LTE Theory to Practice- KPI Optimization (A 4G Wireless Technology)

Damini Rai, Abhishek Dwivedi

Abstract: LTE is the most competitive radio technology nowadays and in coming years by offering high-data-rates with low-latency, improving services, lowering the costs and allowing for spectrum refarming thanks to the frequency and bandwidth flexibility. LTE evolution is going over LTE-A features towards 5G direction. One of the reasons for the success of LTE is that operators are actively driving the LTE standard through the NGMN (Next Generation Mobile Networks) - www.ngmn.org and through 3GPP as well- . On Jan 2016, there were 480 commercial LTE networks launched worldwide (Source www.gsacom.com). The deployment are accompanied by LTE-A features and several VoLTE deployments. As shown in Figure 1 the migration paths for existing mobile operators are multiple which facilitates the success of the technology. Certainly.

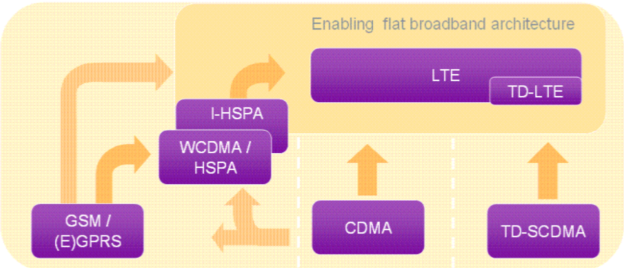


Figure 1: Migration Paths to LTE

LTE brings new technologies like Multiple Input Multiple Output (MIMO) transmission, multiband carrier aggregation, small cells and a number of new uses cases like Voice over LTE (VoLTE). The optimization of Key Performance Indicators (KPI) is still important in LTE including setup success rates, handover success rates and call retainability. LTE uses frequency reuse one without any soft handover which makes the interference management more challenging than in legacy radio networks. Signalling message coding and packet scheduling are example solutions in LTE optimization together with the traditional RF optimization. Voice has been Circuit Switched in 2G and in 3G networks while voice in LTE is VoIP (VoLTE). A number of optimization steps are required to provide similar or better drop rates with VoLTE as with CS voice. Also the handover from VoIP to CS voice requires optimization. That is called Single Radio Voice Call Continuity (SRVCC). LTE will be running in parallel with 2G and 3G network. The interworking between these radios need to be considered as well as the usage of multiple LTE bands.

Keywords: LTE, VoLTE, (SRVCC), LTE Brings New Technologies like Multiple Input Multiple Output (MIMO) Transmission,

Manuscript published on 30 December 2018.
*****Correspondence Author(s)
Damini Rai, M-Tech Research Scholar, Department of Information Technology, Lakshmi Narain College of Technology and RGPV University, Bhopal (M.P), India.
Abhishek Dwivedi, Assistant Professor, Department of Information Technology, Lakshmi Narain College of Technology and RGPV University, Bhopal (M.P), India.

I. INTRODUCTION

Long Term Evolution or LTE is a 3GPP-defined mobile communication technology also known as 4G.
The actual LTE (4G) is based on 3GPP Release 11.This release is the second stage of the LTE-Advanced realization. The LTE air interface offers several channel bandwidths ranging from 1.4MHz to 20MHz. In addition, LTE air interface supports both frequency division duplexing (FDD) and time division duplexing (TDD).

The basic LTE can provide peak data rate of 150 Mbps in the downlink and 50 Mbps in the uplink. However, LTE-Advanced can provide higher peak data rates; 300 Mbps in the downlink and 150 Mbps in the uplink.
LTE is based on Orthogonal Frequency Division Multiplexing (OFDM). The peak data rates can be further increased by using advanced Multiple Input Multiple Output (MIMO), Carrier Aggregation solutions, Coordinated Multipoint (CoMP) and Enhanced Inter-cell Interference Coordination (eICIC).
The Evolved-Universal Terrestrial Radio Access Network (E-UTRAN) contains only one network element called evolved NodeB (eNodeB). Note that E-UTRAN does not include a centralized radio network controller element but is simply a network of base stations.

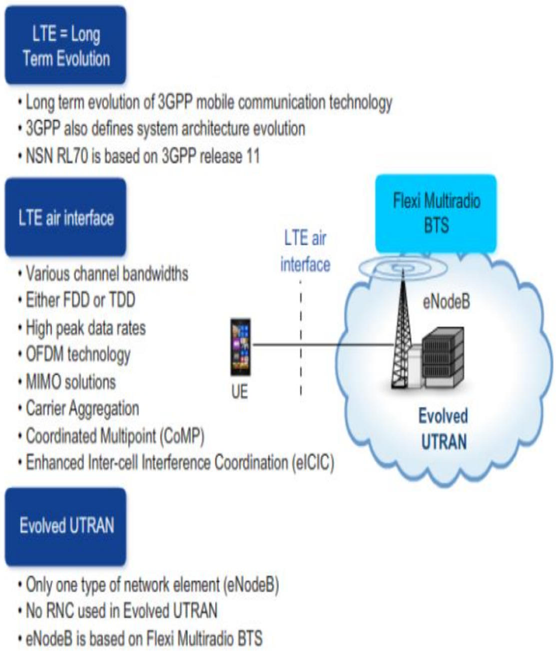


Fig.1

Published By:
Blue Eyes Intelligence Engineering and Sciences Publication (BEIESP)

II. EXPECTATIONS AND MARKET NEEDS

LTE stands for Long Term Evolution and together with LTE-A represent the next step in mobile radio communications after HSPA. 3GPP is the standardization body behind LTE. The technical specifications for LTE air interface are defined in 3GPP since Release 8 and they can be found in the 36-series (TS 36.xxx).Current RL16A release baseline is Release 12 (June 2015) Another name for LTE used in 3GPP is E-UTRA (Evolved-UMTS Terrestrial Radio Access).

LTE requirements are specified in 3GPP TS25.913. Main basic requirements were:

- Peak data rate of 50 / 100 Mbps (uplink / downlink)
- Reduced latency enabling RTT (round trip time) <10 ms
- Packet-optimized
- Improved spectrum efficiency between 2- 4 times higher than Release 6 HSPA
- Frequency flexibility: standard defined 15 FDD and 8 TDD operating bands, the number have been extended over the time
- Bandwidth scalability with allocations of 1.4, 3, 5, 10, 15 and 20 MHz along with carrier aggregation extension (up to 60 MHz since RL15A)
- Operation in FDD and TDD modes
- Support for inter-working with WCDMA and non-3GPP systems (i.e. WiMAX, 3GPP2, TD-SCDMA)
- Good level of mobility: optimized for low mobile speeds (up to 15km/h) but support also high mobile speeds (up to 350km/h)
- Improved terminal power efficiency

A. Architecture

LTE architecture differs from previous UMTS architecture. Principles for LTE architecture design were defined in 3GPP TS25.913. Some of those principles:

Packet based architecture, although real-time and conversational class traffic should be supported

It should simplify and minimize the number of interfaces

It should be designed minimizing the delay variation for traffic requiring low jitter, i.e., TCP/IP

End to end QoS should be supported for the diverse types of traffic

Before getting into more detail, it is worth mentioning some related concepts:

LTE or E-UTRA refers to the radio access network

Evolved Packet Core (EPC) refers to the core network. The 3GPP name for the core network is System Architecture Evolution (SAE)

Evolved Packet System (EPS) refers to the entire system: E-UTRA plus EPC

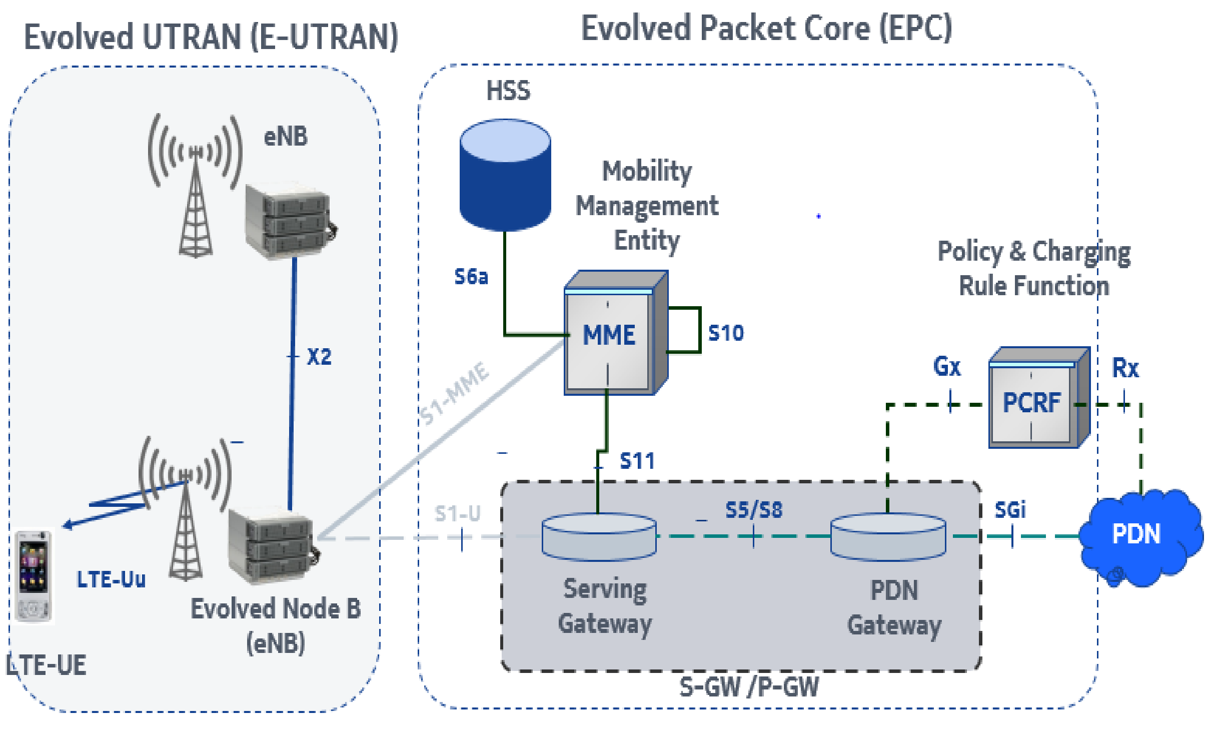


Figure 2: EPS Network Elements

The LTE / EPC architecture is driven to optimize the system for packet data transfer. There are no circuit switched components.

The network architecture for LTE is called flat architecture: there is only a network element in the user plane (the eNodeB) between the radio network and the core network. The RNC is not part of the architecture any more as the eNodeB does the RNC functions. The radio protocols that previously ended in the RNC end in the eNodeB for LTE. Figure 3 shows the network architecture evolution from Release 6 (HSPA) to Release 8 (LTE) and further.

Published By:
Blue Eyes Intelligence Engineering
and Sciences Publication (BEIESP)

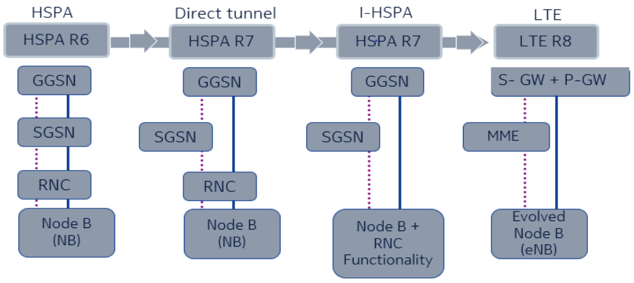


Figure 3: Network Architecture Evolution

This simplification in the architecture not only reduces the costs of the network deployment by using fewer network elements but also allows for shorter round-trip times which is one of the 3GPP requirements for LTE.

B. Network Elements

Figure 2 shows the network elements within the EPS. As mentioned previously, the eNodeB is the only network element on the radio side, replacing the previous eNodeB / RNC combination from UMTS and providing all the radio management functions. Below, a summary of the eNodeB functions:

Radio Bearer Control: setup, reconfiguration and release
Admission Control
Scheduler
Transmission of Paging messages and of Broadcast information (SIBs)
Measurement collection and evaluation
User data routing to the S-GW/P-GW
MME selection at attach of the UE
Security: Ciphering and Integrity protection on the radio interface
IP header (de)compression
Connection Management Control: UE state management

Core network issues are out of the scope of this document however, a brief description of each of its network elements is given for completeness:

Mobility Management Entity (MME): Pure signaling entity within the EPC. Amongst its main functions:
Subscriber attach/detach
Tracking area updates
Triggering and distribution of paging messages to UE
Security and roaming control
Authentication, integrity protection

Serving Gateway (S-GW): Manages the user data in the EPC. Receives packet data from the eNodeB and sends packet data to it.

