Paper submitted for

RACE Mobile Telecommunications Summit

November 22nd-24th, 1995, Cascais(P)

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Title: **Functionality of the ASR-ARQ Protocol for MBS**

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Functionality of the ASR-ARQ Protocol for MBS

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Abstract: *The logical link control (LLC) layer of MBS is responsible for offering reliable transmission of ATM cells according the requested QoS of a virtual channel. Because of the wide range of possible values for mean/peak data rate, maximum delay and cell loss rate which can be chosen during connection setup, the ARQ protocol inside the LLC layer has to be able to adapt its behaviour to the requested QoS and to the current load of the physical channel. This paper describes the functionality of the new ASR-ARQ protocols that automatically discards ATM cells witch have exceeded their maximum delay. It is able to work together with a MAC protocol offering capacity on demand.*

1 Introduction

The goal of MBS is to extend the access to the broadband services of B-ISDN to mobile users. B-ISDN is based on the *Asynchronous Transfer Mode* (ATM) which offers *Virtual Channels* (VC) supporting services with variable data rates. The transmission capacity of VCs can freely be chosen in a wide range by the user by declaring the connection specific parameters *mean data rate* and *peak data rate* during connection set-up.

The LLC layer is responsible for guaranteeing the quality of service that has been requested by the various concurrently existing VCs. Because of the restricted transmission conditions on the MBS air interface in comparison to a fibre link of a fixed ATM network, an additional error correction scheme is necessary. This scheme consist of a hybrid combination of *forward error correction* (FEC) and *automatic repeat request* (ARQ). The FEC is included in an appropriate channel coding under responsibility of the physical layer. The ARQ protocol is executed by the LLC layer.

2 Requirements on the ARQ protocol of MBS

When designing the ARQ protocol for MBS there is a fundamental trade-off between delay caused by retransmissions and residual cell loss ratio (CLR). It is not useful and often not possible to offer CLR values which are available in fixed, fibre based networks. Instead it should be possible to adapt the amount of error control for each virtual channel according to its requirements described by the connection specific parameters *maximum delay* and *cell loss ratio*.

To meet the requirements on error correction in MBS the *Adaptive Selective Reject Automatic Repeat reQuest* (ASR-ARQ) protocol has been developed. It is derived from conventional ARQ protocols like HDLC, ISO 8802.2 and LAP-B of ITU-T. The protocol controls the number of retransmissions in dependency of the requested QoS, taking into account the current queueing delay and channel load. It automatically discards cells, if their maximum delay has been exceeded because of congestion or worst propagation conditions. Furthermore it offers a sophisticated multiplexing and queueing strategy based on a priority mechanism to schedule the cells of parallel virtual channels or virtual paths (VP) in the same station according to their QoS requirements.

The extension of ATM networks to mobile users requires special mobility management functions. Very important for the observance of QoS requirements is the execution of *seamless handover*. As long as only one base station controller is involved in a handover (figure 1), it is executed completely within the LLC layer. Therefore LLC's lower sublayer has to offer functions to prepare a seamless handover by establishing connections to alternate base stations. The execution of a handover has to be done transparently for the instances of the ARQ protocol.

Another task of the LLC layer is the execution of multi-link transmission for services requiring higher data rates than available on one carrier. This mode is only available, if a mobile stations contains multiple transceiver units for parallel transmission on several carriers. The lower sublayer of the LLC layer contains a special splitting and recombining unit for multi-link transmission. The splitting takes place dynamically according to the current capacity availability indicated by the MAC protocol.

