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Experimental Evaluation of LTE and UMTS Performance in an Urban Area

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***Abstract*– The goal of every optimized network is end user's satisfaction. As the increase of network performance allows the usage of more and more time and bandwidth critical applications such as VoIP and streaming, it is important to have a scalable network which support high data rate with reduced latency on both high and low mobility. The current wireless communication standards (GSM/EDGE and UMTS/HSPA) have problems of capacity, latency and low speed of data transfer, and these have led to poor quality of service (QoS) from the service providers and high customer complaints. LTE is the latest communication standard employed to increase the capacity and speed of wireless communication using a different radio interface together with core network improvements. In this thesis, a test LTE network is built and experimentally evaluated against an existing UMTS networks in order to determine which of the technologies offer improvements in data rate, spectral efficiency, power consumption of the terminal, cell edge bit rate; and reductions in transmission latency, connection establishment latency and cost. It was deduced that LTE using orthogonal Frequency Division Multiplexing (OFDM) and scalable bandwidth, together with more advanced MIMO schemes, provides better data rates and improved overall KPIs than the UMTS.**

***Index Terms*– LTE, Key Performance Indicators (KPIs) and UMTS**

I. INTRODUCTION

WHILE the mobile phone market was maturing it was all about the voice network. Mobile network carriers competed on coverage, voice quality, network reliability etc. The value however is moving from the voice network to the data network [1]. This is because of the rise of smart phones and smart devices where data becomes a more central part of the device experience. The competition going forward will be which network carriers have the fastest data network and that is where LTE comes into play. 3G networks had a fundamental problem which wasn't speed. 3G networks were built for faster data than 2G but failed at handling a lot of concurrent consumers consuming data per network node (Scalability issue) [2]. In essence if a lot of people in a particular city or area were on the 3G data network at the same time the network slowed down drastically and thus leading to bad end user experience. The most important outcome of an optimized network is obviously a satisfied end user. As the increase of network performance allows the usage of more and more time and bandwidth critical applications such as VoIP and streaming, it is important to have a scalable network which support high data rate with reduced latency on both high and low mobility. The LTE specification provides downlink peak rates of 300 Mbit/s, uplink peak rates of 75Mbit/s and QoS provisions permitting a transfer latency of less than 5ms in the radio access network. LTE has the ability to manage fast-moving mobiles and supports multi-cast and broadcast streams. LTE supports scalable carrier bandwidths, from 1.4MHz to 20MHz and supports both frequency division duplexing (FDD) and time-division duplexing (TDD). The IP-based network architecture, called the Evolved Packet Core (EPC) and designed to replace the GPRS Core Network, supports seamless handovers for both voice and data to cell towers with older network technology such as GSM, UMTS and UMTS2000 [3]. The simpler architecture results in lower operating costs (for example, each E-UTRAN cell will support up to four times the data and voice capacity supported by HSPA. LTE support of "self-optimizing network (SON)"like Automatic Neighbor Relation (ANR) detection and optimization, automatic parameter reconfiguration on event of network change detection, automatic load balancing etc. makes it very reliable