Packet Gateway (P-GW or PDN-GW): Connection between EPC and external Packet data Networks (PDN). Comparable in functionality with the GGSN in 2G/3G networks.
IP address allocation for UEs
Packet routing / forwarding between S-GW and external data networks
Firewall functionality

Policy and Charging Rule Function (PCRF): As the name indicates, it is responsible for implementing the charging policy and for the QoS negotiation with external packet data networks

Home Subscriber Server (HSS): Permanent and central subscriber database containing mobility and service data for each subscriber. It also contains the AuC (authentication center) functionality

C. Interfaces

Along with the air interface treated in the next section there are two other interfaces of the main interest from the radio point of view:
X2 interface:
Logical interface between eNodeBs since it does not need direct site-to-site connection. It can be routed via core network as well. It is used during inter eNodeB handovers avoiding the involvement of the core network during the handover and forwarding the data between source and target eNodeB. It is also involved in the RRM functions like e.g. exchange of load information between neighboringeNodeBs to facilitate the interference management.
S1 interface:
The S1 interface is divided in two interfaces:
S1-U interface: User plane interface between the eNodeB and the S-GW. Dedicated only to user data.
S1-MME interface: Control plane interface between the eNodeB and the MME for the exchange of Non- Access Stratum messages between MME and UE (e.g. paging, tracking area updates, authentication).

III. BASIC PRINCIPLE

A. Air-Interface

One of the main changes in LTE with respect to UMTS is the use of different transmission schemes in the air interface. LTE downlink air interface is based on OFDMA (Orthogonal Frequency Division Multiple Access) whereas the uplink air interface is based on SC-FDMA (Single Carrier-Frequency Division Multiple Access).

B. OFDMA

OFDMA is an extension of the OFDM transmission scheme by allowing multiple users. That is, allowing for simultaneous frequency-separated transmissions to / from multiple mobile terminals. In OFDM the user data is transmitted in parallel across multiple orthogonal narrowband subcarriers. Each subcarrier only transports a part of the whole transmission. The orthogonal subcarriers are generated with IFFT (Inverse Fast Fourier Transform) processing. The number of subcarriers depends on the available bandwidth as shown in Figure 4. In LTE, they range from less than one hundred to more than one thousand.

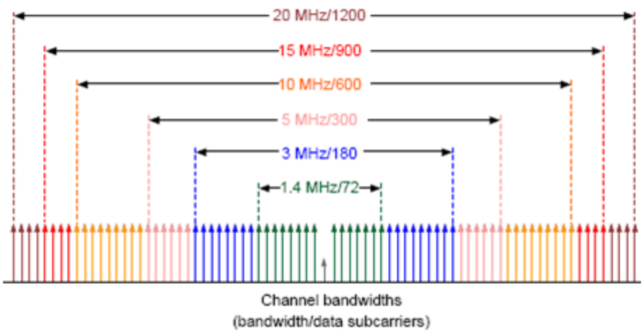


Figure 4: Number of Subcarriers for the Different Bandwidths

Published By:
Blue Eyes Intelligence Engineering and Sciences Publication (BEIESP)

The spacing between subcarriers is fixed in LTE and equivalent to 15 kHz in the frequency domain.

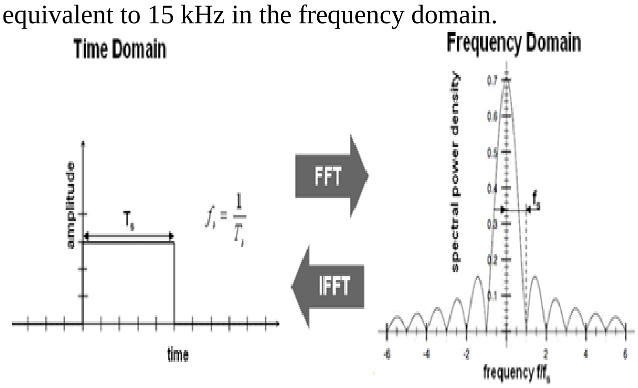


Figure 5: Time and Frequency Domain Representation of an OFDM Subcarrier

Figure 5 represents a subcarrier in time and frequency domain. A rectangular pulse in time domain corresponds to a sinc-square-shaped spectrum in frequency domain. Although the signal spreads considerably across the spectrum, the spectral power density has null points at multiples of the frequency fs= 1/Ts. Orthogonality means the peaks of a subcarrier intercept the null points of the neighboring subcarriers (frequency domain) and therefore there is no interference between subcarriers.

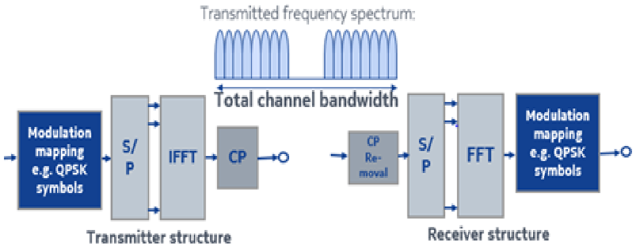


Figure 6: OFDM Operation

Figure 6 summarizes at high level the OFDM operation at the transmitter's and receiver's end. User data is modulated according to the different modulation schemes (depending on the radio link conditions). On the transmitter side, the modulated symbols are interpreted as frequency domain signal and fed into the IFFT algorithm that transforms them into the corresponding time sequence. The number of time symbols is equal to the number of carriers. Then, the cyclic prefix (CP) is inserted. The length of the CP is expressed in the basic time unit Ts and its duration varies for the normal and the extended cyclic prefix (see next page). The bits that define the CP are taken from the end of the symbol and placed as cyclic prefix in front of the symbol (see Figure 7). Finally, the signal is modulated onto the radio carrier and transmitted over the air interface. Inverse operations are carried out on the receiver side i.e., removal of cyclic prefix, FFT to bring the signal back to the frequency domain representation and finally, the symbol de-mapping where the original bit sequence is recovered.

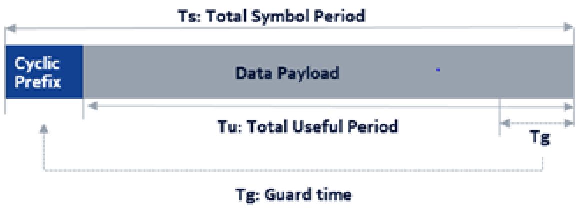


Figure 7: Cyclic Prefix Principle

Cyclic prefixes are used by all modern OFDM systems as a way of fighting against the Inter Symbol Interference (ISI) that may happen in multipath environments where transmitted signals arrive at the receiver with different delays. As previously mentioned, the CP consists of a copy of the last part of a symbol shape for the duration of a guard time and adding it to the beginning of the symbol. This guard time needs to be long enough to capture all the delayed multipath signals and avoid ISI at the receiver. Besides, the CP is used by the receiver to detect the start of symbol due to the high correlation between the CP and the last part of the symbol that precedes so the receiver can start with the decoding.

Using the CP to manage the effects of ISI is possible due to the long symbol duration in OFDM based systems. LTE's typical symbol duration including the CP is around 71.64 µsec. That is considerably longer when compared with GSM 3.69 µsec or 0.26 µsec for WCDMA. Therefore, LTE does not require complex ISI management techniques like other systems.

There are two cyclic prefix options for LTE:

Normal cyclic prefix: For use in small cells or cells with short multipath delay spread. Its length depends on the symbol position within the slot being 5.21 µsec for the CP in symbol 0 and 4.6 µsec for the rest of symbols. The reason for these two different lengths is so that the slot duration is 0.5ms, facilitating at the same time, that the terminal finds the starting point of the slot.

Extended cyclic prefix: For user with large cells or those with long delay profiles. Its length is 16.67µs and it is constant for all symbols in the slot. Extended cyclic prefix appeared at RL15A as part of MBMS feature only. It seems there is not strong will to for regular implementation of extended CP except MBMS solutions in cellular industry at all.

C. Subcarrier Types

There are several types of subcarriers:

Data subcarriers: Represent most of the subcarriers. They carry the modulated user data signals. The data rate of each data subcarrier depends on the symbol rate and the modulation scheme employed.

Null subcarriers. As the name indicates, nothing is transmitted in these subcarriers. There are two types:

Guard subcarriers: They are located at the bottom and top of the channel. Their function is to limit the amount of interference caused by the channel and also to limit the adjacent channel interference from neighboring channels. The more guard subcarriers the less the interference but this also reduces the data throughput of the channel.

In addition, the number of guard subcarriers affects the LTE Tx spectrum mask: the more the guard subcarriers the less the data subcarriers and the 'wider' the Tx spectrum mask will be because there are less subcarriers to cancel out the tails of the sinc signals. LTE Tx spectrum emission mask needs to meet the UMTS spectrum emission mask (from 3GPP specifications) if the same/similar interference is to be caused to the adjacent carriers in both technologies.

Retrieval Number: B2534128218/18©BEIESP
Journal Website: www.ijitee.org

Published By:
Blue Eyes Intelligence Engineering and Sciences Publication (BEIESP)

DC-subcarrier or null subcarrier: It is the center subcarrier of the downlink band (0 Hz offset from the channel's center frequency). This subcarrier is not used because it may suffer from high interference (i.e., due to local oscillator leakage). The null subcarrier does not exist in the uplink because a frequency offset of 7.5 kHz is applied.

D. OFDMA Symbol

The OFDMA symbol is defined in the time and frequency domains:

Time domain: Time period occupied by the modulation symbols on the considered subcarriers. The symbol duration without considering the cyclic prefix is 66.67 µs since the subcarrier spacing is 15 kHz.

Frequency domain: A symbol is made up of subcarriers. Figure 8 shows that each subcarrier only carries information related to a specific modulation symbol. An OFDMA symbol represents all the data being transferred in parallel at a point in time.

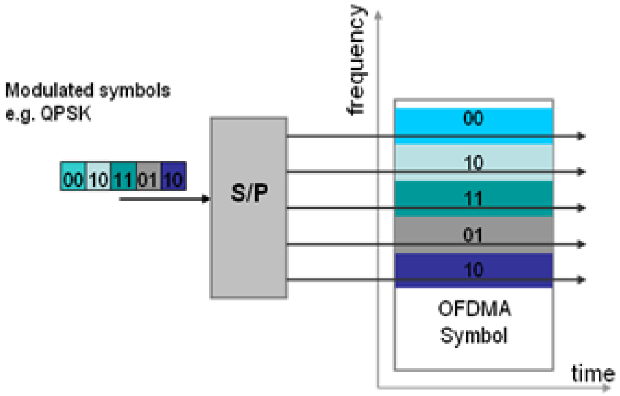


Figure 8: OFDMA Symbol

E. LTE Physical Layer Structure

There are two types of frames defined for LTE: Type 1 frame for FDD and Type 2 frame for TDD. FDD LTE Type 1 Frame (FDD) is common to both, uplink and downlink. Components and durations are illustrated in Figure 9

Frame length: 10 ms. In the FDD case, 10 ms frame for UL and 10 ms frame for DL

1 Frame = 20 slots of 0.5 ms each

1 slot (sx) = 7 symbols (syx) in the case of normal CP or 6 symbols in case of extended CP

1 Frame = 10 Subframes (SF) of 1ms each

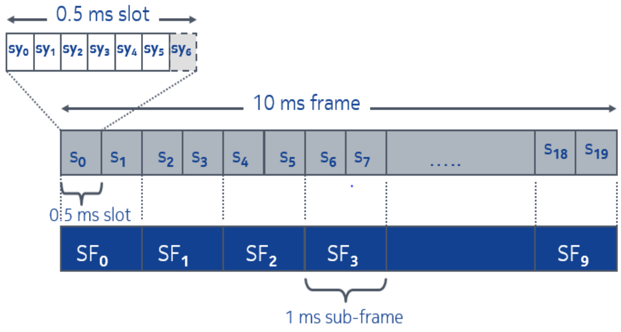


Figure 9: LTE FDD Frame Structure

As shown in Figure 7, the Total symbol duration (Ts) includes the cyclic prefix duration. The extended cyclic prefix duration is equal for all the symbols in the slot (16.67µs). Normal cyclic prefix duration is longer for the first symbol of the slot (5.21 µs). Remaining symbols in the slot have a cyclic prefix duration of 4.7 µs.

The reason why there are fewer symbols per slot in the case where extended CP is used, is that the total symbol duration (with extended CP) is longer and this leaves room for fewer symbols within the 0.5 ms slot.