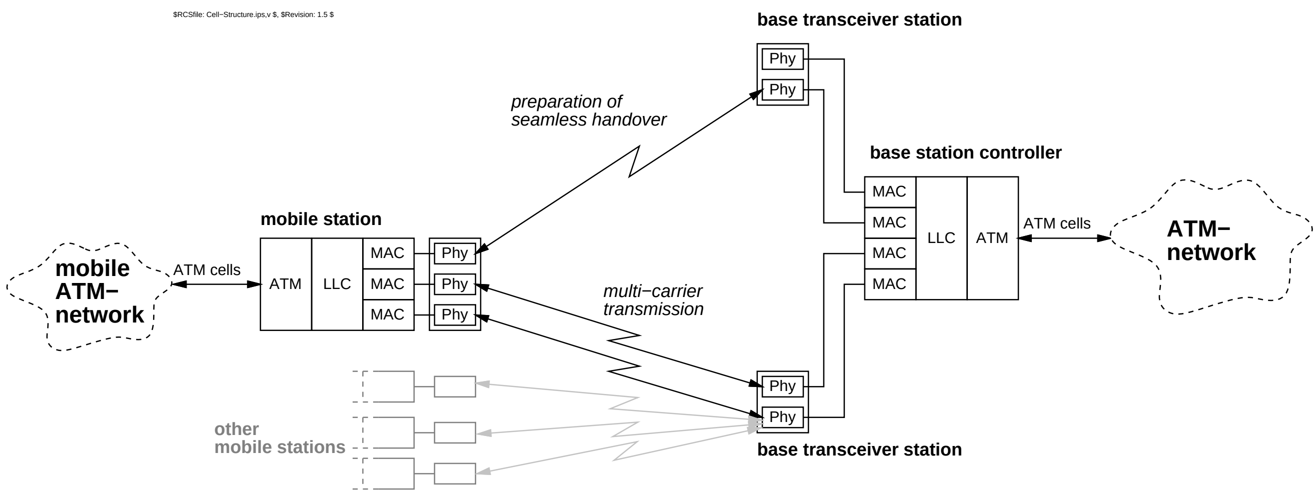

Figure 1: Location of protocol instances in a MBS cell

3 Structure of the logical link control layer of MBS

The development of the LLC layer and the MAC layer are closely related. Especially the *Service Access Points* (SAP) between the two sublayers have been designed according to the requirements and functionalities of both sublayers. The management plane contains the necessary functionality for resource management and radio handover.

The MAC layer contains functions for the dynamic capacity assignment to logical channels [1]. Therefore one instance of the MAC protocols is generated for each transceiver unit. The generation of MAC instances is controlled by the MAC layer controller. In the mobile station the controller is responsible for the generation and update of a data base containing all available channel resources. A resource scanning algorithm is responsible for finding the paging or pilot channel of base stations. This channel resource data base is used by upper layer functions for controlling and executing channel setup, resource management and handover.

An ARQ instance is responsible for executing the ARQ protocol for one link. It contains the sending and resequencing buffers. In contrast to traditional LLC layer protocols which are multiplexing the parallel channels above the ARQ instance, MBS has to establish one ARQ instance per VCs or VP. It is evident, that this increases the complexity of the LLC layer in comparison to a structure with only one ARQ instance responsible for the multiplexed ATM cell stream. Section 4 explains the necessity for this structure. The MBS specific reliable, connection-oriented control channels are also handled by own ARQ instances. In order to reduce complexity of the LLC layer, it seems to be reasonable to possibly multiplex ABR-like VCs above ARQ, because they normally request the same very low cell loss rate and are insensitive to large delays.

The PDUs generated by the ARQ instances and directed to the same destination (mobile station $\leftrightarrow$ base station controller) are multiplexed on one logical channel, the LLC internal traffic channel TCH. The base station establishes one TCH for each registered mobile station. Inside the mobile station's LLC layer only one TCH exists, directed to the base station. A TCH is resistant to switching between transceiver

