We are IntechOpen, the world's leading publisher of Open Access books Built by scientists, for scientists

6,900
Open access books available

185,000
International authors and editors

200M
Downloads

Our authors are among the

154
Countries delivered to

TOP 1%
most cited scientists

12.2%
Contributors from top 500 universities



WEB OF SCIENCE™

Selection of our books indexed in the Book Citation Index in Web of Science™ Core Collection (BKCI)

Interested in publishing with us?
Contact book.department@intechopen.com

Numbers displayed above are based on latest data collected.
For more information visit www.intechopen.com



8

On Efficiency of ARQ and HARQ Entities Interaction in WiMAX Networks

Zdenek Becvar and Pavel Mach
Czech Technical University in Prague, Faculty of Electrical Engineering, Czech Republic

1. Introduction

During data exchange in wireless networks, an error in transmission can occur. Corrupted data cannot be further processed without a correction. A technique based on either Automatic Repeat reQuest (ARQ) or Forward Error Correction (FEC) is conventionally used to repair erroneous data in wireless networks. The ARQ is backward mechanism that uses a feedback channel for the confirmation of error-free data delivery or to request a retransmission of corrupted data. This method can increase a network throughput if radio channel conditions are getting worse (Sambale et al., 2008). On the other hand, the ARQ method increases the delay of packets due to the retransmission of former unsuccessfully received packets. The FEC can increase user's data throughput over the channel with poor quality despite the fact that additional redundant bits are coded together with users' data at the transmitter side. The method combining both above mentioned methods is called Hybrid ARQ (HARQ). All three error correction mechanisms are implemented on physical and/or Medium Access Control (MAC) layer.

The performance of ARQ defined in standard IEEE 802.16e (IEEE802.16e, 2006) depends on the setting of several parameters such as size of user data carried in a frame, size of ARQ block, size of PDU (Protocol Data Unit), limit of retransmission timeout timer, or type of packet acknowledgement (Lee & Choi, 2008). Evaluation of the type of packet acknowledgment for different channel condition is presented in (Kang & Jang, 2008). In other paper, the authors evaluate the ARQ performance for different ARQ parameters (Tykhomyrov et al., 2007). This work is later on enhanced by analysis of the impact of PDU size on IEEE 802.16e networks performance while ARQ mechanism is used (Martikainen et al., 2008). Further, a comparison of ARQ and HARQ performance in IEEE 802.16 networks is presented in (Sayenko et al., 2008). This paper also compares the amount of overhead generated by ARQ and HARQ. The optimal PDU size and MAC overhead due to the packets retransmission is analyzed in (Hoymann, 2005). The authors in (Sengupta et al., 2005) propose to adjust the MAC PDU size depending on the channel state to achieve the best ARQ performance. The paper is extended for analysis of a combination of error correction techniques such as ARQ, FEC or MAC PDU aggregation on the VoIP speech quality (Sengupta et al., 2008). Authors proof the improvement of VoIP speech quality by using these techniques. In (Chen & De Marca, 2008), the authors investigate an optimization of ARQ parameter setting from the link throughput point of view.

In conventional WiMAX network, the ARQ and HARQ work independently on each other (IEEE802.16e, 2006). In standalone ARQ process, a number of blocks received with errors increases as the link quality between the transmitter and the receiver decreases. Thus, if the Block Error Rate (BLER) is more significant, the amount of retransmitted blocks is higher as well. It can be assumed that if the channel quality is high, most of the blocks are transferred without errors and the number of unsuccessfully received blocks is kept to minimum. In such case, the transmission of positive acknowledgement (ACK) of correctly delivered blocks appears more often than negative acknowledgement (NACK) of corrupted blocks. This assumption is considered in (Becvar & Bestak, 2011), where authors propose to send only NACKs to significantly reduce signaling overhead introduced by ARQ mechanism.

On the other hand, the HARQ is able to detect and correct the most of the radio channel errors. However, due to the limitation of a number of retransmissions, some data may not be delivered without errors if only HARQ is utilized. Consequently, these data have to be retransmitted by ARQ process. The conventional ARQ has to acknowledge all data independently on the result of HARQ procedure. In order to significantly reduce signaling overhead, an interaction of both ARQ and HARQ methods should be utilized, see, e.g., (Maheshwari et al., 2008)).

The contributions of this chapter are as follows. Firstly, the results of improved ARQ scheme according to (Becvar & Bestak, 2011) cooperating with HARQ is compared to the results achieved by the conventional ARQ scheme with enabled and disabled cooperation between both entities. Secondly, while only one hop communication is assumed when data are sent only between a mobile station (MS) and a base station (BS) in (Becvar & Bestak, 2011), this chapter analyzes the impact of relay stations (RS), defined in IEEE 802.16j (IEEE802.16j, 2009), on the performance of individual methods. The extended simulations are performed considering various setting of parameters. The amount of generated overhead is the metric for the performance assessment.

The rest of this chapter is organized as follows. In the next section, the principle of ARQ and HARQ used in WiMAX are described. In addition, the optimization of conventional ARQ scheme according to (Becvar & Bestak, 2011) is presented in this section. In the section 3, the overhead of HARQ algorithm in WiMAX networks is evaluated. The section 4 provides an overview on simulation model and contemplates the parameters applied in simulator. The section 5 presents the simulation results. Last section gives our conclusions.

2. ARQ and HAQR in WiMAX

This section provides overview on conventional ARQ and HARQ used in WiMAX networks. Further, the innovative ARQ proposed in (Becvar & Bestak, 2011) is also described to enable easy understanding of results presented in next sections.

2.1 Conventional ARQ

The principle of conventional ARQ method according to the IEEE 802.16e standard and the structure of user's information carried in the frame are depicted in Fig. 1.

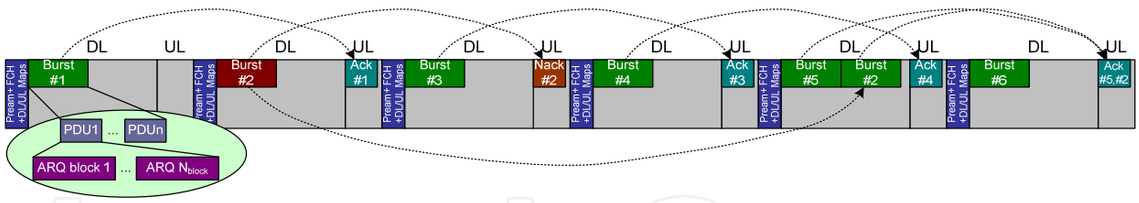


Fig. 1. Principle of conventional ARQ

In WiMAX, each data burst generated either by the MS or the BS is segmented into PDUs. These PDUs are further mapped into MAC frame. A PDU usually consists several blocks N_{block}, which number is given by following equation:

$$N_{blocks}^{i,k} = \frac{S_{data}^{i,k}}{S_{ARQ-blocks}^{i,k}} \tag{1}$$

where $S_{data}^{i,k}$ is a total size of data of *i-th* user in *k-th* frame, and similarly $S_{ARQ-blocks}^{i,k}$ represents a block size defined by parameter denoted in the standard as ARQ_Block_Size (IEEE802.16e, 2006). This parameter is carried in TLV (Type/Length/Value) section of registration messages (REG-REQ/RSP) exchanged between the BS and MS (see (IEEE802.16e, 2006)). The parameter ARQ_Block_Size can take values from the following range: 16, 32, 64, 128, 256, 512 and 1024 bytes. During a transmission, a sequence of consecutive blocks is sent in the PDU. After that the receiver evaluates whether the data are received correctly or not and sends an appropriate feedback message to the transmitter. Note that all transmitted blocks (N_{block}) have to be confirmed by ACK or NACK even if all blocks are received without errors. The IEEE 802.16e standard defines four types of acknowledgments: Selective ACK entry, Cumulative ACK entry, Cumulative with Selective ACK entry and Cumulative with Block Sequence ACK entry.