F. TDD

Type 2 frame is defined for TDD. Type 2 frame shares the same frame structure and the slot duration of Type 1 frame but it contains some TDD specific fields to enable switchovers between UL and DL along with the co-existence with the TD-SCDMA. Figure 10 shows the LTE TDD frame structure:

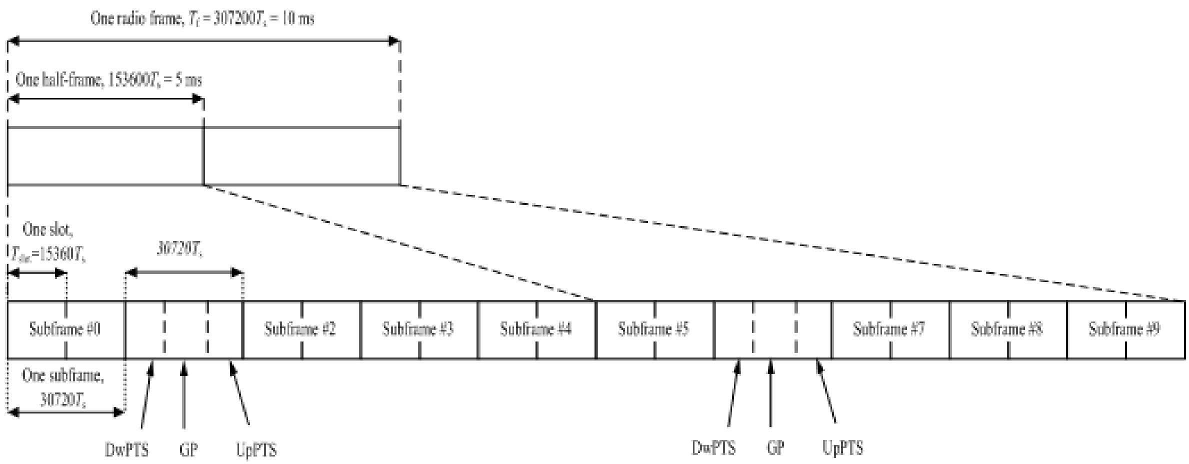


Figure 10: LTE TDD Frame Structure (for 5 ms Switch-Point Periodicity)

Each radio frame of length $T_f = 307200 \cdot T_s = 10$ ms consists of two half-frames of length $153600 \cdot T_s = 5$ ms each. Each half-frame consists of five subframes of length $30720 \cdot T_s = 1$ ms. The supported per 3GPP uplink-downlink configurations are listed in Figure 11 where, for each subframe in a radio frame, "D" denotes the subframe is reserved for downlink transmissions,

Published By:
Blue Eyes Intelligence Engineering
and Sciences Publication (BEIESP)

"U" denotes the subframe is reserved for uplink transmissions and "S" denotes a special subframe with the three fields: DwPTS, GP and UpPTS. Uplink-downlink configurations with both 5 ms and 10 ms downlink-to-uplink switch-point periodicity are supported.

DwPTS always contains reference signals and the Control Information,

like a regular DL subframe (i.e. PDCCH, PCFICH & PHICH), in the first symbol, deviating from usual PDSCH format. One subsequent symbol is consumed by the Primary Synchronization Channel (P-SCH). Further remaining symbols in the DwPTS can be used for DL data (the exact amount of resources depends on the S subframe configuration, that is, the size of the GP). UpPTS can be configured as 1 symbol or 2 symbols, which can be used for PRACH or SRS. If UpPTS length is 1 symbol, it can be used for Sounding Reference Signal (SRS) only.

Only the TDD DL/UL Configuration 1 and Configuration 2 are supported in Nokia releases up to and including TL17A.

Uplink / Downlink Sub frame Configuration	DL to UL Switching Period	Sub frame Number									
		0	1	2	3	4	5	6	7	8	9
0	5 ms	D	S	U	U	U	D	S	U	U	U
1	5 ms	D	S	U	U	D	D	S	U	U	D
2	5 ms	D	S	U	D	D	D	S	U	D	D
3	10 ms	D	S	U	U	U	D	D	D	D	D
4	10 ms	D	S	U	U	D	D	D	D	D	D
5	10 ms	D	S	U	D	D	D	D	D	D	D
6	5 ms	D	S	U	U	U	D	S	U	U	D

Figure 11: Uplink-Downlink Configurations

This figure shows that:

In case of 5 ms downlink-to-uplink switch-point periodicity, the special subframe exists in both half-frames.

In case of 10 ms downlink-to-uplink switch-point periodicity, the special subframe exists in the first half-frame only.

Subframes 0 and 5 and DwPTS are always reserved for downlink transmission. UpPTS and the subframe immediately following the special subframe are always reserved for uplink transmission.

Together with the GP, the length of DwPTS and UpPTS can be configured in 10 discrete special subframe formats as shown in Figure 12.

Nokia support is limited to special subframe configurations 3, 4, 5, 6, 7 and 9.

Special Sub frame Configuration	Normal Cyclic Prefix in DL		
	DwPTS	Guard Period Normal Cyclic Prefix in UL	UpPTS
0	3 sym	714 µs	1 sym
1	9 sym	285 µs	
2	10 sym	214 µs	
3	11 sym	143 µs	
4	12 sym	71 µs	
5	3 sym	643 µs	2 sym
6	9 sym	214 µs	
7	10 sym	143 µs	
8	11 sym	71 µs	
9	6 sym	429 µs	

Figure 12: Configuration of Special Subframe (lengths of DwPTS/GP/UpPTS)

IV. PHYSICAL RESOURCE BLOCK AND RESOURCE ELEMENT

A Physical Resource Block (PRB) or Resource Block (RB) is the physical resource used for transmission. Capacity allocation in LTE is based on Physical Resource Blocks.

A PRB is composed of 12 subcarriers in the frequency domain per 1 slot period (0.5 ms) in time domain. Since each subcarrier occupies 15 kHz, a PRB occupies 180 kHz (12 x 15 kHz) in the frequency domain. A different concept is the scheduling resource block that is composed of two Physical Resource Blocks (1 ms duration) since the scheduling is done per 1 ms (TTI duration)

A resource element (RE) is the theoretical minimum capacity allocation unit. It is formed by 1 subcarrier per 1 symbol.

Figure 13 represents the resource element concept and (physical) resource block concept in the case of normal CP being used (7 symbols per slot). There are 84 (7x 12) resource elements per PRB.

In case of extended CP being used each slot contains 6 symbols and a PRB is composed of 72 (=6 x 12) resource elements.

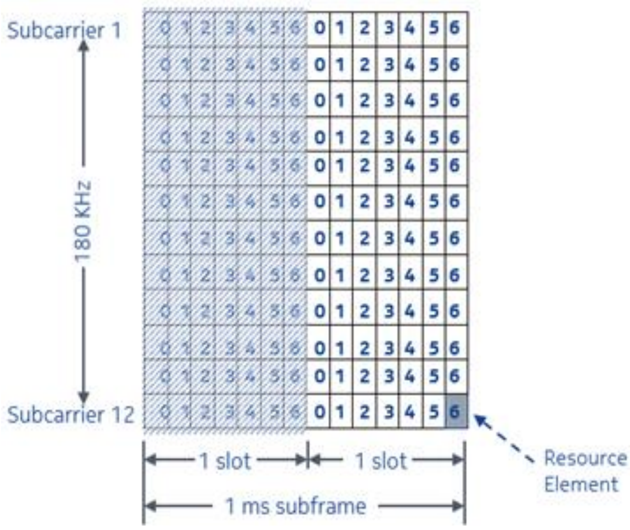


Figure 13: Physical RB and RE Concepts

Published By:
Blue Eyes Intelligence Engineering and Sciences Publication (BEIESP)

A. Downlink Resource Allocation

The physical layer specification allows for a downlink carrier to consist of any number of resource blocks, ranging from a minimum of 6 resource blocks up to a maximum of 100 (equivalent to a downlink transmission bandwidth ranging from around 1MHz up to 20MHz). However, only certain bandwidths are specified in the LTE requirements: 1.4, 3, 5, 10, 15 and 20MHz.

Once the bandwidth is known also the number of available resource blocks for scheduling is known. As Figure 14 shows, several users can be allocated per time period. The number of resource blocks assigned to each user will be decided by the scheduler based on the amount of data to be transmitted. The allocation in time domain (although not specified in Figure 14) refers to 2 slots (1ms).

Resource allocation does not need to be continuous in the frequency domain. This is different to the uplink resource allocation as it will be seen in **Error! Reference source not found.** Uplink Resource Allocation

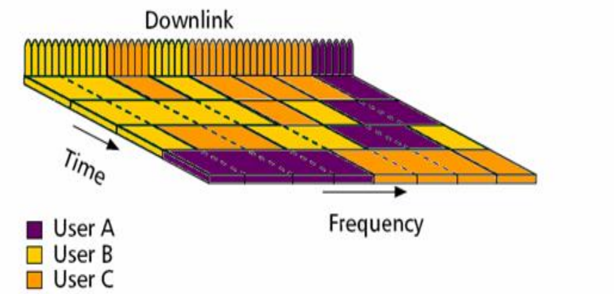


Figure 14: Downlink Resource Allocation

OFDMA Parameters

A summary of the main OFDMA parameters is presented in this section:

	1.4MHz	3 MHz	5 MHz	10 MHz	15 MHz	20 MHz
Frame Duration	10ms					
Subcarrier Spacing	15 kHz					
Sampling Rate (MHz)	1.92	3.84	7.68	15.36	23.04	30.72
Data Subcarriers	72	180	300	600	900	1200
Symbols/slot	Normal CP=7, extended CP=6					
CP length	Normal CP=4.69/5.12 μsec, extended CP= 16.67μsec					

Table 1: Summary of Main OFDMA Parameters

By having a fixed subcarrier spacing (15 kHz) the complexity of a system supporting multiple channel bandwidths is reduced. Additionally, 7.5 kHz subcarrier spacing option is defined for Multimedia Broadcast Multicast systems (MBMS).

To ensure that all signals are received correctly, the receiver sampling rate must be slightly higher than the bandwidth of the signal used to carry it (e.g. for a channel bandwidth of 10 MHz the sampling rate is 15.36 MHz). It is always a factor or multiple of 3.84 to ensure compatibility with WCDMA by using common clocking.

The subcarrier spacing (15 kHz) for the different bandwidths is obtained as: sampling frequency / FFT size. It can be observed that the FFT sizes (equivalent to the number of subcarriers used in the FFT process) vary from 128 in case of 1.4MHz to 2048 in case of 20MHz.

The difference between the subcarriers defined by the FFT size and the subcarriers used for the different bandwidths (shown in Figure 4) determines the number of subcarriers used to protect the system against the ACI (Adjacent Channel Interference), i.e. guard subcarriers or null subcarriers.

Downlink Reference Signals

Reference signals are not subcarriers but reference symbols. They do not occupy a whole subcarrier but they are periodically embedded in the stream of data being carried on a data subcarrier. In fact, each reference signal occupies one resource element (see Figure 13: Physical RB and RE Concepts).

Reference signals are used for channel estimation (signal quality and strength); therefore, they are similar in functionality to the Pilot signal in WCDMA. There are three types of reference signals defined in downlink for LTE: cell-specific, UE-specific and MBSFN (Multicast Broadcast Single Frequency Network).

Within the context of these planning guidelines, cell specific downlink reference signals are the ones with the most interest. They are transmitted in every downlink subframe spanning across the whole downlink cell bandwidth. Additionally, they are modulated to identify the cell to which they belong.

The position of the reference signals in the time domain is fixed (symbols 0 and 4 for the FDD frame) and in the frequency domain it depends on the Cell ID. Distributing the reference signals in both time and frequency domains allows the UE to complete the channel estimation in both domains.

In the case of downlink multi-antenna transmission (e.g. MIMO) the terminals need to estimate the channel for each transmitting antenna, so reference signals are needed per antenna (see **Error! Reference source not found.**). In these cases, the resource elements allocated to reference signals in one antenna cannot be used in the other antennas (DTX: Discontinuous Transmission-).

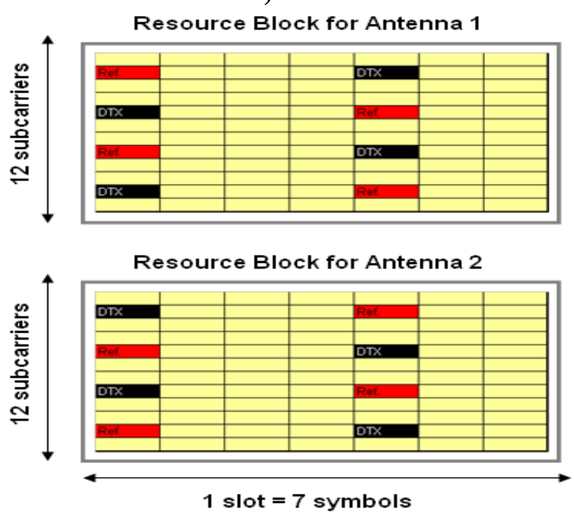


Figure 15: Downlink Reference Signals Example Location (2 Tx antennas case)

Published By:
Blue Eyes Intelligence Engineering
and Sciences Publication (BEIESP)

B. SC-FDMA

Single Carrier-Frequency Division Multiple Access is the technology chosen for the uplink air interface because it does not suffer from high peak-to-average power ratio (PAPR) as OFDMA. SC-FDMA is a more power efficient variation of OFDMA that still employs subcarriers, FFT, cyclic prefix and other OFDM concepts.