II. RELATED WORKS

The author in [4] stated different values as LTE performance that depends on parameters such as system bandwidth, multi antenna schemes, FDD or TDD operation, etc. Note that the proposed maximum data rate of LTE varies from 100 Mbps to 300 Mbps. There was no sufficient clue of how this value is calculated. The researcher's main objective of study was to determine physical layer throughput of LTE Release 8 in different scenarios for uplink and downlink. TDD and FDD operations were considered. Based on the system bandwidth that varies from 1.4 to 20 MHz, different amount of physical resources (from 10080 to 168000) are available during a radio frame. Physical channels and reference signals were mapped to these resources. He maintained that by calculating the overhead of reference signals that actually do not carry information to higher layers and control channels that convey control information, the number of resource elements allotted for data transmission could be determined. Based on different modulation schemes, code rates, and number of antenna ports, the throughput for data channels could be calculated. In TDD operation there were seven configurations for time domain multiplexing of downlink and uplink data transmission that lead to different throughput values in a given channel bandwidth. His simulations were carried out with the minimum and maximum code word sizes (40 and 6144). The channel mode was assumed to be AWGN (Additive White Gaussian Noise) and normal cyclic prefix used. The LTE turbo code basic code rate was 1/3 and supported modulation schemes were QPSK, 16-QAM, and 64-QAM. He calculated the maximum throughput of different scenarios by applying the modulation scheme and puncturing code rate. His example was a case of 15 MHz bandwidth, two antenna ports, and assigning two FDM symbol for PDCCH, the number of resource elements for PDSCH was 196896 in one radio frame. So applying the modulation schemes of 64-QAM, 16-QAM and QPSK with code rates 0.92, 0.85, 0.71 respectively, the throughput was 108.868Mbps, 66.94Mbps, and 27.959Mbps for each case. The author did a good work though, but his major limitation to the maximum throughput obtained was because of the number of antennae he used which employs 2X2 MIMO. Higher throughput is expected with 4X4 MIMO which was still under development during the time of his research.

Zhang in [5] focuses on the end user application performance of LTE, especially depending on the bit rate and latency offered by LTE. LTE provides high peak bit rates by using a bandwidth up to 20 MHz, high-order 64QAM and multi-stream MIMO transmission. Here assumes 13 data symbols per1ms sub-frame. The modulation coding is that QPSK carries 2 bits per symbol, 16QAM 4 bits and 64QAM 6bits; QPSK 1/2 rate coding carries 1 bps/Hz, and 64QAM without coding and with 2 x 2 MIMO carries 12bps/Hz. The items of the sub-carriers number for each bandwidth are 72 per 1.4 MHz, 180 per 3.0 MHz bandwidth and so forth. The detailed assumptions and results for DL peak bit rates could be calculated from equation below:

Peak bit rate (Mbps) = (bits/Hz) × Number of sub-carriers × (Number of symbols per sub-frame/1ms)

Zhang observed that the UL peak data rates were lower than DL peak data rates because single-user MIMO is not specified in UL and MIMO in UL only increases cell data rates. Using 64QAM 4x4 with 2x2 MIMO, peak data rate of 172.8 was obtained. Zhang’s survey took a glance at LTE background motivations, primary adopted technologies and DL/UL specifications in order to gain a general knowledge of LTE in the first stage. Then, taking a close look at the major technical parts of LTE, for instance, LTE architecture, OFDMA, SC-FDMA, MIMO, TDD and FDD in order to further understand the detailed contents, i.e. what consists of LTE flat architecture, what principles of LTE OFDMA and SC-FDMA schemes are, the similarities and differences between OFDMA and SC-FDMA as well as FDD/TDD duplex schemes. He finally examined the main end user application performance such as DL/UL peak data rates and low latency in real world. It is obvious that LTE makes a lot of innovations in terms of technology for the purposes of data rates and other performances. Its peak throughputs have already exceeded what can be achieved by HSPA+. Moreover, LTE obtained low cost per bit for a competitive service, enlarged the UL range and fulfilled the need for power-efficient device transmission.

Zhang’s proposition was based on deduction from several write up on LTE without any practical work to either confirm or disagree on these facts. Notwithstanding, his inference was logically drawn from the given equation. This work will however confirm this from the field test in due time.

Ruiz Grande in [6],analyses the Radio Resource Management (RRM) and Inter-Cell Interference Coordination (ICIC) in Heterogeneous Network, with special focus on managing the co-channel interference from the macro cell to the cell-edge users connected to the LPN (Low Power Node) through time-domain resource partitioning between the macro and LPN layers. He referenced that new applications including video live streaming or real time gaming were becoming more and more ubiquitous, requiring certain guaranteed bit rate (GBR) requirements due to the huge popularity of smart phones and the improvement of mobile networks. It was also needed, therefore, some techniques to guarantee quality of service (QoS) to users making use of these applications.