The first type of acknowledgment uses selective maps to provide feedback to the transmitter. In the selective map, each bit corresponds to one ARQ block. A bit set to "1" indicates error-free reception of the corresponding ARQ block. The second type, Cumulative ACK entry, is based on the utilization of sequence maps. A sequence map defines a group of consecutive blocks where each group includes a sequence of only erroneous blocks or sequence of only error free blocks. The sequence maps can contain two or three sequences with a length of 64 or 16 blocks respectively. The third type of ACK combines the previous two types. Finally, the last type combines the second type with ability to acknowledge ARQ blocks in the form of block sequences.

The ACK or NACK is sent through above mentioned feedback message. The feedback is transmitted in the next frame after the data transmission. The feedback message contains 8 bit field indicating Message ID and the rest of the message is dedicated to field consisting ARQ_Feedback_Payload. The ARQ payload can be carried either via standalone ARQ feedback message or by piggybacking the ARQ payload to the user's data block. The payload is always carried in a single PDU. The ARQ_Feedback_Payload includes one or more ARQ_Feedback_IE (see Table 1) where IE stands for an Information Element.

Syntax	Size	Notes
CID	16 bits	Connection ID
Last	1 bit	Identify the last IE in ARQ_Feedback
ACK Type	2 bits	0x0...Selective ACK 0x1...Cumulative ACK 0x2...Cumulative with Selective 0x3...Cumulative with Block Sequence
BSN	11 bits	Block Sequence Number (0...2047)
Number of ACK Map	2 bits	Number of Maps (M) = 1,2,3 or 4
Maps	M x 16 bits	Selective (16 blocks) or Cumulative maps (2 x 64 blocks / 3 x 16 blocks) Cumulative maps: 1 bit sequence format (2 or 3 blocks), 2/3bits Sequence ACK (ACK/NACK of sequence), (2x6) / (3x4) bits Sequence length

Table 1. Structure of ARQ_Feedback_IE (IEEE802.16e, 2006)

The size of an IE of each ARQ feedback message can be calculated according to equation:

$$Size_{ARQ_FB_IE}\ [bits] = 32 + (M \times 16) \tag{2}$$

where M represents the number of maps carried in one ARQ_Feedback_IE (see Table 1). Consequently, the overall size of whole feedback message is given by following formula:

$$Size_{ARQ_FB}\ [bits] = 8 + \sum_{i=1}^{N_{IE}} Size_{ARQ_FB_IE_i} \tag{3}$$

where N_{IE} corresponds to the amount of information elements carried in one ARQ Feedback message and the first eight bits represents the ARQ feedback message overhead (i.e., Message ID field). The overhead transmitted in all considered frames (N_{frame}) is equal to the sum of partial overheads over the N_{frame}:

$$OH_{ConvARQ}\ [bits] = \sum_{i=1}^{N_{frame}} Size_{ARQ_FB_i} \tag{4}$$

As indicated in Fig. 1, the retransmission of erroneous blocks cannot be accomplished before the third frame after the original transmission since the transmitter receives NACK in the next frame after transmission (2nd frame). Hence a request for additional resources can be created earliest at the upcomming frame (3rd frame). Therefore, the dedicated resources are not available before the 4th frame. The retransmission of data (burst #2 in Fig. 1) can be scheduled either together with normally ordered data (burst #5 in Fig. 1) or the new data

(burst #5 in Fig. 1) can be delayed by one frame. It causes a delay of retransmitted packets with duration that corresponds to at least 3 times of frame duration (e.g., if the frame duration is 10 ms, the packet delay is at least 30 ms).

The new and retransmitted data are sent within the same frame only if the requested capacity (new data plus retransmitted data) is available. The WiMAX technology implements Stop-and-Wait mechanism that requests a confirmation of the previous block before transmitting subsequent blocks. The number of blocks that can be unconfirmed before a transmission of the consequent blocks is defined in the standard by the parameter ARQ_Window_Size.

2.2 Innovative ARQ

The innovative ARQ takes into consideration that the number of blocks received with errors increases as the link quality between transmitter and receiver decreases. This scheme adaptively selects one of three different ways of data delivery confirmation: i) conventional ARQ, ii) transmission of only NACK (ARQ Scheme I), iii) retransmission of only corrupted blocks (ARQ Scheme II).

The first type of data acknowledgement, the conventional ARQ, was already explained before.

The second type (ARQ Scheme I) assumes ARQ feedback message and ARQ_Feedback_IEs with the same structure as the conventional IEEE 802.16 ARQ feedback message. However in this proposal, the ARQ feedback is sent only if a received PDU contains at least one erroneous block. If all blocks in the PDU are error free, no feedback is sent. The PDU is assumed to be correctly transferred if the transmitter receives no feedback in the following W frames after the transmission. If the feedback with NACK is not delivered, the data conveying the delay sensitive services (e.g., VoIP) are assumed to be lost since the delay caused by repeated ARQ retransmission is significant. In case of services not sensitive to delay, data belonging to lost NACK can be retransmitted using upper layer protocols, e.g., TCP (Transmission Control Protocol). As the probability of lost packet or packet with errors together with the NACK feedback is very low, the increase of overhead due to upper layer protocols is negligible.

The third way of data acknowledgement (ARQ Scheme II) is based on the same assumptions as the previous one. The ACK feedback is likewise transmitted only if there is at least one block with errors. A block is assumed to be error-free if no feedback is received in one of the following W frames after the transmission of appropriate data frame.

The overhead generated by the innovative ARQ (denoted as ARQ PIII) by a user in one frame can be calculated according to the following equation:

$$Size_{ARQ_FB_III} = 8 + 18 + min\left\{\sum^{N_{IE}} 16 + 16 \times M_{N_{IE}}, 10 + B \times 11\right\} + res \quad (5)$$

where N_{IE} is the number of IEs carried in one ARQ feedback message, M_{NIE} corresponds to the number of ACK maps in ARQ_Feedback_IE, B stands for the number of BSNs included in one message and res is the number of bits used for an alignment of the feedback message

length to integer number of bytes. The overhead generated by new ARQ scheme is given by the following equitation:

$$OH_{SchemeIII} = \sum^{N_{frame}} Size_{ARQ_FB_III_{N_{frame}}} \tag{6}$$

2.3 HARQ

The utilization of ARQ with support of FEC is known as HARQ. The HARQ method uses not only retransmitted packets to reconstruct the original error free packets, but it also utilizes the packets received with errors. The original packet can be reconstructed by a combination of several versions of packet with errors. The HARQ described in (IEEE802.16e, 2006) uses two different types of reconstruction: Chase Combining (CC) and Incremental Redundancy (IR).

The first version of HARQ is denoted as Type I HARQ Chase Combining. In this case, blocks of data together with a CRC code are encoded using a FEC coder before transmission. If the channel quality is low and errors of data are identified, the data block is not discarded however it is kept in the memory. In the next phase, the receiver requests for retransmission of this data block. The retransmitted block of data is then combined with the previous blocks received with errors. Combining more versions of the data blocks improves the probability of correct decoding even if all of them are received with errors.

