

ABSTRACT

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. Capacity optimization focuses on the high traffic areas and mass event. It is not only about user plane dimensioning but also interference management, signalling solutions and connectivity dimensioning are important. Many mass events are uplink limited while the networks in general are downlink limited, which adds further complexity on the high capacity 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. Many operators have already deployed three LTE frequencies and will deploy even five or six frequencies in the long term

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.

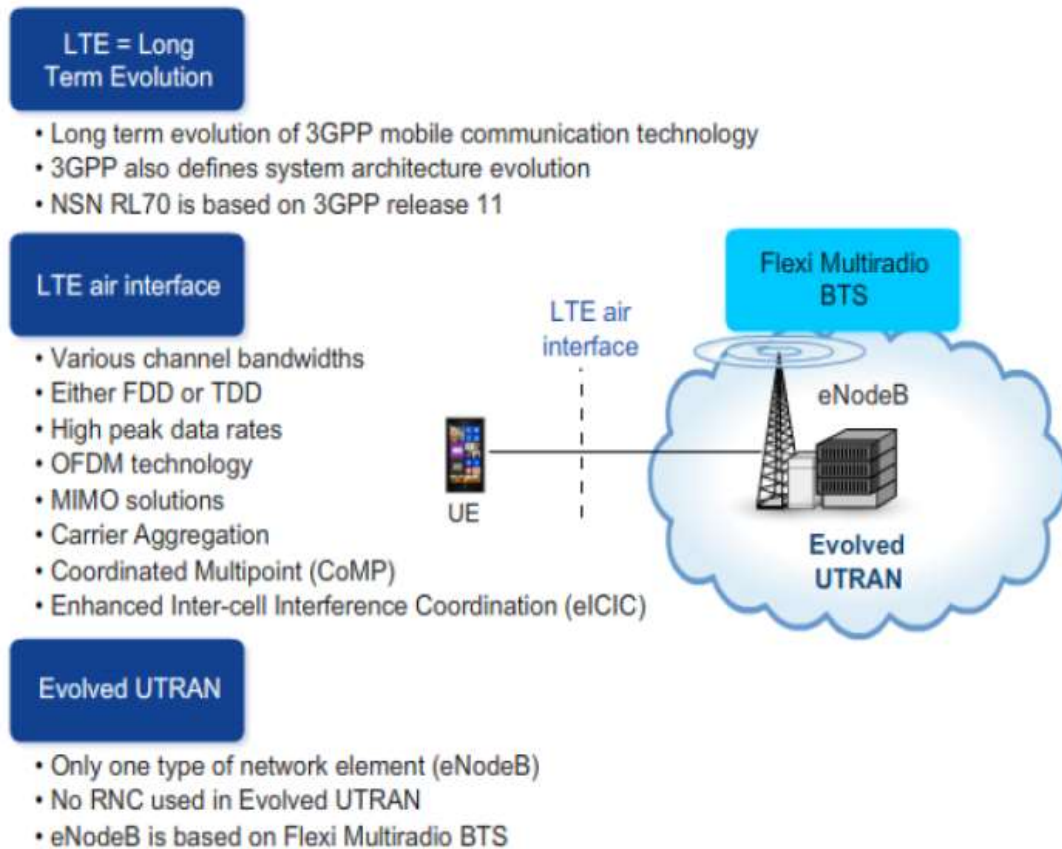


Fig.1

II. LITERATURE SURVEY

LTE Requirements

LTE stands for Long Term Evolution and together with LTE-A (LTE Advanced), they 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 Release 8 and beyond and can be found in the 36-series (TS 36.xxx). Another name for LTE is E-UTRA (Evolved-UMTS Terrestrial Radio Access).

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

- 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 defines 15 FDD and 8 TDD operating bands
- Bandwidth scalability with allocations of 1.4, 3, 5, 10, 15 and 20 MHz, as well as carrier aggregation extension (up to 40 MHz starting with RL45TD)
- Operation in FDD and TDD modes
- Support for inter-working with UMTS 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

LTE offers high-data-rates with low-latency, improved services, lower costs and allows for spectrum refarming, thanks to the frequency and bandwidth flexibility.

