Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA) protocol modelling on OMNET++

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Engineering Project Report

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ABSTRACT

Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA) protocol modelling on OMNET++

In wireless communication systems, it is extremely important to allow users to send data to receiving station while getting information from receiving station. Multiple access techniques provide solutions for high quality communications. CSMA and CSMA/CA protocols are two of the commonly used multiple access techniques.

The main purpose of this project is realizing networks using ALOHA, CSMA and CSMA/CA protocols to observe performance of these protocols under different conditions. Some parameters, such as interval time, pakcet length, number of host or distance, were changed to find out how to utilize from these protocols optimally.

ÖZET

OMNET++ ÜZERİNDE ÇARPIŞMA KAÇINIMLI TAŞIYICI SEZMELİ ÇOKLU ERİŞİM PROTOKOLÜ MODELLEMESİ

Alıcı merkeze bilgi gönderip hem de aynı anda bilgi almak kablosuz haberleşme sistemleri açısından son derece önemlidir. Çoklu erişim teknikleri, yüksek kaliteli haberleşme talepleri için çeşitli çözümler sunar. Taşıyıcı duyarlı çoklu erişim ve çarpışma önleyici taşıyıcı duyarlı çoklu erişim protokolleri bu tekniklerdendir.

Bu projenin amacı, bu protokollerin farklı koşullar altında göstereceği performansı gözlemlemek ve modellemektir. Bu protokollerden hangi koşullar altında en iyi şekilde faydalanılacağını görmek için kullanıcı sayısı, paket uzunluğu ve kullanıcılar arası uzaklık gibi bazı parametreler değiştirildi.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST of SYMBOLS / ABBREVIATIONS

ACK	Acknowledgement
NACK	Negative Acknowledgement
RXed	Received
TXed	Transmitted
τ	Tau (Time Constant)

1.INTRODUCTION

The system resources must be allocated to multiple users in multiuser systems. It is reqiured that signal space dimensions of a multiuser system which bandwidth B and time duration T occupy must be divided among the different users. Multiple access is defined as allocation of signaling dimensions to specific users. Performance of multiple access methods depends on the characteristics of multiuser channels. Since there may be infinite way to allocate signaling dimensions to different users, capacity of a multiuser channel is defined by a rate region instead of a single number. All user rates that may be simultaneously supported by the cannel with arbitrarily small error probability are described by this region.

In wireless communication systems, It is quite desirable to allow the users to send data to the receiver while recieving data from the receiver at the same time. Thanks to multiple access schemes, many users existing in multiuser systems are allowed to share a finite amount of radio spectrum at the same time.It is required to increase capacity by simultaneously dividing the available bandwidth among multiple users.

In packet radio(PR) techniques which is a type of the multiple access techniques, many users try to access a single channel. Using burst of data plays vital role for transmission. Collisions caused by simultaneous transmission are detected by receiver of base station. Although implementation of packet radio multiple access is quite easy, It has low spectral efficiency and may cause latency.

Contention techniques are used to transmit by users on a common channel. ALOHA protocol, developed for satelitte systems at the University of Hawaii in 1971, is the one of the most common used contention techniques. In ALOHA protocol, users can send data whenever they have data to send.

