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Title: **The Estimated PDU Counter**

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The Estimated PDU Counter

1 Introduction

Due to the often harsh radio environment even retransmitted PDUs and Status PDUs may get lost. The result of this is that in many cases it may take quite some time before unacknowledged PDUs are actually received at the receiver. In order to minimise this delay a mechanism where the Status PDUs are retransmitted can be used. With this mechanism, the receiver will send a new Status PDU in which it requests for PDUs not yet received. In order not to wait too long before such a new Status PDU is retransmitted a timer can be started upon the transmission of a Status PDU. If the timer expires and a retransmission of a data PDU is not yet received, the receiver will retransmit the Status PDU. However, due to the fact that the data rate may change, it may be a difficult task to set this timer. This will be explained in the next section. Due to this we propose to use a counter, which counts the PDUs that should have been received every transmission time interval. This mechanism is explained in [1]. The mechanism is based on the fact that the number of PDUs that should have been received during a transmission time interval can be estimated by means of the TFI bits. In Section 3 we describe the mechanism once more, with the additional explanation what to do when the TFI bits are lost.

2 The Timer Problem

In Figure 1 it is shown when the retransmission of the Status report is triggered by the expiry of a fixed timer. In this example the timer is set such as if the rate is continuously high, i.e. as if 4 PDUs are transmitted in each transmission time interval. During the first two transmission time intervals the rate is such that 4 PDUs fit into a transmission time interval. As can be seen from the figure, PDUs 1 and 2 are not received correctly. Therefore the receiver side will transmit a Status PDU, informing the transmitter about the missing PDUs. At that time, the receiver will also start a timer. The timer is set such that it will expire just when the retransmitted PDUs should have been received. However, since the rate is decreased in the mean time, this timer will expire too soon. Thus a new Status report is transmitted too early, resulting in that PDU 2 is retransmitted unnecessarily.

On the other hand, if the timer is set too long, i.e. to account for low rates, the receiver will retransmit its Status PDUs far too late, if the rate is increased. Therefore it is advantageous to adapt the time to retransmit Status PDUs to the rate. The estimated PDU counter, explained in the next section is a method to do so.

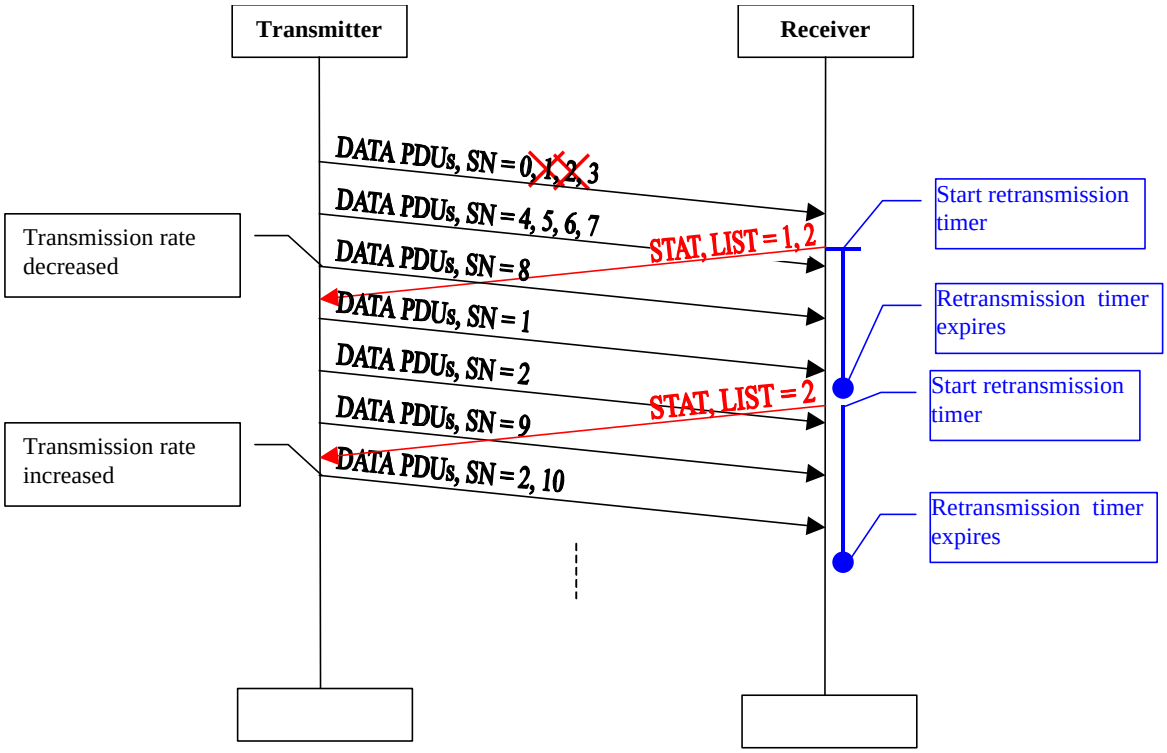

Figure 1. Retransmission of the Status PDUs triggered by the expiry of a timer.