Ruiz Grande’s work shows the need of using inter-cell interference management techniques, resulting in a remarkable improvement in the overall system performance. A gain of up to a factor 2.5 was achieved in terms of user throughput when using eICIC (Enhanced Inter-Cell Interference Coordination) by means of the dynamic strategy. Even the static case gave a user throughput two times higher than the case without eICIC. In addition, regarding the static and dynamic strategies studied to perform eICIC, a relative UE throughput gain of around 25% was obtained when using the dynamic case over the static one, which mainly comes from the Low Power Node - layer due to a more efficient allocation of the available resources. Ruiz Grande’s work offered a positive approach towards achieving GBR and efficient capacity utilization by proper managing of interference. There is no doubt that interference limits the mobile networks capacity especially the IP networks since great proportion of useful power would be required to process the noise figures.

In this work the performance evaluation of the LTE communication standard in comparison with the UMTS (3G) standard is performed using networks from MTN communication Limited for the field test and using simulation software for the performance evaluation and comparison.

III. METHODOLOGY

This work experimentally evaluates the performance of different KPIs of LTE against UMTS in urban area (Port-Harcourt, South-South Region of Nigeria as a case study). In order to achieve accuracy in this evaluation, the first approach was to perform drive tests in operational LTE and UMTS networks in urban area. Drive tests was done in areas with overlapping LTE and UMTS coverage so as to create several scenarios of the inter-RAT handover and also have common ground for judgment. The Statistics of the different KPIs were analyzed. The data collected includes data for serving cell as well as the neighbours and the contain information about the entire network KPI; Call Setup Success Rate, Handover, Throughput, Latency, Radio Capacity status etc. This collected data is then analyzed and deductions made. For example, the success rate of handover from LTE to UMTS and then from UMTS to LTE were analyzed. In addition, the service interruption time and perceived call quality were also examined. This approach is the best as it gives a real-life scenario of the handover under investigation. MTN Nigeria was the closest candidate for this type of testing because they have an existing UMTS network and a 'test LTE network' in Port Harcourt, Rivers state.

A) Experimental Testbed

The hardware setup for the experiment is grouped into the user interface hardware and network interface hardware. A complete drive test kit (TEMS Kit) is connected in a special way to represent the user interface design and it is composed of two mobile stations (UE 1 and 2), two data modem (DC 1 and 2), a GPS antenna, USB dongle (which contain the software license), all connected to a laptop computer. The laptop computer has a TEMS Investigation Drive Test Software installed which has to detect all connected hardware and provides interface to investigate/monitor the radio network during the drive test. The laptop computer is connected through an inverter to a DC source of a vehicle. The network interface design is the BTS (Base Transceiver Station) which is the source of the radio network under evaluation. Fig. 1 shows the block diagram of RF drive test equipment Setup while Fig. 2 shows live setup picture and Fig. 3 shows the map of our experimental testbed.

B). UMTS Network Architecture and Protocol

The UMTS architecture shown in Fig. 4, comprises of the UE, the base station (known as the Node B), the Radio Network Controller (RNC) which together make up the UTRAN. Also shown are the Core Network and the associated interfaces [7], [8], [9].

