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Link Adaptation Metrics of 4G Systems– Survey

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***Abstract:* -- The ever growing data rates in fourth generation (4G) mobile communication systems need to have low feedback delays at cell edges and to achieve peak data rates up to 100 Mbps in the downlink for a bandwidth of 20 MHz. The accuracy of the link adaptation depends on the accurate Signal to Noise Ratio (SNR) estimation and the chosen modulation order, which directly affects the system throughput. This paper seeks to analyze the performance of the system w.r.t. average cell throughput and cell-edge throughput link adaptation metrics.**

***Keywords:*- 4G, Channel State Information, OFDM, SNR**

I. INTRODUCTION

In the wireless environment, usually, the signals are impaired by fading and multipath phenomenon, this leads to errors in the system‘s overall performance and becomes very poor. Channel coding and adaptive modulation techniques have been widely used for high-speed data transmission by combining Orthogonal Frequency Division Multiplexing (OFDM) with Multiple Input Multiple Output (MIMO). The MIMO-OFDM yields enhanced robustness against frequency-selective fading and high scalability in high data rates. And these techniques are used to fulfill the demands of long-term evolution (LTE) and the future fourth-generation (4G) communication systems [1–4].

The evolution of fourth Generation communication systems (4G) by the Third Generation Partner Project (3GPPP) and International Telecommunication Union (ITU) initiated the work on Release 8 (Rel-8) Long Term Evolution (LTE) radio interface in December 2004 [5-8]. The work continued through Rel-10 to define the requirements of International Mobile Telecommunications Advanced (IMT-Advanced) by the International Telecommunications Union (ITU) [4]. Using the novel approaches and technical challenges, the 3GPPP developed Rel-11 and Rel-12 to meet performance IMT-Advanced targets [9].

The performance of the 4G systems can be improved by adjusting the proper modulation and coding scheme for transmissions known as link adaptation. But, there are several parameters that influence the system performance such as:

1. The feedback delay from the time of channel estimation up to the actual transmission of data.
2. Measurement and rounding errors
3. Traffic between eNodeB and UE
4. Channel quality

Link adaptation is based on the channel state information (CSI). Channel Quality can be estimated based on Bit Error Rate threshold, averaging all CSI data, and prediction of CSI [10-11]. Due to the time varying channel, the measured SNR may become outdated. We investigated the channel quality measurement techniques based on cell specific LTE downlink reference signals.

The structure of the paper is organized below. Section 1.2 describes the theoretical background of LTE downlink channels and signals. Section 1.3 describes about simulation model and section 1.4 presents the performance analysis of various approaches in link adaptation. The section 1.5 presents the conclusions.

II. SYSTEM MODEL

The fourth generation radio network standard, Long Term Evolution (LTE) supports more band width flexibility such as 1.25, 1.6, 2.5, 5, 10, 15, 20 and 100MHz. Also, allows high data rates from 100Mbps to 1Gbps in the downlink using efficient radio access

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techniques namely Multiple Input and Multiple Output (MIMO) and multi carrier modulation technique Orthogonal Frequency Division Multiplexing (OFDM). The LTE base stations, eNodeBs (Evolved NodeBs) and mobile stations, User Equipment (UEs) define different protocol layers to carry the information. The modulation and coding at the transmitter and the decoding at receiver are handled by physical layer techniques using physical channels and physical signals [12]. Physical channels carry information from higher layers including control, scheduling and user payload. Physical signals are used for system cell identification, channel estimation and system synchronization.

LTE Downlink Channels:

- Physical Downlink Shared Channel (PDSCH): The channel transports data and multimedia payload. It is designed to achieve very high data rates. This channel is suitable for different modulation techniques QPSK, 16QAM and 64 QAM [13].

- Physical Downlink Control Channel (PDCCH): This channel carries control information like UE specific ACK and/or NACK. It is designed for robustness than achieving the high data rate. QPSK is the only available modulation format used in this channel.

- Common Control Physical Channel (CCPCH): This channel conveys information about cell wide control. The CCPCH is transmitted as close to the centre frequency.

- Physical broadcast channel (PBCH): It carries cell specific and system related information.

- Physical multicast channel (PMCH): It is a downlink physical channel that carries the multicast or broadcast information.

- Physical control format indicator channel (PCFICH): It defines number of PDCCH OFDMA symbols per sub-frame.

