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Performance Comparison between LTE and WiMAX Based on Link Level Simulation

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Abstract – This article presents a framework for performance comparison between Long Term Evolution (LTE) and WiMAX technologies, depended on link level simulation, under different conditions (e.g. a mixture of channel models and modulation coding schemes (MCS)). Two performance metrics have been used: throughput against SNR for both downlink (DL) and uplink (UL) and block error rate (BLER) against SNR for both DL and UL. Simulation results, conducted in network simulator OPNET Modeler ver. 17.1, show that the throughput and the BLER increases as the MCS increase (i.e. MCS=5, 15, 24).

Index Terms – LTE, WiMAX, OPNET Modeler ver. 17.1, DL-BLER, UL-BLER, MCS, DL-SNR, UL-SNR, Throughput.

1. INTRODUCTION

Link level simulation is employed to estimate radio access technologies under enormous changing conditions [1].

System level simulator, which simulates all characteristics of the end to end transmission, supports also channel model functionality. Characteristics of physical layer plus characteristics of MAC layer are simulated by the link level simulator. The results acquired through this system will be more sensible and indicative since it happens in full mobile environment.

In link level simulation the following functions modelled with its parameters. The link level entities that can be modelled in the two systems, (LTE and WIMAX), containing the physical layer aspects, plus MAC layer aspects as shown below:

Physical layer parameters [2]:

- Frequency range.
- TDD or FDD.
- Channel bandwidth.
- Subcarrier permutation.
- OFDM, OFDMA, spread OFDM (SOFDM), spread OFDMA (SOFDMA), SC-FDMA
- Cyclic prefix length.
- Frame length.
- Control channel overheads on the physical channel.
- Channel model.
- Deployment scenario.
- ARQ, HARQ.
- MIMO system.
- Handover impact on the throughput plus delay.

MAC layer aspects:

- Link adaptation procedures [3]

  It is a radio resource management functionality (RRM), it is a layer 2 (MAC) operations that is used to determine the finest modulation and coding scheme for certain transmission anchored in the channel quality indicator (CQI) feedback which provides information to the packet scheduler.

- Scheduling algorithm [3]

  As stated in the ITU-R report M.2135-1.

The principles that are to be followed when evaluating the 4G candidate radio interface technology include:

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- External evaluation group can do complete or else partial evaluation of single or more technology.
- Computer simulation should include system level plus link level.
- Evaluation group may employ their possess simulation tools.
- Self-evaluation has to be complete evaluation and provide a whole compliance template with the required values set by ITU-R.

In this research, many scenarios are created for performance comparison between LTE with WiMAX, where different channel models are applied, each channel model with various MCS=5, 15, 24. Performance metrics measured are throughput against SNR for downlink plus uplink and block error rate (BLER) against SNR for downlink plus uplink.

The rest of the paper partitioned as follows: Section 2 presents the related work. While short note for LTE and its system level is stated in Section 3.Section 4 introduces a brief note for WiMAX IEEE802.16m and its structure. The simulation steps and results based on simulated scenarios are explained in Section 5.Finally section 6 shows the conclusion and consistency of results with the theoretical results.

2. RELATED WORK

Many simulation systems have been used to compare the performance of LTE-advanced and WiMAX IEEE802.16m at the link level (i.e. physical layer, MAC layer).

In [4], toolbox is created for each LTE and WiMAX to simulate both system architecture equipment (SAE) and the network architecture using OPNET modeler.

In [5, 6], LTE plus WiMAX are simulated according to new proposed scenarios which created and modified at the Institute of Communications and Radio-Frequency Engineering.

In [7, 8], LTE lab and WiMAX lab are created using IS-wireless to simulate both SAE and network architecture.

The authors in [9] show influence of scheduling algorithms on the main access technique, (OFDMA), in both LTE plus WiMAX.

The authors in [10] study the effect of vertical handover applied on heterogeneous networks (e.g. LTE, WiMAX).

A comparison between WiMAX, LTE is discussed in [11, 12], where the similarities plus differences between the two systems have been studied to show the need to integrate LTE with WiMAX.

