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Decoding of PBCH in LTE

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ABSTRACT
Based on GSM/EDGE and UMTS/HSPA technologies LTE (Long term evolution) is the latest advancement in the cellular technology. LTE is backed by most 3GPP and 3GPP2 service providers and is commonly known as 4G. Designed to meet the needs of high speed data and mass media transport LTE is the first cellular communication system optimized from the outset to support packet-switched data services. In cellular systems, the basic System Information (SI) which allows the other channels in the cell to be configured and operated is usually carried by a Broadcast Channel (BCH). Therefore the achievable coverage for reception of the BCH is crucial to the successful operation of such cellular communication systems; LTE is no exception. This paper provides an in-depth view on the decoding of PBCH.

General Terms
Downlink, control channel

Keywords
LTE, OFDM, SC-OFDMA, MIMO, TDD, FDD

1. INTRODUCTION
LTE was first proposed in 2004 Toronto conference as the successor to 3G UMTS and HSPA in order to provide reduction in the cost per bit, the flexible use of new and existing frequency bands, a simplified and lower cost network with open interfaces, and a reduction in terminal complexity with an allowance for reasonable power consumption. LTE is an all IP based network, supporting both IPv4 and IPv6.

LTE supports scalable carrier bandwidths from 1.4 MHz to 20 MHz and both frequency division duplexing (FDD) and time division duplexing (TDD). It will enable operators to offer high performance, mass-market mobile broadband services, through a combination of high bit-rates and system throughput – in both the uplink and downlink – with low latency. It exploits Multiple-Input Multiple-Output (MIMO) antenna techniques and OFDM to deliver high data rates. In this paper LTE technical theories such as LTE architecture, physical and transport channels of Downlink (DL) and Uplink (UL), multiple access principles (OFDMA and SC-FDMA), MIMO is explained. The downlink physical channels carry information from the higher layers to the user equipment. PBCH is used to hold the system information for user equipment when requiring o acess te network.

2. LTE SPECIFICATION
LTE supports instantaneous downlink peak data rate of 100Mbit/s in a 20MHz downlink spectrum (i.e. 5 bit/s/Hz) and instantaneous uplink peak data rate of 50Mbit/s in a 20MHz uplink spectrum (i.e. 2.5 bit/s/Hz).It has a cell range of 5 km - optimal size and 30km sizes with reasonable performance and Cell capacity up to 200 active users per cell.Table-1 gives the basic lte specifications.

Table 1. lte basic specification .courtsey-itu journal.

Peak downlink speed 64QAM (Mbps)	100 (SISO), 172 (2x2 MIMO), 326 (4x4 MIMO)
Peak uplink speeds (Mbps)	50 (QPSK), 57 (16QAM), 86 (64QAM)
Data type	All packet switched data (voice and data). No circuit switched.
Channel bandwidths (MHz)	1.4, 3, 5, 10, 15, 20
Duplex schemes	FDD and TDD
Mobility	0 - 15 km/h (optimised), 15 - 120 km/h (high performance)
Latency	Idle to active less than 100ms Small packets ~10 ms
Spectral efficiency	Downlink: 3 - 4 times Rel 6 HSDPA Uplink: 2 -3 x Rel 6 HSUPA
Access schemes	OFDMA (Downlink) SC-FDMA (Uplink)
Modulation types supported	QPSK, 16QAM, 64QAM (Uplink and downlink)

3. LTE ARCHITECTURE
LTE has flat architecture since for normal user traffic (as opposed to broadcast), there is no centralized controller and has been designed to support only Packet-Switched (PS) services, in contrast to the Circuit-Switched (CS) model of previous cellular systems. It consists of two functional elements: Evolved-UTRAN (E-UTRAN) and System Architecture Evolution (SAE) which includes the Evolved Packet Core (EPC) network. Together LTE and SAE comprise the Evolved Packet System (EPS).

SAE is the evolution of the GPRS Core Network, with some differences. The EPS provides IP connectivity between a User Equipment (UE) and an external packet data network using E-UTRAN. An EPS bearer is typically associated with a QoS. Multiple bearers can be established for a user in order to provide different QoS streams or connectivity to different PDNs. A VoIP bearer would provide the necessary QoS for the voice call, while a best-e ff ort bearer would be suitable for the web browsing or FTP session. At a high level, the network is comprised of the CN (i.e.EPC) and the access network (i.e. E-UTRAN). While the CN consists of many logical nodes, the access network is made up of essentially just one node, the evolved NodeB (eNodeB), which connects to the UEs. Each of these network elements is inter-connected by means of interfaces which are standardized in order to allow multivendor interoperability.

