

Metwally, Mohamed; Abu-Gabal, Mohamed

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Spectrum Sharing Proposal for Maximizing Cellular Networks' Spectral Efficiency

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Spectrum Sharing Proposal for Maximizing Cellular Networks' Spectral Efficiency

Mohamed Metwally
Department of Telecommunication
Cairo University
Cairo, Egypt
eng.mohamedmetwally@gmail.com

Mohamed Abu-Gabal
Department of Telecommunication
Cairo University
Cairo, Egypt
gabalnet@gmail.com

Abstract—This work describes the potential gain of spectrum sharing between different mobile technologies. A new bandwidth allocation technique is introduced, allows coexistence and overlap between old and new (relative) mobile generations, operating over the same frequency band. The new proposed technique is tested over UMTS and LTE systems to enhance the overall spectral efficiency. LTE bandwidth is maximized allowing carrier overlap with UMTS. Spectrum sharing feasibility is being assessed in 2100MHz band. The proposed UMTS and LTE coexisting setup allows carrier overlapping in both uplink and downlink channels. Performance is evaluated in terms of statistical analysis and field measurements. The proposed test case evaluate the system's performance and measure the induced interference from each system on the other. Results have shown the do-ability of overlapped spectrum sharing between different mobile generations, in order to enhance the system performance.

Index Terms—Bandwidth Allocation, Coexistence, UMTS, LTE, Bandwidth scalability, spectrum sharing

I. INTRODUCTION

Mobile spectrum is generally scarce, tight and expensive. Mobile operators are continuously investigating different techniques to maximize the spectral efficiently. The main objective of this paper is to increase spectrum efficiency meeting the required quality of service. Recent development of mobile communication application has led to tremendous demand on data. The need for bandwidth to accommodate the huge data traffic is increasing continuously, in order to meet the booming demand. Currently, most used mobile technologies for data traffic are Universal Mobile Telecommunication System (UMTS) and Long Term Evolution (LTE). Out of eight billion mobile subscriber, two billions are supporting UMTS handset and three billion are supporting LTE handset [1].

UMTS was introduced back in 1999 [3], which provides initially data rates up to $384Kb/s$, using a $5MHz$ channel bandwidth. Its based on Wide Code Division Multiple Access (WCDMA). The bandwidth of the spread signal is greater than that necessary to send the information. It ensures increased channel capacity and immunity to interference among different signals [10]. Spreading the signal leads to low Signal to Noise Ratio (SNR), which suppresses the effect of interference [4], [9]. UMTS data rates were developed over the years, starting by Release 99 offering $384Kb/s$. High-Speed Downlink Packet Access (HSDPA) offers $14Mbps$ and last HSDPA+

getting a maximum throughput of $42Mb/s$ [2]. There are several quality indicators for the UMTS, however the focus is on the radio part. The UMTS radio quality is measured by two parameters. First, E_c/N_0 that varies from -24 to 0 . The less E_c/N_0 indicates bad quality. Second, channel quality indicator (CQI), it varies from 0 to 30 . The higher values indicates good channel quality.

LTE was introduced in 2008 by 3rd Generation Partnership Project (3GPP) [11] with the unprecedented demand for mobile broadband data around the world. LTE provides higher user data rates with reduced latency to support the various high traffic applications such as video streaming and high definition video. LTE is based on Orthogonal Frequency Division Multiple Access (OFDMA) that provides flexible carrier configuration, where the configured band is divided into Resource Block (RB), each of bandwidth $180KHz$. In addition, Multiple Input Multiple Output (MIMO) enhanced the user throughput. The Physical Uplink Control Channel (PUCCH) measures the received signal level in the uplink recieved by eNodeB. All these capabilities enabled the LTE