Architecture

Principles for LTE architecture design are defined in 3GPP TS25.913. Some of those principles include:

- 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 in order to minimize the delay variation for traffic requiring low jitter, i.e., TCP/IP
- End to end QoS should be supported for the various 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 whole system: e-UTRA plus EPC

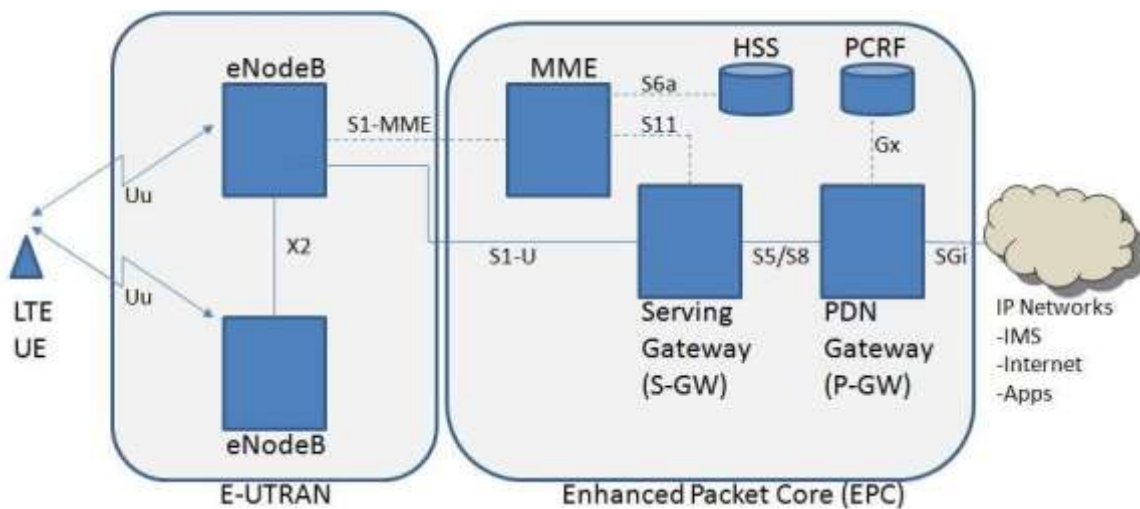


Fig 2. EPC Network Elements

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 as with previous technologies, as the eNodeB performs the RNC functions. The radio protocols that previously ended in the RNC now end in the eNodeB. Figure 3 shows the network architecture evolution from Release 6 (HSPA) to Release 8 (LTE) and beyond.