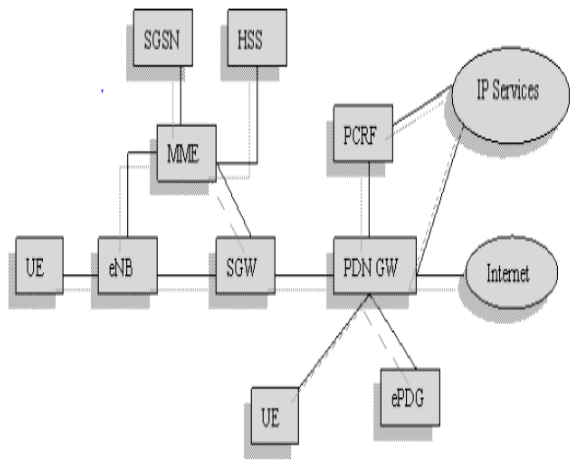

Fig. 1 High Level Architecture for 3GPP LTE Curtsey-Wikipedia

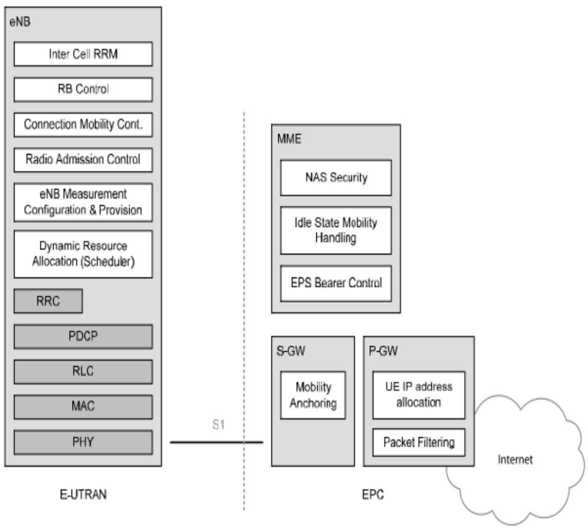

Fig 2. Functional split between E-UTRAN and EPC. Curtsey- Stefania Sesia and Issam Toufik," *LTE – The UMTS Long Term Evolution"*

3.1 The Core Network

The core network consists of four functional units responsible for the overall controls of the user equipment. They are:

1. *Evolved Radio Access Network (RAN)*: it mainly consists of a single RAN node named as eNodeB (eNB). The eNB interfaces with the User Equipment (UE) and hosts the physical layer (PHY), Medium Access Control (MAC), Radio Link Control (RLC), and Packet Data Control Protocol (PDCP) layers. Its functions include radio resource management, admission control, scheduling, enforcement of negotiated UL QoS and compression/decompression of DL/UL user plane packet headers.

2. *Serving Gateway (SGW):* it performs as the mobility anchor for the user plane during inter-eNB handovers and as the anchor for mobility between LTE and other 3GPP technologies. At the same time, it routes and forwards user data packets. The SGW controls the termination of the DL data path and paging while DL data comes to UE and replicates the user traffic when lawful and rational interception. It also manages and stores UE information, for instance, parameters of the IP bearer service, network internal routing information.

3. *Mobility Management Entity (MME):* the key control-node for the LTE access network. It tracks and pages the idle mode UE, even retransmission. MME selects the SGW for a UE at initial attach and at time of intra-LTE handover involving Core Network (CN) node relocation. When authenticating the user, it interacts with the HSS (a master user database supporting IP Multimedia Subsystem and including subscriber information) through the specified interface.

4. *Packet Data Network Gateway (PDN GW):* it has two key roles in terms of functionality. First, the PDN GW supports the connectivity to the UE and to the external packet data networks via the entry and exit of UE traffic. The other key role of the PDN GW is acting as the anchor for mobility between 3GPP and non-3GPP technologies such as WiMAX and 3GPP2 (CDMA 1X and EvDO).

The LTE architecture running normally and efficiently must have the well-designed physical and transport channels between DL and UL, since all the packets transmissions are inevitably involved both two links and then how the channels to be designed to enable dynamic resource utilization naturally becomes important.

