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Effect on System Performance due to Upgradation of 2G/3G System to LTE

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Abstract

In the current environment of burgeoning demand for mobile broadband, Long Term Evolution (LTE) is the most preferred wireless technology for the mobile operators. Considering the legacy multi-technology networks, operators need to strategically work upon maximizing their revenue while minimizing their cost and satisfying the subscriber's requirements as well. Operators have a choice between 2 network strategies- LTE overlay and single radio access network (SRAN). A survey carried out proved SRAN to be the optimum LTE deployment strategy considering the total cost of ownership (TCO). This paper discusses the effect on the system performance due to the up gradation of network from second generation (2G) to third generation (3G) to long term evolution (LTE) systems using Nokia Siemens Network Flexi multi-radio base stations. Measurements of RSRP (Reference Signal Received Power), SINR (Signal to Interference plus Noise Ratio) and throughput were carried out by a drive test within 2Km of the deployed site area which indicated that all the 3 parameters were affected as the user equipment moved away from the site area and towards the cell edges. This problem can be addressed by deployment of low power relay nodes, one of the promising techniques, for increasing the coverage of LTE advanced networks (the future of LTE systems).

Index Terms: Drive test; Received Signal Received Power; Signal to Noise Ratio; throughput; Long Term Evolution system.

1. Introduction

In Internet protocol Multimedia Subsystem (IMS) based 4G/LTE networks; the diameter traffic generated by smart phones and other mobile devices is going to increase exponentially with increase in number of mobile subscribers. This diameter traffic along with session initiation protocol (SIP) traffic results in requirement of

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wider bandwidth. As compared to their legacy GSM 2G and UMTS 3G networks, the LTE wireless networks offer wider bandwidths due to improved spectral efficiency obtained with use of OFDM schemes. These wider bandwidths in turn support higher datarates [1]. But the spectral efficiency decreases with distance from the eNodeB as at larger distances the received power decreases due to path loss, interference and increase in noise level [2]. With distance the radio parameters such as received signal received quality (RSRQ), signal to interference to noise ratio (SINR), received signal received power (RSRP) levels and throughput degrade drastically in case of LTE systems as compared to that in 2G and 3G systems.

2. Related Work

The work carried out in the research article by Prabhat Sainju [3] discusses the performance of LTE 1800, LTE 800 and UMTS 900 networks with respect to the radio parameters like RSRP, RSRQ and SINR. The limitations of the work carried out in the article was that since it was a test network, interference from other UEs and other interfering sites was not taken into consideration while measuring the radio parameters like RSRP, SINR, throughput. Also the coverage analysis was limited to only rural environment. The current work consists of performance analysis of practically deployed LTE network in an urban environment wherein the interference from UEs and other interfering sites affect the measurement of the radio parameters. Also, inter radio access technology handover like LTE to UMTS, LTE to GSM have been verified. Mobility key performance indicators like network accessibility, success rate, e-Radio access bearer (e-RAB) establish success rate, call drop rate etc. have also been measured.

3. Site Configuration

The paper discusses the deployment of LTE system at a site where previously 2G and 3G systems base station (BTS) were already installed. The tables I and II give the BTS configuration of G800/W900 and G1800.While the BTS configuration for W2100 has been shown in table III. The GPS position of this preexisting site was Latitude of N 3.14 °, Longitude of E 101.69 °and the site altitude of 70m. Flexi multicarrier radio base station equipment operating at various frequency bands supporting GSM carriers in GSM dedicated mode and WCDMA carriers in WCDMA dedicated mode were installed at the site [4]. There were 3 multicarrier power amplifiers installed, one for each sector. Configuration used was 1SM + 1RFM/ 2SM + 2RFM for 2G and 3G networks respectively. Single band antennas were used to provide coverage in all the 3 sectors for both 2G/3G systems.

