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Restricting Carriers to Device to Device (D2D) Communication Using Layer 3 Control for LTE

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A Dissertation on,

“Restricting Carriers to Device to Device (D2D) Communication Using Layer 3 Control for LTE”

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Abstract

With increasing demand of high data rate wireless access for multimedia services, the Third Generation Partnership Project (3GPP) Long Term Evolution (LTE) has been proposed to develop new technology components that can meet the requirements of IMT-Advanced systems. IMT-A will offer a high bandwidth up to 100MHz for higher data rates, global operation and economy of scale supporting a wider range of services. Many candidate radio interface technologies have been submitted to the International Telecommunications Union (ITU) to prepare new technology components for LTE to meet IMT-A requirements. Among which, device-to-device (D2D) communication has received increasing attentions as a promising component to improve spectral efficiency.

Unlike the infrastructure based cellular network, D2D users (user equipments or mobile terminals) do not communicate via the central coordinator (base station or evolved NodeB) but operate as an underlay and communicate directly with each other. D2D communication shares the same resources with the cellular system whereas under the control of the evolved NodeB (eNB) of the cellular network. D2D communication is a promising concept which can provide several advantages such as low cost, flexibility etc. Its usage of bandwidth and battery power is more efficient. Indeed, such D2D communication is likely to become integral to the future beyond 3G world to form a hybrid network.

This Thesis work is focused on cell edge D2D users. Normally Cell edge users suffer from high interference from the other cells. Power Control is also a problem for cell edge users as cell edge users need higher power but eNB can’t provide excessively high power because it might interfere others in the cell .As a result performance degradation occurs in case of cell edge users. For this reason, we gave an idea where cell edge users will be entertained with same SNR and same data rate like the other users in the cell. We proposed an idea where the cell edge users of interconnected eNBs will be allocated same resource blocks which will not be given to the cellular users. In this work, we showed the differences of data rate, Shannon capacity, transmit power between cellular and D2D users in the cell edge. In all the cases, our proposed idea showed better performance through simulation using MATLAB.

Preface

First of all, we express our sincere gratitude to the Almighty Allah, Who has kindly given us the energy to accomplish the thesis work.

The undergraduate thesis, “**Restricting Carriers to Device to Device (D2D) Communication Using Layer 3 Control for LTE**” has been written for the completion of Bachelor of Science degree in Electrical and Electronic Engineering at Islamic University of Technology, Bangladesh. This thesis work and writing has been performed during the year 2013 under the supervision of Mr. Tawhid Kawser, Assistant Professor of the department of Electrical and Electronic Engineering.

We would like to dedicate this thesis to our supervisor Mr. Tawhid Kawser. Without the dedicated help of him we won’t be able to complete this work. We are also grateful to all of our will-wishers, who provided their perpetual support towards accomplishing this task successfully.

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Abbreviations and Acronyms

2G 2nd Generation
3G 3rd Generation
4G 4th Generation
3GPP Third Generation Partnership Project
ACK Acknowledgement (in ARQ protocols)
ARQ Automatic Repeat-reQuest
AWGN Additive White Gaussian Noise
BCCH Broadcast Control Channel
BCH Broadcast Channel
BER Bit-Error Rate
BPSK Binary Phase-Shift Keying
BS Base Station
BTS Base Transceiver Station
CC Convolutional Code (in the context of coding)
CDM Code-Division Multiplexing
CDMA Code-Division Multiple Access
CN Core Network
CP Cyclic Prefix
CQI Channel-Quality Indicator
CRS Cell-specific Reference Signal
CSI Channel-State Information
DFT Discrete Fourier Transform
DL Downlink
DL-SCH Downlink Shared Channel
DRX Discontinuous Reception
DwPTS The downlink part of the special subframe (for TDD operation).
EGPRS Enhanced GPRS
eNB eNodeB
eNodeB E-UTRAN NodeB
FDD Frequency Division Duplex
FDM Frequency-Division Multiplex
FDMA Frequency-Division Multiple Access
FEC Forward Error Correction
FFT Fast Fourier Transform
GP Guard Period (for TDD operation)
GPRS General Packet Radio Services
GPS Global Positioning System
GSM Global System for Mobile communications
HARQ Hybrid ARQ
HRPD High Rate Packet Data
HSDPA High-Speed Downlink Packet Access
HSPA High-Speed Packet Access
IP Internet Protocol
IR Incremental Redundancy
LAN Local Area Network
LTE Long-Term Evolution
MAC Medium Access Control
MIMO Multiple-Input Multiple-Output
ML Maximum Likelihood
NAK Negative Acknowledgement (in ARQ protocols)
NodeB NodeB, a logical node handling transmission/reception in multiple cells.
NS Network Signaling
OFDM Orthogonal Frequency-Division Multiplexing
OFDMA Orthogonal Frequency-Division Multiple Access
PAPR Peak-to-Average Power Ratio
PBCH Physical Broadcast Channel
PCCH Paging Control Channel
PCFICHPhysical Control Format Indicator Channel
PCH Paging Channel
PDCCH Physical Downlink Control Channel
PDSCH Physical Downlink Shared Channel
PHICH Physical Hybrid-ARQ Indicator Channel
PHY Physical layer
PRACH Physical Random Access Channel
PRB Physical Resource Block
PSK Phase Shift Keying
PSS Primary Synchronization Signal
PUCCH Physical Uplink Control Channel
QAM Quadrature Amplitude Modulation
QoS Quality-of-Service
QPSK Quadrature Phase-Shift Keying
RACH Random Access Channel
RAN Radio Access Network
RB Resource Block
RE Reseource Element
R-PDCCH Relay Physical Downlink Control Channel
RRC Radio Resource Control
RS Reference Symbol
SSS Secondary Synchronization Signal
TDD Time-Division Duplex
TDM Time-Division Multiplexing
TDMA Time-Division Multiple Access
TD-SCDMA Time-Division-Synchronous Code-Division Multiple Access
UL Uplink
UL-SCH Uplink Shared Channel
UMTS Universal Mobile Telecommunications System

CHAPTER ONE

1.1 LTE OVERVIEW

LTE is based on the GSM/EDGE and UMTS/HSPA network technologies, increasing the capacity and speed. The standard is developed by the 3GPP.

The world's first publicly available LTE service was launched by TeliaSonera in Oslo and Stockholm on December 14 2009.

LTE Advanced is a mobile communication standard, formally submitted as a candidate 4G system to ITU-T in late 2009, was approved into ITU.

The motivation for LTE

- Need to ensure the continuity of competitiveness of the 3G system for the future
- User demand for higher data rates and quality of service
- Packet Switch optimised system
- Continued demand for cost reduction (CAPEX and OPEX)
- Low complexity
- Avoid unnecessary fragmentation of technologies for paired and unpaired band operation

The Evolved Packet System (EPS) is purely IP based. Both real time services and datacom services will be carried by the IP protocol. The IP address is allocated when the mobile is switched on and released when switched off.

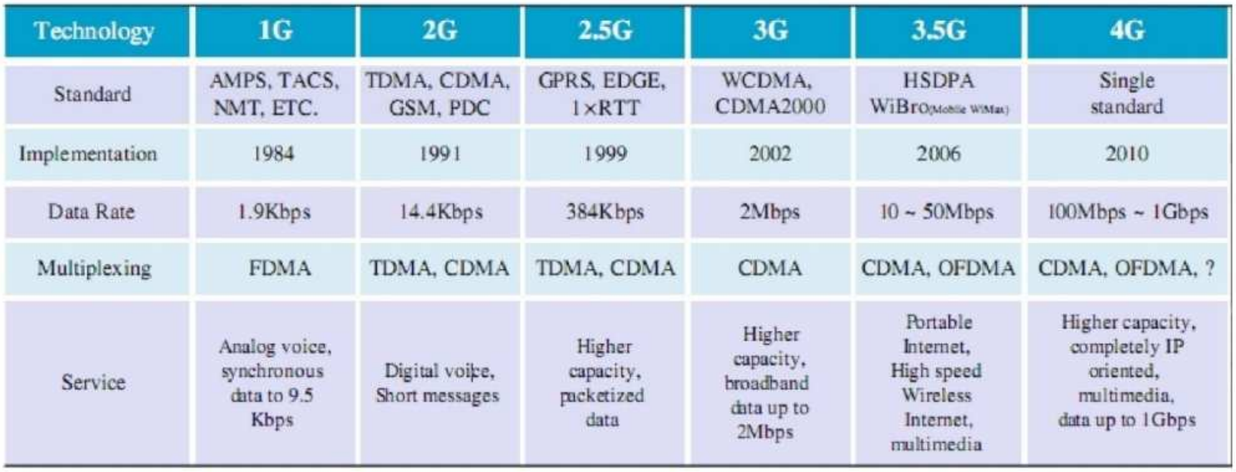
LTE, is based on OFDMA (Orthogonal Frequency Division Multiple Access) to be able to reach even higher data rates and data volumes. High order modulation (up to 64QAM), large bandwidth (up to 20 MHz) and MIMO transmission in the downlink (up to 4x4) is also a part of the solution. The highest theoretical data rate is 170 Mbps in uplink and with MIMO the rate can be as high as 300 Mbps in the downlink.

LTE has some specific additional capabilities such as flexible channel bandwidths and the advantages of Orthogonal Frequency Division Multiple Access (OFDMA). LTE is being developed in Releases 8 and 9 of the 3GPP specifications.

To meet the demand for ever-higher data rates, LTE offers a 100 Mbps download rate and 50 Mbps upload rate for every 20 MHz of spectrum. Support is intended for even higher rates, to 326.4 Mbps in the downlink, using multiple antenna configurations. To allow the use of both new and existing frequency bands, LTE provides scalable bandwidth from 1.4 MHz to 20 MHz in both the downlink and the uplink. LTE is optimized for low speeds (0 - 15 km/h) but will still provide high performance to 120 km/h with support for mobility maintained up to 350 km/h. 3GPP are considering support for even higher speeds up to 500 km/h.

1.2 History of LTE

There have been three different generations of mobile communication networks. First-generation of (1G) wireless telephone technologies are the analog cell phone standards that were introduced in the 80s and continued until being replaced by 2G digital cell phones in 1990s. Example of such standards are NMT (Nordic Mobile Telephone), used in Nordic countries, NTT system in Japan, and the AMPS (Advanced Mobile Phone System) operated in the United States. The second generation (2G) technology is based on digital cellular technology. Examples of the 2G are the Global System for Mobile Communications (GSM), Personal Digital Cellular(PDC), and North American version of CDMA standard (IS-95). The third generation (3G) started in October 2001 when WCDMA network was launched in Japan. The services associated with 3G provide the ability to transfer both voice data (a telephone call) and non-voice data (such as downloading information, exchanging email, and instant messaging).



Technology	1G	2G	2.5G	3G	3.5G	4G
Standard	AMPS, TACS, NMT, ETC.	TDMA, CDMA, GSM, PDC	GPRS, EDGE, 1×RTT	WCDMA, CDMA2000	HSDPA WiBro(Mobile WiMax)	Single standard
Implementation	1984	1991	1999	2002	2006	2010
Data Rate	1.9Kbps	14.4Kbps	384Kbps	2Mbps	10 ~ 50Mbps	100Mbps ~ 1Gbps
Multiplexing	FDMA	TDMA, CDMA	TDMA, CDMA	CDMA	CDMA, OFDMA	CDMA, OFDMA, ?
Service	Analog voice, synchronous data to 9.5 Kbps	Digital voice, Short messages	Higher capacity, packetized data	Higher capacity, broadband data up to 2Mbps	Portable Internet, High speed Wireless Internet, multimedia	Higher capacity, completely IP oriented, multimedia, data up to 1Gbps

LTE is represented as a modern wireless technology beyond 3G. LTE is designed to meet carrier needs for high-speed data and media transport as well as high-capacity voice support well into the next decade It promises to provide not only the advanced mobile broadband capability, but also the enhancement of the existing services and the introduction of the modish multimedia services. It is designed to provide more efficient flexible channel bandwidth, and even over two to four times higher data rate than those supported by the existing 3G technologies. Live LTE network is operating successfully in some major cities of Europe. It is sure that in coming days LTE will lead today‟s wireless technology to the new dimension providing extremely high performance radio access technology.

Although technical specifications are not yet finalized, significant details are emerging. LTE PHY employs some advanced technologies that are new to cellular applications. These include Orthogonal Frequency Division Multiplexing (OFDM) and Multiple Input Multiple Output (MIMO) data transmission. In addition, the LTE PHY uses Orthogonal Frequency Division Multiple Access (OFDMA) on the downlink (DL) and Single Carrier – Frequency Division Multiple Access (SC-FDMA) on the uplink (UL). OFDMA allows data to be directed to or from multiple users on a subcarrier-by-subcarrier basis for a specified number of symbol periods.

1.3 LTE Evolution

LTE can be considered as an emerging and evolutionary technology of its predecessor like GSM/EDGE, UMTS, and HSPA. Although LTE uses different radio access technology it can readily coexist and interwork with other 2G and 3G systems with just some changes in overall network. 3GPP has done lots of work on standard development for LTE in Release 8 and with some enhancements update in Release 9. Until the full standardization and operation of 4G systems (LTE Advance), for many years LTE will serve to provide high speed data capability. The Figure 1.1shows evolution of LTE.

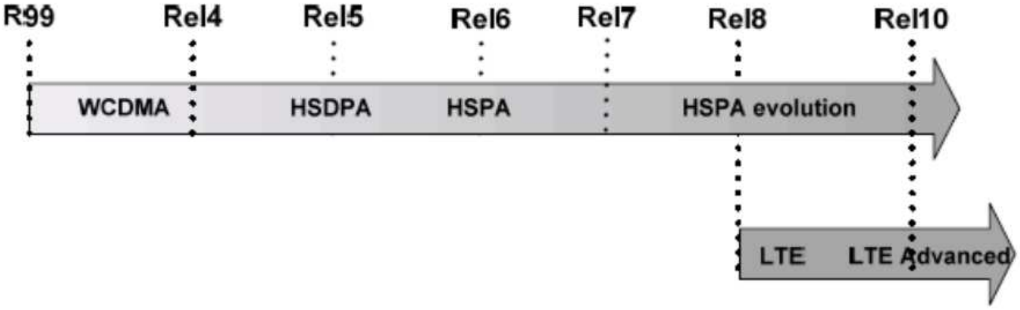


Figure 1.1 LTE and HSPA evolution [2].

1.4 LTE Upgrade Path

LTE provides a smooth evolutionary path for operators deploying all 3GPP and non- 3GPP technologies. It helps operators to enhance their network to LTE even without need to follow any specific path for modification. For example, an operator running GSM or WCDMA can easily enhance their network to LTE without having to employ HSPA [3]. Also LTE can offer smooth migration path towards 4G.

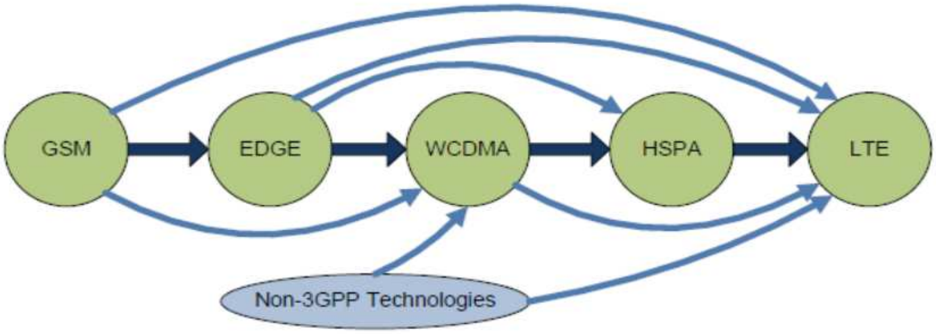


Figure 1.2. Different LTE evolutionary paths [3].

1.5 LTE Network Architecture

The LTE network architecture comprises Evolved UMTS Terrestrial Radio Access Network (E-UTRAN) on the radio access side and Evolved Packet Core (EPC) on the core side. The overall architecture of a LTE network is as shown in Figure 2.4. The EUTRAN consists of eNBs which are interconnected with each other with X2 interface, while they are connected to EPC (mainly MME/S-GW) with S1 interface.

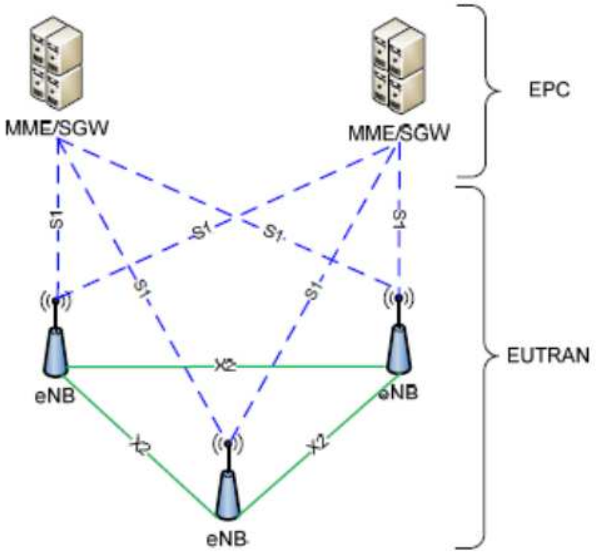


Figure 1.3. E-UTRAN overall architecture

1.5.1 The Core Network

The EPC is all IP mobile core network for LTE which is responsible for overall control of UE and establishment of all bearer services. A combination of UE, E-UTRAN and EPC together represent Internet Protocol (IP) Connectivity Layer, which is also called Evolved Packet System (EPS). The main function of EPS is to provide end-to-end IP connectivity across LTE. In flat IP architecture by separation of control and data planes, EPC improves network performance and reduces requirement of extra nodes between mobile data elements. The goal of the EPC is prompt mobile services, higher throughput, lower latency, simplified interworking between all 3GPP, and non-3GPP networks, enhanced service control and provisioning, and efficient use of network resources.

The main elements of EPC are

- Mobility Management Entity (MME)
- Serving Gateway (S-GW)
- Packet Data Network (PDN) Gateway (P-GW).

The core network connecting to E-UTRAN is shown in Figure 1.4.

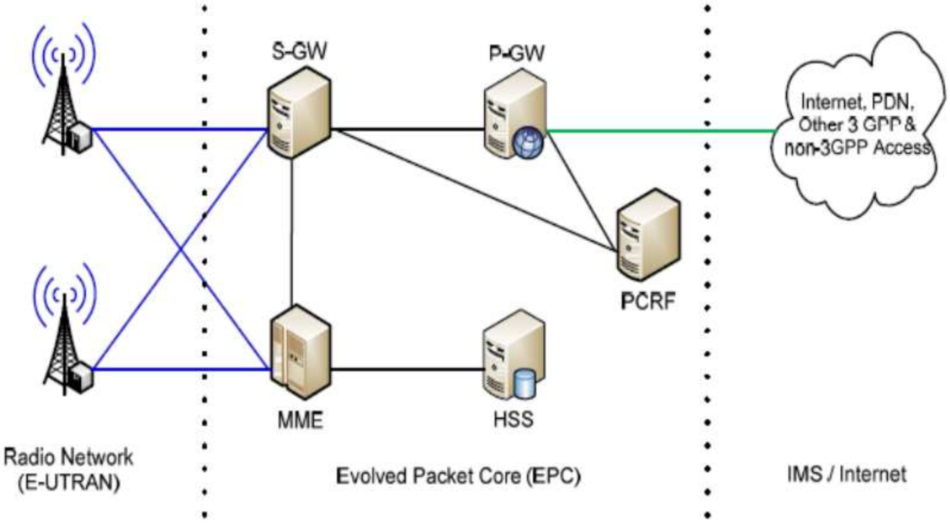


Figure 1.4 SAE and LTE network

1.5.2 The Radio Access Network

The radio access network of 3GPP's Long Term Evolution is called E-UTRAN. The EUTRAN consists of network of eNBs. According to [4] E-UTRAN is described as follows:

The E-UTRAN consists of eNBs, providing the E-UTRA user plane (PDCP/RLC/MAC/PHY) and control plane (RRC) protocol terminations towards the UE. The eNBs are interconnected with each other by means of the X2 interface. The eNBs are also connected by means of the S1 interface to the EPC, more specifically to the MME by means of the S1-MME and to the Serving Gateway (S-GW) by means of the S1-U. The S1 interface supports a many-to-many relation between MMEs / SGWs and eNBs.

