4G Evolution and Multiplexing Techniques with solution to implementation challenges

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***Abstract*—**The new age of 4G technology is upon us which is about to reshape our lives. 4G offers us greater bandwidth, higher data rates, efficient spectrum use, and increased interoperability across the globe. It supports user friendly, innovative, and secure application environment. 4G systems are expected to become a platform capable of providing seamless integrating between the existing systems like GSM and wireless LAN. These systems will support comprehensive personalized services, providing stable system performance and improved quality of service. With these enhanced capabilities 4G promises to bring wireless experience to a whole new level. User will now have access to sophisticated GUI, real time gaming and high definition video. This paper will explore benefits, challenges, Multiplexing techniques and standards of 4G technologies. In it next generation applications and integration is discussed. Solutions to the research problems in developing 4G technologies are examined. Finally a short summary on 5G vision is presented as a continuum of features in the development of mobile technology.

***Keywords* — 4G, 5G, LAS-CDMA, LAS-2000, WiMAX2**

I. INTRODUCTION

During the last few decades, mobile communication has developed rapidly. The 1st Generation deployed in the 1980s was an analog technique. Though Speech chat was the only service available, 1G still laid the basic structure of mobile communications and solved many fundamental problems such as adopting cellular architecture, multiplexing frequency band, roaming across domain, non-interrupted communication etc.

2G was based on digital signal processing techniques deployed during 1990s. It is regarded as an evolution from analog to digital technology. The introduction of Subscriber Identity Module-SIM card and supporting capabilities for a large number of users were 2G's main contributions. 2.5G extended the 2G with data service and packet switching methods. It brought the Internet into mobile personal communications. This was a revolutionary concept leading to hybrid communications. 3G provided higher data rate and broader bandwidth. Based on intelligent DSP techniques, 3G networks transmit various multimedia data communications services.

4th Generation of mobile communication standard introduced its first service Long Term Evolution on 14 December, 2009 in Stockholm and Oslo. 4G allow seamless mobility which supports un-interrupted file transfer in case a terminal moves from one cell (one base station coverage area) to another. While moving the terminal also keeps the same IP address, which means that a mobile server is reachable as long as it is within the coverage area of any server. In 4G systems this mobility is provided by the mobile IP protocol, part of IP version 6 where as in earlier cellular generations it was only provided by physical and data link layer protocols [1]. 4G also provides flexible interoperability between the various kinds of available wireless networks, such as satellite, cellular wireless, PAN, WLAN and systems for accessing fixed wireless networks. 4G is expected to provide a comprehensive and secured IP based mobile broadband solution to laptop computers, wireless modems, smart phones, and other mobile devices. An over view of mobile technologies is given below:

Technology	1G	2G	2.5G	3G	4G
Developed	1981	1991	1995	2001	2010
Services	Mono Voice	Voice, SMS, media	Voice, SMS Media, Data Service	Superior voice quality & always on Broadband data	Converged data & voice over IP, LTE
Standard	AMPS, TACS, NMT	GSM, TDMA	GPRS, I-Mode, HSCSD, EDGE	IMT-2000 (UMTS, WCDMA, CDMA2000)	Single Standard based on LTE Advanced
Architecture	Circuit Switched	Circuit Switched	Packet Switched	Circuit & Packet Switched	Packet Switched
Multiplexing	FDMA	TDMA, CDMA	TDMA, CDMA	CDMA	OFDM+ MIMO, W-OFDM, MC-CDMA & LAS-CDMA
Core Network	PSTN	PSTN	PSTN	PSTN & Some IP networks	Completely IP based
Data Rates	-	9.6 to 14.4 Kbits/s	64 to 144 Kbits/s	384 Kbits/s to 2 M bits/s	100 M bps to 1G bps

Legend:
OFDM - Orthogonal frequency division multiplexing
MIMO - Multiple input multiple outputs
PSTN - Public switched telephone network
WCDMA - Wideband CDMA
LTE - Long Term Evolution
W-OFDM - Wide band OFDM
LAS-CDMA - Large Area Synchronised CDMA

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II. 4 G MULTIPLEXING TECHNIQUES

One of the significant problems in 4G implementation is to form a single standard. Key to solving this dilemma is to improve the existing standards and to merge them in such a way as to create a system which meets the ITU requirements for 4G. Two such contenders LAS-2000 and MIMO-OFDM are discussed below:

A. LAS-2000

A proposed evolution to the IS-2000 series of CDMA2000 air interface standards. It is based on Large Area Synchronised (LAS) CDMA technology. LAS-CDMA relies on the use of new spreading codes called LA and LS codes which replace the PN and Walsh codes used in second generation IS-95 systems as well as in IS-2000. Autocorrelations of LA and LS codes have very high peaks with very small side lobes and their cross-correlations contain an interference free window (IFW) or a zero correlation zone (ZCZ). This results in increased capacity and the spectral efficiency. Basic characteristics such as RF parameters, chip-rate and frame length as well as other layers of the air interface protocol stack are more or less same. LAS-2000 provides backward compatibility with current IS-95/IS-2000 networks and infrastructure equipment. This is provided to the subscriber via multi-carrier overlay. With the help of these new codes, an LAS-CDMA system is able to reduce the detrimental impact of system-generated interference. Therefore dramatically improving capacity, coverage and performance characteristics, compared to previous CDMA systems. Estimates show that capacity gains of at least three times can be achieved by using LAS-2000 over IS-2000. Such improvements make LAS-2000 the most cost-efficient wireless mobile technology and allows it to deploy in high density areas. Similarly, with packet data coding LAS-2000 can be used to deliver high speed and low delay Internet services as well as voice services on the same 1.25 MHz RF carrier. This allows operator to offer attractive wireless Internet services with voice service. As W-LAS and TD-LAS are based on the same spectrum, chip-rate, LAS-CDMA technology can also be used with other IMT-2000 standards, with the same coding method and system procedures as TD-CDMA and W-CDMA respectively. Adopting LAS-CDMA in 3GPP2 is therefore a first step for convergence of wireless standards.

1) LAS-2000 frame structure

The 20 ms IS-2000 frame is divided into one BCh/ACh header and 9 sub-frames. Each sub-frame is regularly spaced and 2559 chips long. Every sub-frame contains 17 Time Slots arranged according to the LA pulse intervals. A Time Slot is 136 chips long and contains LS coded symbols [2].

2) LA codes

LA codes are used in LAS-CDMA to create separate multiple access transmission channels on a same RF carrier. These channels can be used by different cell and sectors. LA codes properties ensure that Adjacent Cell Interference is minimal. These codes are used to identify a cell/sector and have Adjacent Cell Interference (ACI) elimination properties. LA codes are identified by three parameters N, K0 & K [3]:

- N is the number of pulses
- K0 is the minimum pulse interval
- K is the total LA code length

LAS-2000 uses 17, 136 & 2559 LA codes. Same codes are used in W-LAS and TD-LAS.

	Primary LA Code Pulse Positions																
Interval Index	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Length (chips)	136	138	140	142	144	146	148	150	152	154	156	158	160	162	164	172	137
LA pulse position	136	274	414	556	700	846	994	1144	1296	1450	1606	1764	1924	2086	2250	2422	2559

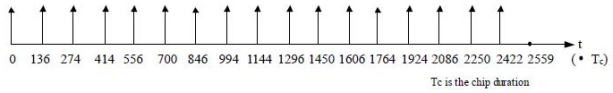

Fig. 1: LAS 17, 136, 2559 primary codes

3) LS codes

LS codes are used in LAS-CDMA to spread the transmitted signal. These codes are used to create multiple Code Divided transmission channels and have Inter-Symbol Interference (ISI) and Multiple Access Interference (MAI) rejection properties. LS codes are defined according to a tree structure where each LS code is made up of a C component and an S component. These components are complementary orthogonal, the sum of their auto correlation functions does not have side lobes and the sum of their cross correlation function is null within the IFW [4].

B. OFDM

Orthogonal frequency-division multiplexing (OFDM) is a frequency division multiplexing (FDM) scheme that uses a digital multi-carrier modulation method. A large number of closely spaced orthogonal sub carriers are used to carry data. This data is then divided into several parallel data streams or channels for each sub-carrier. At a low symbol rate and maintaining total data rates similar to conventional single carrier modulation schemes in the same bandwidth each sub carrier is modulated with a conventional modulation scheme (such as quadrature amplitude modulation or phase-shift keying) [5].