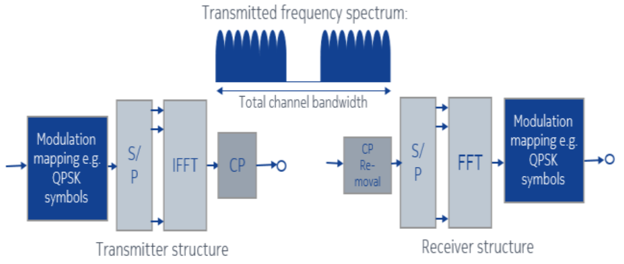


Figure 16: SC-FDMA Operation

Figure 16 shows, at a high level, the SC-FDMA operation. It is similar to the OFDM/OFDMA case. The FFT output size is smaller than the IFFT input size. This is because the granted UL resources to one UE cannot exceed the total resources in the cell. Multiple UEs can be allocated in uplink, each one using different (groups of) subcarriers.

Figure 17 illustrates in a comprehensive way the operation of both transmission techniques: Visually, the OFDMA signal is clearly multi-carrier and the SC-FDMA signal looks more like single-carrier. OFDMA and SC-FDMA symbol lengths are the same at 66.7 µs. However, the SC-FDMA symbol contains N "sub-symbols" that represent the modulated data.

The parallel transmission of multiple symbols creates the undesirable high PAPR of OFDMA. By transmitting N data symbols in series at N times the rate, the SC-FDMA occupied bandwidth is the same as multi-carrier OFDMA but the PAPR is the same as that used for the original data symbols.

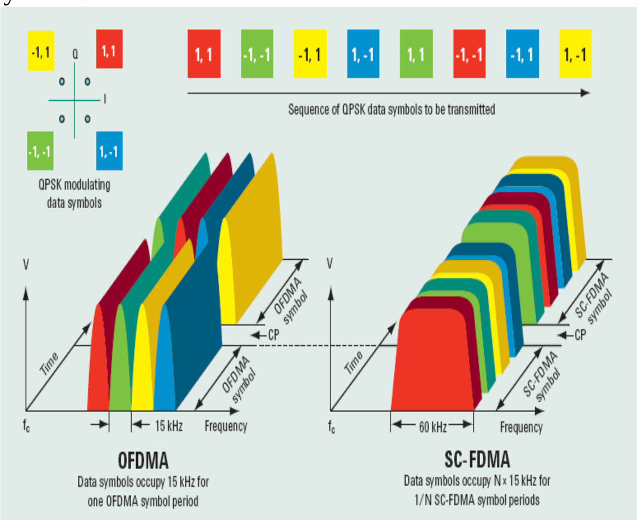


Figure 17: OFDMA and SC-FDMA Operation Comparison

The cyclic prefix in SC-FDMA is added like in the OFDMA case (refer to Figure 16), however there is no cyclic prefix after each symbol because in SC-FDMA the symbols are much more frequent than in OFDMA. Consequently, in the SC-FDMA case each modulation symbol is not protected by the cyclic prefix and the receiver needs to cope with ISI between cyclic prefixes. The receiver will run the equalizer for a block of symbols until reaching the CP that prevents the further propagation of ISI. Therefore, the SC-FDMA receiver is more complex than the OFDMA receiver.

V. RELATED RESEARCH

Physical RF Optimization is the first step to improve the performance of the network in order to get the maximum benefits from any subsequent parameter optimization. Checking the coverage footprint, aiming for good dominance areas, avoiding cross feeders and looking for wrong/not optimized tilts and azimuths are fundamental areas covered in this section.

Performance in LTE is strongly impacted by interference. This is typical to any cellular technology working with a frequency re-use of 1. Thus, the SINR distribution is the main throughput limiting factor. Any interference reduction is reflected by an increase in cell range and user throughput. A basic planning rule to avoid/reduce interference is to minimize cell overlapping by planning clear dominance areas and avoiding overshooting sites. The effect of parameter tuning is limited if a network is badly planned. The effect of the interference on the network performance has been studied since the early days of LTE. Figure 18 shows the impact on throughput and SINR measured across the same drive route with 70% load and without load (0%). Case: 20MHz, OL MIMO, FTP download, 1 UE inside car. Load generated with feature: 'DL Inter-cell Interference Generation, LTE819).

The average throughput for this specific route was 58% better for the no interference case.

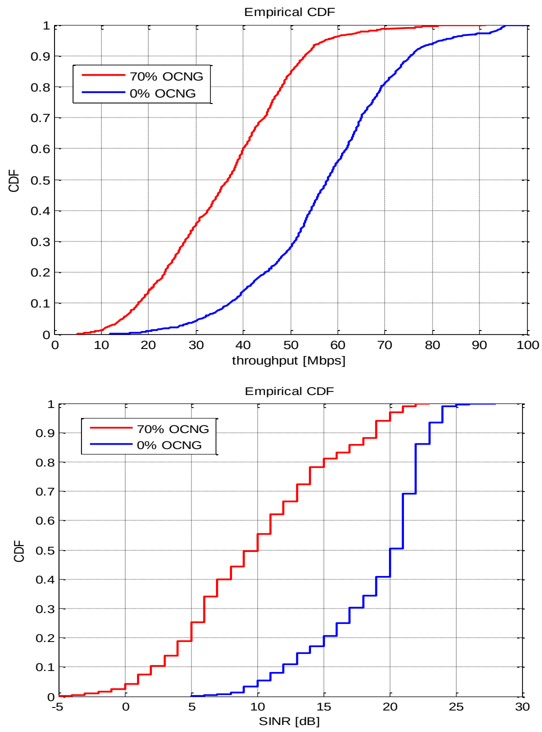


Figure 18: Throughput CDF (left) and SINR CDF (right) under Different Load Conditions)

Published By:
Blue Eyes Intelligence Engineering and Sciences Publication (BEIESP)

Antenna tilts and azimuths together with antenna placement are strong primary RF shaping factors.

A. Physical Layer Optimization

LTE network spectral efficiency is limited by the inter cell interference. Therefore optimizing cells' dominance area can greatly improve the LTE network performance and capacity.

B. Antenna Tilt

Antenna tilt is defined as the angle of the main beam of the antenna with respect to the horizontal plane. Positive and negative angles are referred to as downtilt and uptilt respectively. Antenna tilt can be adjusted mechanically and/or electrically as shown in Figure 19 and Figure 20 respectively.

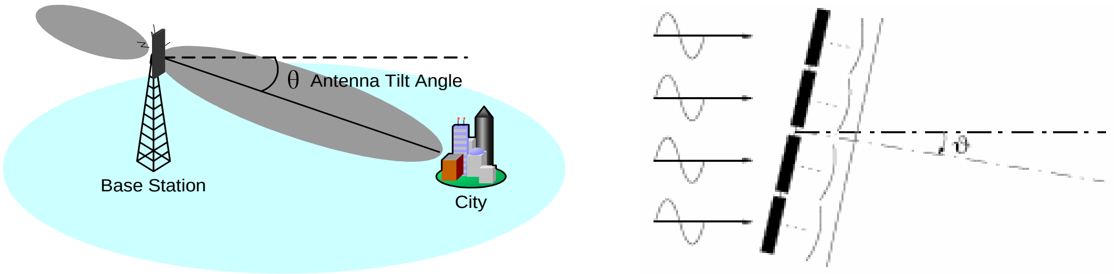


Figure 19: Mechanical Tilt

There are different techniques for managing the electrical tilt such as remote electrical tilt (RET), variable electrical-tilt (VET) and fixed electrical tilt. Usage of RET antennas removes the need for tower climbing and base station site visits by controlling the tilt angle via network management system (OMS) so operational cost is saved. Hence, remote electrical tilt has become more popular for network operators e.g. adjusting tilt angle when eNodeB addition or removal occurs. On the other hand, mechanical tilt is also needed because electrical tilt range is limited compared to the mechanical tilt range.

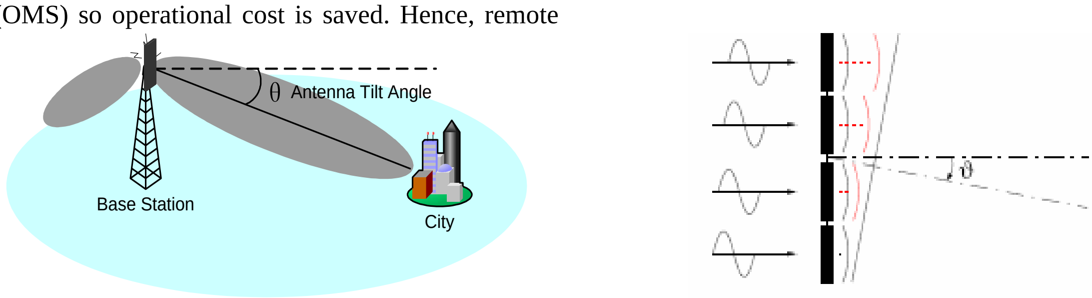


Figure 20: Electrical Tilt

Electrical tilt poses an advantage over the mechanical as tilt is also applied on the back lobe and because the shape of the main radiation lobe is kept constant. Mechanical tilt results in the uptilting of the back lobe which might increase the interference in tower sites. From Figure 21 the gain might be up to 40-50% for a flat hexagonal scenario comparing 0 degrees tilt versus an optimised tilt solution. Antenna tilt has an optimum value as high tilts decrease coverage which increases dominance.

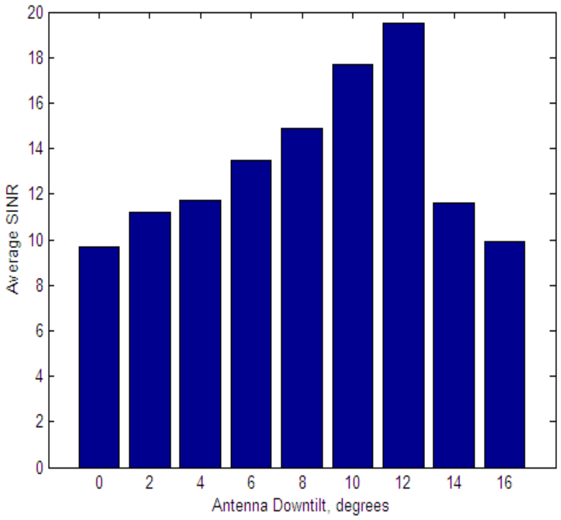


Figure 21: Example of Average SINR as Function of tilt - 1 km Site Radius, 65-Deg Antenna, SNR Measured at Street Level

As discussed, interference can have a significant impact upon throughput, so identification of the strongest interferers is important. From drive test data, an area of strong interference can be identified as an area with good RSRP but low SINR or RSRQ. However, SINR and RSRQ measurements are dependent upon network load and measurement methods. Studies have shown that absolute SINR measurement values cannot be used as a reliable performance indicator as SINR values change considerably depending on the scanner (if it is measuring RS SINR or S-SCH SINR) and the interference situation. Relative SINR changes, if the same measurement tool is used all the time still can be used as performance indicators. During RF optimisation it is useful to understand the initial conditions. This helps to determine whether antenna should up-tilted or down-tilted. Example scenarios include:
Overshooting cell:

VI. PROPOSED METHODOLOGY

A. Key Performance Indicator (KPI) Optimization

i. Introduction

The most common key performance indicators, based on mainly network statistics, are introduced.

Published By:
Blue Eyes Intelligence Engineering
and Sciences Publication (BEIESP)

It is also possible to Retrieve the key performance indicators through drive testing however it is not the preferred method due to limited sample size (only drive test route and single user equipment perceived quality). On the other hand for coverage and performance verification after certain parameter modifications drive testing is still very much needed especially in case of physical layer optimization.

B. Optimization Process

i. Identification and Understanding of KPI

An optimisation process requires a set of KPI to quantify changes in performance as the network is tuned. These KPI could be based upon network statistics, UE drive testing or a combination of both. The requirement for UE drive testing depends upon the metrics to be improved. For example, quantifying reductions in VoLTE connection setup delay and improvements in VoLTE speech quality are likely to require UE drive testing. Optimisation activities which involve UE drive testing tend to be short term projects focused upon specific aspects of network performance. Longer term optimisation processes tend to rely upon network statistics due to the cost associated with drive testing.

An example set of KPI for an optimisation process is:

Data Accessibility
VoLTE Accessibility
Data Drop Call Ratio
VoLTE Drop Call Ratio
Handover Success Ratio
Cell Throughput
User Throughput

The set of KPI should be kept relatively small and focused, while a larger set of PI can be used to support troubleshooting at a lower level. The initial set of PI can be extracted from the set of KPI. For example, Data Accessibility includes components for RRC Connection Setup, S1 Signalling Connection Setup and E-RAB Setup so the set of PI should allow these three components to be studied separately. Similarly, Handover Success Ratio includes components for Handover Preparation and Handover Execution so the set of PI should allow these two components to be studied.

It is very important that the set of KPI are thoroughly understood in terms of their constituent counters, i.e. which counters are being used and how those counters are incremented. It may also be necessary to compare KPI definitions with those belonging to a different network vendor. If an operator uses different vendors in different parts of the network then it is likely that KPI results will be compared across vendors. This requires an understanding of the counters implemented by both network vendors to ensure that any comparison is meaningful and fair.

