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Wireless Network Performance Optimization Using Opnet Modeler

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Abstract: Wireless is quickly spreading into many new applications. The performance optimization is a key requirement in designing and operation of the WLAN. In this study the performance optimization methods have been presented using an advanced network simulator, OPNET modeler. WLAN performance optimization has been shown via a series of simulation tests with different parameters include RTS/CTS threshold, fragmentation threshold and data rate. The simulation results are presented showing satisfactory WLAN performance when the environment parameters are accurately tuned.

Key words: Wireless networks, remote access, performance, optimization

INTRODUCTION

Future Wireless Local Area Networks (WLAN) will enable people on the move to communicate with anyone, anywhere, at any time, using a range of multimedia services. The exponential growth of cellular telephone and mobile systems coupled with the spreading of laptop and palmtop computers indicate a bright future for such networks, both as standalone systems and as part of the larger networking infrastructure. In the last 10 years, the impact of wireless communications on the way we live and do business has been affected by the impact of the Internet. Cellular phones, pagers, have become so common place in our lives that it is easy to forget those 10 years ago, they were a rarity[1-3]. The next stage of its development will be in complementing or replacing the network infrastructure that was traditionally wired as well as enabling network infrastructures. However as the communications field become a key factor in many other fields such as medical, teaching, business, information technology, home and other, the need for the communication to be any were without the problem of cables and the position of the user was increased and applying the wireless network become more important and essential in this fields, thus this help to spread these technology as fast as possible. WLAN technologies employ infrared, laser, spread spectrum, microwave and satellite for supporting voice, video and data transmission in local area and wider area environments[4].

The wireless networks can be employed to provide network connectivity almost anywhere, it gives the large companies to connect the current wired networks to the new wireless network without any problems and gives the user to use any applications regardless to its source or vendors and the type of the application which can be data, video, real-time applications or others. However, the WLAN performance is a key a factor in spreading and usage of such technologies[5,6]. This paper deals with the WLAN performance optimization techniques based on advanced network simulator, OPNET modeler. WLAN Performance optimization has been shown via a series of simulation tests with different WLAN parameters include RTS/CTS threshold, fragmentation threshold and data rate. The simulation results are presented showing satisfactory WLAN performance when the WLAN environment parameters are accurately tuned.

WLAN CONFIGURATIONS

Wireless LAN configurations range from extremely simple to very complex. The simplest WLAN is an independent, peer-to-peer configuration where two or more devices with wireless adapters connect to each other (Fig. 1). Peer-to-peer configurations are often called ad hoc networks since they do not require any administration or pre-configuration[2]. They also do not require the use of an access point, as each adapter communicates directly to another adapter without going through a central location.

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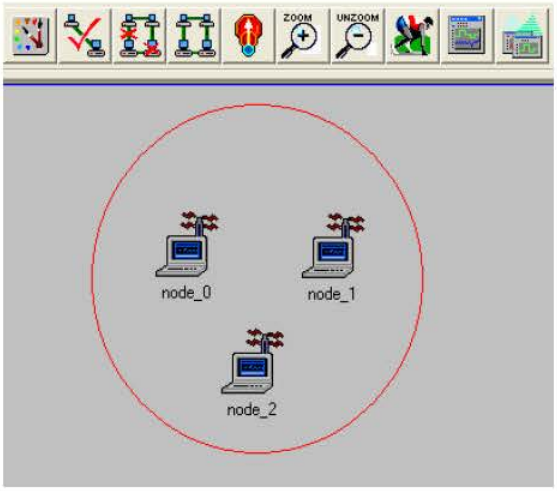