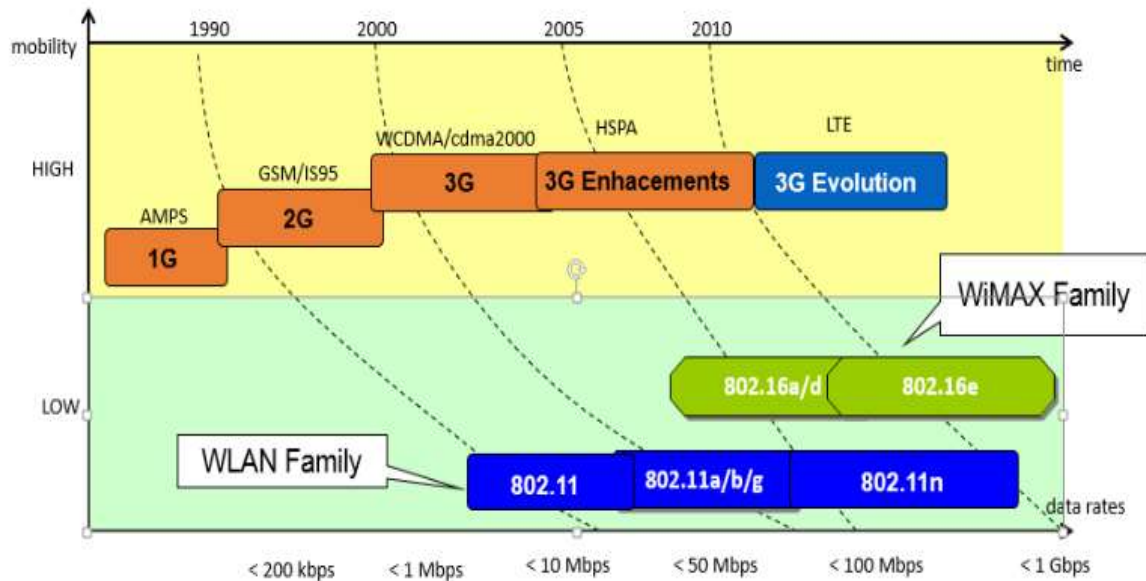


Fig 3. Network Architecture Evolution

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.

Network Elements

Figure 2, above, 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 attachment of the UE
- Security: Ciphering and Integrity protection on the radio interface
- IP header decompression
- Connection Management Control : UE state management

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

- **Mobility Management Entity (MME):** Pure signalling 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

Note: In Nokia's implementation the S-GW and the P-GW are one unique entity.

- **Policy and Charging Rule Function (PCRF):** As the name indicates, it is responsible for implementing the charging policy and also 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 centre) functionality

Interfaces

Along with the air interface treated in the next section there are two other interfaces of 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, e.g. exchange of load information between neighbouring eNodeBs 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, and authentication).

III. PROPOSED METHODOLOGY

Basic Air-Interface Theory

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).

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

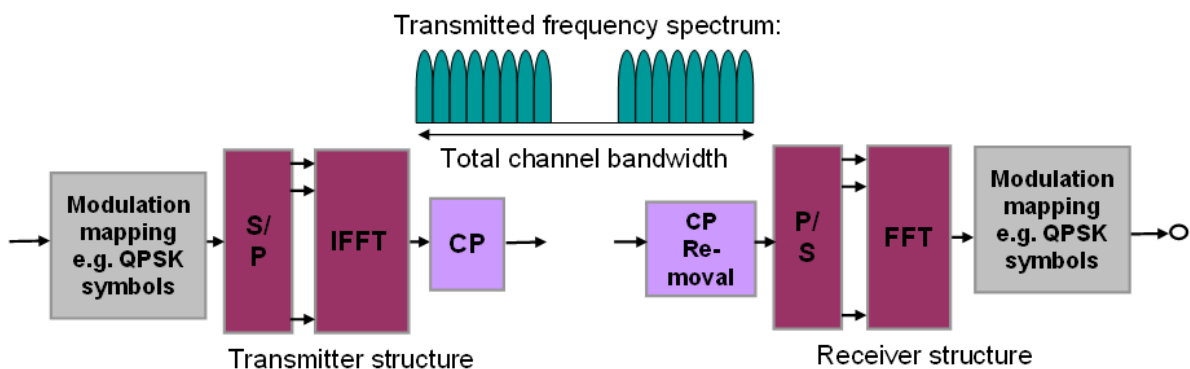


Figure 4 - OFDM operation

Figure 6 summarises at a 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 a 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 T_s 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.

LTE Physical Layer Structure

There are two types of frames defined for LTE: Type 1 frame for FDD and Type 2 frame for TDD. As the scope of this guideline is limited to the LTE TDD version, only Type 2 frame is described. Type 1 frame shares the same frame structure, in which 10 subframes are available for downlink transmission and 10 subframes are available for uplink transmissions in each 10 ms interval. Uplink and downlink transmissions are separated in the frequency domain. Figure 9 shows the LTE TDD frame structure:

