Limiting HARQ Retransmissions in Downlink for Poor Radio Link in LTE

Mohammad T. Kawser, Nafiz Imtiaz Bin Hamid, Md. Nayeemul Hasan, M. Shah Alam, and M. Musfiqur Rahman

***Abstract*—HARQ is a stop and wait protocol supporting soft combination of retransmitted data which is used for facilitating fast error detection and correction. In Long term Evolution (LTE), HARQ is implemented by MAC level module called HARQ entity. The justification of HARQ retransmissions lies in recovering data correctly, though they consume radio resources. In this paper, it is proposed that the maximum number of HARQ retransmissions in downlink may be limited in order to save radio resources for UEs with poor radio link in LTE. Adequate simulation results with LTE link level simulator strengthen the basis of this proposal.**

***Index Terms*—CQI, HARQ, LTE, retransmission.**

I. Introduction

Long term evolution (LTE), based on a 3GPP standard is the next step forward in cellular 3G services. In Release 8, Long Term Evolution (LTE) was standardized by 3GPP as the successor of the Universal Mobile Telecommunication System (UMTS).LTE is a system with larger bandwidth (up to 20MHz), low latency and Packet optimized radio access technology having peak data rates of 100 Mbps in downlink and 50Mbps in the uplink. Radio access technology for LTE is OFDM (Orthogonal Frequency Division Multiplexing) which provides higher spectral efficiency and more robustness against multipath and fading [1]-[3].

HARQ protocol in MAC is complemented by ARQ in RLC for high reliability and radio efficiency. HARQ feedback is sent on L1/L2 control channel. It represents Single, uncoded bit with low overhead sent for each scheduled subframe. But retransmissions are soft combined with previous attempt. On the other hand, ARQ status report is sent as MAC data protected by CRC and HARQ retransmissions. RLC Status is sent on demand as poll, timer or gap detection [4].

In case of the LTE wireless standard, signaling given by eNodeB about the allocation of resources to be shared by UEs is performed over the Physical Downlink Control Channel (PDCCH). The amount of resources allocated to the PDCCH can be varied. However, if the allocated amount is too small then the UL and DL data schedulers will not be able to schedule all UEs that need to be served but if the amount is too large then resources that could have been used for transmitting data are wasted. Determination of the number of resources to be allocated to the PDCCH and how UEs should be efficiently signaled over the PDCCH is addressed in [5].

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II. Downlink Resource Allocation

LTE uses OFDMA for downlink transmission. In this case, a time-frequency resource grid is considered using sub-carriers in the frequency axis and symbols in the time axis. A resource element represents one sub-carrier and one symbol resource in the time-frequency resource grid. Data is allocated to the UEs in terms of Resource Blocks (RB). In time, the length of a RB is one slot which is equal to 0.5 ms. With 15 kHz sub-carrier spacing, The number of symbols in one slot is 6 and 7 for normal cyclic prefix and extended cyclic prefix respectively. In frequency, the length of a RB is 180 kHz. The number of sub-carriers in the 180 kHz span is 12 for 15 kHz sub-carrier spacing [1], [2].

The eNodeB allocates different RBs to a particular UE in either localized or distributed way. The eNodeB uses DCI format 1, 1A, 1B, 1C, 1D, 2, 2A or 2B on PDCCH to convey the resource allocations on PDSCH for the downlink transmission.

The scheduler at eNodeB attempts for appropriate apportionment of the resources among UEs. The eNodeB can exercise Channel Dependent Scheduling (CDS) in both time and frequency domains. The scheduling adapts to channel variations and link adaptation is achieved. A user with better channel quality is given more resources as the user can make good use of these resources leading to higher cell throughput. The Channel Dependent Scheduling (CDS) requires that sufficient information on uplink and downlink channel conditions is made available with the eNodeB. The UE reports CQI (Channel Quality Indicator) which helps eNodeB estimate the downlink channel quality. The UE determines CQI to be reported based on measurements of the downlink reference signals. The UE determines CQI such that it corresponds to the highest Modulation and Coding Scheme (MCS) as follows allowing the UE to decode the transport block with error rate probability not exceeding 10%. The value of CQI can range between 1 and 15. A lower value of CQI indicates weaker radio link [6], [7].

