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Effect of Bandwidth Scalability on System Performance in the Downlink LTE Systems

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Abstract: Long Term Evolution (LTE) system employs Orthogonal Frequency Division Multiple Access (OFDMA) in downlink in order to support network deployment using various system bandwidth configurations i.e., 1.4MHz, 3MHZ, 5MHz, 10MHz, 15MHz and 20MHz. The bandwidth scalability enables operator to access multiple channels to achieve higher peak data rates. Also, the bandwidth scalability allows operators to deploy LTE network with the existing spectrum or newly licensed band. Therefore the study on performance of LTE system with different bandwidth configuration becomes vital. Hence in this paper, an attempt has been made to study and compare the performance of LTE system with different spectrum configuration i.e., 1.4MHz, 3MHz, 5MHz, 10MHz, 15MHz and 20MHz for Constant Bit Rate (CBR) traffic scenario in the downlink. The performance metrics considered for simulation studies are aggregate bytes received, average throughput, average delay and average jitter.

Keywords- *LTE*, OFDMA, downlink, bandwidth scalability, aggregate bytes received, avearge throughput, avearge delay, average jitter

I. INTRODUCTION

Long Term Evolution (LTE) is fourth generation broadband wireless access technology developed by Third Generation Partnership Project (3GPP) to provide higher user data rates, improved system throughput, reduced latency, coverage and reduced cost [1]. The higher data rates and throughput are necessary to support various multimedia applications such as high definition (HD) video, HD video teleconferencing, moving pictures, video streaming and HD TV etc. However the higher data rate and system throughput depends on the availability of bandwidth for the services in LTE systems [2]. Hence LTE has been designed as a highly flexible radio access technology in order to support several system bandwidth configurations i.e., 1.4MHz, 3MHZ, 5MHz, 10MHz, 15MHz and 20MHz. Bandwidth scalability in LTE system is possible due to Orthogonal Frequency Division Multiple Access (OFDMA) in the downlink. With OFDMA, radio resource allocation per user can be made in time-frequency domain for all bandwidth configurations as shown in Figure 1 [3]. In time domain, LTE frame is composed of ten consecutive Transmission Time Intervals (TTIs) of 1ms duration. A TTI consists of two equally sized time slots of 0.5ms where each slot contains 7 consecutive OFDMA symbols (including 1 control and 6 data symbols) for normal cyclic prefix. In frequency domain, the system bandwidth is divided into sub-channels of 180KHz consisting of 12 consecutive subcarriers (15KHz). One sub-channel and the corresponding time slot is called a Resource Block (RB) and a group of two consecutive RBs in a TTI is the minimum scheduling unit which can be allocated to a user [4].

Available RBs can be shared between multiple users at every TTI based on scheduling policy implemented at eNBs. Also the OFDMA assigns each user with needed bandwidth for their transmission. Unassigned subcarriers are off, thus reducing power consumption and interference. This enables the cost-efficient solutions for very wide carriers with high peak rates.

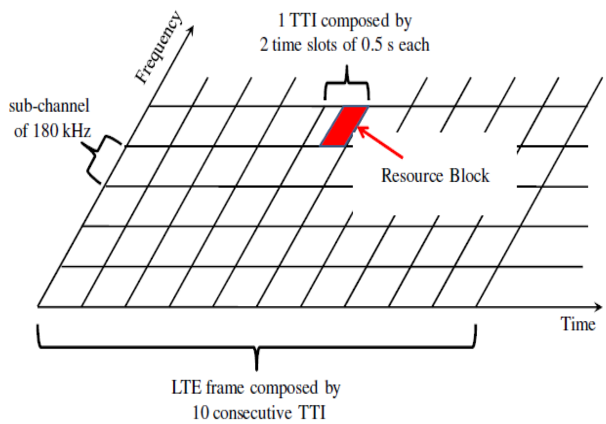

Figure 1. Time-Frequency radio resources grid.

The rest of the paper is organised as follows. Section II gives a brief insight of bandwidth scalability for LTE downlink. Section III gives a brief explanation of LTE architecture. Simulation studies and results are given in section IV and Section V concludes the paper.

