hello Interval (seconds)	2.0
TC Interval (seconds)	5.0
Neighbor Hold Time (seconds)	6.0
Topology Hold Time (seconds)	15.0
Duplicate Message Hold Time (seconds)	30.0
Addressing Mode	IPv4

Fig.4.91. Default OLSR parameters



(OLSR Parameters) Table

Attribute	Value
Willingness	Willingness High
Hello Interval (seconds)	4.0
TC Interval (seconds)	3.0
Neighbor Hold Time (seconds)	6.0
Topology Hold Time (seconds)	12.0
Duplicate Message Hold Time (seconds)	20.0
Addressing Mode	IPv4

Fig.4.92. Optimized OLSR parameters

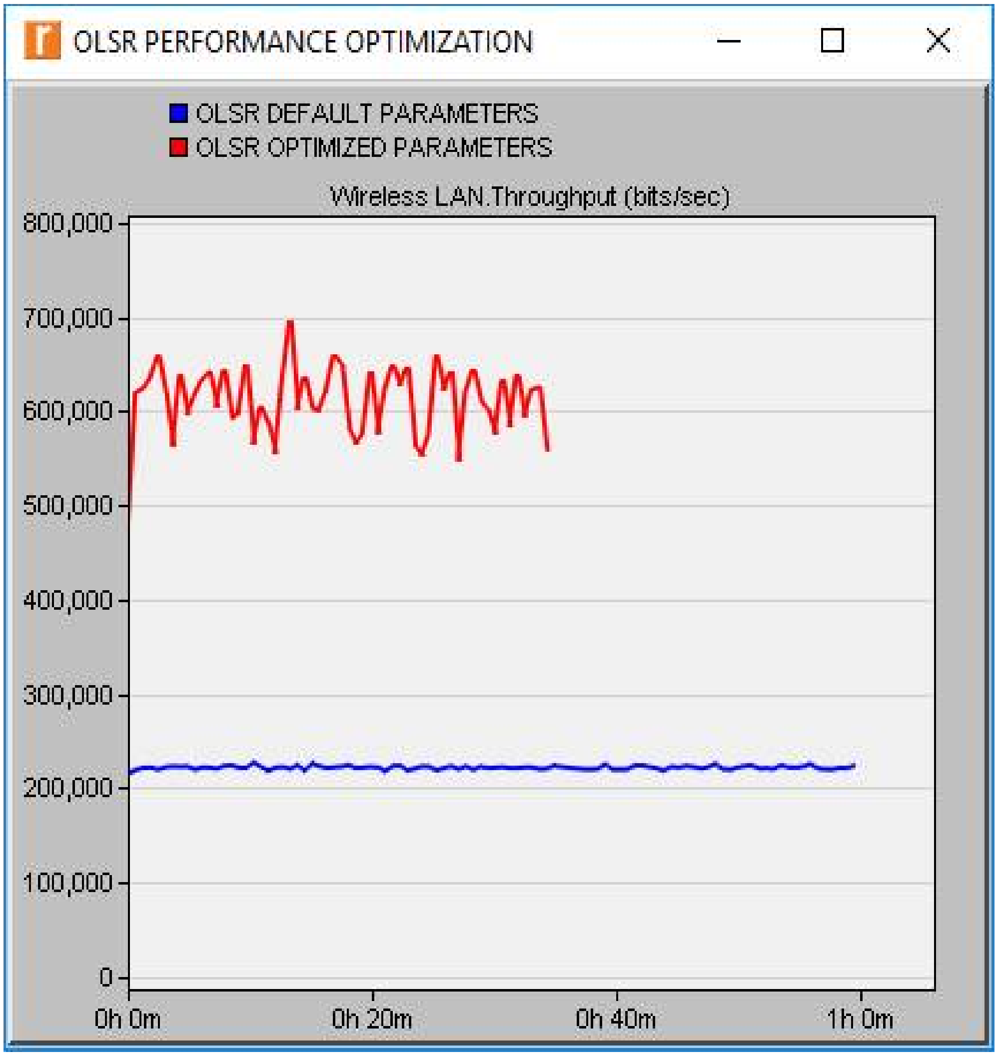


Fig.4.93. WLAN Throughput for default and optimized OLSR parameters

As shown in graphical results, WLAN throughput increases significantly as a result of parameter optimization. Various parameters like Willingness, Hello interval, TC interval, Neighbor hold time, Topology hold time and Addressing modes are optimized for performance enhancement.