Optionally, the IEEE802.16 standard also supports type II HARQ, which is known as Incremental Redundancy. In case of IR HARQ, the FEC coder codes one packet into several subpackets. Each of subpacket is coded with different code ratio. The subpackets are distinguished by 2-bits SubPacket IDentifier (SPID). If the packet is transmitted for the first time, the subpacket with SPID=00 is sent. The successful receive of the packet at the destination station is indicated by ACK. Otherwise, the transmitter sends a NACK and the transmitter has to send another packet carrying one of four subpackets. Both received packet (the first transmission and retransmissions) are again combined by receiver to increase the probability of correct decoding.

The overhead introduced by HARQ in WiMAX depends on the HARQ Type as follows. Firstly, the acknowledgment of HARQ bursts by modification of AI_SN (HARQ Identifier Sequence Number) of appropriate ACID (HARQ Channel ID) is assumed (for more information, see (IEEE802.16e, 2006)). The AI_SN is included in HARQ DL or UL. The size of HARQ map can be described by the subsequent formula:

$$HARQOH_{DL} = \begin{cases} 64 + SubB + res \ldots RegionID_ON \\ 40 + SubB + res \ldots RegionID_OFF \end{cases}$$

$$HARQOH_{UL} = \begin{cases} 48 + SubB + res \ldots RegionID_ON \\ 24 + SubB + res \ldots RegionID_OFF \end{cases} \tag{7}$$

where *SubB* is a size of management overhead according to a sub-burst. The amount of management overhead also depends on the utilization of *Region ID* (see (IEEE802.16e,

2006)). In the simulations performed in this chapter, the *Region ID* is not considered. The actual amount of bits of *SubB* depends on the HARQ Type. Based on the (IEEE802.16e, 2006), the size of message according to the sub-bursts is following:

$$\begin{aligned} SubB_{CC} &= 8 + N_{sub} \times (RCID + 20 + DIUC) \\ SubB_{IR-CTC} &= 8 + N_{sub} \times (RCID + 20) \\ SubB_{IR-CC} &= 8 + N_{sub} \times (R + 22 + DIUC) \end{aligned} \tag{8}$$

where N_{sub} is a number of sub-bursts; *RCID* represents a size of Reduced CID; and *DIUC* represents the size of optional field, denoted as DIUC, containing 8 bits if included.

For the case when a low number of bursts are transmitted within a frame, the utilization of so called Compact HARQ DL/UL maps enables to reduce an overhead (see (IEEE802.16e, 2006)). The overhead generated by compact version of maps is not dependent on the HARQ type. The amount of overhead can be expressed by the next equations:

$$\begin{aligned} HARQOHcomp_{DL} &= 12 + RCID + HCI + CCI \\ HARQOHcomp_{UL} &= 12 + RCID + HCI \end{aligned} \tag{9}$$

where *HCI* is a size of HARQ control IE (8 bits if HARQ is enabled and 4 bits if HARQ is temporary disabled); CCI is a size of CQICH control IE (16 bits if CQICH information are included and 4 bits if the information are not included).

The simple evaluation of equations for full and compact HARQ maps enables to determine which kind of maps generates minimum management overhead over the number of HARQ sub-bursts (see Fig. 2). As the results show, the compact version of maps is profitable for all numbers of sub-bursts in UL as well as for up to 12 sub-bursts in DL over all length of Reduced CID.

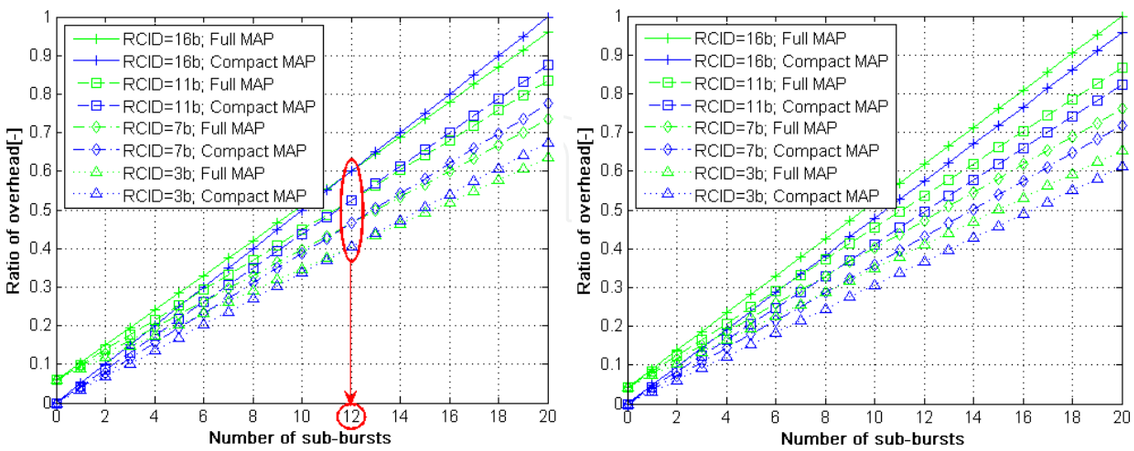


Fig. 2. Comparison of the overhead generated by compact and full HARQ maps for DL *(a)* and UL *(b)*

The relation between BLER (for ARQ confirmation) and PER (for HARQ confirmation) is defined according to (Provvedi et al., 2004) by following equation:

$$PER = 1 - (1 - BLER)^{N_{blocks}} \tag{10}$$

2.4 Cooperation of ARQ with HARQ to reduce signaling overhead

The mutual interaction consists in exchanging of information on successful packets transmission between ARQ and HARQ entities (see Fig. 3). Therefore, the data confirmed by HARQ need not to be confirmed again by ARQ process.

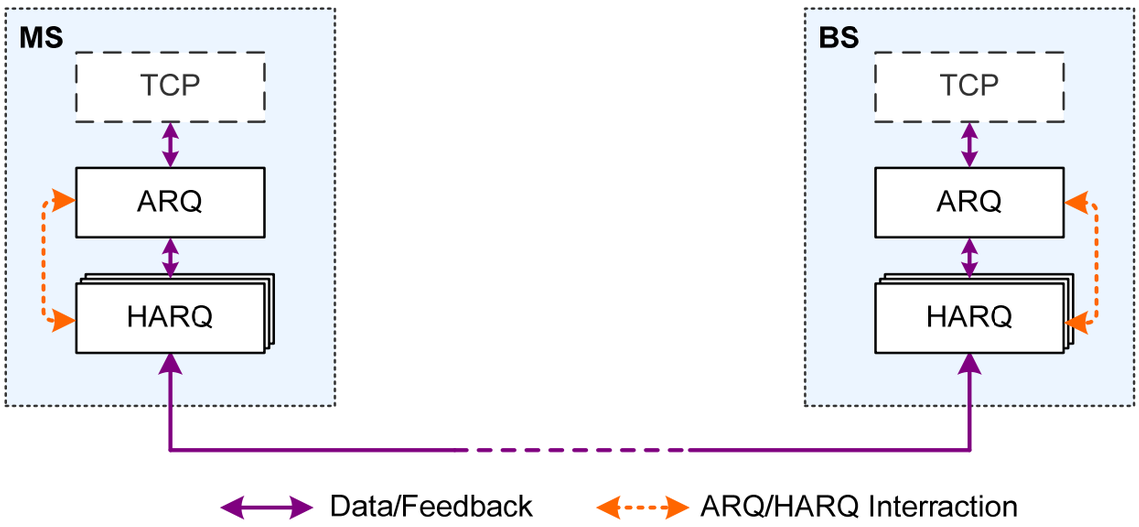


Fig. 3. Principle of ARQ and HARQ cooperation

At the side of transmitter, both ARQ and HARQ are implemented and applied on data. Similarly, the receiving side evaluates both ARQ and HARQ as well. However, ARQ process on the receiving side need not to transmit all requests related to the corrupted data if these data are already requested to be retransmitted by HARQ. The same way is applied for acknowledgement of data. In other words, data confirmed by HARQ are not further confirmed by ARQ. The information on ACK/NACK is delivered to HARQ processes at the side of original transmitter and HARQ just provides information of ACK/NACK data to the ARQ process at transmitter. Therefore, a part of overhead due to duplicated confirmation of data delivery is saved.

