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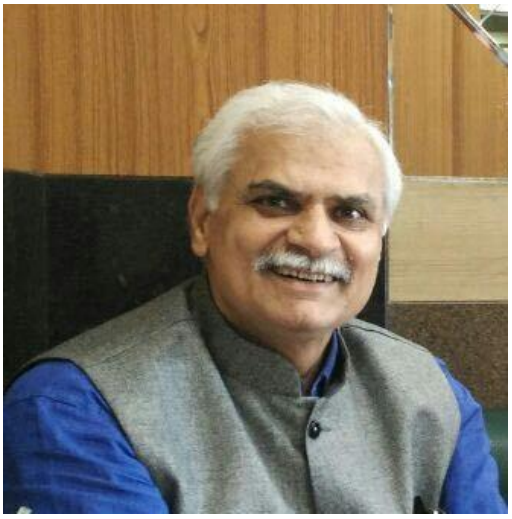
MESSAGE AND NOTE THROUGH DESK

[A]. Mentor - Prof. (Dr). R.K. Khandal



Prof. Dr. R. K. Khandal

Brief Profile:

a. Prof. Dr. R.K. Khandal Is the President, R&D and Business Development at India Glycols Limited, a well renowned and one of its kind companies in the world manufacturing Surfactants from sugarcane molasses. Former Vice Chancellor, Uttar Pradesh Technical University, Lucknow, a Fellow of the Royal Society of Chemistry, London

b. Unanimously elected President of WAITRO (World Association of Industrial & Tech. Organizations), a UN body, 2010-2012 and 2012-2014

c. Expert member of High level Committees of Govt. of India:

   i. Ministry of Science and Technology
   ii. Ministry of Child and Women Welfare
   iii. Ministry of Food Processing Industries
   iv. Recruitment and Appraisal committees of CSIR, DRDO etc.

d. Guided 30 PhD's from 10 Universities. 15 International Patents published 118 research papers in peer reviewed journals, five books and two edited.

e. He has received several awards; prestigious ones include:
   i. INSME (International award for innovation);
   ii. R.N. Bangur Memorial award for novel technologies;
   iii. R.G. Deshpande award for popularizing Radiation processing technology;

iv. U.P. Ratna Award, 2014 for Transforming Technical Education in U.P.
v. Rajasthan Samman Award, 2015 from Rajasthan Associations;
vi. Meri Dilli award, 2010 for improving the living standards of citizens of Delhi
vii. Srishti awards for green technologies, waste management etc.
viii. Amity Academic Excellence award for pioneering research and academics
ix. AMAR UJALA Excellence Award for outstanding contribution to education
x. Life time achievement award by World Environment Congress in food preservation, safety, environment protection and renewable energy,
xi. Eminent Engineers Award by Institutions of Engineers, India
xii. Academic Excellence Award from Engineering Watch, India, in Singapore,

Growth Path:

a. Born on September 6, 1957, he started his career in 1982, as a **lecturer in Indian School of Mines, Dhanbad** at a very young age of less than 25 years.

b. In 1985, joined as a **Group leader in a UNIDO project of Govt. of India.** Post-Doctoral research` ~ 1 year in England and 2 years in France.

c. On return from France in 1991, joined as **Manager, ICI Specialty chemicals**, an MNC and worked for developing Technologies for specialty chemicals.

d. In 1993, joined **India Glycols Limited as General Manager.** Managed team of R&D and Production for 8 years to for new products for growth of the Company.

e. From 2001 to 2012, as the **Director, Shriram Institute, Delhi** established as a leader par excellence. Developed and established a self-sustainability model.

f. **DURING 2012 – 2015, AS THE** VICE CHANCELLOR OF UTTAR PRADESH TECHNICAL UNIVERSITY, **TRANSFORMED THE UNIVERSITY INTO AN INNOVATION UNIVERSITY**.

g. 2015 onwards, Prof. Khandal is, the **President, R&D and Business Development, India Glycols Limited,** a global supplier of Green performance chemicals

h. Prof. Khandal has been associated with leading private universities and institutions as a mentor

Virtues:

Prof. Khandal is a person of eminence with unique expertise and capabilities; a rare profile covering 360° research and innovation cycle in career: as an Academician and a Researcher (Govt. and Pvt.). He knows how to convert challenges into opportunities.

[B]. Patron - in - Chief: – Prof. S.K. Singh

He is serving the nation in the field of science & technology. He has completed his graduation degree in Engineering in Electronics & Communication Engineering, from B.I.T. Sindri, in 1986 and postgraduate in Business Management from X.L.R.I. Jamshedpur, in 2004.