KPI definitions are not always ideal and may vary between software releases. Implementations should be understood as much as possible to help generate an awareness of the likely impact of non-ideal definitions and changes between software releases.

The time interval used for KPI evaluation should be agreed when defining KPI targets. The results from daily averages are likely to be optimistic relative to busy hour performance. An example comparison of busy hour and daily average performance is shown in Figure 22 and Figure **23**. This example is based upon the E-RAB Drop Ratio.

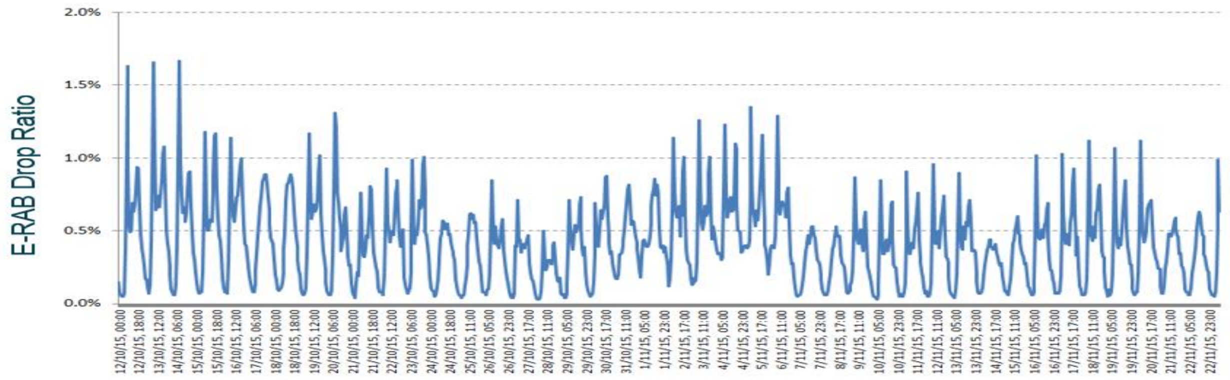


Figure 22: Busy Hour Drop Ratio

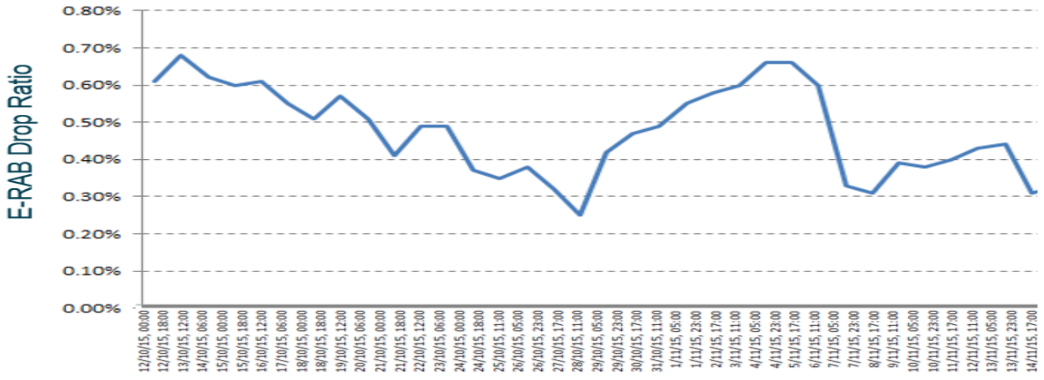


Figure 23: Daily Average Drop Ratio

Published By:
Blue Eyes Intelligence Engineering
and Sciences Publication (BEIESP)

The busy hour Drop Ratio is approximately double the daily average. If it is agreed to use busy hour results then the method used to identify the busy hour should also be agreed. It is likely that different parts of the network will experience different busy hours. Shopping areas are likely to have a busy hour during the working day whereas residential areas are more likely to have a busy hour during the evening

Initial Checks

The optimization process should start with some initial checks to determine whether or not there are any significant issues which require resolution before optimisation can start. These initial checks should include:

check all sites for alarms

check all sites are reachable and are carrying traffic

check for particularly high RSSI

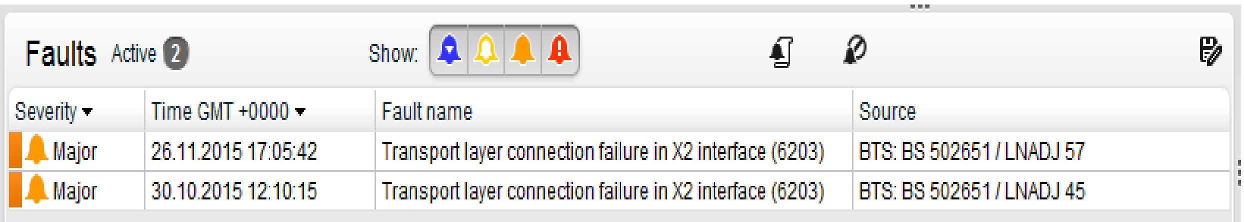
check each of the KPI included within the process

identify worst performing KPI relative to their targets

identify worst performing sites

compare daily averages with busy hour peaks

Alarms should be studied to identify any which could be directly impacting user experience or preventing features from operating. Some features rely upon X2 signalling so any alarm which indicates a loss of X2 connectivity can have a negative impact upon performance. For example, Radio Link Failure triggered Handover relies upon X2 signalling and has a significant impact upon Connection Drop Ratio. Similarly, Active Mode Load Equalisation relies upon X2 signalling and traffic management will be compromised if X2 connections are lost. Figure 24 illustrates an example of alarms indicating a loss of X2 connectivity for a pair of specific LNADJ objects.


Faults Active 2 Show:

Severity	Time GMT +0000	Fault name	Source
Major	26.11.2015 17:05:42	Transport layer connection failure in X2 interface (6203)	BTS: BS 502651 / LNADJ 57
Major	30.10.2015 12:10:15	Transport layer connection failure in X2 interface (6203)	BTS: BS 502651 / LNADJ 45

Figure 24: Example Alarms Indicating Loss of X2 Connectivity

Particularly high RSSI can be an indication of a hardware fault, i.e. faulty RF hardware. Figure 25 illustrates an example cell which experienced a step change in uplink RSSI. The high RSSI caused both poor Accessibility and a poor Drop Ratio. The issue was resolved by installing a replacement RF module.

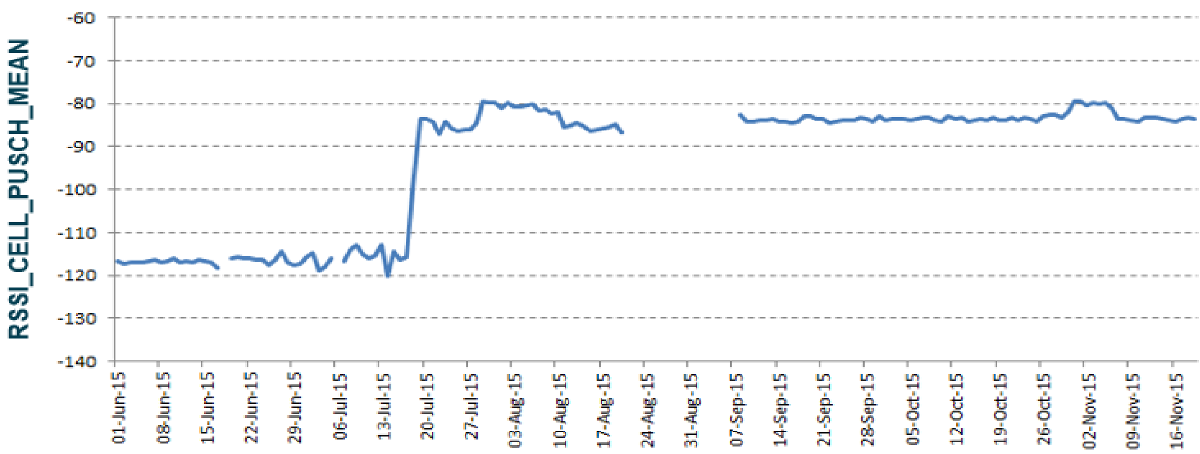


Figure 25: Example Cell Showing Particularly high RSSI after Step Change

The initial checks activity should also include a first evaluation of the KPI. This can be used to direct the focus of the subsequent optimisation activity. All KPI below their target should be identified and an initial site level analysis should be completed to determine whether issues are network wide, cluster specific or site specific. There can also be some value in comparing the busy hour results with the daily averages. If issues predominantly occur during the busy hour then any investigation with network logging is best done during that busy hour.

KPI Improvement

This example illustrates the fundamental changes to KPI definitions which can occur between software releases. The RL70 version of the KPI is defined as 'abnormal releases / total releases', whereas the FDD-LTE16A version of the KPI includes numerator terms in the form of 'total releases – normal releases'. These changes in KPI definition can make it challenging to maintain continuity of results between software releases. However, KPI definitions are modified to generate improved results so there should be a benefit associated with the changes.

In general, for this type of KPI the numerator counters should be studied to identify those which are linked to the highest number of drops. The counters may not indicate the precise source of the issue but they should help to focus any subsequent investigations. An example high level process is illustrated in Figure 26.

Published By:
Blue Eyes Intelligence Engineering
and Sciences Publication (BEIESP)

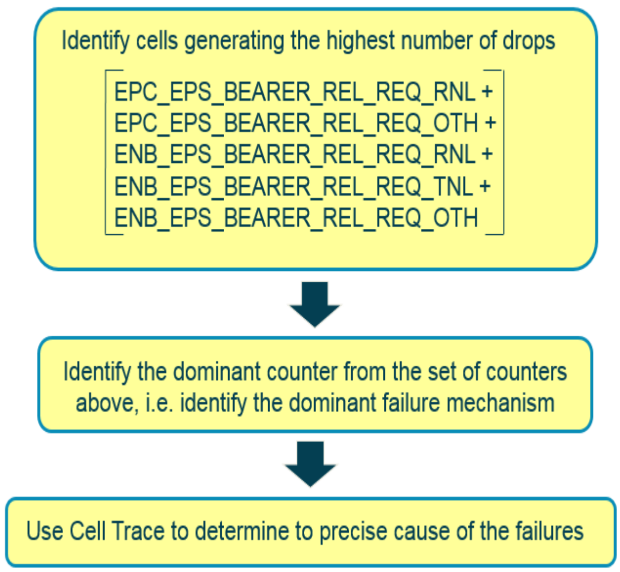


Figure 26: Process to Identify Dominant Source of Dropped Calls

This example uses the counters to identify the general area of focus while Cell Trace is used for detailed analysis. Emil could be used instead of Cell Trace if it is available. It is unlikely that detailed analysis is required for every site with poor performance. It is likely that issues are common across sites so resolving issues at one site should help to provide solutions for other sites.

In this example, the failure counters can be categorised into those initiated by the eNode B and those initiated by the MME. This categorisation can help identify the failure scenarios in network logs, i.e. it helps to determine which messages to search. Figure 27 illustrates the messages associated with each of the counter categories.

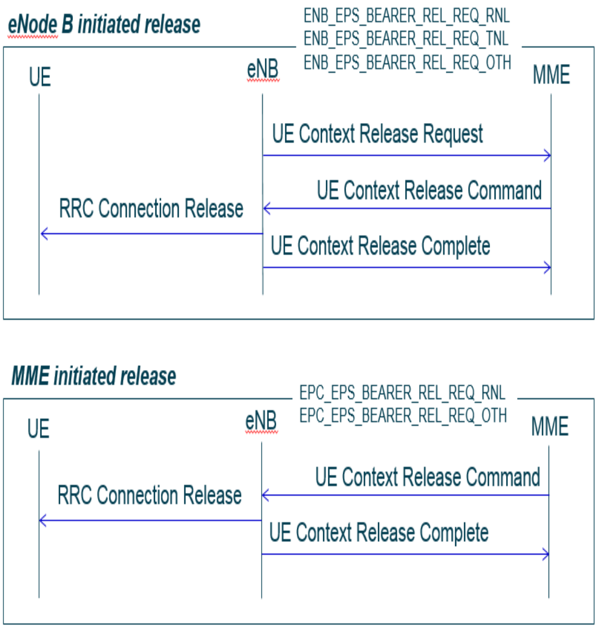


Figure 27: Categorisation of Failure Counters

VII. RESULTS & SIMULATION

Call Drop – abnormal interruption of data or voice session (=call): conversation or data transfer ended before parties wanted it.

Different network elements/services may treat real Call Drops (user perspective) as "normal" procedures.

For example LTE_5025h E-RAB DR, RAN view KPI will count abnormal releases initiated by EPC as "normal". But from User perspective it is a Call Drop.

Notes:

It is necessary to understand what exactly some particular KPI measures and what is not visible with this KPI.

For overall retainability performance, it is necessary to use KPIs which are close to "user perspective" as much as possible.