While the channel dependent scheduling leads to higher cell throughput, on the other hand, the scheduling should maintain some fairness among the users in their resource allocations. Thus, there is a tradeoff between fairness and cell throughput. The scheduler can exercise various methods as shown below in order to address this tradeoff [2], [4].

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1) Round Robin (RR): The scheduler assigns resources cyclically to the users without taking channel conditions into account. This is a simple procedure giving the best fairness. But it would offer poor performance in terms of cell throughput.
2) Maximum C/I: The scheduler assigns resources to the user with the best channel quality. This offers excellent cell throughput but it is not fair.
3) Proportional Fair (PF): The scheduler can exercise Proportional Fair (PF) scheduling by allocating more resources to a user with relatively better channel quality. This offers high cell throughput as well as fairness satisfactorily. Thus, Proportional Fair (PF) scheduling may be the best option.
4) Scheduling for Delay-Limited Capacity: Some applications have very tight latency constraints and so, their QoS require certain guaranteed data rate independent of the fading states. This guaranteed data rate is called delay-limited capacity. The scheduler can allocate resources considering such special requirements.

III. Hybrid ARQ (HARQ) In Downlink

The Hybrid ARQ (HARQ) is a technique combining Forward Error Correction (FEC) and Automatic Repeat Request (ARQ) methods that save information from previous failed decode attempts for use in the future decoding. When the receiver fails to decode the data packet, it sends NACK to the transmitter but it keeps bits from the failed attempt for future use. When the transmitter receives the NACK or a certain time elapses without any feedback, the transmitter retransmits the transport block. The receiver HARQ process then soft combine bits from the previous failed decodes with the currently received retransmission. This helps minimize the number of retransmissions. The maximum number of HARQ retransmission can be 3.

The MAC layer is responsible for HARQ process. Multiple HARQ processes are required to run in parallel in order to keep up the transmission of transport blocks while the receiver is decoding already received transport blocks. This allows the continuous use of the whole transmission resources available. Each HARQ process runs its own Stop-And-Wait (SAW) operation. The maximum number of parallel HARQ processes is set to 8.

The retransmissions in HARQ process are asynchronous in downlink. In this case, the retransmissions of a packet occur at any time relative to the initial transmission. Asynchronous HARQ allows more flexibility in scheduling but the receiver cannot realize which HARQ Process the retransmission belongs to. This requires signaling HARQ Process Identifier. Moreover, the retransmissions in HARQ process are always adaptive in downlink. In this case, the transmitter may change some or all of the transmission attributes in each retransmission as compared to the initial transmission because of variations in the radio channel conditions. Thus, the retransmissions better fit in the radio channel conditions but signaling the transmission attributes for each retransmission is required. The transmission attributes which are changed may include Modulation and Coding Scheme (MCS) and Resource Block allocation in frequency. Thus, the signaling on PDCCH includes HARQ Process Identifier, Modulation and Coding Scheme (MCS) and Redundancy Version [4], [8].

IV. Proposal and Analysis of Justification

The HARQ retransmissions consume radio resources. This consumption is justified with a view to recover data correctly. However, we propose that the maximum number of HARQ retransmissions in downlink may be limited and made less than 3 (three) in order to save radio resources for UEs with poor radio link. Thus, the maximum number of HARQ retransmissions in downlink can be limited to 1 or 2 depending on the radio link quality.

The proposal can be justified as follows.

