3GPP TSG RAN WG1#2 **Tdoc TSG/RAN/WG1#2 ~~xxx/99~~R1-99061**
Yokohama, Japan 22.-25.02.99

Agenda Item:

Source: **Panasonic**[1]

Title: **Hybrid ARQ techniques for efficient support of packet data**

Document for: **Discussion**

Introduction

One main objective of introducing UMTS is the efficient support for high speed data applications using circuit and packet switched data. So far little work has been done to optimise data transmission.
Hybrid Automatic Repeat reQuest (ARQ) schemes are commonly used in order to provide reliable communication over noisy channels. ~~One commonly used technique for error correction is Automatic Repeat Request (ARQ).~~ This technique is not yet specified for UMTS, but should be part of the first draft specification to be approved in April '99.
This paper presents a comparison of different hybrid ARQ schemes with focus on physical layer aspects. It highlights that for third generation mobile systems advantage of novel ARQ schemes should be taken.

Selection of ARQ scheme

So far the specification of ARQ has not yet started. ARQ itself is provided by the Link Layer (Layer 2) and should be standardised in S2.22 "RLC protocol specification". Parameters to support ARQ as CRC, estimated C/I , BER, QoS requirements are close to the physical layer. WG1 should be involved in the selection since performance of the ARQ scheme is closely tied to PDU sizes, coding rates, interleaving schemes etc..

Some selection criteria for ARQ are:
- performance (particularly throughput and delay)
- complexity (e.g. memory, processing power)
- overhead (e.g. signalling (incl. retransmission), coding, allocation granularity)
- QoS requirements (BER, delay, rate)

The most common technique for error detection ~~correction~~ of non-real time services is based on Automatic Repeat r~~Re~~Q~~q~~uest (ARQ) schemes which is combined with Forward Error Correction ~~Detection~~ (FEC), called hybrid ARQ. If an error is detected ~~with help of~~by Cyclic Redundancy Check (CRC), the receiver requests the transmitter to send additional bits.
From different existing schemes the selective-repeat continuous ARQ is seen as the most efficient one. This scheme in connection with FEC could be used for UMTS, wherea~~s~~ one

[1] Contact Person: Eiko Seidel, Panasonic European Laboratories GmbH,
e-mail: eiko@panasonic.de

retransmission unit is referred to as RLC-PDU. The following comparison of ARQ schemes is made with the assumption that a hybrid selective-repeat ARQ is used.

Hybrid ARQ

Depending on the bits that are retransmitted ~~we define 3~~three ~~-~~different types of ARQ are defined [5]:

- Type I: The erroneous RLC-PDU ~~block~~ is discarded and ~~the block~~ an identical copy ~~-~~is retransmitted and decoded separately. ~~The coding rate is usually fixed.~~ ~~There is no combining of earlier and later versions of the RLC-PDU, each is stand alone.~~ The coding rate of the Forward Error Correction (FEC) is usually fixed and may depend on the environment. ~~-~~There is no combining of earlier and later versions of the RLC-PDU, each is stand alone.~~The chosen coding rate may depend on the environement.~~
- Type II: The erroneous RLC-PDU ~~block~~ that needs to be retransmitted is not discarded, but is combined with some incremental redundancy bits provided by the transmitter for subsequent decoding. ~~is stored at the receiver and further redundancy is transmitted.~~ Retransmitted RLC-PDU ~~blocks~~ usually have higher coding rates and are combined at the receiver with the ~~already~~ stored values.
- Type III: Is the same as Type II ~~The main drawback of this methods is~~only that every retransmitted RLC-PDU is now self-decodable. In situations where the transmitted RLC-PDU can be severely damaged, for example, due to interference, it is desirable to have a scheme where any additional ~~information~~block sent is self decodable.

Schemes II and III are obviously more intelligent and show a performance improvement (~~e~~especially for good channel conditions), because they have the ability to adjust the coding rate to the radio environment and to reuse previously transmitted blocks.

In SMG2 Layer 2/3 expert group Hybrid ARQ Type II was under discussion. In [1] it was found for UTRA TDD that Hybrid ARQ Type II greatly outperforms Type I for “UDD 2048 Pico” and “UDD 384 Micro” in capacity as well as delay performance.

