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Feasibility study of Advanced techniques for High Speed Downlink Packet Access

1. Introduction

At the RAN#7 plenary meeting, it was agreed that the appropriate working groups in RAN would conduct feasibility studies in the area of "High speed downlink Packet Access". The idea is to identify the techniques suitable for achieving high speeds for packet access. This document aims to identify some of these techniques. This document lists the proposed items for this study and proposes a working group owner for each of the items. It is further proposed that the outcome of this study be captured in a single new technical report, with the relevant sections being contributed by the appropriate working groups.

2. Enhancements for packet data

Over the past few years a number of research groups in both academia and industry as well as Standards Organization have studied various techniques to improve the capacity of the radio interface in wireless systems for enabling services such as web browsing, multi-media, etc. which typically require very high data rates for a rich user experience. This section will list some of these enhancements.

2.1 Adaptive Modulation and Coding

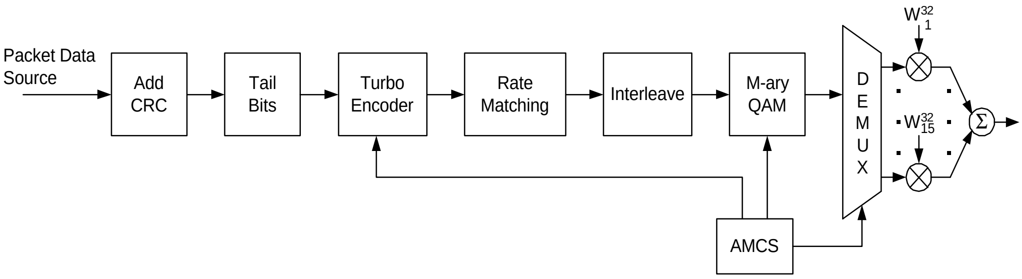
The need for adapting the transmitted signal in a wireless system to the changing local environment is very well known. In fact fast power control is an example of a technique implemented to enable reliable communications while simultaneously improving system capacity. This process of modifying the transmitted signal to compensate for the signal variations is known as *link adaptation*. Another technique which falls under this category of link adaptation, is adaptive modulation and coding (AMC). EDGE is an example of an emerging standard using this technique to greatly improve system capacity, peak data rate and coverage reliability.

The principle of AMC is to change the modulation and coding format based on the received signal quality and channel conditions. This requires feedback from the receiver. Fast power control is disabled over the frame interval. In a system with AMCS, users close to the base station are typically assigned higher order modulation with higher code rates (e.g. 64 QAM with R=3/4 Turbo Codes), but the modulation-order and/or code rate will decrease as the distance from base station increases. AMCS supports higher data rates allowing higher spectral efficiencies to be achieved without the need for fast down link power control. The reduction in interference variation by eliminating fast down link power control makes scheduling easier.

It is proposed that the Downlink Shared Channel (DSCH) be modified to support AMCS. This will enable the support of peak data rates of up to 8.5 Mbps. The basic block diagram of the modified DSCH is shown in Figure 1. The DSCH will have the following modified features:

1. Support for 4QAM, 8QAM, 16QAM and 64QAM modulation.
2. Turbo Code rates of R=1/2 and R=3/4.
3. 8 MCS (Modulation Coding Scheme) as outlined in Table 1.
4. 16 multi-codes with a fixed spreading factor of 32.
5. Provision to disable fast downlink power control.
6. DCH associated with modified DSCH will have the same framing as modified DSCH.

Figure 1. Downlink Shared Channel



MCS	Modulation	Code Rate
8	64	3/4
7	64	1/2
6	16	3/4
5	16	1/2
4	8	3/4
3	8	1/2
2	4	3/4
1	4	1/2

Table 1. MCS Levels

The AMCS will be applied to a special mode of DSCH. It will select the MCS based on channel conditions (C/I measurements) reported by the UE or computed at the Node-B. The DSCH will be modified so that it can use up to sixteen multi-codes per user with a fixed spreading factor of 32. The power control for DSCH needs to be disabled in this special mode since AMCS is used to increase the modulation and coding level to match available power. Finally, the modified DSCH will have to support a smaller frame size (e.g. 3.33 msec) due to reasons explained in the subsequent sections.