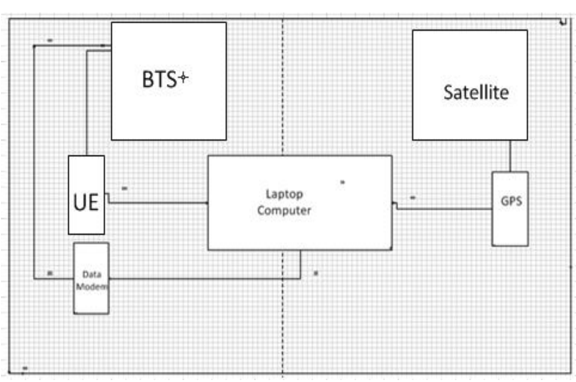

Fig. 1: Block Diagram of RF Drive Test Equipment Setup

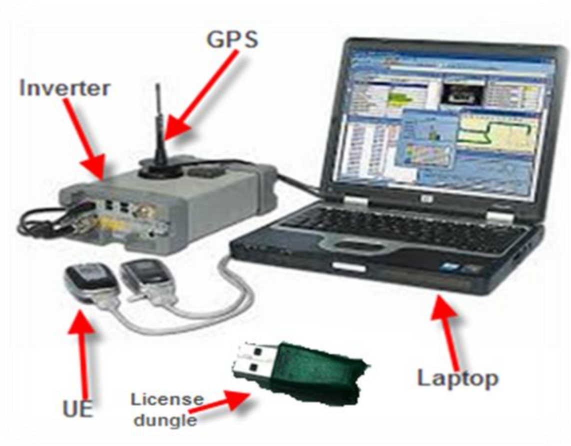

Fig. 2: RF Drive Test Equipment Setup

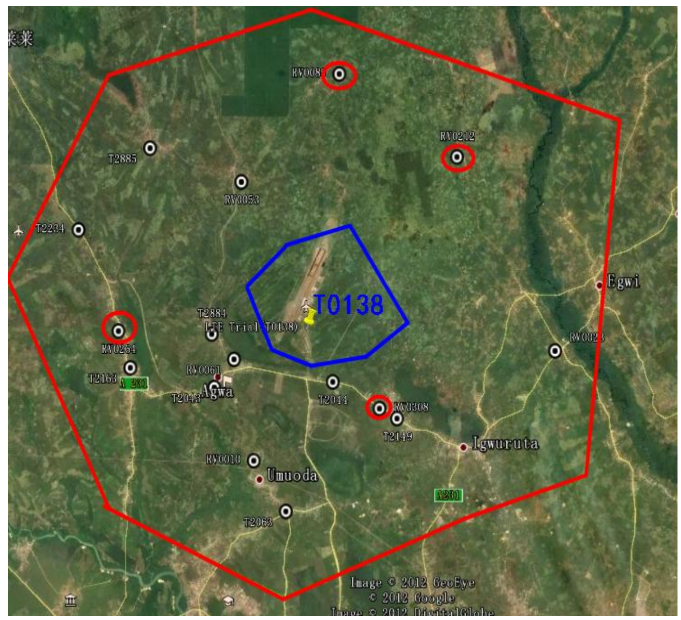

Fig. 3: Map of our Experimental Testbed

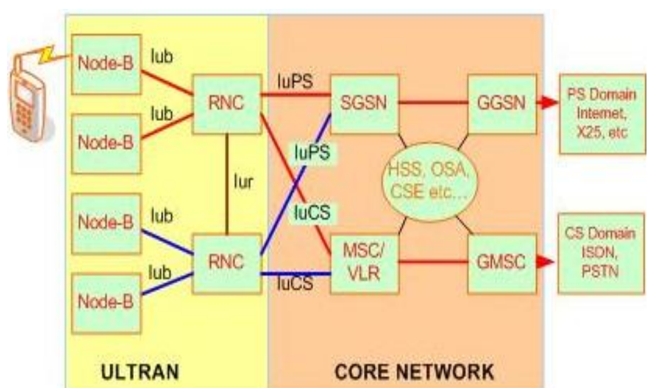

Fig. 4: UMTS Network Architecture

The UE: Consists of the Mobile Equipment (ME) and Universal Subscriber Identity Module (USIM).The ME is a radio terminal used for radio communication over the Uu interface. The Uu interface allows for communication between the UE and the UTRAN. The USIM is a smartcard that holds subscriber identity and performs authentication algorithms.

