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-FINAL PROJECT-

Analysis of LTE Video Conferencing Performance Using OPNET

KamyarJavanmardi (301120403) kjavanma@sfu.ca

Janine Li (301132839) jiayinl@sfu.ca

PetarArnaut (301095130) paa9@sfu.ca

Group 08

ABSTRACT

LTE (Long-Term Evolution) is the wireless mobile telecommunication standard also known as 4G LTE among customers. It is the standard of high-speed data for mobile phones and data terminals. 3G was a standard and represented the base idea for LTE technology, which has a higher capacity and speed.

LTE technology supports variety of applications within large distances such as video conferencing, remote login, and email. In this project, we plan to evaluate the performance of the LTE network technology through a variety of scenarios using OPNET 16.0 software tool.

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1. INTRODUCTION

1.1 Scope of the project

The percentage of population, who is using video conferencing daily, has been increasing every year. Large companies use video conferencing in order to have meetings between offices in different regions around the word. People communicate through P2P applications on their phones with a person as far as on another continent using the wireless technology. Demands for having a high quality video call is the requirement for a high wireless connection network. Also, the condition is to have components such as a video input (eg. video camera or webcam), video output (eg. screen), audio input (eg. microphones), audio output (eg. speakers), data transfer (analog or digital systems), computer (used for data processing) [1].

Due to all these requirements a technology such as LTE (Long-Term Evolution) is needed since it has enough attributed in order to achieve this goal and also has higher speed that other technologies such as WiMAX (Worldwide Inter-operability for Microwave Access). LTE also ismore efficient and economical solution than WiMAX [2]. LTE's bandwidth is between 1.25 and 20 MHz, mobility 350 km/h, multiple access for downlink OFDMA (Orthogonal frequency-division multiplexing access) and uplink SC-FMDA (Single Carrier Frequency Division Multiple Access), and modulation QPSK (Quadrature Phase Shift Keying), 16-QAM (16-quadrature amplitude modulation), and 64-QAM (64-quadrature amplitude modulation) [3]. We will evaluate the performance of LTE during video conferencing application using OPNET software tool.

This project will explain each element and the attributes used, OPNET simulation, analysis of OPNET results, and the conclusions section. In the end of the paper, an appendix page with the specific model attributes used in OPNET will be shown.

1.2 Video conferencing requirements

Video conferencing involves a network system of a minimum 384 kilobits per seconds in order to have a connection of 30 frames per second for a high quality video. Since Companies require a video resolution of 704 x 576 pixels, a low quality video (around 15 frames per second) could be achieved with a 512 kilobits bandwidth. Tthe minimum bandwidth for exactly 30 frames per second is 768 kilobits. Finally, if we want the best results for even higher level of frames per second, a bandwidth of 2 megabits per second would be needed [4]. The summary is shown in table below.

Quality of video conferencing	Frame rate (frames/second)	Bandwidth
Low	Around 15	512 kilobits
Medium	30	768 kilobits
High	30	2 Megabits

Table 1: Requirements for different qualities of video conferencing

1.3 Maximum transmission power

In order to have a better quality of video conferencing and a greater range we need a higher maximum transmission power and more bandwidth. In the table, different bandwidths ofan antenna tower and mobile nodes for LTE technology are shown [5].

LTE element	Bandwidth (MHz)
Base station	1.4, 3, 5, 10, 15, and 20
Mobile node	1.4, 3, 5, 10, 15, and 20

Table 2: Bandwidth requirements for base station and mobile nodes of LTE technology

1.4 Multiple access

Multiple access method is used in order to connect multiple terminals to share the capacity of the same transmission medium. The ones that are used are OFDMA and SC-FMDA, for downlink and uplink, respectively. OFMDA has a lot of benefits such as high spectral efficiency, the ability of performing under complex channel attributes without complex time-domain equalization. SC-FMDA is used for the uplink access method in order to have high data rate.

1.5 Modulation

This technique is used to combine the carrier signal with a modulating signal which carries the information that needs to be sent. There are two different types of modulations used in video conferencing: QPSK and QAM (16-QAM and 64-QAM). Using different types or modulations requires different SNR (signal-noise ratio). QPSK and 16-QAM need lower SNR in comparison with the 64-QAM. Therefore, the best option is to use different kinds of QPSK (rates of 1/2, 3/4, and 1/8).

1.6 Efficiency Mode

There are two modes available that could be used for efficiency settings and mobility in OPNET: Efficiency Enabled and Physical Layer Enabled. The first one contains MAC(media access control) without a physical layer. This method is used for capacity planning without carrying about the distance between the nodes. Physical Layer enabled contains MAC with frame-by-frame rate with a physical layer. This model is used during multipath fading and pathloss scenarios. Therefore, distance between the nodes matters. These two efficiency models will be compared during multiple scenarios.

1.7 Pathloss model

The pathloss models are used to analyze the performance of the network models in different areas. These areas have effects on distances between the mobile nodes and antennas. The further the distance between the mobile nodes and antennas is, the higher the data loss is achieved. The pathloss models that are used are: free space, Erceg’s suburban fixed, outdoor-to-indoor and pedestrian, and vehicular environment. The one that was used in this project is Erceg’s suburban fixed model. It is distributed at 1.9 GHz in 95 macro cells of suburban space through the United States [9]. This model has different terrain territories: A, B, and C. The one that has the most effects and green areas (including hills and mountains) is A which was chosen for this project as the terrain territory of the pathloss model. The formula that explains Erceg's suburban fixed pathloss is the following:

$$PL = H + 10 * \gamma * log_{10}\left(\frac{d}{d_0}\right) + X_f + X_h + s$$

where

PL = instantaneous attenuation in dB

H = intercept given by free space path-loss at the desired frequency with a distance $d_0 = 100\ m$

X_f and X_h are the correlation factors of the model for the operating frequency and the mobile station antenna height

1.8 Shadow fading standard

This standard is used for form different obstacles (such as trees, building) for every taken path. Therefore, data loss would be different for every path. In this project, we will not count this standard and it will be turned off.

1.9 Quality of service (QoS)

Quality of service analyses the performance of a network system. It has several aspects such as packet delay variation (PDV) or packet jitter (ms), packet end-to-end delay (E2E) in ms, traffic sent and received in bytes per seconds or frames per seconds, and throughput in bps. In the project we will analyze E2E, traffic sent and received, and throughput through different scenarios. E2E represents the time required for a packet to be transmitted from source to final destination. Traffic sent and received is the size and type of the traffic sent and received in a particular network. Throughput is the bit rate of a message being delivered through network.

2. Simulation

In this section, we will discuss the simulation objectives, implementation, and various settings that we used for this project. The simulation results will follow after this section. In order to assess the performance of LTE for video conferencing we came up with two cases and five scenarios. We used video conferencing as our application, so we created two rows in the video application of our LTE topology. We named one of the rows Video High, which was set to high quality video conferencing at 30 frames per second, and the other one Video Low, which was set to low quality video conferencing at 10 frames per second. We also created one profile in the Profile Manager of the LTE for each video quality named Video High and Video Low for the high quality and low quality video applications respectively. In the profiles attributes, we set the video instances to both start without any delay at the beginning of the simulation (See appendix 1).

2.1 Case I: Single Base station

In this case, our topologies include only one base station eNodeB1 and two mobile nodes m_usr1 and m_usr2. We implemented three scenarios for this case and addressed some of the QoS aspects of an LTE network.

2.1.1 Scenario 1 (Video Conferencing in Different Bandwidths)

The scenario shown in Fig.1 is our simplest implementation and it was intended to confirm the operation of LTE under the lightest video conferencing load. In this scenario, we looked at the effects of bandwidth on the performance. Although this model is very simple, it was very suitable for the performance evaluation while changing the frequency bandwidth.

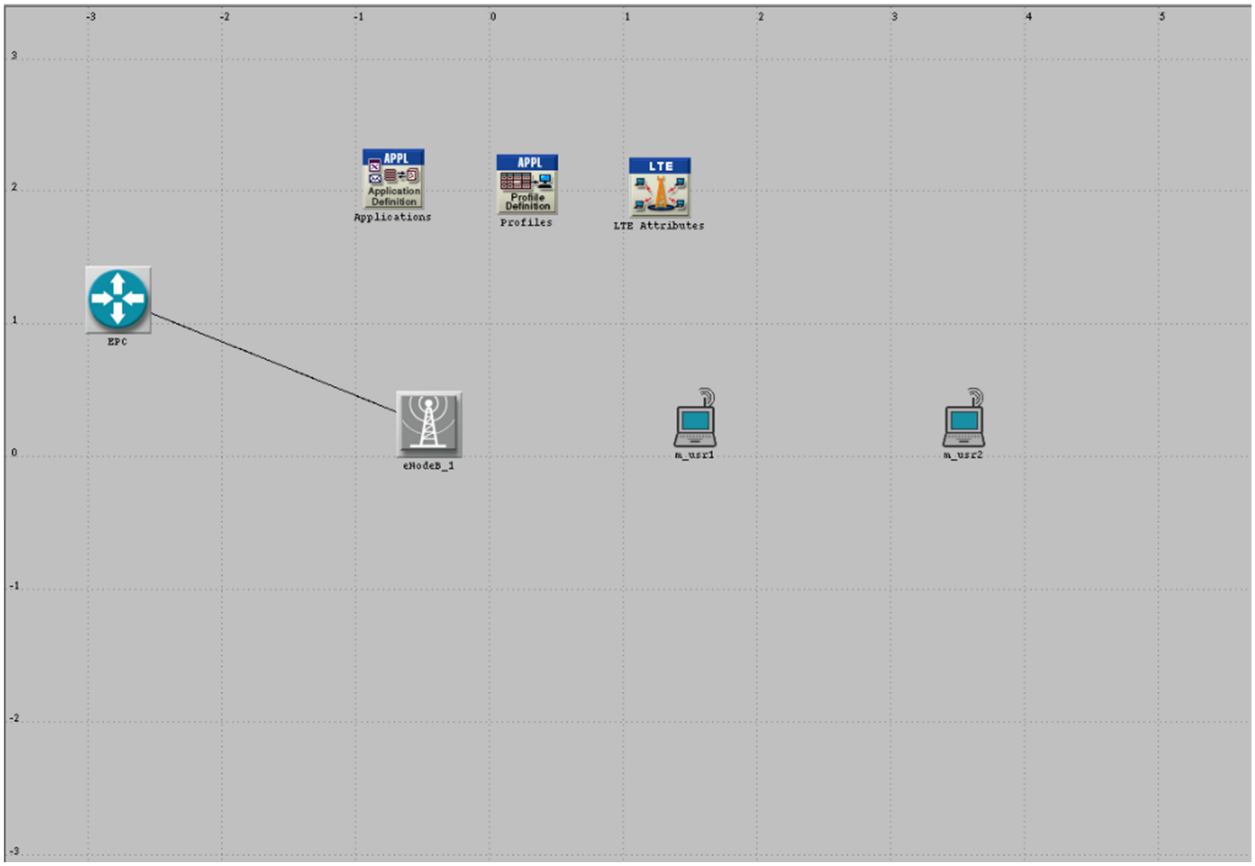


Figure 1: Single base station basic topology

We first set the efficiency mode of the LTE to *efficiency enabled* (See Appendix 1)This mode enabled us to examine the effect of the bandwidth without the influence of the distance.We made four profiles in the LTE Attributes for different bandwidths and we set each profile's UL and DL SC-FDMA bandwidth to the corresponding bandwidth (See Appendix 1). Next, we created different scenarios in our project file and for each scenario we chose the bandwidth of the interest in the eNodeB's Attributes in the physical profile. Look at Table3 for the list of simulation parameters for this part.

Parameter	Details
UL SC-FDMA Bandwidth (MHz)	1.4,5,10,20 MHz
DL SC-FDMA Bandwidth (MHz)	1.4,5,10,20 MHz
PHY Profile	LTE 1.4,5,10,20 MHz FDD
LTE Efficiency Attribute	Efficiency Enabled

Table 3: Case I scenario 1 attributes

2.1.2 Scenario 2 (Video Conferencing from Different Distances)

In this scenario, we changed the efficiency mode of our LTE model from the *efficiency enabled* to *PHY Enabled*in our evaluation of LTE mobile performance. In this mode we could place m_usr2 on different distances from the base station and evaluate the network according to the distance. We used the topology shown in Fig.2For this part and we placed the m_usr2 0.5 km, 0.75km, 1.0km and 1.5km away from the base station.

