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ON THE EVALUATION OF THE LTE-ADVANCED PROPOSAL WITHIN THE CANADIAN EVALUATION GROUP (CEG) INITIATIVE: PRELIMINARY WORK RESULTS

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ABSTRACT

In this paper, we present a preliminary work within the CEG to evaluate the LTE-advanced proposal as a candidate for further improvements of LTE earlier releases. We consider an open-source LTE simulator that implements most of the LTE features. We focus on channel state variations and related link adaptation. We study the performance of channel quality report to the transmitter to track the downlink time-frequency channel variations among users. This process aims at performing link adaptation. To insure this procedure, we implement a CQI feedback scheme to an LTE open-source simulator. SINRs per subcarriers are computed supposing a perfect channel knowledge then mapped into a single SINR value for the whole bandwidth. This SINR is represented by a CQI value that allows for dynamic MCS allocation. CQI mapping is evaluated through different SINR mapping schemes.

1. INTRODUCTION

Recent wireless systems should satisfy the requirements for high peak data rates and high bandwidth efficiency. The 3^{rd} Generation Partnership Project (3GPP) has specified the key technologies to achieve such requirements [1]. LTE for Long Term Evolution is being finalized in 3GPP by defining the new requirements and targets for data rate, system capacity, spectrum efficiency and latency. Based on these requirements, 3GPP LTE has defined the key features to reach such goals.

The 3GPP standardization of LTE is nearing completion leading to start a new study to seek a candidate for further technology enhancement. LTE-advanced is the successor to LTE systems that is targeted to meet the IMT-Advanced requirements keeping the compatibility with LTE Release 8 (IMT for International Mobile Telecommunications). LTE-Advanced aims at improving the performance of the existing release to reach and surpass the requirements of IMT-Advanced based on technologies already supported by earlier releases. In this context, the CEG is operating under the auspices of the ITU Canadian National Organisation (CNO) to evaluate candidate Radio Transmission Technologies (RTTs) and radio interface proposals. Manufacturers, service providers, universities and research institutions are participating in the CEG project. This study is a preliminary work, in the particular context of the CEG initiative, on the evaluation of LTE-Advanced systems which are a successor of LTE systems.

LTE-Advanced technologies support flexible bandwidth deployments and are multicarrier-based technologies for the deployment of 4G systems [2]. Orthogonal frequency division multiple access (OFDMA) and multiple-input multiple-output (MIMO) technologies are the retained candidates in LTE systems for downlink transmissions to mitigate the inter-symbol interference and to cope with the multipath fading problems [3]. The single-carrier frequency division multiple access (SC-FDMA) is used on the uplink.

The flexible nature of the LTE structure allows for adaptive and sharing techniques. On one hand, the sharing resource structure of OFDM-based systems allows for the deployment of scheduling techniques. On the other hand, in LTE the access scheme presents a two-dimensional resource sharing structure with time and frequency dimensions [4]. A scheduling technique should satisfy the following trade-off: maximizing the system throughput and enhancing the spectral efficiency while insuring a fair behavior towards users by meeting the target data rates. Furthermore, the multicarrier nature of the access scheme allows to track the channel variation over time and frequency dimensions. Hence, we talk about advanced radio resource management (RRM) functions [5]. These functions are mainly hybrid automatic repeat request (HARQ), link adaptation (LA) and channel state report. The HARQ process aims at retransmitting the erroneous packets and keeping a minimum radio interface delay.

The channel quality, measured in terms of channel quality indicator (CQI), is utilized to report the channel variation among users and perform LA. In fact the CQI maps the channel state from indirect metrics such as bit error rate (BER) and signal-to-noise and interference ratio (SINR) [6]. The performance of the LA mechanism depends on the quantifying process that computes the CQI values. In the literature, many mapping schemes were studied.

We consider here LA through the feedback of the CQI computed at the receiver to adjust the transmission parameters to the link variation over time seen differently by each user. To do so, we give in the next section a brief overview of LTE systems and the used LTE simulator to develop our approach. In section 3, we state the CQI mapping schemes and the method applied in our work. Numerical results are shown in section

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4. Section 5 draws out some concluding remarks and perspectives.