3. System model and simulation parameters

The simulator, developed in MATLAB, focuses on the evaluation of overhead generated by ARQ and HARQ procedure in the uplink direction by one user (see Fig. 4). In simulations, we assume direct communication between MS and BS as well as multihop communication using RSs.

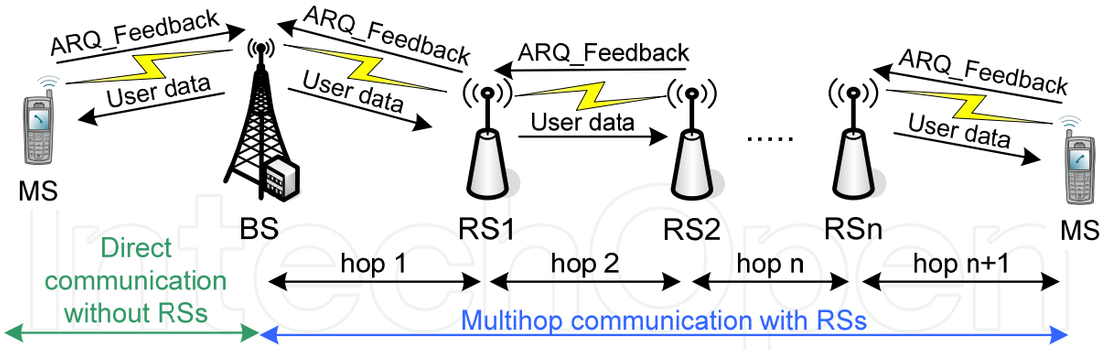


Fig. 4. Link level simulation scenario

Each packet is transmitted either directly to the BS or over particular number of hops. The probability of block error between two stations is the same over all hops. Therefore, the overall BLER of all hops (between the MS and the BS) is calculated according to the following formula:

$$BLER_{MS-BS} = \left(1 - BLER_{hop}\right)^{N_{hops}} \tag{11}$$

where $BLER_{hop}$ represents a BLER over each hop and N_{hops} is the number of overall hops between the MS and the BS. Note that $N_{hops}=n+1$, where n is the number of RS in the communication chain.

If RSs are considered, the absolute level of transmitted overhead rises n times comparing to the direct communication without RSs. This is due to the fact that feedback information is transmitted individually over each hop.

The setting of simulation parameters is depicted in Table 3. The evaluation is performed for BLER up to 10% per one hop. For higher BLER level, the channel is nearly unusable due to high error rate. Note that BLER of overall path from the MS to the BS is significantly increasing with rising number of hops (see (11)). The BLER of whole path from the MS to the BS is 27% if three hops are taken into account and if BLER of a hop is 10%.

For more precise evaluation, the overhead of upper layer is also considered. The TCP protocol is assumed for an error correction by upper layer.

The user's data are transmitted in a number of frames transmitted from the BS to the MS. The overhead size is evaluated per all transmitted frames. A frame consists of one or several PDUs and a PDU itself contains one or several ARQ blocks. The frames are subsequently sent by the BS to the MS. A vector indicating positions of blocks with/without errors is created for each frame based on the given value of BLER. The MS responds to the BS by sending ARQ feedback message that includes selected ARQ scheme, ACK Type, and a vector of errors in the transmission. According to the feedback message, the BS retransmits erroneous blocks as soon as possible, but not before the third frame after the original transmission. The size of user's data in a DL frame is kept the same within each simulation drop (1024 bytes or 4096 bytes).

This process is repeated until all frames are sent to the MS and the MS confirms error-free reception of all blocks. The same vectors indicating positions of blocks with/without errors are considered in all ARQ schemes.

Parameter	**Value**
Number of frames	2000
BLER per hop [%]	0 – 10
Number of hops	1, 3
ARQ_Block_Size [bytes]	16 – 1024
PDU size [blocks]	1 – 16
ARQ ACK Types	Selective, Cumulative
Max. HARQ retransmissions	2, 4
HARQ Type	CC, IR-CTC
HARQ packet/burst size	1 PDU
RCID [bits]	7
Size of data in each DL frame [bytes]	1024

Table 2. Simulation parameters for ARQ and HARQ

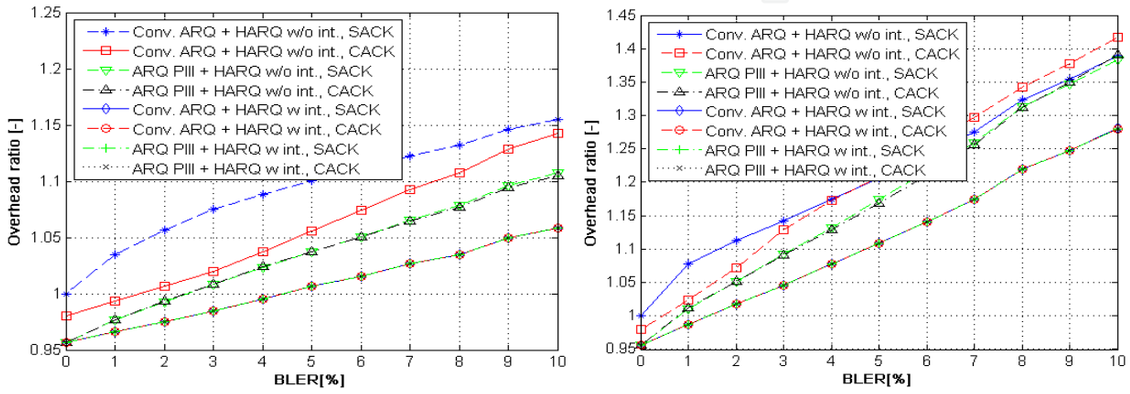
The maximum number of HARQ retransmissions is set to 2 and 4. Both types of HARQ, Chase Combining (CC) and Incremental Redundancy (IR) are considered in evaluations. The Convolutional Turbo Code (CTC) is considered in evaluation if IR HARQ is performed.

