3GPP TSG RAN WG1 Meeting #57bis **R1-092852**
Los Angeles, USA
June 29th – July 3rd, 2009

Agenda item: 15.3

Source: LG Electronics

Title: PUSCH Forwarding in Type II Relay

Document for: Discussion and Decision

1. Introductions

In RAN#57 meeting, an issue was raised regarding PUSCH forwarding in type II relay [1, 2]. The main concern was that, if UE participates in the over-the-air combining with a PUCCH-embedded PUSCH, eNB cannot decode the embedded PUCCH contents.

This contribution discusses how to solve the problem of PUSCH forwarding in type II relay.

2. Problems in PUSCH Forwarding in Type II Relay

Figure 1 illustrates an example of the problematic case in PUSCH forwarding in type II relay.

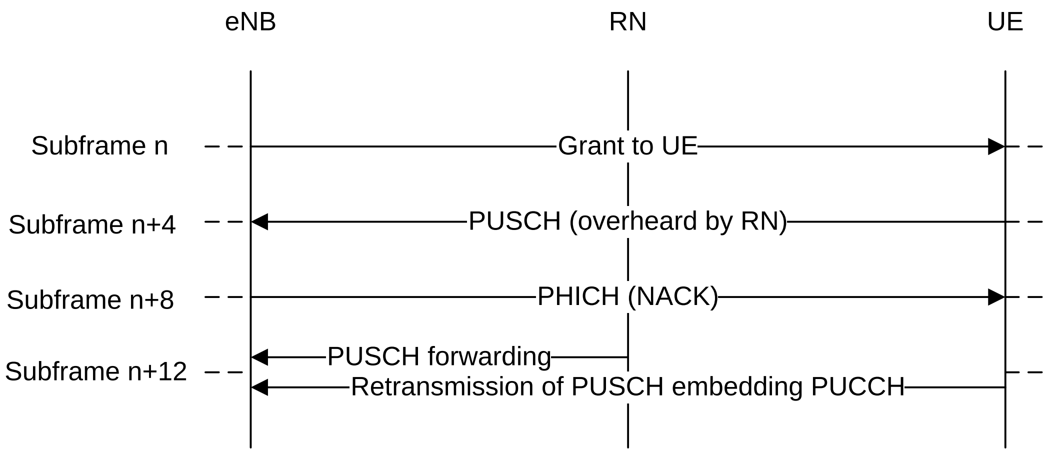

Figure 1. A problematic case in PUSCH forwarding in type II relay.

In Figure 1, eNB cannot decode the PUCCH content (e.g., UL ACK/NACK for PDSCH transmitted at subframe n+8 or periodic PMI/CQI/RI report) embedded in the PUSCH transmitted at subframe n+12. This is because DM RS undergoes the summation of RN-to-eNB and UE-to-eNB channels but only UE is able to transmit the PUCCH contents.

This problem may be avoided by restricting PUCCH scheduling of a UE facilitated by a type II RN such that the UE does not retransmit a PUCCH-embedded PUSCH at the subframes where RN forwards the PUSCH generated by that UE. For example, eNB may schedule PDSCH transmission to the UE at a subframe other than subframe n+8 in the case of Figure 1. However, this operation has some drawbacks in that it requires more complicated scheduler and degrades the system throughput due to the scheduling restriction.

3. A Solution based on “Always PHICH ACK”

An alternative solution to the problem mentioned in the previous section is to block the UE’s retransmission by sending PHICH ACK for the initial PUSCH transmission. Figure 2 shows an example of this “always PHICH ACK” policy.