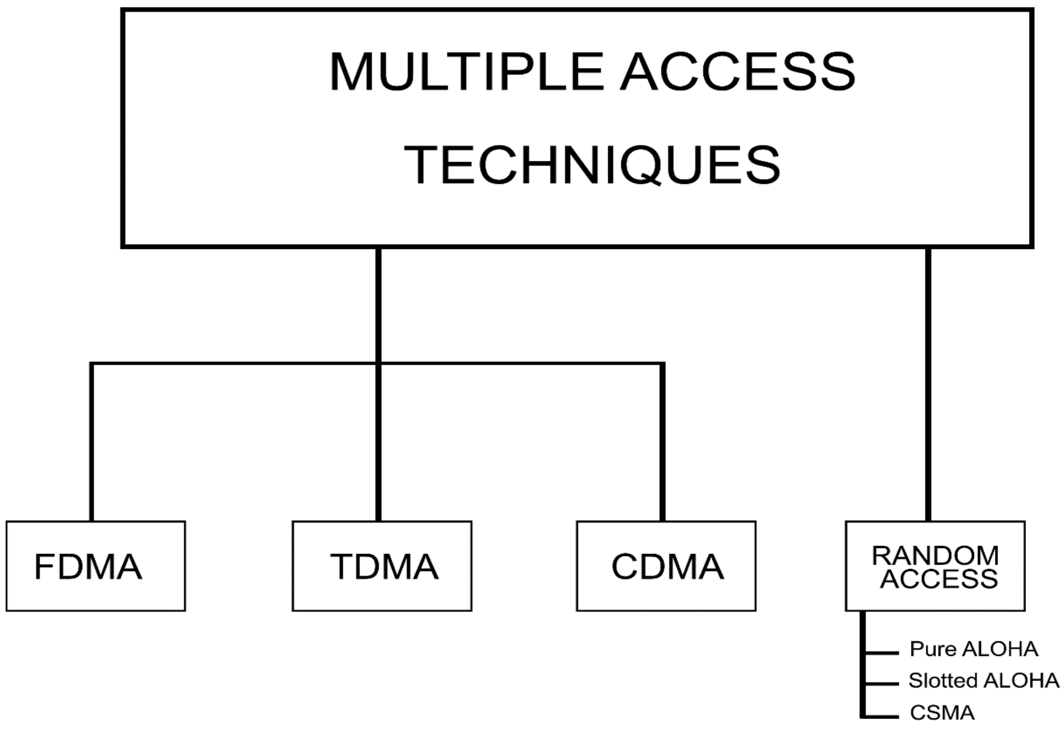
ALOHA protocol is not able to sense carrier before transmission. Therefore users do not get any information about other users in this protocol. Transmission efficiency might be incresed by listening to the channel before transmission. The concept of carrier sense multiple access (CSMA) protocol is based on the fact that each user is able to monitor the channel status before transmitting data. If there is no carrier detected from terminal (channel is idle), then user is allowed to send data .

In CSMA protocol, carrier sensing makes data transmission more efficient. On the other hand, carrier sensing makes propagation delay and detection delay two important factors. These, two factores have significant effects on performance of CSMA protocol.

2.MULTIPLE ACCESS TECHNIQUES

The system in which dedicated channels are allocated to users is called multiple acess [1]. In wireless communication systems, both sending data to the base satation and receiving data from base station at the same time are always in demand. Therefore, efficient allocation of available bandwidth among multiple users is a key point. Applications like voice or video can require continous transmission and lower latency and higher throughput than other other simple applications can require. Dedicated channels are necessary for uninterrupted data transmission. There are a few channelization methods, such as time division or frequency division , to obtain dedicated channels from the system signal space. Different kinds of random channel allocation which does not ensure channel access are generally used for allocation of signaling dimensions for users. The technique in which random channel allocation is used for sharing of spectrum is called multiple access.

Table 2. 1 Multiple Access Techniques



2.1. RANDOM ACCESS

Multiple access techniques are well-suited for continuous applications, such as video or voice, where a dedicated channels improve performance of continuous transmission. On the other hand, continuous transmission is not always necessary for most data applications. These applications generate data at random time. Therefore, it makes dedicated channel assignment quite inefficient. The concept of random access is based on assigning efficiently channels to the active users.

Packet radio is a fundamental thing for all random access techniques as shown in Table2.1. According to packet radio model, users collect packetized data consisting of N number of bit. This bits may include control bits or error correction/detection bits.It is assumed that the packet length and data rate are constant during transmission. The time needed for transmission of a packet is:

$$\tau = N/R \tag{2. 1}$$

All users send their packets without any additional signaling. When packets sent by different users overlap, it causes collision. In that case, collided packets may not be decoded properly. The packet may also not decoded properly as a result of noise.

2.1.1. PURE ALOHA

Pure ALOHA protocol which is a random access protocol was developed at the university of Hawaii in 1970. In pure ALOHA protocol, packets are sent by user whenever they are generated as shown in Figure 2.1. Then, user waits until getting acknowledgement including information whether packet is received succesfully or not. If packets were received succesfully, user gets ACK. Otherwise, user gets NACK which is called negative acknowledgement.In that case, user retransmits the same message again.