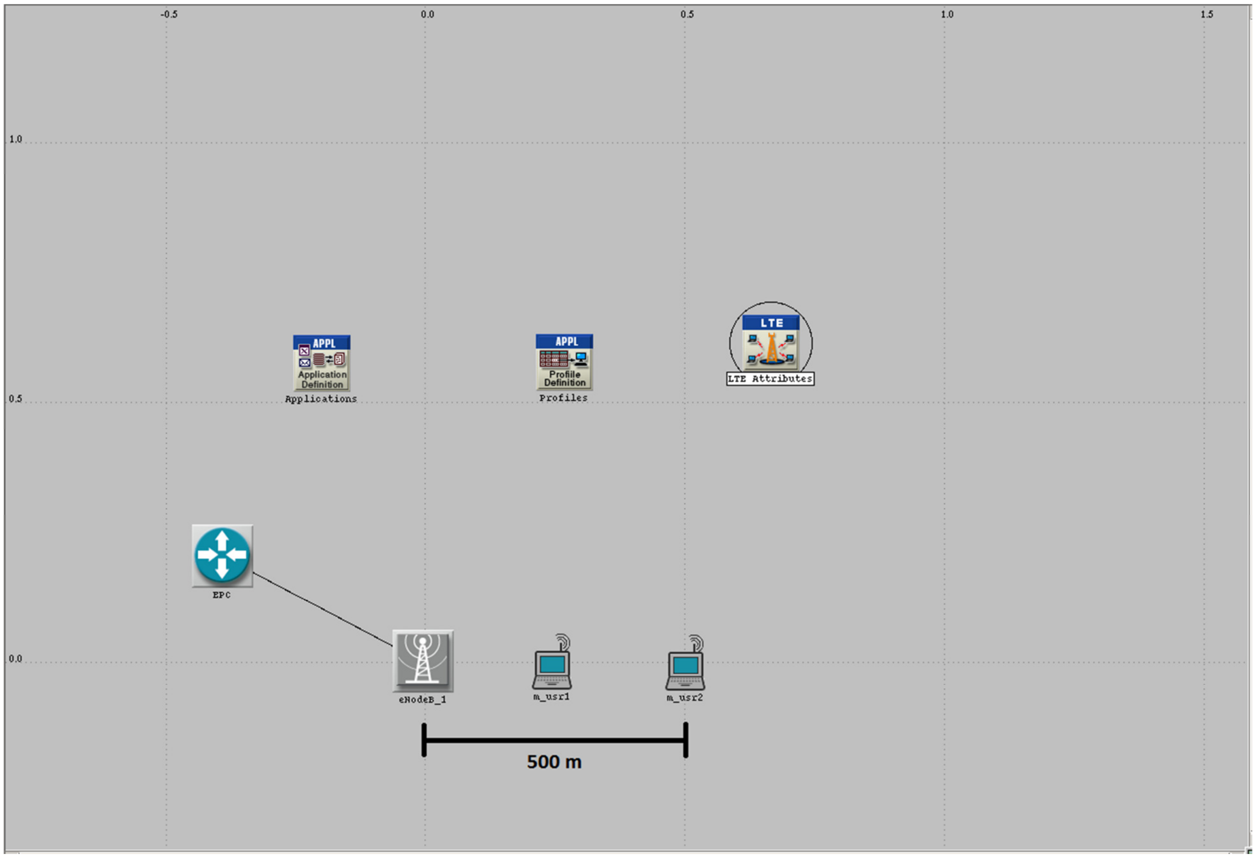


Figure 2(a): Single base station location of m_usr2 (500 m)

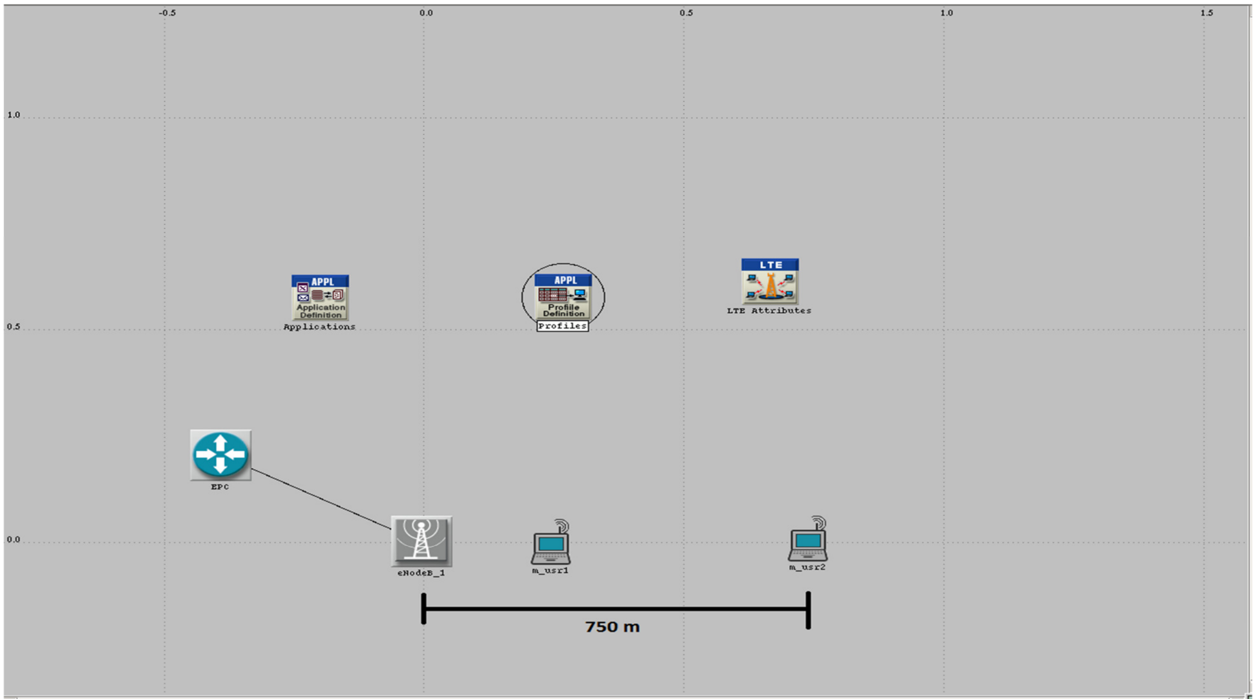


Figure 2(b): Single base station location of m_usr2 (750 m)

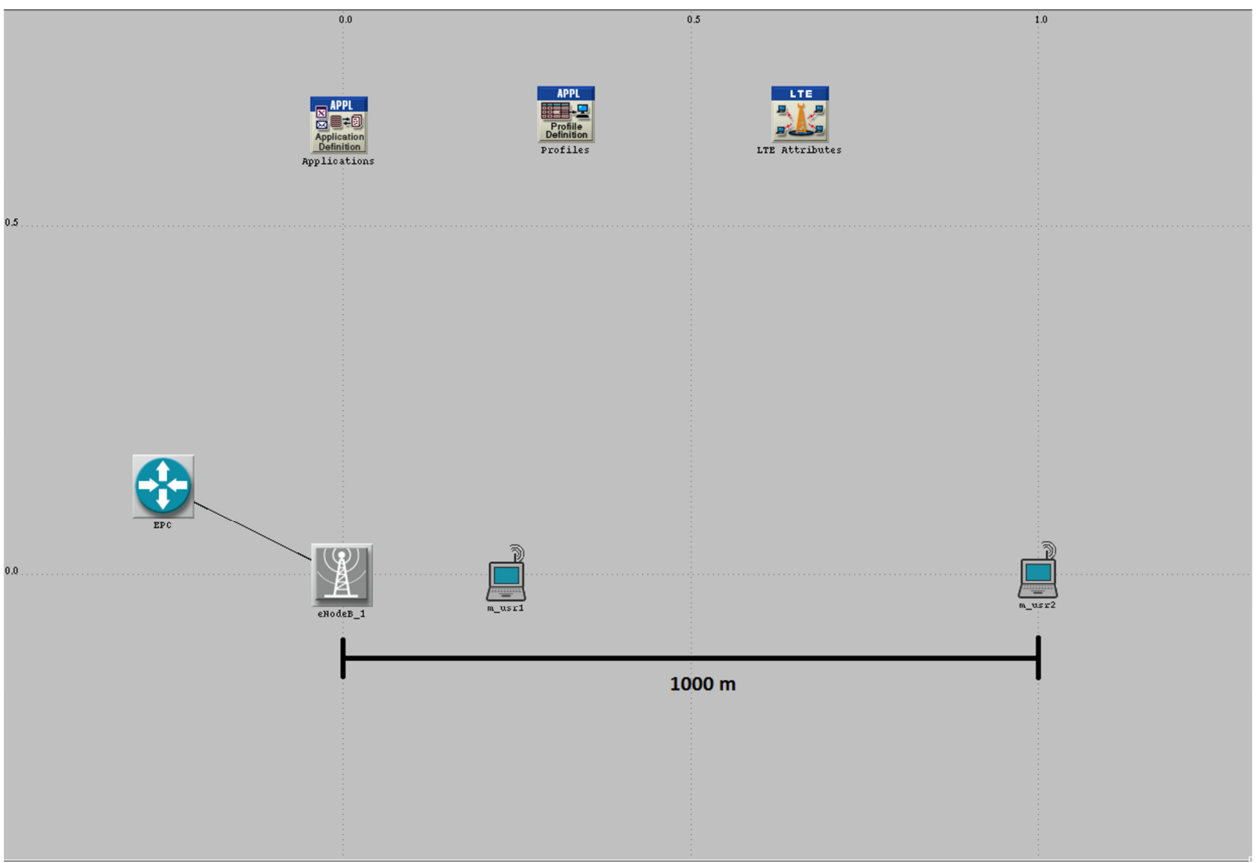


Figure 2(c): Single base station location of m_usr2 (1000 m)

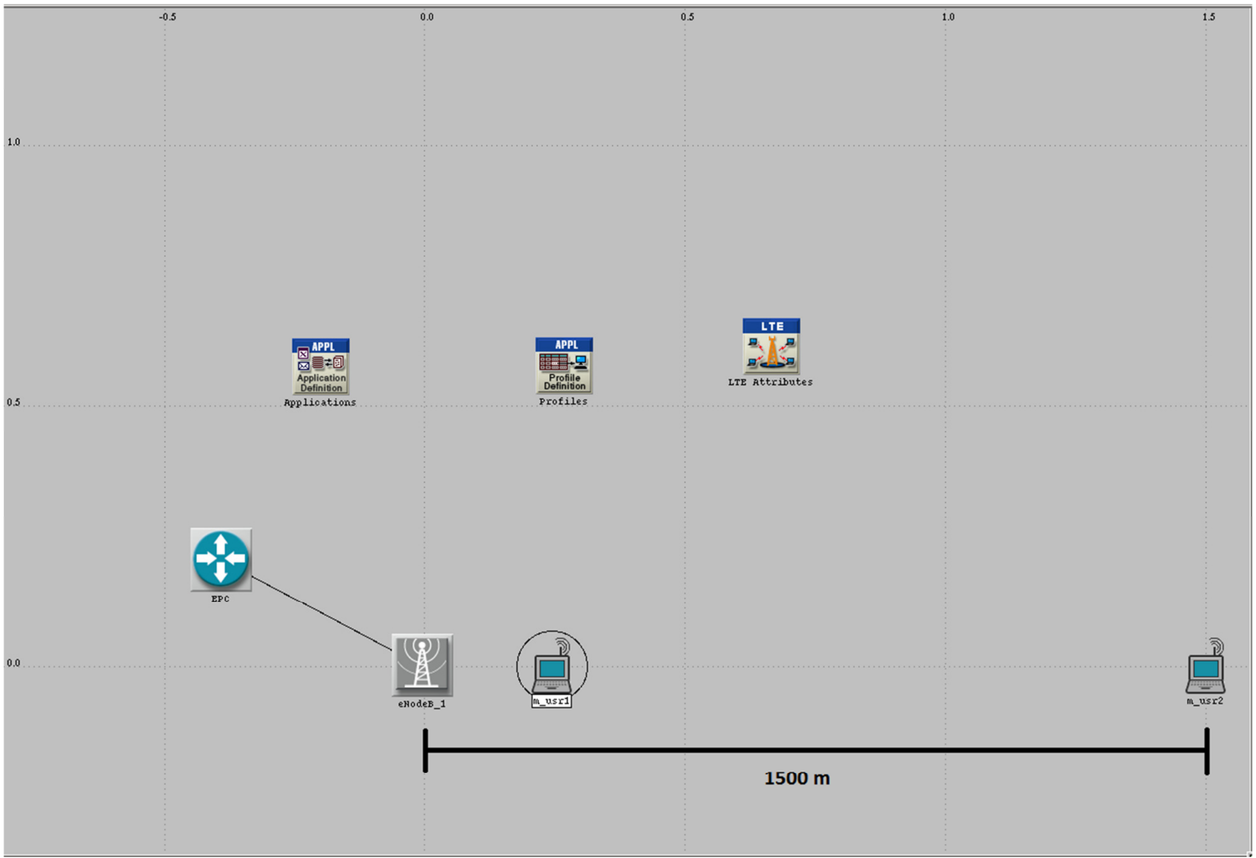


Figure 2(d): Single base station location of m_usr2 (1500 m)

Table4 summarizes the parameters for this scenario:

Parameter	**Details**
LTE Efficiency Attribute	Physical Layer Enabled
Pathloss Model	Suburban Fixed (Erceg)
Terrain Type	Type A
Shadow Fading Standard	Disabled
UL SC-FDMA Bandwidth (MHz)	20 MHz
DL SC-FDMA Bandwidth (MHz)	20 MHz
PHY Profile	LTE 20 MHz FDD

Table 4: Case I scenario 2 attributes

We chose *Suburban Fixed* for the pathloss model and *Type A* terrain for this simulation. According to the OPNET manual, this pathloss mode simulates a hilly terrain with moderate to heavy tree densities. We chose this model because it is the closest to the city environment that is currently available in OPNET 16.0. We also kept the frequency bandwidth of the base station at 20 MHz and set the bandwidth profile in the eNodeBattributes to LTE 20 MHz FDD.