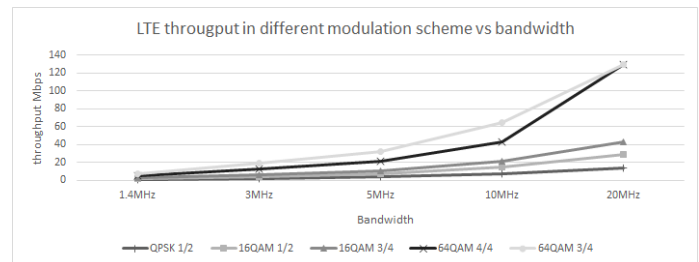


Fig. 1. LTE throughput using different bandwidth and modulation scheme

to offer higher data rates compared to UMTS. LTE bandwidth (BW) varies and could be configured from 1.4,3,5,10,15,20 in multiples of 5MHz. 20MHz configuration has the maximum number of RBs, hence achieving higher throughput. The more bandwidth could be assigned, the more RBs will be available, resulting in higher throughput. There are different modulations scheme used by LTE, higher order modulation contributes in achieving higher throughput. LTE radio quality is measured by several indicators. Reference Signal Received Quality (RSRQ) that varies from -34 to 0 , acceptable range is from 0 to -12 .

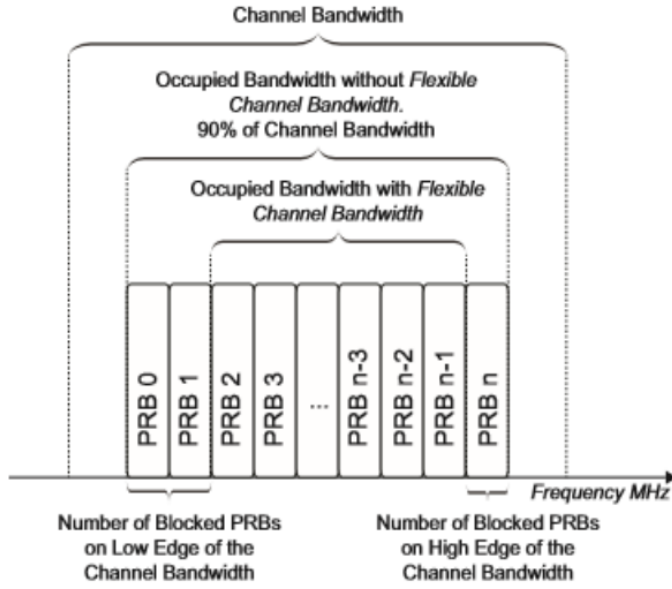


Fig. 2. Flexible Bandwidth Feature

Channel Quality Indicator (CQI) values range from 0 to 30, the higher value represent good quality. Signal to Interference Noise Ratio (SINR) acceptable values are higher than 20 [12]. High SINR represents a good quality for LTE to use high order modulation in order to achieve high throughput as shown in Figure 1. LTE is spectrum scalable as its based on OFDMA, where all the RBs in the assigned bandwidth are ranked [8]. The ENodeB allocates the number of RBs depending on the data demand, the system assigns the highest score RBs as long as they are free. In case the system is highly loaded and all the non-interfered RBs are used for high capacity load, the system will assign the interfered RBs that have low rank. Spectrum scalability extends to prevent selected RBs from data scheduling, but used for both signaling channels and the reference signal. This happens due to the reference signal and signaling channels locations are fixed in the LTE bandwidth by 3GPP standard [5]. Those nonscheduled data RBs are specified from the right and left part of the assigned band shown in Figure 2.

Operators are continuously investigating BW re-allocation in order to gain the maximum benefit of the purchased BW, by using lower frequencies for better coverage or introducing newer technologies. Bandwidth reallocation is a process used in order to change the purpose of assigned frequency band that has historically been assigned to a technology for another one. This process is needed in order to speed up the process of deployment for newer technology in case of band scarcity or better spectral efficiency. The bandwidth allocation concept was first introduced in 2007 in Finland [7], by Elisa Mobile network. The most popular allocation bands are in the 900MHz, because of low band characteristic to have better propagation than higher bands and keep the foot print same as the old technology.