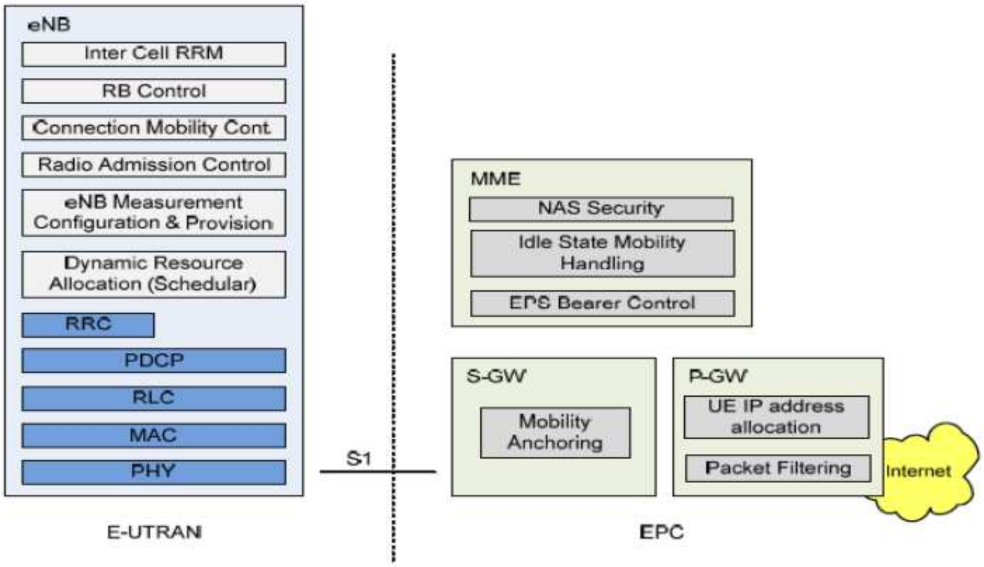


Figure 1.5. Functional split between E-UTRAN and EPC [4]

1.5.3 The LTE Interfaces and Network Elements

The Figure 1.6 illustrates network elements of LTE and various interfaces for interconnection with each other. The meanings and functions of each interface are explained as [5].

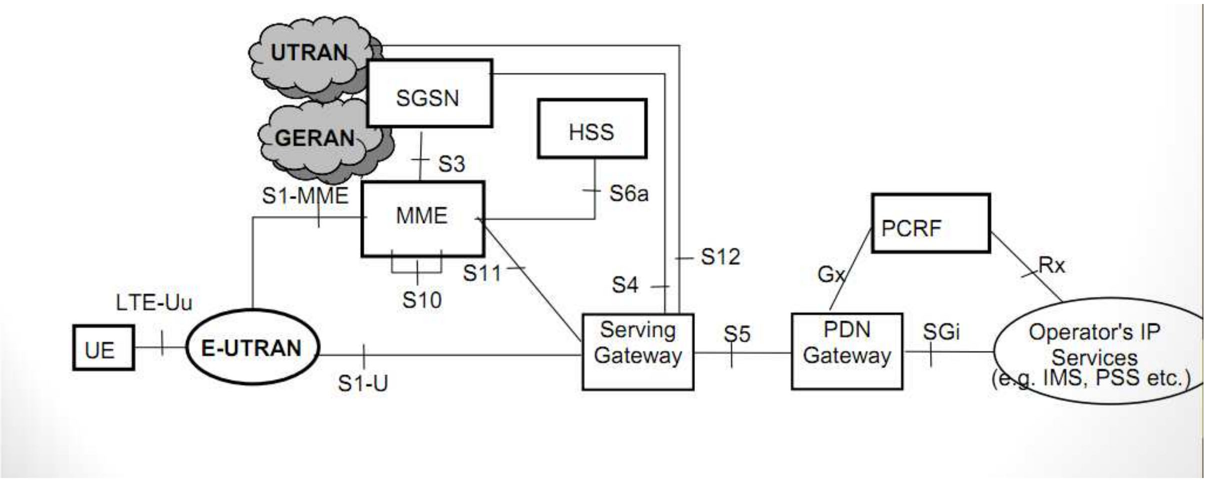


Figure 1.6. LTE system architecture and interfaces [6]

S1-MME: It is an interface for control plane protocol between each E-UTRAN and MME.

S1-U: It is an interface between E-UTRAN and S-GW for per bearer user plane tunneling and inter eNB path switching during handover.

S3: It is an interface between SGSN and MME. It helps for exchange of user and bearer information for inter 3GPP access network (like GERAN, UTRAN) mobility in idle and/or active state.

S4: It provides control and mobility support between SGSN and S-GW.

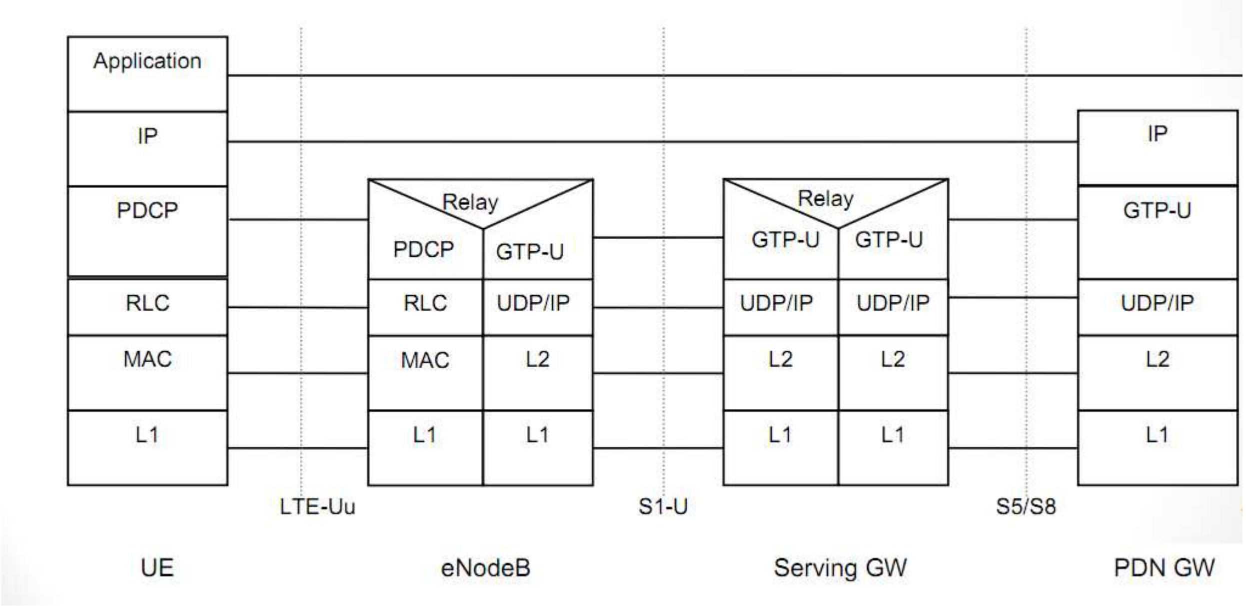
S5: This interface represents connection between S-GW and P-GW. It provides user plane tunneling and tunnel management between them.

S10: It is for interconnection between MMEs for MME relocation and MME to MME information transfer.

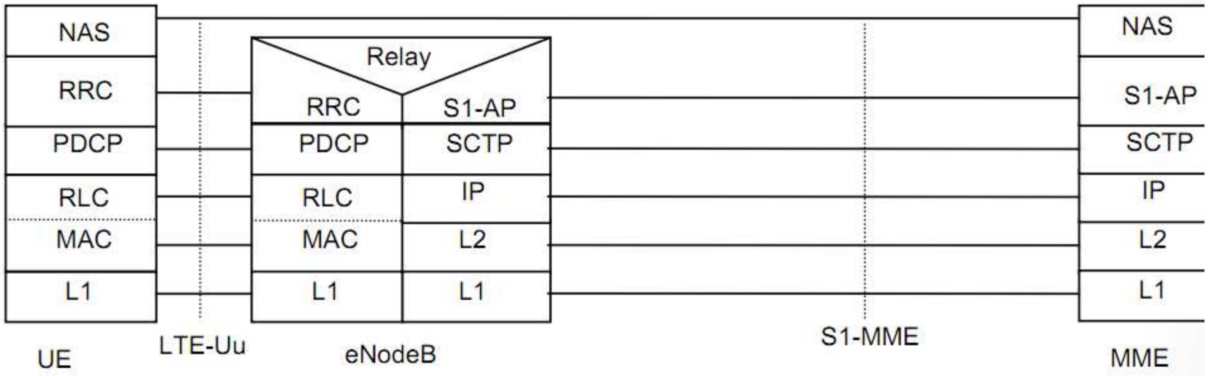
S11: It is a reference point between MME and SGW.

SGi: It is for connection of P-GW with own or external PDN.

1.6 User Plane Protocol Stack



1.7 Control Plane Protocol Stack


NAS
RRC
PDCP
RLC
MAC
L1
UE
LTE-Uu
Relay
RRC
S1-AP
PDCP
SCTP
RLC
IP
MAC
L2
L1
L1
eNodeB
S1-MME
NAS
S1-AP
SCTP
IP
L2
L1
MME

CHAPTER TWO

LTE RADIO INTERFACE

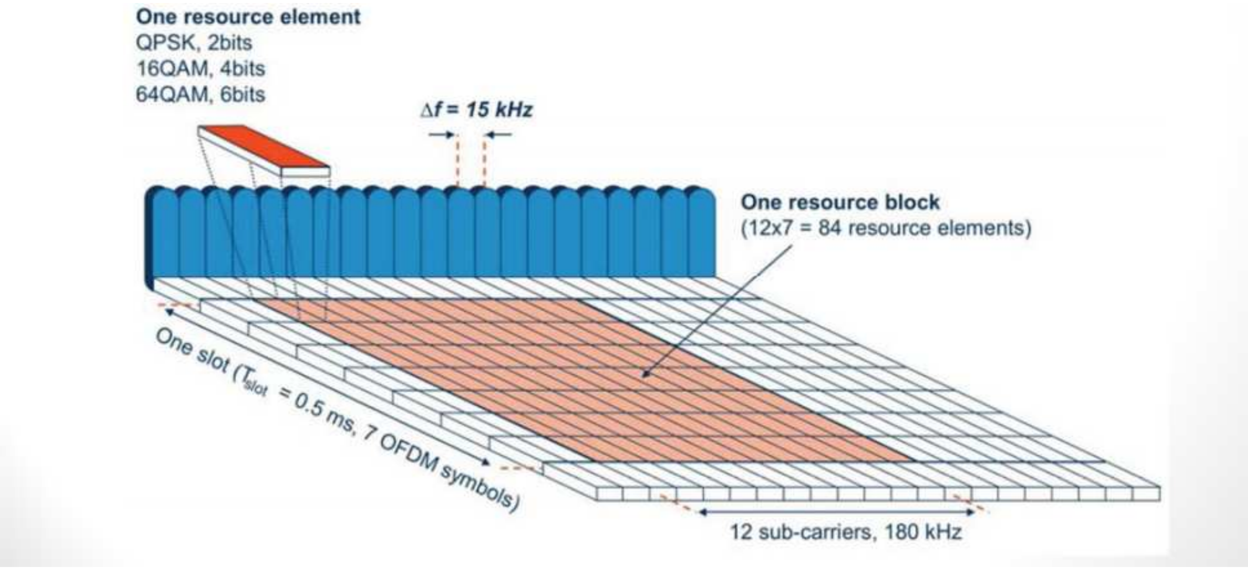
This chapter mainly discusses about radio interface technologies implemented in both uplink and downlink direction of a LTE system.

2.1 OFDMA

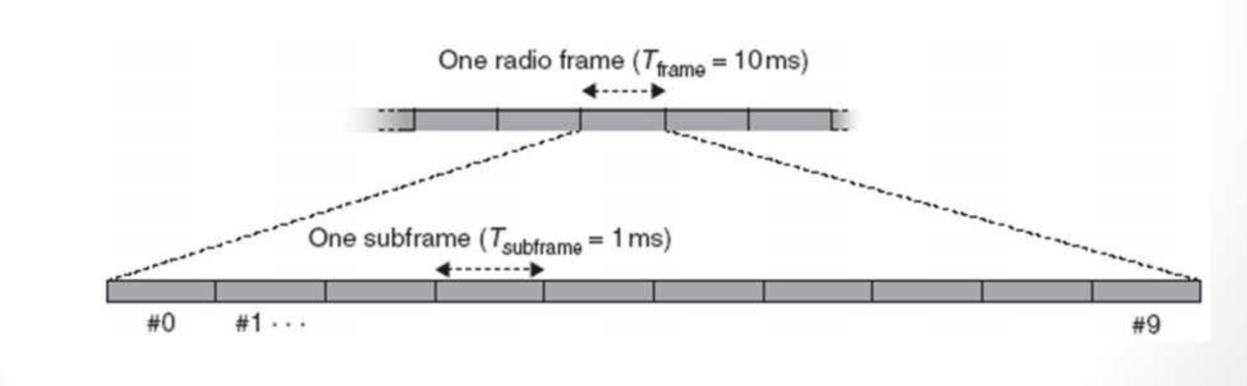
The Orthogonal Frequency Division Multiplex (OFDM) breaks the available bandwidth into many narrow parts with sub-carriers at the center of each of these parts.Then the data symbols are modulated in parallel streams onto the sub-carriers. . The sub-carriers are made orthogonal to each other by choosing a sub-carrier spacing, Δf=1/T where T is the OFDM symbol interval.This makes efficient use of the available bandwidth virtually allowing no Inter Carrier Interference (ICI)among adjacent sub-carriers.

LTE uses 15 kHz sub-carrier spacing. However, it may use 7.5 kHz sub-carrier spacing for MBMS.

Using sub-carriers in the frequency axis and symbols in the time axis, a time-frequency resource grid is considered.Each element in the time-frequency resource grid is called a resource element.



A radio frame consists of ten equally sized subframes. A radio frame has length = 10 ms. Thus, it provides easy backward compatibility with UMTS/HSPA. A subframe has length 1 ms. A slot has length 0.5 ms.



A slot contains 3, 6 or 7 OFDM symbols.

1. Normal Cyclic Prefix: 7 OFDM symbols are used per slot

2. Extended Cyclic Prefix: 6 OFDM symbols are used per slot

3. MBMS: 3 OFDM symbols are used per slot

Resources are allocated to the UEs in terms of Resource Blocks (RB). In time, the length of a RB is 1 slot. In frequency, the length of a RB is 12 subcarriers or 180 kHz.

12 X 7 = 84 resource elements with normal cyclic prefix

12 X 6 = 72 resource elements with extended cyclic prefix

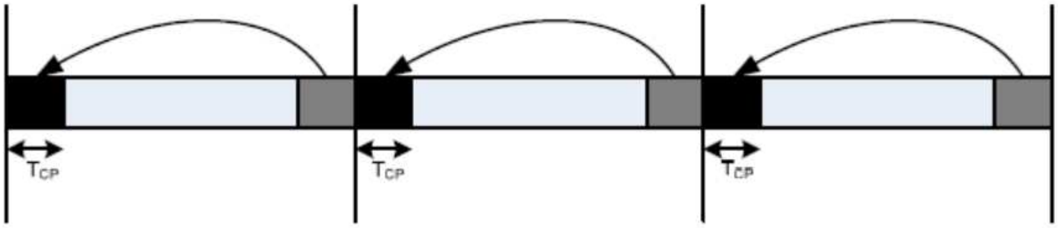
2.2 SC-FDMA

OFDMA offers high Peak to Average Power Ratio (PAPR). The high PAPR requires linear power amplifiers with large dynamic range. This makes the power amplifier less efficient, more expensive and more power consuming. This is a more severe problem in the uplink compared to the downlink because it increases the cost of the UE and consumes the battery power faster. The high PAPR also degrades coverage and cell-edge performance. Therefore, in order to reduce PAPR, Single-Carrier FDMA (SC-FDMA) is used in the uplink instead of OFDMA. The time dispersive or equivalently, the frequency-selective radio channel distorts the SC-FDMA signal. Thus, an equalizer is needed to compensate for the radio channel frequency selectivity. This is the disadvantage of the use of SC-FDMA instead of OFDMA. However, the equalization is not very difficult to perform at the base station becausethe base station can accommodate more power and cost.

The uplink uses the same type of time-frequency resource grid as used in downlink. Resource Blocks are defined the same way as in downlink.

2.3 Cyclic Prefix

To mitigate effect of ISI caused by multipath propagation, there is need of guard interval known as cyclic prefix (CP) which is inserted prior to each OFDM symbol (Figure given below). The CP is a copy of the end of a symbol inserted at the beginning. For normal subcarrier spacing of _f =15 kHz, a CP length of 5 μs is used. The CP with this 5 μs duration is termed Normal CP. Use of long CP duration of 17μs is also possible, which is termed extended CP. In LTE, if normal CP is implemented then the 0.5 ms slot can accommodate seven symbols, whereas if extended CP is used then six symbols are possible. In case of _f = 7.5 kHz (only for MBMS-dedicated cell) sub-carrier spacing, there is only a single CP length TCP-low = 1/_f, corresponding to 3 OFDM symbols per slot.



For fixed subcarrier spacing, increasing the length of the CP will provide additional overhead in terms of power and bandwidth. This makes shorter CP suitable in smaller cellular environment, whereas, longer CP in extreme time dispersive environments and single frequency network operations. The extended CP supports to cover larger cell higher delay spread.

2.4 Physical Channels

Three different types of physical channels are defined for the LTE downlink. One common characteristic of physical channels is that they all convey information from higher layers in the LTE stack. This is in contrast to physical signals, which convey information that is used exclusively within the PHY layer.

LTE DL physical channels are:

1. Physical Downlink Shared Channel (PDSCH)
2. Physical Downlink Control Channel (PDCCH)
3. Common Control Physical Channel (CCPCH)

Transport channels are SAPs for higher layers. Each physical channel has defined algorithms for:

- Bit scrambling
- Modulation
- Layer mapping
- CDD precoding
- Resource element assignment

Layer mapping and pre-coding are related to MIMO applications. Basically, a layer corresponds to a spatial multiplexing channel. MIMO systems are defined in terms of N transmitters x N receivers. For LTE, defined configurations are 1x 1, 2 x 2, 3 x 2 and 4 x 2.Note that while there are as many as four transmitting antennas, there are only a maximum of two receivers and thus a maximum of only two spatial multiplexing data streams.

For a 1 x 1 or a 2 x 2 system, there is a simple 1:1 relationship between layers and transmitting antenna ports. However, for a 3 x 2 and 4 x 2 system, there are still only two spatial multiplexing channels. Therefore, there is redundancy on one or both data streams. Layer mapping specifies exactly how the extra transmitter antennas are employed.

Precoding is also used in conjunction with spatial multiplexing. Recall that MIMO exploits multipath to resolve independent spatial data streams. In other words, MIMO systems require a certain degree of multipath for reliable operation. In a noise-limited environment with low multipath distortion, MIMO systems can actually become impaired.

1. Physical Downlink Shared Channel

The PDSCH is utilized basically for data and multimedia transport. It therefore is designed for very high data rates. Modulation options therefore include QPSK, 16QAM and 64QAM. Spatial multiplexing is also used in the PDSCH. In fact, spatial multiplexing is exclusive to the PDSCH. It is not used on either the PDCCH or the CCPCH.

2. Physical Downlink Control Channel
   The PDCCH conveys UE-specific control information. Robustness rather than maximum data rate is therefore the chief consideration. QPSK is the only available modulation format. The PDCCH is mapped onto resource elements in up to the first three OFDM symbols in the first slot of a sub frame.

3. Common Control Physical Channel
   The CCPCH carries cell-wide control information. Like the PDCCH, robustness rather than maximum data rate is the chief consideration. QPSK is therefore the only available modulation format. In addition, the CCPCH is transmitted as close to the center frequency as possible. CCPCH is transmitted exclusively on the 72 active subcarriers centered on the DC subcarrier. Control information is mapped to resource elements (k, l) where k refers to the OFDM symbol within the slot and l refers to the subcarrier. CCPCH symbols are mapped to resource elements in increasing order of index k first, then l.