2.1.3 Scenario 3 (Video Conferencing of Different Qualities and Bandwidths)

The last scenario of Case1 is shown in Fig.3.In this scenario, we disabled the mobile capabilities of the OPNET modeler and set the UL and DL SC-FDMA bandwidth frequencies at 10 or20MHz constant.

Figure 3: Single base station constant distance topology

We change the video quality from low at 10 frames per second to high at 30 frames per second and compared the results. The settings for this scenario are as stated in Table5.

Parameter	Details
UL SC-FDMA Bandwidth (MHz)	10MHz and 20 MHz
DL SC-FDMA Bandwidth (MHz)	10MHz and 20 MHz
LTE Efficiency Attribute	Efficiency Enabled
PHY Profile	LTE 10 and 20 MHz FDD

Table 5: Case I scenario 3 attributes

To switch between the low and high quality video conferencing, in user'slist of supported services, we set the low and high quality videos to either*Not Supported* or*Supported*(See Appendix 1).

2.2 Case II (Multiple Base Stations)

For this case, we expanded our LTE topologies to two base stations to decrease the load on the eNodeB1 and study the effects of this change.We assigned base stations' MAC addresses, so each mobile node connects to one specific eNodeB and not to the other one. Both base stations share one EPC.

2.2.1 Scenario 1 (Video Conferencing: Single Base Station vs Multiple Base Stations)

This is a basic one-on-one video conferencing simulation between two mobile nodes. The topology for this part can be seen in Fig.4.This topology is similar to the one in Case I Scenario 1 with the modification that two users are now on separate base stations.

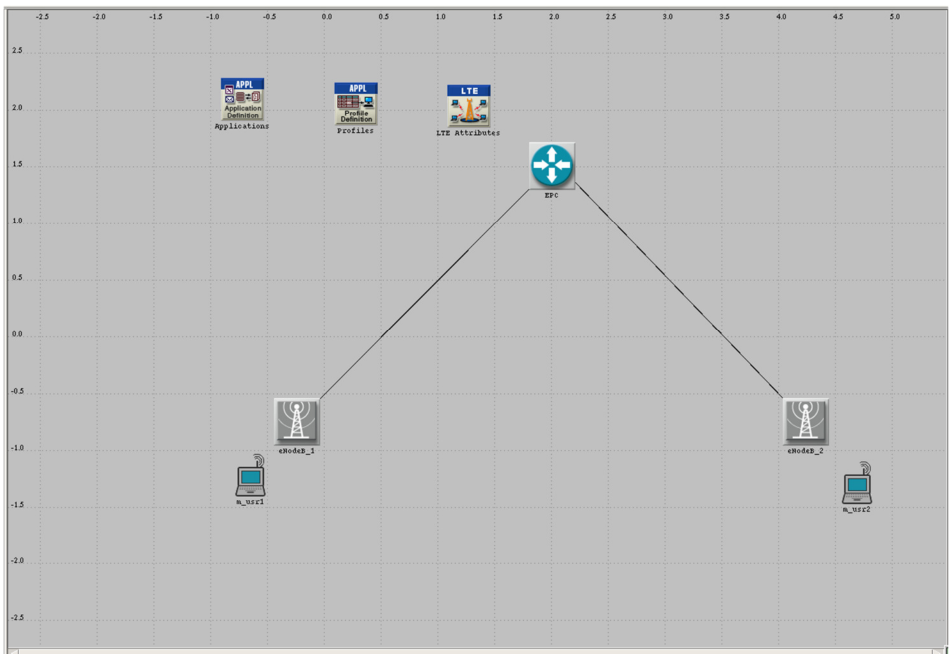


Figure 4: Two base stations one-on-one video conferencing

We disabled the pathloss for the mobile nodes, so that we can study the effects of bandwidth without the influence of the distance. We used UL and DL SC-FDMA bandwidths of 1.4, 5, 10 and 20 MHz for this part and we set the video quality to low at 10 frames per second. The specifications are the same as Table3.

2.2.2 Scenario 2 (Video Conferencing: Two Users vs Multiple Users)

This scenario consists of two topologies. Since we wanted to survey the effects of load on our network, we added two more mobile client nodes to one the base stations (Fig.5) and compared the results with the one-on-one video conferencing in scenario 1.

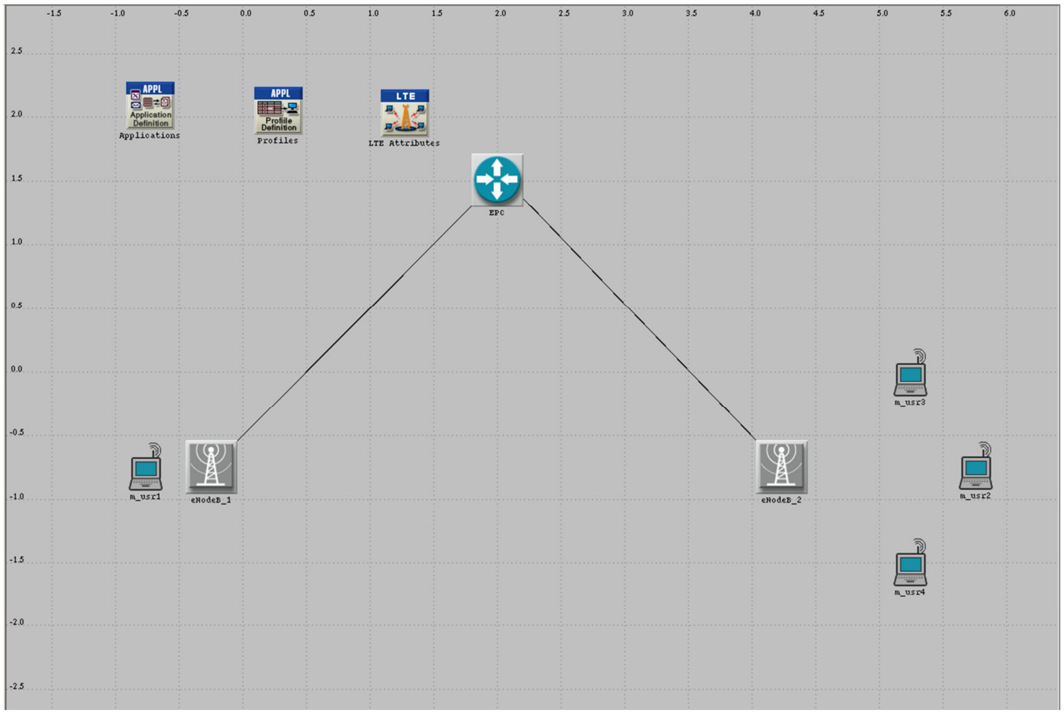


Figure 5: Two base stations multiple users

The settings and parameters are the same as scenario 1 in this case and you can see the summarized settings in table5.

3. Collected Statistics and Results

We chose to collect different sets of data in each case and scenario according to available statistical data options available for the video conferencing in OPNET 16.0. Since we were more interested in the behavior of the LTE rather than detailed and exact numerical values, we decided to look and collect graphical information in each part of our project. Another reason for looking at graphs and the behavior, instead of the exact numerical values, is that the values are usually different in the real world than in the simulation, but the behavior of the system is most likely similar in the simulation and in the real implementation.

In the first scenario of case one, we looked at the End-to-End delay from m_usr1 to m_user2. We also looked at the throughput and the amount of traffic sent/received from and to m_usr2 and m_usr1. In the second scenario, we only looked at the End-to-End delay because our LTE network could easily handle one-on-one video conferencing for every distance at the 20 MHz bandwidth, so the difference in the throughput or the traffic sent/received graphs were almost unnoticeable. For the third scenario of case one, we looked at the graphs of End-to-End delay, traffic sent/received to and from m_usr1, and the throughput. In the fourth scenario we compared the End-to-End delay, throughput, and the sent/received traffic graphs while having one eNodeBwith having two eNodeBs. Finally, we conducted our last scenario in which we evaluated the performance when the number of users increased. We obtained graphs of End-to-End delay and the throughput to see how LTE performs in each situation.

Scenario	Parameter(s)
Case I	
Scenario 1	delay, throughput, traffic
Scenario 2	delay
Scenario 3	delay, throughput, traffic
Case II	
Scenario 1	delay, throughput, traffic
Scenario 2	Delay, throughput

Table 6: Obtained parameters

3.1 Case I

3.1.1 Scenario 1

For this scenario, we simulated for 10 minutes and the LTE simulation statistics is shown in Fig.6, Fig.7, and Fig.8.

Fig.6 indicates that the shapes of the average end-to-end delay are not the same among these four different bandwidth values. The end-to-end delay of 20MHz is the most stable (the bottom graph in Fig.6). The delays of 1.4MHz and 5MHz onesincrease dramatically at the beginning and the reason is that in lower bandwidths, m_usr1 needs more time to initiate the video conferencing (the two top graphs of Fig.6). Also, the figure shows that the greatest bandwidth of the LTE has the shortest period of end-to-end delay as expected.

Fig.7represents the result of the average throughput. The throughput of 20MHz and 10MHz share the same shape. The values of the throughput of these two bandwidths are close. The throughput of the 5MHz bandwidth is half of the 10MHz one. The throughput of 1.4MHz is the lowest as expected.

Fig.8 shows the average traffic received from m_usr1. The traffic in 20MHz and 10MHz increase steadily. The traffic in 5MHz and 1.4MHz bandwidths increase at the beginning and decrease slightly and then approach stable statute. Moreover, both 20MHz and 10MHz have much better performance for traffic received than others, which makes them very suitable for real applications.