He has 30 years of wide experience in applied Research, Product Development and Program Management besides developing algorithms and their implementation for real-time embedded applications for signal processing in technologies like Software Defined Radio, Digital Subscriber Line, Cable Modem, Meteor Burst Communications and Satellite communications.

Background Highlights:-

- 1986 - 1997, Defence Research & Development Organization (D.R.D.O.) as Scientist
- 1997 - 2006, As Engineering Manager / Program Manager in Multinationals like, Freescale Semiconductor, Ishoni Networks, General Electric Plessey etc.
- 2006 - 2008: Cofounded a Telecom Company Hertz Tele Networks Pvt. Ltd
- 2008 - 2010: Director: Genesis Futuristic Technology Ltd, Noida
- 2010 till date: Founded many organizations till date.
- He had Co-authored a paper on the issue of inter modulation products for D.S.P. based Modulators in 2nd International Symposium on "D.S.P. for Communication Systems" held at Adelaide in 2004. D.S.P. based Modulators: Problems and Solutions.

Message from the Patron - in - Chief's Desk:-

"SANKALAN:- The Journal of Science, Technology & Humanities" (I.S.S.N. Online:- 2455 - 3557) is a Journal started with a goal to publish innovative ideas which proposes value in creating technologies for tomorrow and solving problems of today right from concept to implementation.

This Journal will try to set an example for extending opportunities to scholars of different field to publish their papers with ethics and honesty. I wish a grand success to all the stakeholders of the Journal.

[C]. Executive Editor / Publisher: - Rahul Rai

He is working as Deputy Registrar at B.I.T. Mesra, Ranchi, Jharkhand. His areas of interest are Analytics, Marketing & Entrepreneurship. He is M.B.A with Distinction Marks from B.I.T.S., Pilani, Rajasthan and B.Tech with Distinction in IT and Management. He has 06 years of industrial experience in Analytics and Research industry.

Background Highlights:-

- Worked as Academic Associate in Department of Management, B.I.T.S., Pilani, Rajasthan
- Qualified All India Level :- U.G.C. National Eligibility Test – Junior Research Fellowship (U.G.C. – N.E.T – J.R.F.) in Management in the year 2013
- Diverse Experience in various domain like Banking, Retail, Media & Marketing
- Awarded Many Prizes and appreciations in the career in several fields till date
- Organized & Participated in several seminars and events till date

Note from the Publisher / Executive Editor's Desk:-

Wishing you all a great year ahead!!!

Firstly, I will pay my gratitude to Almighty, my parents and all well-wishers with whose blessings and support we are able to start this journal "**SANKALAN:-The Journal of Science, Technology and Humanities",** (I.S.S.N. Online: - 2455 - 3557) We have started this journal publication for publishing new findings on Science, Technology and Humanities.

I hope this initiative will bring great value for academicians, researchers, students and all those who are involved in Research & Development work. We do have a highly reputed pool of advisory board members from well renowned universities, who help us in keeping high benchmark for quality and originality of our publications. Hence, I am confident that our mission to be the leading Research Journal in field of science, technology and humanities will very soon become true.

I hope very soon Buxar- Land of Rishi Vishwamitra; will soon become educational hub of Bihar.

[D]. Editor - in - Chief: - Rishabh Rai

He is the Editor in Chief of this Journal and working as a P.G.T. Physics and Mathematics in Carmel School, Churamanpur, Buxar, Bihar. His areas of interest are the domains of Electronics and Communication Engineering and Physics, Chemistry & Mathematics. He is M.Tech in V.L.S.I. Design specialization with Distinction Marks & B.Tech in Electronics & Telecommunication Engineering with Honours. Further, he is B.Ed. in Science stream with first class.

Background Highlights:-

- Awarded as the Best Innovative teacher of the year award by ISRO & NASA Delegates in the international level conference at Chandigarh, India on 29.09.2019
- Appreciated by the Govt. of India, Govt. of Bihar & Govt. of Jharkhand for the quality publication of the Journal – Sankalan: - The Journal of Science, Technology & Humanities (e - ISSN - 2455-3557), in the year 2016, 2017 & 2018d
- Appreciated by Kyutec University, Japan and Amazon, an online shopping company for the outstanding publication of the book " Be the change for best always and make difference"
- Earned the respective academic degrees in the career till date i.e. (Class X^{th} to M.Tech.) with Distinction / Honours in aggregate
- Published 20 Technical / Research / Review / Study Papers in several National / International Conferences and Journals till date
- Authored many books, chapters in various publications till date
- Awarded Honorarium & Appreciated for the Paper Publication by A.K.G.E.C. International Journal of Technology in 2016
- Academic Excellence Award, for the academic performance in M.Tech. – (2013 – 2015)
- Academic Excellence Award , for the aggregate performance in B.Tech (2009 - 2013)
- I.E.E.E. National Merit Award – 2013, for the best Paper Presentation in National Conference - E.T.E.A.T – 2013
- Project Selection in the Sixth Science Conclave – 2013, at I.I.I.T Allahabad
- Amul Vidya Bhushan Award – 2009, for the academic excellence & performance in A.I.S.S.C.E. – 2009
- Awarded many awards (Winner), recognitions, appreciations at International, National, State, District, College & School Level in various academics and cultural (Solo Singing, Writing Books, Journals etc.) events till date