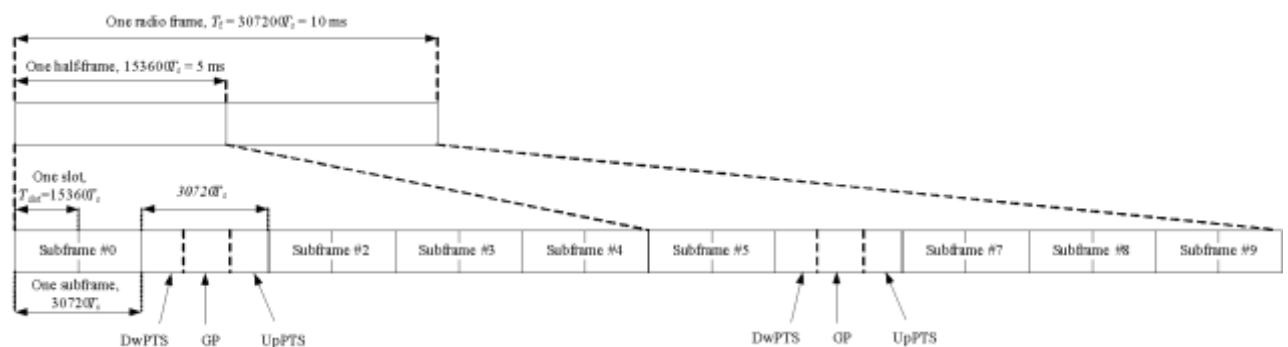


Figure 5 - LTE TDD Frame Structure (for 5 ms switch-point periodicity).

Frame structure type 2 is applicable to TDD. Each radio frame of length $T_f = 307200 \cdot T_s = 10 \text{ ms}$ consists of two half-frames of length $153600 \cdot T_s = 5 \text{ ms}$ each. Each half-frame consists of five subframes of length $30720 \cdot T_s = 1 \text{ ms}$.

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

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

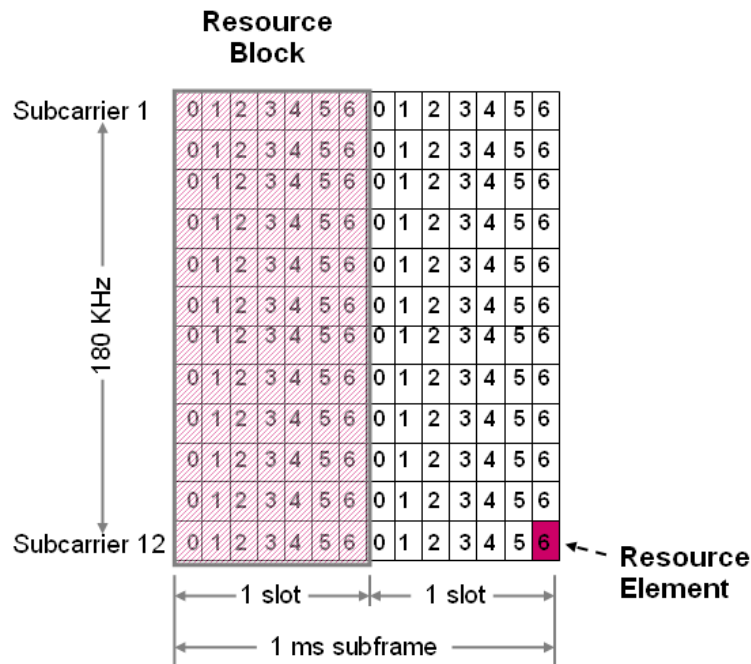


Figure 6- Physical RB and RE concepts

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 12).

Reference signals are used for channel estimation (signal quality and strength); therefore they are similar in functionality to the midamble in TD-SCDMA system. There are three types of reference signals defined in downlink for LTE: cell-specific, UE-specific and MBSFN (Multicast Broadcast Single Frequency Network). There is one reference signal transmitted per downlink antenna port

The position of the reference signals in the time domain is fixed (symbols 0 and 4 for the normal CP ; symbols 0 and 3 for extended CP) 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. Figure 14 shows the mapping of downlink reference signals for one antenna in Normal CP and extended CP structure.