Table 1. 2G BTS Configuration for G800/W900

Parameter	Cell 1	Cell 2	Cell 3
Total no. of Antennas	1	1	1
Antenna height (m AGL)	31.5	25.5	25.5
Antenna direction	50 °	180 °	300 °
Antenna electrical tilt	9°	2°	12°
Antenna mechanical tilt	2°	2°	2°
Antenna Gain (dBi)	15	15	15
Transmitted power (Watts)	20	20	20

Table 2. 2G BTS Configuration for G1800

Parameter	Cell 1	Cell 2	Cell 3
Total no. of Antennas	1	1	1
Antenna height (m AGL)	31.5	25.5	25.5
Antenna direction	20 °	170 °	300 °
Antenna electrical tilt	0˚	1˚	0˚
Antenna mechanical tilt	2˚	2˚	2˚
Antenna Gain (dBi)	18	18	18
Transmitted power (Watts)	20	20	20

Table 3. UMTS BTS Configuration for W2100

Parameter	Cell 1	Cell 2	Cell 3
Total no. of Antennas	1	1	1
Antenna height (m AGL)	31.5	25.5	31.5
Antenna direction	30 °	210 °	310 °
Antenna electrical tilt	4˚	3˚	6˚
Antenna mechanical tilt	2˚	2˚	2˚
Antenna Gain (dBi)	18	18	18
Transmitted power (Watts)	20	20	20

In order to provide LTE coverage to nearby office buildings and residential area, new NSN Flexi multi radio eNodeB was stacked on existing equipment [5]. The eNodeB configuration for the upgraded system is given in table IV. Here the existing W2100 single band antenna was swapped to new dual band W2100/L1800 antenna to support the LTE 1800 technology. Apart from this, existing cabling, rectifier, AC breakers were replaced with new cabling, rectifier and 1 * 63 A DC breaker for new NSN Flexi. New radio resource head (RRH) was mounted on existing antenna main boom for all of the 3 sectors and a feeder was connected from RRH to antenna. Height of the new structure was 27 m/33 m AGL (Above Ground Level).

Table 4. LTE eNodeB Configuration

Parameter	Cell 1	Cell 2	Cell 3
Total no. of Antennas	1	1	1
Antenna height (m AGL)	31.5	25.5	31.5
Antenna direction	30 °	210 °	310 °
Antenna electrical tilt	4˚	3˚	6˚
Antenna mechanical tilt	2˚	2˚	2˚
Antenna Gain (dBi)	18	18	18
Transmitted power (Watts)	20	20	20

4. Performance Analysis

The performance analysis of the deployed network is carried out by considering few of the LTE radio parameters like the Received signal received power (RSRP), Signal to interference to noise ratio (SINR) and user equipment (UE) throughput.

(a) Received Signal Received Power

RSRP proves to be an important measurement factor for determining the coverage of an LTE network. It is used in calculating the Received signal received quality (RSRQ) parameter which in turn determines the quality of the signal. The relationship between RSRP and RSRQ is given as,

$$RSRQ = N * \frac{RSRP}{RSSI} \text{ in dB} \tag{1}$$

Where, N is the number of resource blocks over the measurement bandwidth. RSSI is the received signal strength indicator, which includes all types of power from co-channel serving and non-serving cells; adjacent channel interference; thermal noise within the measurement bandwidth [6]. Hence RSRQ indicates the portion of pure RS power over the whole E-UTRA power received by the UE.