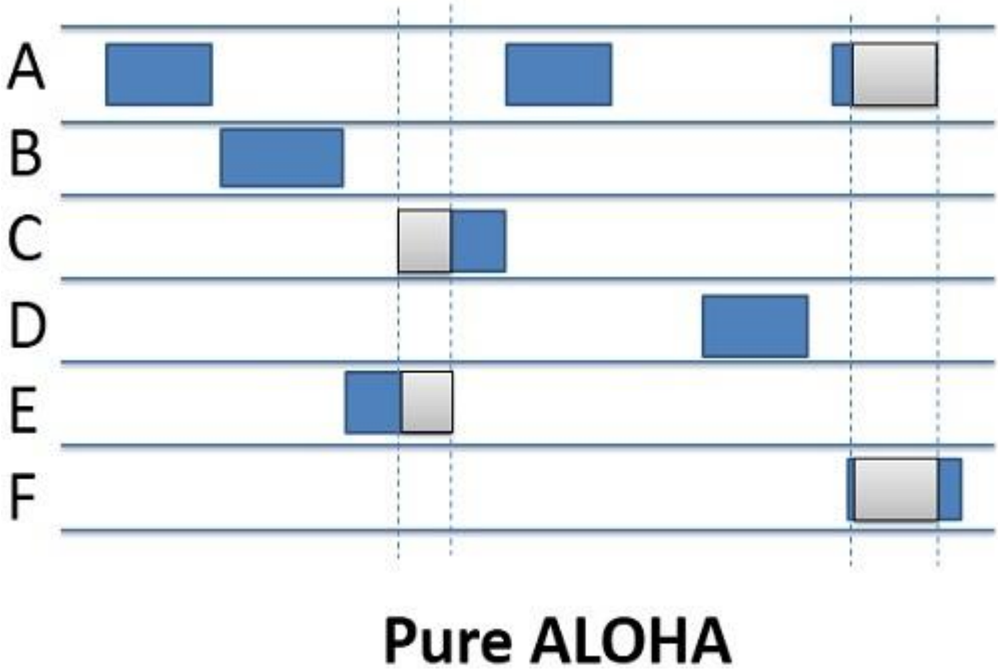


Figure 2. 1 Pure ALOHA-Packet Transmission Model [2]

In pure ALOHA protocol, vulnerable duration is equal to 2τ. Consequently, the probability of no collision in this time is equals to:

$$Pr(n) = \frac{(2R)^n e^{-2R}}{n!} \quad at \quad n=0 \tag{2. 2}$$

In pure ALOHA, the throughput is equal to:

$$T = R\, e^{-2R} \tag{2. 3}$$

2.1.2. SLOTTED ALOHA

In slotted ALOHA, time is assumed to be divided into equal time slotsof packet duration τ. According to this protocol, each user must have synchronized clocks and send a packet just at the beginning of slot time as shown in Figure 2.2. If the number of user increase in slotted ALOHA protocol, it causes greater delay [3].

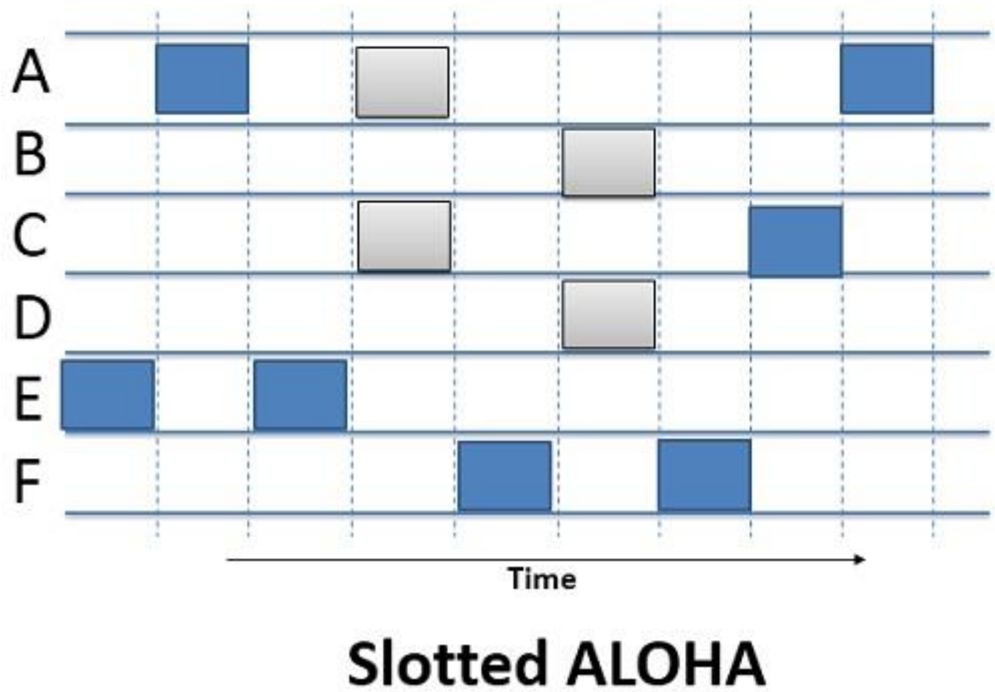


Figure 2. 2 Slotted ALOHA-Packet Transmission Model [4]

Vulnerable duration is equal to τ for slotted ALOHA. Thus, the throughput is equal to:

$$\tau = R\, e^{-R} \tag{2. 4}$$

As it is shown in Figure2.3, data rate of pure ALOHA is just %18. On the other hand, data rate of slotted ALOHA is greater than data rate of pure ALOHA.It is obvious that slotted ALOHA has more reasonable throughput values. Anyway, it is still less than %40.