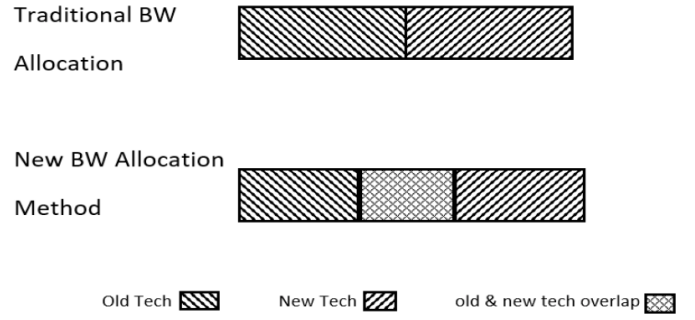


Fig. 3. New proposed re-farming scenario allowing overlap

Typical BW reallocation is performed by reducing the band assigned to the old technology, to free some frequencies to be reused with newer technology. Figure 3 shows the traditional BW allocation technique. This ensures there is no overlap between the old technology and the new one on the same band. Our new proposed BW allocation technique enables an overlap, coexistence, between old and new technologies. Both technologies would share the same frequencies. Figure 3 elaborates the new technology introduced overlapped with old existing technology. This overlap generates an induced inter system co-channel interference, which is assessed in this paper.

There are two motivations for the proposed BW allocation technique. First, the need to use wider bandwidth as much as possible for capacity limitation on legacy technology. Second, bandwidth scarcity that holds new technology activation, as there are no free frequencies. Although 3GPP stated the bandwidth and guard band of old technologies, BW allocation techniques are not mentioned in the standard 3GPP, they are techniques developed by the vendors in order to solve the mobile operator capacity issues.

The current trend of the mobile industry directs UMTS to be switched off, however due to large terminal penetration [1], this will be applied using large steps. Mobile operators currently depends on deploying the standard bandwidth configuration through BW reallocation. This puts some limitation to achieve high relative spectral efficiency. a mobile operator assigned 15MHz bandwidth, where 10MHz are activated using UMTS and 5MHz for LTE. In such situation, UMTS UE penetration is high, in order to activate 15MHz LTE, all the bandwidth has to be reallocated. Capitalizing on the advantage that UMTS is based on WCDMA and uses filter to minimize the UMTS carrier bandwidth suppressing the side bands, 10MHz LTE carrier could be activated.

In this paper, A new BW re-allocation technique is introduced to enhance the spectral efficiency, in terms of the bandwidth allocated per technology. UMTS and LTE systems are used in the setup to apply the new BW allocation techniques over 2100MHz band, using 15MHz bandwidth. The setup aims to increase the spectral efficiency by maximizing the bandwidth allocated to existing LTE carrier. Up to the author knowledge, this is the first field assessment to utilize a new approach for spectrum sharing, taking full advantage of

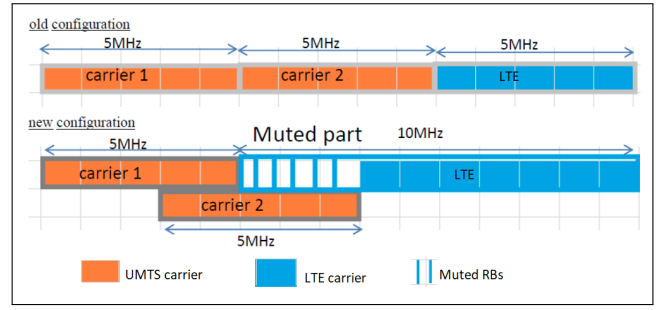
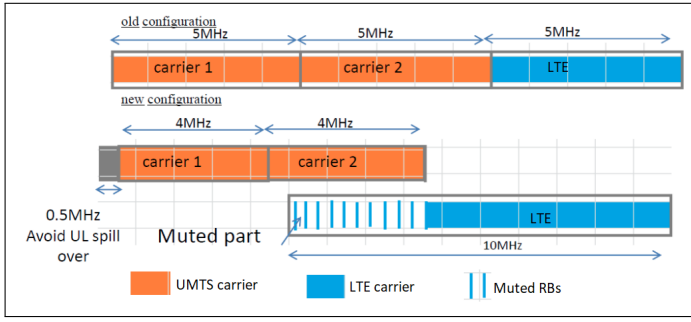


Fig. 4. (Left) downlink bandwidth reconfiguration. (Right) uplink bandwidth reconfiguration.