Fig. 1: Peer-to-peer WLAN configuration

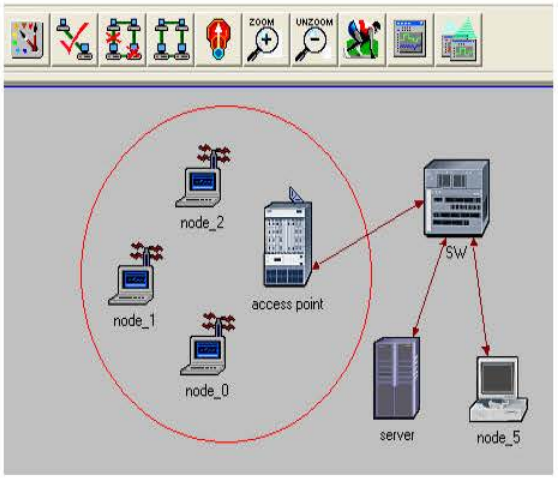

Fig. 2: WLAN configuration with access point

Peer-to-peer networks are very useful when a group of users need to communicate with one another in an unstructured way. A wireless network can also use an Access Point (AP). The access point acts like a hub, providing connectivity for the wireless computers (Fig. 2). It can connect the wireless LAN to a wired LAN, allowing wireless computer access to LAN resources, such as file servers or existing Internet Connectivity.

In a corporate environment, many access points can work together to provide wireless coverage for an entire building or campus. The coverage area from each access point is called a cell.

SETTING UP A WLAN ACCESS POINT

Overlapping AP configuration: When adjacent access points are located close enough to each other, parts of the coverage area of access points may overlap with each other. A and B (Fig. 3) are located close enough to each other, a part of the coverage area of access point A overlaps that of access point B.

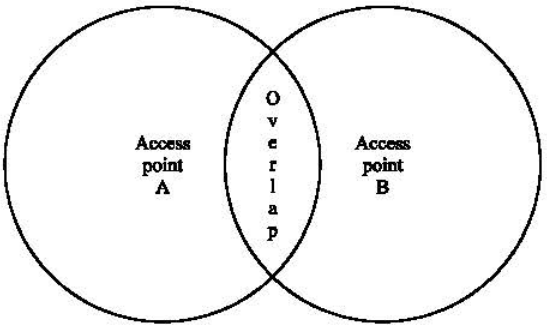

Fig. 3: Overlapping access points

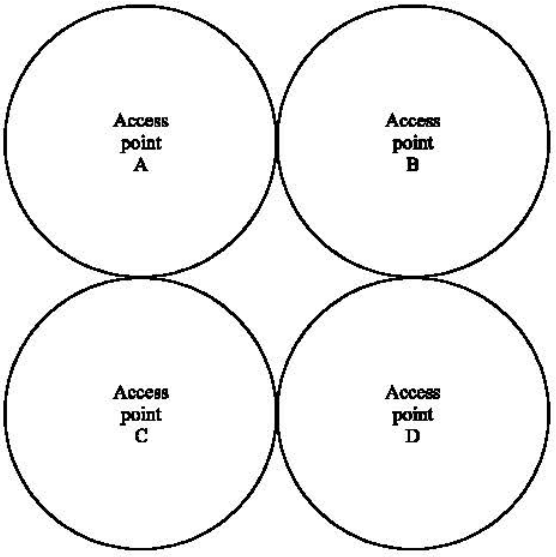

Fig. 4: Non-overlapping AP configuration

The overlapping area has two very important attributes: any workstation situated in the overlapping area can associate and communicate with either AP A or AP B and any workstation can move continuously through the overlapping coverage areas without losing its network connection. This attribute is called roaming[7].

Non-overlapping AP configuration: Wireless LANs congested with many network users and heavy traffic load may require non-overlapping, multi-AP configuration. In a non-overlapping, multi-AP configuration, several APs are installed in the same location (Fig. 4).

In non-overlapping configuration, each AP has the same coverage area, creating a common coverage area

that increases aggregate throughput. Any workstation in the overlapping area can associate and communicate with any AP covering that area.