For GSM EGPRS Hybrid Type II ARQ is under consideration as option or to accomplish Link Adaptation. Hybrid II ARQ typically shows higher throughput at the expense of higher packet delay [2].

Variable Coding Rates

With help of rate compatible punctured convolutional (RCPC) codes variable coding rates ~~code~~ with good coding properties can easily be generated from a mother code [3]. This technique can also be used with Turbo Codes. For self-decodable codes as needed in Type III Complementary Punctured Convolutional codes [6] can be used.

There exist several different strategies to select the best coding rates. Optimum coding rates alter of c~~au~~ourse with a changing radio channel. ~~For~~ Type II/III ~~you could~~ starts with a high coding rate and only increase redundancy when decoding fails. Redundancy is then added adaptively until the code is powerful enough to be decoded. This would improve throughput especially in good radio environments and is often referred to as Incremental Redundancy. For environments where whole blocks are severely damaged it might still be more useful that every retransmitted block can be decoded separately (Type III).

An alternative to ~~the~~a predefined hybrid II/III ARQ scheme~~s~~ might be ~~the~~ link adaptation ~~scheme~~. In this case the link quality is estimated and the most appropriate coding scheme is selected. The link adaptation algorithm can either be predictive or incremental. The signalling overhead might be less than for the hybrid II/III ARQ~~rq~~ case using existing measurement reports. ~~The possibility of using link adaptation schemes is for further study. Similar work is undertaken by ETSI SMG for the specification of enhanced GPRS [2].~~

~~An adaptation of the coding rate does not necessarily mean additional signalling from the receiver, because the transmitter can utilise ARQ requests or existing measurement reports (like raw BER or estimated C/I) from the receiver. Also aspects as velocities, time delay, frequency errors , buffer size etc. could be taken into account.~~
~~If the transmitter receives several ARQ it can decrease the coding rate for new blocks to be transmitted in order to increase the probability of a correct reception. On the other side for a very good environment as in a line of sight connection the coding rate can be quite high, maximising the throughput.~~

Code combining

Soft combining increases probability of correctly decoding retransmitted blocks. On the other hand ~~side~~ signalling overhead is increased because the frame number has to be encoded separately to combine different versions of a RLC-PDU. C~~Also c~~omplexity increases as well with the amount of data to be stored in the receiver. More advanced algorithms using Channel State Information for combining can ~~also~~ be used ~~as well~~ [3].
~~The code combining could terminate at Node B to limit backhaul cost and round trip delay in case of combing. The ARQ protocol can also consider the available memory at the receiver and request more coding if it is running out of memory.~~

Simulator Architecture

Simulations were performed for UTRA FDD downlink. A UDD-480kbps packet service was chosen. The WWW traffic model specified in UMTS 30.03 was used as source.

A simulation was done that compares two simple hybrid ARQ schemes.
Type I ARQ:
- coding rate ½, both code words (c_{w1}, c_{w2}) transmitted together

Type III ARQ:
- (see Fig. 1) transmission starts with code rate 1, meaning that c_{w1} is sent~~d~~. In case of failure c_{w2} is transmitted. c_{w2} will be decoded separately and in the event of an error both are combined decoded. If the block still can-not be decoded c_{w1} is retransmitted, decoded separately or combined later. For further retransmission the procedure is restarted.