* Node B:Is the UMTS base station and converts the data flow between the Iub and Uu interfaces. The Iub interface is used to carry messages between the NodeB and the RNC. The Node B also performs radio resource management functions.
* The Radio Network Controller (RNC): controls radio resources (Node Bs).
* Home Location Register (HLR):is a database in the CN that stores the master copy of the user's service profile.
* Mobile Services Switching Centre/Visitor Location Register (MSC/VLR): is the switch and database that serve the UE in its current location for Circuit-Switched services. The MSC switches the CS services while the VLR holds a copy of the visitor's user profile.
* Gateway MSC (GMSC):is the switch through which the UMTS connects to other CS networks.
* Serving GPRS Support Node (SGSN):is similar to MSC/VLR except that it is used for packet switched services.
* Gateway GPRS Support Node (GGSN):is similar to the GMSC but in relation to packet switched services.

C). LTE Network Architecture and Protocol

In LTE the term EPC [10], [11], [12], Evolved Packet Core, is used to refer to the new core network. The following nodes are present in the EPC as seen in Fig. 5.

* Serving Gateway, SGW: gateway that terminates the interface towards E-UTRAN. For each UE associated with the EPS, at a given point of time, there is a single Serving GW. The S-GW performs several functions but mainly handles mobility management within the LTE network and other 3GPP technologies. SGSN could be connected to the S-GW to enable the smooth running with UMTS.
* Packet Data Network Gateway, PGW: The PDN GW is the gateway which terminates the **SGi**interface towards the PDN. The SGi interface is the reference point between the PDN gateway and the packet network. If a UE is accessing multiple PDNs, there may be more than one PDN GW for that UE; however a mix of S5/S8 connectivity and Gn/Gp connectivity is not supported for that UE simultaneously.
* Mobility Management Entity, MME deals with control plane signalling, mobility management and idle-mode. The MME is connected to the S-GW and P-GW via the S11 interface.
* Policy and Charging Rules Function, PCRF is concerned with QoS policy and charging policy.

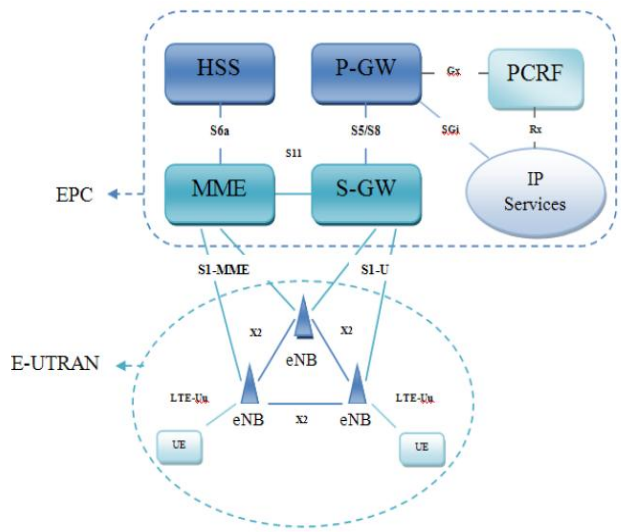

Fig. 5: EPS Architecture

D). Comparison of LTE and UMTS Physical layer

Basically, LTE physical layer is built based on UMTS/HSPA releases. The first LTE release covers aspects of HSDPA and HSUPA e.g., Hybrid Automatic Repeat request (HARQ), base station-based scheduling and link adaptation, multi-antenna downlink transmission [13], [14], [15]. Table 1 shows the comparison of the physical layer of the LTE and UMTS systems.

IV. IMPLEMENTATION AND RESULTS

As discussed earlier**,** the drive test data was collected by making both long and short calls over repeated number of times. The data collected contain information about the entire network KPI. Table 2 shows the UMTS and LTE statistics for various KPI while Fig. 6 compares the statistics under same scenario. Table 3 shows the comparison of LTE and UMTS drawn from both the drive test parameters and analysis.