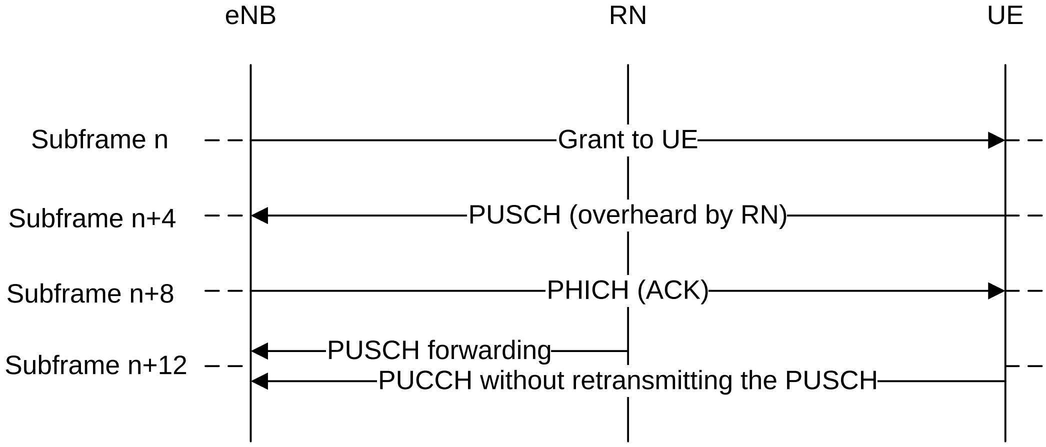

Figure 2. An example of the “always PHICH ACK” policy.

At subframe n+8 in Figure 2, eNB always sends PHICH ACK for the initial PUSCH transmitted at subframe n+4 regardless of its decoding result. Thus, at subframe n+12, UE is not involved in the PUSCH transmission which implies that UE becomes able to transmit PUCCH by using RBs separated from those used for RN’s PUSCH forwarding. As a result, eNB can receive both PUSCH and PUCCH at subframe n+12 without having complicated scheduling restriction. We note that the *partial information relaying* can be applied in forwarding PUSCH at RN to enhance the system capacity.[1]

This “always PHICH ACK” policy can be interpreted as a policy where eNB relies only on RN in receiving PUSCH at subframe n+12, expecting that RN always receives the initial PUSCH transmission correctly. If the unexpected error event occurs, i.e., eNB sends PHICH ACK to UE at subframe n+8 but RN fails to decode the PUSCH overheard at subframe n+4, then eNB may issue a retransmission grant to UE at subframe n+16 to recover the error in the initial transmission as shown in Figure 3. As the UE’s buffer is not flushed until a toggled new data indication is received, UE can retransmit the PUSCH at subframe n+20. To help this operation, RN may notify its PUSCH decoding result to eNB at subframe n+12.

[1] See the appendix for more details on the partial information relaying.

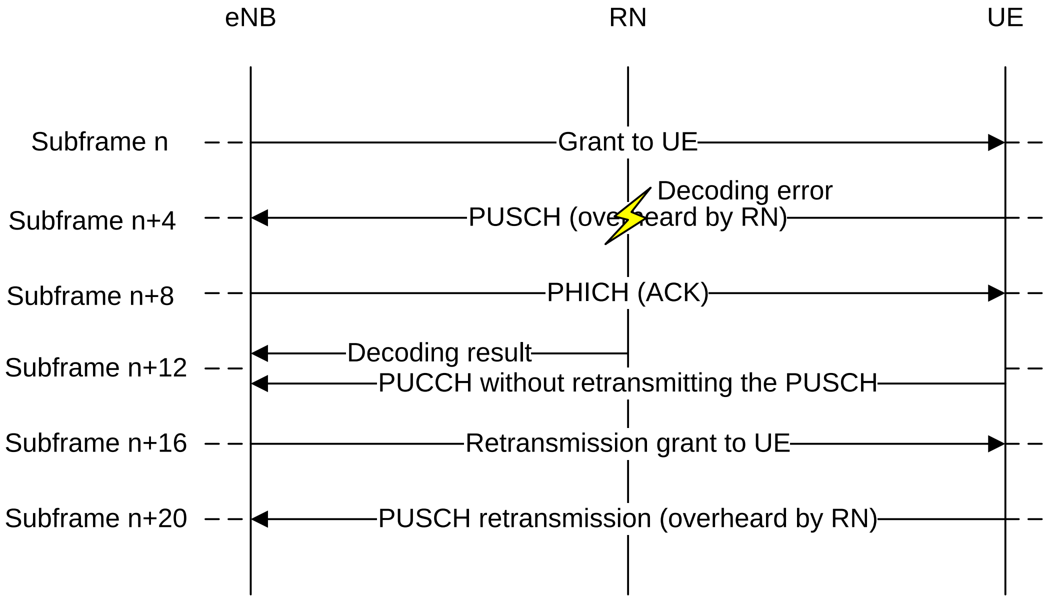

Figure 3. An example of RN's PUSCH decoding error recovery.