SIMULATION TOOL

The OPNET (Optimized Network Engineering Tool) can be best described as a set of decision support tools, providing a comprehensive development environment for the specification, simulation and performance analysis of communication networks, computer systems and applications and distributed systems. Discrete event simulations are used as the means of analyzing system performance and their behaviour. This sophisticated package comes complete with a range of tools which allows us to specify models in great detail, identify the elements of the model of interest, execute the simulation and analyze the generated output data. The OPNET simulator has many features such as object orientation and hierarchical modelling[8,9].

OPNET provides four editors that are used to develop a representation of a system being modeled. These editors, the Network, Node, Process and Parameter Editors, are organized in a hierarchical fashion (Fig. 5). This hierarchical organization supports the concept of model reuse. Models developed at one layer can be used by another model at a higher layer. The Network Domain deals with the specification of the physical topology of a communications network. The basic building block is a node. An underlying model, developed using the node editor, defines the specific capabilities of each node. Each node instance has a set of parameters or characteristics that can be set to customize the node's behavior. The number of node models that can be used in a network model is unrestricted. The Node Domain deals with the specifications of the communication devices created and interconnected at the network level. These nodes correspond to communicating devices such as personal computers, workstations, file servers, printers, bridges, routers or switches. Process Domain created using the

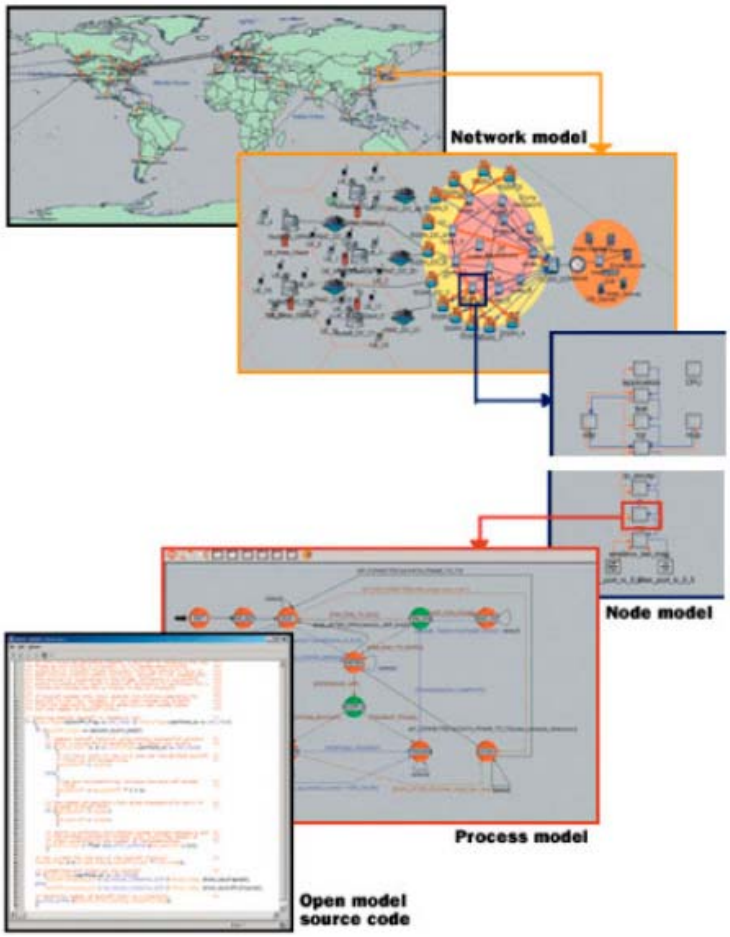

Fig. 5: Four OPNET editors

process editor, which are used to describe the behavior of processor and queue modules within the node domain. These models are used to simulate software subsystems, such as a communication protocol and also to model hardware subsystems, such as the memory of a switching device. Each process that executes in a queue or processor module is an instance of a particular process model. Process models are expressed in a language called Proto-C. OPNET's Proto-C consists of state transition diagrams (STDs), a library of kernel procedures and the standard C programming language. The high level of flexibility offered by the Proto-C language enables almost any type of task, collection of specific data and definition of any protocol is performed[10].