II. BANDWIDTH SCALABILITY IN LTE DOWNLINK SYSTEM

The OFDMA supports bandwidth scalability in the LTE downlink due to flexibility of spectrum usage. Using OFDMA, the service providers can use up to 20MHz of system bandwidth to achieve higher system performance [1]. The increase in system bandwidth increases the numbers of RBs for transferring data. Therefore, 20MHz system bandwidth configuration provide better system performance compared to other bandwidth configurations such as 1.4MHz, 3MHz, 5MHz, 10MHz and 15MHz due to the availability of more numbers of RBs for data transmissions [5, 7]. When the existing spectrum is limited with this bandwidth scalability the service providers can use higher bandwidth configuration to provide better services [5, 6]. The number of RBs is available for transferring data in the downlink LTE system for different bandwidth configurations is listed in Table-I [5, 8]. The bandwidth scalability also enables the reuse of the existing site infrastructure such as antennas, feeder cables, masts, hardware racks and power supply elements and hence the operators can deploy LTE network with the existing spectrum or newly licensed band to upgrade the system capacity with reduced initial investments [9]. In practical terms, the data rate and system throughput achievable in LTE network depends on the bandwidth allocated for services. The LTE network deployed with higher bandwidth increases the throughput whereas lower bandwidth configuration provides cost-effective deployment [2].

Table I. Channel bandwidth with Resource blocks

Channel bandwidth (MHz)	**1.4**	***3***	***5***	***10***	***15***	**20**
Number of resource blocks	6	15	25	50	75	100

III. ARCHITECTURE OF LTE SYSTEM

LTE has IP based flat network architecture which enables high spectral efficiency, low cost and low latency [1, 9]. The network architecture of LTE consists of Evolved UMTS Terrestrial Radio Access Network (E-UTRAN) and the Evolved Packet Core (EPC) as shown in Figure 2. The E-UTRAN and EPC are collectively known as EPS (Evolved Packet System) [10]. The E-UTRAN is the radio access network of LTE which consists of interconnected eNBs by X2 interface. The eNB is responsible for Radio Resource Management (RRM) mechanism such as radio bearer control, radio admission control, mobility management, scheduling and dynamic allocation of radio resources to UEs in both uplink and downlink [11]. EPC is an Internet Protocol (IP) based core network, consists of network entities such as Mobility Management Entity (MME), Serving Gateway (S-GW), Packet Data Network Gateway (P-GW) etc. The main functions performed by the MME are UE location update, roaming management, controlling the UE authentication, the connections establishment and security negation [12]. The S-GW is a switching and routing node that routes and forwards the user data packets to and from the eNB. The Packet Data Network Gateway (P-GW) connects the EPC to the internet. The P-GW is responsible for allocation of the IP address for a specific UE and also it acts as a mobility anchor for non-3GPP radio-access technologies connected to the EPC. The EPC communicates with packet data networks in the outside world such as internet, private corporate networks or the IP multimedia subsystem for accessing the multimedia services, such as online television, moving pictures, video streaming, teleconferencing, blogging, social networking, and interactive gaming with security and privacy for the user.

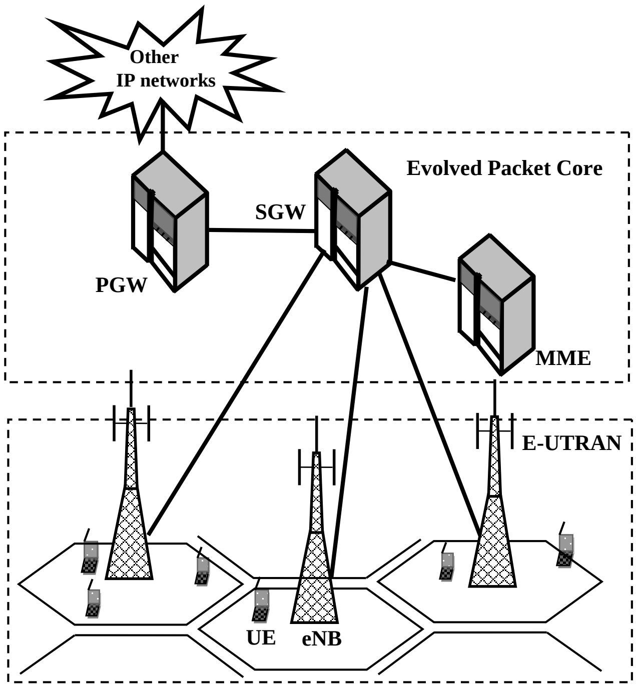

Figure 2. Architecture of LTE system.