Figure 4 shows an example of eNB's PUSCH decoding error recovery. If RN correctly decodes the overheard PUSCH but eNB fails to decode the PUSCH forwarded by RN at subframe n+12, eNB issues a grant to RN at subframe n+16 for the PUSCH retransmission at subframe n+20.

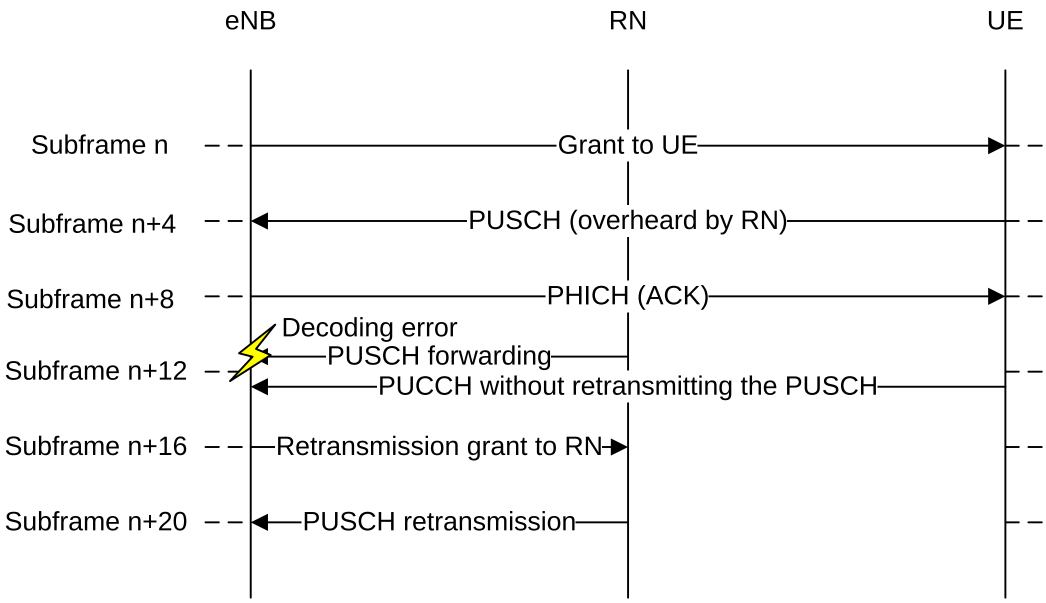

Figure 4. An example of eNB's PUSCH decoding error recovery.

One possible drawback of this method is that UE cannot participate in the PUSCH forwarding at subframe n+12 which would degrade the eNB's PUSCH decoding performance when compared with the over-the-air combining illustrated in Figure 1. However, as RN has more transmission power and RN-eNB link has better channel quality, the signal forwarded by RN is the dominant factor in decoding PUSCH at eNB and the contribution of UE's PUSCH retransmission would not be significant in most cases. Thus, the "always PHICH ACK" policy is expected to cause marginal potential performance degradation in comparison with the over-the-air combining case.

4. Conclusions

In this contribution, we have discussed the method where eNB always sends PHICH ACK to UE whose PUSCH will be forwarded by a type II relay node. The discussed method can be a simple but effective solution to the problem caused when UE retransmits PUSCH in which PUCCH content is embedded.

References

[1] R1-092025, "Characteristics, implications, and assessment of type-II relaying," Ericsson.

[2] R1-092058, "Challenges with Type II relay operation," Qualcomm Europe.

Appendix

The partial information relaying is the method where RN forwards only a proper subset of the successfully decoded data streams. For simplicity, we consider the case of two data streams in SISO channel as illustrated in Figure 5.