Table 1: LTE and WCDMA physical layer comparison

Feature	LTE	HSUPA	HSDPA
Multiple access	OFDMA SC-FDMA	WCDMA	WCDMA
Bandwidth range	1.4-20MHz	5-10MHz	5-10MHz
Fast power control	No	Yes	No (associated DCH only)
Soft handover	No	Yes	No (associated DCH only)
Adaptive modulation	Yes	Yes	Yes
BTS-based scheduling	Time/Frequency	Time/Code	Time/Code
Fast L1 HARQ	Yes	Yes	Yes

Table 2: UMTS and LTE drive test analysis table

Indicators	UMTS Statistics	LTE Statistics
Call Attempts	90	90
Call Setup Success	86	89
Blocked Calls	4	1
Dropped Calls	1	0
Total Good Calls/Call End	84	89
Established Calls	86	89
Total Handover Attempts	103	105
Total Handover Success	97	104
Total Handover Failures	6	1
% Call Setup Success (Accessibility)	95.56	98.89
% Blocked Calls	4.44	1.11
% Dropped Calls	1.16	0.00
% Established Calls	95.56	98.89
% Good Calls	93.33	98.89
% Handover Success	94.17	99.05
% Handover Failures	5.83	0.95
Rx Signal Level > -(95dbm)	0.99	0.94
RxQual_sub<5	0.91	0.95
Overall Network Quality Index - NQI	90.84	98.44
Accessibility (Call Setup Success Rate)	95.56	98.89
Retainability (100 - Dropped Call Rate)	97.44	100.00
Voice Quality (Ec/No >= -11dB)	91.21	98.52
Coverage Reliability (RSCP > -90dBm)	94.93	79.24
BLER (<=2%)	98.43	99.61

Table 3: UMTS and LTE Performance Comparison Table

Parameters	UMTS	LTE
Data Throughput :	Up to 3.1 Mbps with an average speed of 0.5 to 1.5 Mbps	2 to 12 Mbps but potential estimated at a range of 100 to 300 Mbps
Peak Upload Rate	2.97 Mbps (Estimated at 11 Mbps)	16.85 Mbps (Estimated at 72 Mbps)
Peak download Rates	12.56Mbps (Estimated at 28 Mbps)	34.31Mbps (Estimated at 300 Mbps)
Switching techniques	Packet switching	Packet switching,message switching
Network Architecture	Wide area cell based	Integration of wireless LAN and wide area
Services and Applications	CDMA 2000,WCDMA,	WiMax and LTE-advance
Forward error correction (FEC)	UMTS uses Turbo codes for error correction	Uses Concatenated codes for error correction
Frequency Band	1900/2100 MHz	1900/2100 MHz, 1800MHz Refarmed
Call setup time	2s	50ms
Mobility	250Km/h	350Km/h
Bandwidth	5MHz	Scalable up to 20MHz
Web surfing	8 seconds	Immediately

From the data obtained during the drive test and the analysis of the data as shown in Table 2, Table 3 and Fig. 6, it was deduced that LTE using orthogonal Frequency Division Multiplexing (OFDM) and scalable bandwidth, together with more advanced MIMO schemes, provides better data rates and improved overall KPIs than the UMTS.

V. CONCLUSION

Based on this experimental study, LTE has proven itself in today's world as it ensures a very high data rate, low latency, global roaming etc. Nigeria and the world at large are looking forward for the most intelligent technology that would connect the entire globe, and LTE has been launched in many advanced countries. With rapidly evolving mobile technology, phone developers are constantly looking for improved and faster voice and data connections. The current market is already beginning to push forward with LTE which is the fourth-generation or 4G, phone capabilities. Also the fast evolution of IP television in which users can stream/watch online videos with their television has called for urgent improvement in the data service offered by the network operators. Mobile network operators in Nigeria should be allotted frequency band for LTE at a good consideration, otherwise be encouraged to reform available 1800 band frequency for the LTE network.

