TSG-RAN Working Group 1 meeting #15 **TSGR1(00)1084**
Berlin, Germany
August 22nd - 25th , 2000

Agenda item: AH 24

Source: Nokia

Title: Comparison on RLC HARQ and fast HARQ complexity: revision

Document for: Discussion and decision

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1. Introduction

In the RAN WG1 #14 meeting Nokia presented a discussion document on Hybrid ARQ [1] where it was stated that the complexity of RLC level HARQ is too high to be acceptable. This contribution compares the complexity RLC level HARQ to L1 HARQ (from hereon called fast HARQ). There is also a text proposal to be included in the HARQ technical report.

2. Complexity comparison

In Release –99 specification ARQ protocol is operating on RLC level. All the buffering and processing is also done on RLC level on RLC-PDUs. The total latency of ARQ retransmissions is estimated to be about 200 ms in the Release –99 scheme.

For Release –00 there is a work item on Hybrid ARQ that has been explained in a number of contributions [1], [2], [3]. HARQ aims at improving ARQ performance by combining retransmissions on physical layer. This processing on physical layer also requires buffering the received soft symbols in L1.

The number of symbols to be buffered in L1 receiver for RLC HARQ protocol can be estimated roughly as follows:

$$buffer = \left(coded\ bits_{RLC\ PDU} \times failed\ PDUs\, in TTI \times (latency_{retransmit} + latency_{NACK}) \right) \quad (1)$$

The receiver generally collects a few erroneous RLC-PDUs before sending a NACK to the transmitter. This is modelled as the NACK latency. The period from sending NACK to receiving the retransmitted RLC-PDU is the retransmission latency.

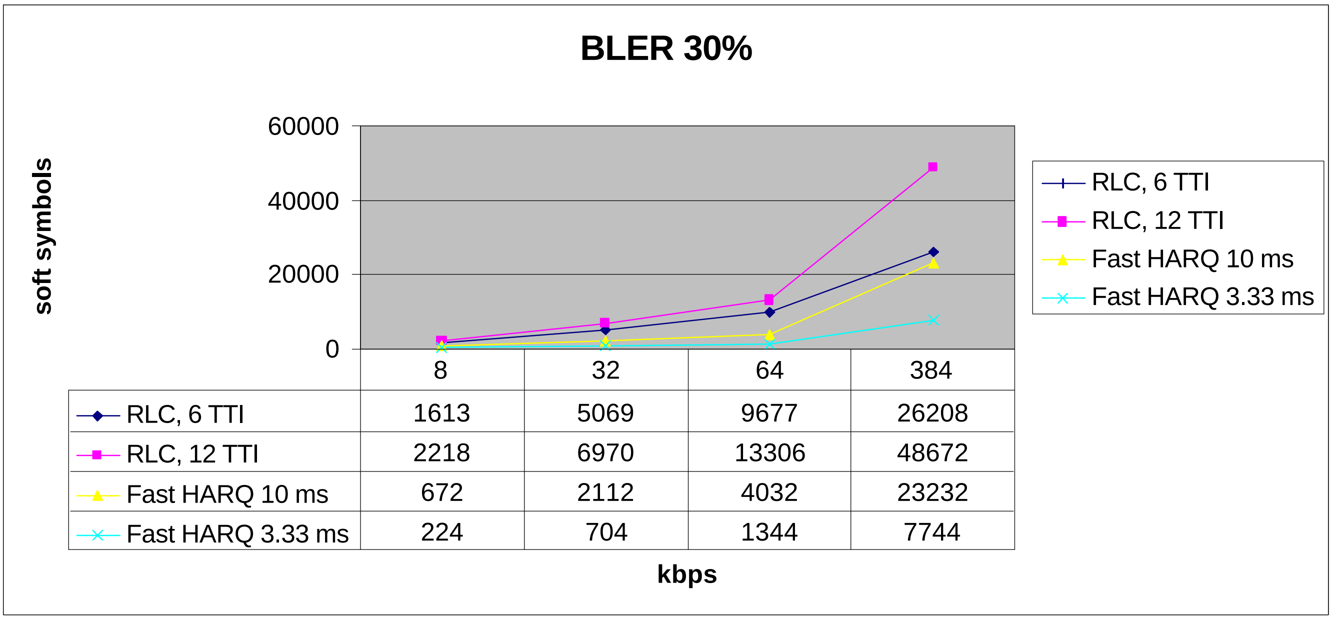
In the previous contribution on HARQ complexity [1] Nokia pointed out that the latency inherent in RLC level HARQ protocol would lead to big buffering memory need. Shortening the latency is directly reducing the buffering memory so steps for decreasing the latency are desirable.