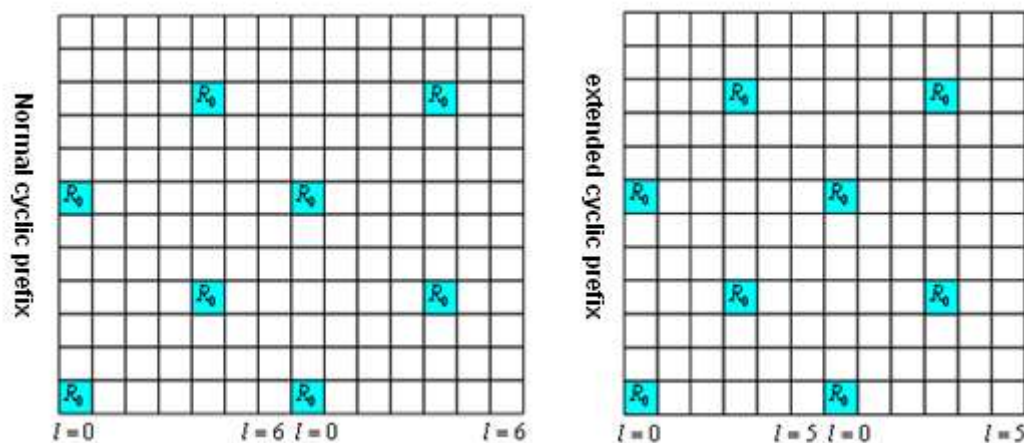


Figure 7- Mapping of downlink reference signals for one antenna

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.

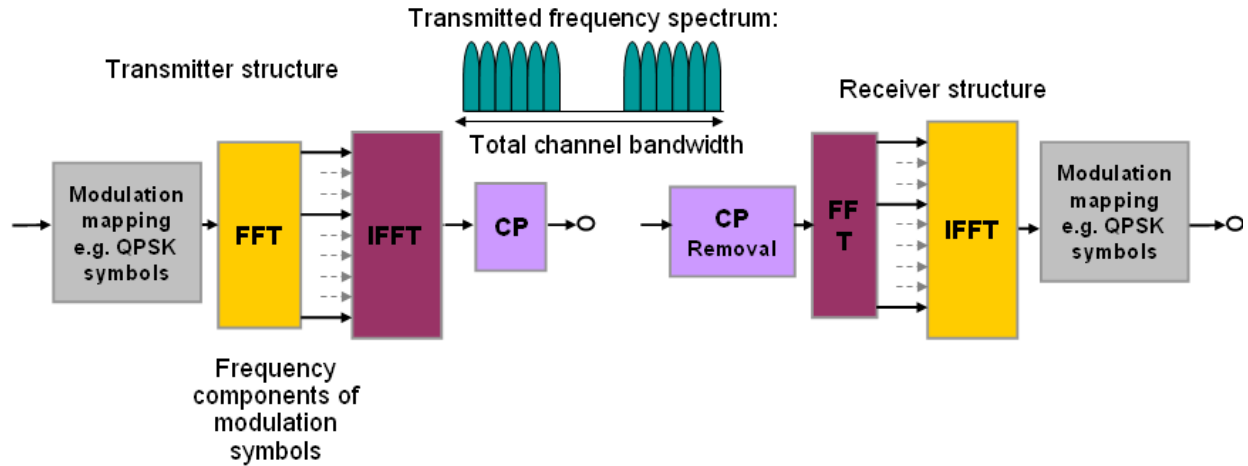


Figure 8 - SC-FDMA Operation

Figure 16 shows, at a high level, the SC-FDMA operation. It is similar to the OFDM/OFDMA case. The main difference is that in the case of SC-FDMA there is additional processing before the IFFT: the modulated symbols (interpreted in this case as time signals) are fed to the FFT processing. The outputs are the frequency components of the modulation symbols. Those frequency components are mapped to the allocated inputs of the IFFT and from there, the normal OFDM processing continues.

SC-FDMA Symbol

The SC-FDMA symbol also has a definition in the time and frequency domains, same as the OFDMA symbol. However, there are differences as shown in Figure 17 :

- The SC-FDMA symbol duration is the same as the OFDMA symbol duration ($66.7\mu\text{s}$). However, whereas in OFDMA each modulated symbol lasts the whole OFDMA symbol duration (see Figure 8), in SC-FDMA, each modulated symbol lasts for '1/n'th of the SC-FDMA symbol (where n is the number of used subcarriers, $1/5^{\text{th}}$ in the Figure 17 example)
- In OFDMA, there is one modulated symbol per subcarrier (see Figure 8). In SC-FDMA each modulated symbol is spread across the used subcarriers.
- In the frequency domain, each OFDMA data symbol occupies 15 kHz and each SC-FDMA data symbol occupies $n \times 15$ kHz bandwidth (see example in Figure 18)

Based on the above points, it can be seen that as the bandwidth increases, the modulated symbol duration decreases. Therefore, to double the data rate in case of SC-FDMA, the total bandwidth needs to be doubled (as well as the amount of FFT inputs in the transmitter) and the modulated symbol duration is halved.