WLAN PERFORMANCE OPTIMIZATION

Several methods and scenarios for optimizing the performance of WLANs were studied. The effect of WLAN parameters: The request-to-send/clear-to-send (RTS/CTS) threshold, Fragmentation threshold and Data rate on the WLAN performance is explored using different configurations, to determine the best value for each parameter. The following performance metrics are used to compare the results obtained in the studied scenarios, to find the best configuration of the IEEE 802.11 WLAN standard[11,12]:

Data dropped: Total number of bits that are sent by wireless node but never received by other node.

Delay: End-to-end delay of all packets received by the node's wireless LAN MAC and forwarded to the higher layer.

Load: Total number of bits received from the higher layer. Packets arriving from the higher layer are stored in the higher layer queue.

Media access delay: Total time (in seconds) that the packet is in the higher layer queue, from arrival to the point when it is removed from the queue for transmission.

Throughput: Total number of bits sent to the higher layer from the MAC layer. The data packets received at the physical layer are sent to the higher layer if they are destined for this station.

OPNET implementation: The model employed for the three cases of the study consists of four workstations and three access points and a single server. WS_1, WS_2 and AP_3 have the same ID (ID = 4). WS_3, WS_4 and AP_1 has the same ID (ID = 1). ID 3 corresponds to the server and AP_2 (Fig. 6). The server provides HTTP, FTP, Email and Telnet services to all clients.

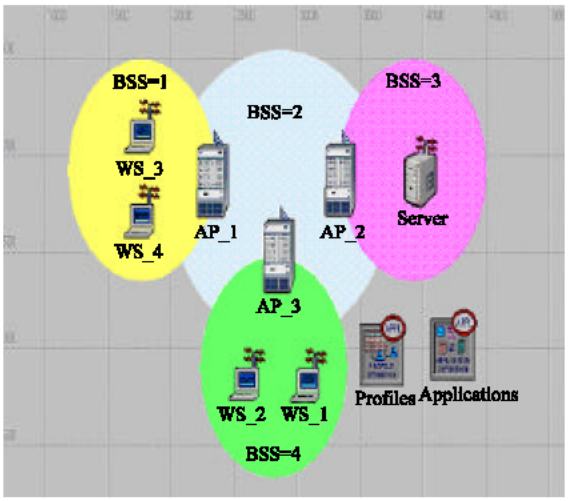

Fig. 6: Wireless LAN

Effect of RTS threshold: The request-to-send/clear-to-send (RTS/CTS) mechanism is an optional handshaking procedure used by the IEEE 802.11 wireless network to reduce the possibility of collision. The RTS Threshold (RT) Specifies a threshold to determine whether or not RTS frames is required for a particular data frame. If the MAC Service Data Unit (MSDU) received from higher layer, has a size greater than the RTS threshold then RTS frames is needed for media reservation[13].

The IEEE 802.11 WLAN standard uses carrier sense multiple access with collision avoidance (CSMA/CA) mechanism as to transmit asynchronous data in the contention period. The RTS/CTS mechanism is very effective in terms of system performance, especially when large packets are considered. In fact, collision may only occur when two or more stations start transmission within the same time. If both sources employ the RTS/CTS mechanism, collisions would only occur while transmitting the RTS frames and would promptly be detected by the source lacking the CTS responses. Basic access mechanism is two-way handshaking technique for packet transmission, an ACK is transmitted by the destination to signal the source of the successful packet reception. An ACK is transmitted after a short inter-frame space (SIFS) at the end of the received packet. RTS/CTS four-way handshaking technique for packet transmission (Fig. 7).