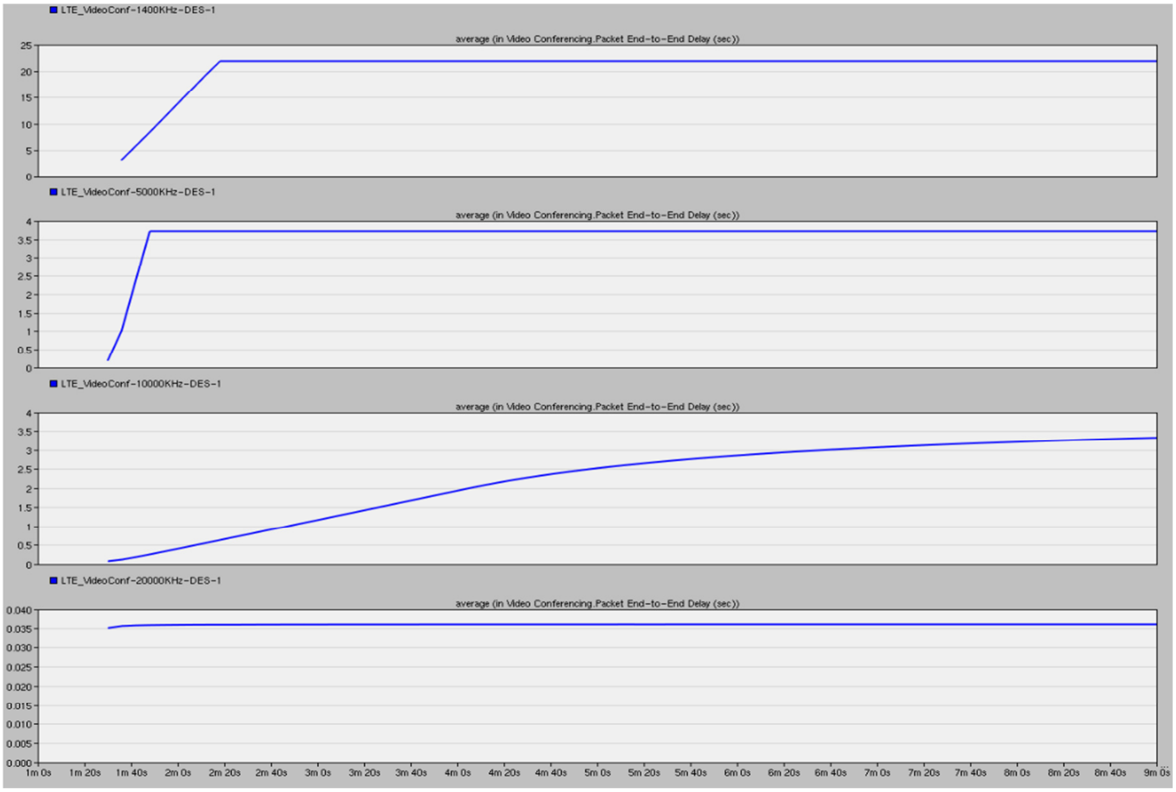


Figure 6: End-to-End delay for different bandwidth frequencies

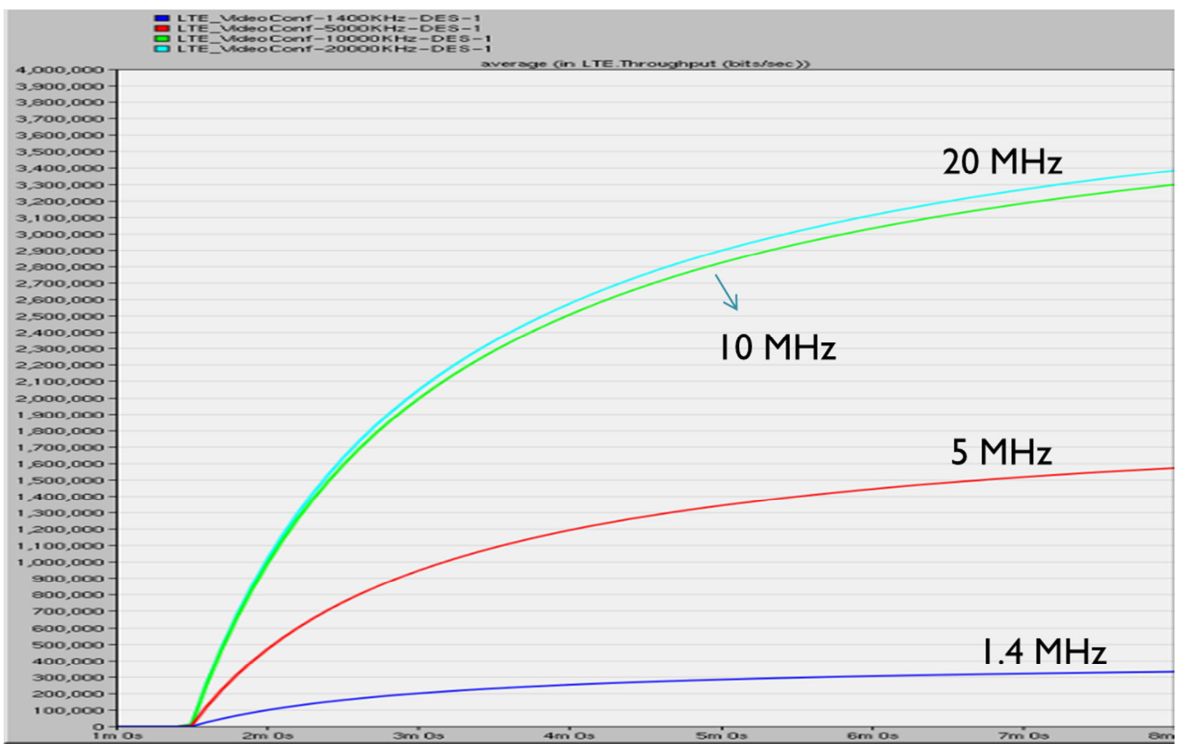


Figure 7: Average throughput for different bandwidth frequencies

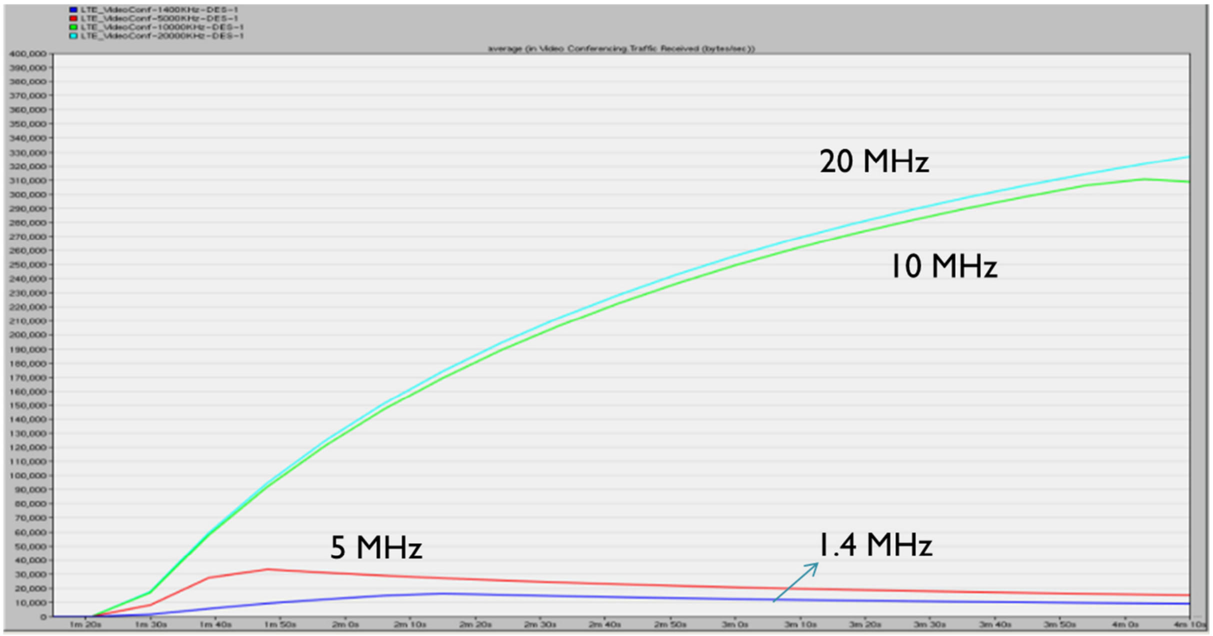


Figure 8: Traffic received at m_usr2

3.1.2 Scenario 2

For this scenario, we simulated for 10 minutes under 20MHz in bandwidth and placed m_usr2 away from the base station at different distances. The LTE simulation statistics is shown in Fig.9.

Fig.9 indicates that the farther away from the base station, the longer the end-to-end delay time. However, the difference of delay time between 500m and 750m is large than the difference of the ones between 750m and 1000m.

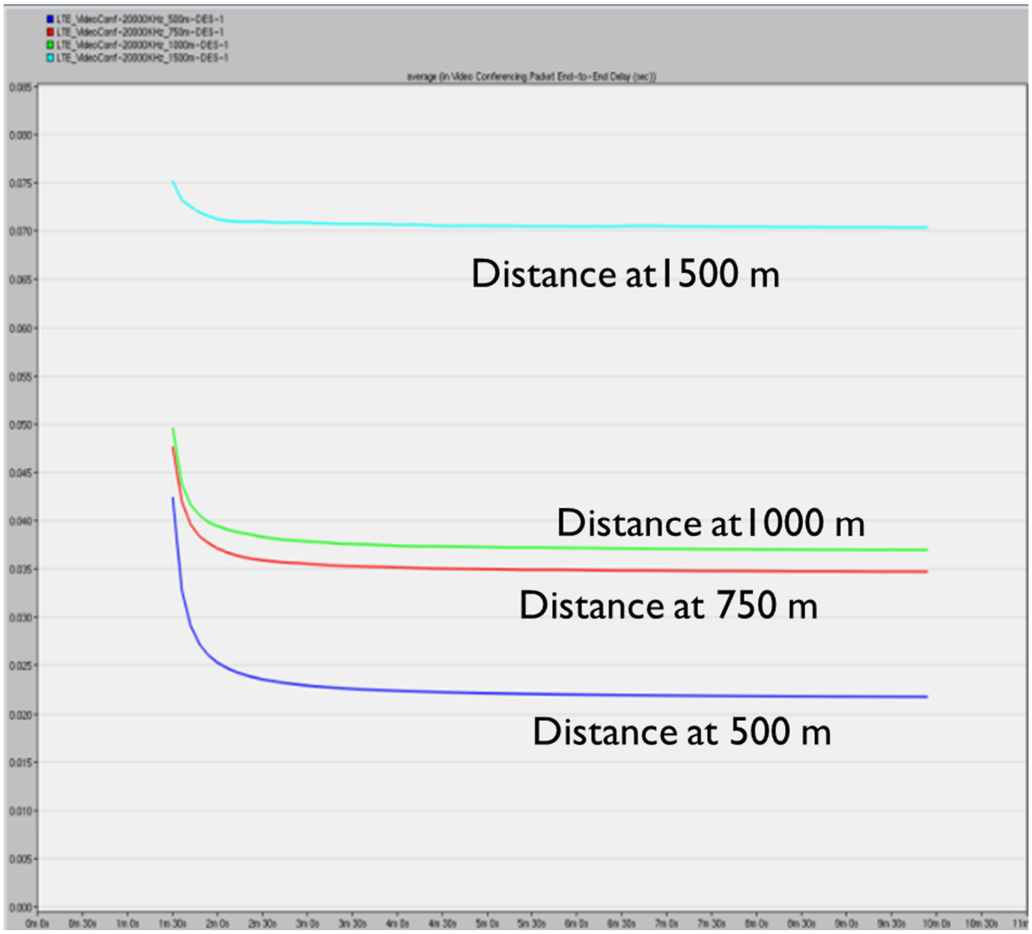


Figure 9: End-to-End delay for different m_usr distances from the base station

3.1.3 Scenario 3

For this scenario, we simulated for 10 minutes in 20MHz and 10MHz bandwidth and two different quality definition of video content. The LTE simulation statistics are shown as Figurs 10, 11, and 12. Fig.10 indicates that the lower bandwidth of LTE and highestquality of video content has the largest effect on the end-to-end delay time. Therefore, high quality of video content in 10 MHz has the highest delay time which is twice as the low quality video content in 20 MHz.We notice that low quality of video conferencing performance is better than high quality ones no matter what bandwidth are used.

The Fig.11 shows that the high quality video content has greater throughput than low quality video. For the high quality of video content, larger bandwidth has a little bit better throughput than the 10 MHz because the larger bandwidth has less packet drops than the smaller bandwidth. However, the results of this graph are very interesting. Although for higher quality video we have 20 MHz bandwidth performing better than 10 MHz, for low quality video 10 MHz performs better. We conclude that, there are tradeoffs involved in increasing the bandwidth and in some cases lower bandwidth may be a better choice.

The traffic received measured at m_usr2 (Fig.12) indicates that the traffic received of the high quality video content is much larger thanthe low quality video content. They have same shape and increase by time. However, at the beginning of simulation, both of them stay at zero because they need time to connect.

