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Title: **Details of high speed downlink packet access**
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Introduction
Currently there is considerable work being performed around the world on adaptive modulation and coding for increasing the spectral efficiency and instantaneous access speed of the downlink channels in WBCDMA systems.

Motorola has proposed that this is studied in 3GPP (PR-000032) to identify if these technologies are suitable for use with our standards. Motorola has performed a study in this area and wishes to share our results, which could be used as the starting point the evaluation study.

This study has shown that data rates of up to 8.5 Mbps are achievable using a single 3.84 mbps carrier in the downlink. This would significantly increase the downlink access speed for packet data services and come close to meeting the UMTS forums objective of having at least a 1:10 up to downlink packet data service, without compromising the current capabilities.

Proposal

We propose several enhancements for packet data services so that the system could support higher peak rates while maximising the capacity and coverage of the system. The following enhancements are proposed:

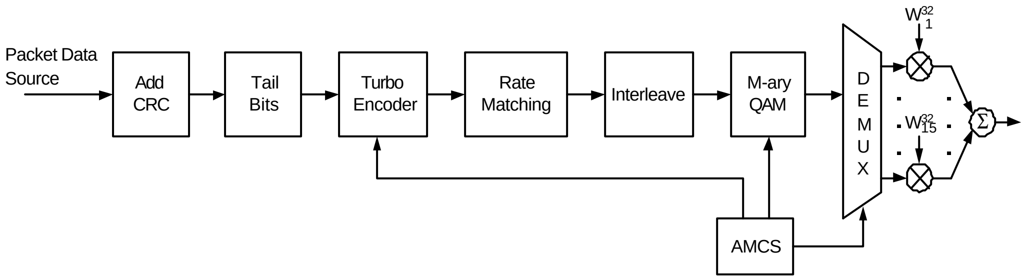
1. **Adaptive Modulation and Coding (AMCS):**

In cellular communication systems, the quality of a signal received by a subscriber device depends on distance from the desired and interfering base stations, path loss, log-normal shadowing, short term Rayleigh fading etc. In order to improve system capacity, peak data rate and coverage reliability, the signal transmitted to and by a particular user should be modified to account for the signal quality variation. The process of modifying the transmitted signal to compensate for signal variations is known as link adaptation. Two known link adaptation techniques are fast power control and adaptive modulation and coding (AMCS). In DS-CDMA systems fast power control in uplink is utilised to mitigate the near-far problem and to compensate for the variation due to short term Rayleigh fading. Fast power control in the downlink is similar to adaptive power allocation which gives more power to disadvantaged users (users with poor geometry also known as Ior/Ioc) and less power to users with good geometry. Fast downlink power control also partially mitigates the variation due to fast Rayleigh fading but is not as efficient as uplink due to limited dynamic range. With AMCS, the power of the transmitted signal is held constant (no fast down link power control) over a frame interval, but the modulation and coding format is changed to match the current received signal quality or channel conditions. 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. In fact, the reduction in interference variation by eliminating fast down link power control makes scheduling easier.

In view of the above, it is proposed that the Downlink Shared Channel (DSCH) be modified to support AMCS which in turn will support peak 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. Should support 4QAM, 16QAM and 64QAM modulation.
2. Turbo Coder rates of R=1/2 and R=3/4.
3. 6 MCS 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
6	64	3/4
5	64	1/2
4	16	3/4
3	16	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 multicodes 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 lower frame size (e.g. 3.33 msec) due to reasons explained in the subsequent sections.

2. Hybrid ARQ (HARQ):

Automatic-Repeat-Request (ARQ) schemes are used in packet data communication system. The simplest form of hybrid ARQ scheme was proposed by Chase [1]. The basic idea in Chase's scheme is to send a number of repeats of each coded data packet and allowing the decoder to combine multiple received copies of the coded packet weighted by the SNR prior to decoding. This method provides diversity gain and is very simple to implement. Turbo codes can also be used to improve the efficiency of hybrid ARQ schemes. Instead of sending simple repeats of the coded data packet, this form of hybrid ARQ sends progressive parity packets corresponding to code rate of R= 3/4, 1/2 etc i.e. in each subsequent transmission of the packet the code rate is increased. Chase combining and Rate Compatible Punctured Turbo Codes (RCPTC) can also be used in conjunction – after sending a number of parity transmissions, the process can repeat with a new information transmission.

Although, AMCS gives the flexibility to match the MCS to the average channel conditions for each user it is sensitive to measurement error and delay and it still needs ARQ in case the packet is received in error. On the other hand, HARQ automatically adapts to instantaneous channel conditions and is independent of various thresholds and is insensitive to measurement error and delay. By combining AMCS with HARQ the best of both worlds can obtained wherein AMCS does the coarse data rate selection and Hybrid ARQ does fine data rate adjustment based on channel conditions. Unfortunately, there are a few drawbacks that need to be overcome based on type of ARQ protocol selected.

