

Performance Evaluation of ARQ Protocols for Realtime Services in IEEE 802.11 and Wireless ATM

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Abstract

The paper presents a performance comparison of two link level ARQ protocols suited for data rates above 1 MBit/s. The first ARQ protocol has been developed as part of the ACTS project AC031 COBUCO and is optimised for a wireless ATM access network [9] [10]. The radio transmission is using the DECT frequency band, a TDMA based MAC layer and several FEC codes and is able to support user data rates of up to 850 kbit/s. The COBUCO wireless ATM protocol stack contains a slot based selective-repeat ARQ protocol (SBSA), which can be adapted to the connection QoS requirements and can therefore be used for realtime applications like video or audio streaming. This protocol is compared to the IEEE 802.11 ARQ concepts for wireless LANs at 2.4 GHz under consideration of throughput, efficiency, complexity and usability for realtime services.

1. Motivation for New ARQ Protocols

The emergence of data services over wireless networks imposes a challenge on the implementation of appropriate error correction strategies. The use of ATM or IP on wireless transmission links requires some means of error correction to compensate the typically high bit error rates. Automatic Repeat Request (ARQ) protocols are a commonly used method for error control in modern data communication systems. The increasing data rates of newly developed wireless communication systems like wireless ATM or wireless LAN impose new challenges to the ARQ protocol design [3], [4], [6]. There are several motivations for the development of an optimized ARQ protocol. Comparatively high bit error rates and increasing data rates on future radio interfaces of up to 25 MBit/s require small ARQ packet sizes, which reduce the bandwidth consumed by retransmissions.

2. The COBUCO Slot Based Selective Repeat (SBSA) Protocol

The SBSA, which has been developed as part of the COBUCO wireless ATM experiment, is based on three main ideas: to achieve the optimum efficiency by using selective repeat, small packets and small overhead. By this concept the protocol is able to adapt to the error characteristics very fast. The approach allows to minimize the retransmitted amount of data and achieves maximum throughput and bandwidth efficiency. The complexity of the protocol is much higher than one would expect from an approach making everything small. In particular the receiver side makes use of several sophisticated algorithms to improve the performance.

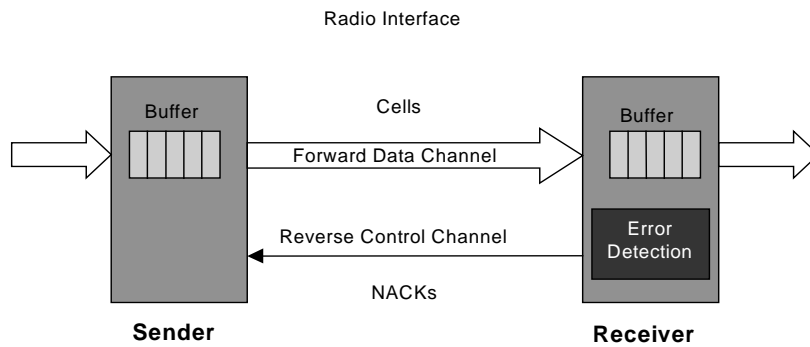


Figure 1: SBSA Protocol Architecture

The ARQ concept is shown in Figure 1. The most important parameters used in the implementation of the SBSA protocol are

- based on DECT TDMA frame structure, frame length 10 ms, 24 slots per frame
- fixed slot / packet size: 392 Bit
- minimal overhead for ARQ: 4 bit sequence number, 1 bit retransmission flag
- error detection based on a BCH code for the slot header and a Reed-Solomon code for the slot payload
- only negative acknowledgements (NACKs) on the reverse link

The size of the receiver buffer is max. 256 slots per connection, the sender uses a fixed buffer of 256 slots, which corresponds to a memory size of approximately 13 kByte. The output scheduler is based on the ATM GCRA (Generic Cell Rate Algorithm) and allows traffic shaping towards the fixed network. This is important for the compliance with the negotiated ATM connection parameters [5].