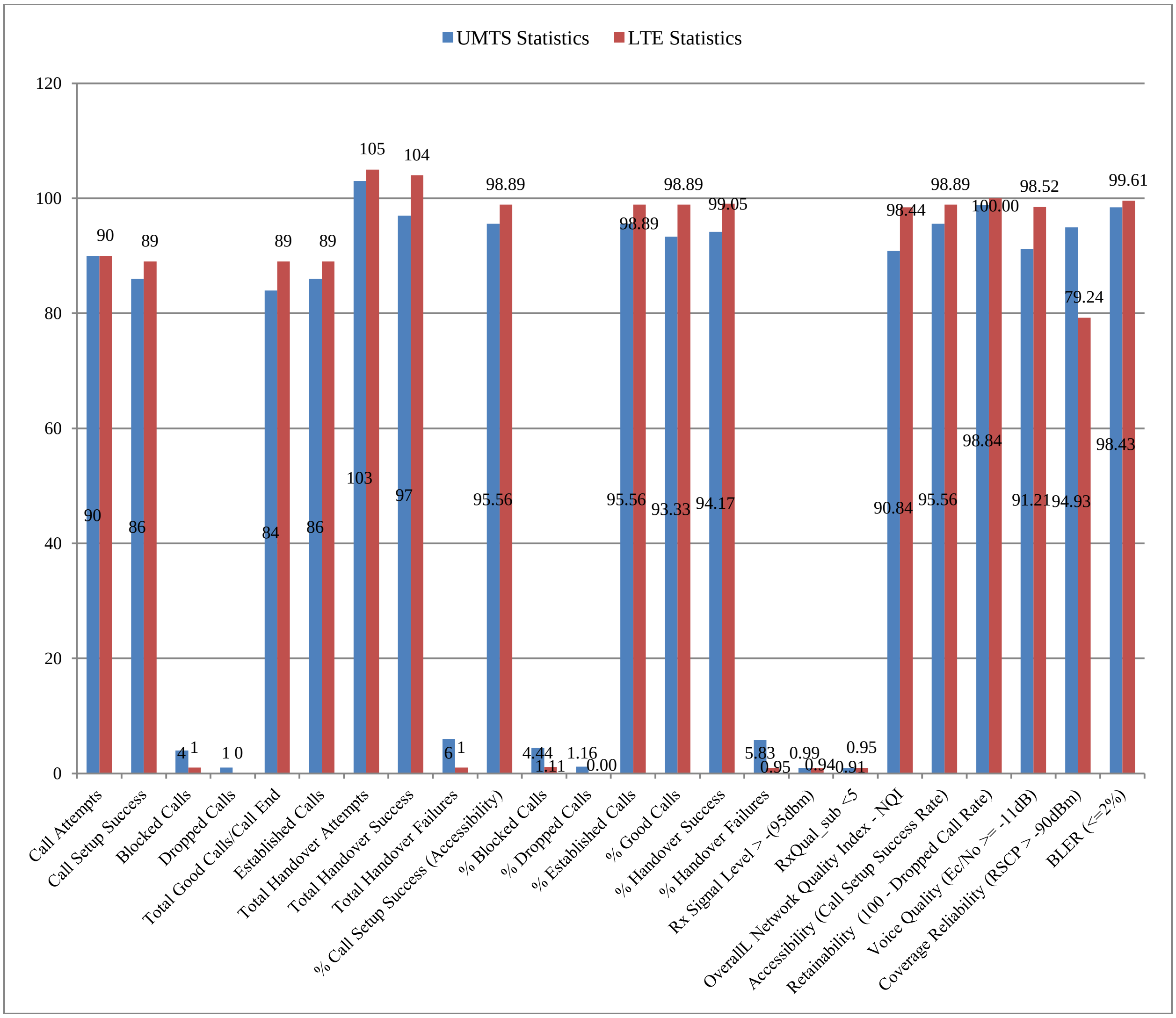

Fig. 6: UMTS and LTE Drive Test Analysis Chart

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