Moving ARQ protocol from RNC to Node B removes the need to signal over the Iub interface. This can be estimated as a saving of <120 ms in retransmission latency for a packet. Furthermore, with fast HARQ the packets are acknowledged individually so the NACK latency is in the order of one frame.

Fast HARQ employs a dual-channel stop-and-wait protocol, i.e. a new packet is sent only when an acknowledgement for the previous one is received. The receiver buffers at most two RLC PDUs, one in odd and one in even channel buffer. Thus, the maximum buffer size for fast HARQ is:

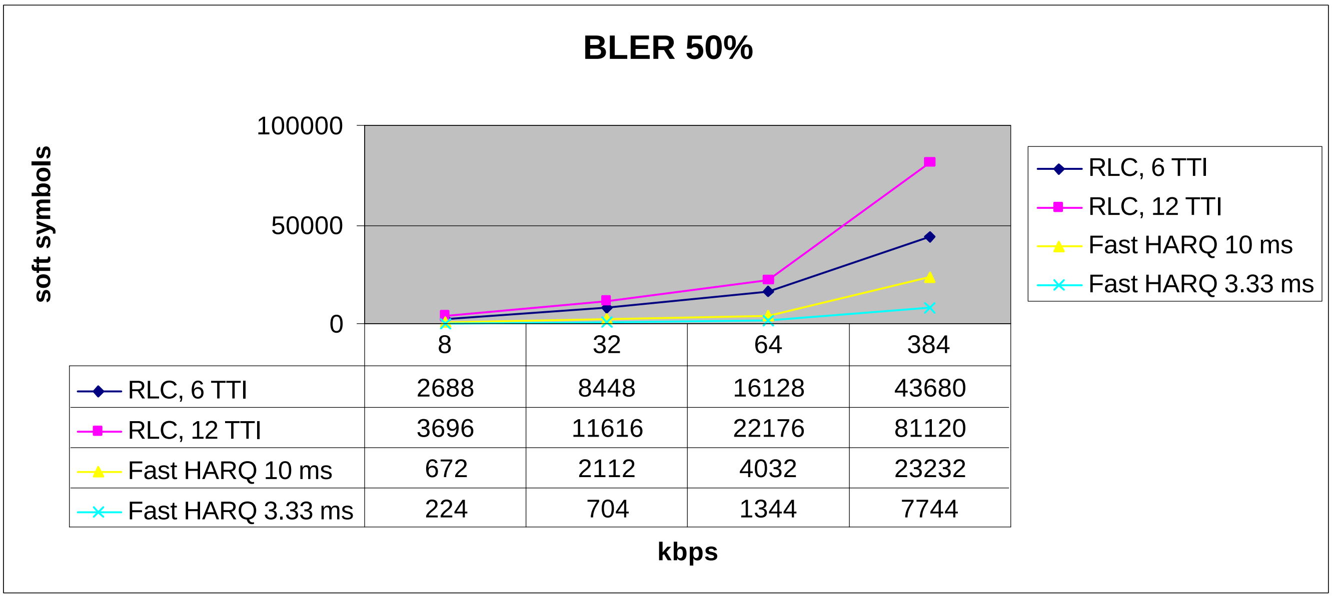
$$buffer = \left(coded\ bits_{RLC\ PDU} \times 2 \right) \quad (2)$$

Figures 1-3 show a comparison of the receiver buffer sizes at several data rates for RLC HARQ and fast HARQ when 1/3 encoding rate is used. For RLC HARQ these charts show an average size of the buffer as defined by equation (1) since the maximum is difficult to estimate for RLC HARQ. For fast HARQ the maximum buffer size from equation (2) is depicted. In figures 1-3 the buffer size for fast HARQ is shown both for the same frame length than RLC HARQ (10 ms) and for 3.33 ms. The shorter 3.33 ms length shows the future potential decrease in buffer size when the default frame size of HSDPA (High Speed Downlink Packet Access) is adopted. For RLC HARQ the NACK latency is assumed as 10 TTIs for bit rates 8 – 64 kbps. However, for 384 kbps a NACK delay of 1 TTI is assumed. The retransmission latency as either 6 TTIs or 12 TTIs (shown in the legend). It is also assumed that a 24-bit CRC field and 8 tail bits are added to the RLC PDU. In the RLC HARQ figures for the bit rates 8, 32 and 64 kbps there is one RLC PDU per a 10 ms frame, for 384 kbps there are 10 RLC PDUs per a 10 ms frame. For fast HARQ one RLC PDU per frame is assumed.