LTE spectral scalability. The systems performance is evaluated by two metrics, first the statistical Operation Support System (OSS) key performance indicators (KPIs) and second field measurements.

II. OUR APPROACH

The trial setup uses 15MHz bandwidth assigned in the 2100MHz band. This band is known to be operated with UMTS technology carriers, each of 5MHz. UMTS uplink carrier bandwidth is 5MHz and couldn't be configured to another value unlike the downlink. Reducing the downlink UMTS carrier bandwidth from 5MHz to 4MHz using filters, leads to UMTS carrier shifting. UMTS central frequency is called UTRA Absolute Radio Frequency Channel Number (UARFCN) which is symmetric for both uplink and downlink. These two constraints force UMTS carriers to overlap in the uplink direction, upon shifting the center frequencies. LTE carrier bandwidth configuration is more flexible compared to UMTS carrier bandwidth, however, LTE bandwidth is configured only in multiples of 5MHz.

LTE bandwidth configuration is symmetric as well, applied for both downlink and uplink directions. The testing is performed over an area that cover most of the user profiles. The area is a mix between high dense and sub-urban in a large main city. The inter-site distance is on average 400m. The selected area ensures there are huge traffic generated in order to access the performance in high loaded network. Also, the close inter-site distance support in assess the induced inter-system interference.

This setup case shows UMTS is operating with two carriers, and LTE is operating with 5MHz bandwidth. LTE throughput is much higher compared to UMTS. The more LTE bandwidth assigned, the more RBs can be assigned to the users to achieve higher throughput. This shows the need to reduce the 10MHz bandwidth assigned for UMTS and allocate the band to have more than 5MHz bandwidth assigned to LTE. The setup aims for a maximize the use of the 15MHz bandwidth to achieve higher user throughput. Overlapping RBs are not scheduled for data in this setup to enhance the LTE performance. Figure 4(Left) illustrates the downlink 15MHz bandwidth, where two UMTS carriers are reduced to be 4MHz and shifted, also the LTE bandwidth is maximized to 10MHz while showing the overlapped data RBs with UMTS carrier. This

allows the actual used LTE RBs bandwidth to be 6.5MHz. Figure 4(Right) illustrates the uplink bandwidth configuration, where two UMTS carriers with 5MHz bandwidth overlap to match the corresponding downlink UARFCN. 10MHz LTE bandwidth is configured while showing the overlapped RBs with UMTS carrier.

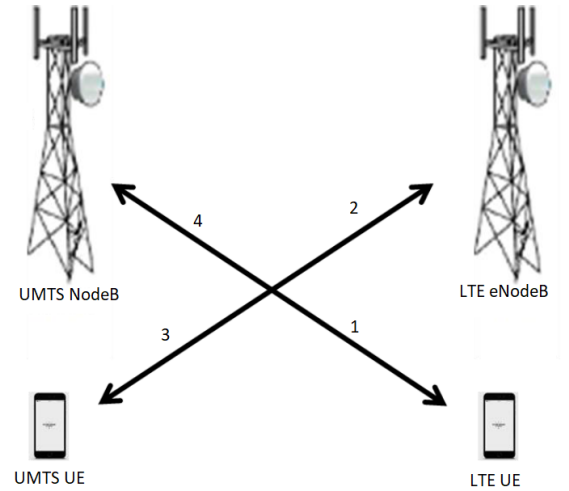


Fig. 5. Four generated sources of interference.