Selective Repeat (SR) is a common type of ARQ employed by many modern data systems. SR is generally insensitive delay and has the favorable property of repeating only those blocks that been received in error. To accomplish this feat, the SR ARQ transmitter must employ a sequence number to identify the each block it sends. SR may fully utilize the available channel capacity by insuring the maximum block sequence number (MBSN) exceeds twice number of blocks transmitted in one round trip feedback delay. The greater the feedback delay the larger the maximum sequence number must be. SR is used in many cellular data systems like GPRS, EDGE,IS-95 and 3GPP W-CDMA. When hybrid ARQ is partnered with SR, several difficulties are seen.

- Mobile memory requirements are high. The mobile must store soft samples for each partially received block. MBSN/2 blocks may be in transit at any time. A large MBSN requires significant storage in the mobile adding to the unit's cost.
- Hybrid ARQ requires that the receiver must know the sequence number prior to combing separate retransmissions. Unlike conventional ARQ protocols, the sequence information must be encoded separately from the data. In addition, the sequence information must be very reliable to overcome whatever channel conditions have induced errors in the data. Typically a strong block code must be used to encode the sequence information effectively multiplying the bandwidth required for signalling.

Stop-n-wait is one of the simplest forms of ARQ requiring very little overhead. In stop-n-wait, the transmitter will operate on the current block has been received successfully by the receiver. As a result, only a one-bit sequence number is required to identify either the current or the next block. Furthermore, acknowledgements may also be signalled concisely in one bit to communicate whether the current block was decoded successfully. Therefore, stop-n-wait ARQ offers much efficiency when combined with hybrid ARQ reducing the overall bandwidth required for signalling. However, one major drawback exists. Acknowledgements are not instantaneous. After every transmission, the transmitter must wait to receive the acknowledgement prior to transmitting the next block. This is a well-known problem with stop-and-wait ARQ. In the interim, the channel remains idle and system capacity goes wasted. In a slotted system, the feedback delay will waste at least half the system capacity while the transmitter is waiting for acknowledgements. As a result, every other timeslot must go idle even on an error free channel.

We propose Dual channel Hybrid ARQ which parallelizes the stop-and-wait protocol and in effect running a separate instantiation of the ARQ protocol in the idle channels. As a result no system capacity goes wasted since one instance of the algorithm communicates a data block on the forward link while the other communicates data on the reverse link.

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.

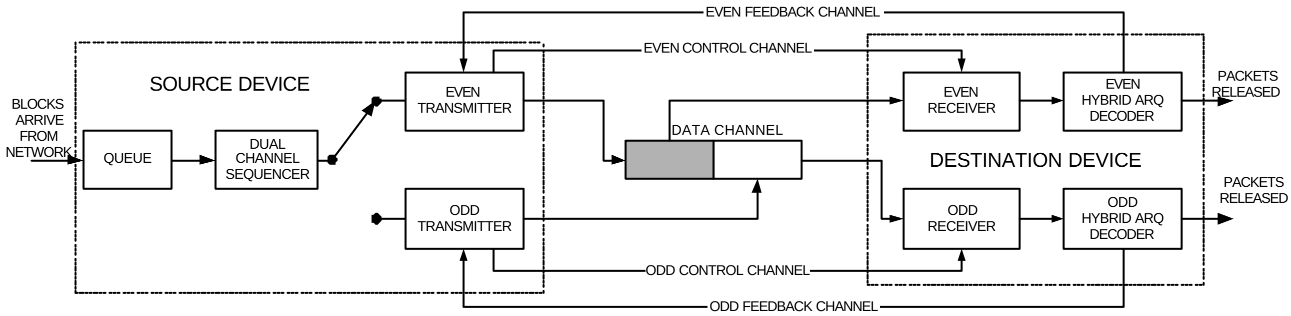


Figure 2. Single User/Single Channel Block Diagram

3. Smaller Frame Size:

The current 3GPP W-CDMA specification supports DSCH with frame size of 10 msec. In order to support Hybrid ARQ in an efficient manner it is desirable to have smaller frame size so that the turn around time is reduced which in turn releases the packets quickly even after few retransmissions. Further, shorter frame sizes reduces the payload to a manageable level. As such it is proposed, to adopt 5.33 msec frame size (8 slots) for the modified.

4. Position of Scheduling Mechanism:

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. As such it is proposed to terminate the RLC protocol in Node B.

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) since it 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

6. Uplink DCH associated with a Access Control Channel (ACCH):

The Uplink DCH associated with a ACCH was proposed for Release-99 but was withdrawn because the details could not be worked out in the time frame for Release-99. Although not essential for the downlink proposal it would be advantageous if this were to be used in the uplink.

The main advantages of the common channel (ACCH) approach is as follows:

a. Data sessions such as web browsing can last several minutes or more and several hundreds of users may share a single 384 kbps data channel simultaneously. Within these sessions, periods of high-activity will be interspersed throughout the session. The common signalling channel will accommodate a large number of users at no extra cost whereas the resources a dedicated channel consumes will be proportional to the number of users active.

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.