4. Results

The results are separated into several groups according to the number of hops (left-hand and right-hand figures corresponds to one and three hops respectively), HARQ Type (CC HARQ in Fig. 5 - Fig. 10 and IR-CTC in Fig. 11 - Fig. 16), and maximum number of HARQ retransmissions for higher clarity. The figures are grouped into set of six figures with the same HARQ Type, with the same maximum number of retransmissions, and further, with varying number of hops, ARQ_Block_Size, and PDU Size. The results are presented in form of figures showing the overhead generated due to ACK/NACK by HARQ and ARQ for 2000 continuously transmitted frames. The expressed overhead is normalized to the overhead generated by conventional IEEE802.16e ARQ (in figures noted as *Conv. ARQ*) for error free channel, using Selective ACK (in figures marked as *SACK*) together with HARQ while no interaction between both is considered. The cumulative ACK (*CACK*) is also taken into account in figures. All figures also depict results for both techniques while interaction is not enabled (without interaction - in figures denoted *w/o int.*) and while the interaction is enabled (with interaction - in figures noted as *w int.*). The overhead for the same cases is

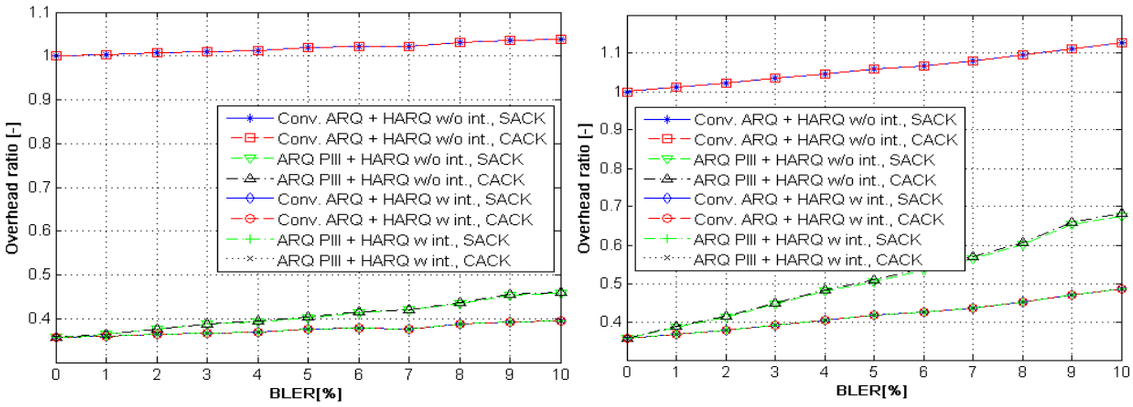
presented also if HARQ and innovative ARQ scheme proposed in (Becvar & Bestak, 2011) (in figures *ARQ PIII*) are simultaneously utilized.

As can be observed from Fig. 5 - Fig. 16, the scenario where ARQ and HARQ interact outperforms all other scenarios. Additional minor improvement is achieved by using innovative ARQ instead of conventional ARQ. However, this improvement is noticeable only as long as ARQ_Block_Size is low (e.g., 16 bytes), PDU Size is higher (e.g., 16 blocks) and mutual interaction of ARQ and HARQ is considered.



(a) (b)

Fig. 5. ARQ & HARQ Overhead vs.BLER for ARQ_Block_Size = 16 B, PDU Size = 1, Size of user data = 1024 B/frame, 4 HARQ retrans., HARQ Type: CC, 1 hop *(a)* / 3 hops *(b)*

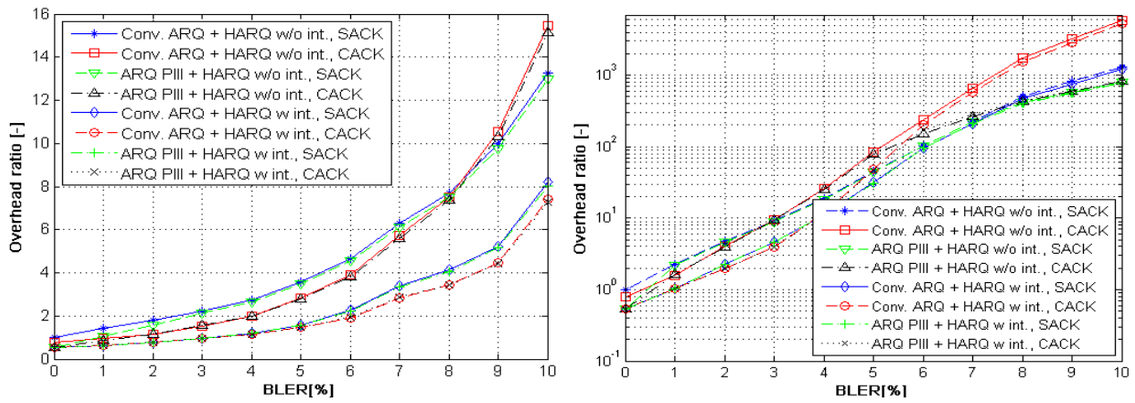


(a) (b)

Fig. 6. ARQ & HARQ Overhead vs. BLER for ARQ_Block_Size = 1024 B, PDU Size = 1, Size of user data = 1024 B/frame, 4 HARQ retrans., HARQ Type: CC, 1 hop *(a)* / 3 hops *(b)*

While no interaction between HARQ and ARQ entities is enabled, the difference between conventional innovative ARQ is more significant. The reduction of overhead is more appreciable for lower number of hops or higher ARQ_Block_Size. The improvement achieved by innovative ARQ in comparison to scenario using conventional ARQ without interaction is due the fact that the ARQ PIII generates lower overhead while the packets are delivered without errors.

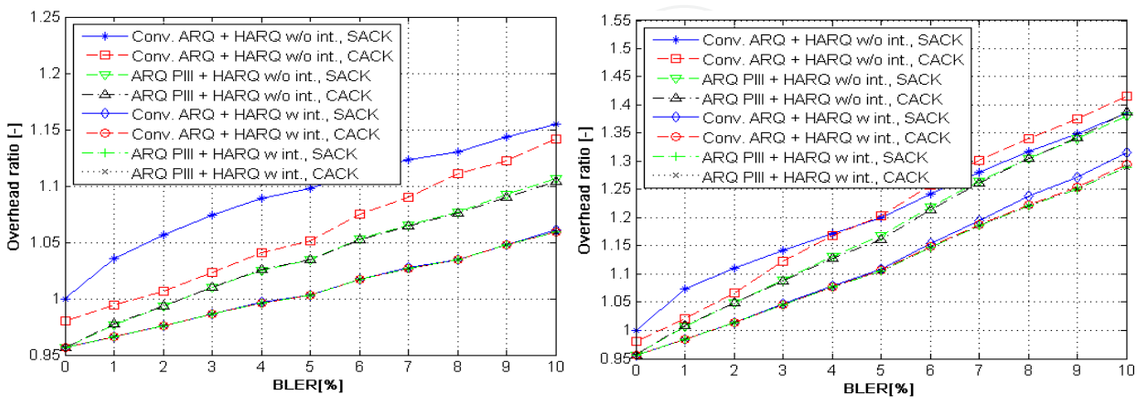
The first group of figures shows the results of CC HARQ for maximum four HARQ retransmissions.



(a) (b)

Fig. 7. ARQ & HARQ Overhead vs. BLER for ARQ_Block_Size = 16 B, PDU Size = 16, Size of user data = 1024 B/frame, 4 HARQ retrans., HARQ Type: CC, 1 hop *(a)* / 3 hops *(b)*

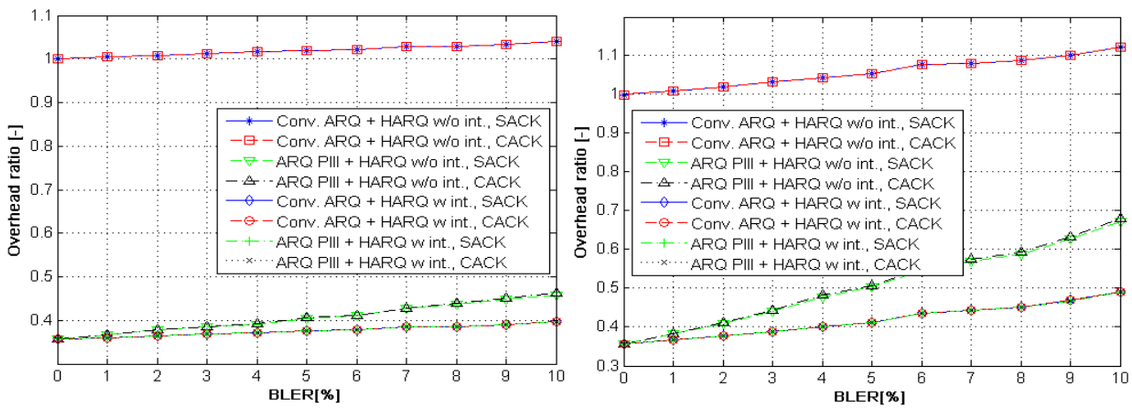
The next group of figures depicts the results of CC HARQ for maximum two HARQ retransmissions.