(b) Signal to interference to noise ratio (SINR) and throughput

For planning of any network, two important planning parameters, to be taken into consideration by the network providers, are the SINR and the throughput.
Shannon's formula states:

$$C = B * \log_2(1 + SINR) \text{ in bits per second,} \tag{2}$$

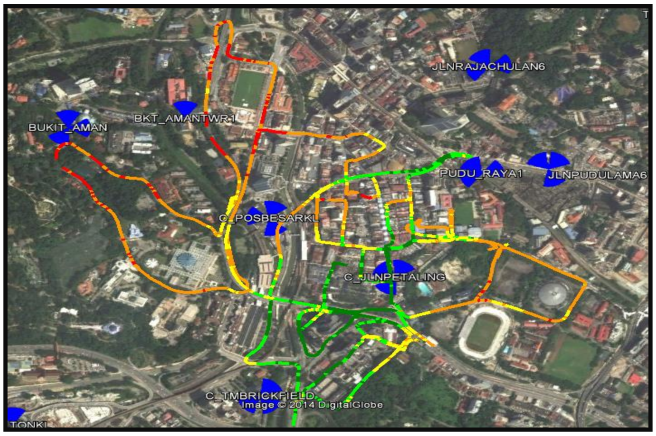
Where, C is the capacity of the channel or throughput (bps), B is the bandwidth of the channel (Hz), SINR is signal to interference to noise ratio (in linear scale). Hence,

$$SINR = 10 * \log_{10}(2^{C/B} - 1) \text{ in dB} \tag{3}$$

The above equation shows that SINR determines the throughput (capacity) of a system. It is used to calculate the Channel quality indicator (CQI), which ranges from 0 to 15. Higher is the CQI, higher is the throughput, as higher order modulation will be used by eNodeB.

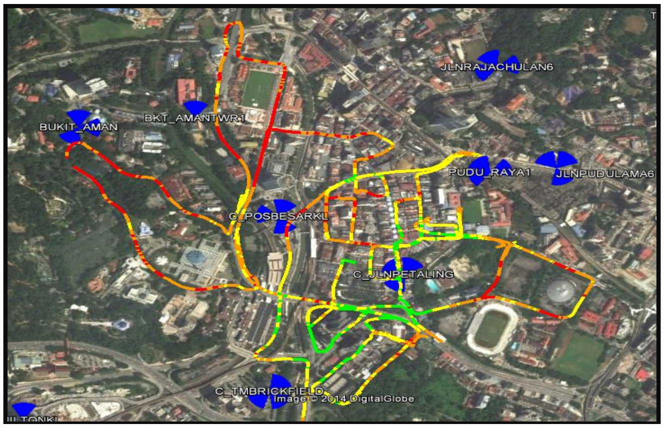
4.1. Performance analysis of network in terms of RSRP, SINR and UE throughput

Drive test was conducted within 2 Km of the area surrounding the site. The user equipment (UE) was locked to LTE so as to ensure that no inter radio access technology (RAT) handovers occurred and the UE was attached to the LTE 1800 network all the time. UE RSRP and SINR levels were monitored. RSRP is one of the important factors fordetermining the coverage of LTE networks [7]. Fig. 1 shows the RSRP plot for the site serving the active cell to the UE. The green color indicates higher RSRP levels and hence better RF levels. Areas nearer to the site show better RF levels. The red color areas which are away from the site indicate poorer RSRP and hence poor RF levels. It can be seen that in the areas nearer to the eNodeB the RSRP level was stronger (~ ≥ (-75) dBm) and as we move away from the site the RSRP level gradually decreases to ≤ (-110) dBm. The RSRP level stayed in the range of < (-95) dBm to ≥ (-110) dBm for about 31% of cases. The better signal level of ≥ (-75) dBm was obtained only in 22 % of cases but at the same time the worst case RSRP level (< (-110) dBm) was obtained only for 8% of total cases. Hence on an average probability of a RSRP level of acceptable range (< (-95) dBm and ≥ (-110) dBm) was about 31%. This supports the theoretical values of RSRP levels for usable signals which is in the range of ((-75) dBm to (-120) dBm from cell site to cell edges for LTE systems [8]. Hence the signal strength is stronger at the center of the cell (nearer to the site) and diminishes as UE moves away from the center and towards the cell edges. The radio frequency (RF) levels, at the deployed site, are better in 31% of cases. Thus the deployed LTE network intended to provide coverage to targeted areas did meet the requirements.