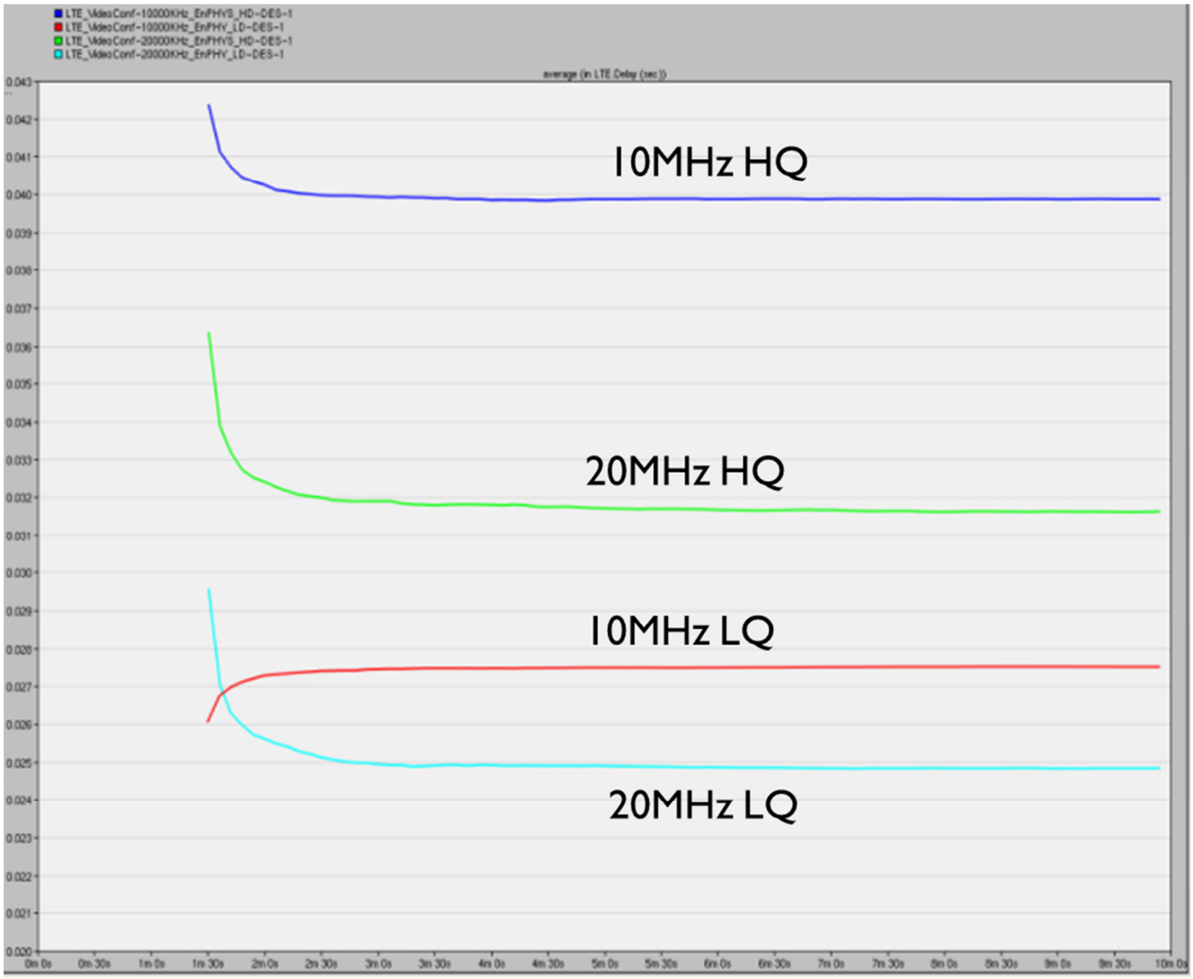


Figure 10: End-to-End delay for different video qualities

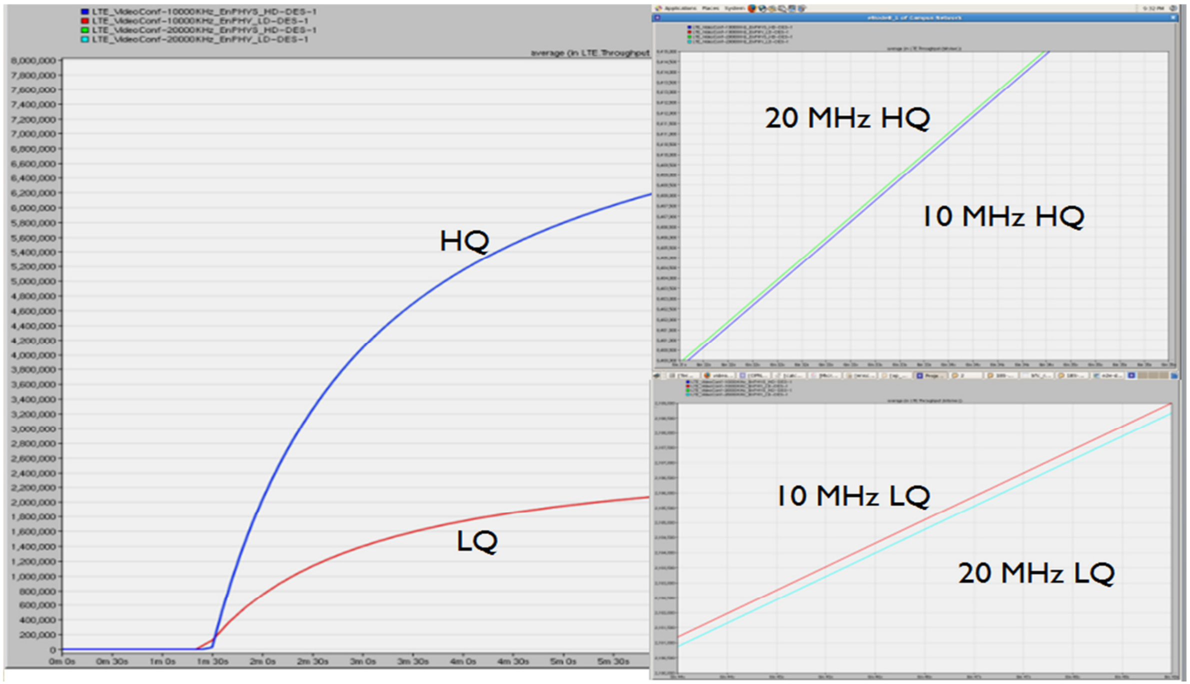


Figure 11: Average throughput for different video qualities

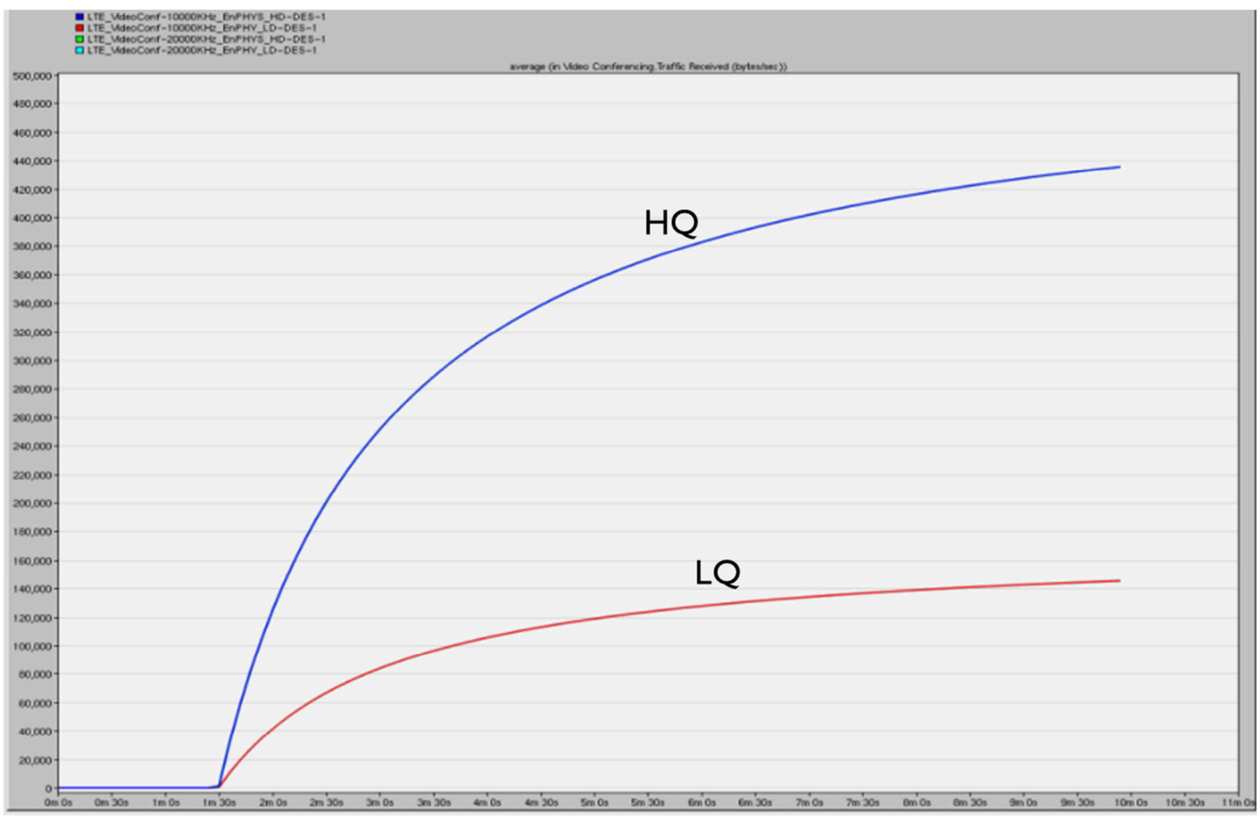


Figure 12: Traffic received measured at m_usr2 for different video qualities

3.2 Case II

3.2.1 Scenario 1

This scenario ran for five minutes. The delay falls 13 ms for the single-base station and 2 ms for the two-base station case. The reason for this behavior is that a single base station does not use EPC and it directly receives and forwards the signal from and to mobile nodes, but in the two-base station case, one base station receives the signal from one mobile node and it forwards it to the second base station to be broadcasted to the other mobile node. This process requires more complicated routing, which is done by the EPC, and the physical layer is doubled; however, since the bandwidth is not shared between the mobile nodes, we have a much smaller delay (Fig.13). The two-base station setup also handles the congestion better than the single-base station setup; hence the delay stabilizes faster at the beginning of the simulation.

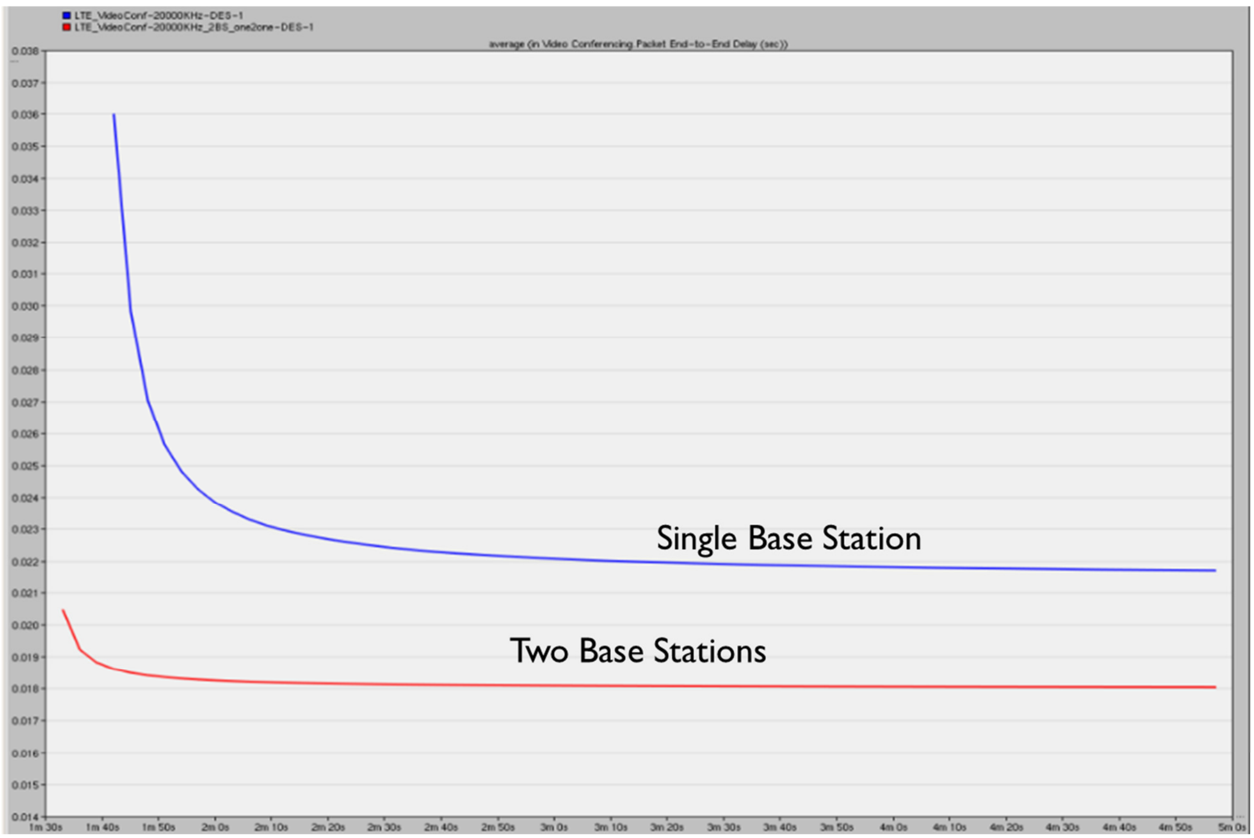


Figure 13: End-to-End delay for one base station and two base stations

Fig.14 and Fig.15 show the throughput and the traffic received respectively. These two graphs show that the single base station has a higher throughput and fewer packets drops than the two base stations. When mobile nodes connect through two separate base stations, EPC is activated for routing and there are also physical links between the EPC and the base stations, hence, the physical layer becomes more complicated, which would in turn cause more packet drops and decreased throughput.