Call Drop common root causes:

Coverage issue:

Noise limited scenario

Volatile coverage

Dominance issue:

Interference limited scenario

Handover to wrong cell

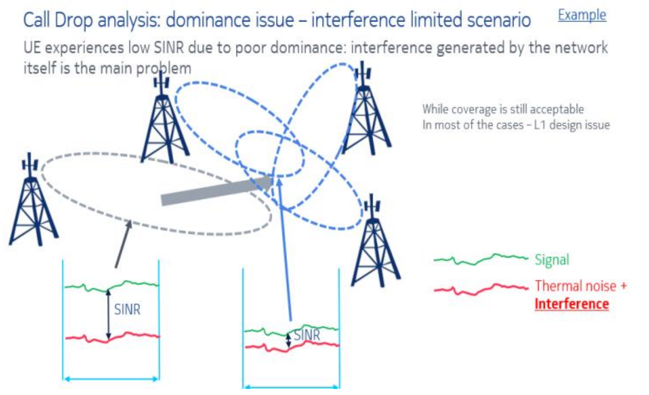
Parameterization issue:

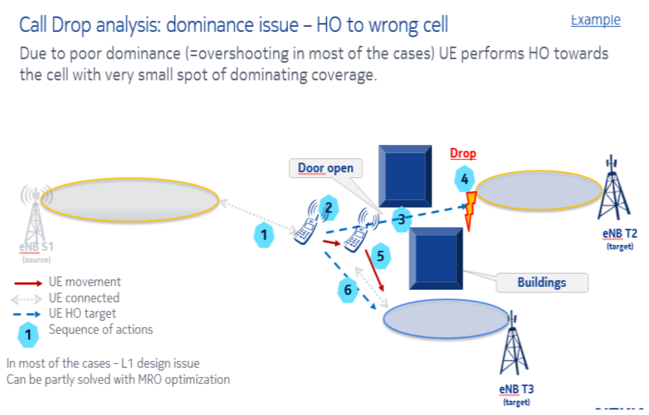
Neighbors

Random Access

Basic RF performance is crucial: retain ability can be improved significantly by improving basic coverage and dominance.

However, these are usually the most expensive optimization activities.





A. Measurement Tools

Drive Test Tools

Drive test measurements are collected using a Field Measurement Tool (FMT). An FMT typically includes:

a UE with testing capabilities (may require a firmware upgrade)

Published By:
Blue Eyes Intelligence Engineering
and Sciences Publication (BEIESP)

a navigation system, e.g. GPS
a laptop loaded with data collection and analysis software
A scanner may also be included depending upon the type of measurements being completed. In some cases, the FMT consists of only a UE with testing capabilities, i.e. the UE uses its own internal GPS capabilities to track location and the logging software runs on the UE itself rather than on a connected laptop. This approach can be more practical for walk testing when carrying a laptop may not be convenient or when the battery life of a laptop is too short. However, it is often useful to have a laptop to view layer 3 signalling and RF measurements during testing. The standalone UE solution is often limited in terms of being able to view and analyse recorded information in real time.
An example FMT kit based upon XCAL software is illustrated in Figure 28.

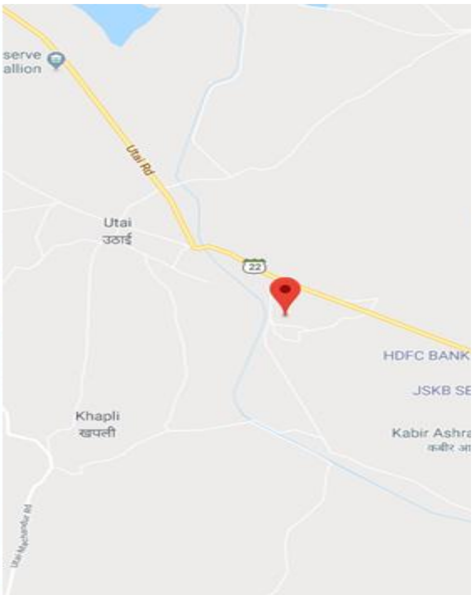
Figure 28: XCAL Sample Configuration

An FMT monitors and measures the performance of the LTE air interface. It also records signalling between the eNodeB and UE at layers 1, 2 and 3. In many cases, packets belonging to the higher layers are also recorded, e.g. TCP, UDP, IP, RTP, RTCP.

B. Case Study and Results

Field test Evaluation
Objective: - During the study we found there was one standalone enodeB where we were facing problem of ERAB drops rate (frequent session drop during the Data browning .below are high level sites details

Site ID	Cell ID	Longitude	Latitude	Antenna Height (m)	Antenna Azimuth	Antenna Tilt Electrical	Antenna Tilt Mechanical	EARFCN	PCI	Bandwidth (MHz)
MP638	5283329	81.39656	21.10732	38	100	2	2	1431	18	10
MP638	5283330	81.39656	21.10732	28	160	2	2	1431	19	10
MP638	5283331	81.39656	21.10732	32	350	2	2	1431	20	10



Field KPI check –

Published By:
Blue Eyes Intelligence Engineering
and Sciences Publication (BEIESP)

C. Physical Cell ID Distribution –

There are 504 unique physical layer cell identities. These identities are organised in 168 groups of 3. A physical layer cell identity is thus uniquely defined by a number NID1 in the range of 0 to 167, representing the physical layer cell identity group, and a number NID2 in the range of 0 to 2, representing the identity within the group, i.e. physical layer cell identity = 3× NID1 + NID2.

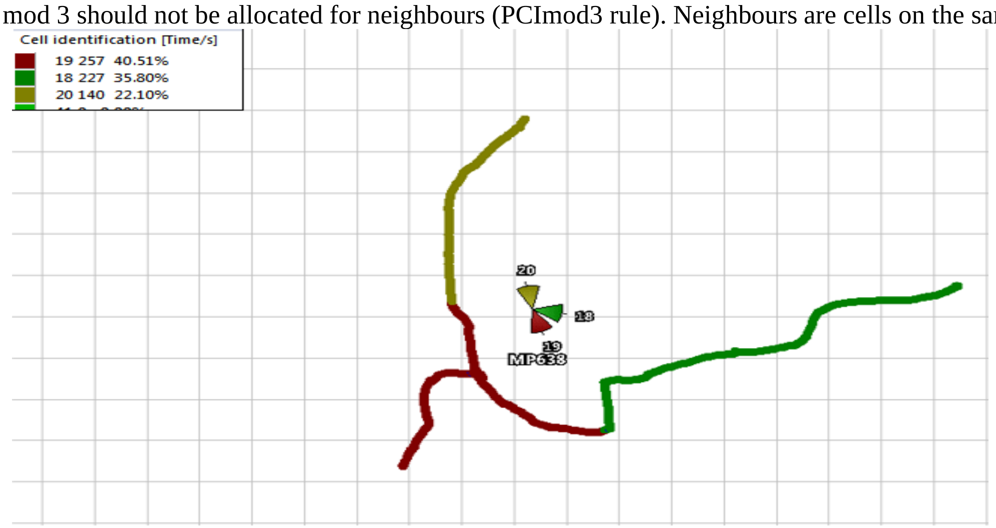
The value of NID2 (0 to 2) defines the Primary Synchronisation Signal (PSS) sequence, whereas the value of NID1 (0 to 167) defines the Secondary Synchronisation Signal (SSS) sequence. The UE can thus deduce the Physical Layer Cell Identity during the cell synchronisation procedure.

As defined in 3GPP TS 36.211, the sequence $d(n)$ for the PSS is generated from a frequency-domain Zadoff-Chu sequence according to

$$d_u(n) = \begin{cases} e^{-j\frac{\pi u n(n+1)}{63}} & n = 0,1,\ldots,30 \\ e^{-j\frac{\pi u (n+1)(n+2)}{63}} & n = 31,32,\ldots,61 \end{cases}$$

$N_{ID}^{(2)}$	Root index u
0	25
1	29
2	34

To avoid having the same PSS sequence among neighbours, CellIDs with identical values mod 3 should not be allocated for neighbours (PCImod3 rule). Neighbours are cells on the same site.



Reference Signal Received Power (dBM)– This is a receivable power at Mobile Handset Antenna. Reference signal received power (RSRP), is determined for a considered cell as the linear average over the power contributions (in [W]) of the resource elements that carry cell-specific reference signals within the considered measurement frequency bandwidth. If receiver diversity is in use by the UE, the reported value shall be equivalent to the linear average of the power values of all diversity branches. Main advantage of RSRP measure is in fact that RSRP is load independent while RSSI depends on load.

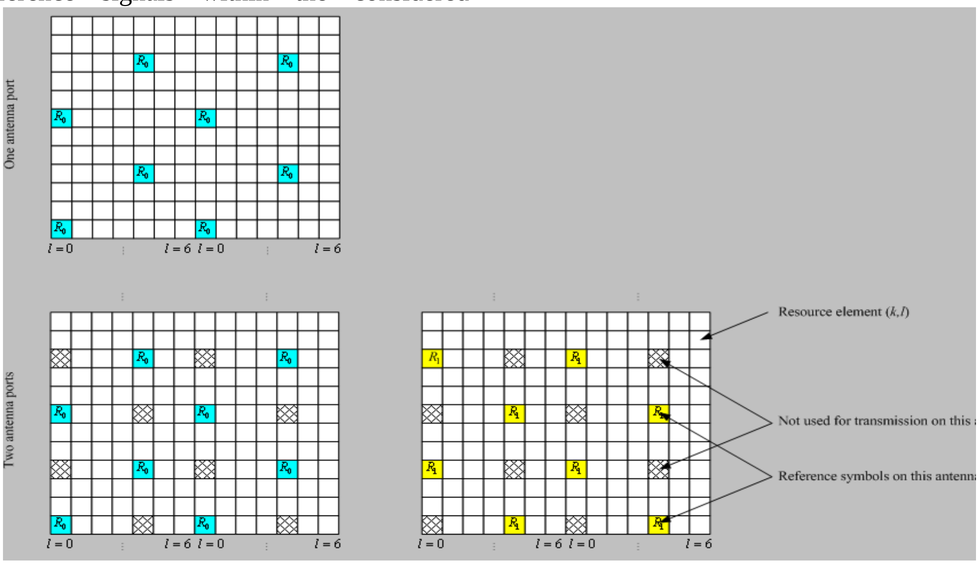
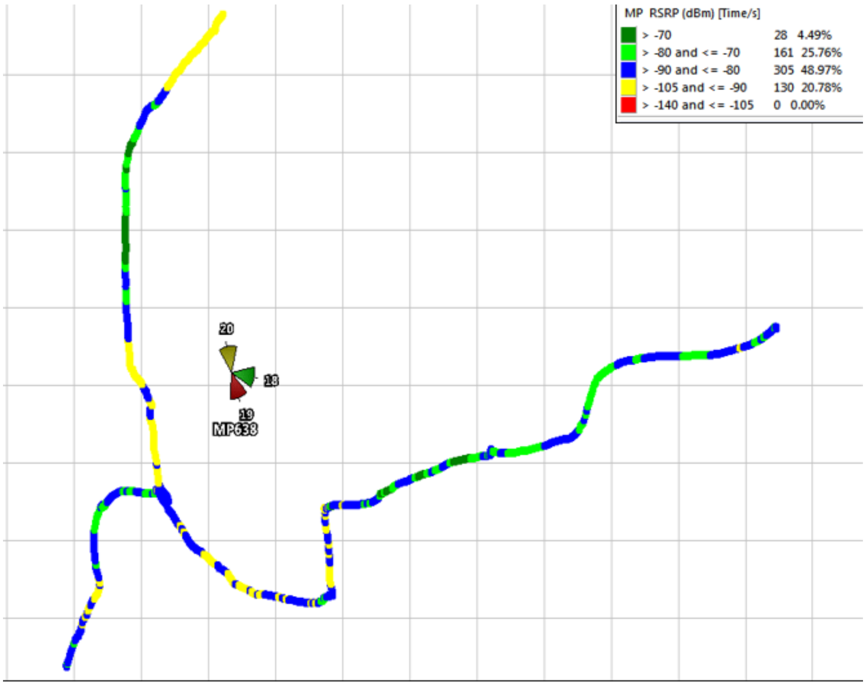


Figure 29: Reference Signal Elements Example as per 3GPP TS 36.211

Important is to keep in mind the proportion between RSRP measurement and RSSI since power budgets and planning tools usually usually use RSSI.