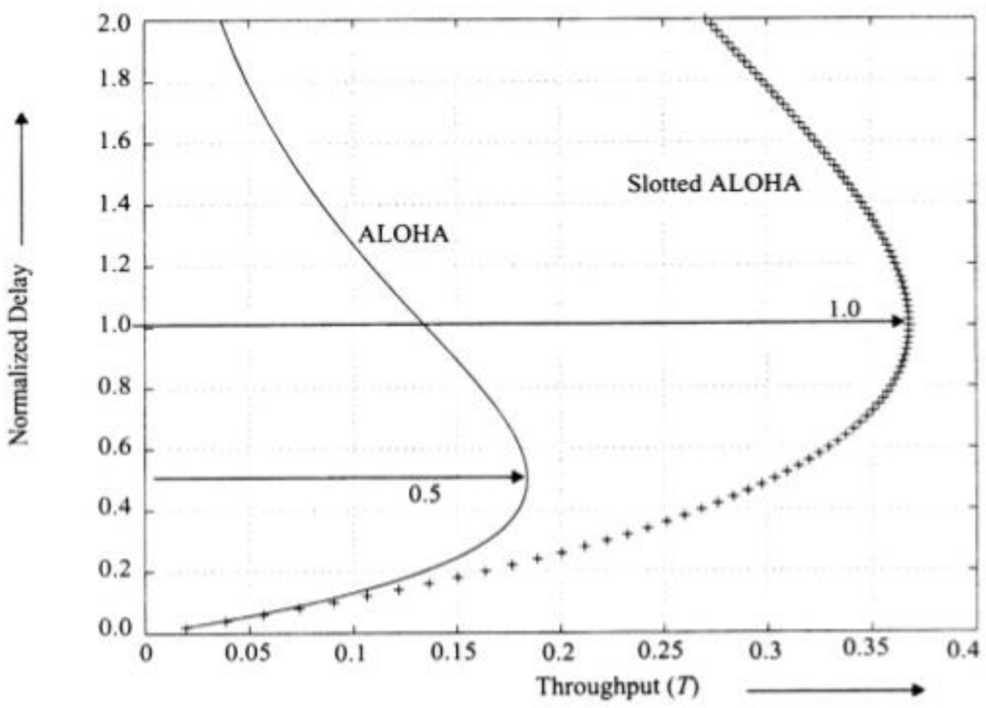


Figure 2. 3 Tradeoff between throughput and delay for pure ALOHA and slotted ALOHA

2.1.3. CARRIER SENSE MULTIPLE ACCESS (CSMA)

Users of ALOHA protocol are not able to sense the carrier before sending packet. Therefore, they do not have any information about about other users during transmission. However, the concept of carrier sense multiple access (CSMA) protocol is based on the fact that each user is able to monitor the channel status before transmitting data. If the channel is idle (no carrier on the network), user can send its packet.

In CSMA protocol, collisions can be reduced by sensing carrier on the network. In addition, sensing carrier makes propagation delay and detection delay two important factors. Detection delay which is a factor depending on receiver hardware is the necessary time to decide whether the channel is idle or not. Propagation delay is a measure of how it takes for a packet to reach the base station.

2.1.4. CARRIER SENSE MULTIPLE ACCESS COLLISION AVOIDANCE (CSMA/CA)

CSMA/CA is also a type of multiple access techniques. One of the users, such as userA, send request to send RTS frame in CSMA/CA protocol [5]. Then, receiving station receives it and issues a clear to send CTS frame. All station within range of receiving station receive the CTS frame and are aware that A has been given the permission to send. So other users remain quiet while userA proceeds with its data frame transmission.

3. CSMA-CSMA/CA PROTOCOLS MODELLING on OMNET++

In this section, performance of CSMA and CSMA/CA protocols is presented for different scenerios. Some parameters, such as inerval time, packet length, distances, transmission range and interference, was changed to observe the performance of the CSMA protocol under different conditions.