3 Estimated PDU Counter

In order to describe the mechanism, we first note that within a transmission time interval, an integer number of PDUs can be transmitted. This number depends on the size of the PDU and the rate with which the PDUs are transmitted. After every transmission time interval, the rate may change and thus the number of transmitted PDUs may change as well accordingly. Due to the TFI bits, which are transmitted in parallel with the data, the receiving RLC is able to estimate how many PDUs should have been sent during a transmission time interval.

The EPC is a counter, which is decremented every transmission time interval with the estimated number of PDUs that should have been transmitted during that transmission time interval.

The EPC timer sets the maximum time that the EPC needs to wait before it will start counting down. This timer starts immediately after a transmission of a retransmission request from the receiver (Status PDU). The EPC timer typically depends on the roundtrip delay, which consists of the propagation delay, processing time in the transmitter and receiver and the frame structure. This timer can also be implemented as a counter, which counts the number of 10 ms radio frames that could be expected to elapse before the first requested DATA PDU is received.

When the EPC exceeds the number of outstanding PDUs (i.e. the PDUs which were requested to be retransmitted) and not all of these requested PDUs have been received correctly, a new Status PDU will be transmitted and the EPC will be reset to zero. The EPC timer will be started once more.

In Figure 2 the EPC and the EPC timer are illustrated. Each arrow in the figure corresponds to a transmission time interval.

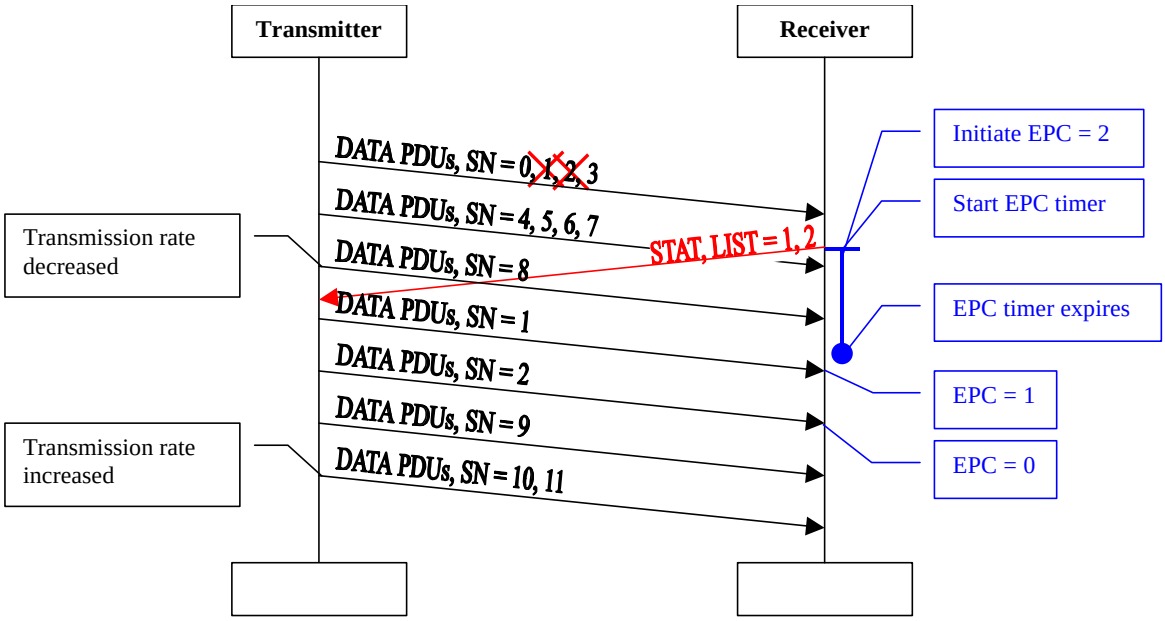

Figure 2. The estimated PDU counter and EPC timer.