Note from the Editor - in - Chief's Desk:-

Firstly, I am thankful to god and grateful to my venerated parents, and all those whose blessings and constant encouragement have helped me to complete this work, i.e. compilation and finalizing of the current issue of the Journal, "**SANKALAN:-The Journal of Science, Technology and Humanities", (I.S.S.N. Online: - 2455 - 3557)**. The papers must not be published, copied in parts or whole or accepted for publication anywhere else. For more information and ideas, one must visit the **"Quality & Plagiarism Check"** for such issues, as given in the website www.sankalan.org .

The entire article will must be double blind peer reviewed by our Advisory Board and will be thoroughly checked on the Plagiarism Software if selected, may be published by completing the copyright policies with the Journal. Lastly, I want to thank all the concerned authorities who are directly or indirectly related to our Journal, and must expect that their co-ordination and support are always valuable and required for us forever.

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OBJECTIVES:

- To develop and promote academic research activities on various contemporary techno-engineering issues and trends in management and humanities.
- To provide a platform to discuss the problems related to the technical as well as the managerial and research issues.

The most valuable and suggestive comments of all the readers are always awaited and welcomed in order to achieve the ultimate goal. We are looking forward for your contributions. All communications must be made only in electronic form e-mailed to:

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CONTENTS

SANKALAN: - The Journal of Science, Technology And Humanities I.S.S.N. (Online): 2455-3557

CRISP VERSION OF THE SPECIAL ISSUE OF THE JOURNAL

EVOLUTION OF LTE-ADVANCED IN WIRELESS COMMUNICATION: A REVIEW

Manju Singh, Academician

Abstract **- 3rd Generation Partnership Project (3GPP) has completed the Long-Term Evolution (LTE) standard. Majority of world's operators and vendors are already committed to LTE deployment, making the LTE market leader in the upcoming evolution to 4G wireless communication systems. But as the LTE standards now comes to an end so, 3GPP is now focusing on LTE Advanced which is basically includes the development from Release 10 and beyond. This paper focuses and explains the differences in technology and performance in LTE Advanced from LTE and describes the overview of the network architecture of LTE Advanced along with the physical layer aspects like wireless relays knows as relaying, Advanced Multiple input multiple output (MIMO) technology, carrier aggregation, coordinated multipoint (CoMP) transmission/reception and enhanced inter cell interference coordination (eICIC).**

Index terms- **Long term evolution (LTE), Multiple input multiple output (MU-MIMO), Physical Downlink Shared Channel (PDSCH), User Equipment (UE).**

I. INTRODUCTION

The telecommunication industry provides a set of relief and a boon to the life of common people. Since, its development from the past few years it is growing at a fast rate. First introduced in eighteenth century as telegraph but does not provide the facility of automatic error correction and from that time further enhancements are made with the introduction of telephone in the year 1876 and then the mobile services were first came into existence in the western countries in 1946 [1].

Initially, First Generation cellular network was developed in Japan in the year 1979 then US developed a standard called Advanced Mobile Phone System (AMPS) in 1983 [2]. Then, in 1987 Groupe Special Mobile standard was introduced which was later known as Global System for Mobile Communication is a 2G technology. GSM shows many improvements in terms of technology and performance like modulation scheme and coding as it uses Time Division Multiple Access (TDMA) while in 1G Frequency Division Multiple Access (FDMA) for serving multiple subscribers. 3rd Generation Partnership Project (3GPP) was introduced by the global mobile communication system for the development of Third Generation technology based on Code Division Multiple Access (CDMA) in 1988. It basically works on the standardization made by GSM and further 3GPP2 was introduced which focuses on the evolution of IS-95 networks and two technologies are developed by the standardization i.e. Wideband CDMA (WCDMA) for 3GPP and CDMA 2000 for 3GPP2 [3].