2. OVERVIEW OF THE LTE SIMULATOR

2.1. LTE specification: requirements and components

LTE is considered as a flexible radio interface that increases the spectrum efficiency with high data rates at low costs [7]. The starting point of LTE study was the definition of requirements and then targets. The key features of LTE to achieve these requirements are the multiple access schemes, adaptive modulation and coding (AMC), multi-antenna techniques, hybrid automatic repeat request and radio resource allocation.

The core transmission scheme in LTE is OFDM where data is transmitted over a large number of parallel narrow-band subcarriers. OFDM is selected due to its robustness to multipath propagation problems and its flexibility to support frequency diversity. For each transmission over a single subcarrier or group of subcarriers, a modulation and coding scheme (MCS) is applied to perform LA through AMC.

2.2. LTE resource structure

For LTE, the access scheme is OFDMA whith its two-dimensional resource sharing structure over time and frequency. The time dimension is described as a transmission time interval (TTI) corresponding to one subframe of 1ms composed of 2 slots of 0.5 ms each. The frequency dimension, known as a chunk, is composed of 12 OFDM subcarriers. In other words a chunk describes a resource block of 6 or 7 OFDM symbols, depending on wether the cyclic prefix (CP) is normal or extended, respectively. Each RB is composed of resource elements (REs) each formed by one subcarrier and one OFDM symbol.

2.3. LTE simulator

In our work, we used the LTE open-source simulator proposed in [8] combined with simulation tools developed by INRS over a span of 15 years.

The simulator operates in three scenarios: the single-cell downlink, the single-cell multi-user and the multi-cell multi-user. For the single-cell downlink scenario, only the link between one user and one base station is considered. In this scenario, the following features are treated: channel estimation, channel tracking, channel prediction, adaptive modulation and coding (AMC) feedback, physical layer modeling, channel coding, MIMO schemes, signal generation and channel model.

The link-level simulator models the downlink shared channel (DL-SCH). A time-frequency grid is considered to perform multiple access and resource allocation. Each element in the grid consists of one OFDM subcarrier during one OFDM symbol. One resource block is composed of 6 to 7 OFDM symbols.

To encode users, a turbo encoder is used for each user's data then each encoded block is interleaved based on quadrature permutation polynomial (QPP). The HARQ process is also considered with rate matching. The simulator can support different diversity schemes, different bandwidth sizes, different channel models and scheduling methods. For scheduling, only round robin is implemented. Proportional fair, adaptive allocation and dynamic MCS assignment are not yet implemented.

3. PROPOSED APPROACH FOR LINK ADAPTATION

3.1. Channel quality mapping

The link adaptation process consists in choosing the appropriate MCS under the current channel conditions for each user. On a particular realization, the channel state is reflected by the BER or the SINR. However, these metrics can not be directly transmitted, so they should be mapped into an accessible measure which is the CQI. In the state of the art, many SINR-to-CQI mapping (respectively BER-to-CQI mapping) are introduced. Some CQI forms are performed supposing a perfect knowledge of the direct metric. In other cases, an error estimation is considered to estimate a more realistic CQI.

3.2. Proposed CQI feedback scheme

The LTE simulator described above is suitable to include many features of LTE systems. In this work, we consider the channel quality feedback and then the link adaptation.

For the moment, the CQI is computed at the channel generation level, which means that the CQI is calculated based on perfect channel knowledge.

The starting point consists of SINR calculation for all the available subcarriers when the channel is generated at the link level. SINR calculation depends on the type of the channel, the fading and the mulitple access scheme. Yet, only block fading is considered in this paper.