At [13] comparison between LTE and WiMAX is performed for the system level under similar conditions and it was simulated using OPNET modeler also, it shows that throughput at WiMAX is higher than throughput in LTE, and the round trip delay response time is better in LTE than WiMAX.

At [14], performance comparison between LTE and WiMAX using different MCS applied on the link level, the performance metrics was throughput and it conclude that LTE surpass WiMAX.

At [15], author proposed QOS framework for LTE plus WiMAX interoperability to reach the optimal traffic at both non-RT and real time (RT) scenarios.

At [16], performance metrics: throughput, latency were measured in both 4G systems, LTE, WiMAX on the system level.

3. LTE SYSTEM

The long term evolution (LTE) is recognized and standardized via 3GPP in release 8 (REL 8) in DEC 2008. Release 8, encompass the Evolved Packet Core (EPC) plus the evolved UTRAN (E-UTRAN) of the LTE networks, [17, 18].This release is adapted according to ITU-R [18-20].

The 3GPP REL 8 defines a novel physical layer anchored in OFDMA used in downlink and SC-FDMA used in uplink. LTE design aims comprise: throughput 100 Mb/s in downlink and 50 Mb/s in uplink when mobile speeds equal 350 Km/h, and throughput increasing to a maximum of 326.4 Mb/s in downlink and 86.4 Mb/s in uplink by MIMO 4×4 with BW=20 MHz .[17, 18].

The architecture of the LTE system is shown in Figure 1, which simulated and compatible with the 3GPP release 8 [17, 18].

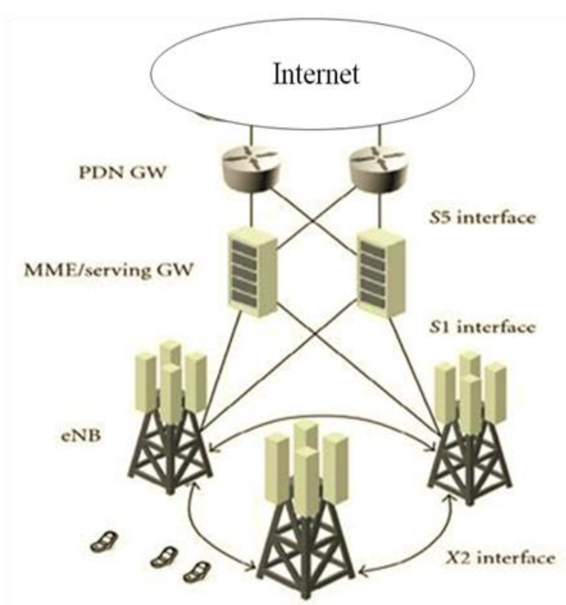

Figure 1: LTE System Architecture Release 8 [17, 18]

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4. WiMAX SYSTEM (IEEE802.16.0.e). [21, 22]

The WiMAX (worldwide interoperability microwave access) be a wireless metropolitan area network anchored in IEEE 802.16 at 2004 standard plus the IEEE 802.16e at 2005 standard which add features to 2004 standard as mobility plus WiMAX used in many applications [23]. These standards describe physical layer plus MAC layer as follows: SOFDMA used in Physical layer, where the assigned frequency band is 2-11 GHZ for NLOS plus frequency range 10-66 GHZ for LOS. The majority of implemented WiMAX networks work at 3.5 GHZ frequency range [20, 24]. MAC layer is planned to support packet transmission plus support IP and ATM protocols. 3 sub layers compromise MAC layer as follows:

- Common part sub layer.
- Convergence sub layer.
- Security sub layer.

Key swap between subscriber station (SS) and base station (BS), authentication plus encryption performs at security sub layer. The common part sub layer carry out connection maintenance, connection establishment plus bandwidth allocation. The convergence sub layer changes data and assign the service class to suitable traffic flow by necessitated quality of service.

WiMAX network [21] comprises: the SS, connectivity service network (CSN) which encompass (visited network service provider (VNSP) with home network service provider (HNSP)) and the access service network (ASN) which encompass (BS with the Access Service Network (ASN) gateway). WiMAX network is illustrated at Figure 2 [20, 21].