- A UE with poor radio link quality cannot make good use of the radio resources. It uses the resources less efficiently and this leads to lower cell throughput. The resources saved from reduced HARQ retransmissions can be better utilized by a UE with good radio link improving cell throughput.
- The eNodeB can easily implement reduction of maximum number of HARQ retransmissions in downlink. The eNodeB receives CQI report from the UE which indicates the downlink radio link quality. When the value of CQI is too low, the eNodeB can simply reduce the maximum number of HARQ retransmissions. The eNodeB may use a mapping of maximum number of HARQ retransmissions with CQI value. It may be left to the implementation of eNodeB how much limitation would be applied with what value of CQI.
- The HARQ retransmissions are invariably asynchronous and adaptive in downlink. Therefore, significant signaling overhead on PDCCH is required for each retransmission. Thus, when the number of HARQ retransmissions is reduced, additional saving of resources is achieved by avoiding signalling overhead.
- With poor radio link quality, there is chance that the receiver fails to decode the data packet even after all three HARQ retransmissions. In this case, the radio resources for the whole attempt with three HARQ retransmissions are wasted. But if the maximum number of HARQ retransmissions was limited to 1 or 2, then such wastage of resources would be less.
- The difficulties imposed by the limitation of maximum number of HARQ retransmissions can be partly overcome by the retransmission of Acknowledged Mode of RLC entity or TCP.

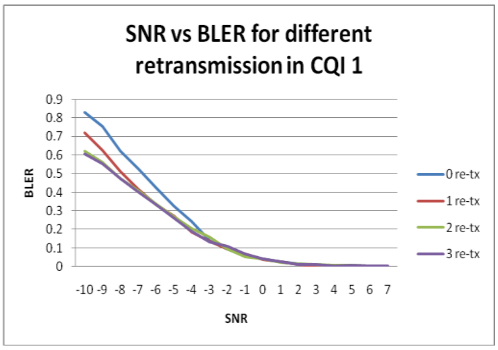

Fig. 1. SNR vs BLER in CQI 1 for various retransmissions

V. Simulation Results

LTE link level simulator [9] was used to support the proposal given for limiting the HARQ retransmission for poor radio link.Fig. 1, 2, and 3 represent SNR vs BLER plot for various number of HARQ retransmission i.e from 0 to 3. They have been shown for CQI 1, 2 and 3 respectively in these 3 plots.

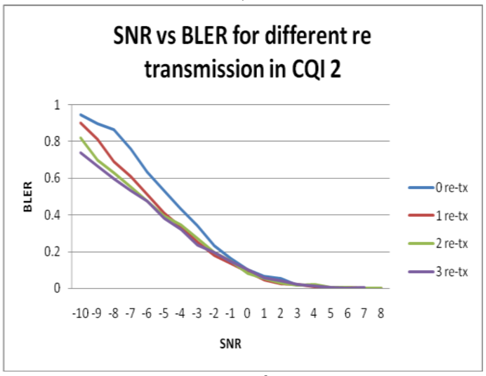

Fig. 2. SNR vs BLER in CQI 2 for various retransmissions.

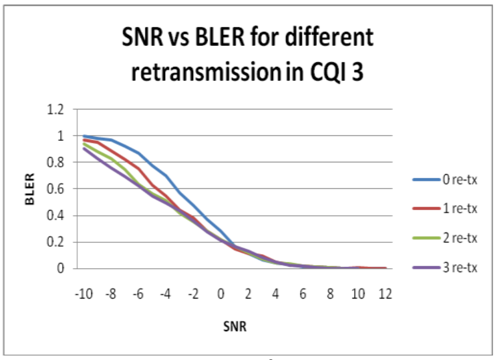

Fig. 3. SNR vs BLER in CQI 3 for various retransmissions.

VI. Result Analysis

The lower CQI values expected for poor radio link quality and simulation is therefore performed for the lowest three value of CQI. The results manifest that the improvement of BLER with higher number of retransmission is obvious but it is not substantial. Therefore, a sacrifice of this improvement can be justified allowing saving of resources as mentioned in section IV.

In a nutshell, the obtained simulation result reiterates the proposal suggested by us that HARQ retransmission can be minimized to 1 or at best 2 with poor radio link especially when the network is overloaded. It can also lead to a better scheduling methodology for DL resource allocation in LTE.

VII. Conclusion

In this paper, a proposal of limiting the maximum number of HARQ retransmissions in LTE downlink is given. Downlink resource allocation methodology and vivid HARQ procedure have been discussed to successfully lucidly explain the proposal. The given proposal is aimed at saving radio resources for UEs with poor radio link in LTE. Simulation results consolidate the basis of this proposal and elevate its significance.

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