RSRP (dBm) [Samples]			
	>= -75	1356	22.32%
	< -75 and >= -85	1198	19.72%
	< -85 and >= -95	1199	19.74%
	< -95 and >= -110	1864	30.68%
	< -110	458	7.54%

Fig.1. RSRP plot and Legend



SNR (dB) [Samples]			
	>= 20	1332	21.94%
	< 20 and >= 10	2052	33.80%
	< 10 and >= 3	1886	31.07%
	< 3	801	13.19%

Fig.2. SNR plot and Legend

For coverage limited environment as with the currently deployed system the SINR can be approximated with SNR [3]. The UE SNR plot with its legend has been shown in Fig. 2. The green color areas depict regions with higher SNR while red color areas depict regions experiencing lower SNR. Signal to interference to noise ratio can be given as, S/ (I+N) in dB. Where, S is the signal power received. I is the interference signal power and N is the noise power at the UE. As the UE distance from eNodeB increases, the received signal power from its home eNodeB reduces and the interference power which is the summation of both, the own cell interference power and the other cell interference [9], increases. Thus interference affects the SINR value drastically [10].

At the cell edges, lower SINR values also result due to delay in handover. As the UE is moving towards the cell edge, it comes under the coverage of more than one cells. Only when handover is completed, the UE can be strongly served by a particular cell. In cases of lower SNR, the services to the UE could be provided by the second best cell [11]. The maximum SNR value >= 20 dB is obtained in 22% of cases while the minimum SNR of < 3dB is obtained only in 13% of cases (where the UE is away from the site). This supports the theoretical concept that as UE moves away from the site the noise level increases and hence the SINR decreases [12]. Probability of SINR values of < 20 dB and >= 10 dB is 34% i.e. on an average SNR of the LTE 1800 system, configured presently, remains between 10 dB and 20 dB.

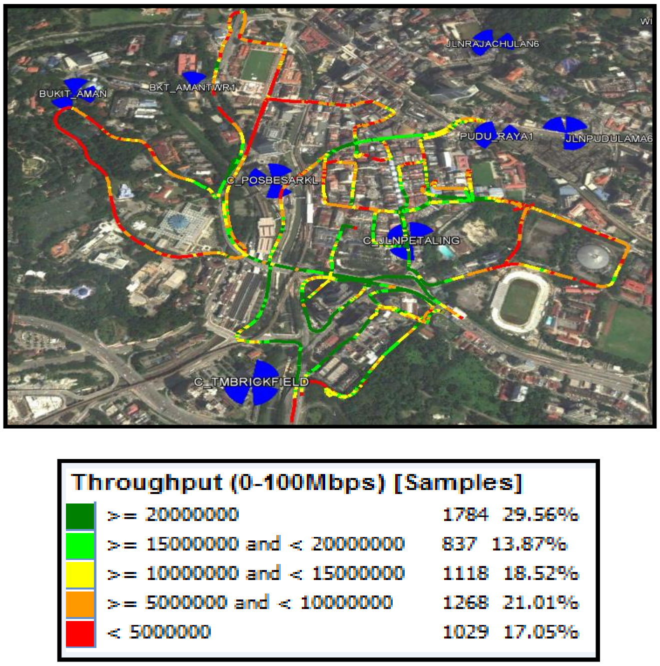


Fig.3. Downlink Throughput Plot and Legend

Downlink throughput is also one of the important parameters revealing the performance of a radio network. Fig. 3 shows the downlink throughput of a UE using the LTE coverage. It can be concluded that UE downlink throughput also follows the trend of RSRP and SINR. Areas with green indicate higher throughputs and red areas symbolize lower throughputs. The UE downlink throughputs are higher in areas nearer to site and reduces gradually as the UE move towards the cell edges. Wide variations in UE throughput, within the coverage areas may also result due to changes in the radio conditions (channel quality, path losses etc.) of the currently deployed network. Path loss is a major component affecting the RF levels and hence the channel quality in any telecommunication network. Various path loss prediction models have been worked upon till date [13-18] for link budget analysis of a communication network, operating in different environmental conditions.