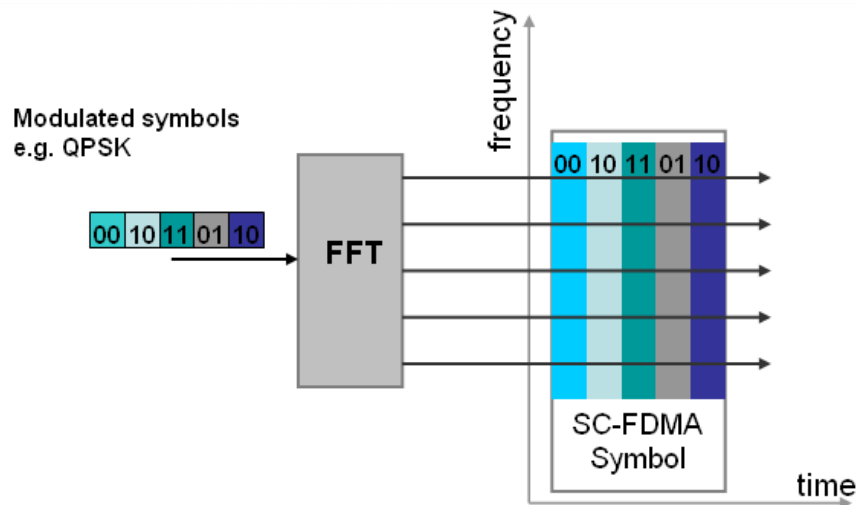


Figure 9 - SC-FDMA symbol

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.