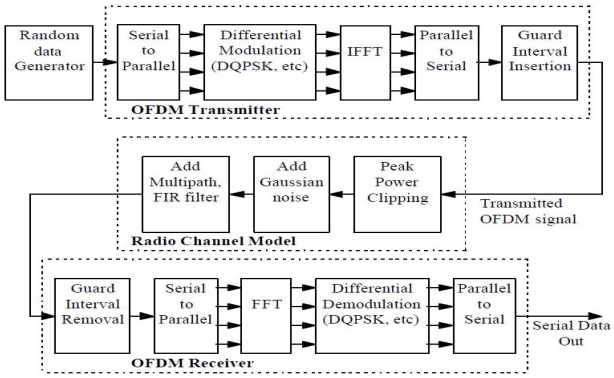

Fig. 2: OFDM model

Main areas of focus in OFDM are Impulse noise & mitigation (particularly with application to digital television broadcasting), efficient digital signal processing implementation of OFDM and Peak-to-average power reduction in OFDM [6]. Advantages and Disadvantages of OFDM are given below:

Advantages	Disadvantages
Adaptable to severe channel conditions without complex time-domain equalization.	Sensitive to Doppler shift.
Robust against narrow-band co-channel interference, inter symbol interference (ISI) and fading caused by multipath propagation.	Sensitive to frequency synchronization problems.
High spectral efficiency	Loss of efficiency caused by cyclic prefix/guard interval.
Low sensitivity to time synchronization errors.	High peak-to-average-power ratio (PAPR)

III. 4G STANDARDS

A. LTE Advanced

LTE (Long Term Evolution) is standardization within the 3GPP (3rd Generation Partnership Project). Since 2010 operators have started to replace GSM and UMTS with LTE mobile communication systems. First LTE 'Release 8' 2008 was All-IP Network with new OFDMA, FDE and MIMO based radio interface. Release 8 was not backwards compatible with previous CDMA interfaces and contained Dual-Cell High Speed Packet Access (HSDPA) wireless broadband standard. 'Release 9' launched in 2009 came with SAES Enhancements, WiMAX and LTE/UMTS Interoperability. 'Release 9' has Dual-Cell HSDPA with MIMO, Dual-Cell HSUPA. 'Release 10' introduced in 2011 also known as LTE Advanced fulfils IMT Advanced 4G requirements.

1) LTE Physical layer Implementation:

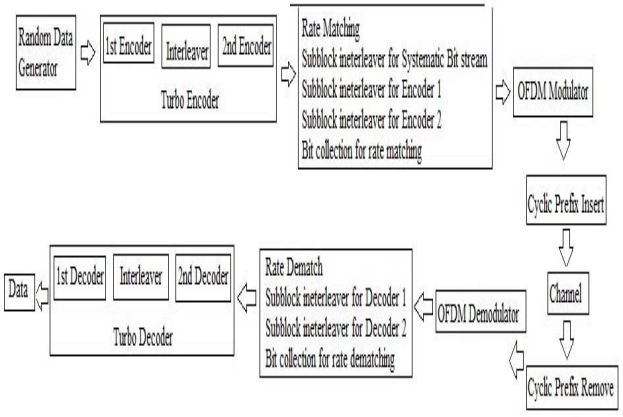

Fig. 3: Simulation Block set

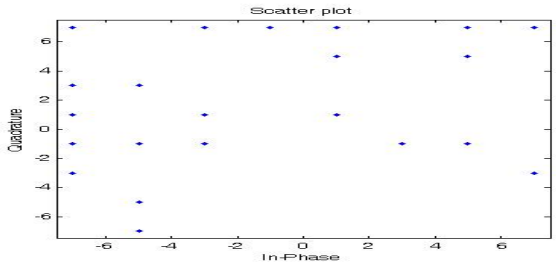

Fig. 9: Scatter Plot

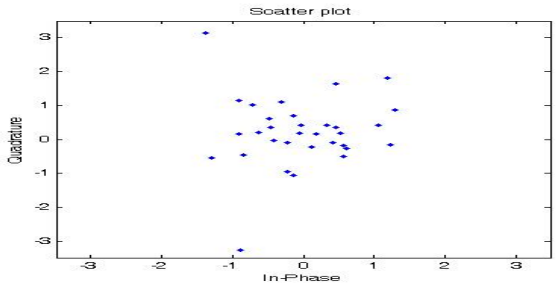

Fig. 4: Result

The pattern in figure 2 confirms the result that the FFT block enhances the overall signal pattern.

B. WiMAX 2

WiMAX stands for Worldwide Interoperability for Microwave Access. It provides fixed & mobile Internet. WiMAX 2 also called Wireless MAN-Advanced has become the first true 4G technology to be approved by the IEEE and ITU. WiMAX is backward compatible with Release 1; operators could migrate from release 1 to release 2 by upgrading hardware or software. The IEEE has introduced it as 802.16m and acknowledged WiMAX 2 alongside LTE Advanced as a standard 4G technology. 802.16m systems can provide four times faster data speed than the WiMAX Release 1.WiMAX 2 will allow downlink speeds of up to 300Mbps. This technology supports MIMO, femto cells, self-organizing networks & relays, and multicarrier operation. It supports both 120Mbps downlink and 60Mbps uplink speeds [8].