LTE Physical Signals

- Primary Synchronization Signal: This signal used for cell search and identification by the user equipment (UE). It carries a part of the cell ID.
- Secondary Synchronization Signal: Performs the same function as the primary but carries the remainder of the cell ID.
- Reference Signal: It is used for downlink channel estimation. There are three types of reference signals such as cell specific downlink reference signals, UE specific reference signals and multicast broadcast single frequency networks (MBFSN) reference signals.

LTE Downlink time frequency structure of OFDM subcarriers:

Each LTE downlink radio frame is of length 10 ms, which is divided into 10 sub frames of length 1 ms each. Each of downlink sub frame is divided into two slots of equal length of 0.5 ms each comprises with two resource blocks. Each resource block (RB) defined as one time slot in time domain and chunk of subcarriers in frequency domain. The number of symbols in each subcarrier can be 7, 6 or 3 and the number of subcarriers defined as 12 or 24 depending on subcarrier spacing either 15 KHz or 7.5 KHz. The figure 1 represents time – frequency grid for LTE downlink resources.

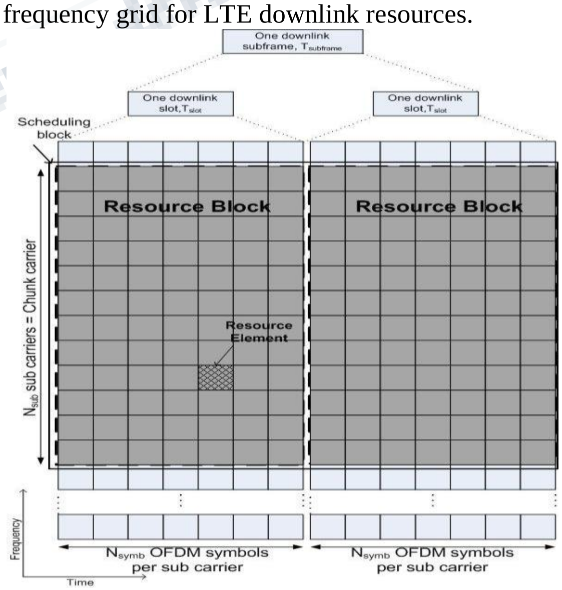

Figure1. LTE Downlink time frequency grid

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Link adaptation depends on channel state information (CSI), user ID, scheduled resources and modulation scheme to be used. Different channel estimation and link adaptation techniques have been proposed in the literature [14]. The proposed work is able to adjust the channel state information based on channel impairments. The paper presents two algorithms, namely link adaptation for fast varying channels (LAFVC) and link adaptation for slowly varying channels (LASVC), differ by channel quality.

III. LINK ADAPTATION FOR FAST VARYING CHANNELS (LAFVC) ALGORITHM

This algorithm is used in LTE downlink simulations for the MIMO antenna configuration based on the feedback ACK and NACK information for the last transmission of data. The ratio, ACKadj and NACKadj can be regarded as a target BER and will be referred to as BER target. For link adaptation under fast varying channels (LAFVC) algorithm adjusts the individual user link adaptation margin on a frame by frame basis depending on whether the last transmission attempt was successful or not. It involves two parameters, if the last transmission was successful (ACKadj) or unsuccessful (NACKadj). consider the optimum values of the ACKadj (successful transmissions) and NACKadj (unsuccessful transmissions) parameters based on the user environment shown in table 1.1.

Table 1.1. Optimum values for ACKadj and NACKadj parameters.

Optimum value	ACKadj	NACKadj
average cell throughput (1.0613 bps/Hz/cell)	0.1	0.6667
cell-edge user throughput (0.0233 bps/Hz)	0.15	0.4286

Algorithm:

Step 1: If an ACK is received for the last transmission, meaning that the last transmission was successful, the link adaptation data is decreased by a positive constant ACKadj dBs.

Step 2: If a NACK is received for the last transmission, meaning that the last transmission was unsuccessful, the LAM for that user is increased by a positive constant.

IV. LINK ADAPTATION FOR SLOWLY VARYING CHANNELS(LASVC) ALGORITHM

This algorithm is based on Bit Error Rate (BER) during a defined period and the number of negative ACKs in that period. WINsize is defined as the period of transmissions for a particular user. LOWerr and HIGHerr are the BER thresholds can be considered as low or high, respectively. For link adaptation under slowly varying channels (LASVC) algorithm is based on three parameters such as WINsize, LowBER and HighBER. The downlink transmissions being affected by interference and the presence of a LOS signal path greatly helps to overcome interference.