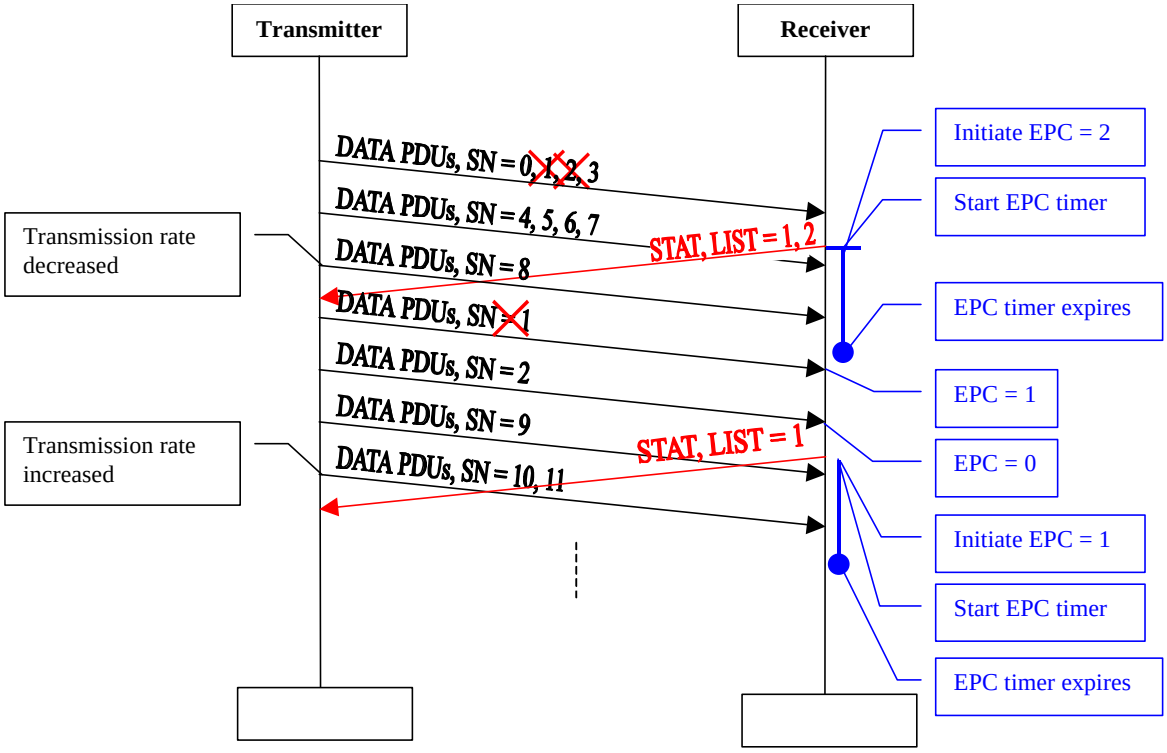

Figure 3. The Estimated PDU counter and EPC timer, a retransmission attempt fails

The transmitter sends the PDUs 0, 1, 2 and 3 to the receiver. The PDUs 1 and 2 are lost. When the receiver detects that the PDUs are missing it generates and sends a Status PDU to the transmitter. Simultaneously it sets EPC equal to the number of requested PDUs (in this case 2) and starts the EPC timer.

In the next radio frame the transmitter sends the DATA PDUs 4, 5, 6 and 7. After that the transmission rate is decreased and the transmitter continues by sending DATA PDU 8. The transmitter then receives the Status PDU. It processes the Status PDU and, as a response, it retransmits the DATA PDUs 1 and 2. However, in this case it sends the PDUs in separate transmission time intervals, due to the low rates on the channel.

The receiver receives the DATA PDUs 4, 5, 6, 7 and 8 without decreasing the EPC. During this time, the EPC timer is still ticking, meaning that the receiver could not expect retransmitted PDUs. The receiver starts to decrease the EPC when the EPC timer has expired. In this case it starts after DATA PDU 8 but before DATA PDU 1 has been received. EPC is then decreased for each virtually received DATA PDU. To be able to do this the receiver can use the Transport Format Information (TFI) provided by MAC. The TFI indicates how many RLC PDUs should be received in each transmission time interval. When the receiver receives DATA PDU 1 it decreases the EPC by 1 and when it receives DATA PDU 2 the EPC reaches 0.

In the case where any of the retransmitted DATA PDUs 1 or/and 2 is lost a new Status PDU will be transmitted to the transmitter. This is illustrated in Figure 3. The EPC would even in this case reach 0, due to its estimation of the number of PDUs transmitted in the transmission time intervals. But due to the fact that PDU 1 is not received correctly, the receiver would transmit a new Status PDU requesting once more for PDU1.

The EPC is based on the estimation of the number of PDUs that should have been received during a transmission time interval. To estimate this number is easiest done by means of the TFI bits. However, if these bits are lost due to some reason or another, this estimation must be based on something else. A straightforward solution is to base the estimation on the number done in the previous transmission time interval. Only if the rate has changed this estimation is incorrect. Another method of estimating the number of PDUs is based on the maximum allowable rate. The consequence of this is that if the estimation is incorrect, the Status PDU is sent too early. Alternatively, the estimation can be based on the lowest possible transmission rate. In this case, if the estimation is incorrect, the Status PDU will most likely be transmitted too late.

As illustrated, there can be scenarios where the Status reports are sent either too late or too early. However, compared to setting a timer this possibility is decreased significantly. If a fixed timer would be used to trigger the retransmission of Status PDUs, and if the rate would change during this time, the time to retransmit is never set optimal. This was illustrated in section 2.

4 Conclusion

We propose to include the EPC function into the RLC toolbox in TS 25.322: RLC protocol specification.

5 References

[1] Ericsson, TSG RAN WG2, TSGR2#2(99)149, “The estimated PDU counter”.