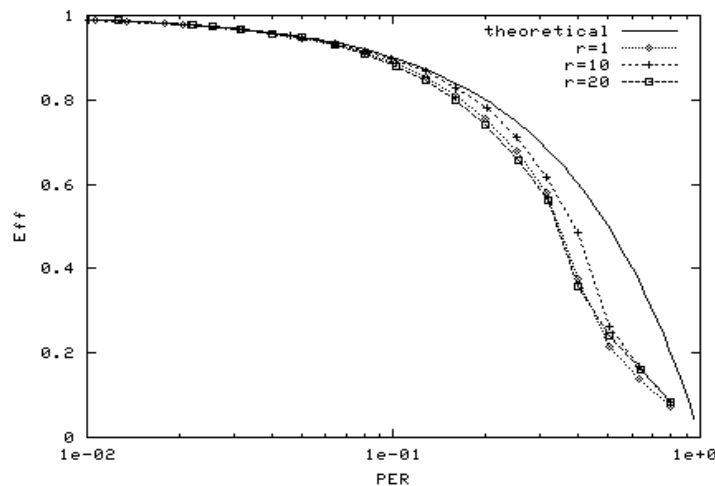


Figure 2: SBSA Efficiency vs. Channel Packet Loss Rate (PLR)

Figure 2 shows the simulated efficiency of the SBSA protocol for a slot rate of 1, 10 and 20 slots per DECT frame versus the channel packet loss rate. The protocol shows a good performance even for very high packet loss rates in the order of 0.1, i.e. in the average every 10th packet is corrupted. The simulated results are close to the theoretical limit of a selective repeat ARQ protocol. The main source of errors is the small sequence number space of only 16, which leads to the danger of misinterpretation of NACK messages for larger queue sizes. This also explains the dependence of the efficiency on the slot rate, because a higher slot rate leads to larger queues and a higher misinterpretation probability. This effect is shown in Figure 3, again for different slot rates. The graph shows the size of the retransmit queue and the fill level of the slot buffer in the receiver (denoted as the 'main' queue).

