Analysis of Channel Quality Indicator in Long Term Evolution Networks

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Abstract

Long Term Evolution (LTE) has the vision of providing higher speed and ubiquitous access to mobile cellular users. In order to set the best coding scheme, user equipment (UE) of LTE network sends channel state information in shape of SINR at a fixed interval. In our work, we analyzed the SINR of a static and mobile users and its effect on the chosen modulation and coding scheme (MCS). Our analysis reveals that the amount of information (SINR) sent from a single user is of such a high frequency that a significant amount of resources are consumed.

1. Introduction

Long term Evolution (LTE) standard is a step towards the 4G networks with interoperability work facility and complete connectivity with previous cellular wireless standards. The goal of the standard is to provide high performance using high data rate modulation schemes and simplification of the existing IP network architecture in an economical way. The high data rates help to support services like voice over IP, streaming videos etc. A number of novel techniques have been incorporated in LTE standard as compared with previous cellular standards to enhance its performance.

A Physical Resource Block (PRB) is the smallest allocation unit which can be assigned by the enhanced node (eNB) scheduler to a user. The scheduling decisions are totally dependent on the channel quality experienced by the user equipment (UE). A UE periodically transmits a channel quality indicator (CQI) to the eNB which is used as a feedback. According to this feedback the most suitable modulation and coding scheme is employed with the objective of enhancing the spectral efficiency. It can be very evident that each frame has a limited number of resource blocks which can be allocated to each user. This makes PRB a scarce resource and intelligent techniques are required to utilize these resources. In this work, we focus on approaches used in the downlink direction of LTE networks and draw our analysis depending upon the throughput of individual user and its overall impact over other users due to mobility and incomplete channel state information.

Rest of the paper is formulated as follows. Section 2 presents the problem definition. Research methodology is given in section 3 followed by simulation setup & results in section 4, and finally we conclude the paper in section 5.

2. Problem Definition

We draw our analysis on the basis of channel quality indicator (CQI) as it is the only feedback received from the UE to eNB. After two Transmission Time Interval (TTIs), a UE measures and estimates the SINR for all available downlink sub channels from the received reference signal. The estimated SINR for each sub channel is then mapped accordingly to a CQI value and sent to the eNB through an uplink channel. A block error rate (BLER) of at least 10 percent is guaranteed while mapping the estimated SINR values against the CQI values [3]. The CQI value is sent by the UE periodically (typically 1ms) to eNB for all the available sub channels. The eNB after receiving the CQI values over different channels chooses a MCS scheme for each available sub-channel. The channel with the best MCS is chosen for a user to carry its transmission. In case of multiple RBs requirement, each user is assigned a number of RBs with a common MCS. Each group of RB would have a common MCS and normally the MCS chosen depends upon the least CQI value among the RBs [1]. Higher MCS values over RBs are directly related to lower number of resources for a user and vice versa. Users in a cell of LTE are either static or mobile; the former case has less chances of inaccurate SINR estimation while the latter case can have multiple reasons explained in the following discussion for inaccurate SINR estimations which correspond to inaccurate CQI values over a sub channel.

LTE is a logical extension of GSM networks which supports both the static and mobile users. This requirement is also expected from LTE network. The users in a cell move with different speed and LTE is bound to support their transmission with minimum quality of service. The CQI at different mobility needs to depict accurate SINR values. However at high mobility the CQI values are inaccurate due to user displacement. The major issue is that eNB's unawareness of user's new position which may have deep fades over some frequencies. The transmission over this frequency will result in loss and wastage of RB(s). The second issue is inefficient RBs assignment which will not only lead to performance degradation of the individual users but will also affect the complete system's performance.

Our contribution includes the performance analysis of user mobility and signal strength effect on the decision of chosen MCS value in a single cell LTE network.

3. Research Methodology

In our analysis we have considered flows from nonguaranteed bit rate (NGBR) class only [4] generated by a number of users at different mobility levels in a cell. NGBR is chosen to maintain fairness among the user demands. These flows are then scheduled by a scheduler; we have used the proportional fair (PF) scheduler for our analysis. All the user equipment's that are connected to the eNB periodically send their CQI over available sub channels after estimating there SINR. The SINR is calculated by the received reference signal. Mathematically it can be expressed as equation 1.

$$SINR_{i,j}(t) = \frac{P_{total}C_{i,j}(t)}{N(N_0 + I)} \quad (1)$$

Where P_{total} is the received aggregated power of eNB for the downlink direction, Ci,j(t) is the channel gain at time t for a user i at RB j, N represents the total available Rb, N_0 is a measure of thermal noise and I is the interference of a neighboring cell. As a future work of our analysis we aim to evaluate the aggregated cell throughput, system delay and packet loss ratio (PLR) which are mathematically represented by equation 2, 3 and 4 respectively in a cell for an individual user at pedestrian(3Km/h) and vehicular mobility (120Km/h).

$$Throughput = \frac{1}{T}\sum_{m=1}^{M}\sum_{t=1}^{T} p_{size}(t) \quad (2)$$

Where T is the total simulation time expressed in seconds, psize represents the packet size in bits from eNB to a user m during simulation, and M represents the total number of users.

$$Delay = \frac{1}{T}\sum_{t=1}^{T}\frac{1}{M}\sum_{m=1}^{M} HOL_m(t) \quad (3)$$

Where T is the total simulation time, M is the total number of users in a flow and HOL represents head of line packet.

$$PLR = \frac{\sum_{m=1}^{M}\sum_{t=1}^{T} P_{discard,i}(t)}{\sum_{m=1}^{M}\sum_{t=1}^{T} P_i(t)} \quad (4)$$

Where $P_i(t)$ is the total packets sent to eNB.