2.5 Transport Channels

Transport channels are included in the LTE PHY and act as service access points (SAPs) for higher layers. Downlink Transport channels are:

Broadcast Channel (BCH)
- Fixed format
- Must be broadcast over entire coverage area of cell

Downlink Shared Channel (DL-SCH)
- Supports Hybrid ARQ (HARQ)
- Supports dynamic link adaption by varying modulation, coding and transmit power
- Suitable for transmission over entire cell coverage area
- Suitable for use with beam forming
- Support for dynamic and semi-static resource allocation
- Support for discontinuous receive (DRX) for power save

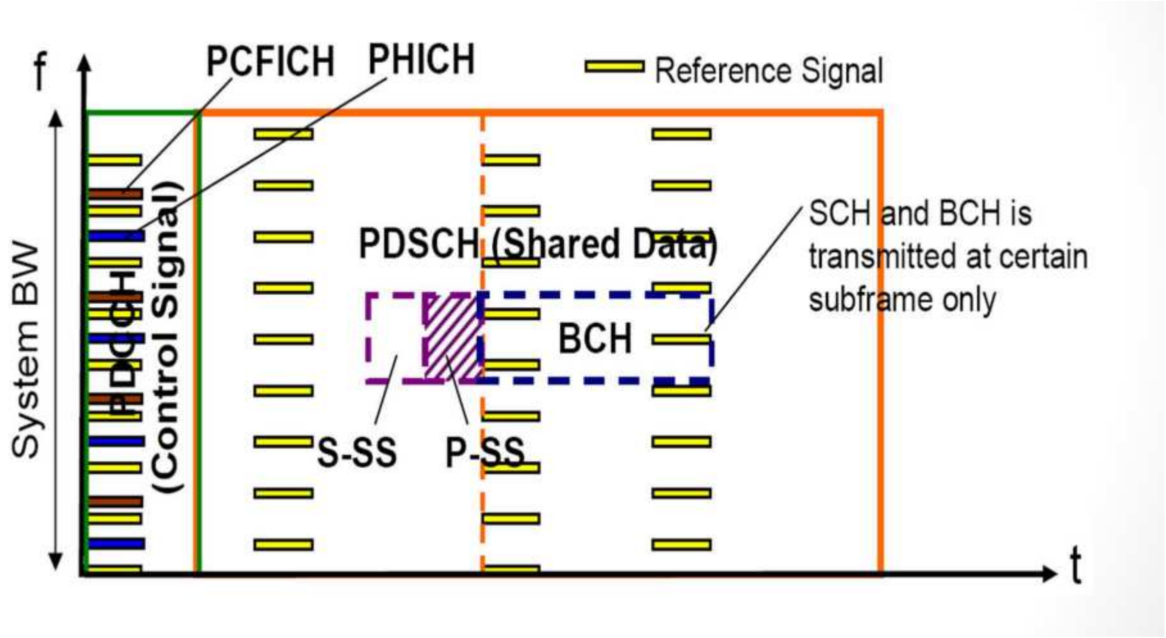
Paging Channel (PCH)
- Support for UE DRX
- Requirement for broadcast over entire cell coverage area
- Mapped to dynamically allocated physical resources

Multicast Channel (MCH)
- Requirement for broadcast over entire cell coverage area
- Support for MB-SFN
- Support for semi-static resource allocation

Uplink and Downlink Channels in LTE

Downlink Channels (DL):
- Physical Broadcast Channel (PBCH)

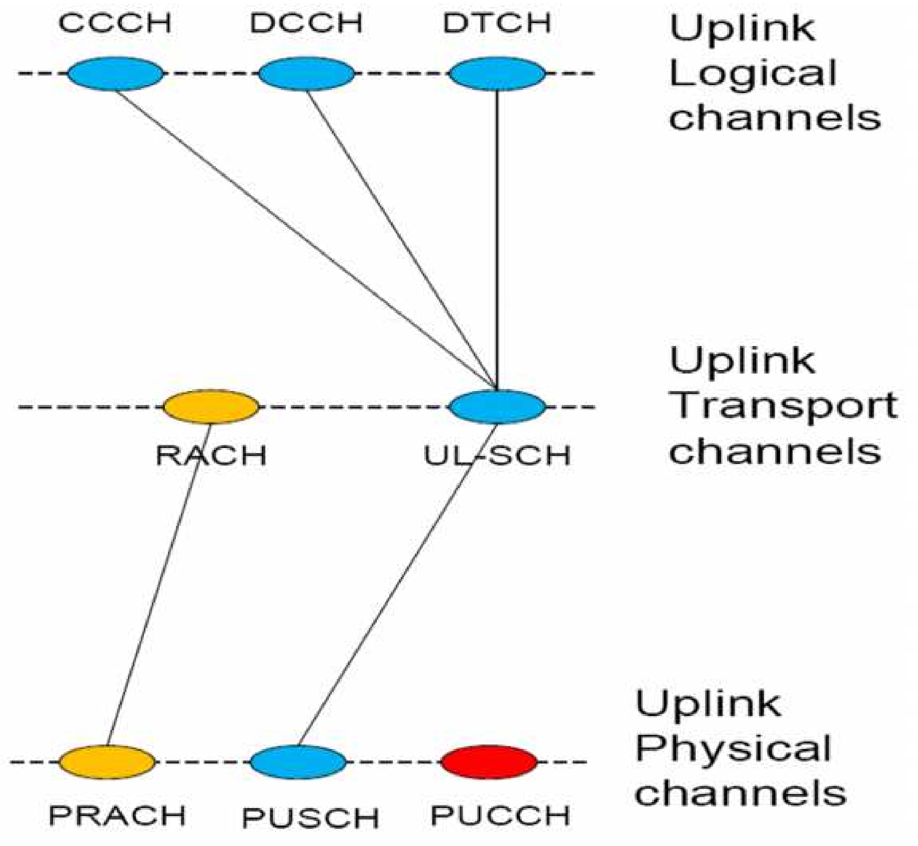
- Physical Format Control Indicator Channel (PFCICH)
- Physical Downlink Control Channel (PDCCH)
- Physical Hybrid ARQ Indicator Channel (PHICH)
- Physical Downlink Shared Channel (PDSCH)
- Physical Multicast Channel (PMCH)



Uplink Channels (UL):

- Physical UL Control Channel (PUCCH)

- Physical UL Shared Channel (PUSCH)
- Physical Random Access Channel (PRACH)



2.7 The First LTE Release to LTE-Advanced

As a result of intense activity by a larger number of contributing companies than ever before in 3GPP, the specifications for the first LTE release (Release 8) had reached a sufficient level of completeness by December 2007 to enable LTE to be submitted to ITU-R as a member of the IMT family of radio access technologies. It is therefore able to be deployed in IMT-designated spectrum, and the first commercial deployments were launched towards the end of 2009 in northern Europe.

Meanwhile, 3GPP has continued to improve the LTE system and to develop it to address new markets. In this section, we outline the new features introduced in the second LTE release, Release 9, and those provided by LTE Release 10, which begins the next significant step known as LTE-Advanced.

Increasing LTE's suitability for different markets and deployments was the first goal of Release 9. One important market with specific regulatory requirements is North America.LTE Release 9 therefore provides improved support for Public Warning Systems (PWS) and some accurate positioning methods (see Chapter 19). One positioning method uses the Observed Time Difference of Arrival (OTDOA) principle, supported by specially designed new reference signals inserted in the LTE downlink transmissions. Measurements of these positioning reference signals received from different base stations allow a UE to calculate its position very accurately, even in locations where other positioning means such as GPS fail (e.g. indoors). Enhanced Cell-ID-based techniques are also supported.

2.8 LTE-Advanced

The next version of LTE, Release 10, develops LTE to LTE-Advanced.While LTE Releases 8 and 9 already satisfy to a large extent the requirements set by ITU-R for the IMT-Advanced designation, Release 10 will fully satisfy them and even exceed them in several aspects where 3GPP has set more demanding performance targets than those of ITU-R.

The main Release 10 features that are directly related to fulfilment of the IMT-Advanced requirements are:

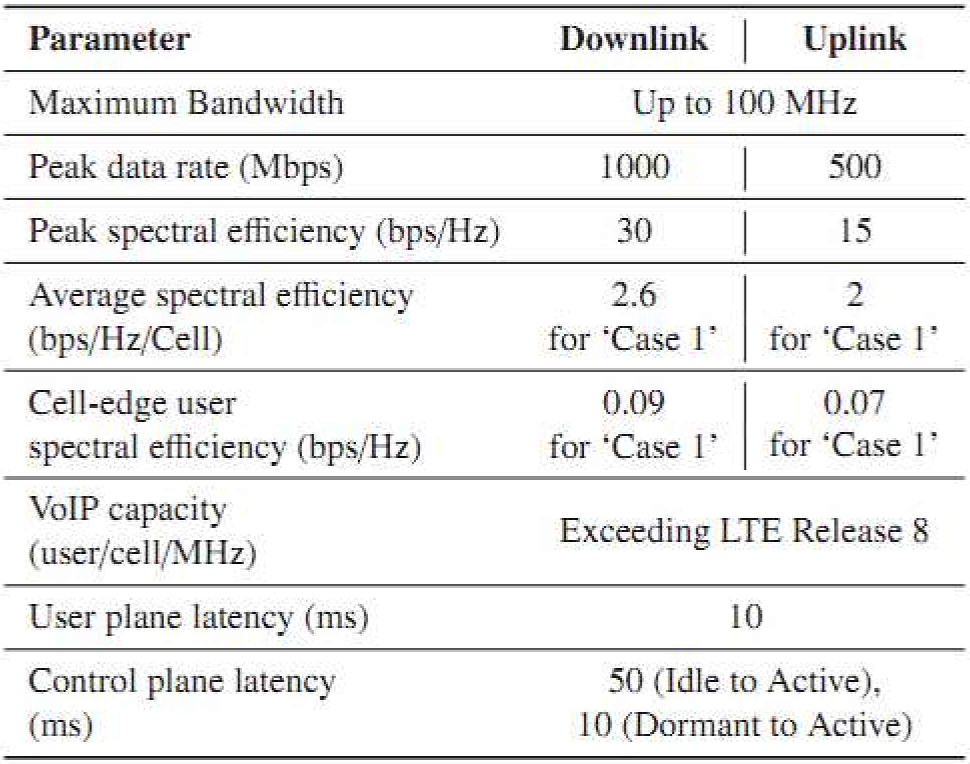
- Carrier aggregation, allowing the total transmission bandwidth to be increased up to 100 MHz .
- Uplink MIMO transmission for peak spectral efficiencies greater than 7.5 bps/Hz and targeting up to 15 bps/Hz .
- Downlink MIMO enhancements, targeting peak spectral efficiencies up to 30 bps/Hz.

Besides addressing the IMT-Advanced requirements, Release 10 also provides some new features to enhance LTE deployment, such as support for relaying,enhanced inter-cell interference coordination and mechanisms to minimize the need for drive tests by supporting extended measurement reports from the terminals.

The key radio access requirements set by ITU-R for IMT-Advanced for different deployment scenarios are summarized in the following Table.Note that the spectral efficiency requirements in downlink and uplink are defined on a per-cell basis, and no explicit peak data rate requirements are defined.

Parameter	**Downlink**	**Uplink**
Maximum Bandwidth	At least 40 MHz	
Peak spectral efficiency (bps/Hz)	15	6.75
Average spectral efficiency (bps/Hz/Cell)	3.0 (Indoor Hotspot) 2.6 (Urban Micro) 2.2 (Urban Macro) 1.1 (Rural Macro)	2.25 (Indoor Hotspot) 1.8 (Urban Micro) 1.4 (Urban Macro) 0.7 (Rural Macro)
Cell-edge user spectral efficiency (bps/Hz)	0.1 (Indoor Hotspot) 0.075 (Urban Micro) 0.06 (Urban Macro) 0.04 (Rural Macro)	0.07 (Indoor Hotspot) 0.05 (Urban Micro) 0.03 (Urban Macro) 0.015 (Rural Macro)
VoIP capacity (user/cell/MHz)	50 (Indoor Hotspot) / 40 (Urban Micro and Urban Macro) / 30 (Rural Macro)	
User plane latency (ms)	10	
Control plane latency (ms)	100	

Key radio access targets for LTE-Advanced as set by 3GPP



Parameter	Downlink	Uplink
Maximum Bandwidth	Up to 100 MHz	
Peak data rate (Mbps)	1000	500
Peak spectral efficiency (bps/Hz)	30	15
Average spectral efficiency (bps/Hz/Cell)	2.6 for 'Case 1'	2 for 'Case 1'
Cell-edge user spectral efficiency (bps/Hz)	0.09 for 'Case 1'	0.07 for 'Case 1'
VoIP capacity (user/cell/MHz)	Exceeding LTE Release 8	
User plane latency (ms)	10	
Control plane latency (ms)	50 (Idle to Active), 10 (Dormant to Active)	

2.9 Backward Compatibility

LTE-Advanced is defined as an evolution of LTE which can also be deployed on new bands.Hence, one of the design targets for LTE-Advanced was backward compatibility between LTE Release 8 and LTE Release 10 and beyond. This is reflected in [3] by requiring that a Release 8 LTE UE can work in a Release 10 LTE-Advanced network, and that an LTE-Advanced UE can work in a Release 8 LTE network.This is an important requirement to give operators confidence to deploy LTE and to build upon it, as it means that LTE operators upgrading their network to LTE-Advanced will be able to do so without swapping their existing UE base; Release 8 LTE UEs will be able to enjoy service continuity in an LTE-Advanced network. Backward compatibility is also of key significance for UE and network complexity, as well as for the cost of implementation and verification, since it enables implementation reuse on both the UE and the network sides, and minimization of interoperability testing.The requirement for backward compatibility does not, in general, prevent the introduction of new features, thereby providing a degree of future-proofness for LTE. New functionality can be configured by the network on a per-UE basis without affecting legacy UEs, for example by scheduling the Physical Downlink Shared CHannel (PDSCH) in a UE-specific way. It is more difficult to introduce new cell-wide features, which have to be compatible with both Release 8 and Release 10 terminals. LTE-Advanced will therefore be visible in the 3GPP specifications simply as ‘LTE Release 10 and beyond’, including the base functionality of Release 8 LTE. This reflects the nature of LTE-Advanced as the further evolution of LTE.

2.9 Deployment Aspects

The existence of internationally identified common frequency bands is a key factor for significant economies of scale in the development and production of terminals.

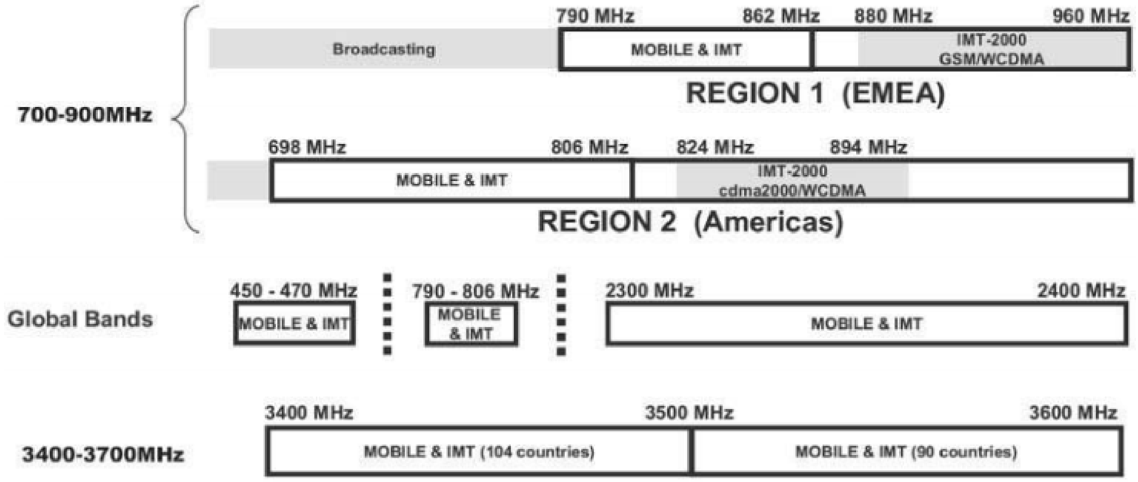
A key outcome of the WRC 2007 was that a total of 136 MHz of new global spectrum was allocated for use by IMT-designated radio technologies:

- 450–470 MHz;
- 790–806 MHz;
- 2300–2400 MHz.

Other region-specific bands were also allocated:

- 790–862 MHz for ITU Region 1 (EMEA5) and ITU Region 3 (all other Asia Pacific);
- 698–806 MHz for ITU Region 2 (North and South America) and ITU Region3 (nine countries, including Japan, China and India);
- 3400–3600 MHz allocated to mobile use on a primary basis for ITU Region1 (EMEA in 82 countries), ITU Region 2 (Americas in 14 countries, except US/Canada) and Region 3.

All new bands identified by the WRC 2007 are valid generically for IMT technologies i.e. they are not specific to IMT-2000 or IMT-Advanced only. The deployment of the frequency bands for the different regions is illustrated in the following Figure.



2.10 LTE-Advanced System Performance

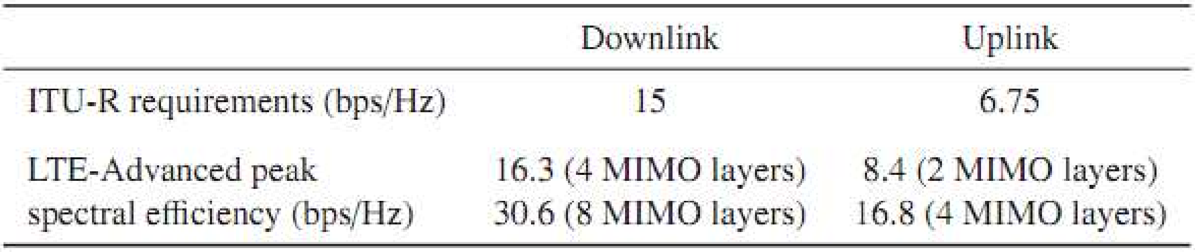
ITU-R specified eight items as the minimum requirements for IMT-Advanced:

1. Peak spectral efficiency;
2. Cell spectral efficiency;
3. Cell-edge user spectral efficiency;
4. Bandwidth;
5. Latency;
6. Mobility;
7. Handover interruption time;
8. VoIP capacity.

Some of the results of the assessment of LTE-Advanced conducted by 3GPP against these criteria are presented below:

The more stringent peak spectral efficiency requirements set by 3GPP for LTE-Advanced can be satisfied using up to 8-layer spatial multiplexing in the downlink and up to 4-layer spatial multiplexing in the uplink, according to the Release 10 specifications for SU-MIMO.

Peak spectral efficiency for LTE-Advanced Release 10:



	Downlink	Uplink
ITU-R requirements (bps/Hz)	15	6.75
LTE-Advanced peak spectral efficiency (bps/Hz)	16.3 (4 MIMO layers) 30.6 (8 MIMO layers)	8.4 (2 MIMO layers) 16.8 (4 MIMO layers)

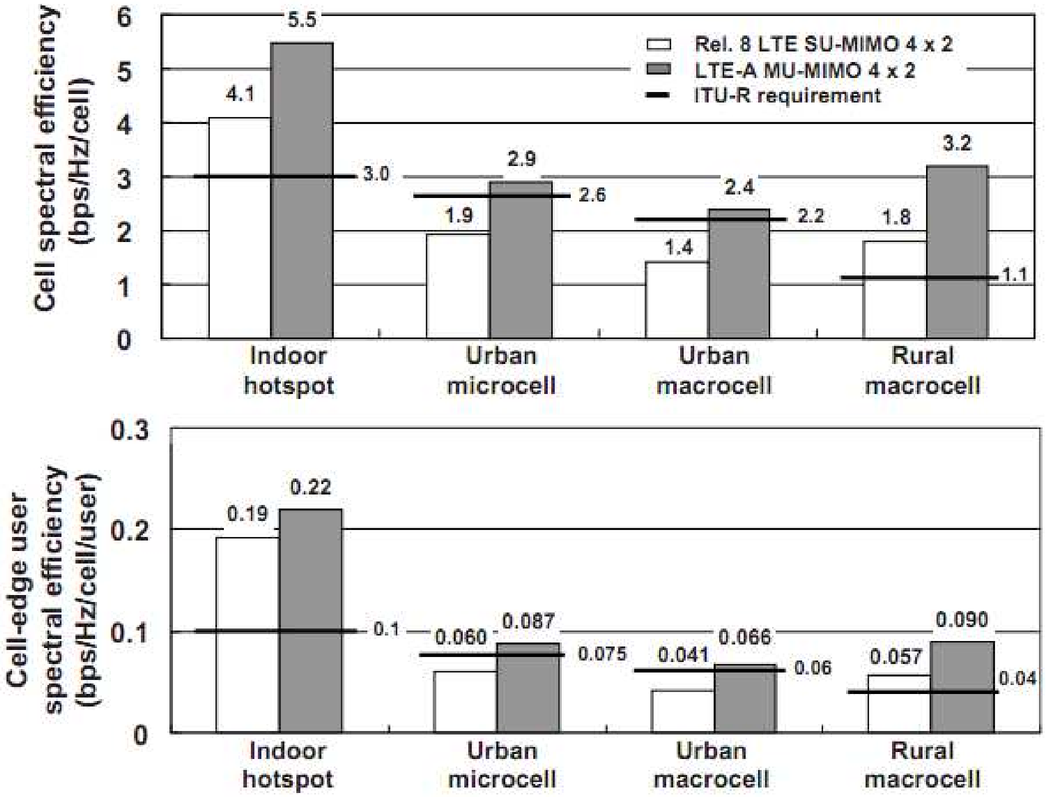


Figure: Downlink performance of LTE-Advanced in ITU-R deployment scenarios.