3.1. CSMA PROTOCOL MODELLING for SCENERIO 1

According to first scenerio, it is known that hostA sends packets to hostB and hostX sends packets to hostY by using CSMA protocol. It is expected that number of collision is decreased.

We observed the values of some parameters, such as throughput and dropped/collided frames, for different intervals like e^{2s}, e^{5s}, e^{10s}, e^{30s}, e^{60s}.

Listing of some parameters for scenerio 1:

- Packet Length : 1000 B
- Distance between users and destinations : 400 m
- Transmitter communication range : 500 m
- MAC Type for all hosts : CSMA
- Interference ignored : False
- Interference range : 500 m
- Bit rate for all users : 1 Mbps
- Destination for hostA : hostB
- Destination for hostX : hostY

To design environmental model of scenerio-1 shown in Figure 3.1, .NED file was created on OMNET++. Some parameters, such as distance between hosts, are able to be defined in this file.

After initializing of transmiision range of hosts in .INI file, the circles representing transmission range of host became visible as shown in Figure 3.2.

Figure 3. 1 Environment model for scenerio 1

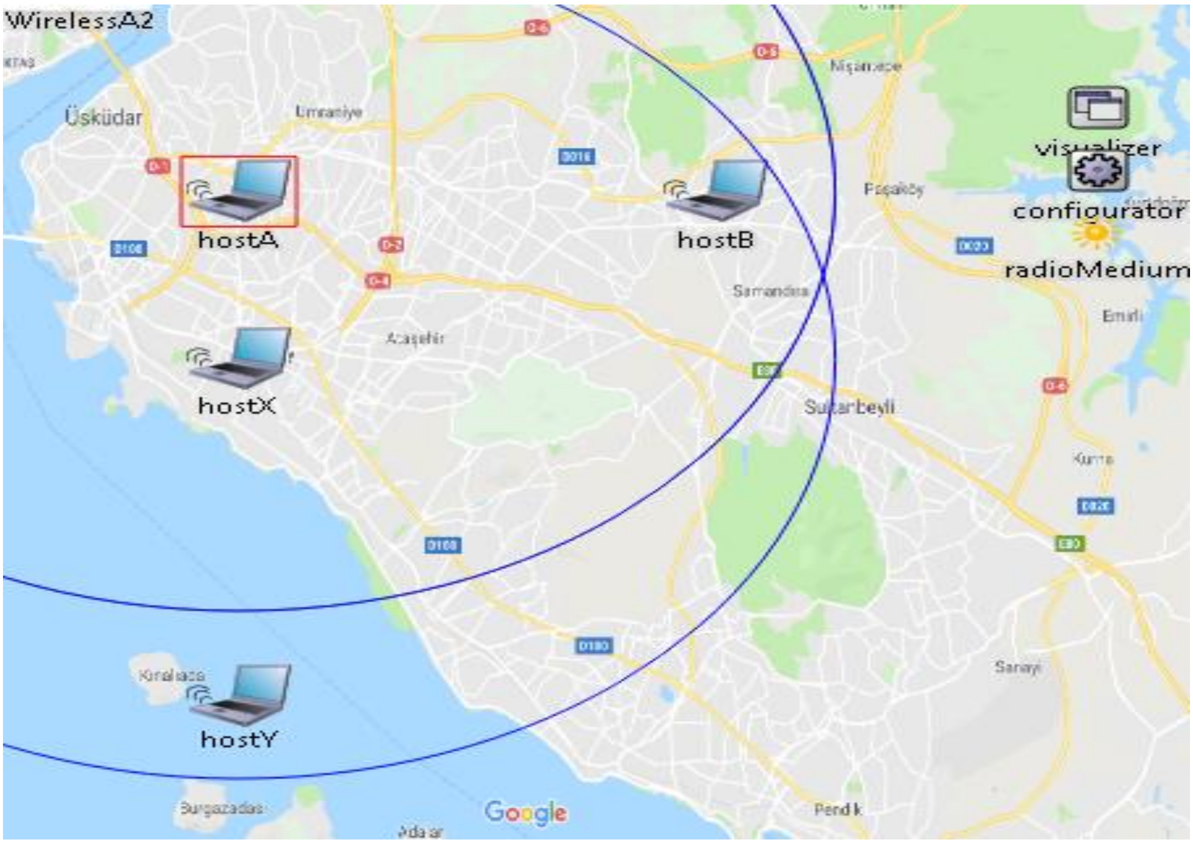


Figure 3. 2 Transmission range of users

3.1.1. SIMULATION RESULTS for SCENERIO 1

According to scenerio-1, there are two users, which are hostA and hostX, sending packet and two base station, which are hostB and hostY, receiving packets. Although the hostB is in transmission range of the hostX, the hostY is outside of transmission range of the hostA.