Figure 8 shows the effect on throughput with an increasing number of stations and a constant Offered

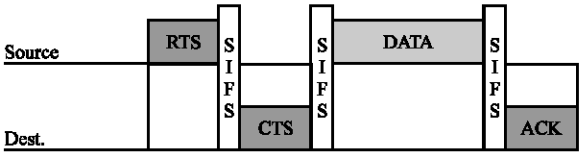

Fig. 7: RTS/CTS mechanism

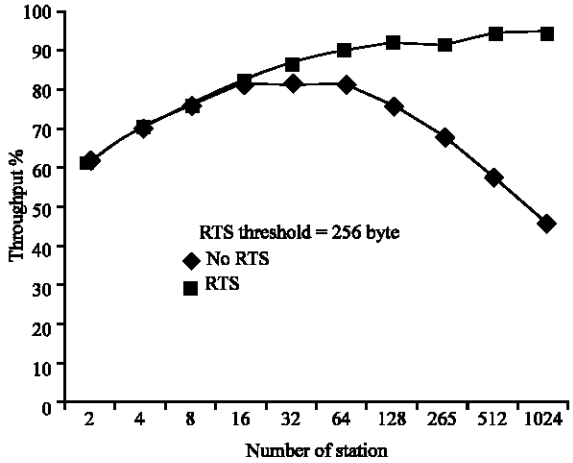

Fig. 8: Throughput VS number of stations

Table 1: RTS/CTS scenarios

Attribute	Default	Rts_threshold_256	Rts_threshold_1024
RTS Threshold (byte)	None	256 Byte	1024 Byte
Fragmentation Threshold (Byte)	None	None	None
Data rate(bps)	1 Mbps	1 Mbps	1 Mbps
Physical characteristics	Frequency hopping	Frequency hopping	Frequency hopping

Load. The wireless LAN throughput will reduce when the number of stations in the network increase which will increase the number of detected collisions, this problem can be solved using RTS/CTS mechanism.

Table 1 shows three suggested scenarios with different RTS threshold values: none (RTS/CTS mechanism is not used), 256 byte and 1024 byte.

Media Access Delay is increased when using RTS/CTS mechanism since sending RTS frame and waiting to receive CTS frame will take a certain period of time while the data are waiting in the transmission buffer (Fig. 9). However, without using RTS/CTS mechanism the data will be sent immediately once it is ready to send. The probability of sending RTS frame increases in case of 256 byte threshold rather than 1024 byte threshold. Obviously the frequent reservations of the channel in the network reduces the WLAN throughput, 1024 byte RTS Threshold produces less number of reservations (Fig. 10).

Effect of fragmentation threshold: Fragmentation threshold Specifies the value to decide if the MSDU

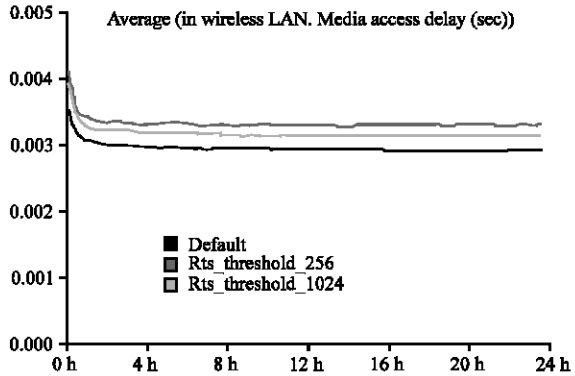

Fig. 9: Media access delay (sec)

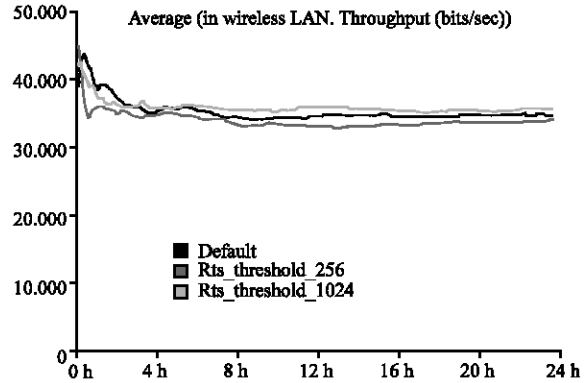

Fig. 10: Throughput (bits/sec)

received from the higher layer needs fragmentation before transmission. The number of fragments to be transmitted is calculated based on the MSDU size and the fragmentation threshold. The default value for this attribute is none which means that fragmentation will not take place regardless of the MSDU size. The destination station receives these fragments and store them in the reassembly buffer until all fragments have been received. This fragmentation and reassembly is implemented using the built-in SAR (segmentation and reassembly) package in OPNET.