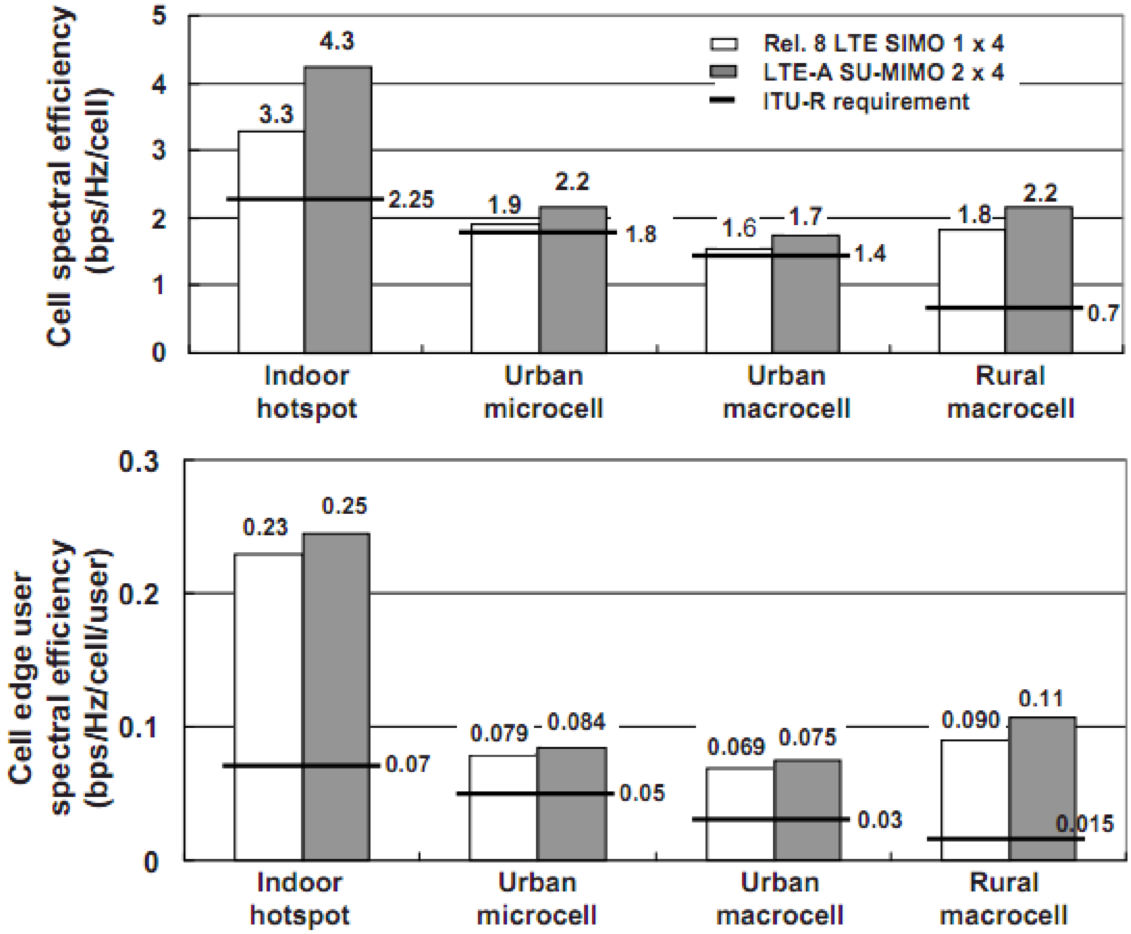


Figure: Uplink performance of LTE-Advanced in ITU-R deployment scenarios.

Future Developments

Compared to previous mobile radio systems such as those based on HSPA, the achievable system performance is greatly improved by LTE Releases 8 and 9 followed by LTE-Advanced. Nevertheless, expectations from the market side continue to increase inexorably.In recent years, unprecedented market trends have been observed: the proliferation of high-specification terminals, especially smartphones, is bringing video delivery/streaming and other innovative applications within the reach of ever more consumers. In the future, mobile

data traffic will grow at a pace that far outstrips that previously experienced. Meanwhile, it is becoming more challenging to achieve revenue growth as a result of the introduction of flat-rate data tariffs by many network operators around the world. Further reduction of the cost per bit will be a necessity in the future more than ever before in the history of mobile communication technology.

From another perspective, ecological concerns are steadily attracting more attention.Mobile communications needs innovative solutions to decrease the power consumed.

A further global concern is the so-called ‘digital divide’ – the regional differences in service availability, for example between rural and urban areas. In the future, comparable mobile services need to be provided for all areas in a cost-effective way.

Following these global trends, the main requirements for future releases of LTE can be broadly identified as follows:

1. Increased capacity and spectral efficiency. It is necessary to improve system capacity in order to support the tremendous growth of data traffic. In particular, further improvement of spectrum utilization efficiency is very important, since the available spectrum bands that are suitable for mobile communications are limited.

2. Improvement of throughput experienced by the user. For video delivery/streaming and new content-rich applications, the throughput actually experienced by the individual user is paramount and needs further improvement, not just the system capacity. In indoor scenarios, non-voice traffic is becoming dominant, and this will become even more obvious in the future. Further optimization of the system specifications for the indoor environment is therefore important.

3. Fairness of throughput provision. HSPA system design is primarily best-effort-based, which results in a throughput gap between cell-centre and cell-edge users. In both LTE and LTE-Advanced, potential solutions to reduce the throughput gap

have been studied. To further improve fairness among users in future systems, improvements of cell-edge performance are required without sacrificing cell-centre performance.Fairness between cells and different geographical regions is also important from the perspective of the digital divide.

4. Reduction of cost per bit. Growth in data traffic is out-pacing growth in revenues.Besides, further network expansion and performance improvement in rural areas are key to addressing the digital divide.

5. Energy saving. Solutions to reduce energy consumption need to be considered at both system and device levels, in order to address both environmental and operational costs.

CHAPTER THREE

3.1 D2D(Device to Device) COMMUNICATION

A communication procedure where UE directly communicates with the peer UE over-the-air.

4G LTE Advanced device to device, D2D communications for high data rate local communications and machine to machine, M2M links.

One of the schemes that is being researched and considered for 4G LTE Advanced is the concept of Device to Device communications.

4G LTE device to device, D2D would enable the direct link of a device, user equipment UE, etc to another device using the cellular spectrum(Cellular spectrum is just the frequency bandwidth used for cellular communication). This could allow large volumes of media or other data to be transferred from one device to another over short distances and using a direct connection.This form of device to device transfer would enable the data to be transferred without the need to run it via the cellular network itself, thereby avoiding problems with overloading the network.

The provision of high data rate local services is likely to emerge as the use of rich multimedia services becomes more commonplace as the use of mobile computers such as tablets, netbooks, and latest generation smartphones increases.

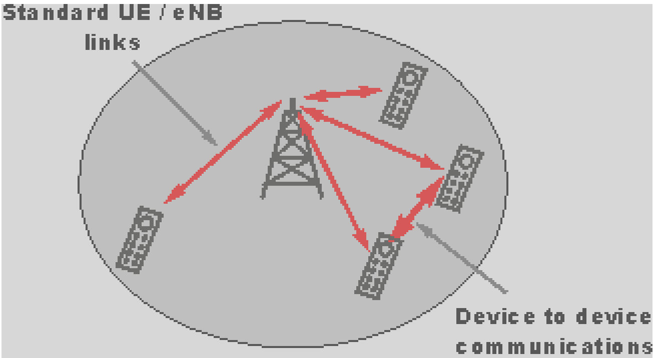
The LTE platform would have the advantage over others such as Wi-Fi and Bluetooth.

There are several advantages to using LTE device to device communications:

- The network can advertise the presence of the LTE device to device connection possibility.

- Devices do not need to scan for available WLANs - this reduces power consumption.

- The LTE network can distribute the security keys in a safe fashion.



LTE device to device, D2D concept

D2D communications is expected to become a key feature to be supported by next generation cellular networks. The advantages are manifold: offloading the cellular system, reduced battery consumption, increased bit-rate, robustness to infrastructure failures and thereby also enabling new services.

3.2 Why D2D is especially helpful in cell edge areas?

- In cell edge areas, both the eNB and the UE need to use high power for transmission of signal. This high power causes high interference to other cells. But D2D communication allows use of very low power overcoming the interference problem greatly.
- In cell edge areas, the link quality between the eNB and the UE is very poor resulting in very low data rate. But D2D communication provides for good signal strength allowing high rate data transfer.
- The data does not need to flow via eNB, the core network, etc. for D2D communication. So, the latency will be much lower.
- There will be great power saving for both the eNB and the UE in the case of D2D communication.
- The resource blocks for D2D communication can be potentially used by other users in the cell. This improves spectral efficiency greatly.

3.3 D2D Session Setup

1. A session is initiated by one of the UE units.

2. The gateway detects IP traffic originating from and destined to UE in the same subnet and to be tunneled within the same serving eNB or between eNBs serving neighboring cells.
3. If the traffic fulfills certain criteria (e.g., data rate), the gateway earmarks the traffic as potential D2D traffic.
4. The eNB(s) request measurement from the UE to check if D2D communication offers higher throughput
5. If both UE units are D2D capable and D2D Communication offers higher throughput, the eNB(s) may set up a D2D bearer.
6. Even if the D2D connection setup is successful, the eNB(s) still maintain the SAE bearer between the UE and the gateway for cellular communications.
7. Furthermore, the eNB maintains the radio resource control for both cellular and D2D communication.
8. The UE will send/receive packets to/from the IP address of the peer UE using the D2D connection without the eNB or SAR being involved in routing.

The decision to establish a D2D connection can be based on a defined policy such as limiting the number of D2D connections to keep the interference to the cellular network below a tolerable level.

CHAPTER FOUR

Resource Block

OFDMA can be used in combination with Time Division Multiple Access (TDMA), such that the resources are partitioned in the time-frequency plane – i.e. groups of subcarriers for a specific time duration. In LTE, such time-frequency blocks are known as Resource. Blocks (RBs), the figure below depicts such an OFDMA/TDMA mixed strategy as used in LTE.

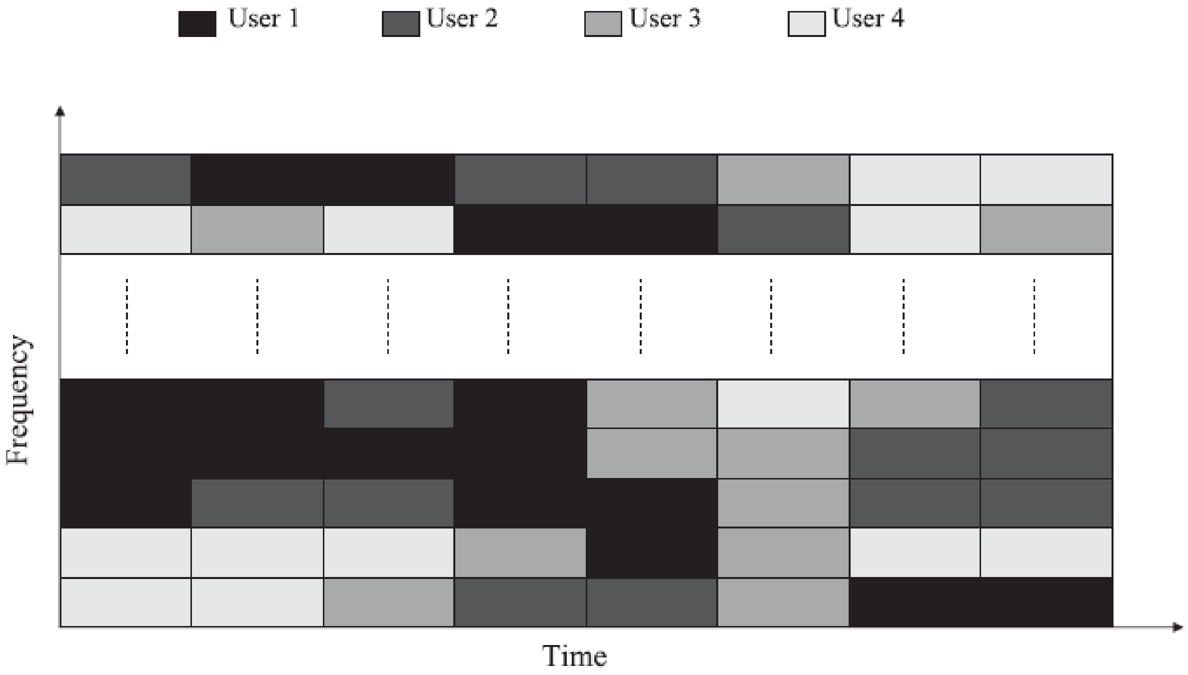


Figure 4.1: Example of resource allocation in a combined OFDMA/TDMA system.

4.1 FRAME

The downlink transmission resources in LTE possess dimensions of time, frequency and space. The spatial dimension, measured in ‘layers’, is accessed by means of multiple ‘antenna ports’ at the eNodeB; for each antenna port a Reference Signal (RS) is provided to enable the User Equipment (UE) to estimate the radio channel ; the techniques for using multiple antenna ports to exploit multiple spatial layers are explained in upcoming part.

The time-frequency resources for each transmit antenna port are subdivided according to the following structure: the largest unit of time is the 10 ms radio frame, which is subdivided into ten 1 ms subframes, each of which is split into two 0.5 ms slots. Each slot comprises seven OFDM symbols in the case of the normal Cyclic Prefix (CP) length, or six if the extended CP is configured in the cell. In the frequency domain, resources are grouped in units of 12 subcarriers (thus occupying a total of 180 kHz with a subcarrier spacing of 15 kHz), such that one unit of 12 subcarriers for a duration of one slot is termed a Resource Block (RB).1
The smallest unit of resource is the Resource Element (RE), which consists of one subcarrier for a duration of one OFDM symbol. An RB thus comprises 84 REs in the case of the normal cyclic prefix length, and 72 REs in the case of the extended cyclic prefix.The detailed resource structure is shown in Figure below for the normal cyclic prefix length.

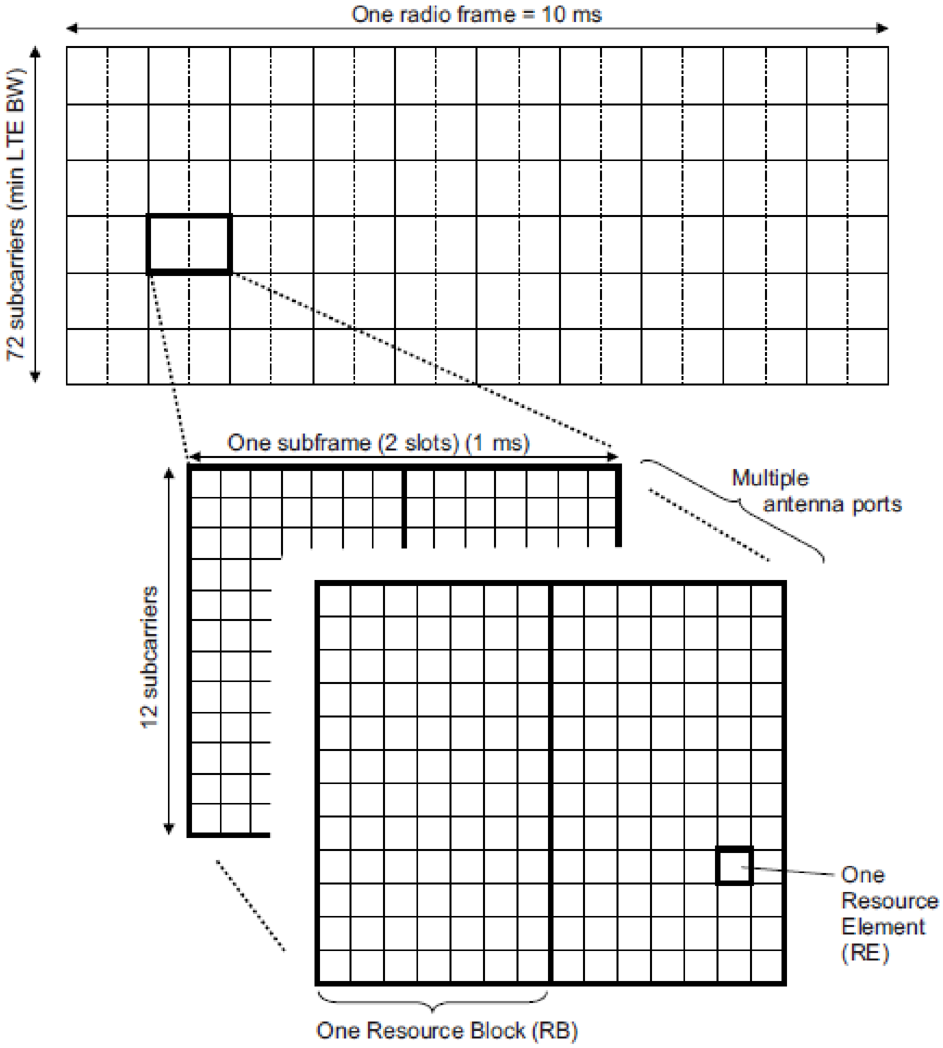


Figure 4.2 : Basic time-frequency resource structure of LTE (normal cyclic prefix case).

Within certain RBs, some REs are reserved for special purposes: synchronization signals, Reference Signals (RSs), control signalling and critical broadcast system information. The remaining REs are used for data transmission, and are usually allocated in pairs of RBs (the pairing being in the time domain).
The structure shown in Figure 4.2 assumes that all subframes are available for downlink transmission. This is known as 'Frame Structure Type 1' and is applicable for Frequency Division Duplexing (FDD) in paired radio spectrum, or for a standalone downlink carrier. For Time Division Duplexing (TDD) in unpaired radio spectrum, the basic structure of RBs and REs remains the same, but only a subset of the subframes are available for downlinktransmission; the remaining subframes are used for uplink transmission, or for special subframes which contain a guard period to allow for switching between downlink and uplink transmission. The guard period allows the uplink transmission timing to be advanced. This TDD structure is known as 'Frame Structure Type 2', of which seven different configurations are defined, as shown in Figure 4.3; these allow a variety of downlink-uplink ratios and switching periodicities.

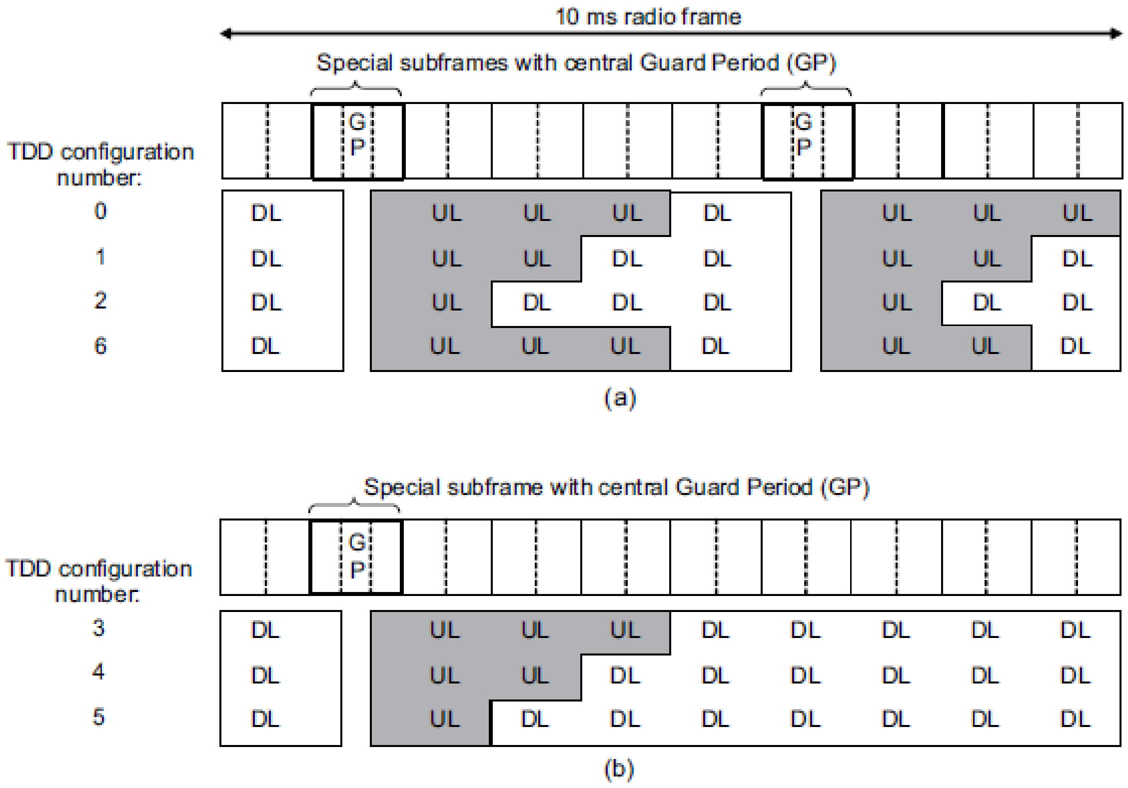


Figure4.3 : LTE sub-frame structure for TDD operation:

(a) configurations with 5 ms periodicity of switching from downlink (DL) to uplink (UL);
(b) configurations with 10 ms periodicity of switching from downlink (DL) to uplink (UL).

In the frequency domain, the mapping of the PSS and SSS to subcarriers is shown in Figure 4.4 The Primary Synchronization Signal (PSS) and the Secondary Synchronization Signal (SSS) are transmitted in the central six Resource Blocks (RBs), enabling the frequency mapping of the synchronization signals to be invariant with respect to the system bandwidth (which can in principle vary from 6 to 110 RBs to suit channel bandwidths between around 1.4 MHz and 20 MHz); this allows the UE to synchronize to the network without any a priori knowledge of the allocated bandwidth. The PSS and SSS are each comprised of a sequence of length 62 symbols, mapped to the central 62 subcarriers around the d.c. subcarrier, which is left unused. This means that the five resource elements at each extremity of each synchronization sequence are not used. This structure enables the UE to detect the PSS and SSS using a size-64 Fast Fourier Transform (FFT) and a lower sampling rate than would have been necessary if all 72 subcarriers were used in the central six resource blocks. The shorter length for the synchronization sequences also avoids the possibility in a TDD system of a high correlation with the uplink demodulation reference signals which use the same kind of sequence as the

PSS.