The table 1.2 depicts the BER optimum values depending on user category. Also, consider the window sizes in the range of 5-100 frames.

Table 1.2. Optimum values for LowBER and HighBER parameters.

User Category	Downlink LowBER	User Category	Downlink HighBER
Outdoor LOS Slow users	0.2017	Outdoor NLOS Fast users	0.4096
Outdoor LOS Fast users	0.2576	Outdoor NLOS Slow users	0.2912

Step 1: Count the number of NACKs treated as Block errors received in a period.
Step 2: At the end of the period, calculate the BER of the user.
Step 3: If the measured BER<=LOWerr, decrease the link adaptation SNR of the user by 1 dB.
Step 4: If the measured BER>=HIGHerr, increase the link adaptation SNR of the user by 1 dB. And, continue with a new window period.

V. SIMULATION PARAMETERS

The simulation is based on MATLAB to investigate the effects of various CSI on system performance (throughput). Consider maximum transmission attempts set to 1 in order to assess the user behavior under channel information inaccuracies. Table 1.3 depicts the simulation environment specifications based on modified ITU standards. Consider the performance metrics are average cell throughput and cell edge throughput.

Table 1.3. LTE Downlink modified simulation parameters [1].

S.No.	Downlink Parameter	Value
1.	Carrier frequency	2.5 GHz
2	Base station antenna height	10 m
3.	UE antenna height	1.5 m
4.	Indoor user speed	3km/h
5.	Outdoor user speed	30km/h
6.	Number of cells	21 cells (7 sites X 3 sec per site)
7.	Load	10 users per cell
8.	CSI reporting period	5ms
9.	CSI reporting delay	6ms

Based on actual known SNR, measure the SNR values experienced by the user at the time of transmission. Downlink reporting delay (~ 6 frames) refers to the time from channel estimation start time until the CSI used in link adaptation. From figure 2, the performance decrease in average cell throughput with increase in CSI report delay from 1 frame to the practical operating point of 6 frames is about 2.2%.

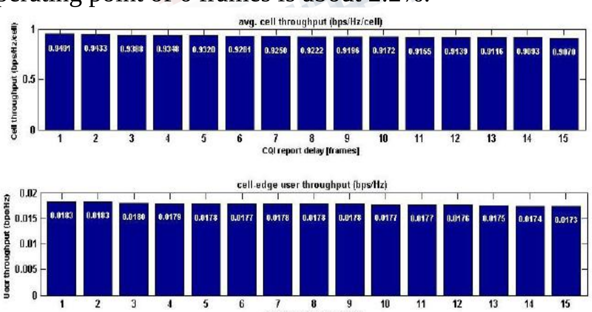

Figure 2. report delay vs. average cell-throughput, cell-edge user throughput.

On the other hand, fixed link adaptation margin refers to adjusting the CQI, for all the transmission streams by the same constant value. Using different fixed link adaptation margins in the range of -2 to 2 dB figure 3 shows the average cell throughput and cell-edge user throughput for different fixed link adaptation margins.

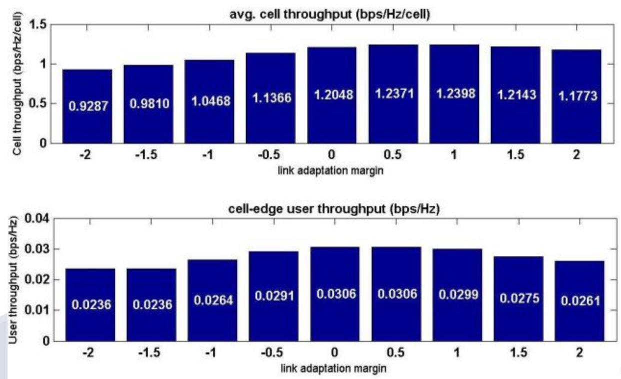

Figure 3. Downlink fixed link adaptation margins.

VI. CONCLUSION

The performance of downlink LTE systems has been studied and analyzed in terms of average cell throughput and cell-edge throughput. The performance was evaluated for link adaptation under fast varying channels and slowly varying channels, and observed that LAFVC algorithm performance is better in terms of average cell throughput and cell-edge user throughput in downlink, under imperfect CSI, when compared to the actual situation.

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