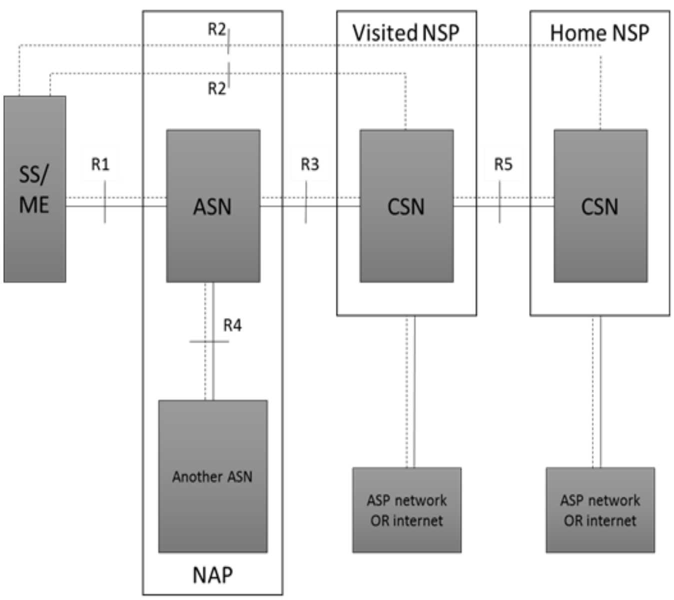

Figure 2: WiMAX network [20, 21]

5. COMPARISON BETWEEN LTE-ADVANCED AND WiMAX IEEE802.16m BASED ON LINK LEVEL SIMULATION USING OPNET MODELER VER. 17.1

The link level simulation of LTE (LTE-advanced) and WiMAX (IEEE802.16m) is performed using the same link level parameters set by ITU-R [21, 25-27]. The OPNET modeler ver. 17.1 dialog boxes for choosing the system and link parameters are as:

- Environment.
- Duplex technique: FDD, TDD.
- Operating frequency.
- Bandwidth=10MHz.
- Modulation technique: QPSK, 16 QAM and 64 QAM.
- Coding scheme: convolutional coder (CC) and convolutional turbo coder (CTC).
- Channel model: Pedestrian A, Pedestrian B, Vehicular A, and Vehicular B, which are described in ITU-R report M.2135-1.
- Number of subcarrier.
- OFDM, OFDMA, SOFDMA and SC-FDMA.
- Cyclic prefix.
- MIMO (uplink and downlink).

6. SIMULATION RESULTS AND DISCUSSIONS

The link level simulation results for both LTE and WiMAX IS presented here. OPNET modeler ver. 17.1 and MATLAB have been used to get the results and Figures 3 to 18. Different scenarios are created for LTE and WiMAX, for three cells using application demand (i.e. end to end call in OPNET Modeler ver. 17.1) which established between two devices in two different cells and applying different channel models (pedestrian A, pedestrian B, vehicular A and vehicular B) each one with three different MCS= (5, 15, 24).

The symbol A in the channel model pedestrian A or vehicular A indicates low delay spread, and the symbol B in the channel model pedestrian B or vehicular B indicates medium delay spread.

Different scenarios can be classified as follows (R= coding rate):

6.1. Scenario 1:

Channel models: pedestrian A

For LTE:

MCS=5 (equivalent to QPSK, R=1/2 in WiMAX)

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MCS=15 (equivalent to 16QAM, R=1/2 in WiMAX)

MCS=24 (equivalent to 64QAM, R=1/2 in WiMAX)

For WiMAX:

QPSK, R =1/2

16QAM, R =1/2

64QAM, R =1/2

6.2. Scenario 2:

Channel models: vehicular A

For LTE:

MCS=5 (equivalent to QPSK, R=1/2 in WiMAX)

MCS=15 (equivalent to 16QAM, R=1/2 in WiMAX)

MCS=24 (equivalent to 64QAM, R=1/2 in WiMAX)

For WiMAX:

QPSK, R =1/2

16QAM, R =1/2

64QAM, R =1/2

6.3. Scenario 3:

Channel models: pedestrian B

For LTE:

MCS=5 (equivalent to QPSK, R=1/2 in WiMAX)

MCS=15 (equivalent to 16QAM, R=1/2 in WiMAX)

MCS=24 (equivalent to 64QAM, R=1/2 in WiMAX)

For WiMAX:

QPSK, R =1/2

16QAM, R =1/2

64QAM, R =1/2

6.4. Scenario 4:

Channel models: vehicular B

For LTE:

MCS=5 (equivalent to QPSK, R=1/2 in WiMAX)

MCS=15 (equivalent to 16QAM, R=1/2 in WiMAX)

MCS=24 (equivalent to 64QAM, R=1/2 in WiMAX)

For WiMAX:

QPSK, R =1/2

16QAM, R =1/2

64QAM, R =1/2

The performance comparison between LTE and WiMAX is based on the following performance metrics:

- Throughput against DL-SNR
- Throughput against UL-SNR
- BLER (Block Error Rate) against DL-SNR
- BLER (Block Error Rate) against UL-SNR

6.5. Scenario 1: Channel models-pedestrian A

Figure 3 shows LTE throughput of user equipment (UE) against DL-SNR for MCS= 5, 15, 24, with channel model pedestrian A.

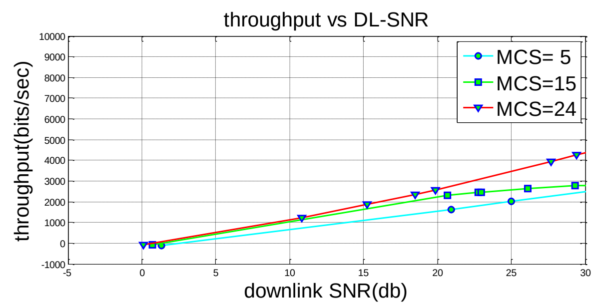

Figure 3 LTE Throughput against Downlink SNR, MCS=5, 15, 24, with Channel Model Pedestrian A

Figure 4 shows WiMAX throughput against DL-SNR for QPSK, 16QAM, 64QAM, R=1/2 with channel model pedestrian A.

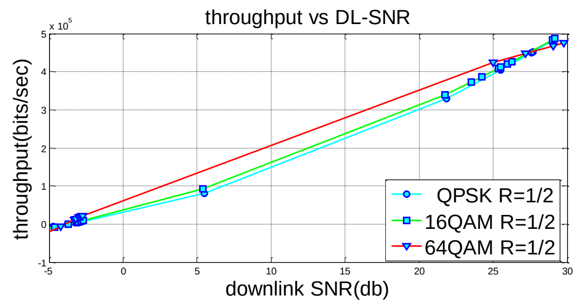

Figure 4 WiMAX Throughput against Downlink SNR for QPSK, 16QAM, 64QAM, R=1/2 with Channel Model Pedestrian A

It can be shown that from Figure 3 and 4 as MCS increases at LTE (which mean higher order modulation at WiMAX but larger coding rate), the throughput increases as SNR increases. Also, we note that the throughput of WiMAX is higher than that of LTE, for all values of MCS, because the release simulated in OPNET Modeler is LTE REL 8 and for WiMAX is IEEE802.16m

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Figure 5 shows LTE UL-BLER against UL-SNR for MCS=5, 15, 24, with channel model pedestrian A.

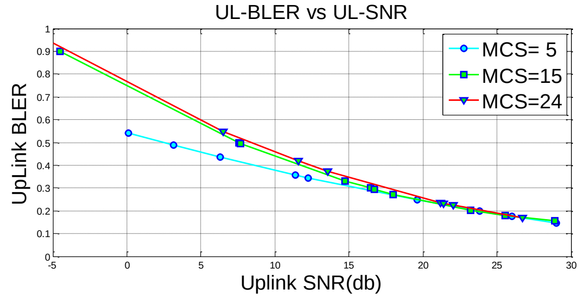

Figure 5 LTE UL-BLER against Uplink SNR, MCS=5, 15, 24, with Channel Model Pedestrian A

Figure 6 shows WiMAX UL-BLER against UL-SNR for QPSK, 16QAM, 64QAM, R=1/2 with channel model pedestrian A.