III. EVALUATION

The new BW allocation approach allows two different technologies to overlap partially in the allocated bandwidth. As a result, this generates an induced interference in both uplink and downlink. The induced interference has to be measured in order to assess its effect. Accordingly, the system performance has to be monitored closely, in order to assess the effect of the new proposed settings of reduced bandwidth and bandwidth allocation overlap. Two sources of information will be considered in our test:

- *Field test*: performing drive test to simulate the user experience by special phone equipment, in order to check the network propagation and measure the exact transmitted signal. The uplink and downlink throughput is measured to check the end user experience. Also the quality indicators such as SINR and E_c/N_o .

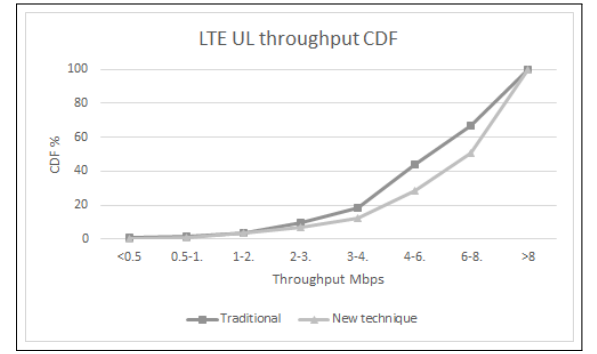
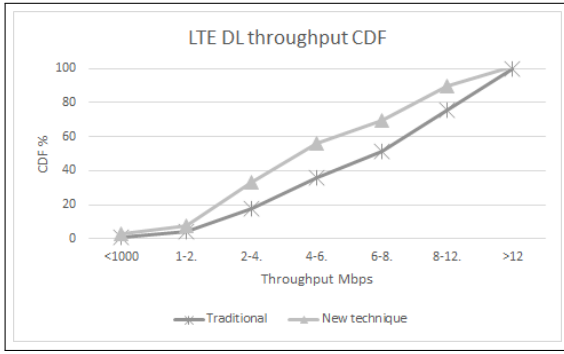


Fig. 6. (Left) LTE downlink interfered throughput. (Right) LTE uplink throughput.

- *OSS counters statistics (KPIs)*: they are the raw counters monitored by the network that counts events and actions taking place by each user request such as the requested throughput, CQI and RSSI [6].

The aim is to measure the induced interference effect from UMTS on LTE and vice versa. The above tests and statistics will be observed through different directions for the uplink and downlink channels to assess the setup scenario as shown in Figure 5. Four different interference effects generated from the over lapping are assessed:

- 1) UMTS on LTE in DL: UMTS NodeB interferers on the LTE UE in the downlink direction.
- 2) UMTS on LTE in UL: The effect of interference on LTE in the uplink direction due to a UMTS UE.
- 3) LTE on UMTS in DL: LTE eNodeB interferes the UMTS UE in the downlink direction.
- 4) LTE on UMTS in UL: LTE UE interferes on the UMTS NodeB in the uplink direction.

IV. PERFORMANCE ANALYSIS

Sufficient statistics were collected from in order to assess the performance, all statistics showed improvement of LTE performance in terms of throughput. Downlink effect of

	LTE	3G
DL	+35%	-15%
UL	+10%	No change

TABLE I
PERFORMANCE RESULTS

UMTS on LTE. The UMTS NodeB interferes on the received signal received by the LTE UE in the downlink direction. During this setup 18 RBs are chosen not to be scheduled for data in the test, resulting in effective of 6.5MHz of RBs used for data. Upon increasing the bandwidth of LTE from 5MHz to effective 6.5MHz the statics downlink LTE throughput enhanced from average 8Mb/s to 11Mb/s. Bandwidth increase reflects more RBs assigned to the user. The field test has shown the same results, 35% LTE DL throughput increase, mainly driven by the increase in very medium throughput sample as shown in Figure 6Left. Consequently, the RSRQ decreases by 1dB from -12dB to -13dB, however the SINR is severely degraded