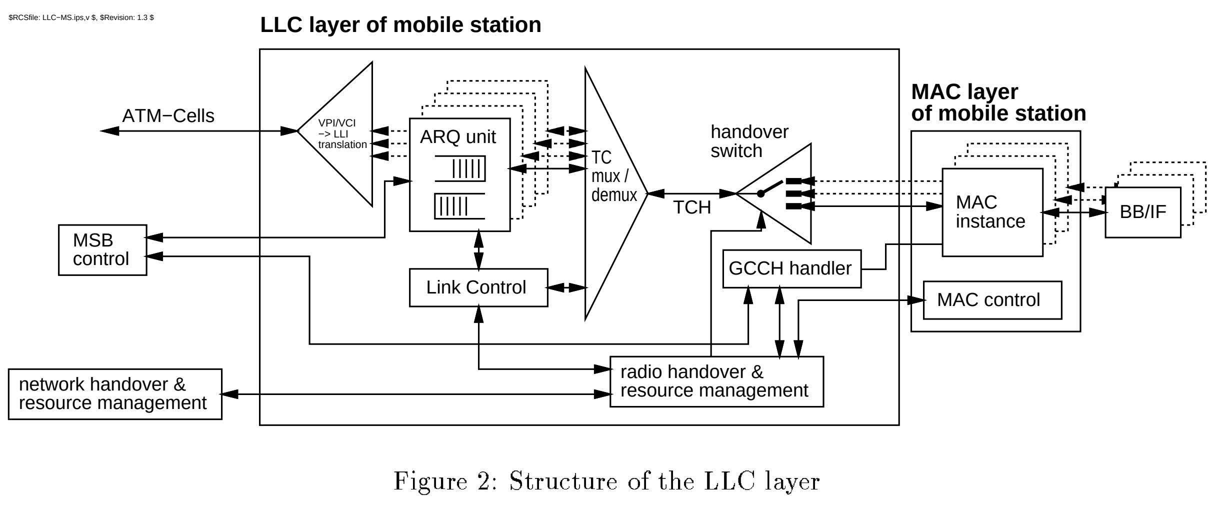

Figure 2: Structure of the LLC layer

units during execution of handover or by the usage of a multi-link protocol. The lower sublayer of the LLC layer contains a multi-link splitter which is also used as handover switch. It maps the TCH on one or in case of multi-link transmission on several of the available MAC instance.

The TCH multiplexer is responsible for controlling the order of access from ARQ instances on a TCH. It contains a priority controlled mechanism for determining that ARQ instance that is allowed to transmit the next frame. The priorities for the ARQ instances are calculated based on following parameters:

residual lifetime Difference between maximum delay and queueing period of the first ATM cell (the most critical cell) in a queue

queue length Number of buffered ATM cells

exception situations Transmission of supervisory frames becomes necessary, e.g. *receive ready* in case of a closed window (too much pending acknowledgements)

4 Advantages of multiple ARQ instances

The usage of one ARQ instance per VC allows the adaptation of the amount of error correction for each VC according to the required QoS. The connection specific QoS parameters of a VC, i.e. maximum transmission delay and minimum cell loss ratio, must be taken into account to compute the number of retransmissions. Although it is necessary to keep the sequence of ATM cells of one VC in order, it often is useful to handle VCs of realtime-oriented services with higher priority than VCs with high maximum delay resulting in a changed sequence of ATM cells which do not belong to the same VC.

There is another advantage of using multiple ARQ instances leading to shorter delays. If all ATM cells would be processed by only one ARQ instance, situations will occur, in which ATM cells have to wait for the retransmission of missing cells although not necessary: In case of an incorrect transmission of a cell, cells with higher sequence numbers than the missing cell have to be buffered in the receiving ARQ instance until the missing cell is retransmitted correctly. But if the rejected ATM cell belongs to a different VC than the waiting ones, the delaying of these cells would not be useful. Forwarding the buffered cells to the upper layer would have been possible before, if the belonging of cells to VCs is known by the receiver. This lack of knowledge is avoided by using multiple ARQ instances.

5 Functionality of the ASR-ARQ protocol

The *Adaptive Selective Reject Automatic Repeat reQuest* (ASR-ARQ) protocol used in the LLC layer of MBS is based on a HDLC–like window algorithm which is adapted to the special needs of wireless ATM transmission. The PDUs of the ARQ protocol, the so called frames, can carry one or more ATM cells as payload, dependent on the size of a MAC-PDU. The protocol uses *selective reject* (SREJ) commands in order to force the retransmission of frames.

The buffer length of an ARQ instance will be adapted to the QoS requirements of the associated VC. The queueing delay of every buffered ATM cell is stored to automatically adapt the number of retransmission to the maximum delay, the maximum cell loss rate and the current traffic load. ATM cells, which exceed their maximum delay, will be discarded.

The ARQ instance in the receiving station is responsible for the resequencing of received ATM cells according to their *frame sequence number*. If the interference of bursts was too high for the FEC to decode them correctly, the information frame that was included in the interfered burst will be missing in the sequence and has to be requested for retransmission. The protocol makes use of a SREJ (N(R)) command (Selective REJect), which orders retransmission of the information frame marked with the *receive sequence number* N(R). If the received sequence is complete, the receiver acknowledges the transmitted data by sending an I(N(R)) command (Information frame) or a RR (N(R)) command (Receive Ready) with N(R) being the sequence number of the next I frame to be awaited.