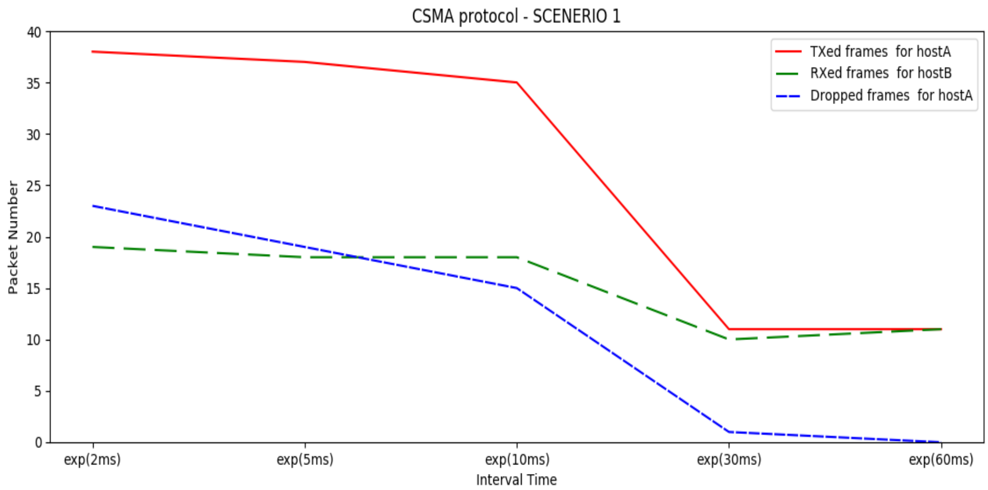


Figure 3. 3 Simulation Results for HostA and HostB

The number of transmitted packets by hostA, received packets by hostB and dropped packets of hostA are shown in the Figure3.3 above by red, green and blue respectively. It is obvious that decrease of interval time causes gradual increase of the number of transmitted packets. When the interval time is defined as $e^{2\,ms}$, the number of transmitted packets by hostA reaches the saturation and the number of collided packets increases dramatically.

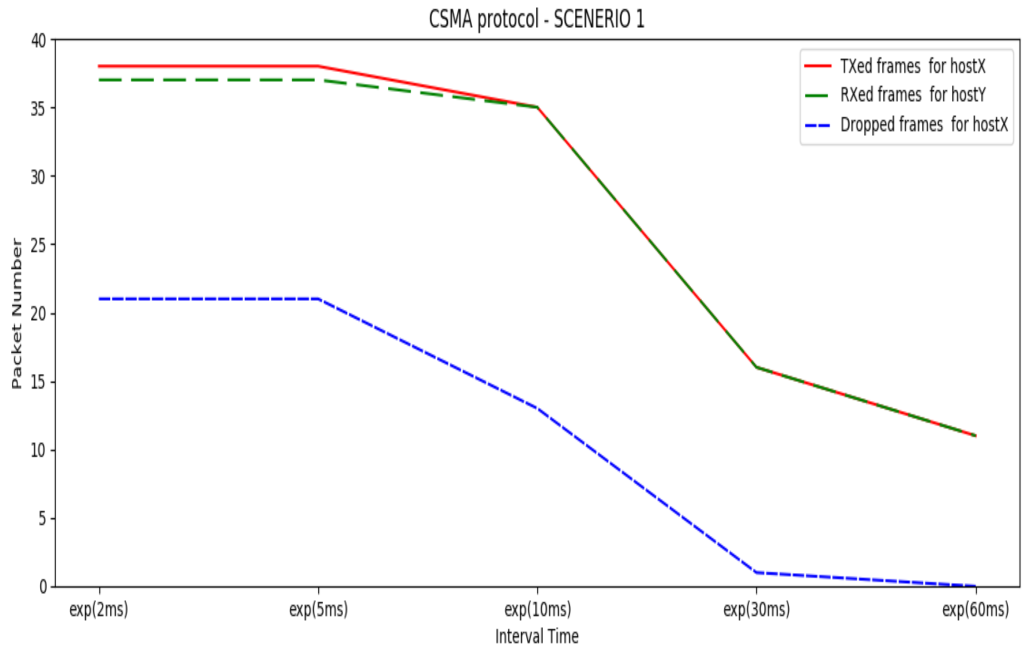


Figure 3. 4 Simulation Results for HostX and HostY

The number of transmitted packets by hostA, received packets by hostB and dropped packets of hostA are shown in the Figure3.4 above by red, green and blue respectively. Since the hostY is outside of the transmission range of hostA, number of collided packets is very low.

