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Re:	IEEE 802.16.ab-01/01 ETSI TS 101 351 V8.6.0 (2000-12)
Abstract	
Purpose	To propose a set of operational procedures for the ARQ protocol based on the GPRS standard.
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A Proposal for ARQ Procedures Based on the GPRS Standard

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Introduction

The GPRS standard [1] defines a logical link control protocol for reliable wireless datagram delivery using ARQ. This protocol belongs to a family of protocols derived from the High-Level Data Link Control (HDLC) standard, whose other members include 802.2 LLC for LANs, LAPB for X.25, LAPD for ISDN, LAPM for V.42 modem, Frame Relay, SDLC for SNA, and many PPP variants. It is therefore a familiar and mature protocol, with many commercial and public domain implementations available. The purpose of this contribution is to discuss how to adapt this standard for the purpose of TG3 MAC.

There are two main aspects to an ARQ protocol. One is the definition of retransmission unit. The current version of the working document [2] already contains several options. The other aspect is the operational procedures, namely the initialization and updating of communicating ARQ state machines, and how to recover from errors. This contribution will focus on the second topic.

A Summary of ARQ Procedures

This section will provide a brief description of the relevant elements of ARQ procedures as defined in the GPRS standard. Please refer to the official specification [1] for the full detail.

ARQ Messages

The GPRS standard defines a set of messages between communicating ARQ state machines, called Logical Link Entities (LLE). Below is a summary of defined messages:

1. XID (Exchange Identification): This can be either a command or a response, used to negotiate ARQ parameters such as window size, timer value, etc.
2. SABM (Set Asynchronous Balanced Mode): This is a command used to initialize ARQ state machines, or reset them if errors occur. It can have optional parameters the same as XID, providing an alternative method for the negotiation or ARQ parameters.
3. UA (Unnumbered Acknowledgement): This is a response used as the reply to SABM. The ARQ state machines can be initialized with a single exchange of SABM and UA.
4. DISC (Disconnect): This is a command used to terminate the logical link.
5. DM (Disconnected Mode): This is a response used as the reply to DISC. The logical link is terminated with a single exchange of DISC and DM.
6. RR (Receive Ready): This can be a command or a response. It is used for cumulative acknowledgement of all received sequence numbers.
7. SACK (Selective Acknowledgement): This can be either a command or a response. It contains a bitmap mask indicating which sequence numbers are received and which are missing. The length of the mask is variable, up to the ARQ window size.
8. ACK (Acknowledgement): This can be a command or a response. The standard uses it as a special case of SACK, but it provides the same indication as REJ that is used in go-back-N algorithms.
9. RNR (Receive Not Ready): This can be a command or a response. It is used to throttle the sender if a local busy condition is detected.

10. FRMR (Frame Reject): This is a response used to report unrecoverable errors. The receipt of this message will cause the logical link either to re-initialize or terminate.

11. I (Information): This is actually a user data frame with piggybacked control fields. It can be a command or a response, and requires both sequence numbers. Frames sent with this header require ARQ. (It is associated with LL-Data.XXX primitives.)

12. UI (Unnumbered Information): This is also a user frame. It is a command and requires no sequence numbers. In contrast to the I format, user data sent with UI format do not need retransmission. (It is associated with LL-UnitData.XXX primitives.) Therefore, the LLC standard provides a mechanism to bypass the ARQ machines.

The GPRS also defines the encoding of the above messages. However, the detailed encoding does not matter, as long as we provide the same fields. To encode the above 12 messages, we need 4 bits. Some messages also require additional fields, as described below:

1. Acknowledge Request (A): This is a 1-bit field used by sender to request acknowledgement from receiver. It is needed in I and S formats (S stands for Supervisory, which includes ACK, SACK, RR, and RNR messages).

2. Send Sequence Number (N(S)): This field is needed only in I format. In the Working Document [2], this can be 6 bits, 11 bits, or 14 bits.

3. Receive Sequence Number (N(R)): This field is needed in I and S formats. Its size is the same as N(S).

4. SACK Bitmap: This field is needed only in SACK message. It has a maximum size equal to the ARQ window size, but truncated based on the actual sequence received numbers.

5. Poll/Final (P/F): This is a 1-bit field used in U format. (U stands for Unnumbered, which includes SABM, UA, DISC, DM, XID, and FRMR). It can take the same position as the A bit.

6. Command/Response (C/R): This is a 1-bit fields used only a XID message. As pointed earlier, XID parameter negotiation can be accomplished by SABM message, so this field is not essential.

Altogether, we see that a minimum of 5 bits are required for ARQ messaging, beside the sequence numbers, which is determined by the bandwidth-delay product of the logical channel. This is a very low overhead.

ARQ State Variables

The GPRS standard defines the following parameters for the ARQ state machine:

1. Send State Variable (V(S)): This is the next in-sequence I frame to be transmitted. It is incremented by 1 every time an I frame is transmitted.
2. Receive State Variable (V(R)): This is the next in-sequence I frame expected.
3. U Frame Retransmission Timer (T200): This is the timer associated with retransmission of U frames, during link initialization and error recovery.
4. I and S frame Retransmission Timer (T201): This is the timer associated with retransmission of I and S frames, during information transfer phase. Note that T200 and T201 are running at the different times, so in implementation, only one timer is needed.
5. Max Number of Retransmission (N200): There is one retransmission count for each message. The logical link is reset when N200 is exceeded.
6. Max Number of Outstanding Frames (k): This is the ARQ window size.

The GPRS standard provides a clear and complete specification for the robust, asynchronous operation of ARQ state machine. I was able to draw a detailed software flow chart using the specification without any difficulty.

It should be noted that timer management specification is of critical importance in implementation. A complex timer management specification can make it impractical to implement a protocol. GPRS uses a very simple timer management scheme, where only one timer is needed for an instance of ARQ state machine.

Link Setup and Reset

In the Working Document, it is proposed to modify the DSA/DSC protocol to include ARQ. In particular, MAC messages DSA-REQ, etc. need to be modified.

Here we propose make the ARQ negotiation as an additional step following DSA/DSC, using SABM and UA messages provided in the GPRS standard. We do not need to make any changes to the baseline DSA/DSC mechanisms. This decouples ARQ operation from MAC connection management, and simplifies implementation.

Go-back-N Algorithm

The GPRS standard treats ACK as a special case of SACK. In order to support go-back-N algorithm, we can simply re-interpret ACK to mean REJ, since the condition that cause them are exactly the same.

Note that SACK and Go-back-N have different requirements on ARQ sequence number sizes. SACK requires roughly twice the size than Go-back-N. It is important to make sure that we do choose a number that is adequate for SACK. The size is usually determined by the delay-bandwidth product of the logical link, but the Working Document chooses 6, 11, and 14 bits, without giving any justification.

Conclusion

In conclusion, we propose a set of operating procedures for the ARQ protocol based on the GPRS standard. This standard is derived from a very mature and robust scheme, which has a long implementation history, with both commercial and public domain available. People are familiar with it. The overhead is very low, requiring only 5 bits. We considered some minor modifications aimed at simplifying the implementation, for example re-interpreting the ACK message to support go-back-N algorithm.

References

[1] ETSI TS 101 351 V8.6.0 (2000-12)

[2] IEEE 802.16ab-01/01.