The sending station has the possibility to discard cells, which have reached their maximum allowed delay. If discarded cells have not been involved into the transmission process until the moment of their discardence, the receiver does not have to be informed of the discardence. A different situation occurs if the receiving station has requested the discarded cell for being transmitted again. In this case the sender has to signal that the rejected cell will not be sent again. This is done by setting the discard number *N(D)*, which is sent within the header of a frame. Figure 3 shows the structure of the frames with the various counters and parameters in the header.

Another feature of the ASR-ARQ protocol is, that it repeats the transmission of previously sent but still unacknowledged cells in supervisory frame, when the sending station is polling for an acknowledgement. This type of frame is sent when the transmitting station has reached the end of its transmission window. Because acknowledgements of the receiver are missing, the sender is not able to shift its transmission window in time. All ATM cells have the same length, hence a reduction of the frame length like in other

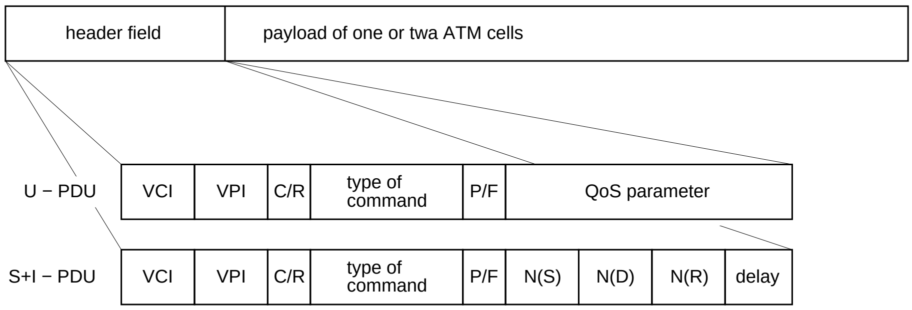

Figure 3: ARQ frames format

ARQ protocols is not possible. Therefore the usage of the empty information field for retransmission of not requested ATM cells makes sense, even if the transferred cell was already received and not the reason for the pending acknowledgement.

The protocol sequence shown in figure 4 demonstrates the above mentioned features with an example of an asymmetric data transmission from base station to mobile station.

The I frame with the *send sequence number N(S)* = 2 has not been received by the mobile station. A first *SREJ command* to request the retransmission of the missing cell fails, so that after the second attempt the selected cell has to be discarded by the sender. Therefore the base station sends an I frame transporting the ATM cell with *N(S)* = 5, which is next to be dealt with, and sets the discard number *N(D)* to 1. When receiving this frame the mobile station knows that the pending I frame with N(S) = 1 will not be send again, since it has been discarded. The mobile station forwards all received I frames to the upper layer and sends a RR acknowledgement with N(R) = 6, which indicates that all I frames with "lower sequence" number have been received. Because this acknowledgement is not received by the base station and the base station is not allowed to transmit any new ATM cells with "higher" sequence number, it polls for an acknowledgement.

6 Outlook

First performance evaluations by computer simulation have shown, that the transmission of acknowledgements is a critical task for the protocol. Short round-trip delays between transmission of an I frame and its acknowledgement are essential for keeping the QoS for real-time oriented services. But especially for asymmetrical VCs fast acknowledgements lead to a high overhead because piggy-back transmission in I frames of the back-direction is not always possible.

Whenever an I frame is received, the receiving ARQ instance is able to schedule an acknowledgement for transmission. The TC multiplexer now has to decide, how urgent the transmission of an acknowledgement is and if it has to request capacity at the MAC protocol. Because the MAC layer offers capacity on demand, the urgency of acknowledgement transmission not only depends on internal requirements but also on the current load on the physical channel.

Further studies have to investigate the influence of dynamic capacity assignment and priority determination of acknowledgements on the performance of the whole system.

7 Acknowledgements

The author would like to thank the members of the MBS project for their suggestions. Furthermore this work would not have been possible without the hard work and enthusiasm of the students working on their diploma thesis.