The first version of the standard introduced by 3GPP known as Release 99 in 2000 with UMYE having data rate of 384kbps in DL and 128kbps in UL. Then further releases show improvement as with HSDPA and HSUPA in release 5 and release 6 and in release 7 HSPA+ [4] using MIMO and 64AM was introduced. As the demand for data traffic increases, 3GPP decided to develop a standard which will meet the requirements in terms of high data rate, spectral efficiency etc. known as Long Term Evolution (LTE) is 4G technology came into existence in release 8 of 3GPP and further dual carriers introduced in release 9 in which Orthogonal Frequency Division Multiple Access (OFDMA) is used in DL and Single Carrier FDMA (SC-FDMA) in UL.

LTE Advanced is introduced in release 10 of 3GPP as an enhancement of LTE to fulfill the requirements of International Mobile Telecommunication (IMT) Advanced which is defined by International Telecommunication Union (ITU). The important technologies specified for fulfilling the requirements of ITU are carrier aggregation, enhanced inter cell interference coordination, wireless relaying,

advanced multiple input multiple output technology, coordinated multipoint transmission/reception.

II. FEATURES OF LTE AND LTE-ADVANCED

- LTE supports peak data rate of 100/50 Mbps in DL and UL while LTE-A supports 1 Gbps/ 500Mbps in DL and UL respectively.
- LTE uses a scalable bandwidth up to 20 MHz while LTE-A supports a bandwidth up to 100 Mhz.
- LTE supports a spectral efficiency of 15/6 bps/hz in DL and UL while in LTE-A its value is 30/15 bps/Hz respectively.
- LTE-A is backward compatible with previous releases.
- The antenna configuration used in LTE is 4X4 in DL and 2X2 in UL and in LTE-A is 8X8 in DL and 4X4 in UL.
- The mobility and coverage requirements are same as that of the Release 8.
- In LTE, Link Adaptation and turbo Coding and MIMO is used while in LTE-A carrier aggregation, advanced MIMO, e ICIC etc. are used.

Initially, the component carriers are aggregated to obtain a bandwidth of 100 MHz of contiguous spectrum then, arises the case of having noncontiguous component carriers that are aggregated either in same spectrum band or in different spectrum bands. This helps in achieving higher data rates and better coverage for medium data rates too and in the reduction of transmission power, interference and link budget [7].

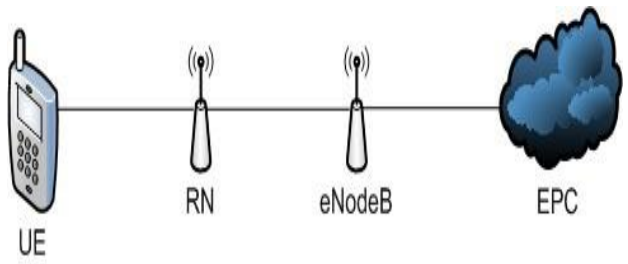
III. *ADVANCED MIMO*

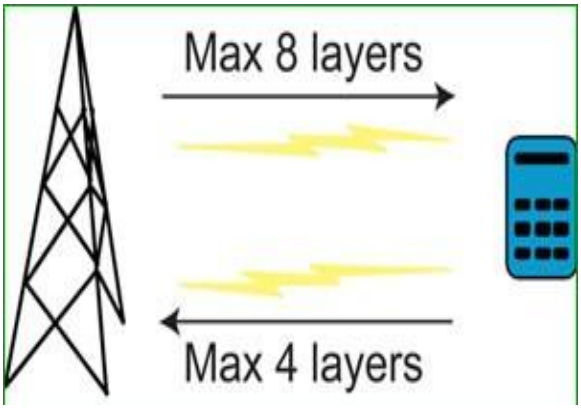
Multiple – input Multiple –output technology (MIMO) basically is a technique by using multiple antennas at both transmitter and receiver end means at both the base station and user equipment side for both downlink and uplink [8].

MIMO is used for achieving higher data rates and it is very helpful in higher spectral efficiency also. The spectral efficiency needs to be achieved here is 30 bps/Hz by using 8X8 spatial multiplexing in downlink and 15 bps/Hz in uplink by using 4X4 spatial multiplexing as shown in Fig. 3 that in LTE-Advanced up to eight layers are supported in downlink and up to four layers are supported in uplink.

IV. *WIRELESS RELAYS*

The use of wireless relays in LTE-Advanced cellular systems improves the coverage of the Cell edge performance while it also increases the throughput and group mobility by reducing the coverage holes efficiently. This will definitely reduce the overall cost because the cost of relay is very less and the transmission power can also be reduced as the total distance between evolved Node B and UE is divided into two parts as a relay node is placed between them. So, the distance is from evolved Node B and relay node and from relay node to UE. So, in this way the power consumption can be reduced shown in the figure.