Using fragmentation for larger sized packets improves the reliability of data exchange between the stations. Since every data fragment requires an acknowledgment, the overall frame exchange per MSDU is higher than it would be without fragmentation. Fragmentation may also impact the total channel reservation time per data frame exchange. Table 2 represents the settings of the required parameters.

Fragmentation mechanism will increase the overall WLAN delay (Fig. 11). When sending a data packet as multiple fragments, it will reassembled at the destination after a period of time. When the fragmentation threshold

Table 2: Fragmentation threshold scenarios

Attribute	Default	Rts_threshold_256	Rts_threshold_1024
Rts threshold (byte)	None	None	None
Fragmentation threshold (byte),	None	256 Byte	1024 Byte
Data rate(bps)	1 Mbps	1 Mbps	1 Mbps
Physical characteristics	Frequency hopping	Frequency hopping	Frequency hopping

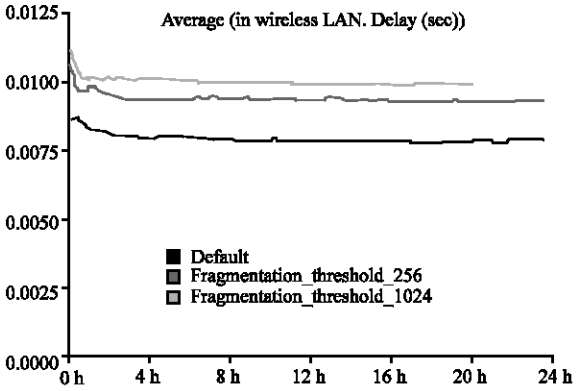

Fig. 11: WLAN delay (sec)

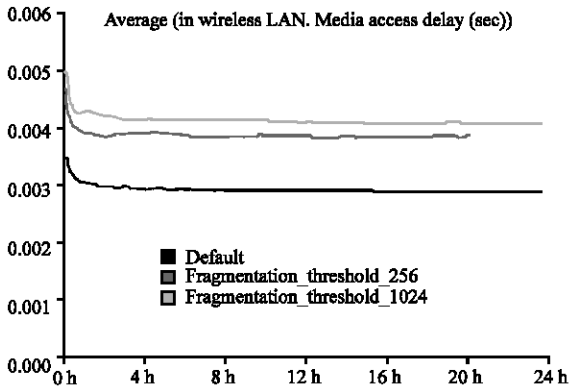

Fig. 12: WLAN media access delay

is 256 byte, more packets will be fragmented and this will produce higher WLAN delay.

When a packet is fragmented in certain node, other packets have to wait until sending all the fragments of the previous packet, so the fragmentation process increases the media access delay in each node (Fig. 12). It can be noted that larger fragments results a decrease in performance. Each collision requires retransmission of a much larger fragment. But with RTS/CTS mechanism better throughput will be carried out even with large fragment threshold values (Fig. 13).