8 References

[1] D. Petras. *Medium Access Control Protocol for transparent ATM access in MBS.* In *RACE Mobile Telecommunications Summit*, Cascais(P), November 1995. to be published.

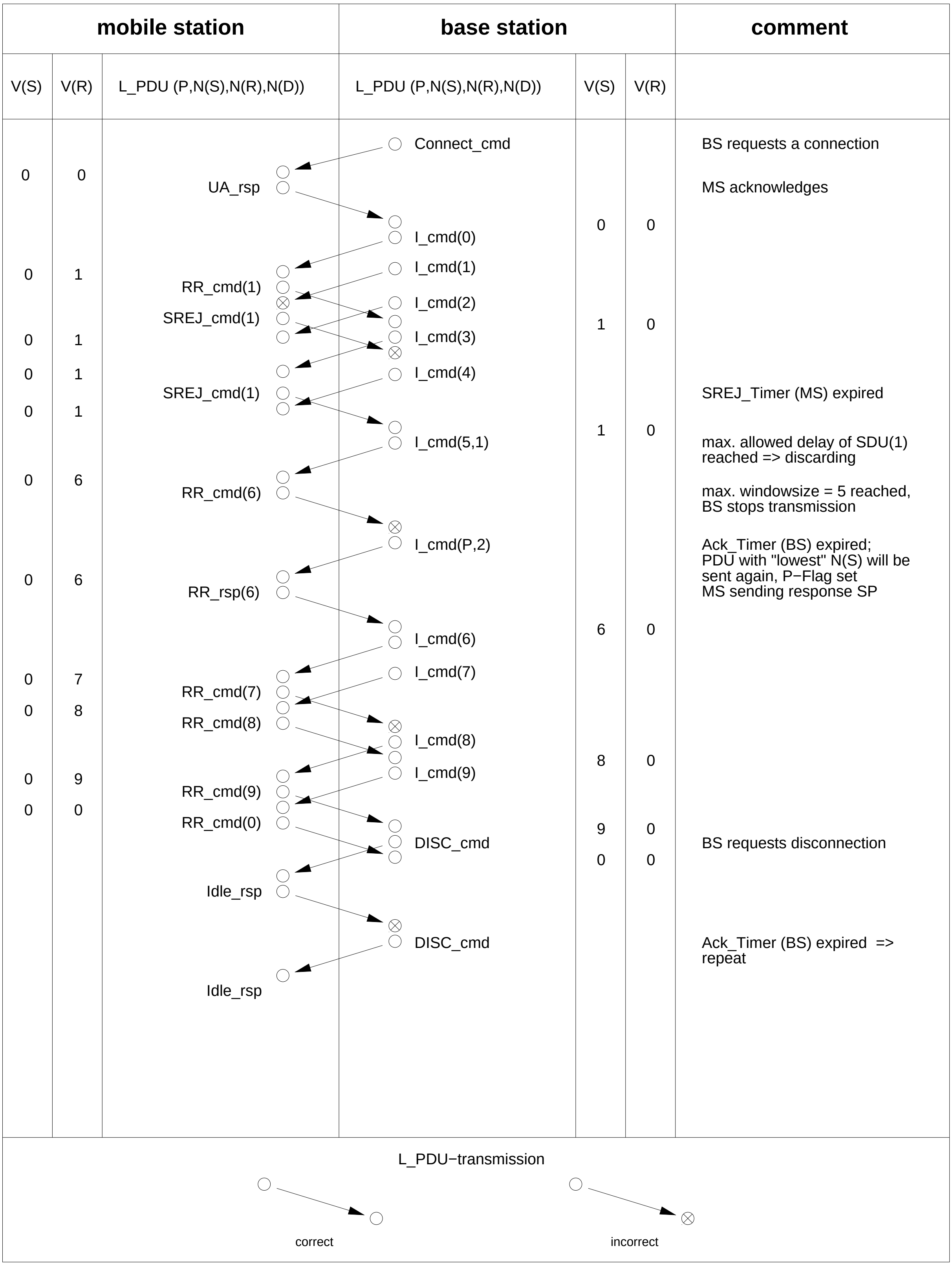

Figure 4: Message sequence chart of the ASR-ARQ protocol