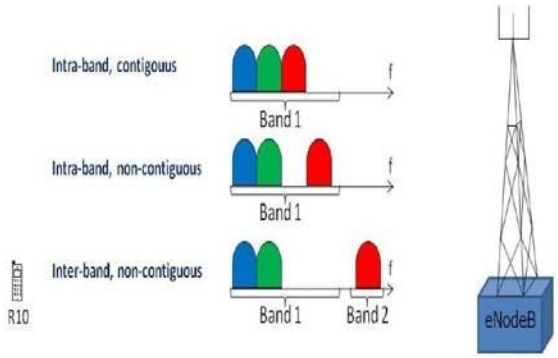




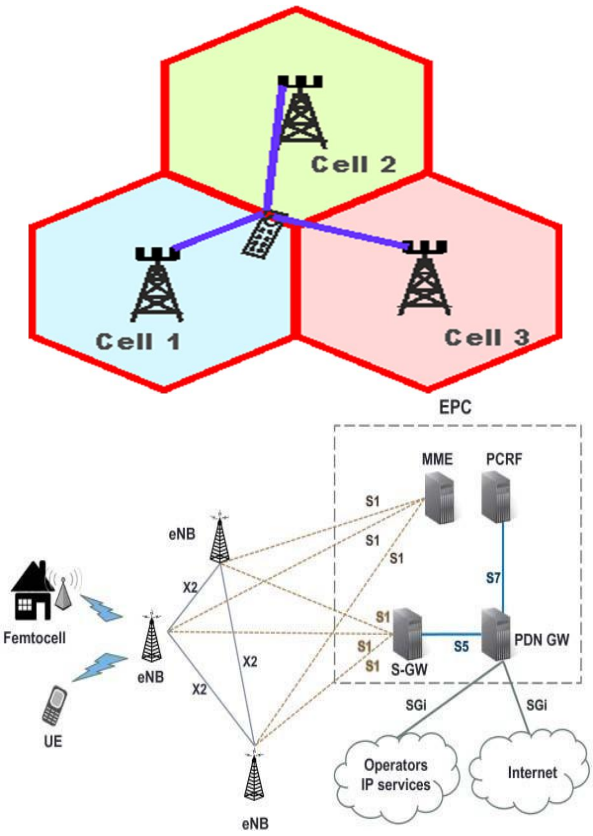
NETWORK ARCHITECTURE

The 3GPP network architecture is shown in Fig.1. It is basically the Evolved Packet System (EPS) architecture which comprises of mainly LTE and System Architecture Evolution (SAE) which corresponds to Evolved Packet Core

(EPC), Evolved Universal Terrestrial Radio Access Network (EUTRAN) and Evolved Universal Terrestrial Radio Access (EUTRA) in which EPC corresponds to the basic core network, EUTRAN to the radio access network while EUTRA to the air interface between the components. Node B which is used in 3G is replaced by evolved Node B and its basic function is to serve more number of cells at a time by communicating with the user equipments. For serving small femto cells i.e.



small indoor area Home evolved Node B are used [5, 6].



V. IMPORTANT TECHNOLOGIES

In Carrier Aggregation, upto five component carriers are aggregated to achieve high data rate i.e. 1Gbps in DL and 500 Mbps in UL and to obtain the bandwidth of 100 Mhz. In Release 10 of 3GPP, two types of carrier aggregation were defined i.e. intra-band contiguous spectrum aggregation and inter-band noncontiguous spectrum aggregation while intra-band noncontiguous spectrum aggregation is defined in Release 11 shown in Fig. 2.

The communication between evolved Node B and UE is done in two ways. In the first way, communication link uses same frequency band known as in band and in another way it uses different band so, known as out band. There are two types of relay nodes basically Type 1 and Type 1a. In Type1 relay nodes, it controls cells and appear as a new cell to the UE and its cells are having their own physical ID, channels etc. and all the control and synchronization information is exchanged directly between RN and UE while in Type 1a relay nodes, the whole functioning is same but it operates out band.

VI. COORDINATED MULTIPOINT (COMP) TRANSMISSION/RECEPTION

CoMP is a technique to improve the cell edge user performance in terms of data rate and spectral efficiency [10]. As shown in Fig. 5, the coordination of network basically results in choosing antennas from different base station in efficient way so as to improve the spectral efficiency and reduces the inter cell interference as the information is exchanged among different base stations.

The joint transmission and dynamic cell selection in downlink. In Joint transmission, from the multiple cells that are associated with User specific reference signal same resource block of PDSCH is transmitted and this can be achieved by using codebook based precoding to reduce the overheads while in Dynamic cell selection method, resource block of PDSCH is transmitted for single cell which is associated and other cells which are coordinated are muted

means they do not transmit any resource block [11].