Furthermore, an effect of various PHY as well as MAC parameters are also investigated by changing transmission power, RTS and fragmentation threshold.

Fig.4.94 shows the default parameters and Fig.4.95 shows the optimized parameters. Results show a significant improvisation in throughput.

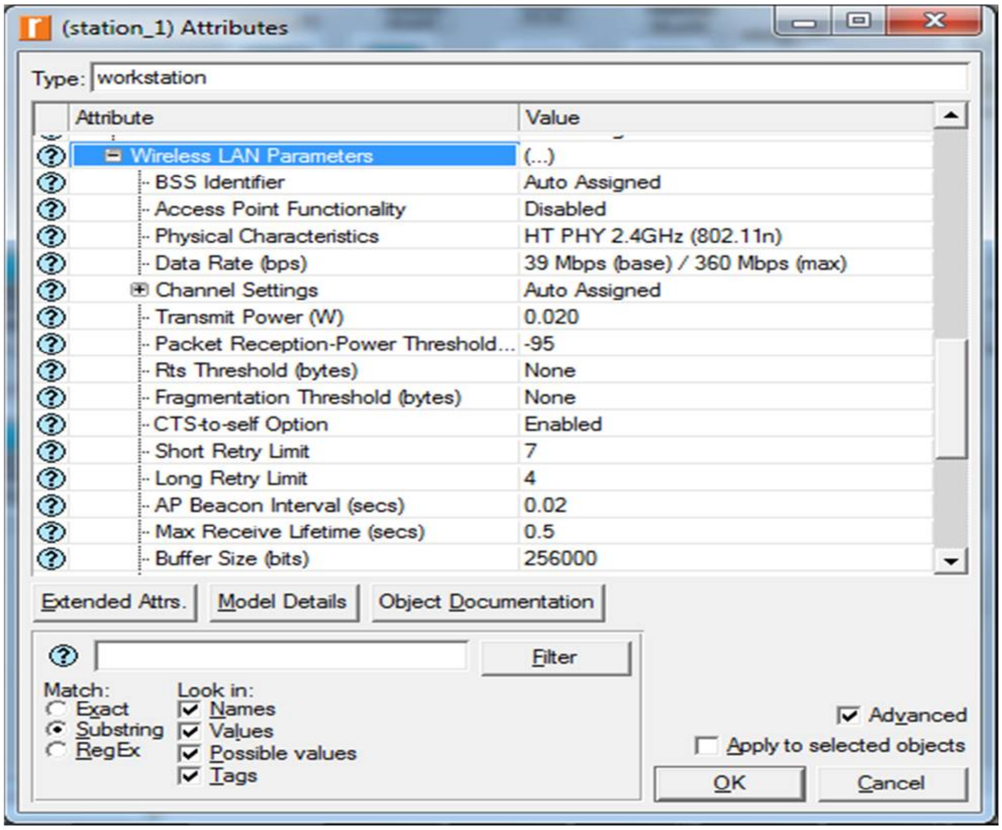


Fig.4.94. Default parameters

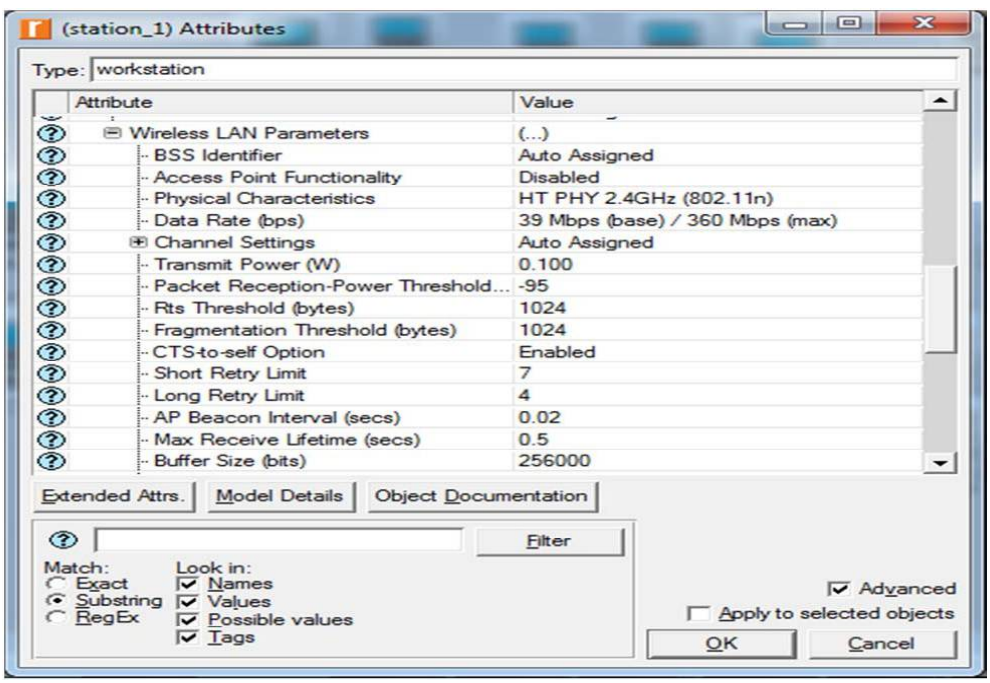


Fig.4.95. Optimized parameters

Fig. 4.96 and 4.97 show the comparative results of MAC delay and throughput of WLAN network for default and optimized parameters.