3.2 The Access Network

eNodeBs of LTE E-UTRAN constitutes the access network of LTE. Where the eNodeBs are normally inter-connected with each other by means of an interface known as X2, and to the EPC by means of the S1 interface – more specifically, to the MME by means of the S1-MME interface and to the S-GW by means of the S1-U interface.

The protocols which run between the eNodeBs and the UE are known as the Access Stratum (AS) protocols.

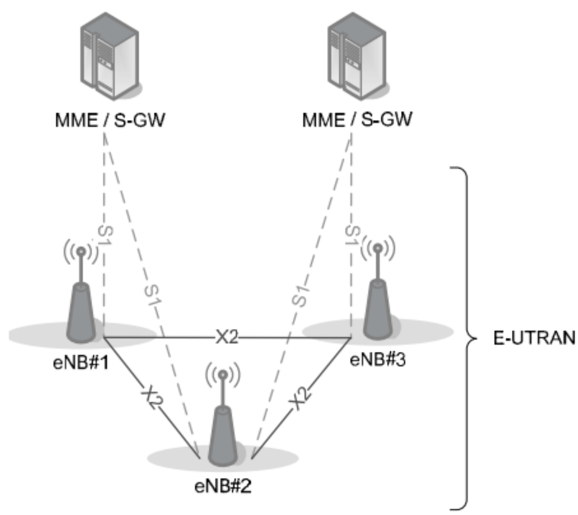

Fig .3.Overall E-UTRAN architecture.. Curtsey- Stefania Sesia and Issam Toufik," *LTE – The UMTS Long Term Evolution*

3.3 LTE Uplink and Downlink Control Channels

Control channels are integral part of any communication system. Both uplink and downlink consist of physical channels and transport channel. These are:

1. *Physical and Transport Channels for Uplink*

Physical Channels:

- Physical Uplink Control Channel (PUCCH): To send Hybrid ARQ acknowledgement.
- Physical Uplink Shared Channel (PUSCH): This channel on the UL is the UL counterpart of PDSCH.
- Physical Random Access Channel (PRACH): This UL physical channel is for the purpose of random access functions.

Transport Channels:

- Uplink Shared Channel (UL-SCH): Similar as Downlink Shared Channel (DL-SCH).
- Random Access Channel (RACH): To be used for random access requirements.

2. *Physical and Transport Channels for Downlink*

Physical Channels:

- Physical Broadcast Channel (PBCH): It holds the system information for UEs when requiring accessing the network.
- Physical Control Format Indicator Channel (PCFICH): This channel is used for managing the transmission format.
- Physical Downlink Control Channel (PDCCH): The purpose of this physical channel is primarily to carry the scheduling information.
- Physical Hybrid ARQ Indicator Channel (PHICH): This channel is used to report the Hybrid ARQ status.
- Physical Downlink Shared Channel (PDSCH): This is used for unicast and paging.
- Physical Control Format Indicator Channel (PCFICH): It supplies information to decode the PDSCH via UE.

Transport Channels:

- Broadcast Channel (BCH): This transport channel maps to Broadcast Control Channel (BCCH)
- Downlink Shared Channel (DL-SCH): This is the main channel for downlink data transfer, used by many logical channels.
- Paging Channel (PCH): To convey the Paging Control Channel (PCCH)
- Multicast Channel (MCH): To transmit Multicast Control Channel (MCCH) information.

3.4 PBCH

It is the most important of the downlink control channel in LTE. The 'Master Information Block' (MIB), which consists of a limited number of the most frequently transmitted parameters essential for initial access to the cell,1 and is carried on the Physical Broadcast Channel (PBCH). The design of PBCH reflects some specific requirements:

- Detectability without prior knowledge of the system bandwidth;
- Low system overhead;
- Reliable reception right to the edge of the LTE cells;
- Decodability with low latency and low impact on UE battery life.

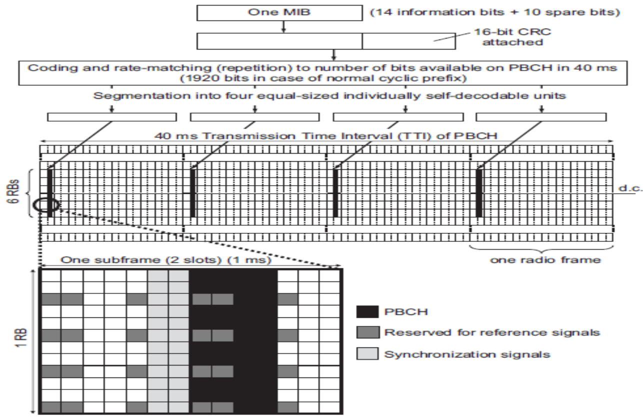

Fig4. Pbch structure

Detectability without the UE having prior knowledge of the system bandwidth is achieved by mapping the PBCH only to the central 72 subcarriers of the OFDM2 signal (which corresponds to the minimum possible LTE system bandwidth of 6 Resource Blocks (RBs)), regardless of the actual system bandwidth. The UE will have first identified the system centre frequency from the synchronization signals.