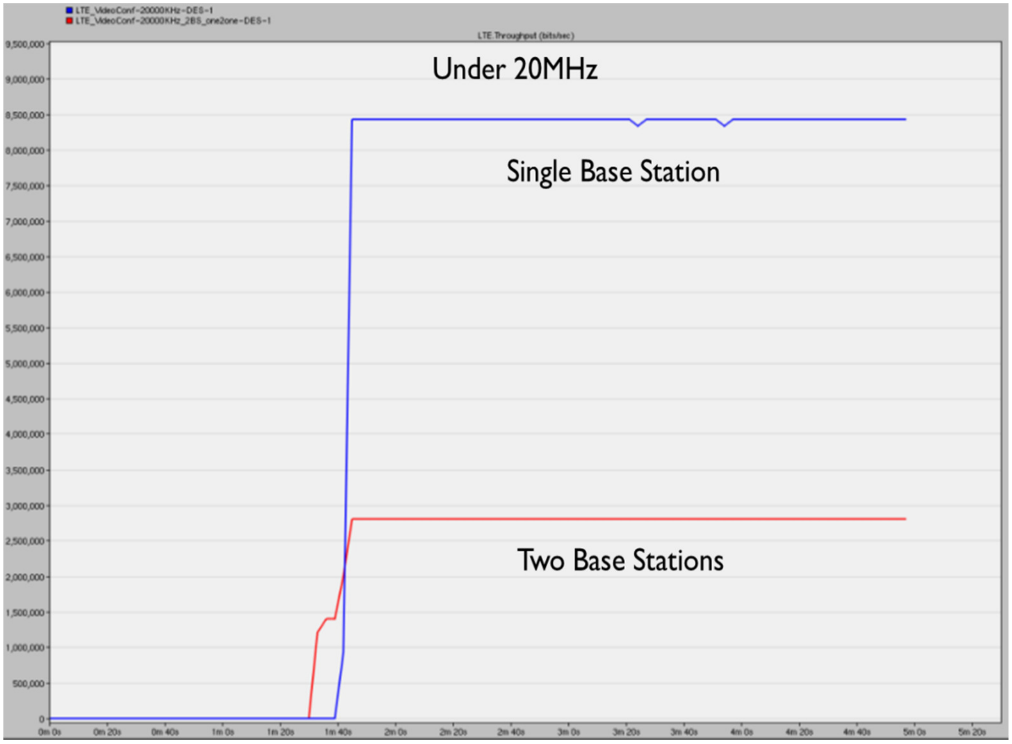


Figure 14: Average throughput for one base station and two base stations

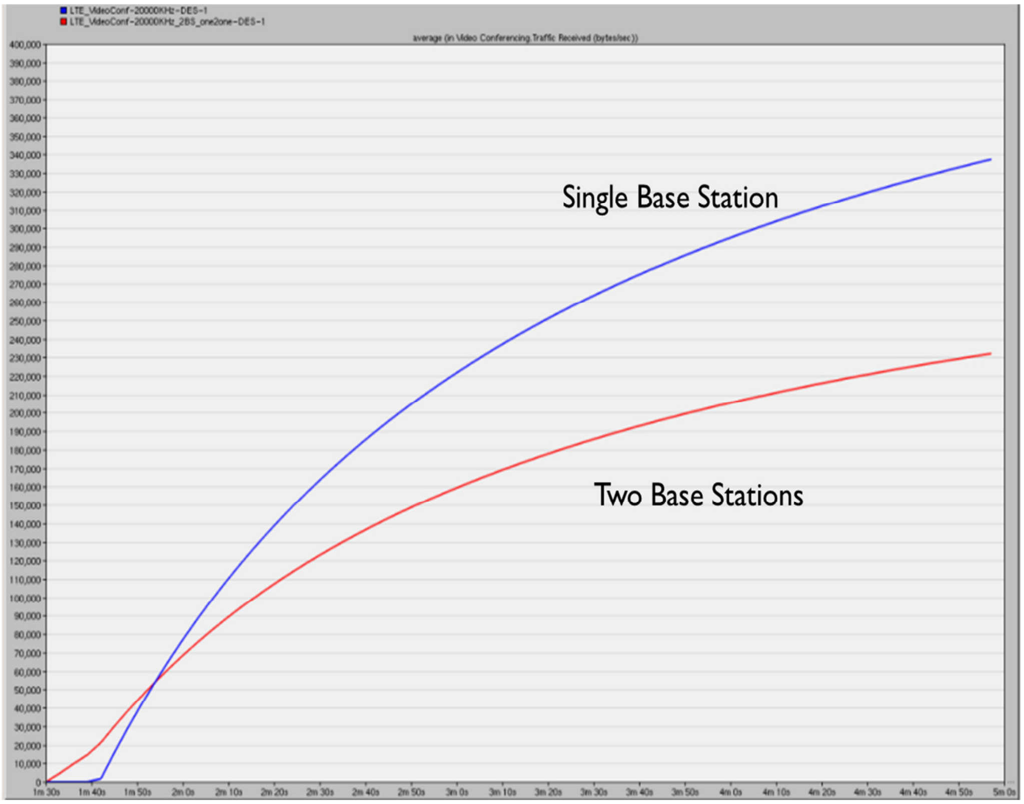


Figure 15: Traffic received by m_usr2 for one base station and two base stations

Parameter	Result
End-to-End Delay	Multiple Base Stations < Single Base Station
Throughput	Multiple Base Stations > Single Base Station
Traffic Received	Multiple Base Stations > Single Base Station

Table 7: Case II scenario 1 result summary

3.2.2 Scenario 2

As we increased the number of users, delay increased drastically. The reason for this behavior is that users have to share the constant bandwidth. Fig.16 shows that multiplying the number of users by three increases the delay almost ten times.

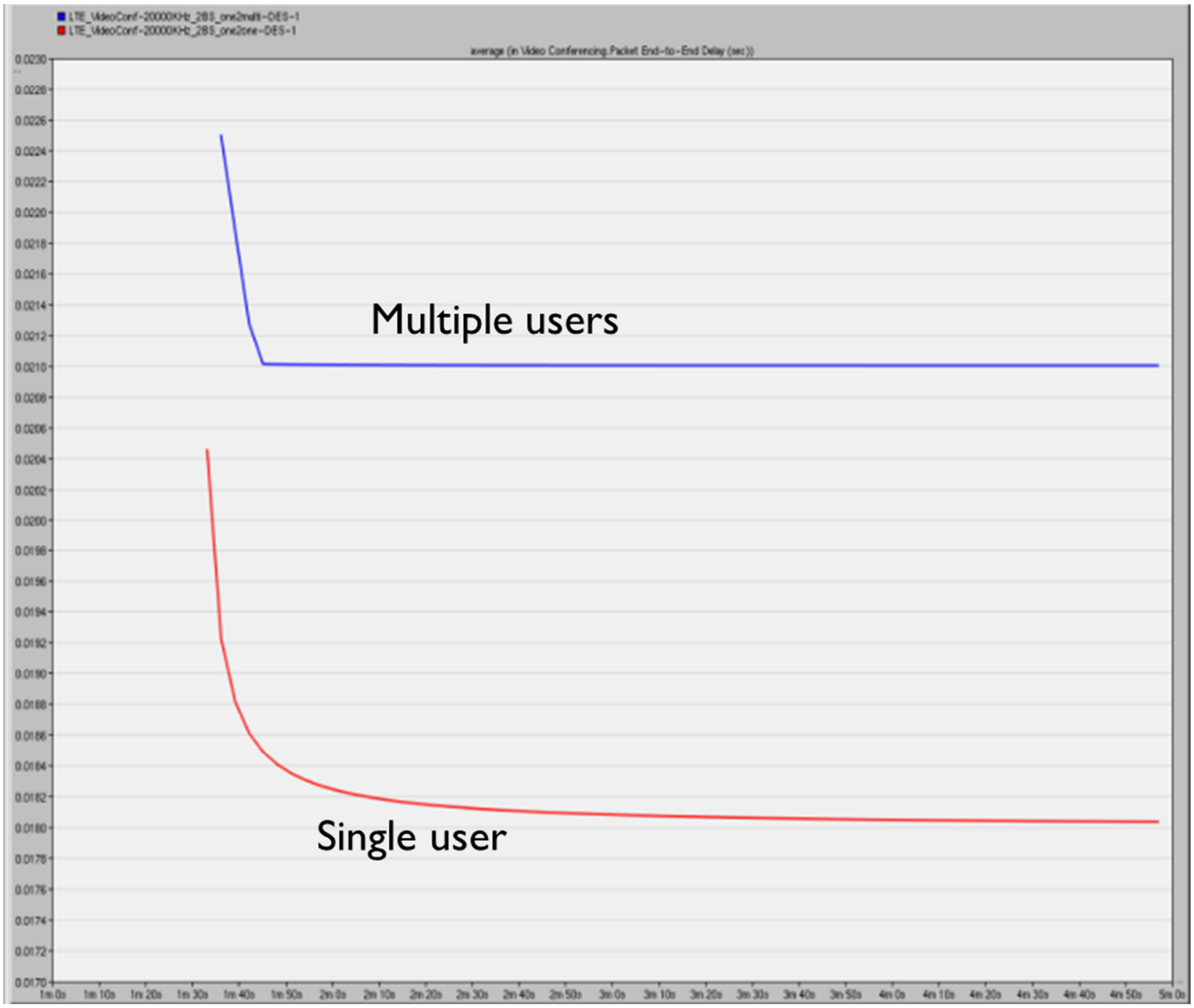


Figure 16: End-to-End delay for one user and multiple users

Since we measured the throughput at the base station of the receiving side, our results matched our expectations. The throughput is increased because although the amount of packet drops stays the same for one user, packets are transmitted to multiple users, which will increase the amount of successful transmission rate and in turn the throughput.

4. DISCUSSIONS AND CONCLUSIONS

4.1 Summary

Several different scenarios were performed using OPNET software tool in order to analyze the performance of LTE in the video conferencing application. All the obtained data agree with the theoretical results. First, increasing the signal bandwidth of the antenna outputs a lower E2E delay and higher throughput from the mobile nodes. In addition, modifying the distance between the base station and mobile nodes causes the throughput from the mobile nodes to change proportionally but has the opposite effect on the E2E delay. In terms of a video quality, low quality videos produce less E2E delay and higher throughput. Finally, the higher number of users requires higher bandwidth of the base station for more efficient performance.

We could not place the mobile nodes more than 1500 m away from the base station when physical layer was enabled. After researching this issue, we found that there is a bug in OPNET 16.0 and it prevents any transmission above about 2000 m.

We also could not start the data transmission and measurements at the start of the simulation (0 seconds) because LTE needs an initial setup time. Therefore, all the simulation results show 1-2 minutes delay at the beginning of the data collection.

4.2 Challenges

Using OPNET for the first time was a big challenge for the entire team. Even though it looked as a simple program, we did not expect to have problems understanding a lot of attributes in the network models. The main problem the group had was trying to achieve correct results when the distances between the base station and mobile node were changed. The group expected OPNET to be more user-friendly and comfortable for use but we concluded that we were wrong. In case we had to do a project again, we would definitely use ns-2 simulator because we already have programming skills. However, we are glad that the results from OPNET were correct and that our goals were achieved.

4.3 Future work

In the future we would like to analyze the LTE performance using different applications such as VoIP (Voice over IP), email, and remote login. In addition, we would expand our topology to more nodes and antennas. Furthermore, LTE could be compared to WiMAX using different scenarios since some resources claim that WiMAX has a higher throughput than LTE under certain situations. Therefore, we would be able to possible prove that there is a better option than LTE.

5. REFERENCES

[1] Basic Requirements for Successful Videoconferencing, Video Development Initiative, [Online]March 2005, http://www.vide.net/cookbook/cookbook.en/list_page.php?topic=5&url=req-basic.html&level=1&sequence=1&name=Basic+Components (Accessed: April 10 2014).

[2] Why is LTE better than Wimax?,KnowsWhy, [Online] April 2, 2011, http://www.knowswhy.com/why-is-lte-better-than-wimax/ (Accessed: April 10 2014).

[3] F. Khan, *LTE for 4G Mobile Broadband,* Now York, Cambridge University Press, 2010.

[4] B. Cohen. *Bandwidth Requirements for Video Conferencing.*[Online]. Available: http://www.ehow.com/list_6805403_bandwidth-requirements-video-conferencing.html

[5] LTE (FDD) Transmitter Characteristics, [Online]. Available: http://www.ntia.doc.gov/files/ntia/meetings/lte_technical_characteristics.pdf (Accessed: April 10 2014).