IV. SIMULATION STUDIES AND RESULTS

The system performance of LTE network with bandwidth scalability is evaluated using QualNet 5.2 network simulator.

Table II. Channel bandwidth with Resource blocks.

Property		***Value***
Simulation-Time		30S
Downlink-Channel-Frequency		2.4GHz
Uplink-Channel-Frequency		2.5GHz
Propagation-Model		Statistical
Channel-Fading-Model		Rayleigh
Channel-Bandwidth		1.4, 3, 5, 10, 15 and 20MHz
Antenna-Model		Omnidirectional
eNB	PHY-Tx-Power	46dBm
	PHY-Tx-Antennas	1
	Antenna-Height	10m
	MAC-Tx-Mode	1(SISO)
UE	MAC-Scheduler-Type	Simple-Scheduler
	PHY-Tx-Power	23dBm
	PHY- Rx-Antennas	1
	Antenna-Height	1.5m
Traffic type		CBR
Data rate		367Kbps

A single cell scenario of terrain area 1.5Km X 1.5 Km with two-ray path loss model and constant shadowing of mean 4dB is considered for the simulation studies. The remaining simulation parameters considered for simulation studies are listed in Table- II. The snapshot of the scenario designed for the simulation studies using QualNet 5.2 simulator is shown in Figure 3. In this scenario, performance of LTE network is evaluated for bandwidth scalability by varying the node density. Initially, the simulation study is carried out for a system bandwidth of 1.4MHz by considering an eNB and a UE with a CBR connection. The performance metrics such as aggregate bytes received, average throughput, average delay and average jitter are evaluated. Simulation studies are repeated by increasing the number of UEs (with a downlink CBR connection for each UE) from 2 to 10 in steps of 1 node, from 10 to 20 in steps of 5 nodes and from 20 to 100 in steps of 20 nodes. The simulation studies are also repeated by considering the system bandwidths 5MHz, 10MHz and 20MHz.

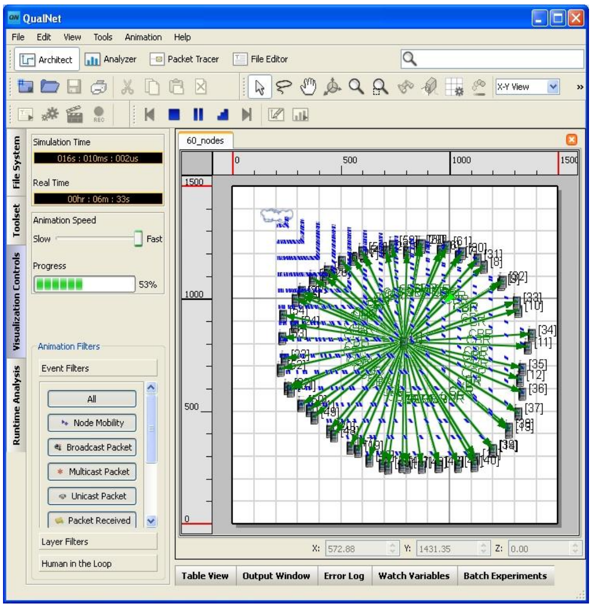

Figure 3. Snapshot of the Scenario designed for simulation studies.

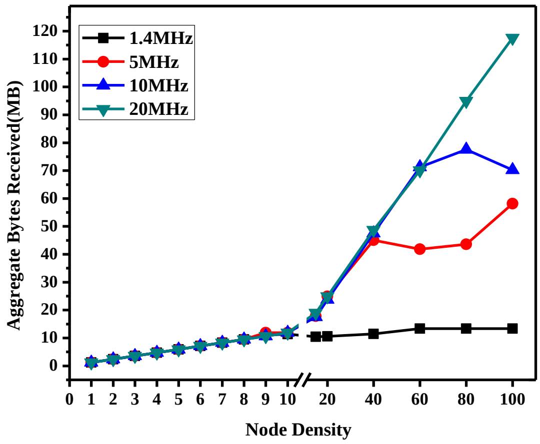

Figure 4. Aggregate bytes received performance for different bandwidth configurations with varying node density.