Also as the RSRP reduces with distance, the CQI value decreases which in turn affects the spectral efficiency resulting in lower throughput. About 30% of measurement data yields a throughput above 20 Mbps while only 17% of measurement data has throughput < 5 Mbps.

The downlink UE throughput histogram for the sector 1 has been shown in Fig. 4.

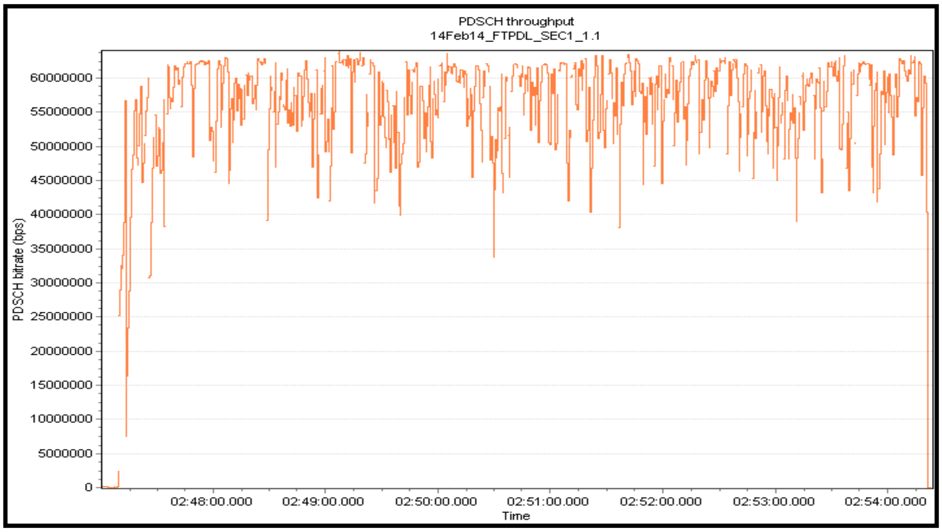


Fig.4. Downlink Histogram of Sector 1

The elevation variation plays an important role in reduction of RSRP level in a radio network. Due to the knife edge diffraction loses, reflections etc. the signal strength at the UE decreases which in turn reflects the throughput in the area. The elevation variation profile of sector 1 (shown in Fig. 5) reveals that there are lots of elevation variations in this sector. Due to this the achievable throughput in sector 1 varies from 25 Mbps to 60 Mbps and SINR is >= 10 dB.

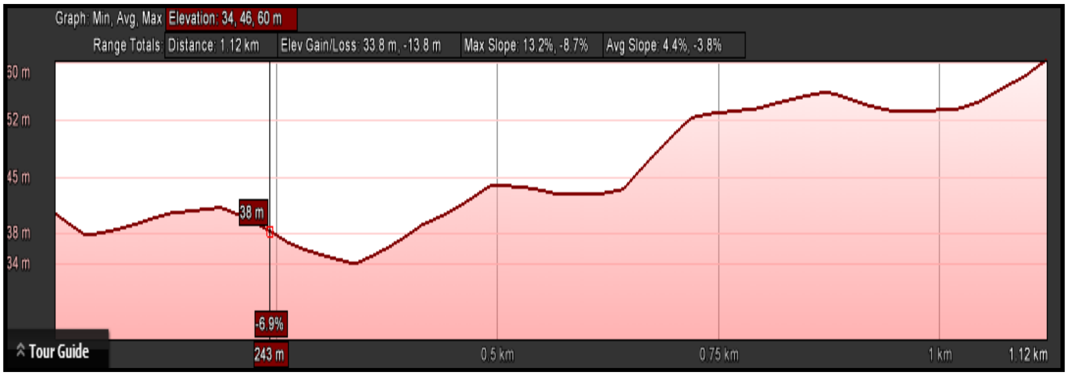


Fig.5. Elevation Variation in Sector 1

In sector 2 coverage area there is dense clutter of high rise buildings, causing multipath propagations, which also results in low RSRP and SINR is of >= 10 dB. Thus throughput also decreases in this area and varies from 55Mbps to 22Mbps.