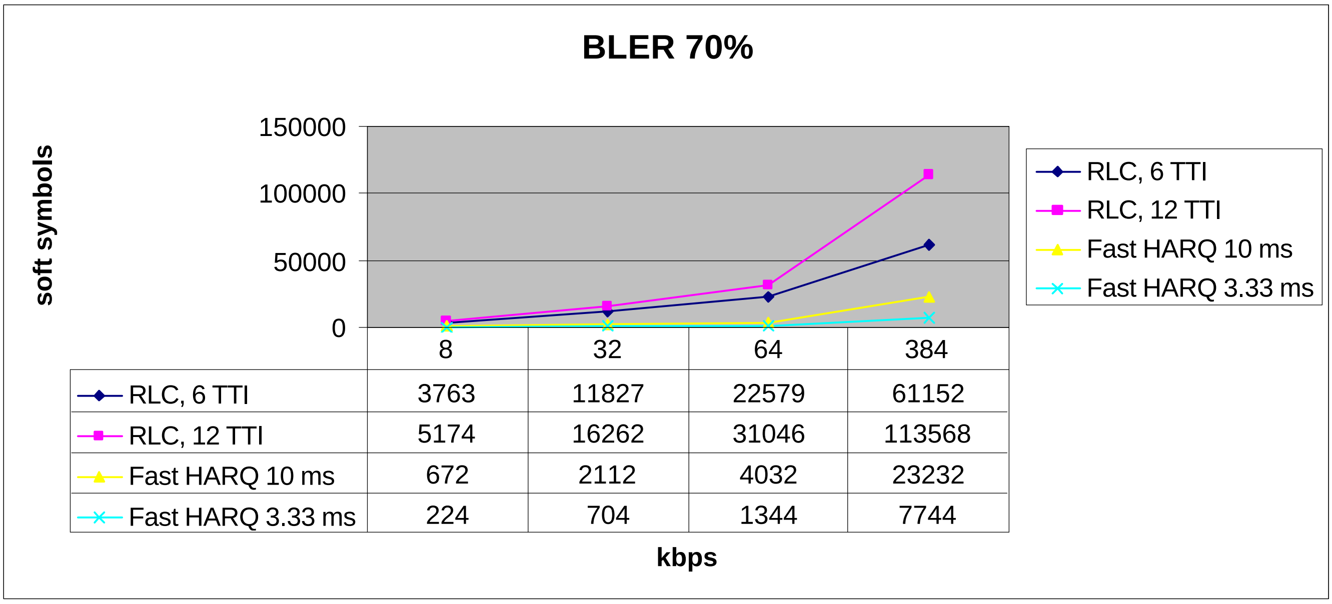
	8	32	64	384
RLC, 6 TTI	1613	5069	9677	26208
RLC, 12 TTI	2218	6970	13306	48672
Fast HARQ 10 ms	672	2112	4032	23232
Fast HARQ 3.33 ms	224	704	1344	7744

Figure 1. Average receiver L1 buffer size for BLER = 30%



	8	32	64	384
RLC, 6 TTI	2688	8448	16128	43680
RLC, 12 TTI	3696	11616	22176	81120
Fast HARQ 10 ms	672	2112	4032	23232
Fast HARQ 3.33 ms	224	704	1344	7744

Figure 2. Average receiver L1 buffer size for BLER = 50%



	8	32	64	384
RLC, 6 TTI	3763	11827	22579	61152
RLC, 12 TTI	5174	16262	31046	113568
Fast HARQ 10 ms	672	2112	4032	23232
Fast HARQ 3.33 ms	224	704	1344	7744

Figure 3. Average receiver L1 buffer size for BLER = 70%

It can be seen that fast HARQ gives a clear reduction in L1 receiver buffer size. An additional advantage for fast HARQ is that the maximum buffer size can be easily calculated and it is independent of BLER. Depending on channel conditions receiver buffer for RLC HARQ may overflow the average size by considerable amount.

On the other hand, with the RLC protocol in Node B some buffering is now needed in Node B L1. Moreover, assuming that an upper level RLC protocol is retained in RNC also flow control between Node B L1 RLC and RNC RLC protocols is needed to prevent the L1 buffer from overflowing. However, these considerations do not impact the receiver buffer in the UE where memory size impact on hardware is biggest.