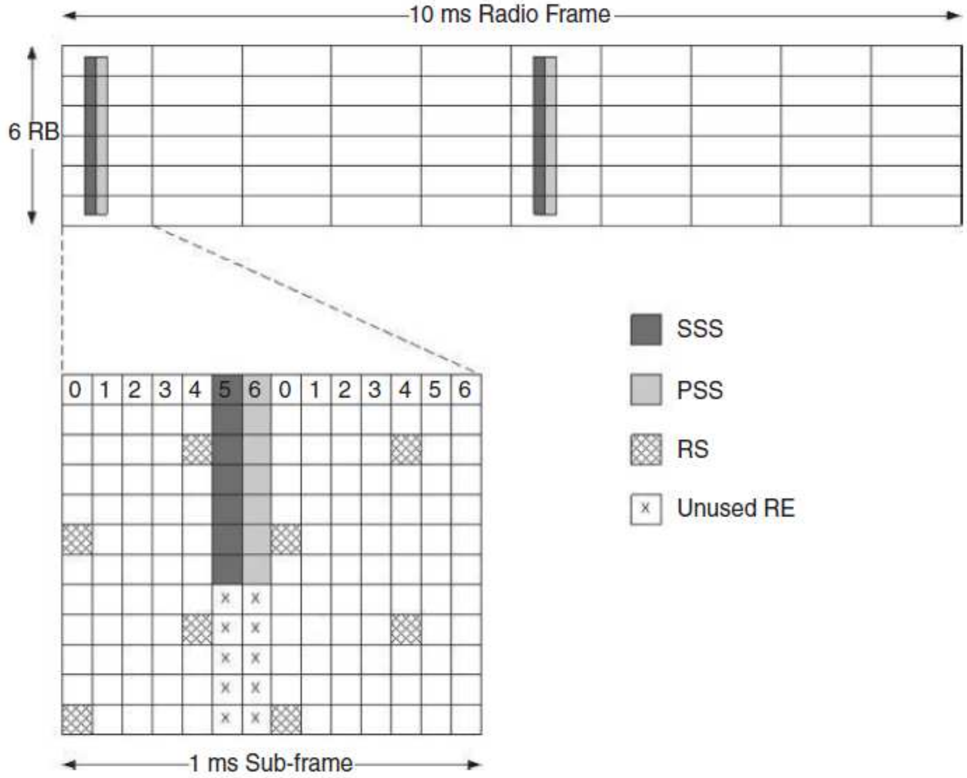


Figure 4.4: PSS and SSS frame structure in frequency and time domain for an FDD cell.

The main uplink physical channels are the PUSCH for data transmission and the PUCCH for control signalling.

The PUSCH supports resource allocation for both frequency-selective scheduling and frequency-diverse transmissions, the latter being by means of intra- and/or inter-subframe frequency hopping. In Release 10, dual-cluster resource allocations on the PUSCH are also supported.

Control signalling (consisting of ACK/NACK, CQI/PMI and RI) is carried by the PUCCH when no PUSCH resources have been allocated. The PUCCH is deliberately mapped to resource blocks near the edge of the system bandwidth, in order to reduce out-of-band emissions caused by data transmissions on the inner RBs, as well as maximizing flexibility for PUSCH scheduling in the central part of the band. The control signalling from multiple UEs is multiplexed via orthogonal coding by using cyclic time shifts and/or time-domain block spreading.

Simple multiple antenna techniques in the uplink were already incorporated in LTE Releases 8 and 9, in particular through the support of closed-loop switched antenna diversity and SDMA. These techniques are cost-effective for a UE implementation, as they do not assume simultaneous transmissions from multiple UE antennas. SU-MIMO is introduced inRelease 10.

4.2 Frame Structures

Ts is the basic time unit for LTE. Time domain fields are typically defined in terms of Ts. Ts is defined as

Ts = 1/(15000 x 2048) seconds or about 32.6 nanoseconds.Downlink and uplink transmissions are organized into frames of duration Tf= 307200 Ts.The 10 ms frames divide into 10 subframes. Each subframe divides into 2 slots of 0.5 ms. In the time domain, a slot is exactly one Resource Block long.

Two frame types are defined for LTE: Type 1, used in Frequency Division Duplexing (FDD) and Type 2, used in Time Division Duplexing (TDD).

Type 1 frames consist of 20 slots with slot duration of 0.5 ms.

Type 2 frames contain two half frames. Depending on the switch period, at least one of the half frames contains a special subframe carrying three fields of switch information: Downlink Pilot Time Slot (DwPTS), Guard Period (GP) and Uplink Pilot Time Slot (UpPTS). If the switch time is 10 ms, the switch information occurs only in subframe one. If the switch time is 5 ms, the switch information occurs in both half frames, first in subframe one, and again in subframe six. Subframes 0 and 5 and DwPTS are always reserved for downlink transmission. UpPTS and the subframe immediately following UpPTS are reserved for uplink transmission. Other subframes can be uplink or downlink.

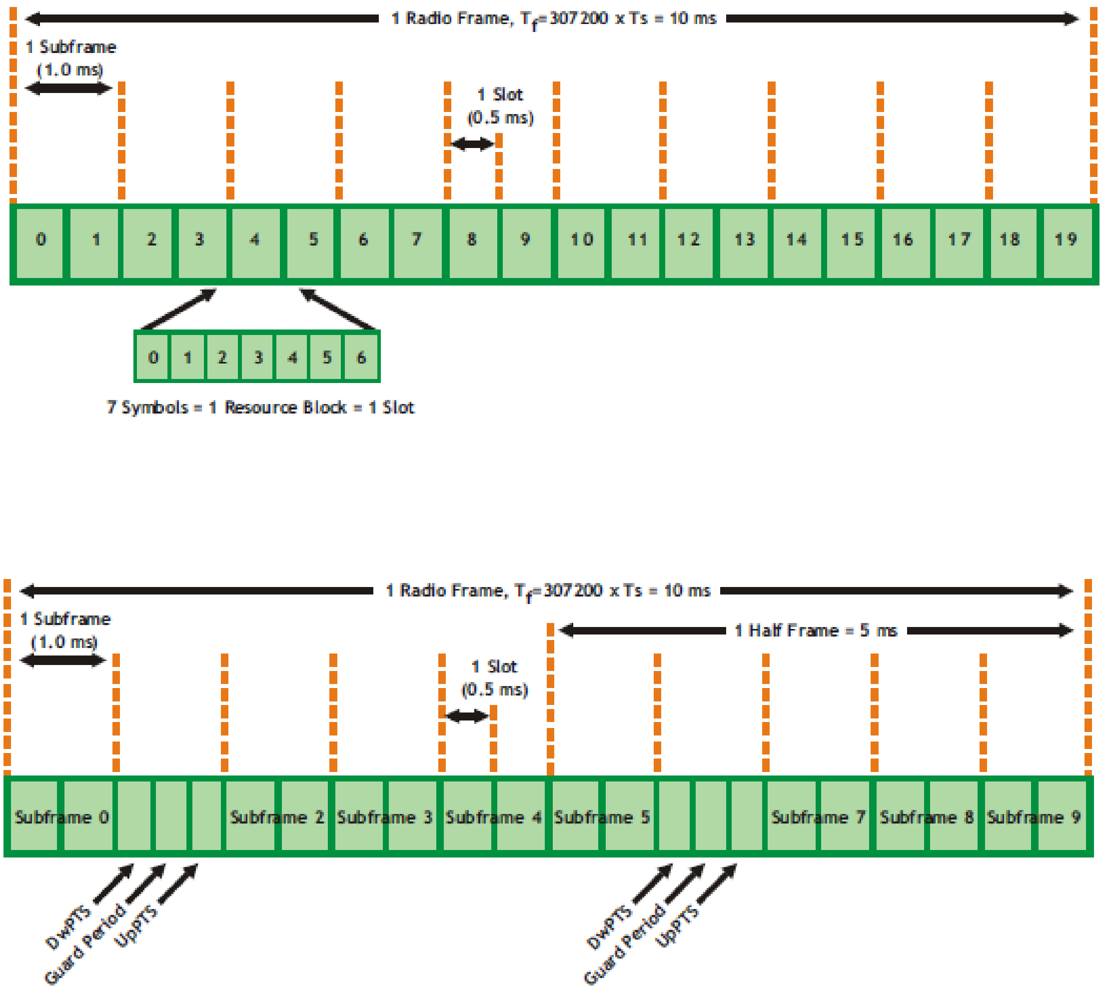


Figure 4.5 : Type 1 Frame Type. Timing and symbol allocations shown for FDD with normal cyclic prefix (CP) and Type 2 frame type. Special fields are shown in Subframes 1 and 6.Guard period separates the Downlink and Uplink. This TDD example represents a 5 ms switch point.A 10 ms switch point would not have the special fields in subframe 6.

4.3 LTE Frame Structure and Bandwidth Concepts

In LTE, ten 1 ms subframes compose a 10 ms frame. Each subframe divides into two slots. The smallest modulation structure in LTE is the Resource Element. A Resource Element is one 15 kHz subcarrier by one symbol. Resource Elements aggregate into Resource Blocks. A Resource Block has dimensions of subcarriers by symbols. Twelve consecutive subcarriers in the frequency domain and six or seven symbols in the time domain form each Resource Block. The number of symbols depends on the Cyclic Prefix (CP) in use. When a normal CP is used, the Resource Block contains seven symbols. When an extended CP is used, the

Resource Block contains six symbols. A delay spread that exceeds the normal CP length indicates the use of extended CP.

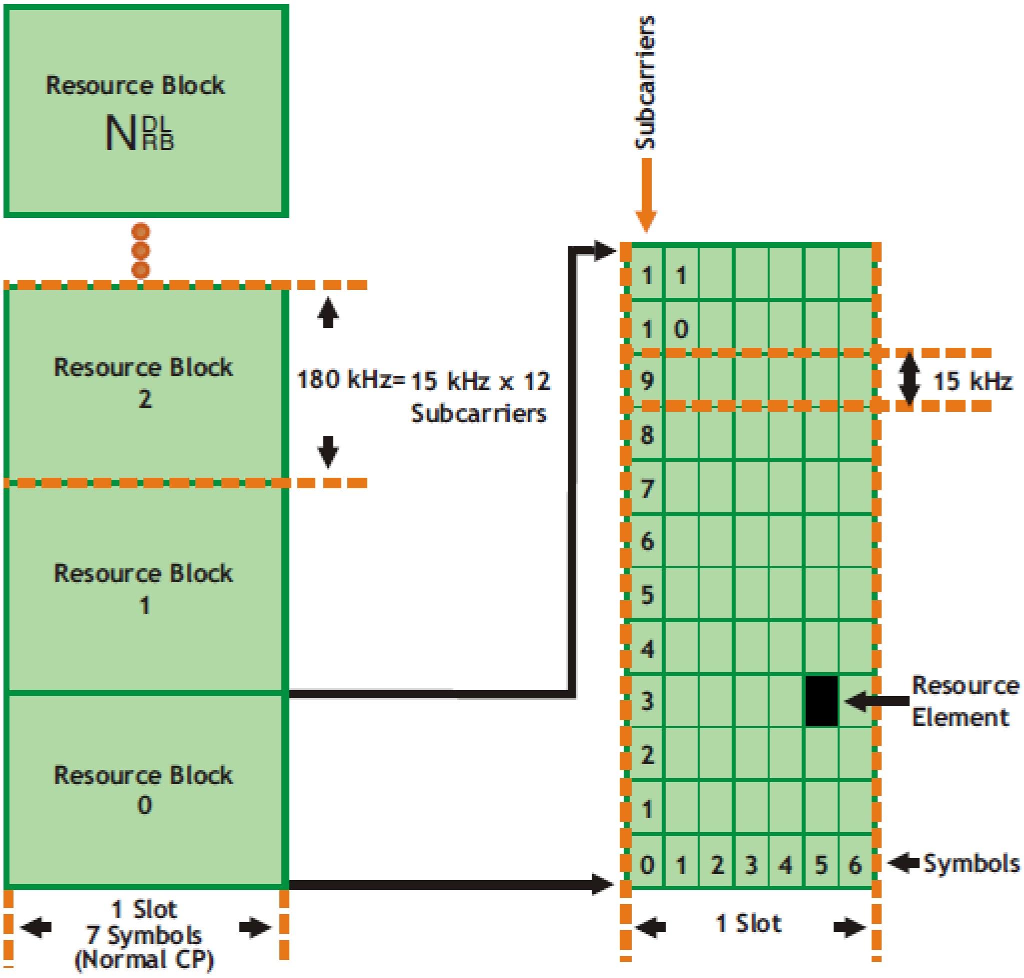


Figure 4.6 : Relationship between a slot, symbols and Resource Blocks

Channel Bandwidth is the width of the channel as measured from the lowest channel edge to the highest channel edge.The channel edge is the center frequency ± (channel bandwidth/2).
Transmission Bandwidth is the number of active Resource Blocks in a transmission. As the bandwidth increases, the number of Resource Blocks increases. The Transmission Bandwidth Configuration is the maximum number of Resource Blocks for the particular Channel Bandwidth. The maximum occupied bandwidth is the number of Resource Blocks multiplied by 180 kHz

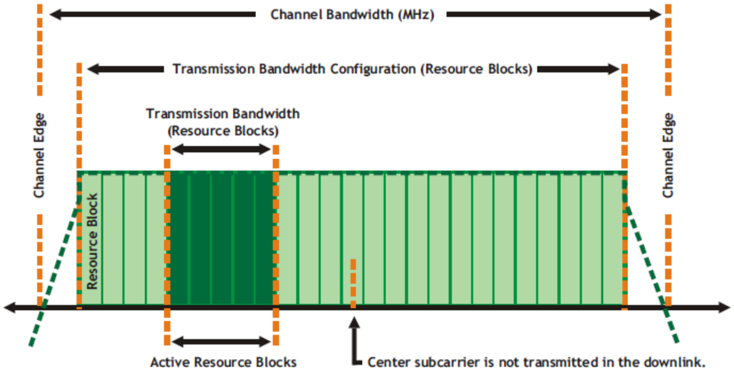
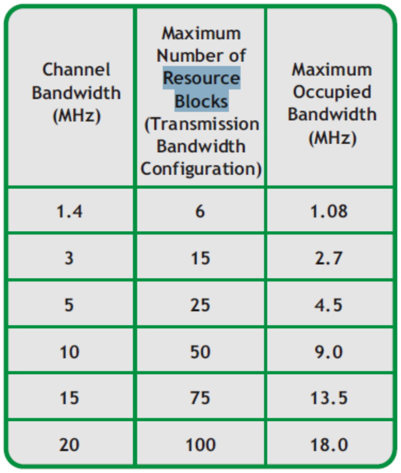


Figure 4.7 : Relationships between Channel Bandwidth, Transmission Bandwidth Configuration, and Transmission Bandwidth



Channel Bandwidth (MHz)	Maximum Number of Resource Blocks (Transmission Bandwidth Configuration)	Maximum Occupied Bandwidth (MHz)
1.4	6	1.08
3	15	2.7
5	25	4.5
10	50	9.0
15	75	13.5
20	100	18.0

Figure4.8 : Transmission Bandwidth Configuration.

4.4 LTE Downlink Channels and Signals

The LTE frame carries physical channels and physical signals. Channels carry information received from higher layers. Signals originate at the physical layer. The framing structure is common to the uplink and downlink, but the physical signals and physical channels are different.

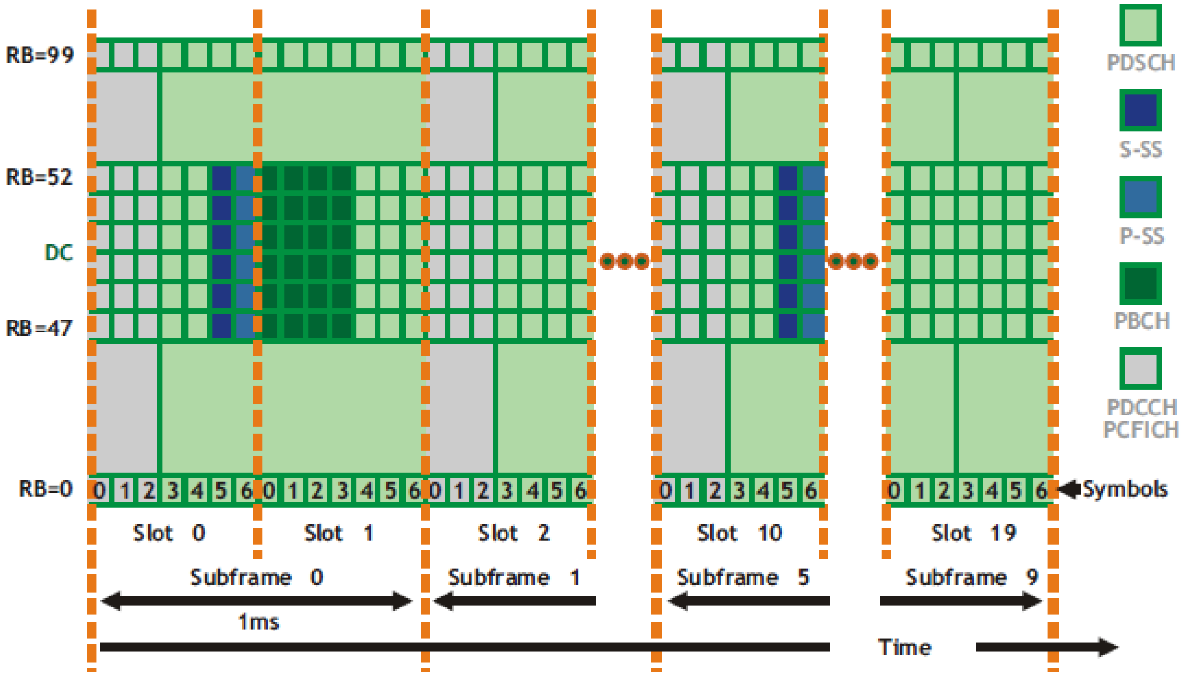
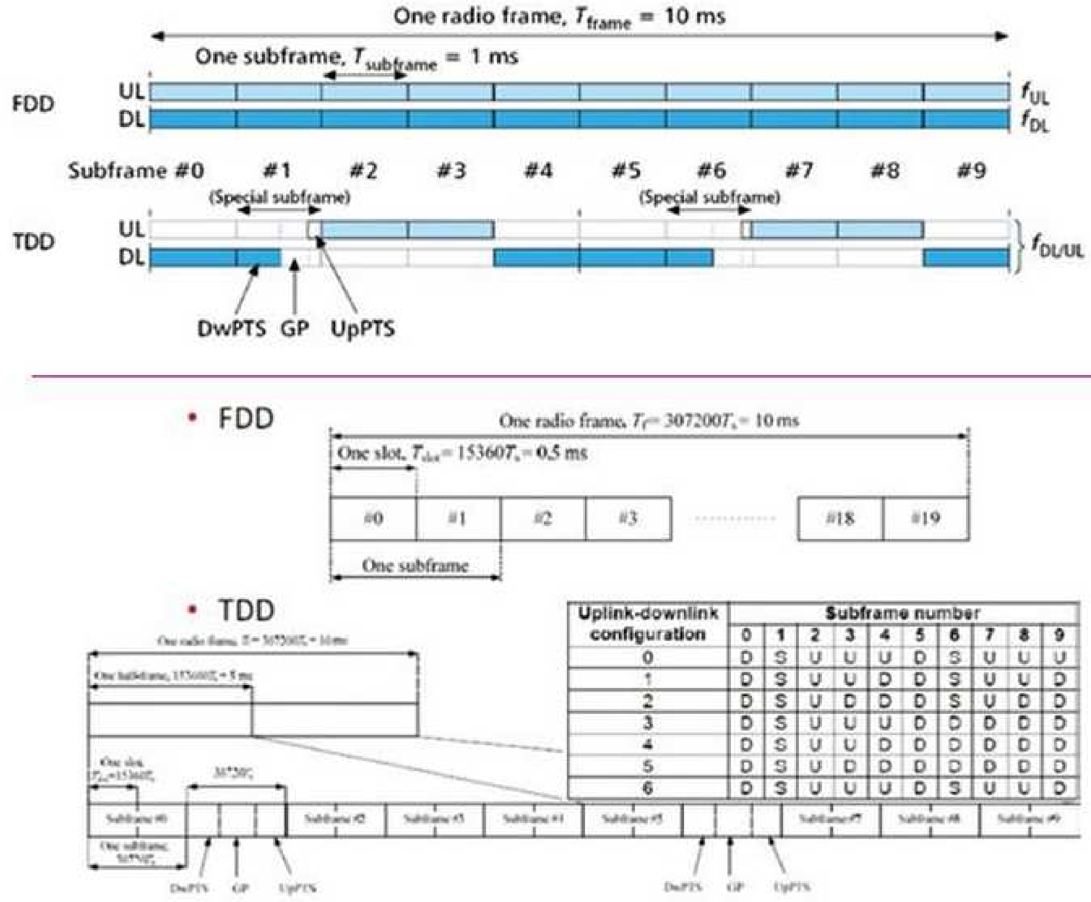


Figure4.9: This diagram of a downlink frame using FDD and normal CP shows the relative location of the various physical channels. Frames in systems using extended CP or TDD would be slightly different

The figure 4.10 shows the frame structure for LTE under Time division mode (TDD) Type 2 and Frequency Division mode (FDD) Type 1.
Main differences between the two modes are

- Frame 0 and frame 5 (always downlink in TDD)
- Frame 1 and frame 6 is always used as for synchronization in TDD
- Frame allocation for Uplink and Downlink is settable in TDD

The sampling rate in both FDD and TDD is the same and both technologies operate under a 1-ms sub-frame (TTI TransmissionTime Interval) and 0.5us timeslot definition.
The first 3 configurations (0-2) for TDD can also be viewed as 5ms allocation due to repetition. The figure below shows a detailed relationship between rates and frame structure.