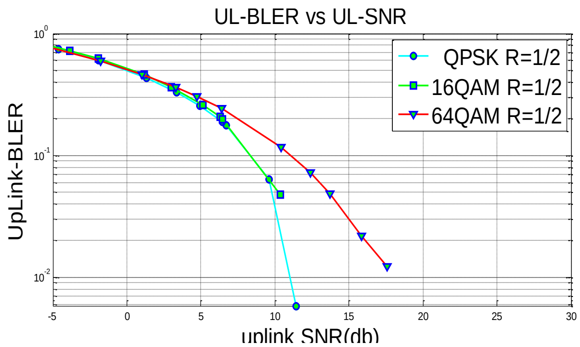

Figure 6 WiMAX UL-BLER against Uplink SNR, QPSK, 16QAM, 64QAM, R=1/2 with Channel Model Pedestrian A

From Figure 5 and 6 it can be shown that the block error rate of LTE is lower than that of WiMAX, for all MCS, due to LTE using SC-FDMA in uplink than OFDMA in WiMAX.

6.6. Scenario 2: Channel Models – Vehicular A

Figure 7 shows LTE throughput user equipment (UE) against DL-SNR for MCS=5, 15, 24, with channel model vehicular A.

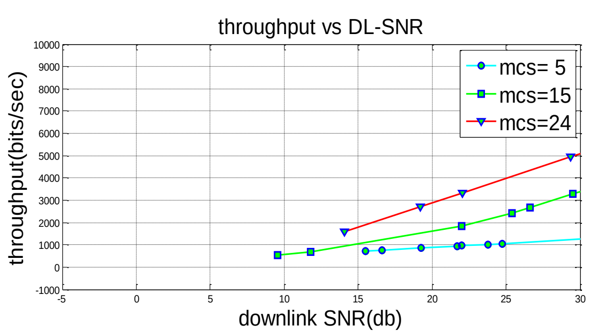

Figure 7 LTE Throughput against Downlink SNR, MCS=5, 15, 24, with Channel Model Vehicular A

Figure 8 shows WiMAX throughput against DL-SNR for QPSK, 16QAM, 64QAM, R=1/2 with channel model vehicular A.

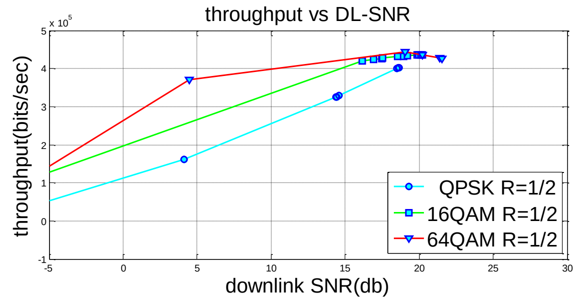

Figure 8 WiMAX Throughput against Downlink SNR, QPSK, 16QAM, 64QAM, R=1/2 with Channel Model Vehicular A.

We note that from Figure 7 and 8 the achieved throughput for LTE and WiMAX in case of pedestrian A is higher than that in case of vehicular A. this is due the fading effect. Also, we note that the throughput of WiMAX is higher than that of LTE, for all values of MCS.

Figure 9 shows LTE UL-BLER against UL-SNR for MCS=5, 15, 24, with channel model vehicular A.

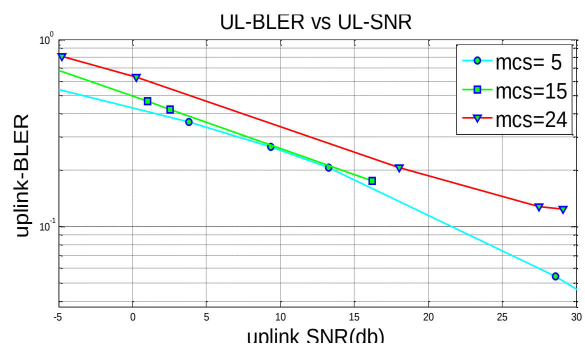

Figure 9: LTE UL-BLER against Uplink SNR, MCS=5, 15, 24, with Channel Model Vehicular A

Figure 10 shows WiMAX UL-BLER against UL-SNR for QPSK, 16QAM, 64QAM, R=1/2 with channel model vehicular A.