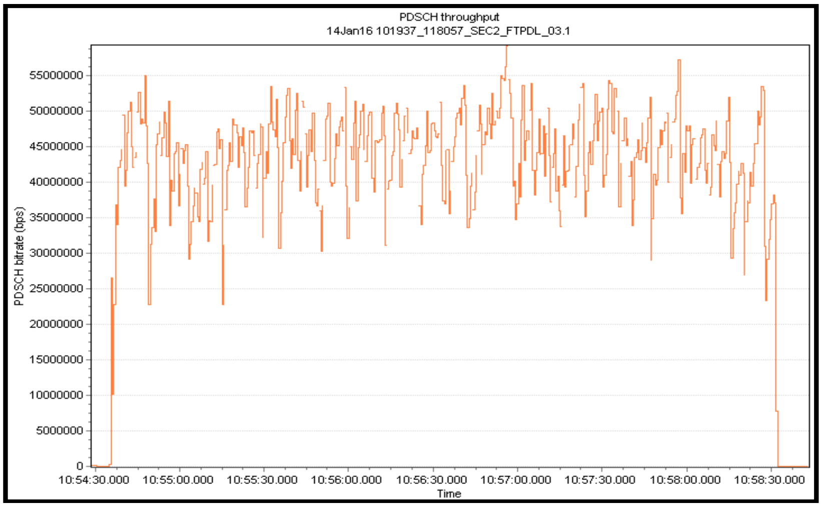


Fig.6. Downlink Throughput of Sector 2

Whereas in sector 3 low RSRP and hence poor SINR (>= 10 dB) is observed and the throughput varies from about 60 Mbps to 15 Mbps. The Physical downlink share channel (PDSCH) throughput is considered for the performance analysis because PDSCH is used for data transmission only and does not consider the control information. On an average the downlink throughput of the 3 sectors comes out to be 20 Mbps. The multipath fading affects the performance of the system, but its effect can be mitigated by use of diversity combining scheme such as those discussed in [19].