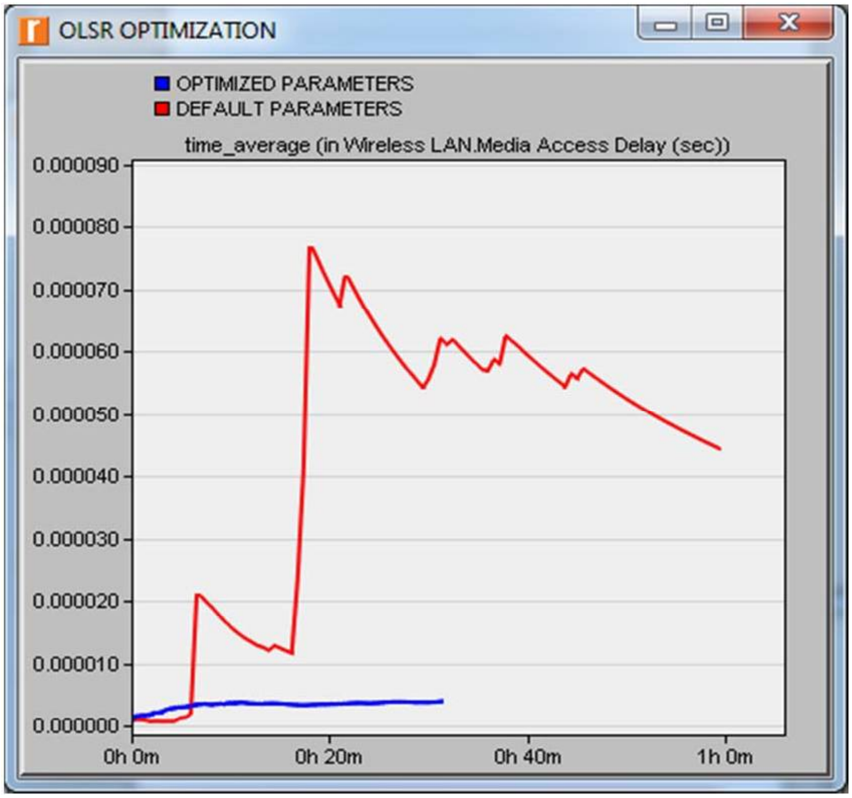


Fig.4.96. WLAN Media access delay for default and optimized OLSR parameters

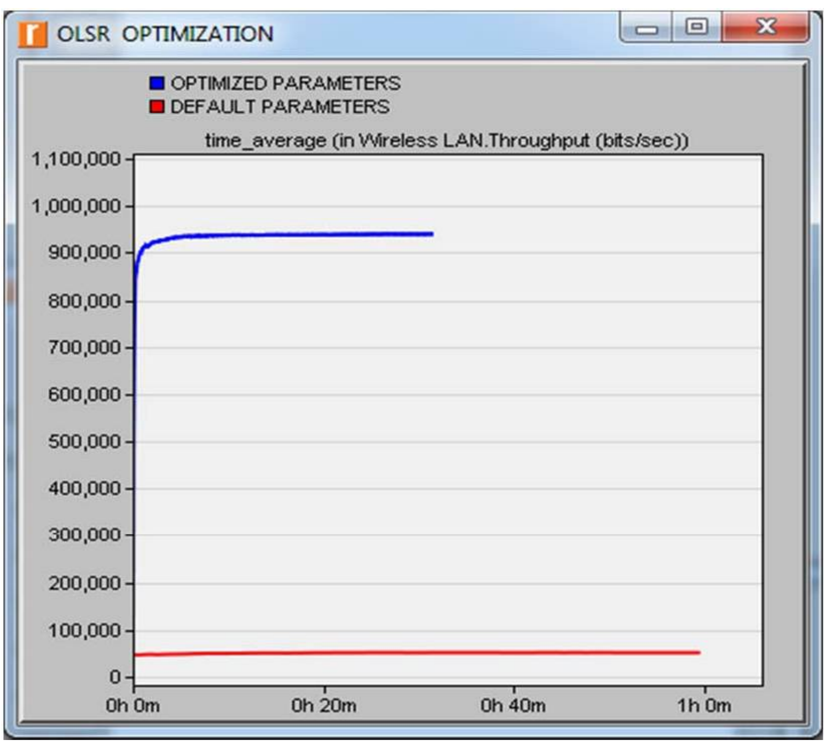


Fig.4.97. WLAN Throughput for default and optimized OLSR parameters

Results depict a time average graphical representation of throughput and media access delay of WLAN network. Increase in transmission power enhances the throughput and reduces the media access delay as shown in Fig.4.96 and 4.97.

CHAPTER SUMMARY

Cross layer optimization is an innovative approach for enhancement in network performance. The purpose of this research work is to optimize various parameters to achieve higher throughput and lower overall and MAC delays for IEEE 802.11 standard used for Smart grid Home Area Network as well as Neighborhood Area Network. This chapter includes the simulation results of parameter optimization of different network layers. Riverbed-OPNET simulator is used for optimization of parameters pertaining to different layers. Riverbed-OPNET modeler consists of various network protocols and elements. It includes very rich library for network planning, design and optimization. It facilitates parameter adaptation and optimization through discrete event simulations. It includes diverse set of communication protocols. Riverbed modeler facilitates integrated development environment for network design. User can design, analyze, plan and test different types of network with enormous parameters and protocols. Various parameters of different protocols and its network layers can be optimized by running simulations for different amount of time. This software facilitates joint optimization of diverse set of parameters pertaining to different network layers. Results show that the use of block acknowledge function increases the throughput as the data frame is acknowledged in a single block in which an overhead is reduced. A combination of fragmentation with RTS and frame aggregation mechanisms improves the network performance. Furthermore, an intermediate buffer size of 256000 provides enhanced results. Performance of OLSR protocol is better compared to other protocols. OLSR protocol is further optimized for improvement in network performance. Parameter optimization of IEEE 802.11 based HAN and NAN significantly enhances the network performance. A novel consolidation of various parameters for performance enhancement has been developed from simulation results.