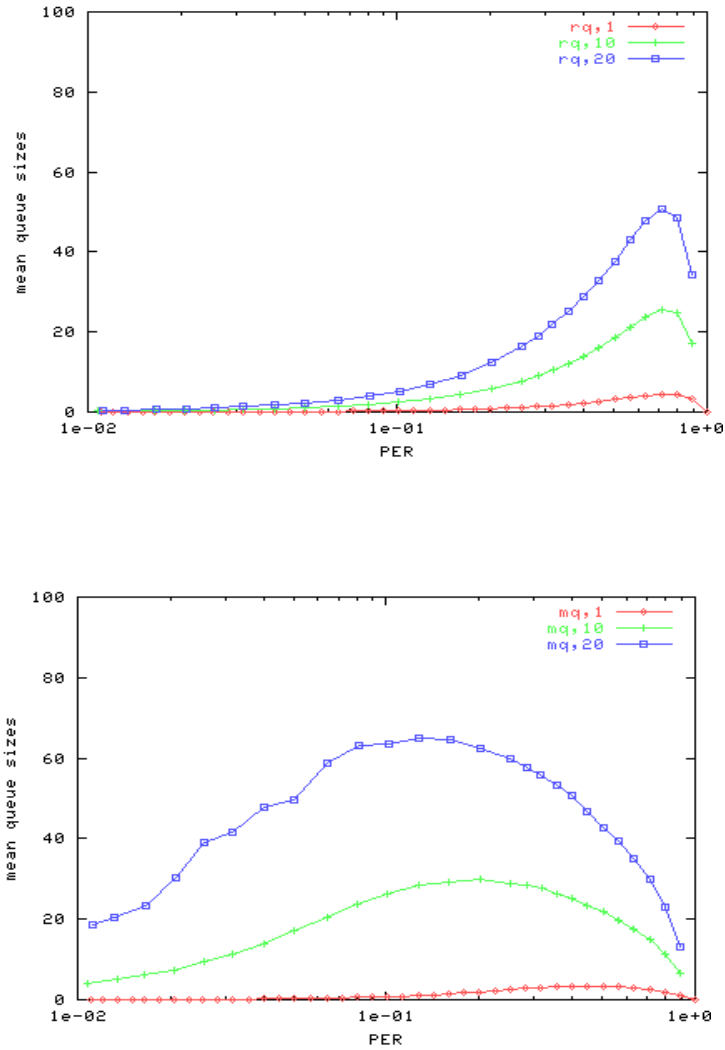


Figure 3: Buffer Usage of the SBSA Protocol

3. The IEEE 802.11 ARQ Concept

The ARQ concept of the IEEE 802.11 standard is integrated with the MAC layer, which determines the ARQ relevant round trip delay by specifying the inter frame space. The relevant inter frame space for the ARQ is the Short Inter Frame Space (SIFS). The ARQ is the only error control method specified in the standard and no FEC coding is used. The ARQ can be adapted to the channel conditions by a fragmentation - defragmentation procedure, which transmits larger MAC layer service data units (MSDU) in smaller MAC layer protocol data units (MPDU) as shown in Figure 4. The degree of fragmentation is variable and can be determined by the fragmentation threshold parameter. All packets larger than this thresholds have to be transmitted as fragments, which are acknowledged separately. The ARQ is a stop-and-wait ARQ with positive acknowledgements after each packet. The detection of lost frames is achieved by an ACK timeout. The standard uses two different retry limits for short and long frames.

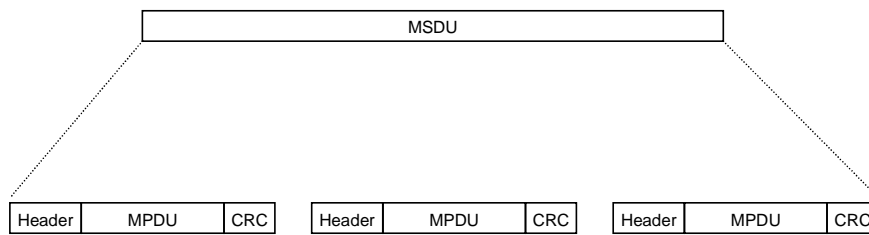


Figure 4: IEEE 802.11 Fragmentation

The main difference to the SBSA protocol described in the previous section is the packet size. IEEE 802.11 uses much larger packets and can therefore utilize much larger packet headers as well. The maximum size of a MSDU is 2304 octets and of a MPDU 2312 octets, i.e. without fragmentation. However for the direct sequence spread spectrum (DSSS) physical layer with a data rate of 2 MBit/s the recommended maximum MPDU size is 800 octets, which corresponds to a packet duration smaller than 3.5 milliseconds. The MAC and PHY overhead per packet is 58 octets. On the reverse link the size of an ACK frame is 38 octets or 152 microseconds. As shown in Figure 5, an additional inter frame space with a duration of 10 microseconds is required.

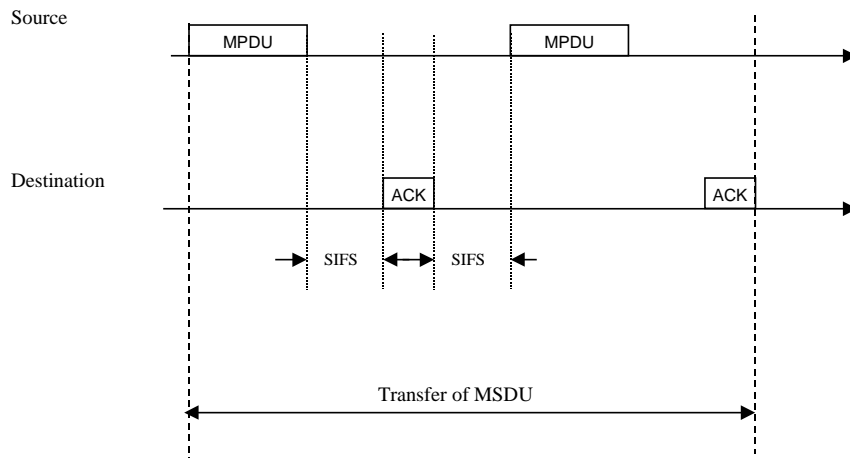


Figure 5: IEEE 802.11 Retransmission

Figure 6 and Figure 7 show the performance of the IEEE 802.11 ARQ protocol for a set of MPDU sizes. It is obvious, that for high bit error rates the throughput can be increased by using smaller packets. The reason is, that the error probability for a number of smaller packets is lower than for one large packet. This result is also reflected in the mean transmission times shown in Figure 6.