(a) (b)

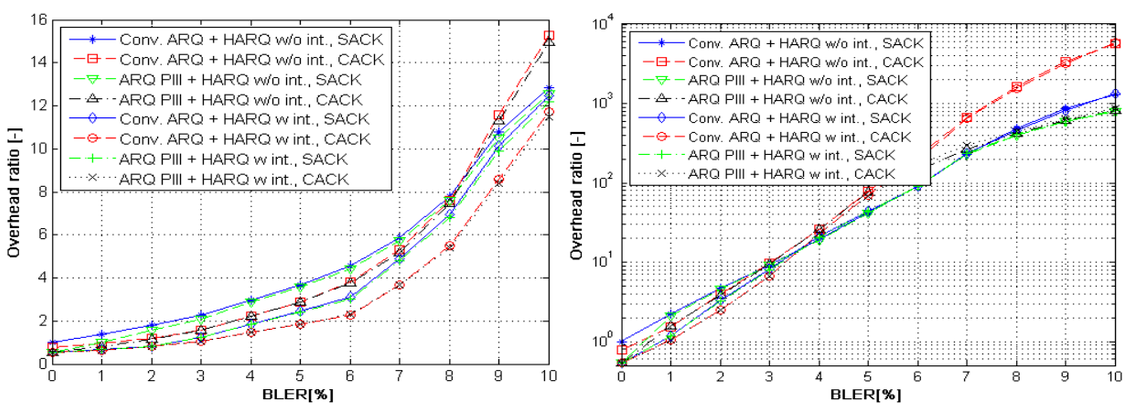
Fig. 8. ARQ & HARQ Overhead vs. BLER for ARQ_Block_Size = 16 B, PDU Size = 1, Size of user data = 1024 B/frame, 2 HARQ retrans., HARQ Type: CC, 1 hop *(a)* / 3 hops *(b)*

The following group of figures represents the results of IR_CTC HARQ for maximum four HARQ retransmissions.



(a) (b)

Fig. 9. ARQ & HARQ Overhead vs. BLER for ARQ_Block_Size = 1024 B, PDU Size = 1, Size of user data = 1024 B/frame, 2 HARQ retrans., HARQ Type: CC, 1 hop *(a)* / 3 hops *(b)*



(a) (b)

Fig. 10. ARQ & HARQ Overhead vs. BLER for ARQ_Block_Size = 16 B, PDU Size = 16, Size of user data = 1024 B/frame, 2 HARQ retrans., HARQ Type: CC, 1 hop *(a)* / 3 hops *(b)*

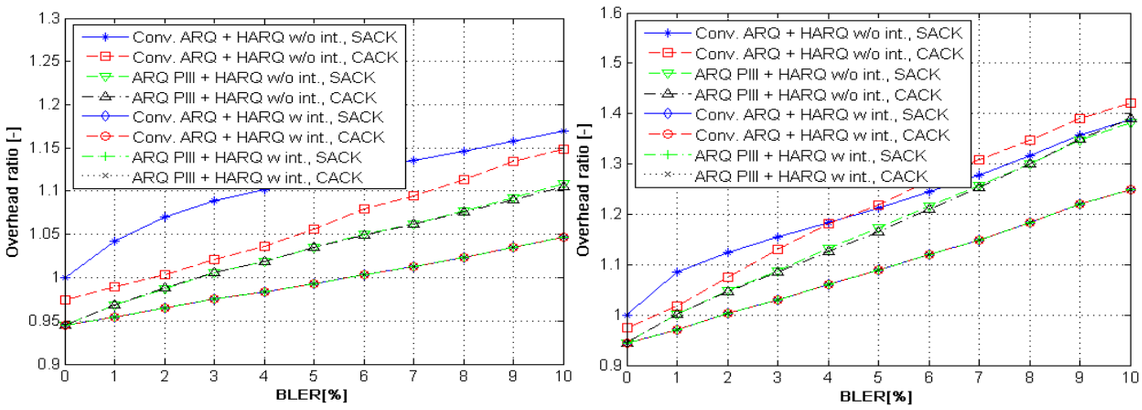


Fig. 11. ARQ & HARQ Overhead vs. BLER for ARQ_Block_Size = 16 B, PDU Size = 1, Size of user data = 1024 B/frame, 4 HARQ retrans., HARQ Type: IR, 1 hop *(a)* / 3 hops *(b)*

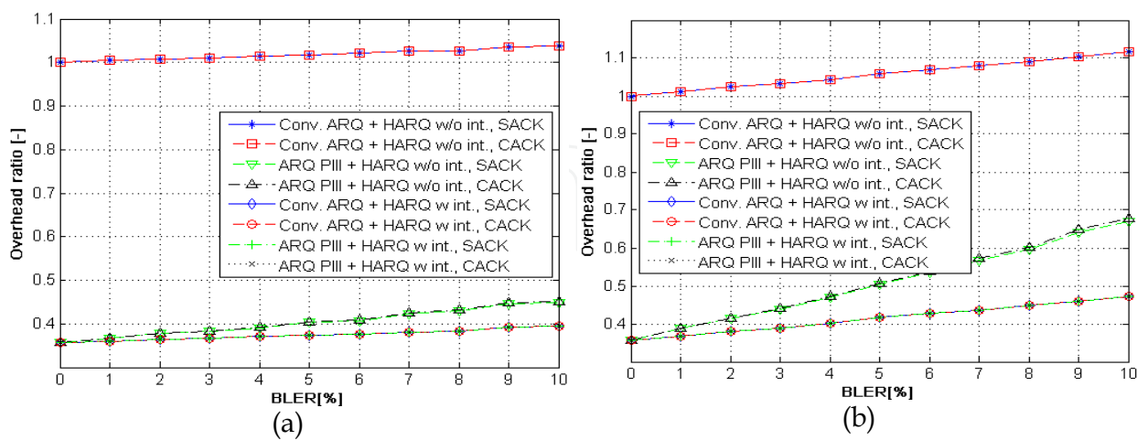
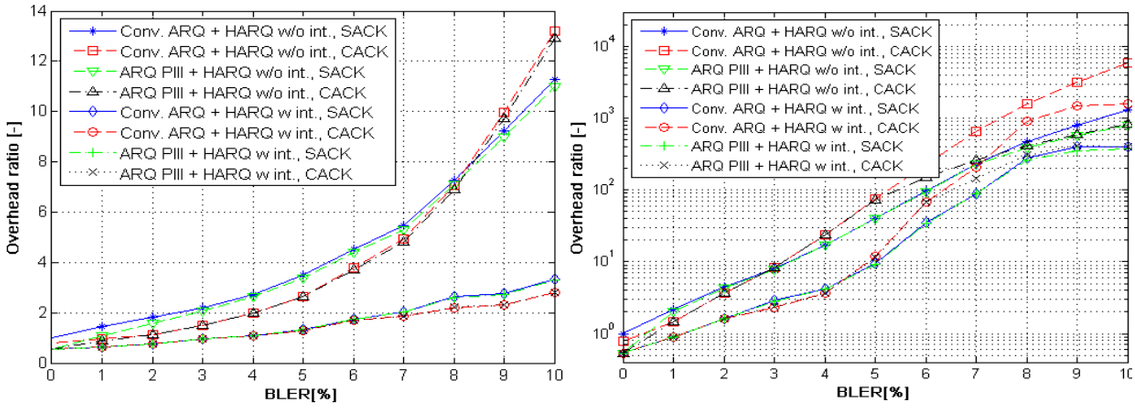