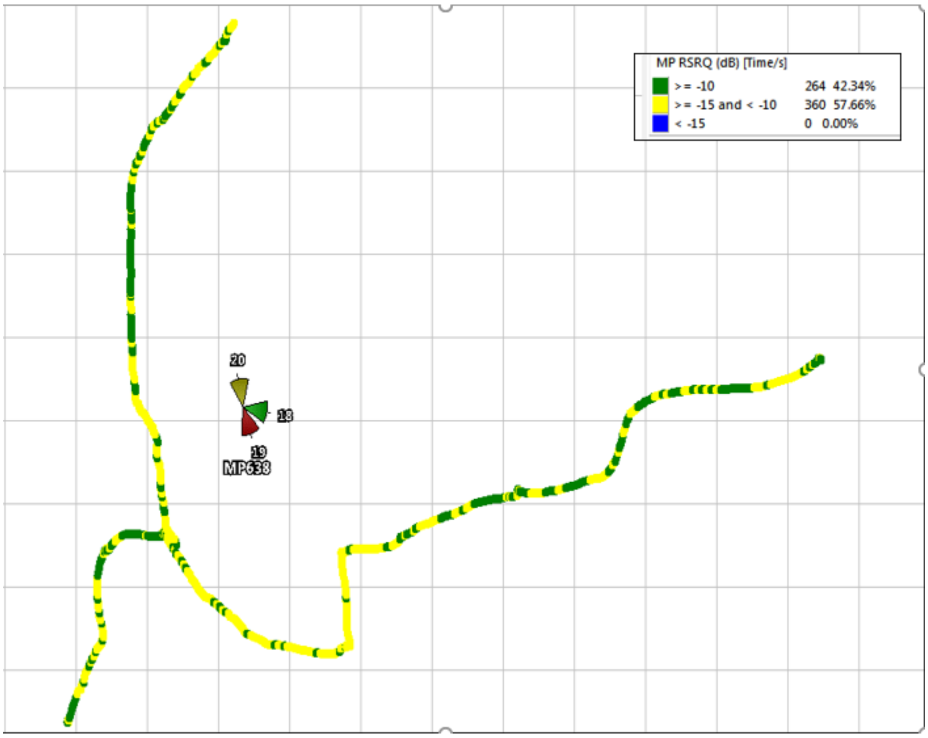
Published By:
Blue Eyes Intelligence Engineering
and Sciences Publication (BEIESP)



Average RSRP - -82dBM

D. Reference signal Received Quality –

Reference Signal Received Quality (RSRQ). RSRQ is defined as the ratio N×RSRP/(E-UTRA carrier RSSI), where N is the number of RB's of the E-UTRA carrier RSSI measurement bandwidth. The measurements in the numerator and denominator shall be made over the same set of resource blocks.



Average RSRQ -9dB

E. Signal to Noise Ratio –

3GPP equivalent of SINR measuring reportable by UE is defined based on RSSI and RSRP is the E-UTRA Carrier Received Signal Strength Indicator (RSSI), comprises the linear average of the total received power (in [W]) observed only in OFDM symbols containing reference symbols for antenna port 0, in the measurement bandwidth, over N number of resource blocks by the UE from all sources, including co-channel serving and non-serving cells, adjacent channel interference, thermal noise etc. If receiver diversity is in use by the UE, the reported value shall not be lower than the corresponding RSRQ of any of the individual diversity branches.

Published By:
Blue Eyes Intelligence Engineering
and Sciences Publication (BEIESP)

Average RSRP -22dB

F. RSSI Versus RSRP and RSRQ Measurements

RSSI represents the whole power of the signal. That means the measure is dependent on the load in real conditions. To remove this, 3GPP [**Error! Reference source not found.**] has defined a measure dependent on the reference signal part only. Reference signal is transmitted continuously.

Paper [**Error! Reference source not found.**] shows this in section 2.2 when deriving the maximum possible RSRP value. The example is based upon 6 RB (6x12=72 resource elements in the frequency domain). The RSRP is then 1/72 of the total power, which means scaling down by 18.57 dB.

So, as an example, if we are transmitting 6 RB with 43 dBm and there is a link loss of 100 dB then the RSRP would be 43-100-10LOG(72)= -75 dBm. If we take 10 MHz (=50RB) bandwidth we have offset 10*LOG(1/(50*12))=10*LOG(1/600)= -27.82 dB This means for a theoretical 100% loaded case and RSSI level -90dB to report RSRP -118dBm.

The relation between (100% loaded case) RSSI and RSRP measure might be expressed as

RSRP (dBm)= RSSI (dBm) -10*log (12*N), where N is the number of RB in frequency domain. The offset is precalculated on the Table 2.

BW	1.4MHz	3 MHz	5 MHz	10 MHz	15 MHz	20 MHz
# RB	6	15	25	50	75	100
Scaling:[-10log (12N)]	-18.57	-22.55	-24.77	-27.78	-29.54	-30.79

Table 2: Scaling Factor for Different LTE Bandwidth

Practical explaination of RSRQ is in the paper [**Error! Reference source not found.**]. RSRQ is defined as

RSRQ = RSRP / (RSSI/N)

where N is the number of resource blocks over which the RSSI is measured. So effectively, the equation is:

RSRQ = RSRP / (RSSI per resource block)

As an example if all resource elements are active and are transmitted with equal power then

RSRQ = N / 12N = -10.8 dB (because RSRP is measured over 1 resource element out of 12 and RSSI per resource block is measured over 12 resource elements)

Referenced paper makes the point that when there is no traffic, and assuming only the reference symbols are transmitted (there are 2 of them within the same symbol of a resource block) then the RSSI is generated by only the 2 reference symbols so the result becomes;

RSRQ = N / 2N = -3 dB (for 1 antenna – SIMO case) and

RSRQ = N/4N = -6 dB (for 2 antennas – MIMO 2x2 case)

These calculations ignore intercell interference which in practise would decrease the results. Intercell interference appears as wideband RSSI increment on the denominator side.

There is natural question about the relation between between SINR and RSRQ measures. Unfortunately, there is no straightforward expression. RSRQ measure depends on the load, function of packet scheduler, results averaging and reporting (i.e. on chipset implementation). The explaination of the such relation in laboratory condition can be found in next paragtaph.

All the simulations, MCS thresholds and throughput curves are using SINR (and no RSRQ) as parameter. Consequently, there is recommended to avoid any guarranteesand statements based on RSRQ up to time of better practical knowledge about it and behavour from measurements from commercial networks.

The relation between SINR and RSRQ can be given expressed as:

Published By:
Blue Eyes Intelligence Engineering
and Sciences Publication (BEIESP)

International Journal of Innovative Technology and Exploring Engineering (IJITEE)
ISSN: 2278-3075 (Online), Volume-8 Issue-2, December 2018

RSRQ=RSRP/(RSSI/N) = RSRP*N/(IN_n + ρ*12*N*Psc) and
SINR=S/(IN_m)
Where
N is # of PRBs for RSRQ
M is # of PRBs allocated to UE based on which SINR is measured
Psc is average Rx power per subcarrier. In case of no power boost for RS, Psc=RSRP.
IN_n is Interference plus noise over N PRBs used for RSRQ measurement
IN_mis Interference plus noise measured over M PRBs allocated to UE (for SINR). In case that I+N is evenly distributed in all PRBs, then IN_n/N=IN_m/M.
ρ: loading (% of subcarriers transmitted) over N PRBs for RSRQ
S=Psc*M*12 is signal power.
Without RS power boost and with evenly distributed interference over all PRBs, we have
RSRQ = 1/[(1/SINR+ ρ)*12]
The challenge of relation between SINR and RSRQ is the dependency on the load as one can see on the Figure 30

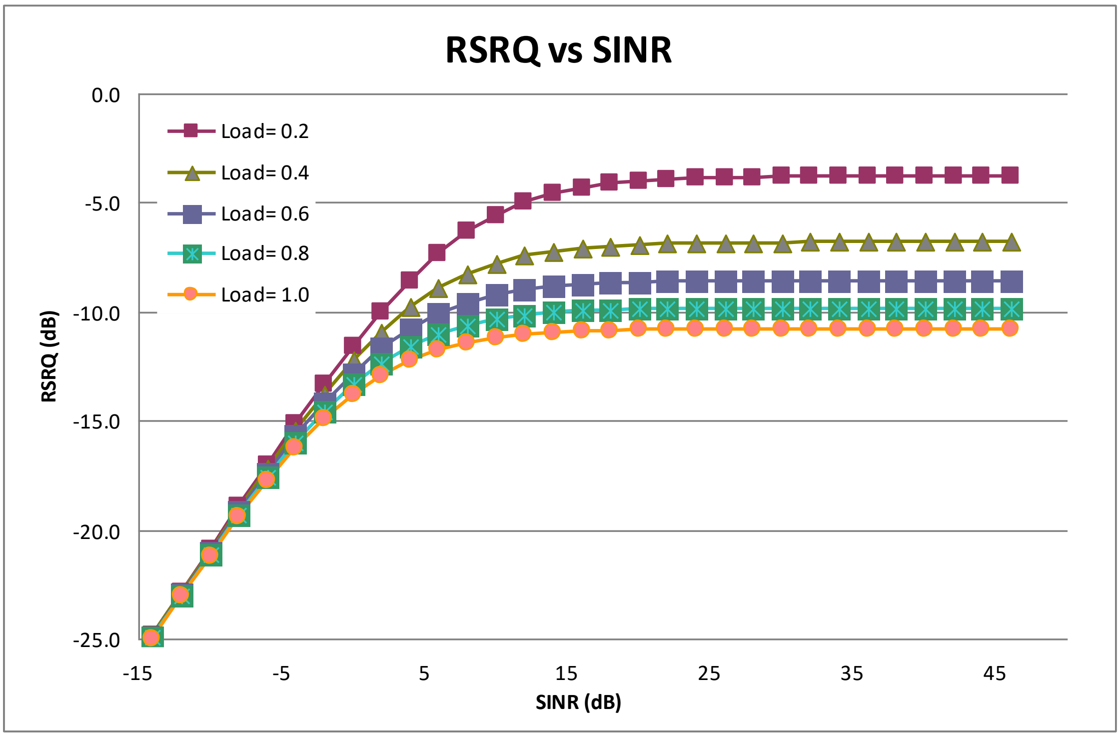
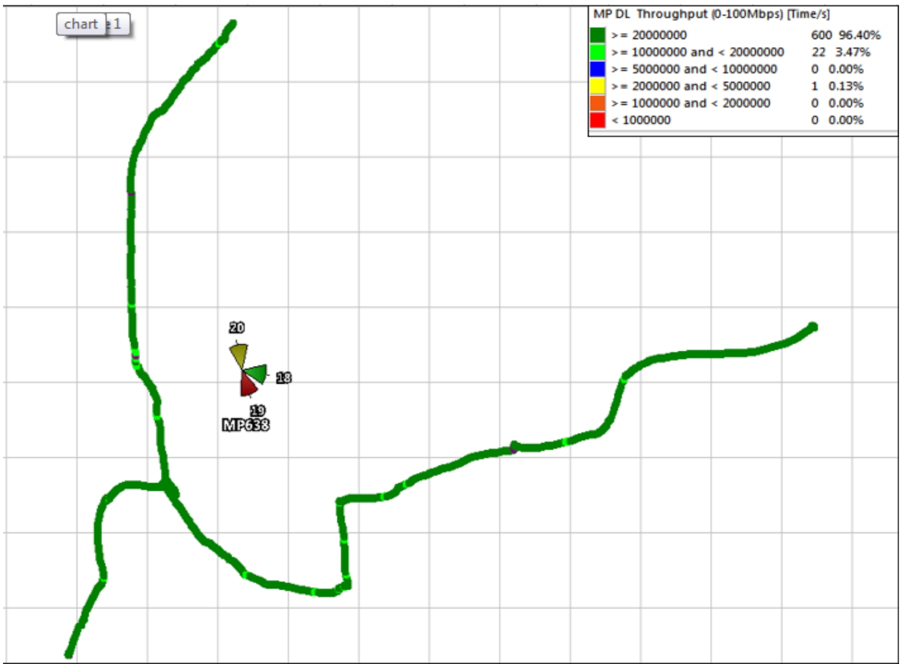


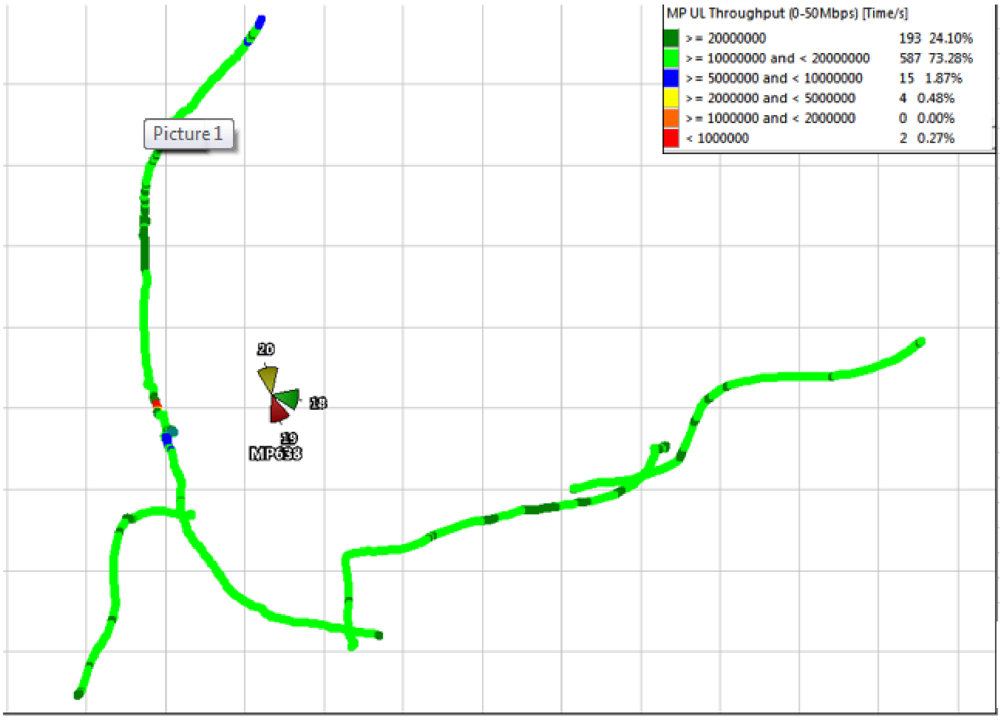
Figure 30: Relation between SINR and RSRQ