The proposed CQI calculation is processed as follows:

1. First, the SINR is computed per carrier for all the available subcarriers over the bandwidth, and hence we obtain a vector of SINRs,

2. Then, we map the obtained vector of SINRs to a single value to get an effective SINR. The effective SINR is computed using one of the three proposed methods in the literature. These methods are mainly, linear , geometric and exponential mapping.
   - the linear effective SINR is given as follows:

$$SINR = \frac{1}{N_{subcarriers}} \sum_{i=1}^{N_{subcarriers}} SINR_i,$$

   - the geometric effective SINR is as computed as:

$$SINR = exp(\frac{1}{N_{subcarriers}} \sum_{i=1}^{N_{subcarriers}} ln(SINR_i)),$$

- the exponential SINR is defined in [9]:

$$SINR = -\beta ln(\frac{1}{N_{subcarriers}} \sum_{i=1}^{N_{subcarriers}} exp(\frac{-SINR_i}{\beta})).$$

$SINR_i$ is the per subcarrier SINR and β is a scaling factor that depends on the MCS.

3. Once we get the effective SINR, we map it to a CQI value that translates the channel state for each user.
4. Finally, the obtained CQI is fed back to the transmitter to identify the equivalent parameters for the following transmission.

This process is executed periodically to track the channel variations. In this way, we could perform the link adaptation by setting the MCS based on the previous channel state and then adjust the current transmission parameters to the channel variations over time for each user.

4. NUMERICAL RESULTS

To evaluate the performance of the proposed SINR-to-CQI mapping scheme, some simulations were conducted and LA is performed for block fading channels.

4.1. Simulation environment

To conduct simulations over a single-input single-output scenario (SISO), the same parameters detailed in [8] are used over a Pedestrian A channel model. The scheduling scheme is based on round robin resource allocation. The dynamic MCS allocation is performed through CQI report to the transmitter. First, SINRs per subcarrier were collected then mapped to an effective SINR value as described above. Then, the corresponding CQI value is computed reflecting the channel state and reported to the transmitter. Finally, the transmitter adjusts the MCS regarding the received CQI from the previous iteration.

Since the channel used in these simulations is a block fading channel, it is supposed to be constant during one TTI interval. For this reason, the SINRs per subcarrier are computed over a period of 1 TTI corresponding to 7 OFDM symbols for a normal cyclic prefix.

Here, the CQI is computed periodically each 4 subframes corresponding to 2 TTIs to give one CQI report over the whole available subcarriers. The choice of the reporting period of 2 TTIs instead of 1 TTI aims at reducing the payload related to the CQI feedback in the case of block fading channels.

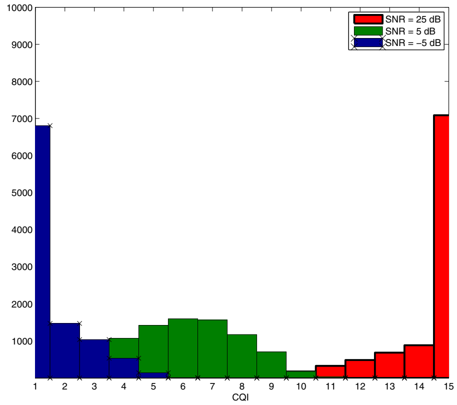

Fig. 1. CQI distribution over time for different SNRs.

4.2. Simulation results

Matlab-based simulations were conducted to study the performance of the system with CQI feedback. During simulation, the channel presents different conditions and so different SINR per subcarriers. The effective SINR is then changing which leads to different CQI values. In our simulations, the different measured effective SINRs are mapped to different CQIs which allows the transmitter to adjust the MCS regarding the received CQI. Fig. 1 illustrates the CQI variations over time when the input SNR is equal to -5 dB, 5 dB and 25 dB and the EESM (Effective Exponential SINR Mapping) is applied.

We compare our CQI feedback-based LA scheme with the case where no CQI feedback is conducted. To do so, we run simulations over a Pedestrian A (PedA) channel with a constant CQI value equal to 4 corresponding to a $QPSK$ modulation. This case corresponds to static MCS during the whole transmission independently of the channel conditions over time. For the dynamic scheme, we consider the EESM to map subcarrier SINRs to a single SINR value over the whole bandwidth.

We represent the system performance in terms of BER and throughput variation per cell. In Fig. 2, we show the performance of the system when the CQI is illustrating the channel variations (dynamic CQI). We notice that the BER is still under 10^{-1}. The performance is worse than the case when the CQI is maintained to 4.