3. Text proposal for HARQ TR

7 Physical Layer impacts

7.1 Overview of physical layer mechanisms

7.2 Performance evaluation

7.3 Impacts to UE and Node B complexity

One important aspect to consider is the complexity of introducing HARQ into Release –00. If HARQ is terminated in the SRNC, ACKs are communicated between UE and RNC RLCs, and soft combining is done on L1. However, RLC level round trip delay (ca 120 ms) and polling period (ca 80 ms) for ACKs makes the buffer memory requirement in UE L1 considerable.

The number of symbols to be buffered in L1 receiver with RLC HARQ can be estimated roughly as follows:

$$buffer = \left(coded\ bits_{RLC\ PDU} \times failed\ PDUs\ in\ TTI \times (latency_{retransmit} + latency_{NACK})\right)$$

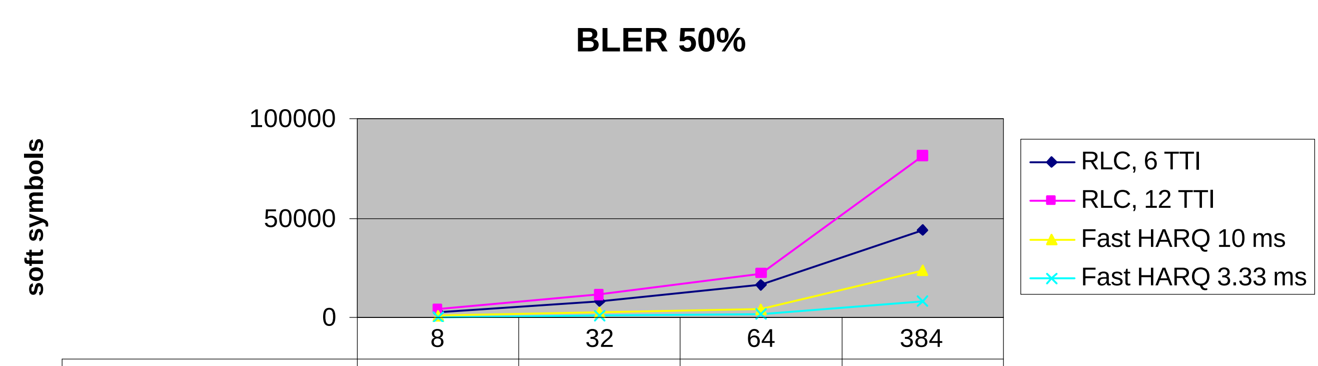
where it is assumed for the sake of clarity that an integer number of RLC PDUs fit into one L1 TTI. The latencies are also considered as multiples of a TTI. For HARQ with soft combining all retransmissions are combined and stored in the same location as the first transmitted symbol, so the number of retransmissions does not increase the buffering need. For HARQ employing additional redundancy smaller blocks are transmitted, but in practice one has to reserve room for a complete encoded symbol in the receiver for assembling the incremental information; thus the difference between soft combining and additional redundancy combining is small when the lowest encoding rate is the same.

The number of symbols to be buffered in L1 receiver with fast HARQ is at most two TTIs:

$$buffer = \left(coded\ bits_{RLC\ PDU} \times 2\right)$$

and this figure is independent of the BLER.

In practical cases for RLC HARQ, with a total latency around 200 ms, there is a need to buffer several tens of ksymbols of soft symbol decisions in the receiver. Depending on how many bits are used to represent a soft symbol in the decoding stage this memory requirement becomes a multiple of the soft symbol memory usage. Buffer memory consumption for both RLC HARQ and fast HARQ is shown in Figure x for BLER = 50%. The retransmission latency for RLC HARQ is either 6 TTIs or 12 TTIs.



	8	32	64	384
RLC, 6 TTI	2688	8448	16128	43680
RLC, 12 TTI	3696	11616	22176	81120
Fast HARQ 10 ms	672	2112	4032	23232
Fast HARQ 3.33 ms	224	704	1344	7744

kbps

Figure x. Average receiver L1 buffer size for BLER = 50%

4. References

[1] TSGR1#14(00)0869, "Hybrid ARQ methods for FDD in Release 2000", Nokia

[2] TSGR1#01(99)061, "Hybrid ARQ techniques for efficient support of packet data", Panasonic

[3] TSGR1#02(99)355, "Support of Hybrid ARQ type II/III by the physical layer", Siemens