3.2. CSMA PROTOCOL MODELLING for SCENERIO 2

According to second scenerio, only bit rate parameter is different from the scenerio-1. It was increased from 1 Mbps to 10 Mbps. It is expected to increase the number of TXed and RXed packets. Due to the high bit rate, it is expected to observe very low number of dropped packet.

Table 3.1. Comparison of simulation result for different bit rate values

User	**Interval Time**	**Packet Length**	**Bit Rate**	**TXed packet number**	**RXed packet number**	**Dropped packet number**
HostA	$e^{2\ ms}$	1000 B	1 Mbps	38	-	23
HostB	$e^{2\ ms}$	1000 B	1 Mbps	-	37	-
HostX	$e^{2\ ms}$	1000 B	1 Mbps	37	-	21
HostY	$e^{2\ ms}$	1000 B	1 Mbps	-	19	-
HostA	$e^{2\ ms}$	1000 B	10 Mbps	126	-	0
HostB	$e^{2\ ms}$	1000 B	10 Mbps	-	112	-
HostX	$e^{2\ ms}$	1000 B	10 Mbps	91	-	0
HostY	$e^{2\ ms}$	1000 B	10 Mbps	-	90	-

As it is expected, the number of RXed and TXed packets were increased by increasing bit rate of protocol as 10 Mbps. Moreover, there is no dropped packet for this bit rate value.

3.3. CSMA PROTOCOL MODELLING for SCENERIO-3

According to scenerio-3, there are three users, which are hostA, hostC and hostD, sending packet and only one base station, which is hostB, receiving packets. As shown in Figure 3.5 and Figure 3.6, since hostA is inside of transmission range of both hostC and hostD, it is expected that the numbers of transmitted and received packet are the least ones among the other users' transmitted and received packet number.

Figure 3. 5 Environment model for scenerio-3

Figure 3. 6   Transmission range of users

3.3.1. SIMULATION RESULTS for SCENERIO 3

The simulation result of secenerio-3 is shown in Figure 3.7. As it is expected, the number of TXed packets by hostA is very low for short interval time values. In addition, it also has a large number of dropped packets for these values, since it is affected by congestion on the network.

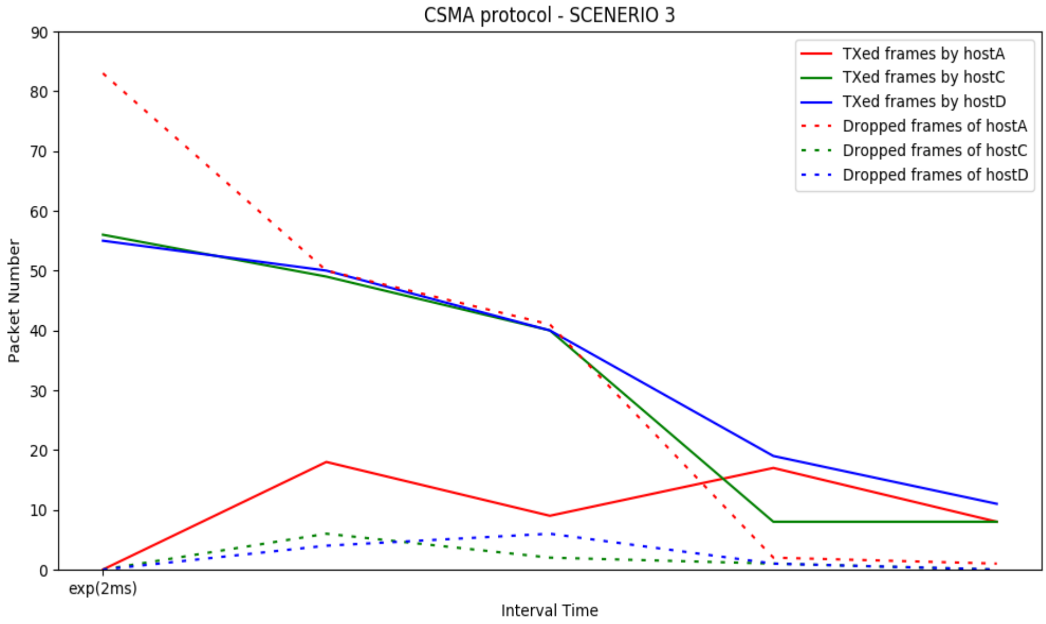


Figure 3. 7 Number of TXed and Dropped packets for Scenerio-3

When the interval time is increased, it was observed that hostA finds opportunity to send its packets. Because other users sends message with larger interval time. Therefore, it makes number of TXed packets by hostA larger. Besides, the number of dropped packet number was also decreased in that way.