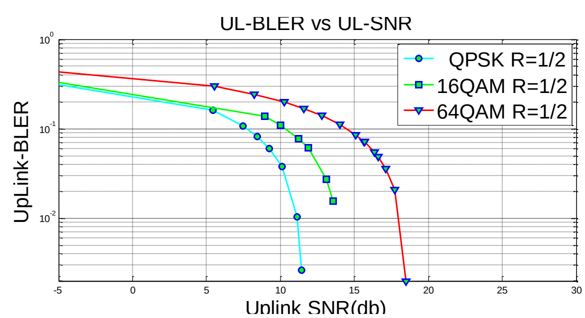

Figure 10 WiMAX UL-BLER against Uplink SNR, QPSK, 16QAM, 64QAM, R=1/2 with Channel Model Vehicular A

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It's obvious from Figures 9 and 10 that LTE has achieved better performance in BLER than WiMAX (low BLER at higher uplink SNR).

6.7. Scenario 3: Channel models -pedestrian B

Figure 11 shows LTE throughput user equipment (UE) against UL-SNR for MCS=5, 15, 24, with channel model pedestrian B.

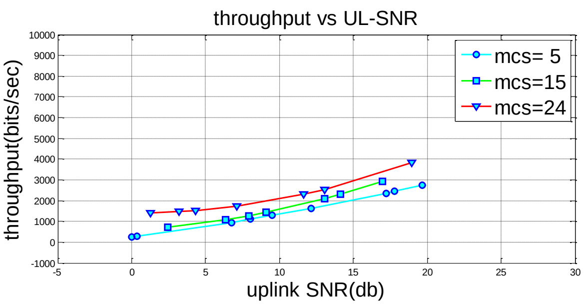

Figure 11 LTE Throughput against Uplink SNR, MCS=5, 15, 24, with Channel Model Pedestrian B

Figure 12 shows WiMAX throughput against UL-SNR for QPSK, 16QAM, 64QAM, R=1/2 with channel model pedestrian B.

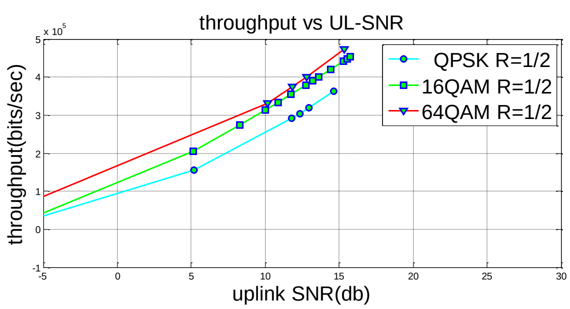

Figure 12 WiMAX Throughput against Uplink SNR, QPSK, 16QAM, 64QAM, R=1/2 with Channel Model Pedestrian B

From Figure 11 and 12 it is clear that the throughput of WiMAX is higher than that of LTE, for all values of MCS. Also it should be noted that the throughput in case of pedestrian B is less than that one in case of pedestrian A, this due to the higher delay spread in case of pedestrian B.

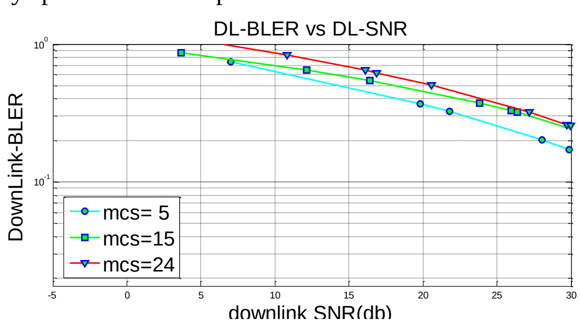

Figure 13 LTE DL-BLER against Downlink SNR, MCS=5, 15, 24, with Channel Model Pedestrian B

In the Figures 13 and 14 BLER will be analyzed. Figure 13 shows LTE DL-BLER against DL-SNR for MCS=5, 15, 24, with channel model pedestrian B.