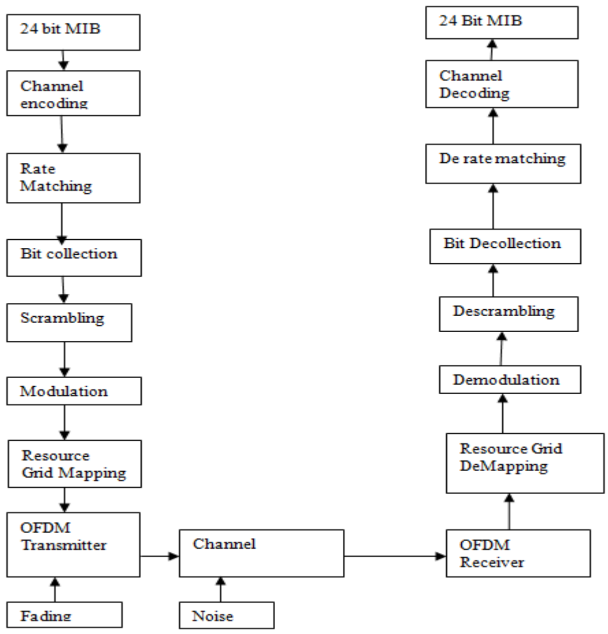

Fig. 5 Block diagram showing signal processing of PBCH

3.4.1. Transmitter

The 24 bit sequence of once and zeros of master information block act as the input. This then convolutionally coded after CRC attachment.This is followed by rate matching of the bits. The first operation on the physical layer is scrambling. A codeword of 32 bits in length is scrambled with a scrambling sequence which is unique for each cell. Scrambling sequences are pseudo-random sequences created by the generator of

Gold Sequences of 31 bits in length [4]. At the beginning of every subframe this generator is initialized using the slot number in radio frame ns and the cell identification number Ncell ID . The scrambling sequence, which is unique for each cell in the system, is a means of supressioning intercell interference. Interference received together with the correct data stream will be descrambled incorrectly and they will be decoded only as a non-correlated noise.

The scrambled bits are modulated by QPSK modulation and then form a block of complex-value symbols [4]. Next, complex symbols are mapped into one, two or four layers; depend on the number of transmitting antennas. Next, complex symbols are mapped into one, two or four layers; depend on the number of transmitting antennas. Complex, modulated symbols denoted d(0)(i) are mapped into n-layers

x(0)(i);x(1)(i); : : : ;x(n□1)(i). In the case of one transmitting port, layer mapping is not used, thus x(0)(i) = d(0)(i). In the case of two or four transmitting ports, layer mapping and symbol selection are provided sequentially.

The block of layer-mapped symbols goes into the coder, from which a data sequence is generated for every transmitting antenna port yp, where p is the number of antenna ports. If only one antenna is used for transmitting (SISO), coding is not implemented. Coding for Transmit Diversity (TxD) is available only for two or four antenna ports. The block of complex-valued symbols $y^{(p)}(0),\ldots,y^{(p)}(M_{\mathrm{symb}}-1)$ for each antenna port is transmitted during 4 consecutive radio frames starting in each radio frame fulfilling $n_{\mathrm{f}} \bmod 4 = 0$ and shall be mapped in sequence starting with $y(0)$ to resource elements (k,l). The mapping to resource elements (k,l) not reserved for transmission of reference signals shall be in increasing order of first the index k , then the index l in slot 1 in subframe 0 and finally the radio frame number. The resource-element indices are given by

$$k = \frac{N_{\mathrm{RB}}^{\mathrm{DL}} N_{\mathrm{sc}}^{\mathrm{RB}}}{2} - 36 + k', \qquad k' = 0,1,\ldots,71$$
$$l = 0,1,\ldots,3$$