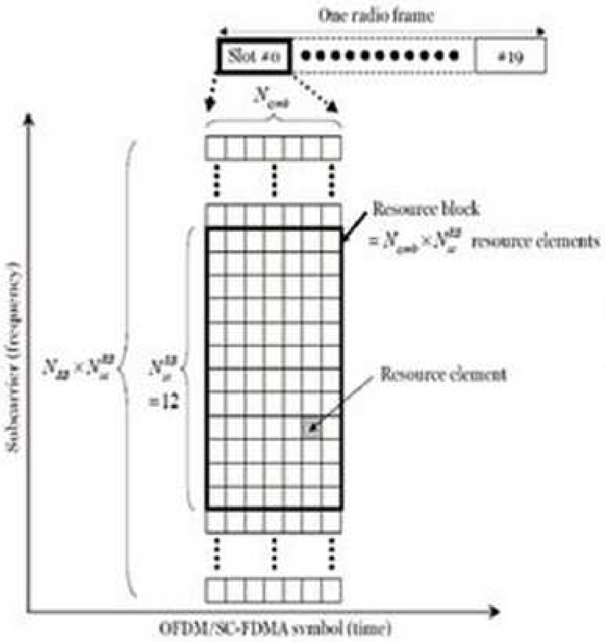


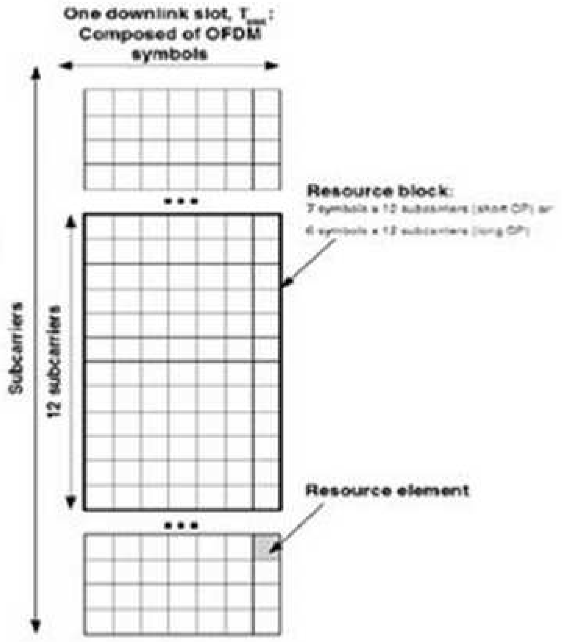
Uplink-downlink configuration	Subframe number									
	0	1	2	3	4	5	6	7	8	9
0	D	S	U	U	U	D	S	U	U	U
1	D	S	U	U	D	D	S	U	U	D
2	D	S	U	D	D	D	S	U	D	D
3	D	S	U	U	U	D	D	D	D	D
4	D	S	U	U	D	D	D	D	D	D
5	D	S	U	D	D	D	D	D	D	D
6	D	S	U	U	U	D	S	U	U	D

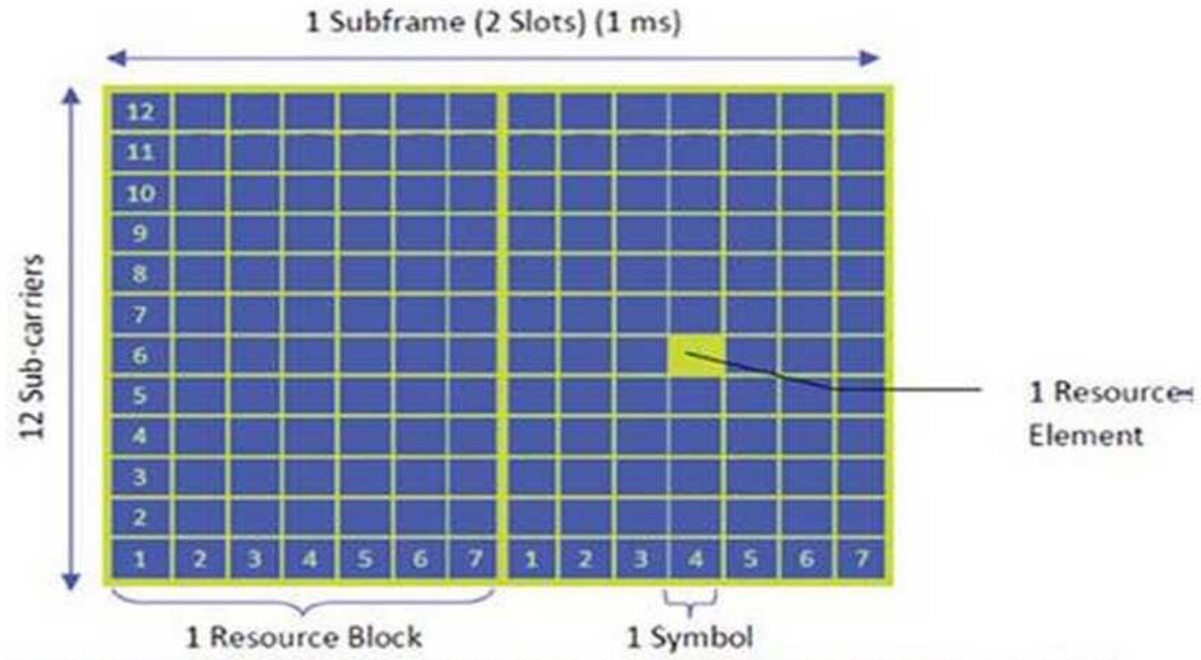
Figure 4.10: LTE under Time division mode (TDD) Type 2 and Frequency Division mode (FDD) Type 1.

- One frame is 10ms and it consists of 10 sub-frames
- One subframe is 1ms and contains 2 slots
- One slot is 0.5ms in time domain and each 0.5ms assignment can contain N resource blocks [6 < N < 110] depending on the bandwidthallocation and resource availability.
- One resource block is 0.5ms and contains 12 subcarriers for each OFDM symbol in frequency domain.
- There are 7 symbols (normal cyclic prefix) per time slot in the time domain or 6 symbols in long cyclic prefix.

Resource element is the smallest unit of resource assignment and its relationship to resource block is shown as below from both a timing and frequency perspectiv

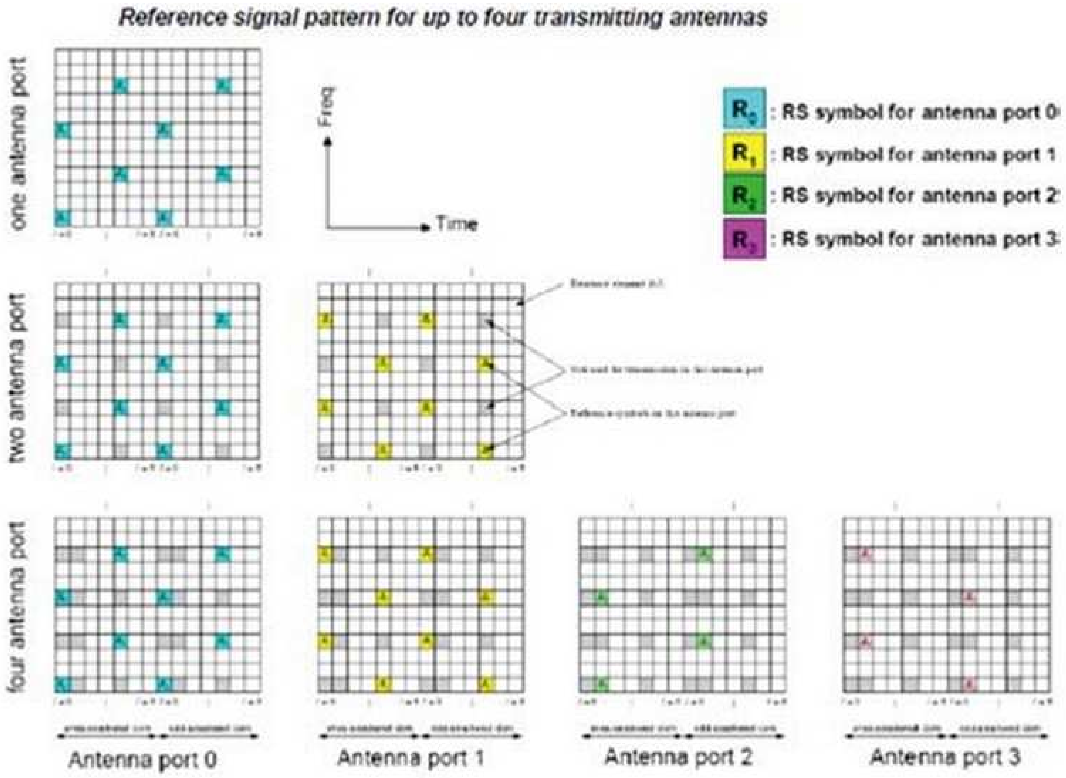






4.5 Reference Signal Structure

Reference signal is the “UMTS Pilot” equivalent and it is used by UE to predict the likely coverage condition on offer for each of the eNodeB cell received. The figure below shows the locations of the reference signal within each sub-frame when transmit antennae are used by the cell.



As LTE is a MIMO based technology, it can have more than two transmit antennae and in order to avoid reference signals from the same cell interfering with each other, different antennae will be transmitting reference signal at different time and frequency and how these are allocated are shown below.

As defined in the standard for TDD operations, the channel-sounding mechanism involves the UE’s transmitting a deterministic signal that can be used by the eNodeB to estimate the UL channel from the UE.

If the UL and DL channels are properly calibrated, the eNodeB can then use the UL channel as an estimate of the DL channel, due to channel reciprocity.

CHAPTER FIVE

HANDOVER:

Handover means to pass UE from one eNodeB to another eNodeB.

5.1 Procedure :

1. Measurements and Reporting
2. Handover Request
3. Handover Request Acknowledgement

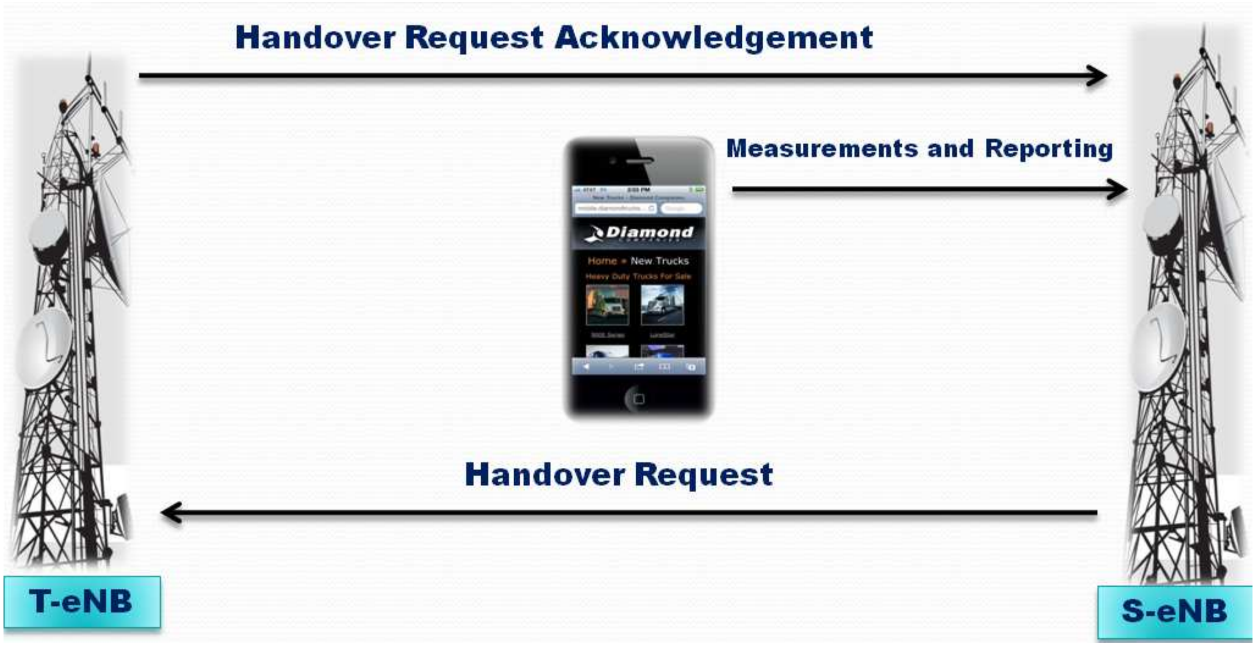


Figure5.1: Fundamental HANDOVER Procedure

The Third Generation Partnership Program (3GPP) has defined Long Term Evolution (LTE) as part of the 3GPP Release 8 specifications. LTE introduces the possibility of complementing High-Speed Packet Access (HSPA) networks with higher peak data rates, greater flexibility for heterogeneous networks and flatter network architecture.

One of the main goals of LTE, or any wireless system for that matter, is to provide fast and seamless handover from one cell (a source cell) to another (a target cell).

This is especially true for LTE system because of the distributed nature of the LTE radio access network architecture which consists of just one type of node, the base station, known in LTE as the eNodeB (eNB).

The impact of the LTE handover procedures on the overall user experience depends very much upon the type of application that is being used. For example, a short interruption in service during a long FTP session (e.g. large file download) may be tolerable, while an interruption in a VoIP call or a streaming video session or short FTP session (e.g. image download) or a latency sensitive gaming application may not. While the LTE handover procedures defined in Release 8 provide mobility support, they may not be suitable for all scenarios and could result in unsatisfactory user experience even when compared to legacy 2G and 3G systems.

This paper discusses the LTE handover procedures that are standardized in 3GPP Release 8 and describes a new LTE handover procedure called Forward handover which improves the overall handover performance in LTE systems. Forward handover is successful even if the radio conditions are not good enough for the message exchanges between the UE and network in the current Release 8 framework, and hence allows for a more robust mechanism. Some aspects of forward handover have already been standardized in 3GPP Release 9.

5.2 Handover Procedures

Mobility support for User Equipment (UE) in connected-state comprises of two types of handover procedures:

1.Backward handover

2.Radio Link Failure (RLF) handover (e.g., triggered by RLF, backward handover failure, RLC unrecoverable error, or reconfiguration compliance failure)

Both of these handover procedures require the source eNB to *prepare* a target cell for handover concurrently with the handover decision (i.e., the UE’s context must be available and resources must be reserved at the target cell when the UE accesses the target cell); otherwise, the UE transitions to idle-state where it attempts to complete the handover procedure by transitioning back to connected-state via a procedure called Non-Access Stratum (NAS) recovery. The target cell may belong to either the source eNB (intra-eNB handover) or a target eNB (inter-eNB handover).

Handovers in LTE are ‘hard’ handovers, meaning that there is a short interruption in service when the handover is performed. This is true for both intra-eNB and inter-eNB handovers. In addition, during inter-eNB handovers (with the exception of the NAS recovery procedure), the UE's control plane and user plane context are transferred from the source eNB to the target eNB. Also, in order to minimize packet loss and provide in-order delivery, the source eNB forwards the UE's downlink (and optionally uplink) user plane data to the target eNB. Data forwarding and in-order delivery are extremely important for TCP-based applications in order to:

(1) achieve high TCP throughput performance; and

(2) conserve valuable backhaul and core network resources by eliminating packet losses during handover which would otherwise trigger a TCP retransmission.

5.2.1 Backward Handover

Figure 5.2 illustrates the backward handover procedure. Backward handover can be described as network-controlled/UE-assisted mobility. Handover related information is exchanged between the UE and the source eNB via the *old* radio path (thus, the usage of the term 'backward'). Specifically, the radio conditions need to be good enough for the source eNB to be able to decode the Measurement Report from the UE and subsequently prepare the target cell for handover. The radio conditions also need to be good enough for the UE to be able to decode the Handover Command from the source eNB.

There is a short interruption in service between the time that the UE decodes the Handover Command from the source eNB and the time that the target eNB decodes the Handover Confirm from the UE. However, data forwarding and in-order delivery ensures that none of the data buffered in the source eNB is lost.

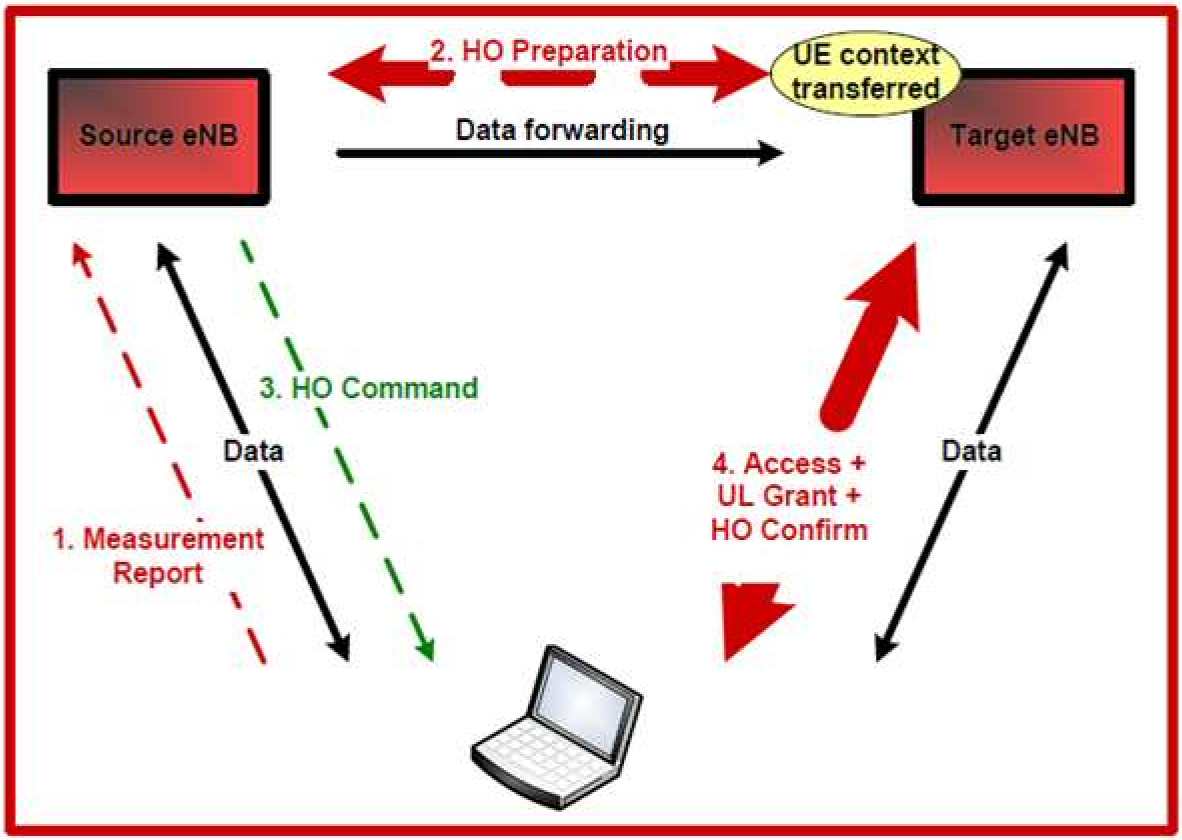


Figure 5.2 - LTE Backward Handover Procedure

5.2.2 RLF Handover

Figure 5.3 illustrates the RLF handover procedure, also known as the RRC Connection Reestablishment procedure in the 3GPP Release 8 specifications. RLF handover is UE-based mobility and provides a recovery mechanism when the backward handover signaling with the source cell *partially* fails due to poor radio conditions. Specifically, the radio conditions are good enough for the source eNB to be able to decode the Measurement Report from the UE and subsequently prepare the target cell for handover, but not good enough for the UE to be able to decode the Handover Command from the source eNB1.

When the UE detects radio link problems, it starts the RLF timer, a typical setting for which is 500 ms or 1000 ms. The RLF timer is carefully fine tuned by the service provider based upon extensive drive tests within the network. Upon expiration of the RLF timer, the UE searches for a suitable target cell and attempts to re-establish its connection with the target cell while remaining in connected-state. The re-establishment is successful if the target cell has been *prepared* by the source eNB (i.e. if the source eNB received the Measurement Report from the UE). The RLF handover procedure incurs additional delay versus the backward handover procedure and, consequently, a longer interruption in service. However, data forwarding and in-order delivery ensures that none of the data buffered in the source eNB is lost.