If we translate these results to CQI variations shown in Fig. 1, we can predict this behavior. In fact, for low SNR input, the CQIs are small leading to low BERs. For SNR = -5 dB, the CQIs are less than 5 which approaches the BER given by a constant CQI$=4$. However, for high SNR input, the CQIs are high, hence giving high BER values as can be noticed for an SNR input of 25 dB giving CQI values greater than 7 corresponding to higher-order modulation and higher BER compared to a lower-order modulation as when CQI$=4$.

Considering the perviously described behavior, the perfor-

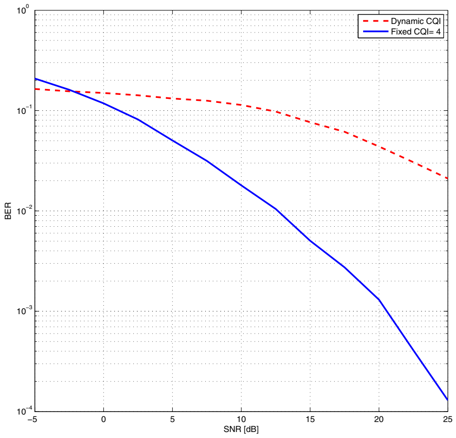

Fig. 2. BER: dynamic CQI feedback and fixed CQI scheme.

mance in terms of throughput is enhanced when using dynamic CQI metric, and hence MCS. We notice an improvement in the overall cell throughput when the channel variations are tracked. This result is shown in Fig. 3.
The three SINR mapping schemes give almost the same results. We opt for the EESM since it introduces a MCS depending factor. This is shown in Fig. 4.

5. CONCLUSION

In this paper, we gave an overview of LTE systems and the main features to achieve the target requirements. This work is stated within the initiative of the CEG to evaluate the proposal of the LTE-based candidate to reach the requirements of IMT-Advanced systems. We showed preliminary results of the implementation of the LTE-Advanced features. We presented a dynamic modulation and coding allocation scheme and performed channel quality feedback to the receiver to support link adaptation. To do so, we used an open-source LTE simulator that implements most features of LTE systems. Three SINR mapping schemes were introduced into the LTE simulator, linear, geometric and exponential mapping. Then we compared the system performance using with LA to the case without LA. This work will be followed by considering the IEEE proposal as a candidate for further enhancement of LTE technologies. Both technologies, 3GPP and IEEE, will be compared through link and system-level simulations considering several environments as required by the CEG.

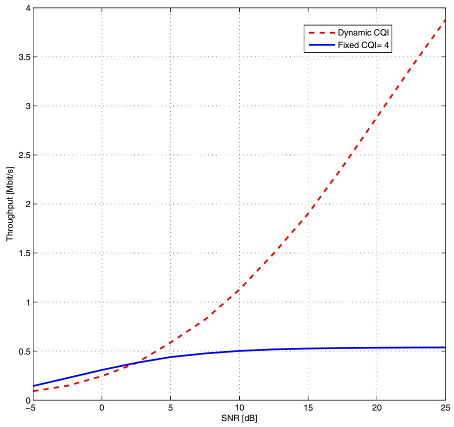

Fig. 3. Cell throughput of a dynamic CQI feedback and a fixed CQI scheme.

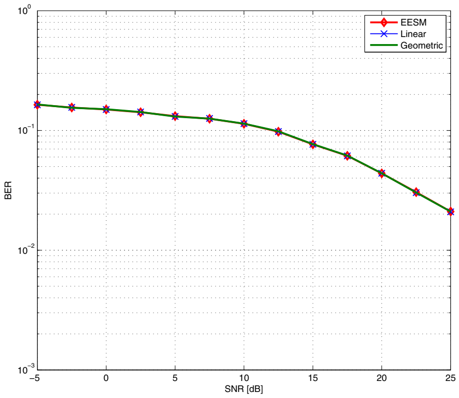

Fig. 4. Cell BER of the 3 mapping schemes.

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