3.4. CSMA/CA PROTOCOL MODELLING for SCENERIO-4

According to scenerio-4, there are two users, which are hostA and hostC, sending packet two receiver station as shown in Figure 3.8, which are hostB and hostD, receiving packets. Also, CSMA/CA prtocol is used for transmission for this scenerio.

Figure 3. 8 Environment Model for Scenerio-4

It is expected that very low number of collision will occur during transmission on this network, since CSMA/CA was used as protocol of the network.

3.4.1. SIMULATION RESULTS for SCENERIO 4

As you see in the Figure 3.9 below, number of collision on the network is very close to zero for each different interval time values. When we compare scenerio-1, which CSMA choosen as transmission protocol, and scenerio-4, it is obvious that number of packet received succesfully in scenerio-4 is greater.Moreover, number of collided packet is too less than the number of collision occured in scenerio-1.

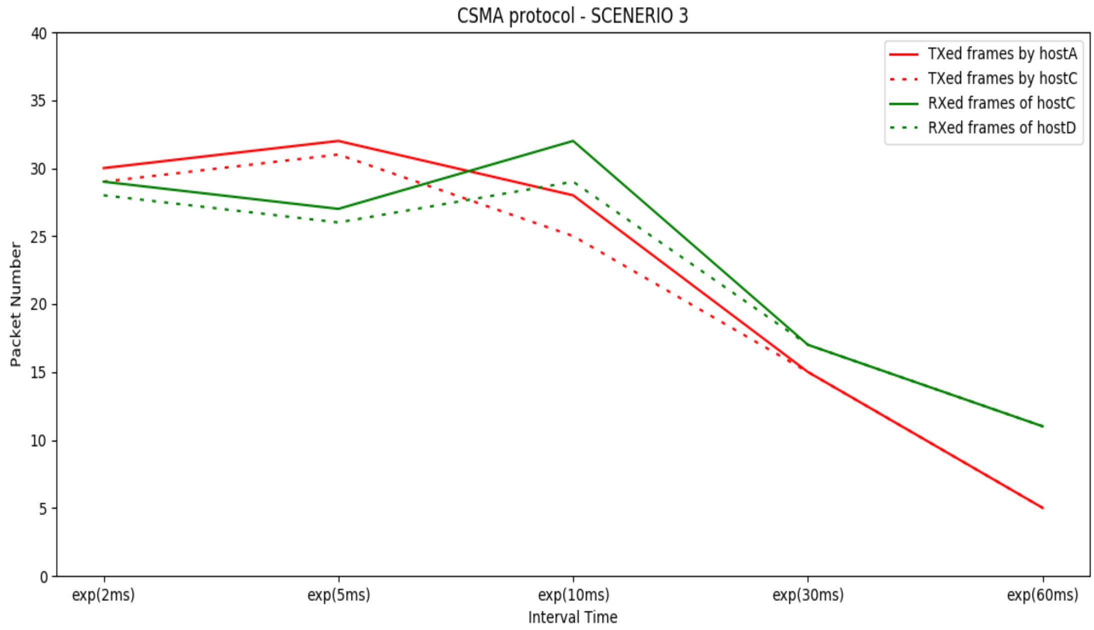


Figure 3. 9 Number of TXed and RXed packets for Scenerio-4

4.CONCLUSION

As it is mentioned before, the main goal of this project is realizing network using ALOHA, CSMA and CSMA/CA protocols to observe performance of these protocols under different conditions. For this purpose, Omnet++ which is component based C++ simulation library and framework was used for network modelling. It is a very useful software, since we can get data sets in comma separated form. Moreover, python libraries, such as matplotlib and pandas, were used to plot data sets to get reasonable result.

We achieved remarkable performance improvements on the networks using CSMA and CSMA/CA protocols. In spite of the propagation delay and detection delay, the realized networks using these protocols reached the reasonable throughput level.

5.REFERENCES

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