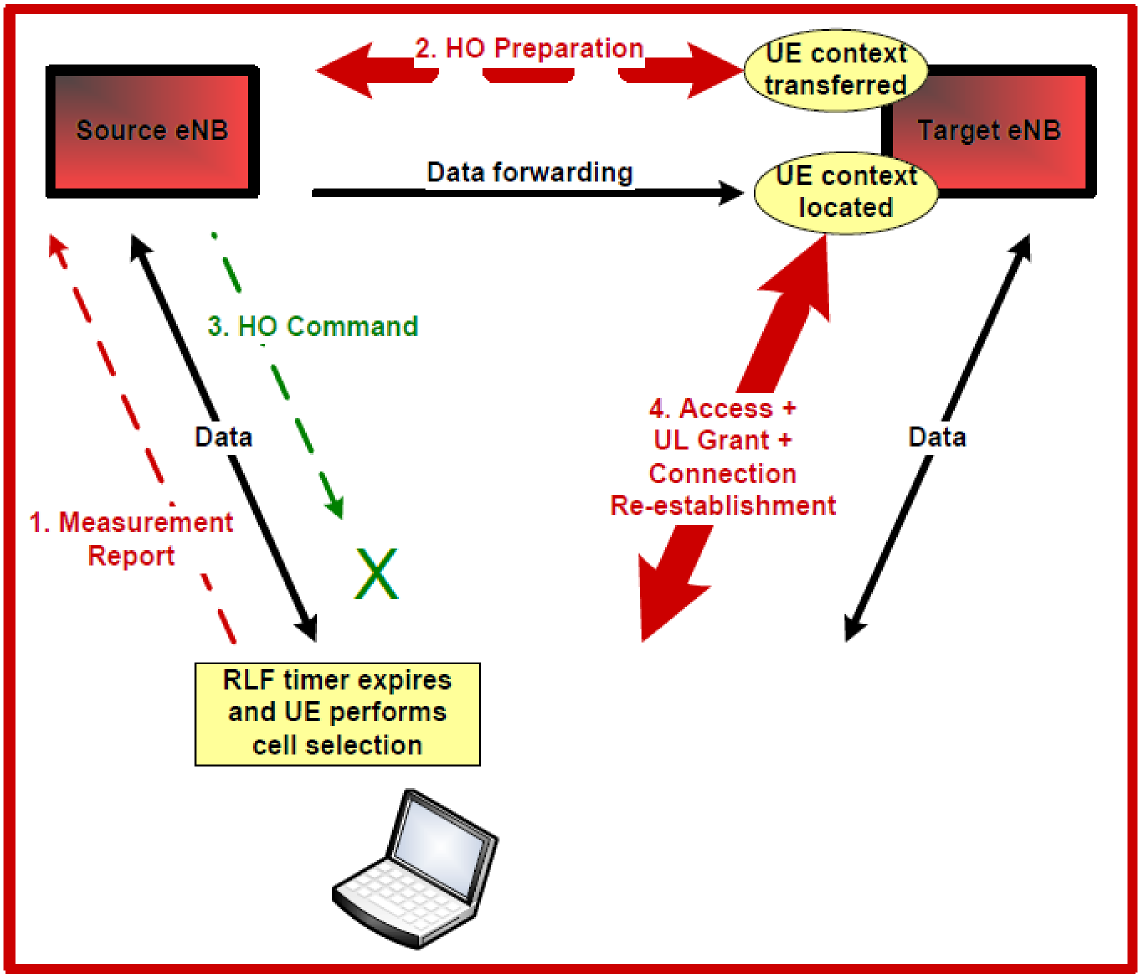


Figure 5.3 - LTE RLF Handover Procedure

5.3 NAS Recovery

Figure 3 illustrates the NAS recovery procedure. NAS recovery can be described as UE-based mobility and is triggered if the target eNB is not prepared when the UE attempts re-establishment. Specifically, the radio conditions are not good enough for the source eNB to be able to decode the Measurement Report from the UE. Consequently, the source eNB does not prepare the target cell for handover. With NAS recovery, the UE does not remain in connected-state; instead, upon re-establishment failure, the UE transitions from connected-state to idle-state and attempts to establish a new connection.

The transition to idle state incurs additional delay versus the RLF handover procedure and, consequently, an even longer interruption in service. To make matters worse, data forwarding and in-order delivery cannot be performed; therefore, all of the data buffered in the source eNB is lost. This will consume valuable backhaul and core network resources by triggering TCP retransmissions which will negatively impact TCP throughput performance. Also, TCP timeouts are very likely to occur.

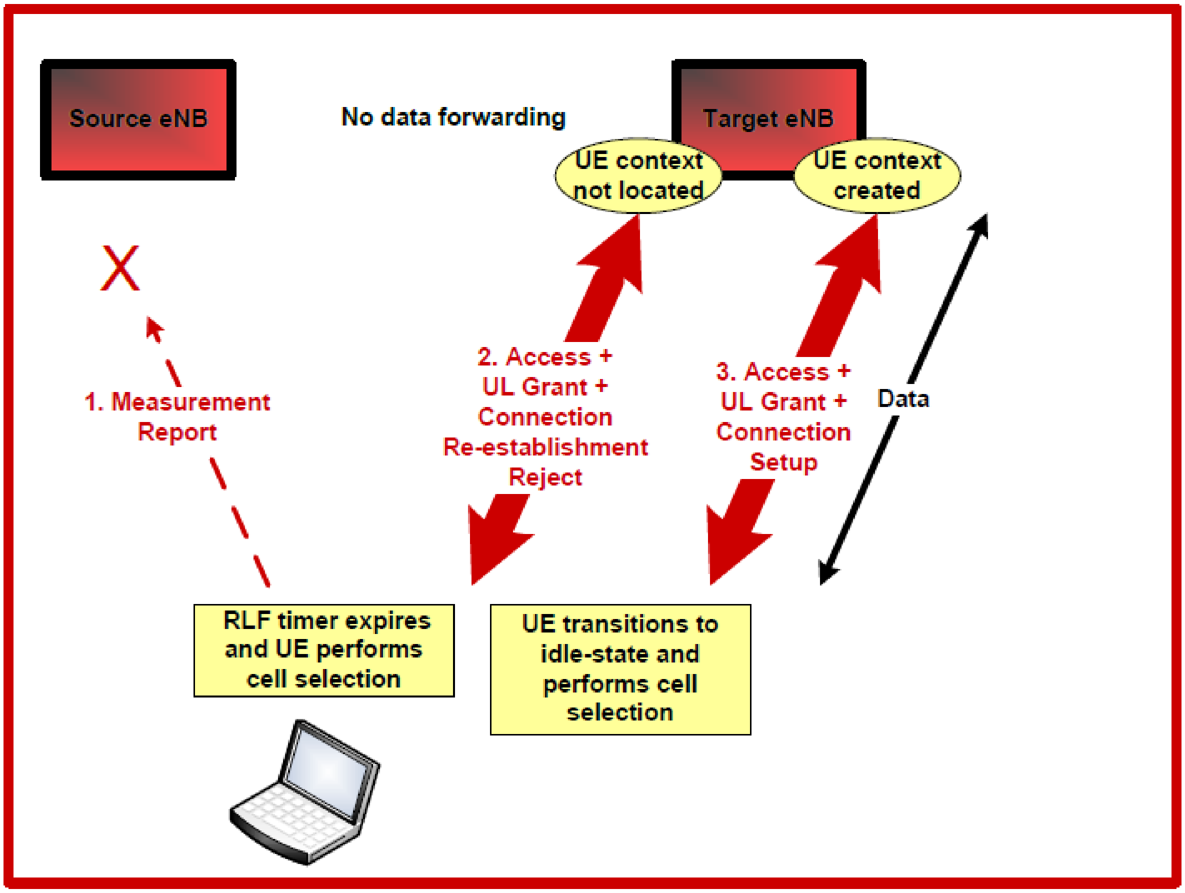


Figure 5.4 - LTE NAS Recovery Procedure

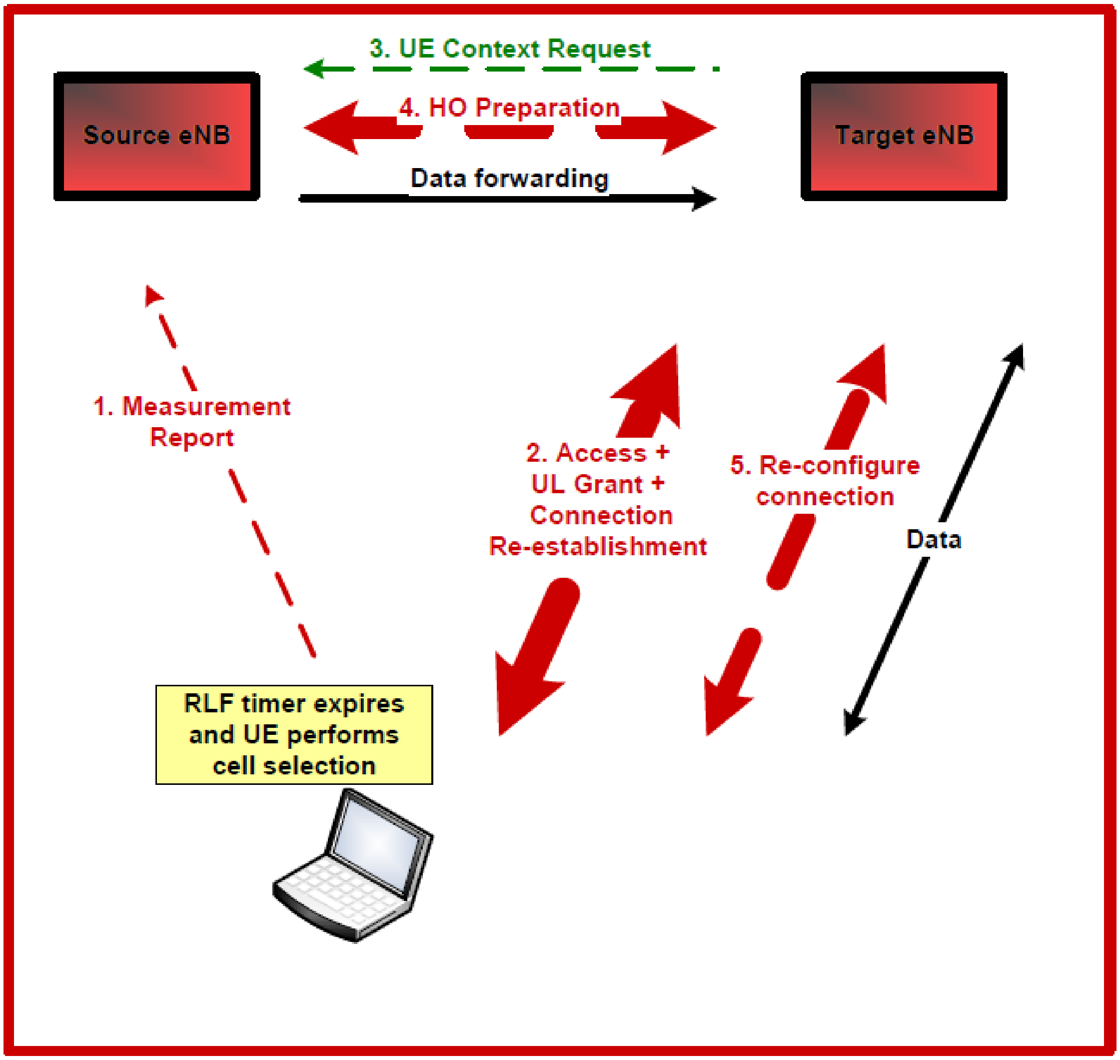
5.4 LTE Forward Handover

Figure 4 illustrates the forward handover procedure. Forward handover can be described as UE-based mobility. Handover related information is exchanged between the UE and target eNB via the *new* radio path after the UE context is fetched by the target eNB from the source eNB (thus, the usage of the term 'forward'). Forward handover is successful even if the radio conditions are not good enough for the source eNB to be able to decode the Measurement Report from the UE and prepare the target cell. The success of the handover procedure even with complete failure of signaling with the source eNB makes forward handover robust to rapidly changing signal strength conditions.

As is the case with the other types of handover procedures, when the UE detects radio link problems, it starts the RLF timer. However, unlike the RLF handover and NAS recovery procedures, the service provider can set the RLF timer value more aggressively (e.g., 50 ms versus 500 ms or 1000 ms) because the cost of RLF is reduced (i.e., the target cell can be *prepared* after the UE attempts to re-establish its connection with the target cell). Further, the RLF timer value does not have to be carefully optimized by the service provider using extensive drive tests. Upon expiration of the RLF timer, the UE searches for a suitable target cell and attempts to re-establish its connection with the target cell while remaining in connected-state. If the target cell is not prepared, the target eNB fetches the UE's context from the source eNB. This will still incur an additional delay versus the backward handover procedure and, consequently, a longer interruption in service. However, when compared to both the RLF handover and NAS recovery procedures, the forward handover procedure will result in a shorter interruption in service due to the ability to set a more aggressiveRLF timer value. In addition, data forwarding and in-order delivery ensure that none of the data buffered in the source eNB is lost (unlike the NAS recovery procedure).

From the UE's perspective, forward handover requires no changes to the 3GPP Release 8 specifications.

Mobility using forward handover is also robust and cost attractive in an evolving network topology, wherein new nodes can be added on an ad-hoc basis in hot-spots without the need for extensive drive tests to recompute optimal RLF timers.



In summary, forward handover offers the following advantages:
1. Forward handover is successful even if the radio conditions are not good enough for the source eNB to be able to decode the Measurement Report from the UE and prepare the target cell.

2. When compared to both the RLF handover and NAS recovery procedures, the forward handover procedure will result in a shorter interruption in service due to the ability to set a more aggressive RLF timer value. This also reduces the number of drive tests needed when deploying base stations and optimizing the network.

3. New nodes can be added on an ad-hoc basis in hot-spots without the need for extensive drive tests to recompute optimal RLF timers

CHAPTER SIX

Proposed Idea

- The idea is applicable to cell edge D2D users.

- When the serving eNB receives Measurement Report from the UE about serving and neighboring cells, it can recognize
  - the D2D users is at cell edge
  - which eNBs are close to the D2D users(high neighbor cell signal strength)

- Sub-carriers used by cell edge D2D users in a cell will be notified to eNBs close to the D2D users using a Layer 3 message (LOAD INFORMATION message)

- For cell edge users, after receiving notifications on Layer 3 message, the adjacent interfering cell will restrict the same sub-carriers to be used only by D2D users and not by cellular users.

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- For cell edge users, after receiving notifications on Layer 3 message, the adjacent interfering cell will restrict the same sub-carriers to be used only by D2D users and not by cellular users.

- The same neighboring eNBs are potential for any imminent handover. The notification on LOAD INFORMATION message can optionally include the S-TMSI (UE ID) of the UEs in order to prepare the eNBs for potential handover.

- The handover is proposed to be forward handover. This can take place as follows:

-When any of the D2D UEs find one of the notified eNB with better signal quality, the UE performs random access and attempts for RRC connection set up. The RRC Connection Request message contains S-TMSI which will enable the target eNB to identify the UE. The target eNB will then allow access. The UE simply sends Handover indication to the previous eNB and starts communication at the new enB.

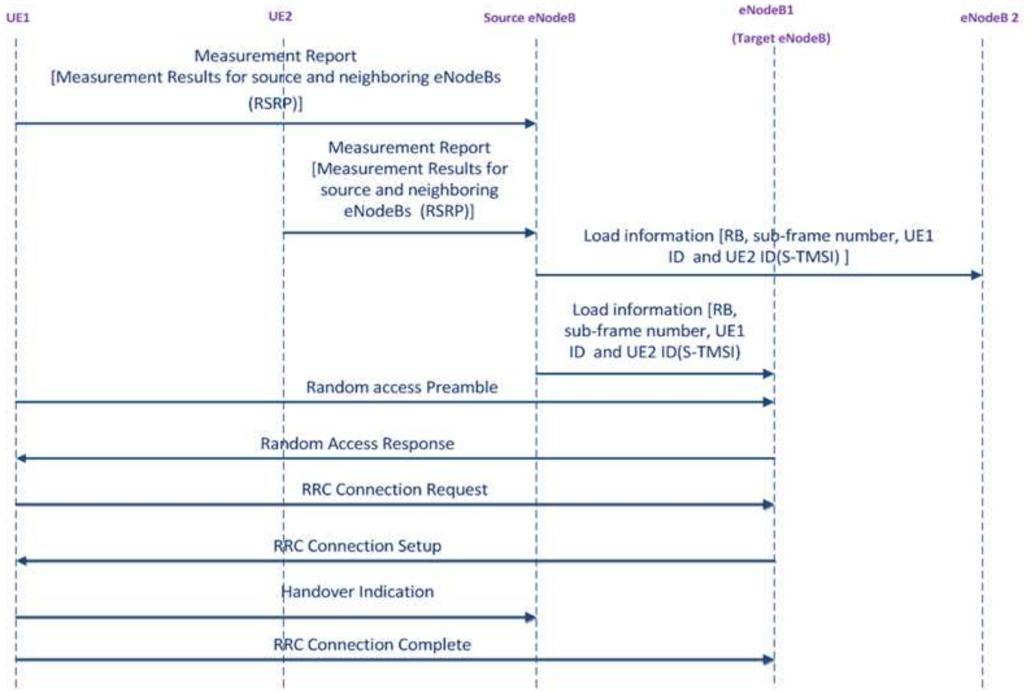


Figure 6.1 : Proposed Handover Procedure

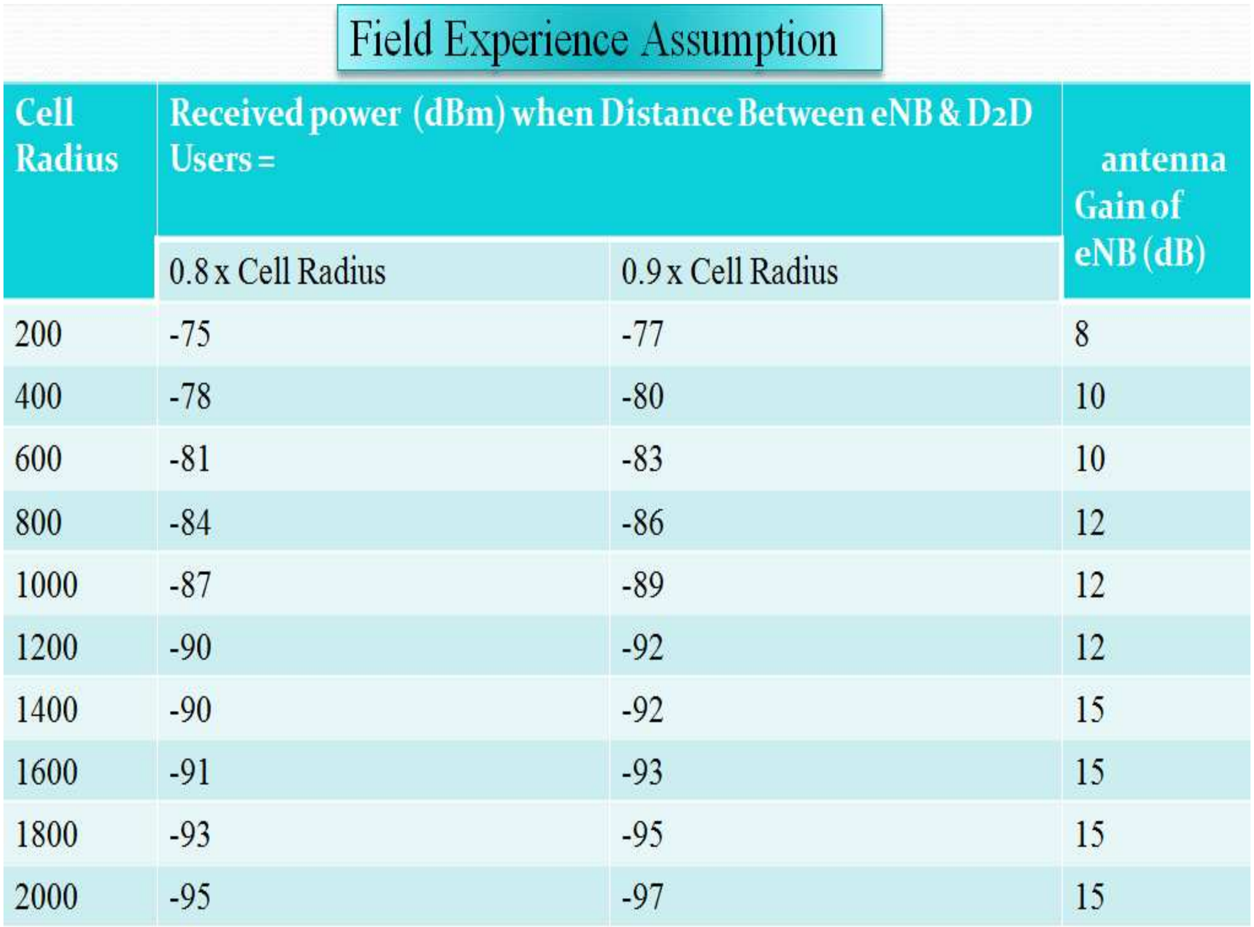
CHAPTER SEVEN

7.1 Simulation parameters

Simulations were done in two cases;

1. Cell edge distance = 0.8 x Cell Radius
2. Cell edge distance = 0.9 x Cell Radius

- The Cell Radius is varied between 200 and 2000 meters.
- The distance between D2D users are varied from 10 to 50 meters.
- Used BW: 2 groups of subcarriers = 2x 180 kHz = 360 kHz
- Operating frequency =750 MHz
- Path loss Model :Okumura Hata



Field Experience Assumption

Cell Radius	Received power (dBm) when Distance Between eNB & D2D Users =		antenna Gain of eNB (dB)
	0.8 x Cell Radius	0.9 x Cell Radius	
200	-75	-77	8
400	-78	-80	10
600	-81	-83	10
800	-84	-86	12
1000	-87	-89	12
1200	-90	-92	12
1400	-90	-92	15
1600	-91	-93	15
1800	-93	-95	15
2000	-95	-97	15