2.2 Hybrid ARQ (H-ARQ)

H-ARQ is an implicit link adaptation technique. Whereas, in AMC explicit C/I measurements or similar measurements are used to set the modulation and coding format, in H-ARQ, link layer acknowledgements are used for re-transmission decisions. There are many schemes for implementing H-ARQ - Chase combining, Rate compatible Punctured Turbo codes and Incremental Redundancy. Chase combining involves the retransmission by the transmitter of the coded data packet. The decoder at the receiver combines these multiple copies of the transmitted packet weighted by the received SNR. Diversity (time) gain is thus obtained.

Incremental redundancy is another implementation of the H-ARQ technique wherein instead of sending simple repeats of the entire coded packet, additional redundant information is incrementally transmitted if the decoding fails on the first attempt.

AMC by itself does provide some flexibility to choose an appropriate MCS for the channel conditions based on measurements either based on UE measurement reports or network determined. However, an accurate measurement is required and there is an effect of delay. Also, an ARQ mechanism is still required. H-ARQ autonomously adapts to the instantaneous channel conditions and is insensitive to the measurement error and delay. Combining AMC with H-ARQ leads to the best of both worlds - AMC provides the coarse data rate selection, while H-ARQ provides for fine data rate adjustment based on channel conditions.

The choice of H-ARQ mechanism however is important. There are two main ARQ mechanisms - selective repeat (SR) and stop-and-wait (SAW). In SR, only erroneous blocks are re-transmitted. A sequence number is required to identify the block. Typically, in order to fully utilize the available channel capacity the SR ARQ transmitter needs to send a number of blocks while awaiting a response (or lack of it in this case). Hence when combined with H-ARQ the mobile needs to store soft samples for each partially received block. Thus mobile memory requirements can be huge. More importantly, H-ARQ requires that the receiver must know the sequence number prior to combining separate re-transmissions. The sequence number must be encoded separately from the data and must be very reliable to overcome whatever errors the channel conditions have induced in the data. Hence a strong block code is needed to encode the sequence information - increasing the bandwidth required for signalling.

Stop-and-Wait is another scheme of ARQ and perhaps the simplest requiring little overhead. Here the transmitter simply waits for a one-bit acknowledgement to be informed that the block was encoded successfully. Also only a one bit sequence number is necessary. However, this method of operation leads to an inefficient channel utilization since in the time period while the transmitter is waiting for a response no blocks are being sent. It is proposed that a dual-channel H-ARQ be implemented to avoid this disadvantage of the simple Stop-and-Wait scheme. This scheme parallelizes the stop-and-wait protocol, in effect running two separate instantiations of the ARQ protocol in parallel channels.

In packet systems one often finds that a single user occupies the entire channel over a series of timeslots. Therefore, Figure 2 considers the case where a single user is using the channel. In Figure 2, the system consists of a single source and destination over a slotted data channel. The data channel is divided into even and odd timeslots to identify the independent instances of the ARQ protocol. The even or odd state may be signalled explicitly on the control channel or derived globally from system information such as a timeslot counter. The lease significant bit of the timeslot counter would be enough to identify the even or odd channel. Data blocks arrive from the network and are queued at the source. The source than employs a dual channel sequencer to admit data blocks to either the even or odd transmitter. Once admitted, each transmitter performs a conventional stop-n-wait ARQ algorithm in its respective even or odd timeslot by transmitting the data block on the data channel and sequence bit on the associated control channel. Similar to the source, the destination device contains both an odd and even receiver receiving blocks from the respective even and odd timeslots. Each receiver is coupled with an independent hybrid ARQ decoder. The hybrid ARQ decoder signals the success (or failure) of the data block on a separate feedback channel. Both an even and odd feedback channels exist to support each independent instance of the stop-and-wait.