Figure 4 shows the aggregate bytes received performance for different bandwidth configurations with varying node densities. It is observed from Figure 4 that for node densities less than 10, the aggregate bytes received is almost same for all the system bandwidths. Since, for lower node densities number of RBs required for transferring data are less than the available RBs of the system bandwidths [9, 13]. Further from Figure 4, it is also depicted that the aggregate bytes received saturates as the node densities increases for all system bandwidths. As the node densities increases, number of RBs required for transferring data are also increases leading to scarcity of RBs [14, 15]. Also, from Figure 4 it is evident that aggregate bytes received for 20MHz saturates for higher node densities compared to other bandwidth configurations due to the availability of more number of RBs [5, 16].

Figure 5 shows the aggregate bytes received performance for various node densities with bandwidth scalability. From, Figure 5 it is observed that the aggregate bytes received is better for higher node densities because more numbers of RBs of the system bandwidth is utilized for transferring data.

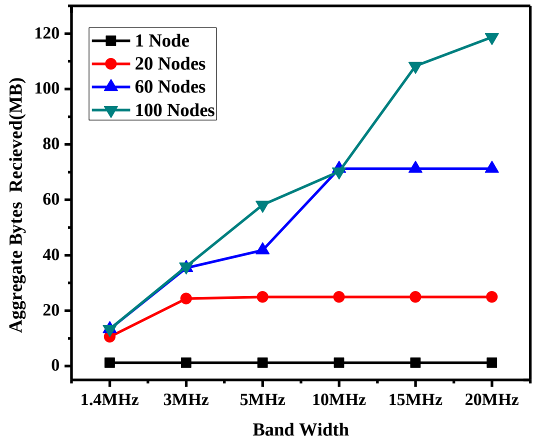

Figure 5. Aggregate bytes received performance for various node density with bandwidth scalability.

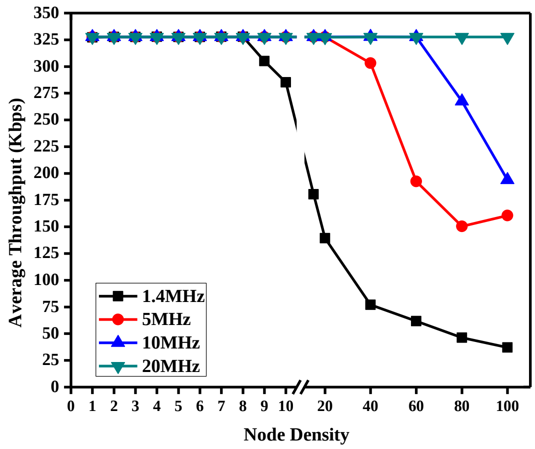

Figure 6. Average Throughput performance for different bandwidth configurations with varying node density.

Figure 6 illustrates the average throughput performance for different bandwidth configurations with varying node densities. It is evident from Figure 6 that the average throughput performance is same for all bandwidth configurations for node densities less than 8 due to the less complexity and the availability of sufficient number of RBs for transferring data. Throughput performance for 20MHz is better due to the availability of more numbers of RBs [17].

Average throughput performance for various node densities with bandwidth scalability is illustrated in Figure 7. The average throughput performance of LTE network is better for lower node densities. Since sufficient number of RBs are available for transferring data.

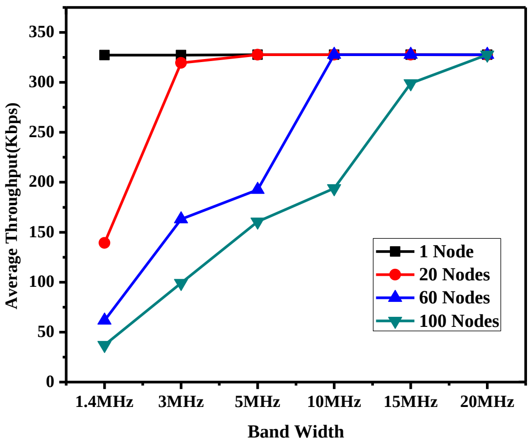

Figure 7. Average throughput performance for varying node density with bandwidth scalability.

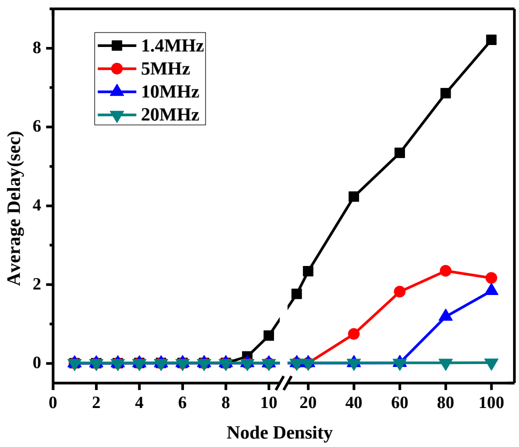

Figure 8. Average delay performance for different bandwidth configurations with varying node density.