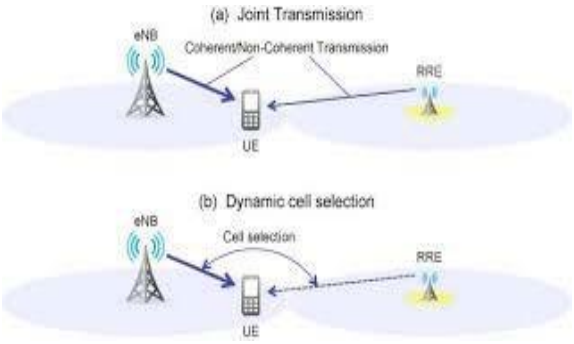


Fig. 6 Joint transmission and Dynamic cell selection in downlink

VII. ENHANCED ICIC

Heterogeneous network is considering the deployment of a number of small sized low power base stations to serve a small area like

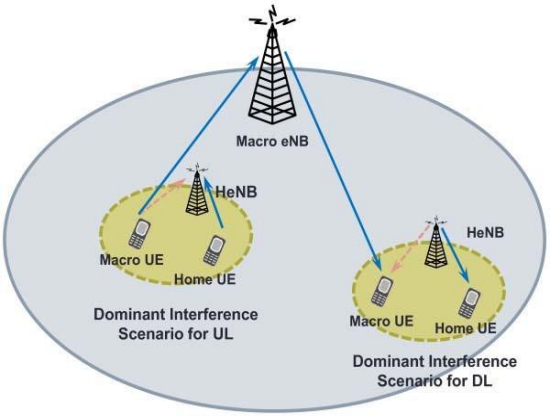


Fig. 7 Interference scenario

offices etc. Inter cell interference becomes a challenging issue as a number of heterogeneous cells exist in an area. In some situations, the signal comes from the serving cell becomes weaker as compared to the signal from interfering cell known as dominant interference scenario shown in Fig. 7. Between femto cells and macro cells in which the femto cells are closed subscriber groups means every user cannot access the femto cell [12].

The ICIC methods used in release 8 and 9 do not consider the dominant interference scenario. So, LTE-Advanced is developing enhanced ICIC methods used in different categories i.e. time domain, frequency domain and power control techniques [13].

VIII. CONCLUSION

This paper provides a review of the techniques required to meet the requirements in LTE-Advanced established by IMT-Advanced. All the technologies i.e. carrier aggregation, advanced MIMO, enhanced ICIC, coordinated multipoint (CoMP) transmission/reception and wireless relaying plays important role in achieving the requirements not only a single one. However, each issue still requires further research.

LTE-FDD AND LTE-TDD FOR CELLULAR COMMUNICATIONS

Amrit Kumar Paliwal, Academician

Abstract – **In the case of cellular networks, a limited shared resource (spectrum) needs to be shared with all users. Technologies deployed for cellular communications are introduced in this short review article.**

Keywords: *Frame structure, Frequency bands, Wireless phones, Long Term Evolution, Frequency Division Duplexing, Time Division Duplexing, Radio Base Stations*

I.INTRODUCION

In communication systems, a user needs to exchange data with one or more parties through a shared resource – a common channel. Depending on whether the data is transmitted / received simultaneously, the following transmission techniques exist:

**Simplex* – One party transmits data and the other party receives data. No simultaneous transmission is possible – the communication is one-way and only one frequency (channel) is used. Examples of simplex communication are traditional (non-interactive) radio and television.

**Half Duplex* – Each party can receive and transmit data, but not at the same time. The communication is two-way and only one frequency (channel) is used. Examples of half duplex communication are walkie-talkies or other two-way radio systems.

**Full Duplex* – Each party can transmit and receive data simultaneously. The communication is two-way and two frequencies (channels) are used – one for transmitting and one for receiving.

In the case of cellular networks, a limited shared resource (spectrum) needs to be shared with all users so full duplex communication is possible (Note that full duplex service, like regular phone conversation, can be carried over a half-duplex channel). The two main methods used are:

Time Division Duplexing (TDD): The communication is done using one frequency, but the time for transmitting and receiving is different. This method emulates full duplex communication using a half-duplex link.

Frequency Division Duplexing (FDD): The communication is done using two frequencies and the transmitting and receiving of data is simultaneous.

The advantages of TDD are typically observed in situations where the uplink and downlink data transmissions are not symmetrical.

Also, since the transmitting and receiving is done using one frequency, the channel estimations for beam forming (and other smart antenna techniques) apply for both the uplink and the downlink. A typical disadvantage of TDD is the need to use guard periods between the downlink and uplink transmissions.