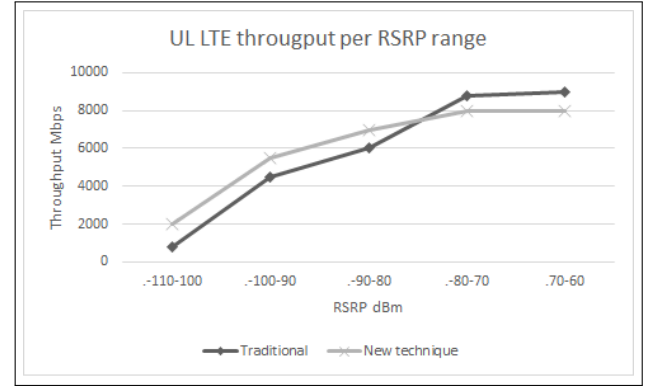


Fig. 7. Uplink LTE throughput per RSRP range (field)

from 12.3dB to 4dB, reflecting on the higher order modulation penetration. Its noticed that for OFDMA, the RBs are very sensitive to interference, however, the added RBs reflected in a huge increase for the user throughput.

The uplink radio signal received by LTE eNodeB from both LTE and UMTS UE. The UMTS UE acting as an interferer. Upon monitoring the effect of the uplink induced interferer. It was observed LTE is not affected by the UMTS UE interferer. The uplink throughput is maintained from KPIs. The field test showed an uplink throughput change from 6.6Mb/s to 7.3Mb/s as illustrated in Figure 6(Right). However, this increase in the uplink throughput doesnt indicate any system error but the samples in medium throughput range during after-implementation testing is more, that lead to this slight increase in the numbers. Breaking down the uplink throughput per RSRP range, Figure 7 highlights the average uplink throughput per each RSRP range condition. Weak RSRP throughput slightly increase by 1MHz and the RSRP stronger than -90dBm has 1MHz throughput decrease which indicates the average uplink throughput is nearly the same as before.

The uplink interference from UMTS UE on LTE eNodeB is detected from the received signal on the uplink channel PUCCH. The power level received on PUCCH increased from -118 to -115. Around 3dB increase in the UL interference from the statistics.

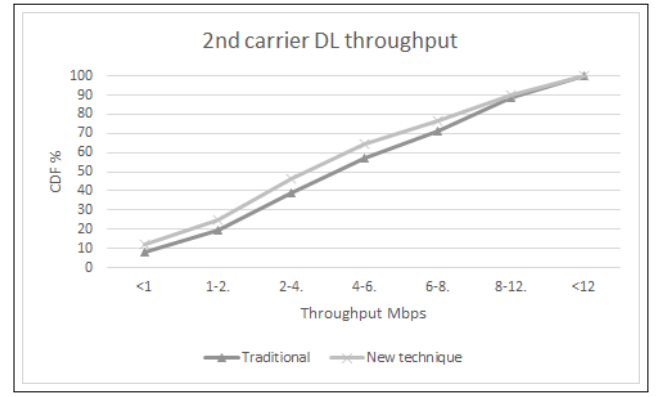
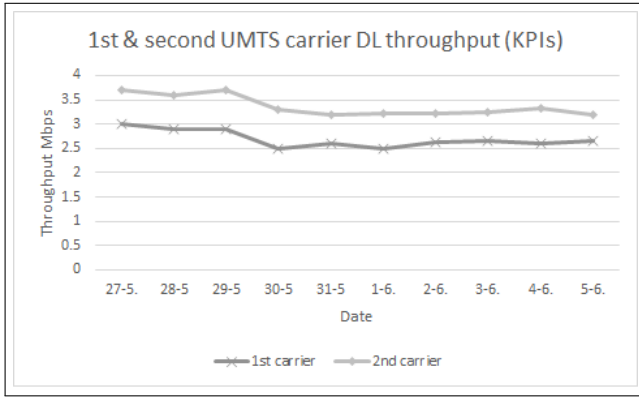


Fig. 8. (Left) UMTS Downlink throughput per carrier (KPIs). (Right) UMTS downlink throughput on carrier2.