Figure 14 shows WiMAX DL-BLER against DL-SNR for QPSK, 16QAM, 64QAM, R=1/2 with channel model pedestrian B.

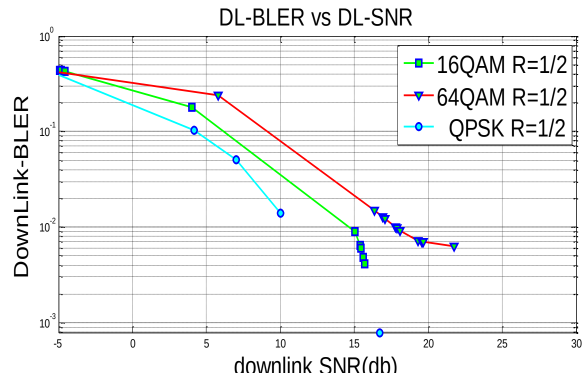

Figure 14 WiMAX DL-BLER against Downlink SNR for QPSK, 16QAM, 64QAM, R=1/2 with Channel Model Pedestrian B

From Figure 13 and 14 it can be shown that the block error rate changes from 0-1 the block error rate is smallest for QPSK (MCS=5) moderate for 16QAM (MCS=15) and highest for 64QAM (MCS=24); generally block error rate decrease as SNR increase. Also we note that WiMAX achieves higher BLER than LTE, for all MCS, due to LTE using SC-FDMA in uplink than OFDMA in WiMAX. Also it should be noted that the BLER in case of pedestrian B is higher than that one in case of pedestrian A, this due to the higher delay spread in case of pedestrian B.

6.8. Scenario 4: Channel models –vehicular B

Figure 15 shows LTE throughput user equipment (UE) against UL-SNR for MCS=5, 15, 24, with channel model vehicular B.

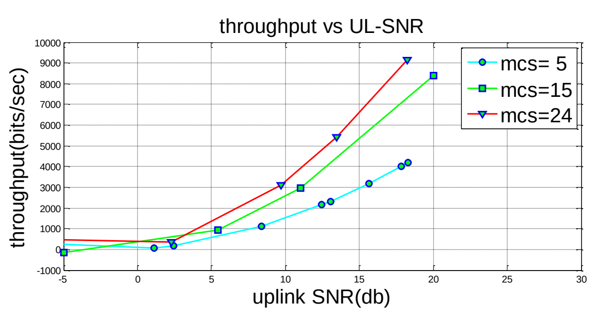

Figure 15 LTE Throughput against Uplink SNR, MCS=5, 15, 24, with Channel Model Vehicular B

Figure 16 shows WiMAX throughput against UL-SNR for QPSK, 16QAM, 64QAM, R=1/2 with channel model vehicular B.

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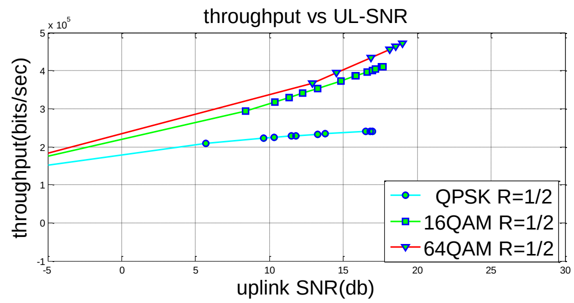

Figure 16 WiMAX Throughput against Uplink SNR, QPSK, 16QAM, 64QAM, R=1/2 with Channel Model Vehicular B

It can be shown that from Figure 15 and 16 as MCS increases at LTE (which mean higher order modulation at WiMAX but larger coding rate), the throughput increases as SNR increases in all MCS, comparing results here with the results of Figures 7 and 8, we note that the throughput is better when using channel model vehicular A due to its lower delay spread. Also, WiMAX achieve higher throughput than that of LTE in the previous Figures 7, 8, 15, and 16.

Figure 17 shows LTE DL-BLER against DL-SNR for MCS=5, 15, 24, with channel model vehicular B.