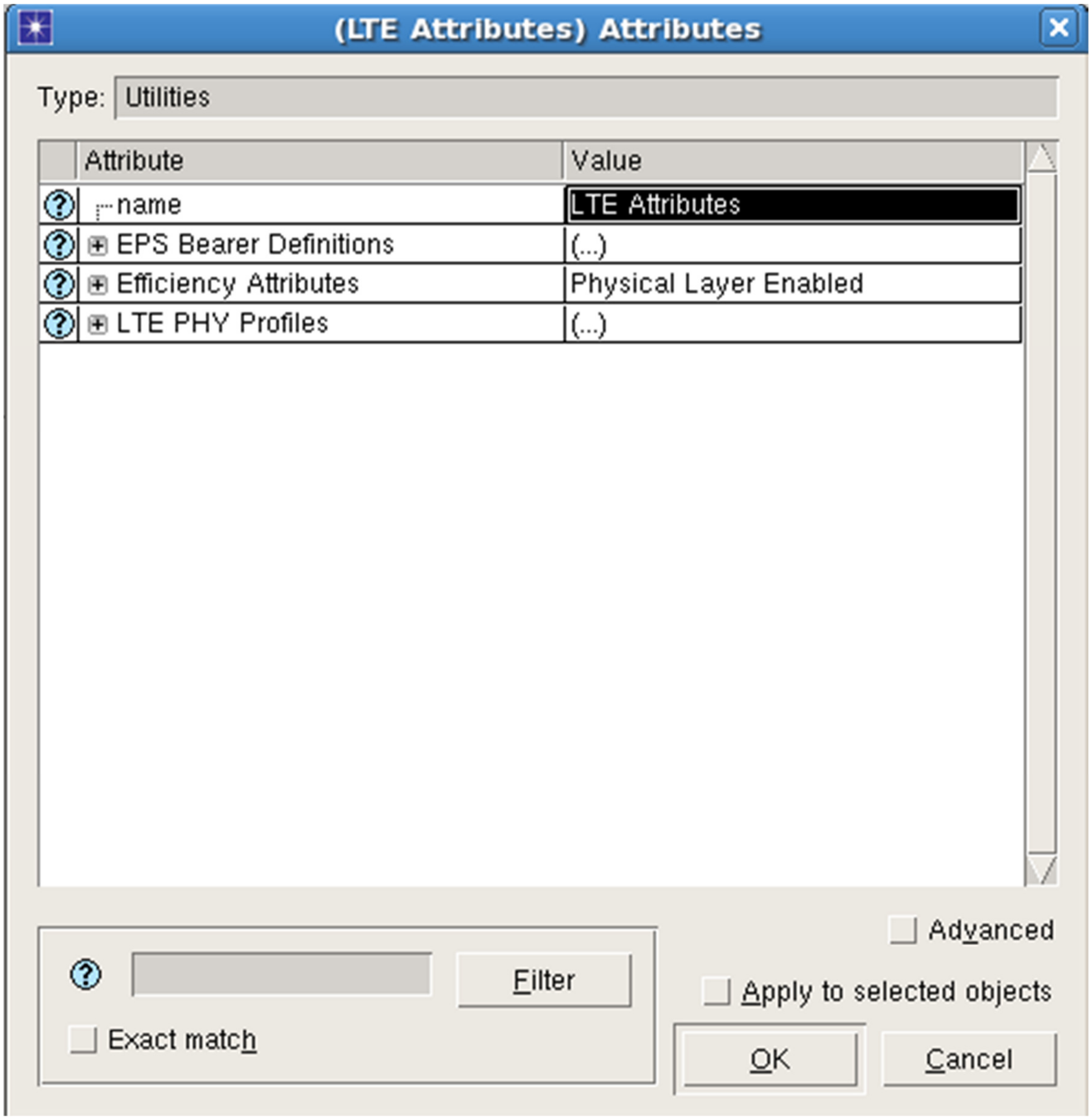
[6] *Planning of LTE Radio Networks in WinProp,* 4th ed, AWE Communications GmbH, [Online]. Available: http://www.awe-communications.com/Download/ApplicationNotes/NetworkPlanningLTE.pdf (Accessed: April 10 2014).

[7] *SC-FDMA Single Carrier FDMA,* IXIA, Calabasas, CA, 2009, [Online]. Available: http://www.ixiacom.com/pdfs/library/white_papers/SC-FDMA-INDD.pdf (Accessed: April 10 2014).

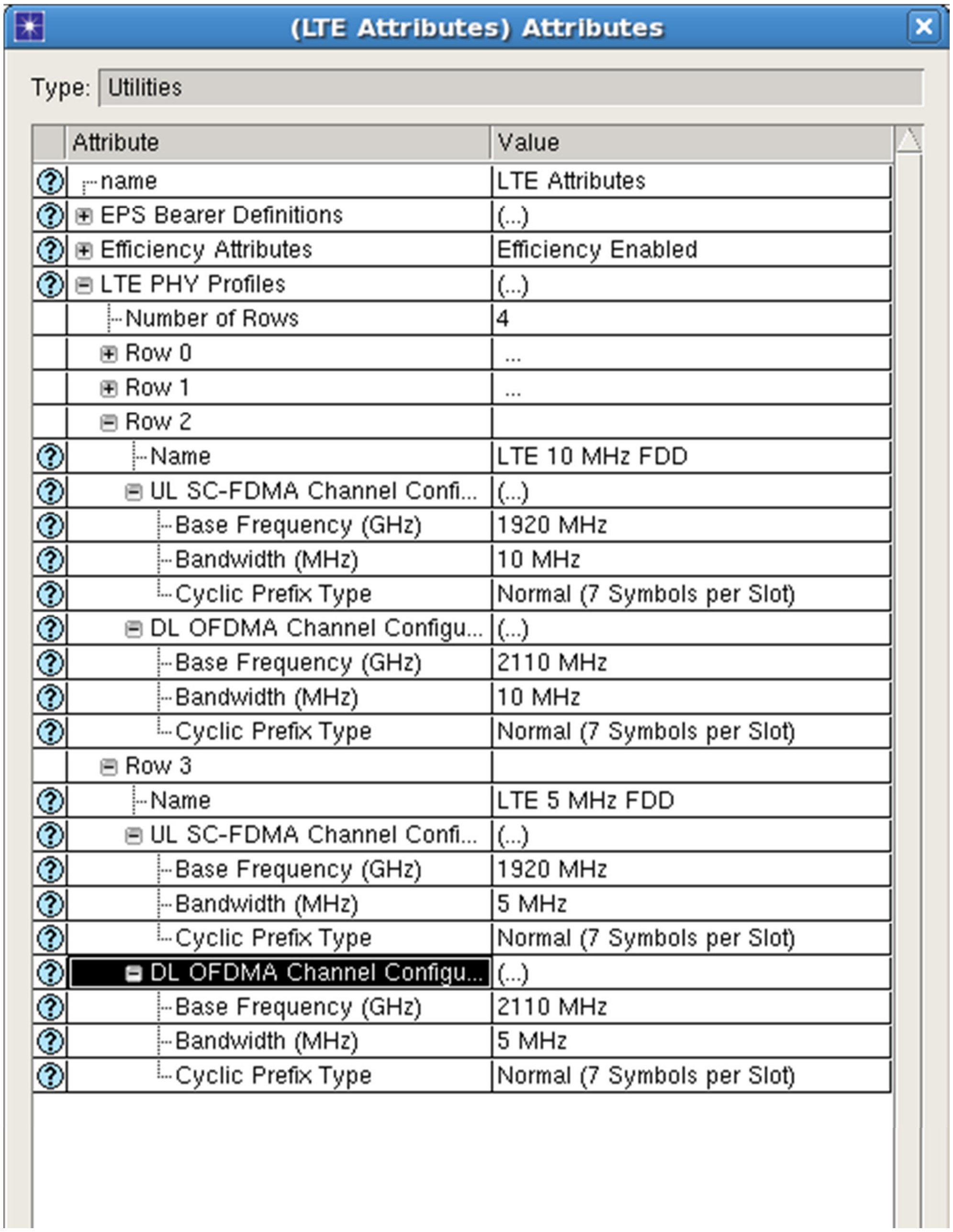
[8] E. Boyer and A. Chowdhury, *"Analysis of Quality of Service (QoS) for Video Conferencing in WiMAX Networks"* [Online]. Available: http://www.sfu.ca/~asc13/ensc427/afrin_eric_final_report_2010.pdf (Accessed: April 10 2014).

[9] J. Hamodi*et al.*, "Performance Study of Mobile TV over Mobile WiMAX Considering Different Modulation and Coding Techniques" [Online] January 11 2014, http://arxiv.org/abs/1401.2542 (Accessed: April 10 2014).