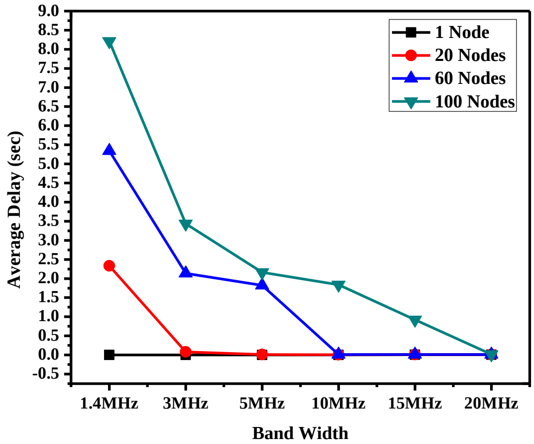

Figure 9. Average delay performance for varying node density with bandwidth scalability.

Figure 8 shows the average delay performance for different bandwidth configurations with varying node densities. It is observed from Figure 8 that the average delay is less for higher bandwidth configurations, since more number of RBs are available for data transfer with higher bandwidth configurations (Table I)[5, 16].

Figure 9 shows the average delay performance for various node densities with bandwidth scalability. It is depicted from Figure 9 that the average delay is less for lower node density due to the less complexity and the availability of sufficient number of RBs for transferring data [5, 16].

Figure 10 shows the average jitter performance for different bandwidth configurations with varying node densities. It is observed from Figure 10 that the average jitter is less for lower system bandwidth configurations due to less complexity [5, 16]. Further it is depicted from Figure 10 that as the node density increases beyond 8, the additional jitter incur due to scarcity of RBs [14, 15].

Figure 11 shows the average jitter performance for various node densities with bandwidth scalability. From Figure 11 it is evident that average jitter performance better for lower node densities due to the availability of sufficient number of RBs for transferring data [5, 16].

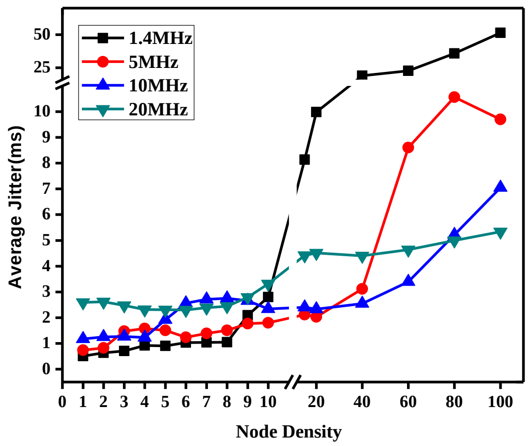

Figure 10. Average jitter performance for different bandwidth configurations with varying node density.

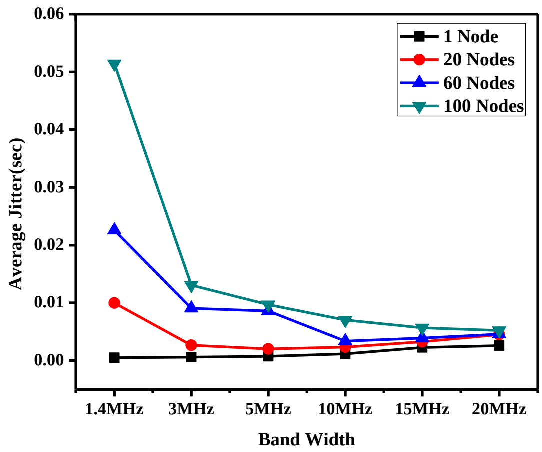

Figure 11. Average jitter performance for varying node density with bandwidth scalability.

V. CONCLUSIONS

In this paper, the effect of bandwidth scalability with various node density on system performance is evaluated using QualNet 5.2 simulator considering aggregate bytes received, average throughput, average delay and average jitter are performance metrics. The simulation results show that the performance of 20MHz system bandwidth is better than all other system bandwidth configurations i.e., 1.4MHz, 3MHz 5MHz, 10MHz and 15MHz.

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