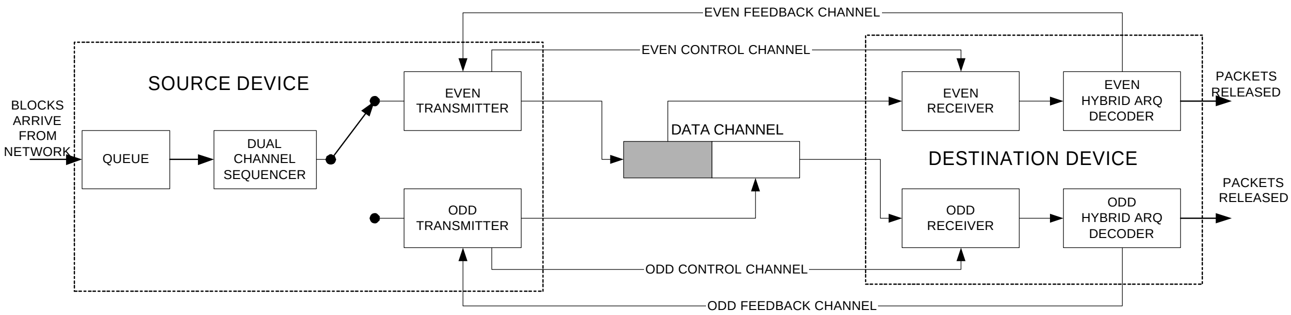


Figure 2. Single User/Single Channel Block Diagram

2.3 Frame Size

Current 3GPP specifications support frame sizes of 10 ms (and also 20ms in case of RACH). In order to support H-ARQ in an effective manner it is desirable to have a smaller frame size. This is easily understood from the fact that H-ARQ relies on feedback of error situations and subsequent re-transmissions and thus smaller frame size leads to shorter turn around times. Further, shorter frame size makes use of fat pipe multiplexing more efficient.

2.4 Functional Split

In order to accomplish the gains of Hybrid ARQ, the scheduling functions needs to be relocated from RNC to the Node B thus allowing distributed scheduling across peer Node Bs. This allows retransmissions to be scheduled within a very short time. Also, the scheduler needs to make assignments based on physical parameters such as interference, LPA power, Queue size etc. Capacity is improved if the delay is reduced between this measurement information becoming available and the signalling of the allocations which can be accomplished using de-centralised scheduling. It is proposed to terminate the RLC protocol in Node B.

2.5 Fast Cell Site Selection:

For high data rate systems it is not desirable to implement soft-handoff since it introduces additional interference in the forward link and also tie up hardware resources at multiple base stations. As such, Fast Cell Site Selection is recommended when receiving the DSCH for packet data. In this scheme, the UE does not receive simultaneous data transmission from multiple sectors and therefore performs no combining of traffic channels carrying packet data. Instead, the UE selects the best cell site every frame from which it requests the data to be transmitted. The DCH on the uplink is used to indicate the required sector from which the network should direct its data transmission to the mobile station on a frame by frame basis. This technique is a very special case of Site Selection Diversity (SSDT) and applies only to the enhanced DSCH. In the case of SSDT, each cell is assigned a temporary ID and UE periodically informs a primary cell ID to the connecting cells. The non-primary cells selected by the UE switch off their transmit power. However, in the case of Fast Cell Site selection, the UE selects the best cell site every frame from which it wants to receive data on the DSCH. The other cells in the active sets simply do not transmit since they were not selected by the UE. In the case of SSDT, its activation, termination and ID assignment are all carried out by higher layer signalling while Fast Cell Site Selection is used whenever the enhanced DSCH is activated

3. Proposal

Based on the discussions in the RAN plenary and subsequent e-mail on the RAN reflector, it has been agreed that RAN WG2 will be responsible for studying and proposing the work division of the proposed items among the RAN working groups.

- It is proposed that the above study items be distributed among the working groups as follows:

RAN WG1

1. Adaptive Modulation and Coding - Feasibility of multi-level modulation and coding schemes.
2. H-ARQ - link performance of different H-ARQ mechanism - Chase, Incremental Redundancy, etc.
3. Frame size - one of the outputs of study item 2 above (H-ARQ link performance) should be an optimum frame size
4. Reverse control channel - frame formats and need for multiple physical DCH to support Hybrid ARQ and Fast Cell Site Selection.
5. Power control for DSCH - physical layer procedures
6. Implications on mobile station requirements
7. Agreed simulation assumptions for link and system simulations

RAN WG2

1. Protocol termination points for enhanced DSCH.
2. H-ARQ - protocol, messaging, etc.
3. Fast site cell selection - message structure
4. Power control for DSCH

RAN WG3

1. Impacts on Iub
2. Impacts on Iur

RAN WG4

1. Impacts on BS and UE

- It is further proposed that there be one Technical Report containing this feasibility study with the relevant sections filled in by the working groups identified as responsible for the section. The outline of the report will be submitted in the next meeting.

References

[1] D. Chase, "A Class of Algorithms for Decoding Block Codes With Channel Measurement Information," *IEEE Trans. Inform. Theory*, vol. IT-18, pp. 170-182, Jan. 1972.