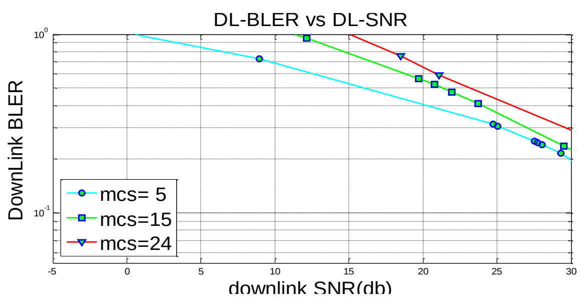

Figure 17 LTE DL-BLER against Downlink SNR, MCS=5, 15, 24, with Channel Model Vehicular B

Figure 18 shows WiMAX DL-BLER against DL-SNR for QPSK, 16QAM, 64QAM, R=1/2, with channel model vehicular B.

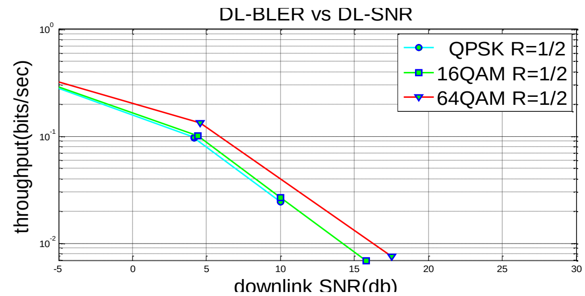

Figure 18 WiMAX DL-BLER against Downlink SNR, QPSK, 16QAM, 64QAM, R=1/2 with Channel Model Vehicular B

From Figure 17 and 18 we note that WiMAX achieves higher BLER than LTE, for all MCS. And it's clear that the BLER is lower at channel model pedestrian B than that of vehicular B.

Finally, as comprehensive vision we note that, in case of downlink the LTE technique achieves lower BLER than WiMAX and at uplink and downlink, this due to access technique used in uplink at LTE, which is SC-FDMA. Table 1 illustrates the overall performance metrics comparison results between LTE and WiMAX.

7. CONCLUSION

Link level simulation results showed that WiMAX is outperforming LTE and give better throughput performance whatever the channel model. Also, the LTE BLER is lower than that in WiMAX in downlink, and uplink.

The final conclusion from link level simulation is that the two systems (LTE and WiMAX) present almost similar performance based on different channel models and different SNR value.

Scenario	MCS	LTE				WiMAX			
		Down-Link		Up-Link		Down-Link		Up-Link	
		Average Throughput	Average BLER	Average Throughput	Average BLER	Average Throughput	Average BLER	Average Throughput	Average BLER
1 Pedestrian A	5	2,355.24	0.188	2,355.24	0.326	168797.2	0.211	168797.2	0.358
	15	1,822.35	0.068	1,822.35	0.363	206294.6	0.134	206294.6	0.365
	24	2,614.68	0.106	2,614.68	0.396	181190.3	0.262	181190.3	0.357
2 Vehicular A	5	1236.176	0.381	1236.176	0.332	160497.1	0.392	160497.1	0.397
	15	2,694.77	0.332	2,694.77	0.32	214748.5	0.371	214748.5	0.420
	24	3,526.19	0.312	3,526.19	0.27	176794.8	0.317	176794.8	0.357
3 Pedestrian B	5	1,972.50	0.223	1,972.50	0.381	162288.2	0.303	162288.2	0.419
	15	2,191.64	0.340	2,191.64	0.382	209106.2	0.328	209106.2	0.426
	24	1,383.83	0.319	1,383.83	0.395	180531.3	0.219	180531.3	0.396
4 Vehicular B	5	1808.333	0.458	1808.333	0.322	123431.1	0.457	123431.1	0.442
	15	2,179.16	0.402	2,179.16	0.350	202396.6	0.487	202396.6	0.386
	24	3739.09	0.329	3739.09	0.382	177887.5	0.490	177887.5	0.393

Table 1: The Overall Performance Metrics Comparison Results between LTE and WiMAX

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