The advantages of FDD are typically observed in situations where the uplink and downlink data transmissions are symmetrical (which is not usually the case when using wireless phones).

More importantly, when using FDD, the interference between neighboring Radio Base Stations (RBSs) is lower than when using TDD. Also, the spectral efficiency (which is a function of how well a given spectrum is used by certain access technology) of FDD is greater than TDD.

II. DIFFERENCES BETWEEN FDD-LTE AND TD-LTE

The two versions of LTE are very similar. In fact, they differ only in the physical layer and, as a result, the version implemented is transparent to the higher layers. This means that UEs will be able to support both TD-LTE and FDD-LTE with one chipset with only minor modifications required.

All major chipset vendors – ST-Ericsson (M700/M710 chipsets), Altair Semiconductor (FourGee-6150 chipset), and Qualcomm (MDM9200/ MDM9600 chipsets) have already released chipsets that support both LTE flavors.

UEs based on those chipsets are (or will soon be) available from Sony, Huawei, Samsung, Nokia, and others.

The following features are unique to TD-LTE:

Frame structure – 3GPP has specified a special subframe that allows switching between downlink and uplink transmission.

Random access – Several additional random-access formats exist in certain sub-frames. Also, several random-access channels exist in every sub-frame.

Scheduling – The scheduling for the uplink is multi-frame.

HARQ – The number of HARQ processes depends on the uplink/downlink resource allocation.

ACK/NACK – Multiple acknowledgements and negative acknowledgements are combined on the uplink control channels. This ultimately leads to increased control signaling and lower spectrum/resource utilization.

Guard periods – These are used in the center of special sub- frames. They allow for the advance of the uplink transmission timing.

Another difference between FDD-LTE and TD-LTE is that in FDD-LTE every downlink sub-frame can be associated with an uplink sub-frame. In TD-LTE the number of downlink and uplink sub-frames is different and such association is not possible.

Additionally, the uplink coverage with respect to a specific data rate in TD-LTE is generally worse than FDD-LTE due to the fact that the uplink transmission is not continuous. The percentage of coverage for control and data channels is, however, very similar to that of FDD-LTE.

In terms of spectrum efficiency, the performances of TD-LTE and FDD-LTE are similar for non-delay sensitive traffic. The lower performance of TD-LTE is due to the guard periods mentioned above.

Configurations are chosen correctly and both systems are synchronized to the same time source).

III. FREQUENCY BANDS FOR FDD-LTE AND TD-LTE

The frequency bands listed in Table 1 are currently defined by 3GPP for TD-LTE and FDD-LTE - Finally, TD-LTE and TD-SCDMA work together with minimum interference issues, even if both technologies are deployed in the same frequency band (assuming that the TD- LTE UL:DL configurations are chosen correctly and both systems are synchronized to the same time source).

The frequency bands listed in Table 1 are currently defined by 3GPP for TD-LTE and FDD-LTE.

Finally, TD-LTE and TD-SCDMA work together with minimum interference issues, even if both technologies are deployed in the same frequency band (assuming that the TD- LTE UL: DL configurations are chosen correctly and both systems are synchronized to the same time source).

Table 1 LTE Frequency Bands

LTE Operating Band	Uplink, MHz $F_{UL\_low} - F_{UL\_high}$	Downlink , MHz $F_{DL\_low} - F_{DL\_high}$	Duplex Separation, MHz	Duplex Mode
1	1920 – 1980	2110 – 2170	190	FDD
2	1850 – 1910	1930 – 1990	80	FDD
3	1710 - 1785	1805 – 1880	95	FDD
4	1710 – 1755	2110 – 2155	400	FDD
5	824 – 849	869 – 894	45	FDD
6	830 – 840	875 – 885	45	FDD
7	2500 – 2570	2620 – 2690	120	FDD
8	880 – 915	925 – 960	45	FDD
9	1749.9 – 1784.9	1844.9 – 1879.9	95	FDD
10	1710 – 1770	2110 – 2170	400	FDD
11	1427.9 – 1447.9	1475.9 – 1495.9	48	FDD
12	698 – 716	728 – 746	30	FDD
13	777 – 787	746 – 756	31	FDD
14	788 – 798	758 – 768	30	FDD
17	704 – 716	734 – 746	30	FDD
33	1900 – 1920	1900 – 1920	N/A	TDD
34	2010 – 2025	2010 – 2025	N/A	TDD
35	1850 – 1910	1850 – 1910	N/A	TDD
36	1930 – 1990	1930 – 1990	N/A	TDD
37	1910 – 1930	1910 – 1930	N/A	TDD
38	2570 – 2620	2570 – 2620	N/A	TDD
39	1880 – 1920	1880 – 1920	N/A	TDD
40	2300 – 2400	2300 – 2400	N/A	TDD

Typically, a wireless operator will be allowed to operate a LTE network in a certain band and its bandwidth will be allocated in terms of Resource Blocks (RBs), as listed in Table 2.