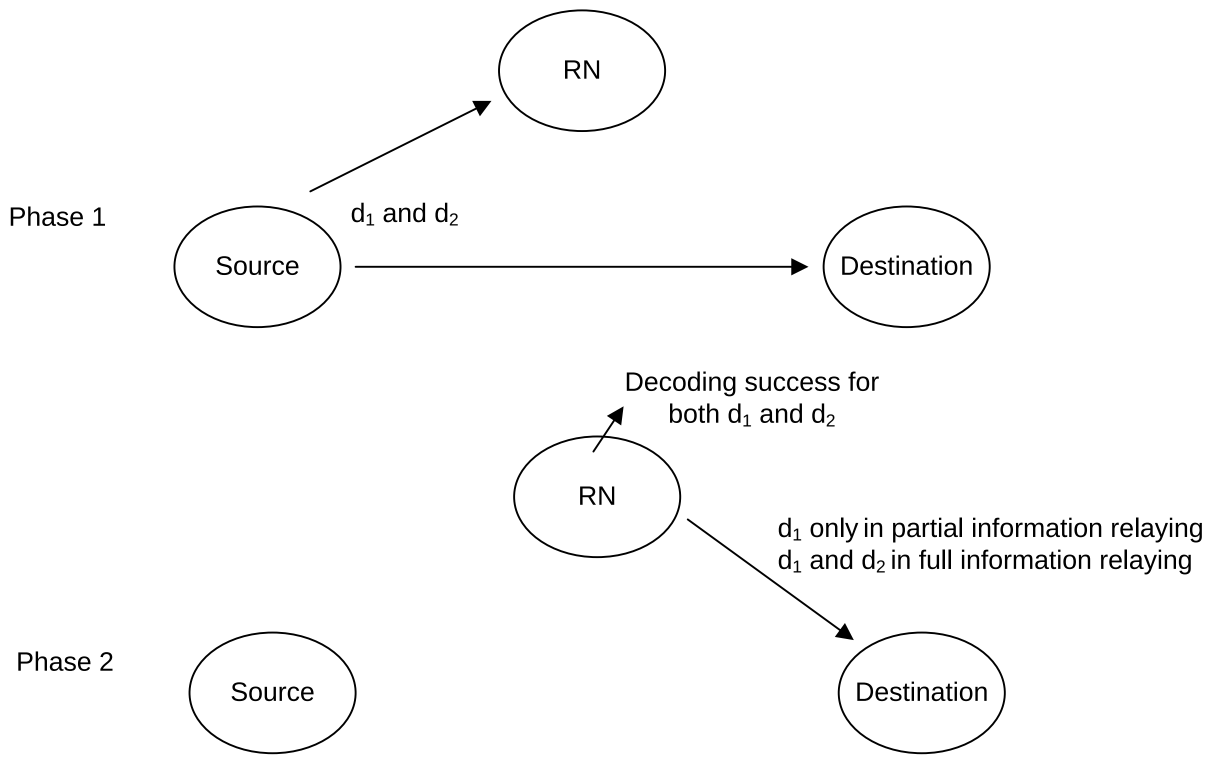

Figure 5. An example of partial information relaying for two data streams.

We denote SNRs of source-destination, source-relay, and relay-destination links by γ_0, γ_1, γ_2, respectively, where $\gamma_0 < \gamma_1$ and $\gamma_0 < \gamma_2$. At phase 1, source encodes the data stream d_1 at the rate R_{1S} by using the fraction of the transmission power α. The remaining fraction of the transmission power $(1-\alpha)$ is used in encoding the data stream d_2 at the rate R_{2S}.

Now, we compare the capacity achieved by partial information relaying with that of full information relaying under the assumption that both RN and destination are equipped with SIC receiver. At phase 1, RN can decode d_2 correctly in the presence of noise and inter-stream interference if

$$R_{2S} \leq \log_2\left(1+\frac{(1-\alpha)\gamma_1}{1+\alpha\gamma_1}\right).$$