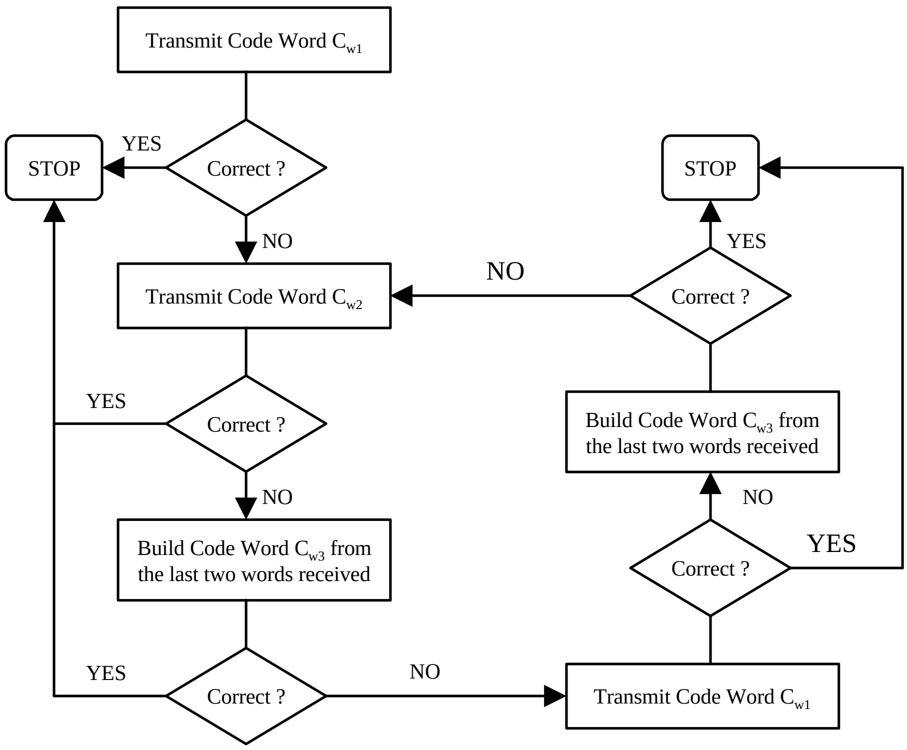

Figure 1: Type III Hyrid ARQ transmission flow

Simulation results

Simulation results in Figure 2 clearly show that there are environments where Type III ARQ largely outperforms Type I. For very good E_b/~~N_o~~ N_0 the throughput is almost doubled since the first packets are transmitted without redundancy.

This throughput decreases rapidly in environments with smaller E_b/N_0 ~~Eb/No~~ since few erroneous bit instantly trigger a retransmission.

For E_b/N_0 ~~E_b/N_o~~ about 3dB both techniques have the same bad efficiency. Very few blocks are received correctly. A change in transmission parameters or even a rejection of the service should be initiated, because a lot of interference is generated for a relative small throughput.