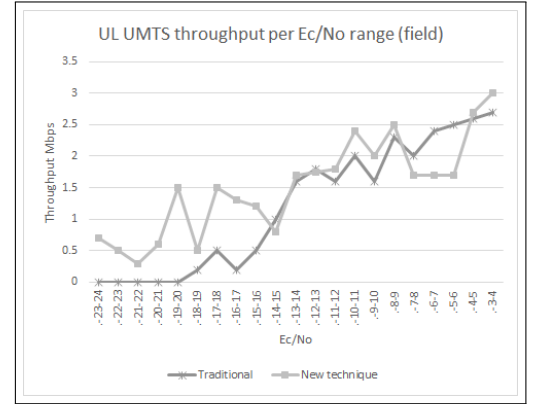
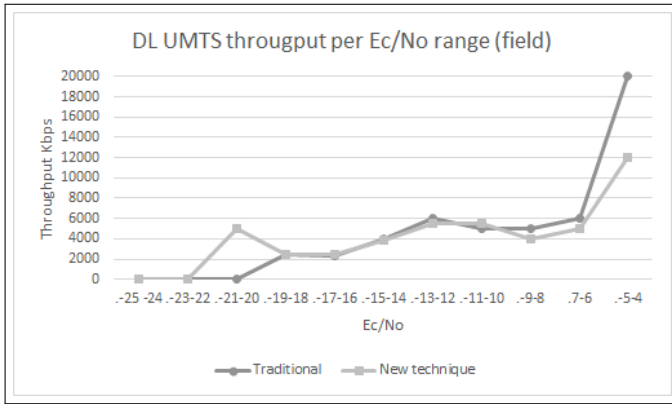


Fig. 9. (Left) UMTS downlink throughput per Ec/No range. (Right) UMTS uplink throughput per Ec/No range.

The effect of downlink interference from LTE eNodeB on UMTS UE is minimal, as the UMTS technology proved to be more robust to handle the interference using the WCDMA technology. The throughput was degraded by 0.5Mbps from statistics counter on the UMTS carrier due to the interference effect which is about 12% degradation. Figure 8(Left) visualizes the effect of interference on UMTS carriers.

The field test indicated that downlink throughput decreased by around 13%, Figure 9(Left) is showing the downlink throughput distribution. A slight decrease in the high throughput samples is observed. carrier1 throughput is decreased by 7% by the bandwidth reduction effect, however carrier2 has severely affected by reducing the bandwidth and induced interference from LTE. carrier1 will be the reference for band reduction effect as to subset it from carrier2. The RSCP level was maintained as the CPICH power was kept the same, the average Ec/No from the field was deteriorated by 1dB from -11 to -12dB. The CQI is degraded by 2 points from 25 to 23 on the UMTS which is around 8%. The QPSK percentage increased from by 3% from 31% to 34% which was reflected by the slight decrease in the high throughput samples.

The induced uplink interference on the UMTS NodeB from LTE UE is nearly negligible in the uplink. The uplink RSSI on UMTS, which is showing a small deterioration from -105dBm to -103dBm around 2dB interference level in the uplink on

UMTS from statistical KPIs. Field test shows UL throughput decreased by 5% from average of 1.8 to 1.7, derived by slight decrease in the high throughput samples as illustrated in Figure 9Right. A minor degradation around 0.3Mbps in each Ec/No range is noticeable. However few samples are extended to the weaker Ec/No range. Its noticed the UL UMTS is not affected because of low power transmission from UEs in the uplink and the robust WCDMA technology that makes UMTS system immune to interference.

V. CONCLUSION

A new spectrum re-allocation approach is introduced, for better spectrum utilization through partially band overlapping. The new technique has shown enhanced spectral efficiency by assigning bigger bandwidth to LTE within the same limited bandwidth, resulting in higher throughput achieved without sacrificing the quality. Results have matched the theoretical expectations for UMTS being immune to interference using WCDMA technology.

The new technique gained from LTE spectrum scalability giving mobile operators flexibility to go for effective non-standard bandwidth configuration based on the demand, while keeping the old technology configuration.

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