7.2 Simulation

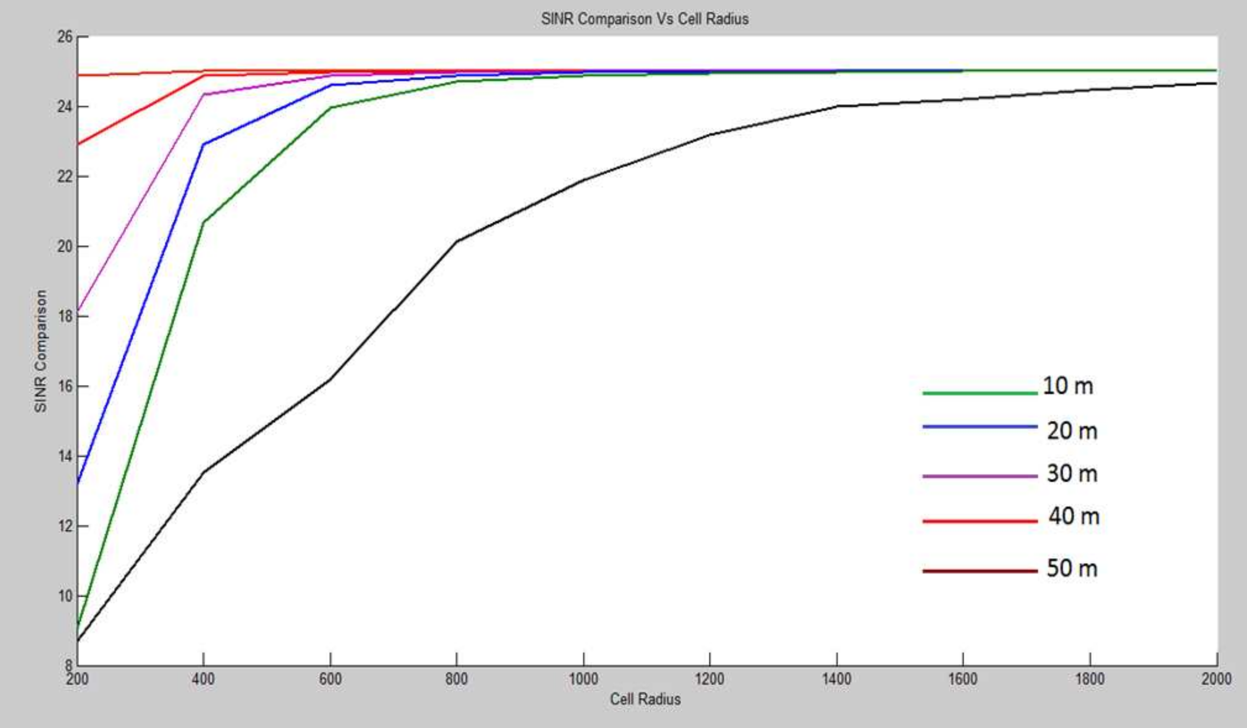


Figure7.1 : SINR Comparison Vs cell Radius For Cell edge distance = 0.8 x Cell Radius

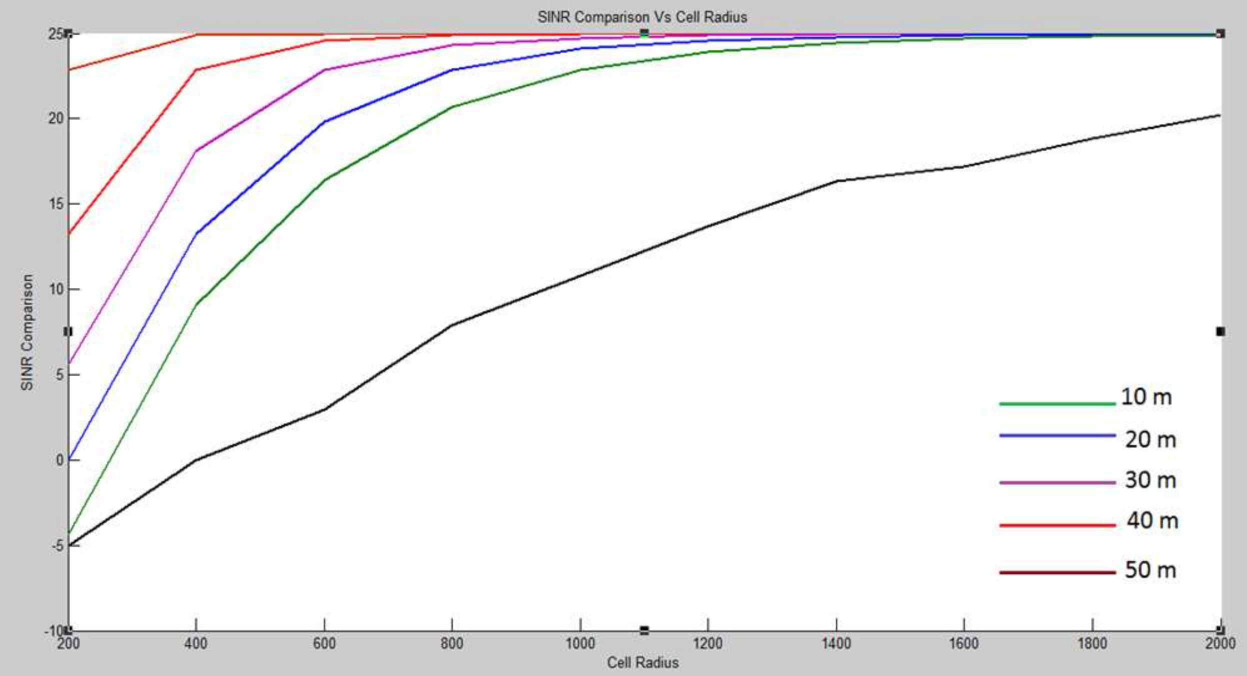


Figure 7.2 : SINR Comparison Vs cell Radius For Cell edge distance = 0.9 x Cell Radius

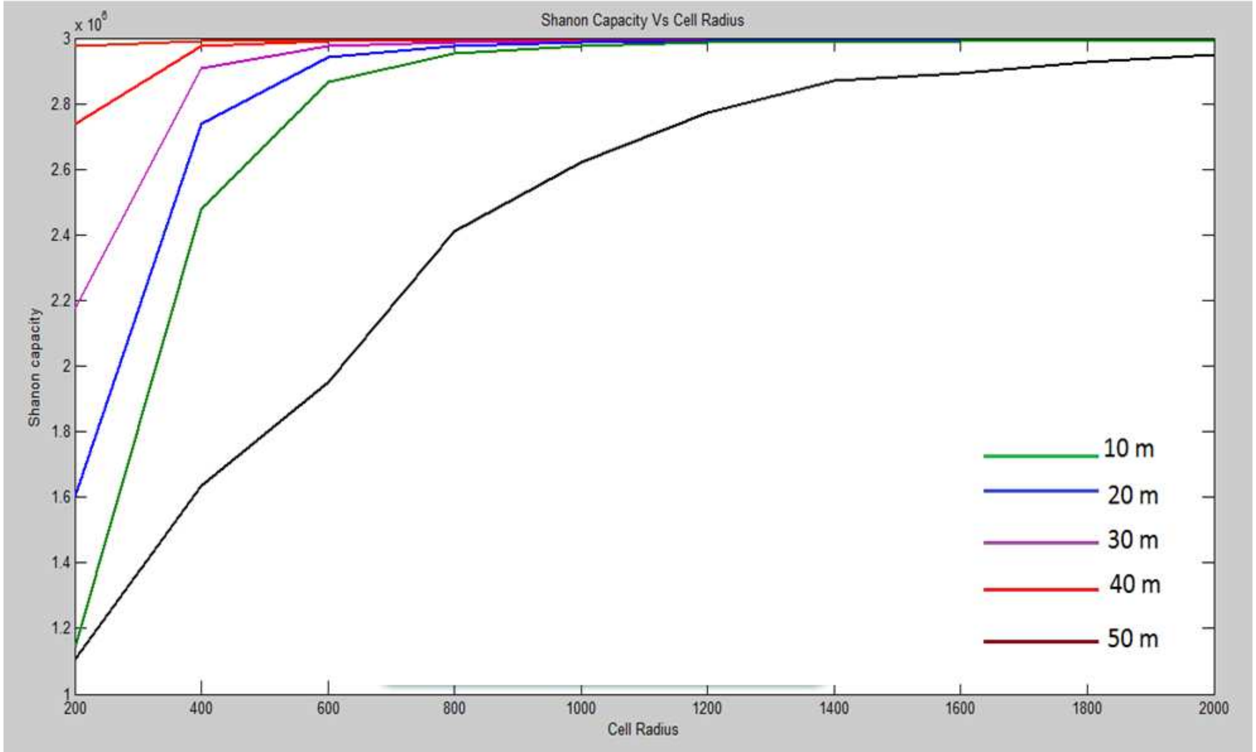


Figure7.3 : Shannon Capacity Vs cell Radius For Cell edge distance = 0.8 x Cell Radius

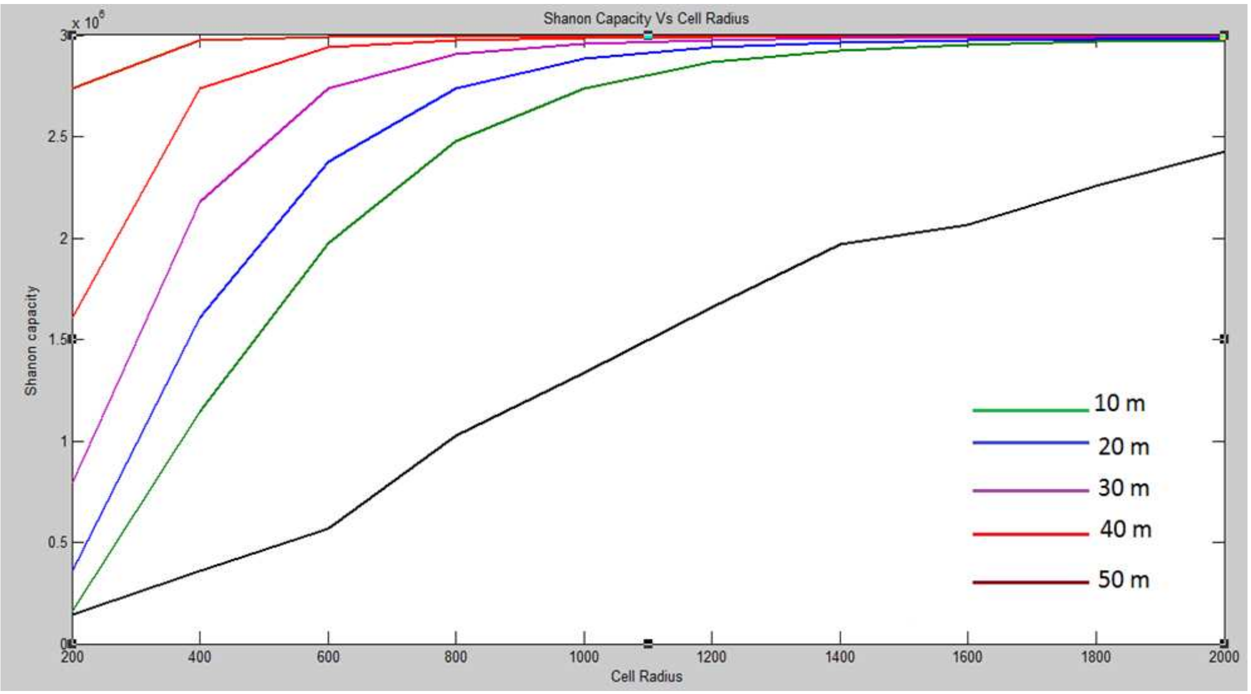


Figure7.4 : Shannon Capacity Vs cell Radius For Cell edge distance = 0.9x Cell Radius

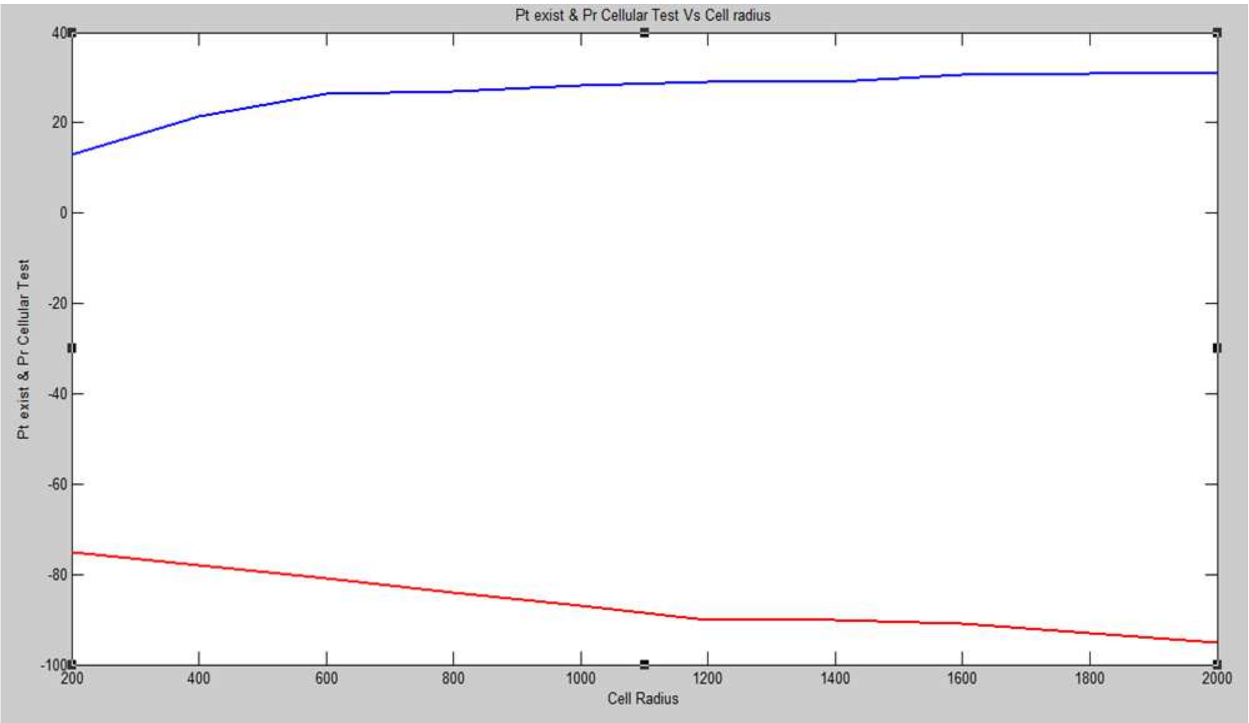


Figure 7.5 : Existing case: Transmit & Received Power Vs cell Radius For Cell edge distance = 0.8 x Cell Radius

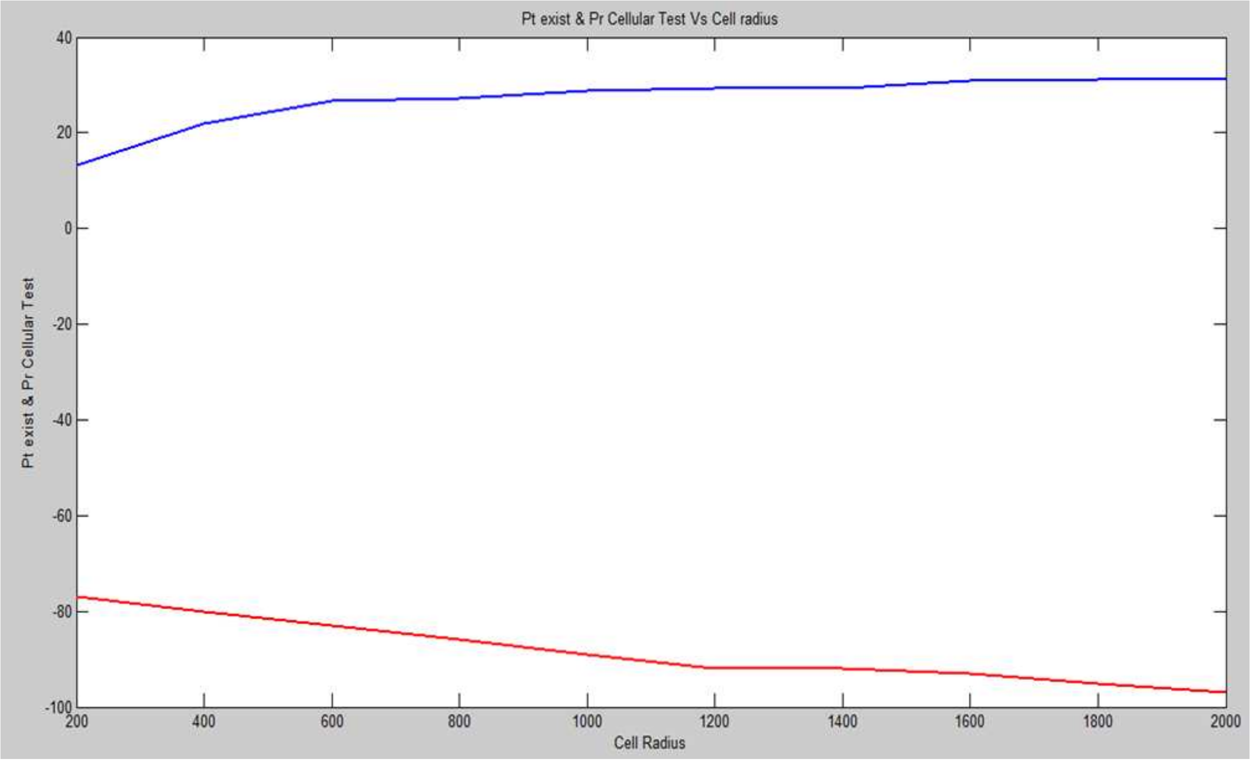


Figure 7.6: Existing case: Transmit & Received Power Vs cell Radius For Cell edge distance = 0.9 x Cell Radius

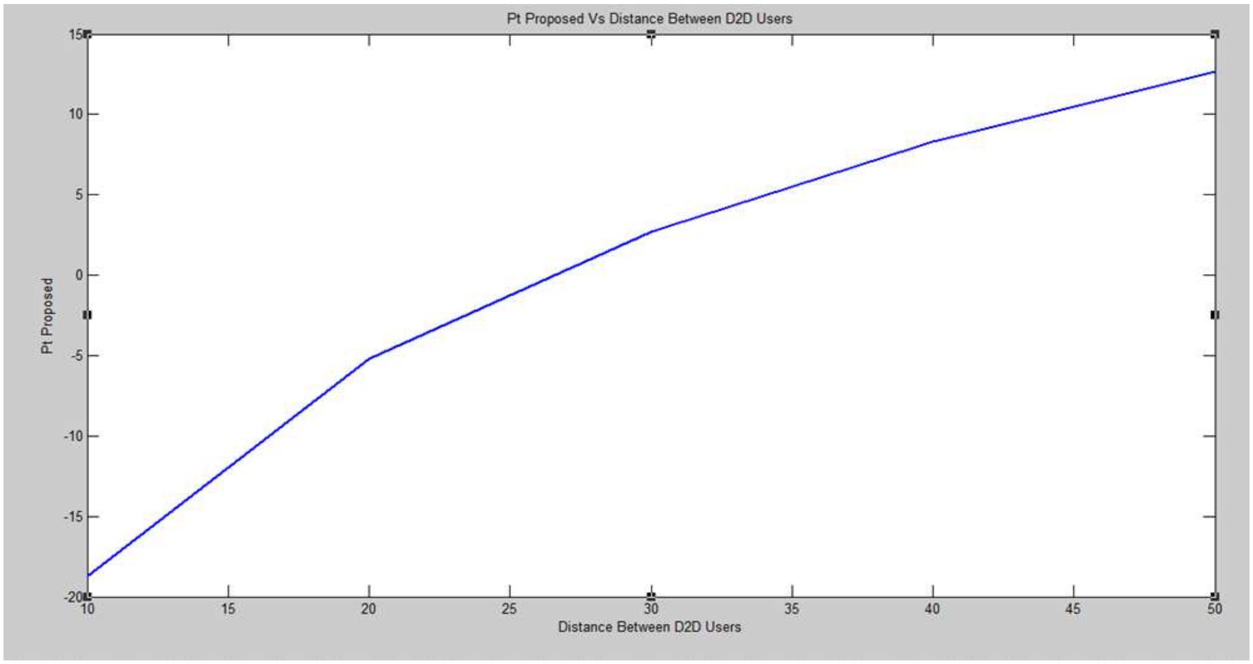


Figure 7.7 : Proposed Case: Transmit Power Vs Distance Between D2D User in the interfering cell For both Cell edge distance = 0.8 x Cell Radius and Cell edge distance = 0.9 x Cell Radius

Summary

LTE is a technology which represents a technology beyond 3G. As it is still in the germinal stage, continuous feedback from researcher is needed for developing it towards the fulfillment. Some network providers have already initiated LTE and it has the potential to suppress the contemporary wireless technologies.

In this paper, we tried to co-ordinate among eNBs for improving D2D communications for the UEs which are in cell edge areas suffering from high interference and hence low SNR.As the eNBs are interconnected, they are supposed to allocate the same resource blocks for D2D users. Whenever the D2D users are at cell edges,they measure the signal power and quality of the eNBs.If the SNR of the serving eNB seems poorer to the UEs, they go under the eNB having better signal power and quality notifying the serving eNB.

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