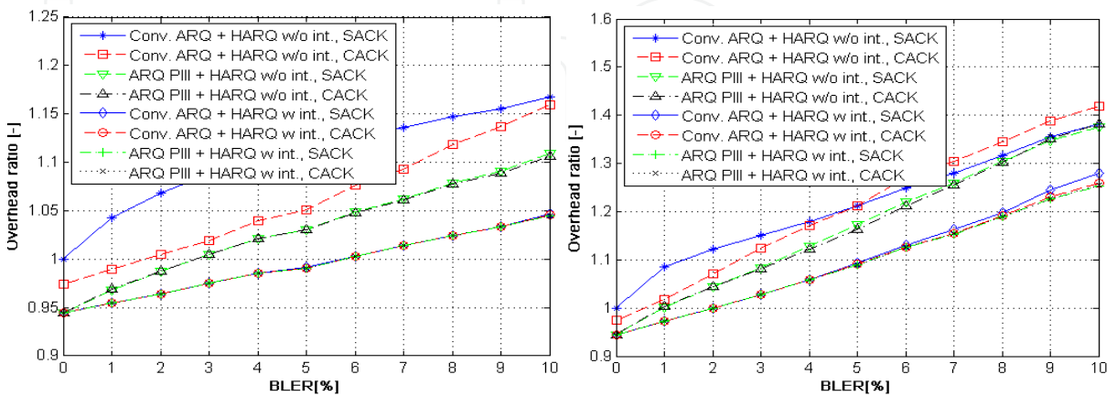
Fig. 12. ARQ & HARQ Overhead vs. BLER for ARQ_Block_Size = 1024 B, PDU Size = 1, Size of user data = 1024 B/frame, 4 HARQ retrans., HARQ Type: IR, 1 hop *(a)* / 3 hops *(b)*



(a) (b)

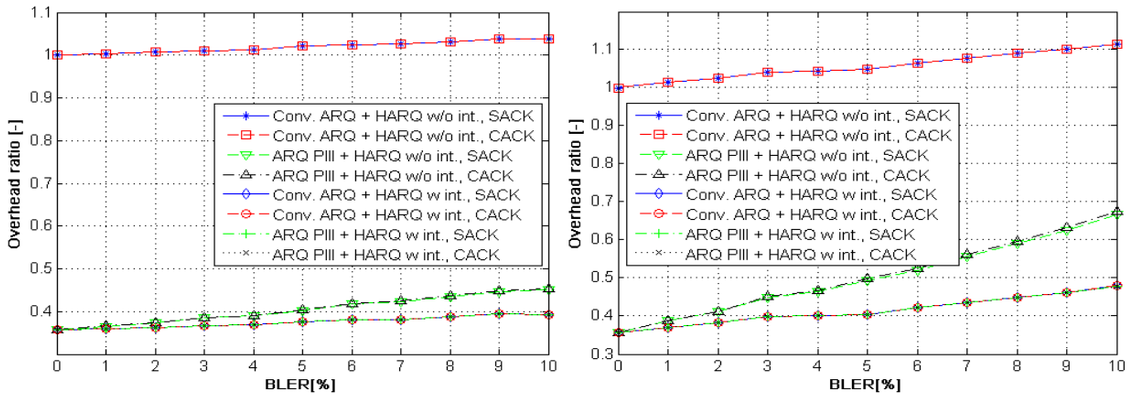
Fig. 13. ARQ & HARQ Overhead vs. BLER for ARQ_Block_Size = 16 B, PDU Size = 16, Size of user data = 1024 B/frame, 4 HARQ retrans., HARQ Type: IR, 1 hop *(a)* / 3 hops *(b)*

The last group of figures represents the results of IR_CTC HARQ for maximum two HARQ retransmissions.



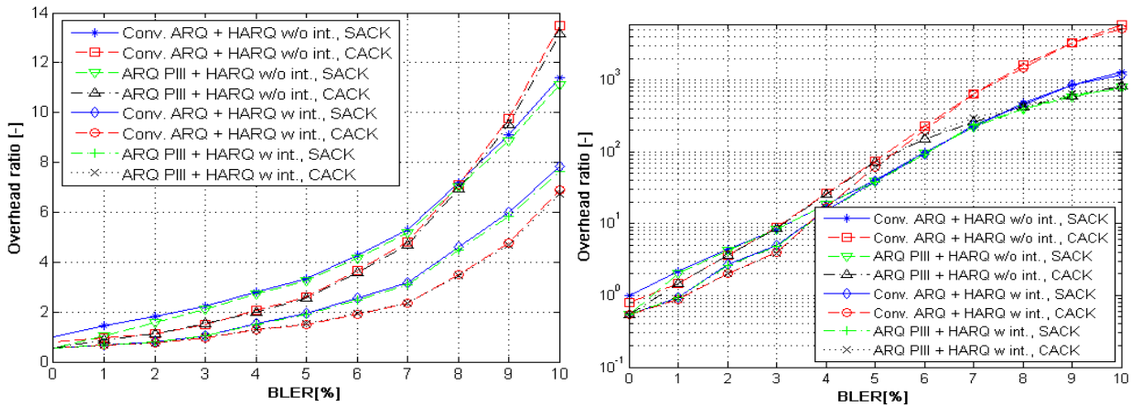
(a) (b)

Fig. 14. ARQ & HARQ Overhead vs. BLER for ARQ_Block_Size = 16 B, PDU Size = 1, Size of user data = 1024 B/frame, 2 HARQ retrans., HARQ Type: IR, 1 hop *(a)* / 3 hops *(b)*



(a) (b)

Fig. 15. ARQ & HARQ Overhead vs. BLER for ARQ_Block_Size = 1024 B, PDU Size = 1, Size of user data = 1024 B/frame, 2 HARQ retrans., HARQ Type: IR, 1 hop *(a)* / 3 hops *(b)*



(a) (b)

Fig. 16. ARQ & HARQ Overhead vs. BLER for ARQ_Block_Size = 16 B, PDU Size = 16, Size of user data = 1024 B/frame, 2 HARQ retrans., HARQ Type: IR, 1 hop *(a)* / 3 hops *(b)*

The impact of individual parameters observed from the previous figures on the efficiency of overhead reduction can be summarized into the following concluding remars:

- **Number of hops**: the efficiency of innovative ARQ scheme is decreasing with higher number of hops if no interaction is considered; however the reduction of the overhead is not influenced by a number of hops if interaction is enabled.
- **ARQ_Block_Size**: the more significant reduction of overhead is achieved by utilization of innovative ARQ with HARQ even without interaction for higher ARQ_Block_Size; additional reduction of overhead by increase of this parameter is enabled by the interaction for both conventional ARQ as well as for innovative ARQ; the level of this additional reduction is getting higher with BLER since the higher BLER increases the amount of packets not corrected by HARQ.
- **PDU Size**: the overall overhead of ARQ and HARQ rises considerably with PDU size as more blocks have to be corrected by ARQ since the probability that certain part of PDU

is delivered with errors is increasing as well; however influence of the level of overhead reduction by this parameter is only minor.