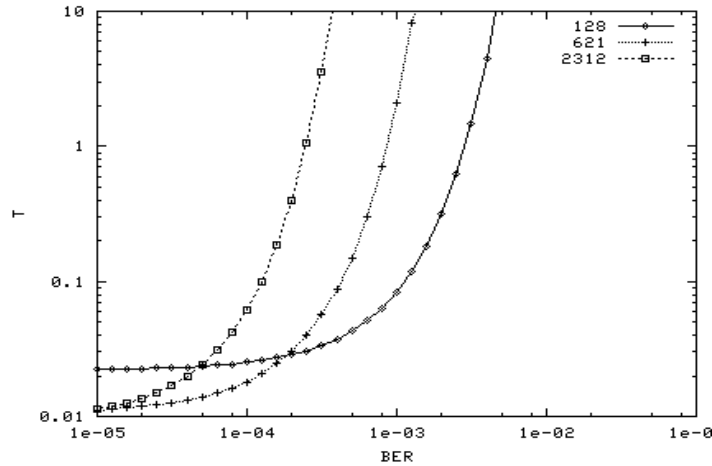


Figure 6: Mean Transmission Time for 1 MSDU with 2254 Octets

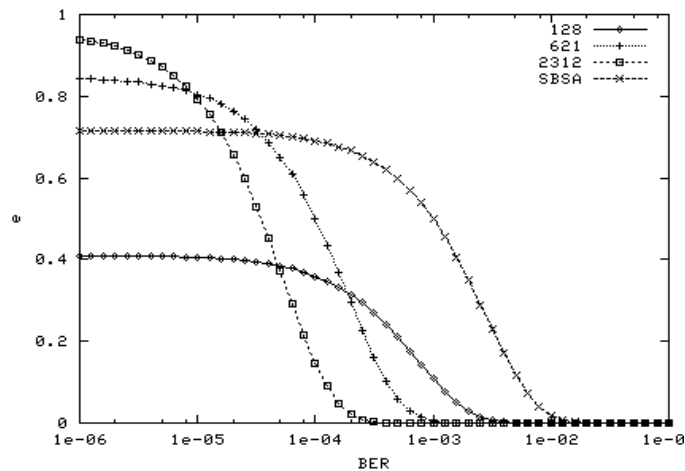


Figure 7: ARQ Efficiency of the IEEE 802.11 ARQ

The efficiency in Figure 7 also contains the efficiency of the SBSA protocol. In contrast to Figure 2 only the theoretical efficiency is shown with additional consideration of the packet overhead. The overhead of the SBSA protocol is calculated with the DECT slot size of 480 bit and a payload size of 344 bytes. 136 bits are used for MAC header, synchronisation, error detection and guard space. This allows a maximum efficiency of 0.72. For a fair comparison the Reed-Solomon error correction, which can be used in the COBUCO protocol, has not been enabled.

4. Conclusions

The comparison of the two protocols in this paper reflects two main applications for high bit rate wireless links: wireless LANs and wireless access networks. Wireless ATM and IEEE 802.11 are mainly aimed at indoor systems, while the COBUCO wireless ATM system with the DECT physical layer could be used in wireless local loop (WLL) applications as well. For all these systems realtime applications are considered to be used in the future, and suitable ARQ protocols are an important issue to improve the QoS and the bandwidth efficiency.

3 main criteria were used to compare the two protocols: The transmission delay, the efficiency and the complexity. The transmission delay determines the suitability of an ARQ protocol for realtime services like audio or video streaming. With respect to the delay the SBSA has a clear advantage compared to the IEEE 802.11 ARQ, main reason is the small packet size of the SBSA. With very small packets the IEEE 802.11 protocols becomes inefficient due to the large overhead of 58 bytes. The maximum achievable protocol efficiency depends on the channel BER and the packet size. For low channel BERs the efficiency is determined by the packet overhead. For large packets and small BERs the IEEE 802.11 ARQ can achieve a better efficiency due to the smaller relative overhead. For BERs higher than $10e-04$ the efficiency of the

SBSA is higher, due to the superior algorithm (selective repeat) and due to the smaller packet size. The lower complexity is the main advantage of the IEEE 802.11 ARQ: the implementation of selective-repeat requires a more sophisticated implementation with various buffers on receiver and transmitter side.

5. References

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