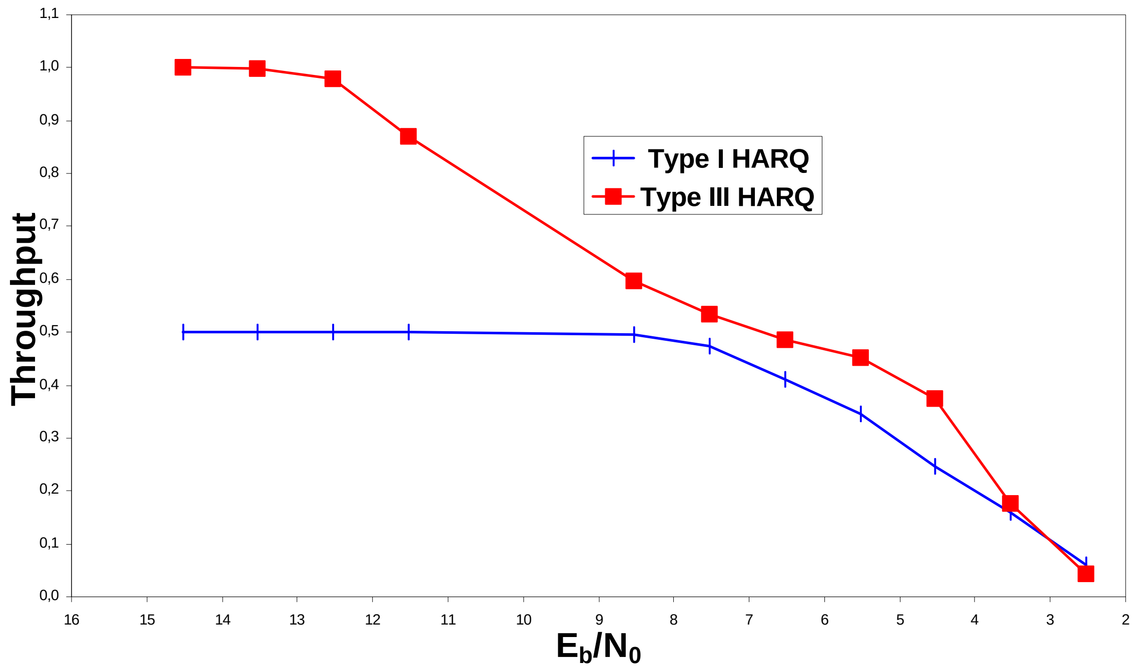

Figure 2: Throughput of hybrid ARQ Type I and III

Even this very simple Type III hybrid ARQ scheme shows the significant gain in using ~~you can get from~~ more intelligent ARQ techniques. Type II and III give under good channel conditions a throughput gain. Further benefit could reached by adaptively changing the code rate.

The sensible interaction of code rate, power control and resource allocation in a multi-user/multi-cell system with a time varying CIR has to be understood ~~carefully~~ well and demands also a very flexible retransmission technique. The use of power control is limited from the physical capabilities of the dynamic range and to maintain a certain interference level. An adaptation of the coding rate might be preferable in some cases since it has less effect on the interference situation of other users in the cell.

~~< irgenwas mit power control... Further evaluations considering power control has to be done to identify in how far the increase in power will not cause unaccepatble interference in the system ...>~~

~~**Figure 2: Throughput of hybrid ARQ Type I and III**~~

~~Also in SMG2 Layer 2/3 expert group Hybrid ARQ Type II was under discussion. In [1] it was found for UTRA TDD that Hybrid ARQ Type II greatly outperforms Type I for “UDD 2048 Pico” and “UDD 384 Micro” in capacity as well as delay performance.~~

~~Also for GSM EDGE Hybrid Type II ARQ is under consideration as option or to accomplish Link Adaptation. Hybrid II ARQ typically shows higher throughput at the expense of higher packet delay [2].~~

Conclusion

The need to start work on the retransmission protocol was identified. The ARQ scheme should be selected by RAN WG1 and WG2 jointly since the physical layer has a large influence on its performance. It was -shown that novel ARQ schemes can result in a large performance gain. These techniques are also under investigation in RAN WG2. A~~ and can give a~~ ~~large flexibil~~flexible~~ity~~ ~~in~~ deployment using different code rates and code combining of retransmitted blocks should also be considered ~~.~~ RAN Working Group 1, since there is a large impact on the physical layer. Services with different requirements might also require different ARQ methods [4]. Maybe this document can start the discussion how to progress on the selection of a ARQ schemes and the code rates to be used. ~~should consider the use of variable code rates. Code combining of retransmitted block should also be studied. Different services might also require different ARQ methods [4]. The built up of an Ad~~_h~~oc group should be discussed.~~

~~*Ackknowledgement*~~

~~< ich muss Uli anrufen, ob er unbedingt mit aufs papier will>~~

Literature

[1*] Comparison of Hybrid ARQ Types I and II for TDD Mode*, Siemens Tdoc SMG2 UMTS-L23 308/98

[2] *EDGE: Refined link performance comparison of link adaptation and hybrid II ARQ for enhanced GRPS*, Ericsson, Tdoc SMG2 WPB 255/98

[3] *Rate-compatible punctured convolutional codes (RCPC Codes) and their applications*; Hagenauer, Joachim; IEEE Transactions on Communications, vol. 38, November 1988, pp. 389-400.

[4] *Performance of H.263 video transmission over wireless channels using hybrid ARQ*; Hang LIU and Magda EL ZARKI , IEEE Journal on Selected Areas in Communications, Vol.15, N0.9, december 1997, pp 1775-1786

[5] *Performance of punctured channel codes with ARQ for multimedia transmission in Rayleigh fading channels*; Lou, H. and Cheung, A. S.; 46th. IEEE Vehicle Technology Conference, 1996.

[6] *Complementary punctured convolutional codes and their application*; Lallel, S., IEEE Transactions on Communications, vol. 43, No.6, June 1995, pp 2005-2009