Table 2 LTE Channel Bandwidth

Channel bandwidth, MHz	1.4	3	5	10	15	20
Number of Resource Blocks	6	15	25	50	75	100

IV. PEAK DOWNLINK AND UPLINK DATA RATES

The peak data rates for various channel bandwidths and antenna options for both FDD-LTE and TD-LTE are shown in Tables 3 and 4-

Table 3 Peak Downlink Data Rates for FDD-LTE & TD-LTE (frame structure type 1)

Channel bandwidth, MHz		1.4	3	5	10	15	20
Number of Resource Blocks		6	15	25	50	75	100
Modulation	MIMO	Data Rate[1], Mb/s					
QPSK	Not Used	1.728	4.32	7.2	14.4	21.6	28.8
16 QAM	Not Used	3.456	8.64	14.4	28.8	43.2	57.6
64 QAM	Not Used	5.184	12.96	21.6	43.2	64.8	86.4
64 QAM	2x2	10.368	25.92	43.2	86.4	129.6	172.8
64 QAM	4x4	20.736	51.84	86.4	172.8	259.2	345.6

Table 4 Peak Uplink Data Rates for FDD-LTE & TD-LTE (frame structure type 1)

Channel bandwidth, MHz		1.4	3	5	10	15	20
Number of Resource Blocks		6	15	25	50	75	100
Modulation	MIMO	Data Rate[2], Mb/s					
QPSK	Not Used	1.8	4.5	7.5	15	22.5	30
16 QAM	Not Used	3.45	8.64	14.4	28.8	43.2	57.6
64 QAM	Not Used	5.184	12.96	21.6	43.2	64.8	86.4

[1] Assumes no coding and 12 RE per RB for control channels and reference signals
[2] Assumes no coding and 12 RE per RB for reference signals (PUCCH will reduce the rate slightly)

[3] Assumes allocation of 4 timeslots in the DL and 1 in the UL
[4] Assumes allocation of 3 timeslots in the DL and 1 in the UL
[5] Assumes allocation of 4 timeslots in the DL and 1 in the UL
[6] Assumes allocation of 8 timeslots in the DL and 6 in the UL
[7] Assumes Dual Cell HSDPA (10 MHz) with 64 QAM and 2x2 MIMO
[8] Assumes the use of IS-95-B
[9] Assumes EVDO Rev B. N is the number of 1.25 MHz carriers that are used. 64 QAM is used in the DL
[10] Assumes single carrier TD-SCDMA HSPA+ and 64 QAM
[11] Assumes 20 MHz of bandwidth, 64 QAM and 4x4 MIMO in the DL

V. COMMERCIAL CHALLENGES

Wireless operators are constantly looking for ways to reduce their operational expenses while increasing their revenue. In recent years, the focus has been on introducing and/or identifying data applications that are attractive to consumers while being inexpensive to implement and support. Additionally, operators such as China Mobile are searching for a next-generation technology that will overcome the limitations of TD-SCDMA (limited/expensive handsets available only in the domestic market; multiple mode handsets needed for global roaming). Finally, a technology that will address the continuously growing data traffic is needed. LTE seems to address all these challenges. Even though many operators around the world have committed to deploying LTE as their next-generation wireless network, the possibility of using TD-LTE has not been generally considered. Recently, however, more and more operators (including Aircel (India), China Mobile (China), Aero2 (Poland), and Infotel (RIL India), vivid wireless (Australia)) have expressed their support

for TD-LTE, which is a clear indication that the technology will become widely accepted.

VI. CONCLUSION

The main reasons for that sudden interest are the following:

a. The differences between FDD-LTE and TD-LTE are minimal, and single devices can support both technologies with one chipset – device availability will not be an issue.

b. The TDD spectrum is less expensive.

c. Both offer similar performance/spectral efficiency.

d. Handovers can be performed between FDD-LTE, WCDMA, TD-SCDMA, GSM, and CDMA.

e. Some of the frequency bands for TD-LTE overlap with WiMAX bands, making it an attractive evolution path for WiMAX operators.TD-LTE is suitable for M2M (machine-to-machine) applications (such as Point of Sale, Fleet Management, Health Care Monitoring, etc.) due to its adaptable UL and DL configuration. Overall, TD-LTE offers operators a great alternative to FDD. Its natural suitability for asymmetric applications, low latency, high throughput, and security. make it a flexible and cost- effective solution for the next generation wireless networks.

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