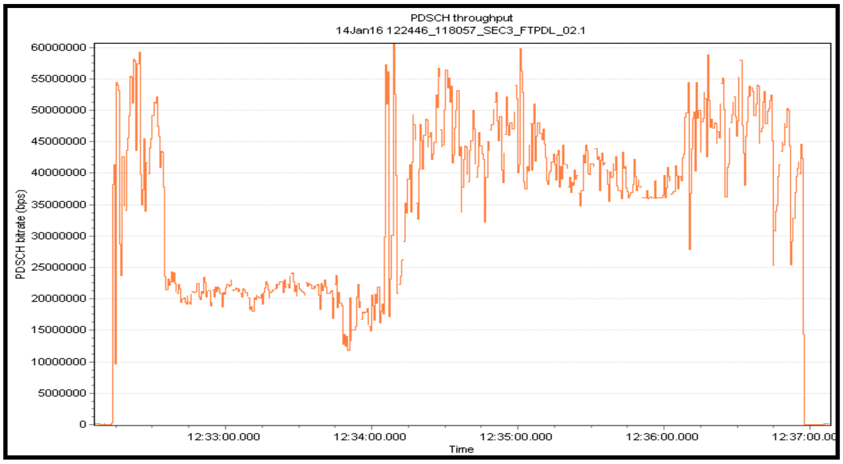
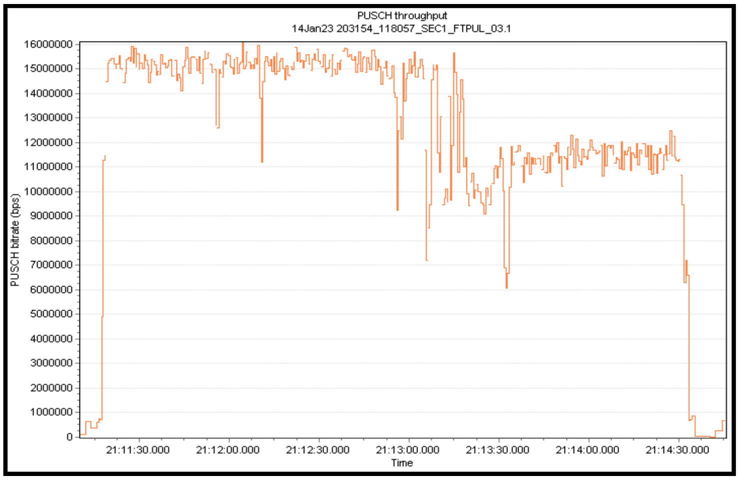
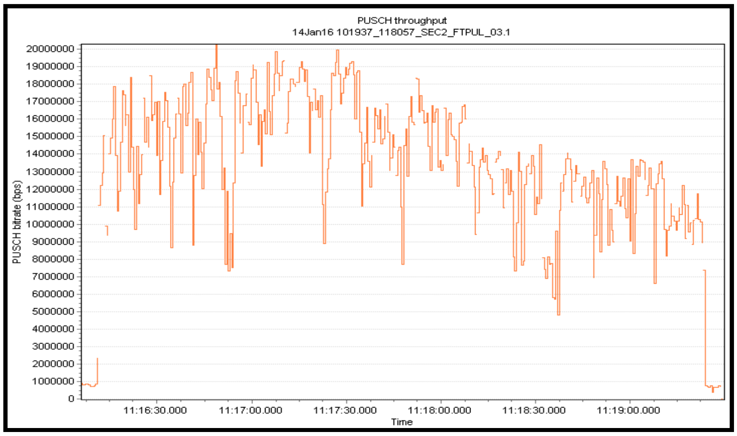


Fig.7. Downlink Throughput of Sector 3

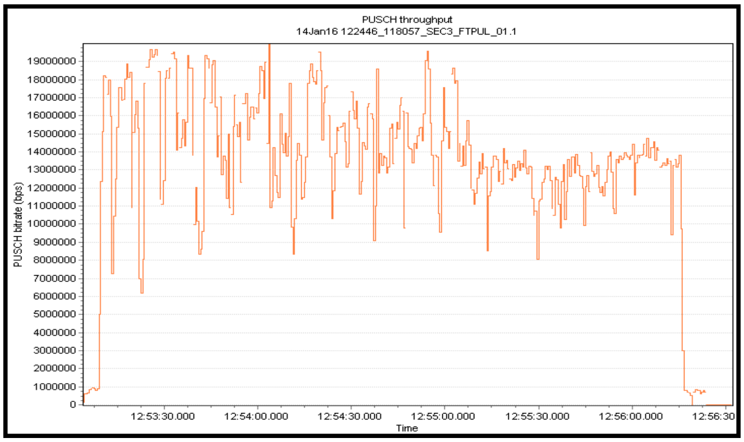
The uplink UE throughput histograms for the 3 sectors have been shown in Fig. 8. The uplink UE throughput varies from 16 Mbps to 5 Mbps for sector 1 and 20 Mbps to 5\6 Mbps for sector 2 and 19 Mbps to 6 Mbps for sector 3. The average uplink throughput for the 3 sectors was 12 Mbps as depicted in the table V. The Physical uplink share channel (PUSCH) throughput has been considered here as PUSCH contains user information data as well as control signals data and is usually found to be a limiting link.