Where resource elements reserved for reference signals shall be excluded. The mapping operation shall assume cell-specific reference signals for antenna ports 0-3 being present irrespective of the actual configuration

Payload bit pattern (2 bits)	Modulated symbol	
	In-phase (I)	Quadrature (Q)
00	$1/\sqrt{2}$	$1/\sqrt{2}$
01	$1/\sqrt{2}$	$-1/\sqrt{2}$
10	$-1/\sqrt{2}$	$1/\sqrt{2}$
11	$-1/\sqrt{2}$	$-1/\sqrt{2}$

Fig 6 . QPSK Modulation Pattern

3.4.2. Receiver

When the signal passes through the channel (here signed as MIMO channel), first the cyclic prefix (CP) of OFDM symbol is removed and FFT is performed. After that, resource demapping and selection of symbols corresponds with PBCH from the resource (time-frequency) grid take place.

In the MIMO detection block, decoding and symbol combination (in the case of transmission using multiple antennas) are performed. Symbols are demodulated and descrambled.

4. SIMULATIONS

In order to visualize the effect of this type of channel on a system, we add the fading channel to a system containing coding scrambling and modulation and observe the input signal to the demodulator. Note that by running the experiment in the using MATLAB function, we can observe how even a static flat-fading channel that represents a mild form of channel response significantly degrades the performance. Figure 7 shows the frequency response of the transmitted and received signals within the transmission bandwidth. It explains why this is called a flat-fading channel, as throughout the bandwidth at each frequency the response is faded by the same value.

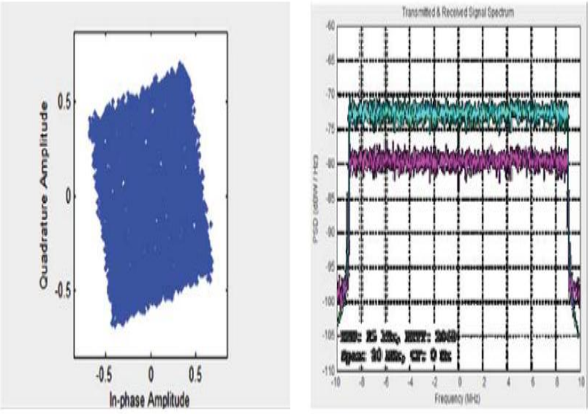

Fig 7. flat-fading channel

The mapped bits are fed to the channel where AWGN noise is added. On plotting the bit error ratio against the SNR we get the following graph.

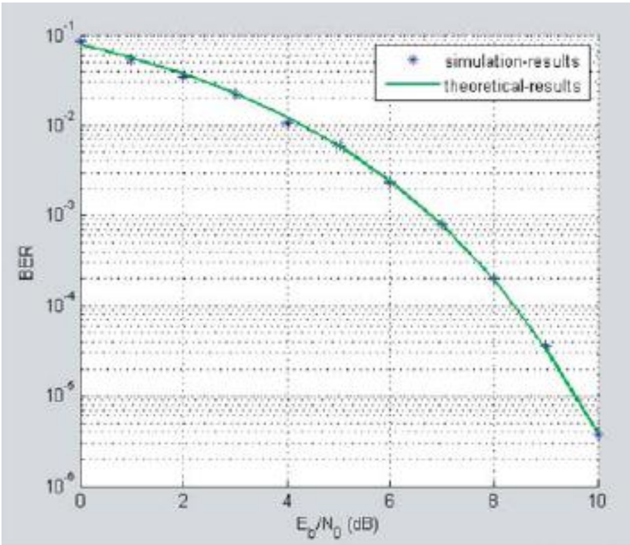

Fig8. Plot of BER vs. SNR for AWGN channel

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5. CONCLUSIONS

LTE is a highly optimized, spectrally efficient, mobile OFDMA solution built from the ground up for mobility, and it allows operators to offer advanced services and higher performance for new and wider bandwidths.

LTE is based on a flattened IP-based network architecture that improves network latency, and is designed to interoperate on and ensure service continuity with existing 3GPP networks. LTE leverages the benefits of existing 3G technologies, OFDM techniques and enhances them further with additional antenna techniques such as higher-order MIMO. In order to remove the fading we can replace the normal cp by extended cp. One of the most important features of the OFDM is its robust and efficient treatment of multipath fading. OFDM compensates for the effect of fading through a frequency-domain approach to equalization. In this case,to lower BER it is strongly recommended to use receiving diversity with two receiving antennas.

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