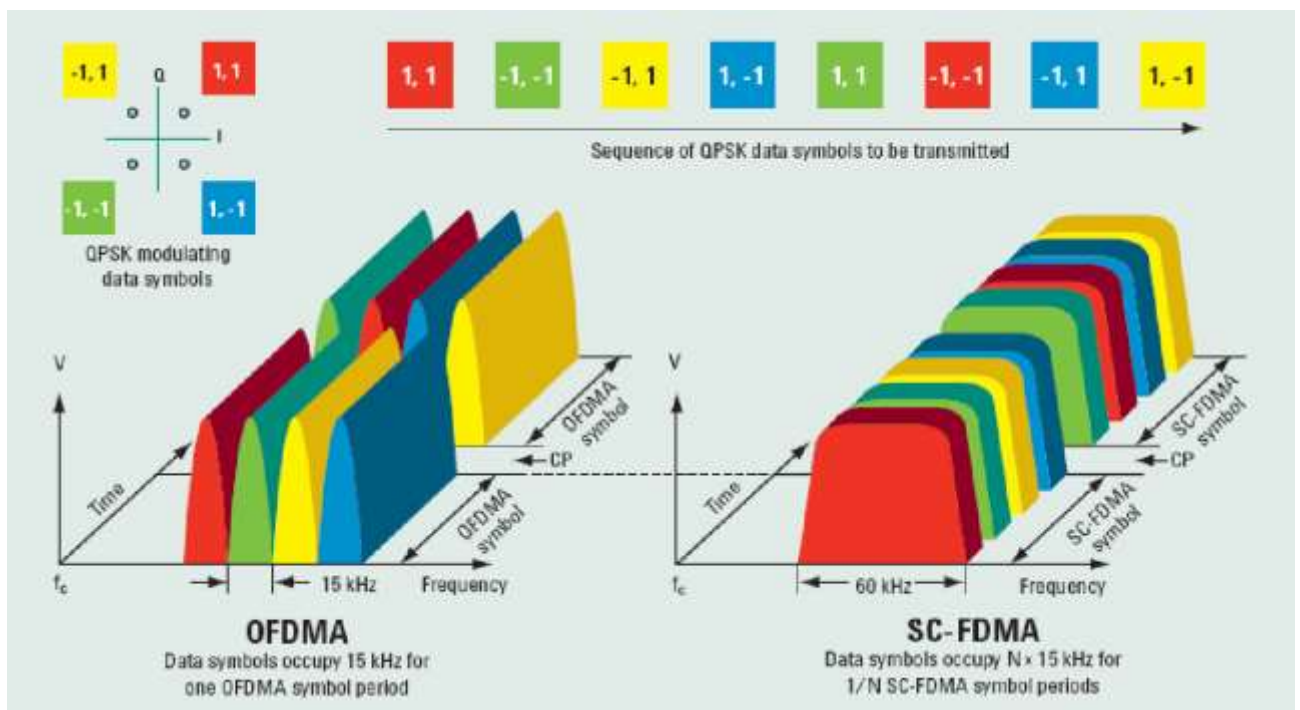


Figure 10 - OFDMA and SC-FDMA operation comparison

IV. KEY PERFORMANCE INDICATOR (KPI) OPTIMIZATION

Introduction

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

Key Performance Indicators

The most common key performance indicators which can be based on either network statistics or drive testing are listed below together with example calculation formula.

- Random access setup success rate : number of received Radio Resource Control (RRC) connection request messages (message number 3) sent by the user equipment (successfully acknowledged by eNodeB) / number of preambles received by eNodeB sent by user equipment (UE).
- Call setup success rate (CSSR) can be further split into (see Figure 8) :
 - Radio resource control connection setup success rate : number of received RRC connection request messages sent by user equipment / number of RRC connection setup complete messages (message 5) sent by UE and successfully received by eNodeB.
 - Evolved radio access bearer (E-RAB) setup success rate from UE point of view : number of sent RRC connection reconfiguration completions / number of sent service requests.
 - E-RAB setup success rate from eNodeB point of view : number of S1 application protocol (S1AP) : Initial context setup response messages sent by the eNodeB to the mobility management entity (MME) / number of S1AP:Initial context setup request sent by MME to the eNodeB.
- E-RAB drop rate : number of abnormally released radio bearers leading to release of E-RAB / number of successfully setup radio bearers
- Intra LTE handover success rate which can be further split into:
 - Intra frequency handover preparation success rate ; inter/intra eNodeB from UE point of view : number of RRC connection reconfiguration messages with mobility info included (new cell) received by the UE / number of measurement reports sent by UE.
 - Intra frequency handover preparation success rate ; inter/intra eNodeB from eNodeB point of view : number of received handover request acknowledgement messages / number of sent handover requests (over X2 or S1 for inter eNodeB and inside eNodeB in case of intra eNodeB).
 - Intra frequency handover execution success rate ; inter/intra eNodeB from UE point of view : number of sent RRC connection reconfiguration complete messages / number of received RRC connection reconfiguration messages.
 - Intra frequency handover execution success rate ; inter/intra eNodeB from source eNodeB point of view : number of received RRC Connection reconfiguration messages by target cell that leads to release request message received over X2 or received UE context release command message received over S1 in case of inter eNodeB handover or successful handover indication delivered inside the eNodeB to source cell in case of intra eNodeB handover / number of sent RRC connection reconfiguration complete messages (caused by received handover request acknowledgement over X2 or received handover command over S1).

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. Dominance area optimization is typically done by antenna downtilt, direction and height modifications and this is often referred as physical layer or layer one optimization. The physical layer performance can be evaluated for example by the slope of decrease in average reported (by UE) channel quality indicator (CQI) caused by increased downlink data volume per cell. The more negative this slope is the more the network suffers from inter cell interference. Figure 7 below shows one example of cluster level physical layer optimization results. The slope (CQI decreased due increased downlink data volume per cell) has improved significantly from -0.009 to -0.0035 which means that network can deliver 50% more data volume during year 2 compared to year 1 with the same spectral efficiency. This means better end user experience and higher network capacity

V. REFERENCES

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