Effect of data rate: The WLAN model in OPNET modeller supports data transfer at 1 Mbps, 2 Mbps, 5.5 Mbps and

Table 3: Data rate scenarios

Attribute	Default	Data_Rate_2	Data_Rate_5.5	Data_Rate_11
Rts threshold (byte)	None	None	None	None
Fragmentation threshold (byte)	None	None	None	None
Data rate(bps)	1 Mbps	2 Mbps	5.5 Mbps	11 Mbps
Physical characteristics	Frequency hopping	Frequency hopping	Frequency hopping	Frequency hopping, none

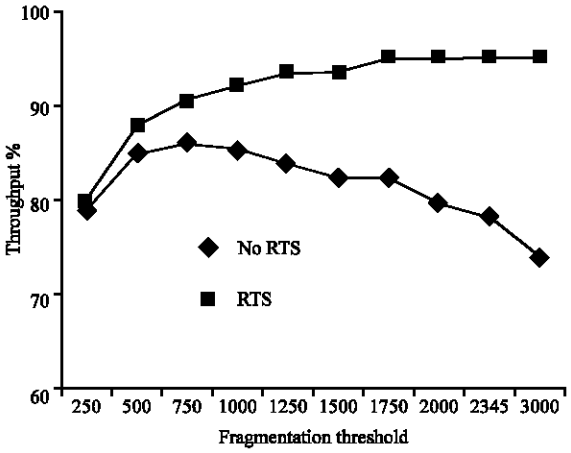

Fig. 13: Throughput VS fragmentation threshold

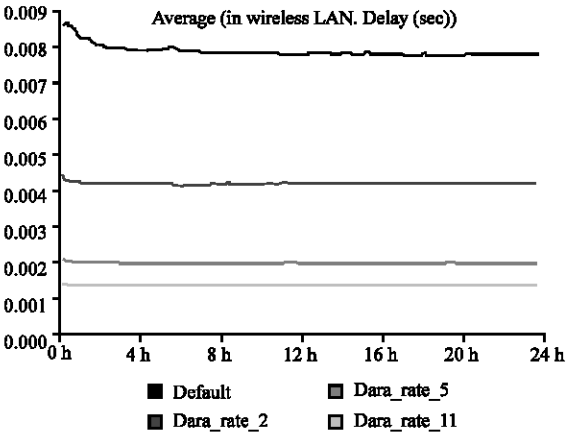

Fig. 14: WLAN delay

11Mbps. These data rates are modelled as the speed of the transmitter and receiver connected to the WLAN. A station can only transmit data packets at the data rate specified by the attribute. However, it can receive data at any data rate. The three scenarios are configured as shown in Table 3.

As the transmission data rate increases in the network, the end-to-end delay will reduce (Fig. 14). The 11Mbps transfer rate produces minimum delay than other rates. It can be seen that the media access delay also

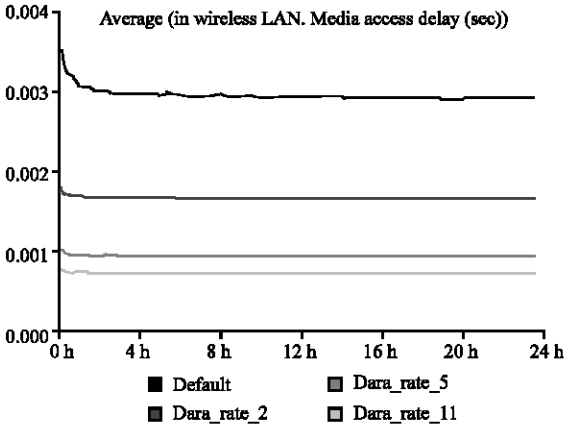

Fig. 15: WLAN media access delay

decreases by increasing the provided data transmission rate, since the data will spend less time in the transmission buffer in case of highly data rate (Fig. 15).

CONCLUSIONS

In this study, OPNET simulator results indicate that we can greatly improve the WLAN performance. The WLAN simulation results, show that the throughput can be improved by using RTS/CTS mechanism, this mechanism increases the reliability of the transmission. Fragmentation threshold is another parameter used to enhance the throughput of the WLAN. Simulation results show that increasing this parameter will reduce the throughput unless the RTS/CTS mechanism is employed, which will change the result (increase fragmentation threshold will increase the WLAN throughput). The data rate simulation results show that it has a large effect on the performance since changing this parameter will alter the common performance metrics.

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