- **Maximum number of retransmissions**: the impact of a number of retransmissions on the overhead is negligible in most of scenarios; nevertheless the noticeable overhead reduction if four retransmissions occur is achieved only for low ARQ_Block_Size together with high PDU Size when interaction is enabled; the reason is that number of uncorrected errors by two retransmissions do not differ to much from four retransmissions. Hence the ARQ overhead in similar for both cases.
- **Type of HARQ (CC vs. IR)**: the IR slightly outperforms CC, however the difference in overall overhead between both HARQ types is also negligible with exception of scenarios with low ARQ_Block_Size, high PDU_Size and enabled interaction. The reason for this conclusion is the same as explained in the previous bullet.

5. Conclusions

The chapter investigates the efficiency of ARQ and HARQ mechanism used in WiMAX. The conventional ARQ, innovative ARQ, and HARQ are described. In addition, their cooperation is contemplated for stand alone operation of both ARQ and HARQ as well as for cooperation between both.

The results demonstrate that if the HARQ and ARQ are enabled and no mutual interaction between both entities is considered, the difference between conventional ARQ and innovative ARQ is significant. The exact level of overhead reduction depends heavily on the setting of the ARQ and HARQ parameters. The local interaction between ARQ and HARQ enables additional reduction of the overhead. If interaction is considered, the significant improvement by using innovative ARQ instead of conventional ARQ is achieved only while ARQ_Block_Size is low and PDU Size is high.

6. Acknowledgment

This work has been performed in the framework of the FP7 project ROCKET IST-215282 STP, which is funded by the European Community. The Authors would like to acknowledge the contributions of their colleagues from ROCKET Consortium (http://www.ict-rocket.eu).

7. References

Becvar, Z. & Bestak, R. (2011). Overhead of ARQ mechanism in IEEE 802.16 networks. *Telecommunication Systems*, Vol.46, No.4, (March 2010), pp. 353-367, ISSN 1018-4864

Hoymann, C. (2005). Analysis and performance evaluation of the OFDM-based metropolitan area network IEEE 802.16. *Computer Networks*, Vol.49, No.3, pp. 341-363, ISSN 1389-1286

IEEE 802.16e. (2006). Air Interface for Fixed and Mobile Broadband Wireless Access Systems: Amendment for Physical and Medium Access Control Layers for Combined Fixed and Mobile Operation in Licensed Bands. Standard IEEE

IEEE 802.16j. (2009). Air Interface for Broadband Wireless Access Systems, Amendment 1: Multihop Relay Specification. Standard IEEE

Kang, M. S. & Jang, J. (2006). Performance evaluation of IEEE 802.16d ARQ algorithms with NS-2 simulator, *Proceeding of Asia-Pacific Conference on Communications*. Busan, Republic of Korea, 2006

Lee, B.G. & Choi,S. (2008). *Broadband Wireless Access and Local Networks: Mobile WiMAX and WiFi*. USA: Artech House

Maheshwari, S., Boariu, A. & Bacciccola, A. (2008). ARQ/HARQ inter-working to reduce the ARQ feedback overhead. Contribution to IEEE 802.16m No. C802.16m-08/1142

Martikainen, H.; Sayenko, A.; Alanen, O. & Tykhomyrov, V. (2008). Optimal MAC PDU size in IEEE 802.16, *Proceeding of 4th International Telecommunication Networking Workshop on QoS in Multiservice IP Networks,* pp. 66-71

Nuaymi, L. (2007). *WiMAX: Technology for Broadband Wireless Access*. West Sussex: Wiley&son Ltd.

Provvedi, L.; Rattray, C.; Hofmann, J. & Parolari, S. (2004). Provision of MBMS over the GERAN: technical solutions and performance. *Proceeding of Fifth IEEE International Conference on 3G Mobile Communication Technologies*, pp. 494- 498, 2004.

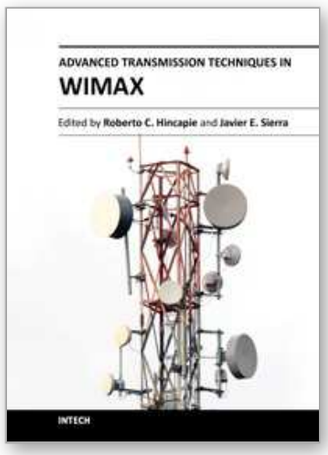
Sambale, K.; Becvar, Z. & Ulvan, A. (2008). Identification of the MAC/PHY key reconfiguration parameters, ICT ROCKET project milestone 5M2, ICT-215282 STP

Sayenko, A.; Martikainen, H. & Puchko, A. (2008). Performance comparison of HARQ and ARQ mechanisms in IEEE 802.16 networks, *Proceeding of International symposium on Modeling, analysis and simulation of wireless and mobile systems*. Vancouver, Canada

Sengupta, S.; Chatterjee, M. & Ganguly, S. (2008). Improving Quality of VoIP Streams over WiMax. *IEEE Transactions on Computers*, Vol.57, No.2, 145-156

Sengupta, S.; Chatterjee, M.; Ganguly, S. & Izmailov, R. (2005). Exploiting MAC Flexibility in WiMAX for Media Streaming, *Proceedings of World of Wireless Mobile and Multimedia Networks*, pp. 338-343, Taormina - Giardini Naxos, Italy, 13-16 June 2005

Tykhomyrov, V.; Sayenko, A.; Martikainen, H.; Alanen, O. & Hämäläinen, T. (2007). Performance Evaluation of the IEEE 802.16 ARQ Mechanism, *Proceeding ofNext Generation Teletraffic and Wired/Wireless Advanced Networking*, pp. 148-161



Advanced Transmission Techniques in WiMAX

Edited by Dr. Roberto Hincapie

ISBN 978-953-307-965-3
Hard cover, 336 pages
Publisher InTech
Published online 18, January, 2012
Published in print edition January, 2012

This book has been prepared to present the state of the art on WiMAX Technology. The focus of the book is the physical layer, and it collects the contributions of many important researchers around the world. So many different works on WiMAX show the great worldwide importance of WiMAX as a wireless broadband access technology. This book is intended for readers interested in the transmission process under WiMAX. All chapters include both theoretical and technical information, which provides an in-depth review of the most recent advances in the field, for engineers and researchers, and other readers interested in WiMAX.

How to reference

In order to correctly reference this scholarly work, feel free to copy and paste the following:

Zdenek Becvar and Pavel Mach (2012). On Efficiency of ARQ and HARQ Entities Interaction in WiMAX Networks, Advanced Transmission Techniques in WiMAX, Dr. Roberto Hincapie (Ed.), ISBN: 978-953-307-965-3, InTech, Available from: http://www.intechopen.com/books/advanced-transmission-techniques-in-wimax/on-efficiency-of-arq-and-harq-entities-interaction-in-wimax-networks

INTECH
open science | open minds

InTech Europe
University Campus STeP Ri
Slavka Krautzeka 83/A
51000 Rijeka, Croatia
Phone: +385 (51) 770 447
Fax: +385 (51) 686 166
www.intechopen.com

InTech China
Unit 405, Office Block, Hotel Equatorial Shanghai
No.65, Yan An Road (West), Shanghai, 200040, China
中国上海市延安西路65号上海国际贵都大饭店办公楼405单元
Phone: +86-21-62489820
Fax: +86-21-62489821

© 2012 The Author(s). Licensee IntechOpen. This is an open access article distributed under the terms of the Creative Commons Attribution 3.0 License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

IntechOpen

IntechOpen