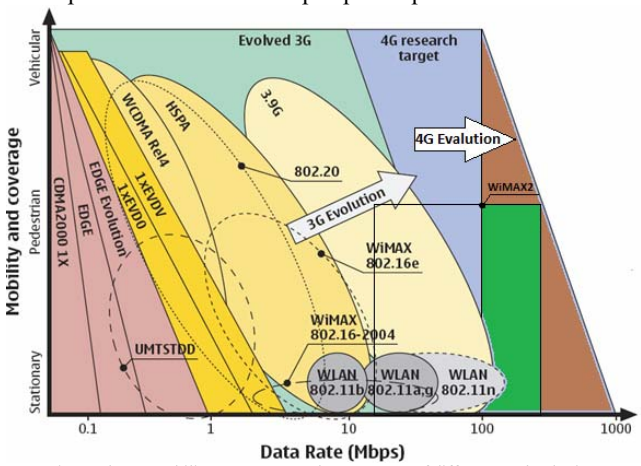

Fig. 5: Shows Mobility & Coverage v/s Data Rates of different Technologies

IV. IMPLEMENTATION CHALLENGES & SOLUTIONS

Technically 4G creates all integrated IP-based environment that supports voice, broadcasting media and Internet which enables users to enjoy both fixed and wireless communication networks. This makes user the centre of focus. Having intelligent terminals allows the user to simply get connected to broadband access with range of features that takes his personal preferences into consideration. With no interruption in active work; the user can change or switch terminals between fixed and mobile networks such as WCDMA and PSTN. The user is unable to detect this switching. With the help of Ad-Hoc networks the mobile terminals can automatically build networks, with the terminals of a third party or with each other [9]. In all this complex hierarchy the user always has full control of privacy and expenditure.

4G implementation challenges include:

1) Security and Privacy

4G is IP based network which is prone to serious security threats. Implementation of internet protocol security which has better encryption and authentication techniques like IPv6 can reduce this venerability.

2) Quality of Service

Application performance is an area of grave concern. With 4G, wireless users expect easy access to everything from Face Book & E-mail to video from their wireless devices. As a result consumers will judge quality of service based on application performance rather than traditional phone services.

3) Service & Billing

To reduce operating costs, devices that operate on 4G networks should have the capability to support different networks. This would reduce the operating cost, simplify design problems and will reduce power consumption. 4G networks are using "multi-mode devices" in which software radio allow the end-user device to adapt and interface to various wireless networks automatically. Due to the heterogeneity nature of 4G networks, wireless devices have to process, discover and connect to signals from different service providers with distinct protocols. These can be incompatible with each other. "System initiated discoveries". This mechanism allows automatic installation of software modules based on the wireless system the user is connected to. Another approach is based on overlay networks which perform all necessary tasks such as protocol translation and Quality of service negotiations. Managing user account and billing them becomes more hectic. Frame work need to be established to perform this task with utmost diligence.

4) Distinct Services

Distinct and fresh services which will provide new applications with increased benefits for the users are still scarce. Therefore, it is envisioned that the real advantage in shape of services that future foretell will be based upon the integration of technologies that are structured to match the needs of different segments of market.[10]

V. 5G VISION

With the deployment of LTE-Advanced in 2010 we are currently living the 4th Generation era. The 3G technologies WiMAX, LTE, IPv6 & IMT-2000 etc are at the heart of WiMAX-2 and LTE-Advanced 4G technologies. There is a shift in user approach from voice-driven wireless revenue model to a focus on non-voice services such as broadband, data & video services. So voice average revenue per user (ARPU) has come down over the previous 5 years. Short message service (SMS) is similar strained position. Hope of future lay in data & content services that include video. 4G technologies can become stepping stone towards 5G. To comply with these growing demands we need to follow the suite of technology evolution. The goal is to govern our desires and enjoy extreme environment where virtual & real are one or the same. To explore these un-chartered territories we need to broaden our imagination to vision a world where wireless personalized services have no limitation and shortage of bandwidth.

VI. CONCLUSION

Though 4G technology is around the corner but there is some work to be done. Deploying LTE-Advanced & WiMAX-2 is of utmost importance. Steps need to be taken now so that we may lay provisions for a global network. This global network will be able to cater the needs of users on personalised bases. Backwards compatibility is the core issue so that the new emerging technology supports the previous infrastructure. Our best hope is to start developing next generation technologies now.

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