After successfully cancelling out d_2, d_1 is then decoded correctly if

$$R_{1S} \leq \log_2(1+\alpha\gamma_1).$$

At phase 2, RN re-encodes and forwards only d_1 at the rate R_{1R}

$$R_{1R} \leq \log_2(1+\gamma_2).$$

with no inter-stream interference, and d_1 can favourably be decoded at destination when the total power of RN is used. Finally, d_2 (received at phase 1) is decoded at destination after successfully cancelling out d_1 (decoded at phase 2), whose rate is limited to

$$R_{2S} \leq \log_2(1+(1-\alpha)\gamma_0).$$

If $R_{1R} > R_{1S}$, we can reduce the amount of RBs used for data forwarding at phase 2 by the factor of R_{1S} / R_{1R}, which yields the overall capacity of the partial information relaying

$$C_P = \frac{R_{2S}+R_{1S}}{1+R_{1S}/R_{1R}} = \frac{(R_{2S}+R_{1S})R_{1R}}{R_{1R}+R_{1S}}.$$

For comparison, the full information relaying offers the capacity

$$C_F = \frac{R_1}{1+R_1/R_2} = \frac{R_1 R_2}{R_1+R_2},$$

where $R_1 = \log_2(1+\gamma_1)$ (the capacity of the source-relay link). Here, the capacity R_2 can be bounded as $\log_2(1+\gamma_0+\gamma_2) \leq R_2 \leq \log_2(1+\gamma_0)+\log_2(1+\gamma_2)$ where the lower bound is achieved by maximal-ratio combining (MRC) of source-destination and relay-destination links and the upper bound is reached if the optimal codeword combining is employed across the signals transmitted from source and relay. In the case of direct transmission from source to destination, we get the capacity

$$C_D = \log_2(1+\gamma_0).$$

Figure 6 compares the capacity achieved by the above-mentioned relaying methods. Here, we set γ_1 and γ_2 to 20 dB while varying γ_0. This figure reveals that the partial information relaying achieves higher capacity than the full information relaying and the direct transmission. Note that the upper bound is plotted in Figure 6 for the full information relaying.

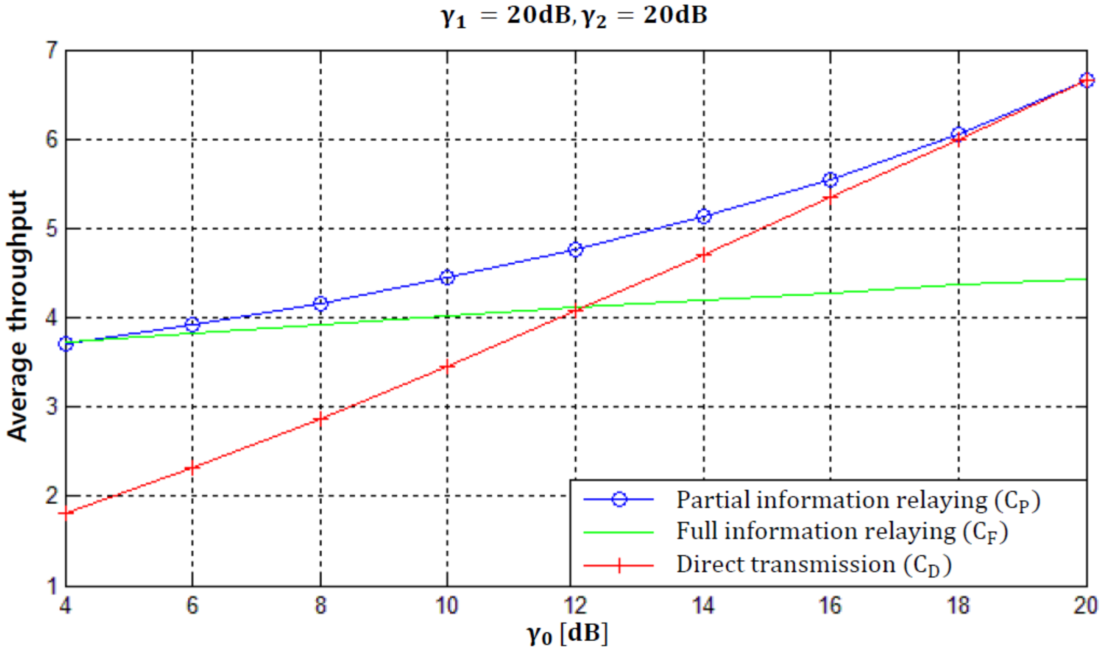

Figure 6. Achievable capacity of various relaying methods.