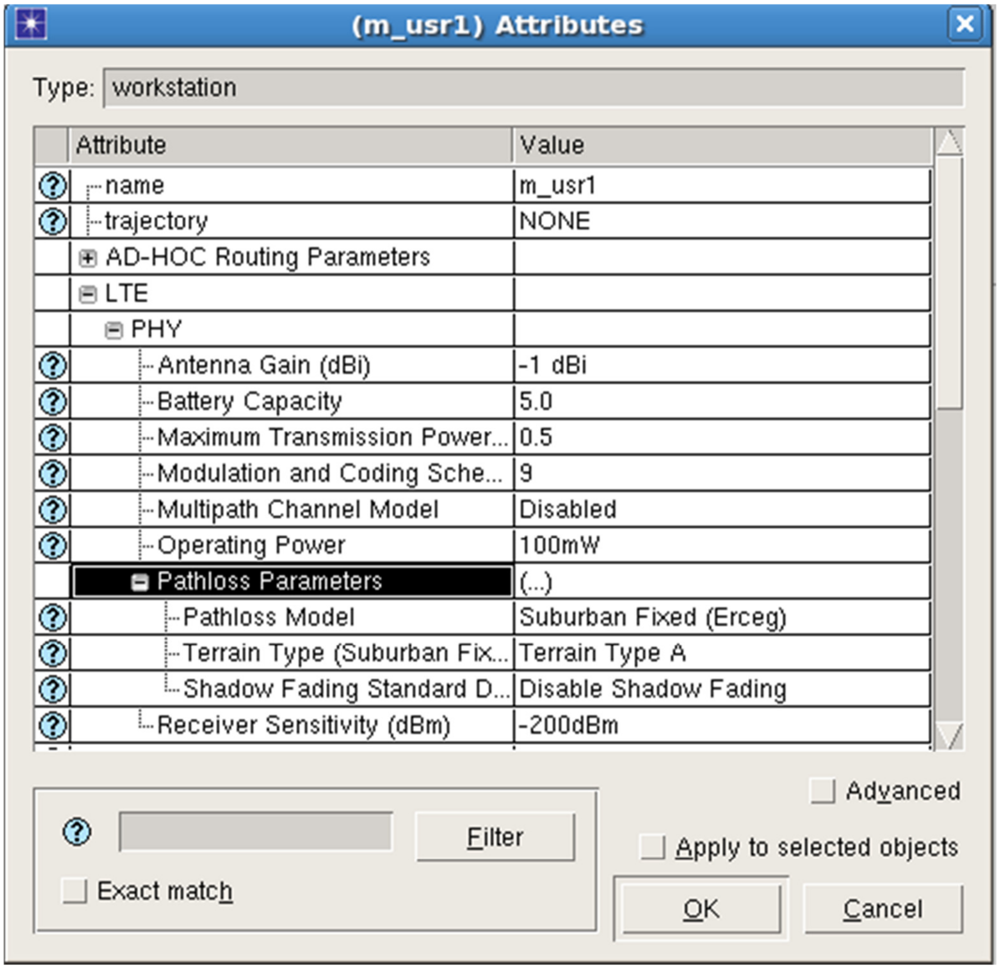
6. Appendix 1: Configurations



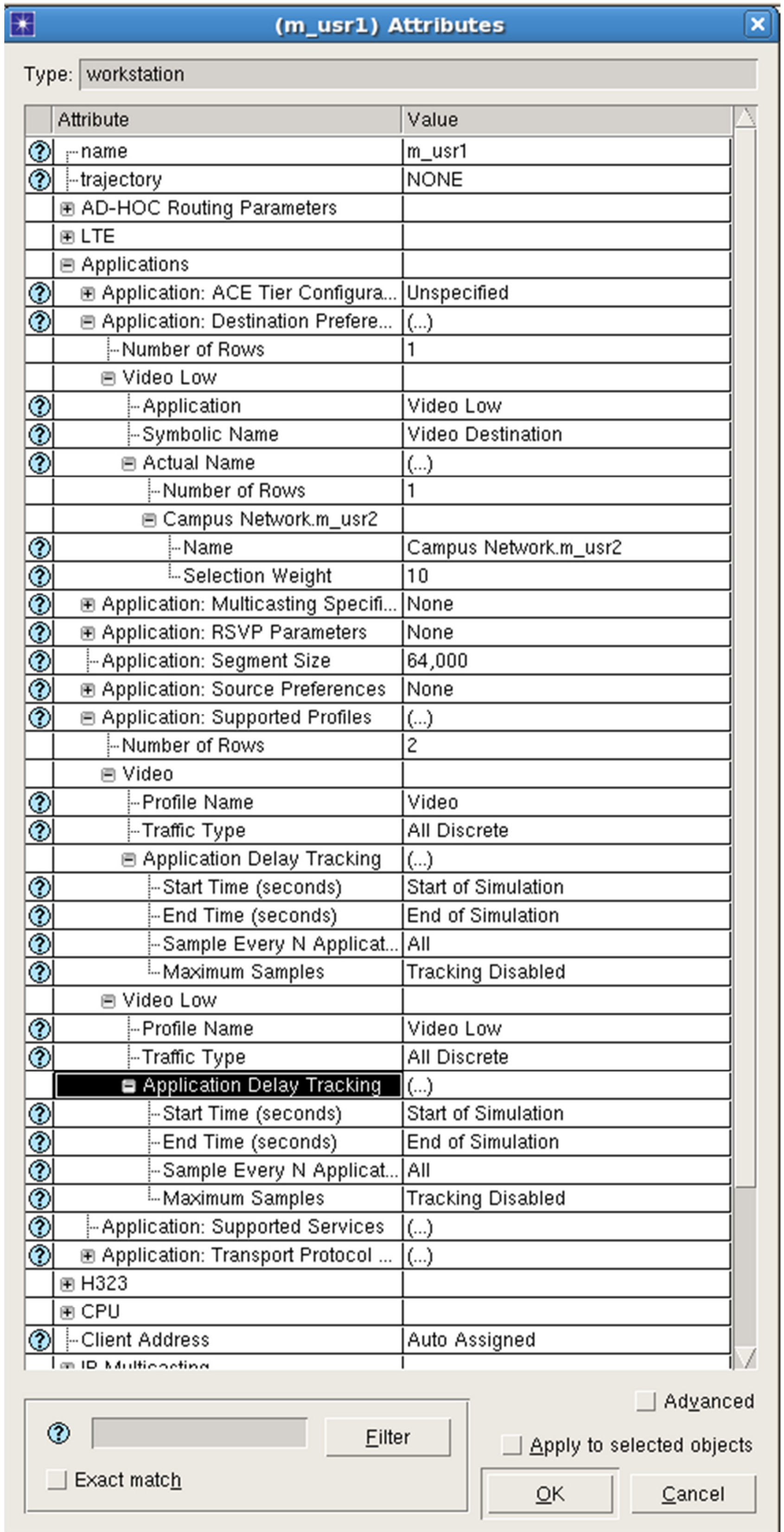
LTE Attributes: Physical layer



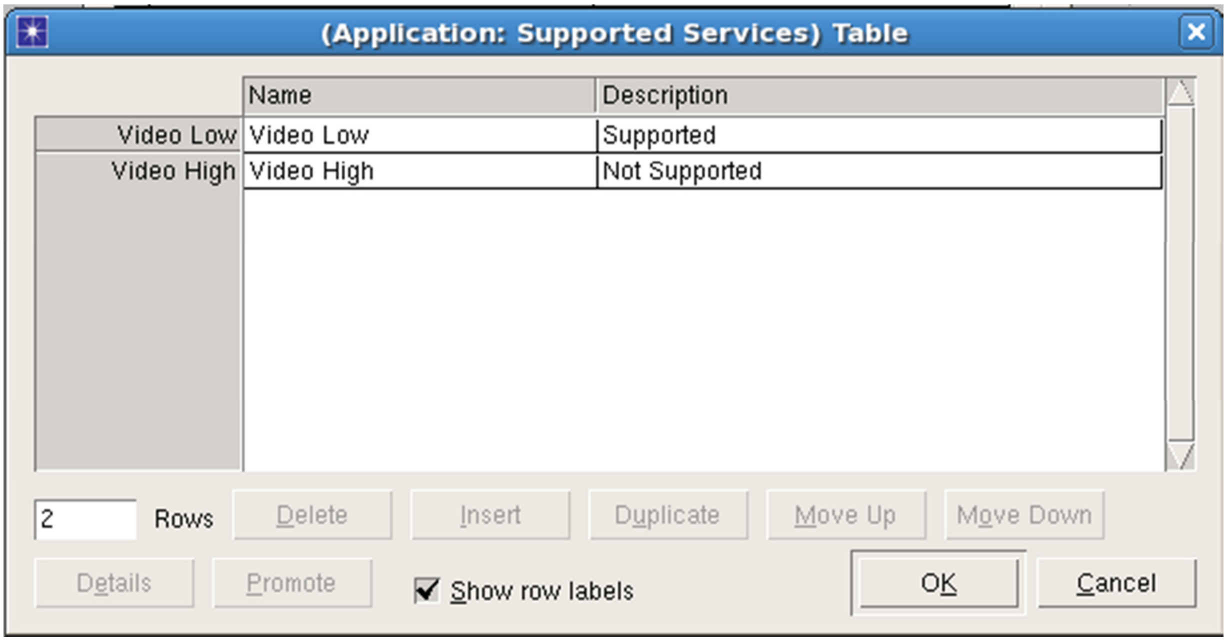
LTE Attributes: Channel configuration



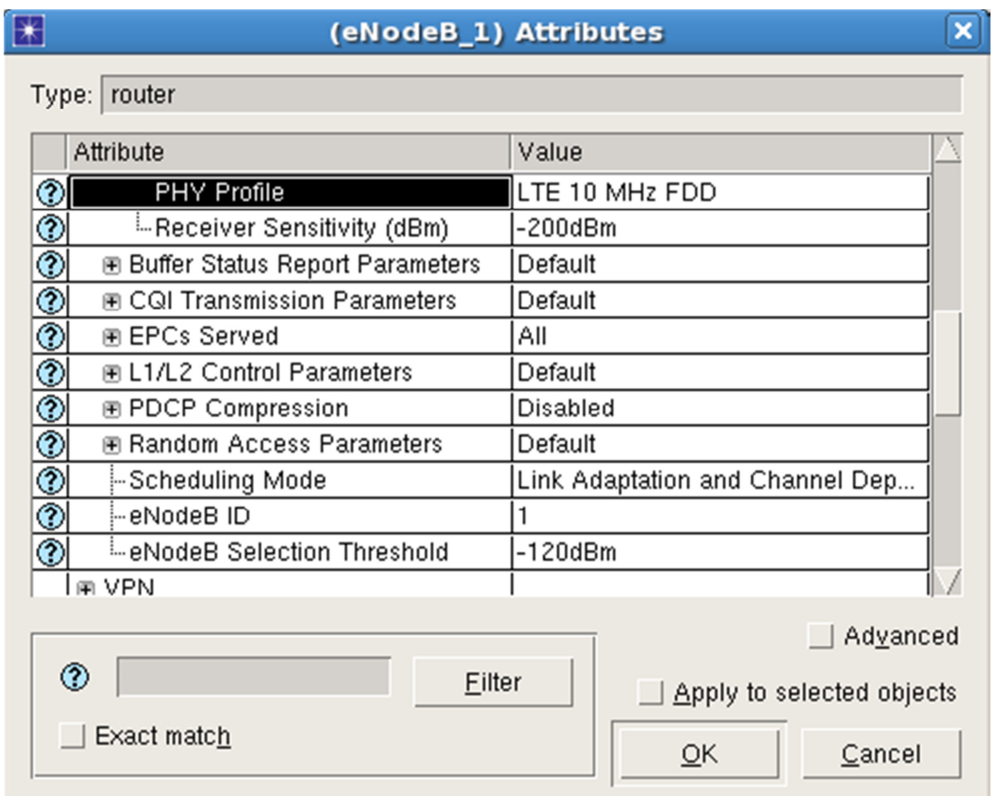
m_usr: Pathloss



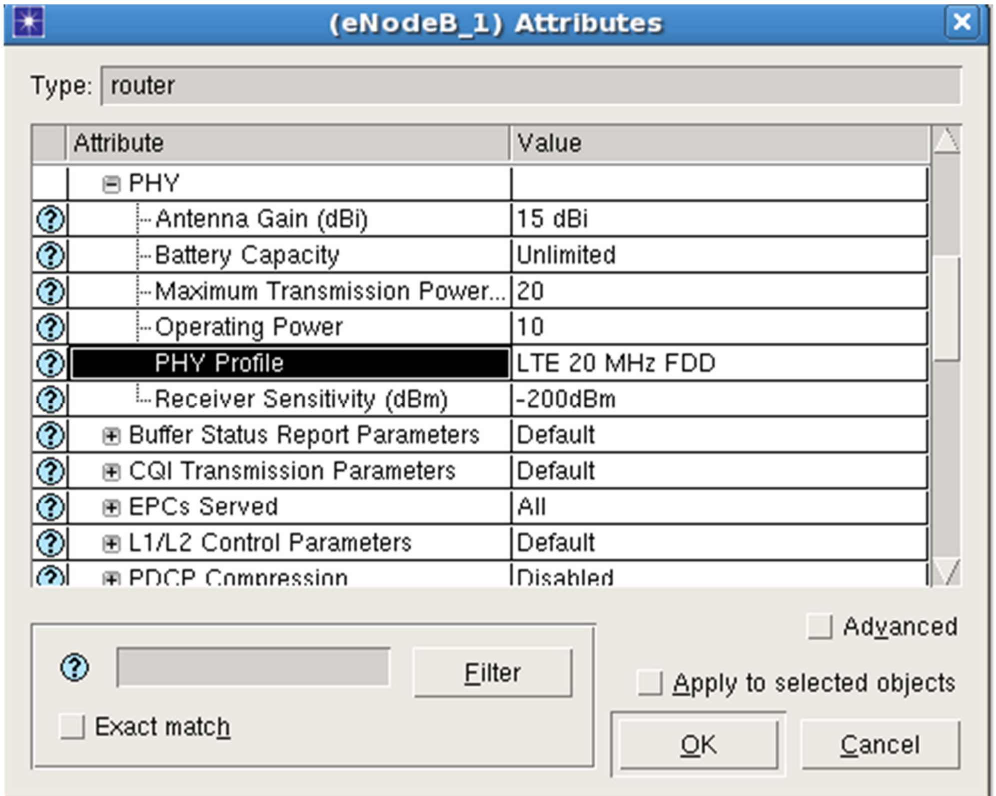
m_usr: application configuration 1



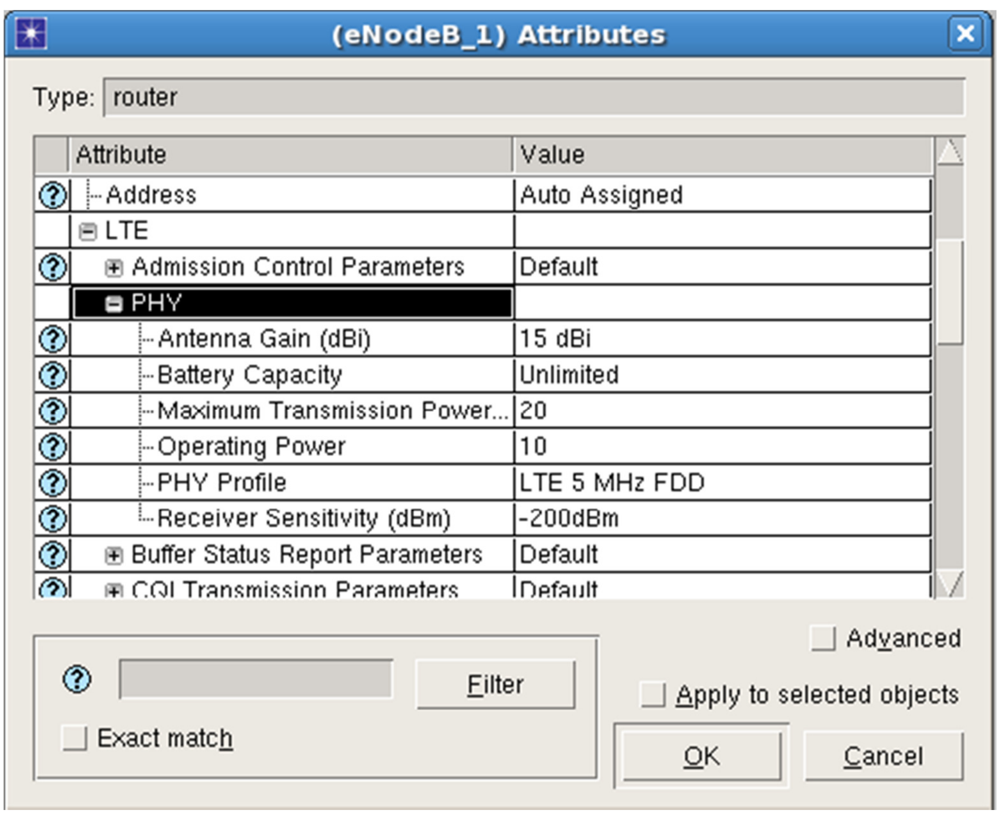
m_usr: application configuration 2



eNodeB: Bandwidth 10MHz



eNodeB: Bandwidth 20MHz



eNodeB: Bandwidth 5MHz