4. Simulation Setup & Results

We have used the LTE-Sim [5] simulator to draw our analysis. The system operational bandwidth used for the simulation was 10 MHz which allows 50 RBs in total to be transmitted in a frame. A cell without interference is considered in our analysis. The radius of the cell is 1 Km and no sectoring is considered in our system. The UEs are randomly placed in the system and the mobility model for the UEs is random direction. The UEs either support pedestrian or vehicular mobility that correspond to (0-3 km/h) and 120 km/h. the subcarriers per RBs are fixed to 12 and spacing between the subcarriers is considered to be 15 KHz. The slot duration of the frame is fixed to 0.5 ms and each frame has 20 slots using an FDD type configuration of a frame. There are three types of application flows in a cell with different requirements. Constant bit rate (CBR) operates at 100 kbps, 12 kbps for voice over IP (VOIP), and 242 kbps for video applications. In our analysis, each user has a demand of five flows of all the application flows from the base station during the complete simulation time.

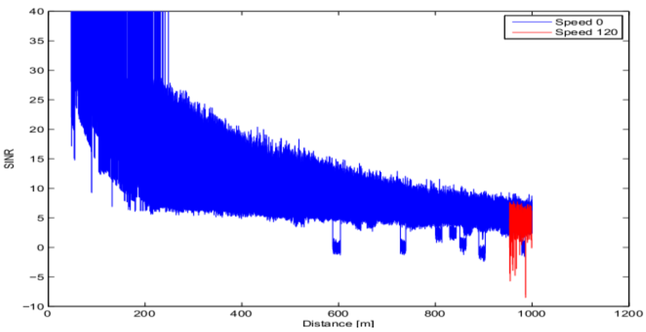

Figure 1: SINR vs Distance

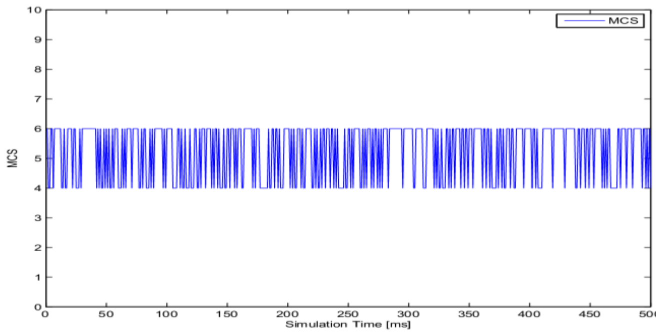

Figure 2: MCS vs Simulation Time

The overall SINR (dB) values for both a low mobile and high mobile user can be seen in figure 1 with respect to distance from the eNB in meters. It can also be seen that the SINR values drop drastically as the user is moving away from the eNB towards the edge of the cell. In this graph it can be inferred that the change in mobility does not have much of an impact on the SINR values of the users. The simulation lasts for 500 seconds.

In figure 2, the MCS values are shown over the simulation time (500 ms). It can be seen from the trend in the graph that MCS remains constant for a long period of time when the user is considered highly mobile and the total numbers of users in a cell are five. It can be seen that the MCS values fluctuates in between 4 and 6. This is because even at high mobility (120 Km/h) the maximum displacement is equal to 0.03 meters for a single user. This also shows that SINR values which is sent periodically to the eNB provides a lot of redundancy which can be reduced that will result in saving a significant amount of bandwidth while maintaining the same quality of performance for the base station (eNB).

5. Conclusion

An analysis for pedestrian and vehicular mobility in a single cell LTE network is presented with varying number of users in this study. The analysis was performed using the simulation tool LTE-Sim. The SINR values send by UE to eNB at different mobility were analyzed. The analysis reveals that even at a very high mobility, the amount of information from a single user is of such a high frequency that a significant amount of resources is consumed.

These resources can be utilized for multiple reasons to enhance the overall performance of the network. Our study also shows that MCS values remain constant over a long period of time at high mobility. As a future course of research, we would draw an analysis to compute the performance when lesser number of CQI feedbacks are received to the eNB by an individual user. We also aim to study its overall effect on the network performance in terms of throughput, delay and packet loss ratio.

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7. References

[1] J. Fan, Q. Yin, G. Y. Li, B. Peng, and X. Zhu, "Adaptive block-level resource allocation in ofdma networks", IEEE Transactions on Wireless Communications, 10 (11) (2011) 3966-3972.

[2] J. Niu, D. Lee, X. Ren, G. Y. Li, and T. Su, "Scheduling exploiting frequency and multi-user diversity in LTE downlink systems", IEEE Transactions on Wireless Communications, 12 (4) (2013) 1843-1849. doi:10.1109/TWC.2013.022013.121020.

[3] G. Piro, L. A. Grieco, G. Boggia, R. Fortuna, and P. Camarda, "Two-level downlink scheduling for real-time multimedia services in LTE networks", IEEE Transactions on Multimedia, 13 (5) (2011) 1052-1065.

[4] [4] M. Alasti, B. Neekzad, J. Hui, and R. Vannithamby, "Quality of service in wimax and LTE networks" [topics in wireless communications], IEEE Communications Magazine, 48 (5) (2010) 104-111.

[5] G. Piro, L. A. Grieco, G. Boggia, F. Capozzi, and P. Camarda, "Simulating LTE cellular systems: an open-source framework", IEEE Transactions on Vehicular Technology, 60 (2) (2011) 498-513.