G. Downlink Data throughput –



Average DL Throughput -22 Mbps

H. Uplink Data throughput –



Average UL Throughput -17 Mbps

I. Field Test Summary –

Following test were performed to evaluate single site performance and give go ahead for commercial use

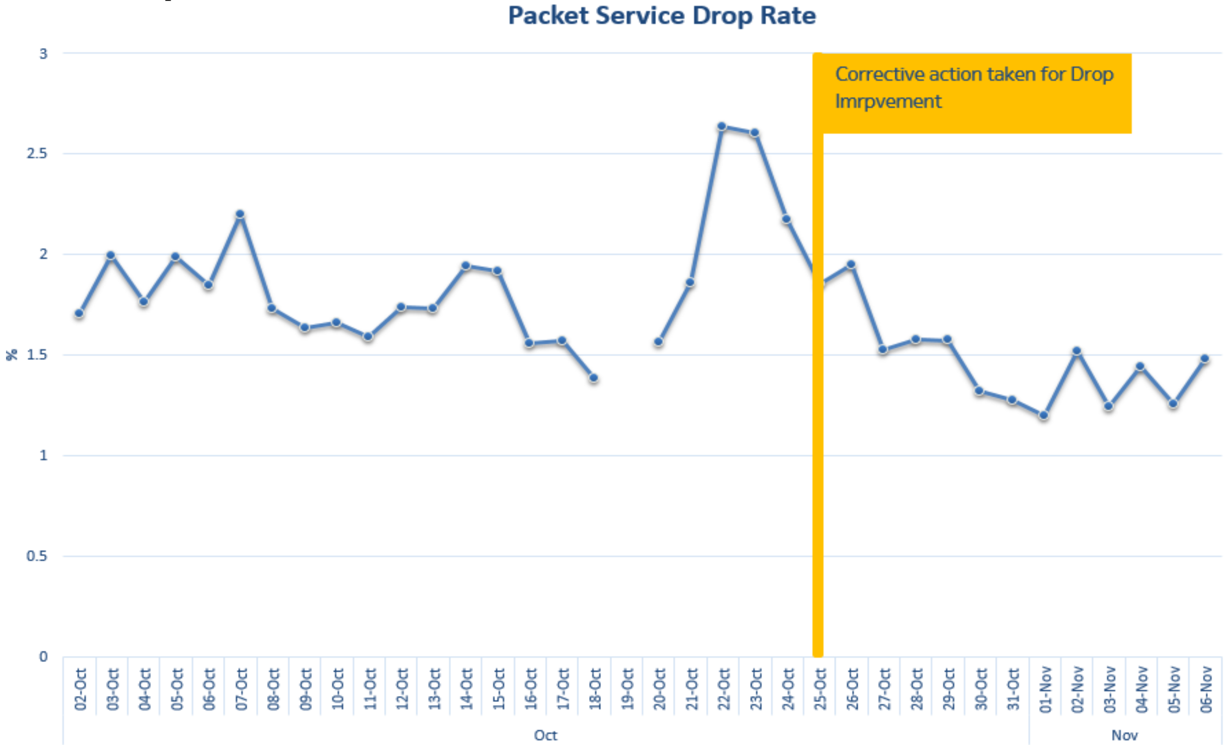
Single Cell Function Test (SCFT)

Site ID		MP638	Site Name:			5283329, 5283330, 52833
New Site:		New	Site Connected to EPC:			
	No.	Activity/Process	cell 1	cell 2	cell 3	result
			Check	Check	Check	
Idle	1	MNC	93	93	93	
	2	MCC	404	404	404	
	3	LAC	910	910	910	
	4	TAC	510	510	510	
	5	EUARFCN	1431	1431	1431	
	6	PCI	18	19	20	
	7	Pa & Pb values for RS power	dB3, 1	dB3, 1	dB0, 1	
	8	RSRP (Average Value)	-81.20	-85.56	-81.89	
	9	SINR (Average Value)	20.25	21.79	24.16	
Downlink and Uplink Peak user throughput	13	TCP DL	60.43	54.34	61.68	
	a	CQI, Downlink Peak MCS & Peak RB Allocation	15,0,50	15,0,50	15,0,50	
	b	CQI, Uplink Peak MCS & Peak RB Allocation	15,0,40	15,0,40	15,0,40	
	21.3	TCP UL	47.87	47.81	47.68	
Handover Delays	17	Handover delay/ Interruption time	43	44	NA	
Idle Mode & Reselection	18	FDD/TDD LTE to 3G/2G(ms)	408	366	400	
		3G to LTE FDD/TDD(ms)	722	723	734	
Attach and Detach	19	Network attach time(ms)	1166	868	748	
		Network attach success rate	100.00%	100.00%	100.00%	
		UE Capability Information Mesaage FGI Bits	Yes	Yes	Yes	
		Network Detach time(ms)	64	63	76	
		Network Detach Success rate	Yes	Yes	Yes	
Delays	20	Round trip time or Latency(ms)	62	38	38	
CSFB	21	CSFB and VoLTE: MO call set up time Originate calls when device was in RRC_Idle and RRC_connected mode and capture the callsetup	4.468	4.877	3.921	
		CSFB and VoLTE: MT call set up time Terminate calls when device was in RRC_Idle and	3.841	4.152	3.70	
		CSFB success rate	100.00%	100.00%	100.00%	
		Fast Return to LTE and the return priority defined in case of multiple LTE carriers in the circle	Yes	Yes	Yes	
Others	22	Number of RACH Attempts for each call attempts	1	1	1	
		RA /LA update during CSFB call	NO	NO	NO	
		TAU Success during Fast Return (3G to 4G redirectio	YES	YES	YES	
		Fast Return Time(ms)	1041	1113	1209	
		Fast Return Priorities (TDD, FDD)	FDD	FDD	FDD	

Test Results Summary – Since this is a Single User behaviour from filed test in no load condition so we didn't find any issue related to Coverage and Quality.

J. Oss KPI's Verification–

Since the Cell site is serving to the large coverage Area so we observed high Packet Service Drop rate, we tried to investigate it and take it lowest possible



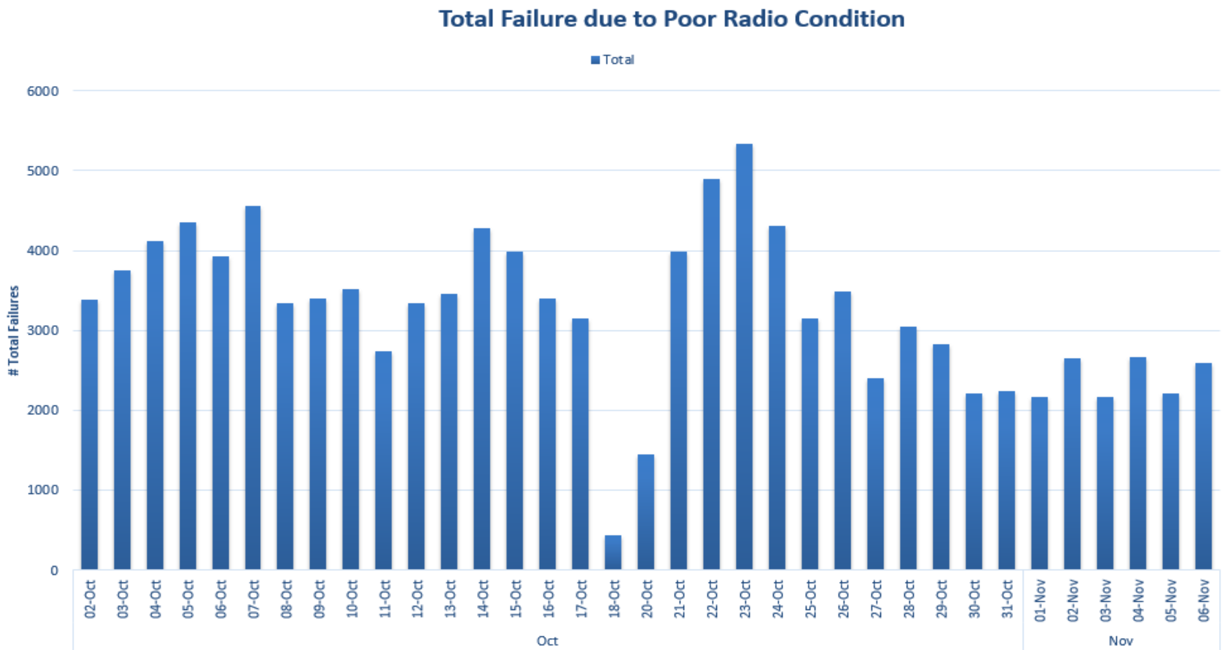
From the sub- counter study, it's found that its mainly happening due to the poor Radio condition. So the users who were residing at cell edge (Away from the BTS) they have high probability of getting dropped. So we recommended to reduce the coverage of the cell to increased density near to the site.

So now we have had two ways to achieve this goal, first by reducing the Transmitting Power and secondly by adjusting the downlit to control overshooting signals

Since reducing the power may impact Indoor Coverage so we decided to go with Tilt change also there were some surrounded neighbouring sites, so we were safe to shift those remote users to Next possible serving sites by applying physical optimization.

VIII. RESULTS

After Modifying Tilt from 2 Degree to 5 Degree we could see Radio Drops have been reduced significantly



User vs Distance pattern from BTS

Published By:
Blue Eyes Intelligence Engineering
and Sciences Publication (BEIESP)

			UE distance to base station		UE distance distribution in 2.1km cells										
Period start	MRBTS/SBTS nam	LNCE	Cell size	Avg UE dist	0-78m	78-156m	156-312m	312-468m	468-624m	624-780m	780-1092m	1092-1404m	1404-1794m	1794-2262m	+2262m
			LTE_1340A	LTE_1339A	LTE_1341A	LTE_1342A	LTE_1343A	LTE_1344A	LTE_1345A	LTE_1346A	LTE_1347A	LTE_1349A	LTE_1350A	LTE_1351A	LTE_1352A
10.15.2018	MRBTS-804168	3													
10.16.2018	MRBTS-804168	3													
10.17.2018	MRBTS-804168	3													
10.18.2018	MRBTS-804168	3													
10.20.2018	MRBTS-804168	3													
10.21.2018	MRBTS-804168	3	No Pre Data available because counters related to the distance mesurement was not actviated earlier												
10.22.2018	MRBTS-804168	3													
10.23.2018	MRBTS-804168	3													
10.24.2018	MRBTS-804168	3													
10.25.2018	MRBTS-804168	3													
10.26.2018	MRBTS-804168	3	2.100	0.344	0.50	2.74	40.56	41.71	12.79	1.21	0.20	0.05	0.04	0.03	0.18
10.27.2018	MRBTS-804168	3	2.100	0.350	0.57	2.65	37.98	44.12	12.33	1.44	0.28	0.08	0.07	0.04	0.46
10.28.2018	MRBTS-804168	3	2.100	0.351	0.78	2.83	37.19	44.25	12.74	1.16	0.65	0.06	0.06	0.02	0.27
10.29.2018	MRBTS-804168	3	2.100	0.347	0.61	2.90	38.34	42.15	13.99	1.54	0.21	0.03	0.05	0.02	0.16
10.30.2018	MRBTS-804168	3	2.100	0.350	0.56	2.62	38.19	44.09	12.87	1.16	0.17	0.03	0.09	0.05	0.18

REFERENCES

1. "Architectural requirements", 3GPP TS 23.221 V9.5.0 (2012-12)
2. "Circuit Switched (CS) fallback in Evolved Packet System (EPS); Stage 2",3GPP TS 23.272 V9.14.0
3. Miikka Poikselkä et al, "Voice over LTE (VoLTE)", Wiley, 2012
4. A. Catovic et al, "Impact of SIB Scheduling on the Standby Battery Life of Mobile Devices in UMTS", Mobile and Wireless Communications Summit, 2007. 16th IST. IEEE, 2007
5. ITU Recommendation P.863 http://www.itu.int/rec/T-REC-P.863
6. POLQA http://www.polqa.info/
7. The Internet Engineering Task Force (IETF®), RFC3550 http://www.ietf.org