Sector 1 throughput



Sector 2 throughput



Sector 3 throughput

Fig.8. Uplink Throughput of UE in all three Sectors

The graphs show that UL throughput degrades with time in all 3 sectors as the factors like, eNodeB receiver sensitivity, antenna diversity gain, UE transmit power , propagation loss of UL radio signals, impact of tower-mounted amplifiers (TMA) etc. affect the signal power level. Higher minimum UL throughput can be achieved by increasing the number of resource blocks the mobile, at cell edge, can use. This in turn will affect the noise bandwidth, which the receiver must consider, thereby reducing the maximum allowable path loss (MAPL) for the PUSCH. Hence for applications like live streaming in UL, it is important to clearly define the minimum UL throughput required at the cell edge as this will affect the MAPL.

4.2. Key Performance Indicators (KPI)

The key performance indicators (KPI), for the deployed LTE radio network, are shown in the table V. From the table it can be seen that the practically achieved results of various KPI, for all the three sectors, were within the limits of the desiredtarget values defined for all the three different polygons. Hence the deployed LTE network provided a good coverage in all the three sectors.

Table 5. Kpis for the Deployed LTE System

KPI	Suburban Polygon	Site Results (Sector 1)	Site Results (Sector 2)	Site Results (Sector 3)
Static Test				
Network Accessibility Success Rate	>= 99%	100.00%	100.00%	100.00%
e-RAB Establish Success Rate	>= 99%	100.00%	100.00%	100.00%
Call Drop Rate	<= 1.5%	0.00%	0.00%	0.00%
Idle to Active Transition Time	<= 100ms	98.23 ms	92.07 ms	85.13 ms
Network Attach Latency	<= 450ms	164 ms	152 ms	152 ms
Download throughput @ 20MHz bandwidth	Avg 20Mbps	55.04 Mbps	36.60 Mbps	32.90 Mbps
Upload throughput @ 20MHz bandwidth	Avg 10Mbps	11.53 Mbps	12.89 Mbps	12.27 Mbps
Ping Round Trip Time	20ms	18 ms	16 ms	20 ms
HTTP session time	<= 3 sec (6 sec)	0.45 s	0.47 s	0.54 s
Video Streaming	Success/Fail	Success	Success	Success
VOIP (Skype)	Success/Fail	Success	Success	Success
CS Fall Back Call Setup	Success/Fail	8.2s	5.8s	6.0s
CS Fall Back 3G -> LTE Reselection	Success/Fail	43.5s	45.0s	42.6s
Mobility KPI		Mobility Result		
Mobility Test (Short Call)				
Network Accessibility Success Rate @ 50km/h	>= 98%	100.00%		
e-RAB Establish Success Rate @ 50km/h	>= 97%	99.30%		
Call Drop Rate @ 50 km/h	<= 1.5%	0.00%		
Mobility Test (Long Call)				
Download throughput	15Mbps	25.15Mbps		
PS Services				
Intra-LTE Handover Failure	<= 2%	0.00%		
LTE <-> UMTS reselection	Success/FAIL	Success	Success	Success
LTE -> UMTS handover	Success/FAIL	Success	Success	Success
LTE -> GSM reselection	Success/FAIL			

5. Conclusions

The results tabulated and the plots for RSRP, SNR and throughput support the fact that with increase in RSRP and SINR the UE throughput also increases [20]. If the radio coverage of a network decreases due to UE travelling away from the site or due to interferers in the line of sight link, both the RSRP and SNR tend to decrease which in turn decrease the UE throughput. The coverage provided by 2G and UMTS radio networks was wider than that provided by LTE radio network but due to the increasing demand of mobile broadband LTE radio coverage was provided to the customers in the site area at the cost of reduction in cell size thereby requiring an increase in the number of eNodeB deployments in a particular city. LTE advanced systems wherein relaying techniques will be incorporated would support wider coverage with help of low power relay nodes deployed as substitutes of frequent high cost eNodeB so as to enable wider inter site distances and still provide cell edge coverage.

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