Proposal for the ARQ Error Correction Mechanism for the 802.16.4 MAC Layer

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This document's purpose is to facilitate the author's presentation and the reader's understanding of the Base Document

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802.16.1 MAC Layer ARQ Proposal

Why FEC and ARQ for 802.16.4 ?

March 12, 2001

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ERROR CONTROL DESIGN OBJECTIVE:

ACHIEVING THE REQUIRED IEEE 802.16.4 P-MP FBWA PERFORMANCE WITH AN EFFICIENT AND COST-EFFECTIVE ERROR CONTROL TECHNIQUE

FBWA ERROR CONTROL DESIGN CONSIDERATIONS:

- ENVIRONMENTAL AND TIME STATISTICALLY VARIABLE PROPAGATION CONSTRAINTS

- COST- EFFECTIVE MEANS TO MEET APPLICATIONS PERFORMANCE REQUIREMENTS

- EC IMPLEMENTATION FLEXIBILITY TO EFFECTIVELY MEET FBWA SYSTEM REQUIREMENTS

FBWA ERROR CONTROL MEANS TOWARD OBJECTIVES:

- FEC: CONSTRAINED BY ERROR STATISTICS INSTABILITY, NO FEEDBACK, AND FEC REDUNDANCY/INEFFICIENCIES, COMPLEXITY, AND DELAY

- ARQ: CONSTRAINED BY RETRANSMISSION AND ACK/NACK CHANNEL INEFFICIENCIES, STORAGE COMPLEXITIES, AND DELAY

-FEC HAS A FIXED BW PENALTY ASSOCIATED WITH THE CODE RATE. WITH ARQ BW TAKEN BY RETRANSMISSION IS DEPEDENT ON THE CHANNEL BER AND HENCE THE Eb/No

-HYBRID FEC- ARQ: COMPLEMENTARY MEANS FOR OPTIMALLY MEETING EC REQUIREMENTS THROUGH ADAPTIVE CONSOLIDATION OF MAC-LAYER ARQ AND PHY-LAYER FEC

Proposed ARQ Scheme Structure

Proposed ARQ Scheme packet length is approx. 500 bits to send an ATM cell. Each packet contains a 16 bit CRC word to enable the selective ARQ scheme to detect if the packet has been received error free or not. It one or more bit errors is detected, then that ATM cell is repeatedly resent, until it has been received error free, or its retransmit lifetime has expired.

AIR ATM Cell Payload	16 bit CRC

The maximum code rate for the ARQ scheme is therefore: (500 - 16) / 500 = 0.968

If the ARQ scheme retransmits data then the code rate will decrease e.g.

¥ If 5% of packets are re-sent once then the code rate is

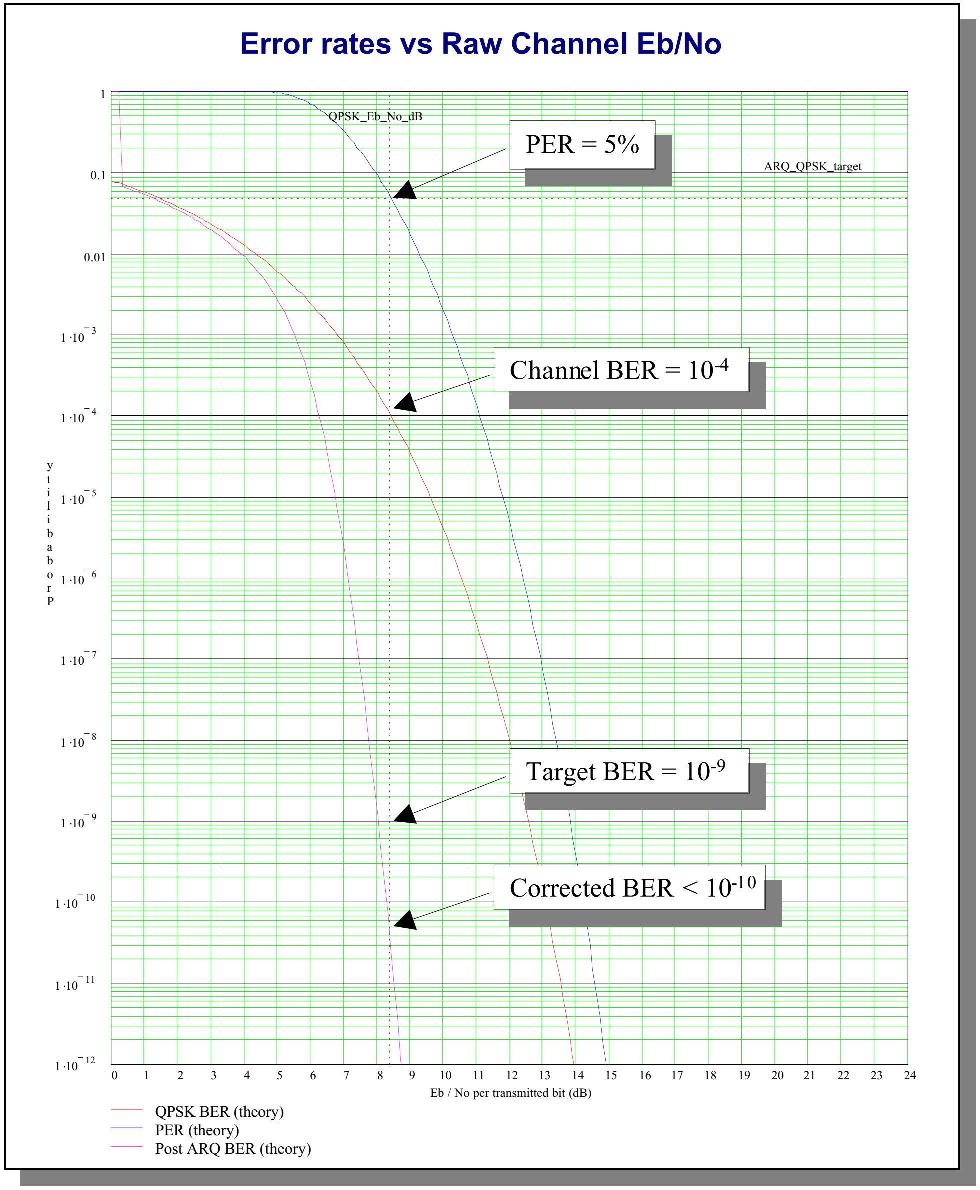
0.95 * 0.968 + 0.05 * (500-16) / 1000 = 0.9438

or

¥ If 100 % of packets are resent 5 times then the code rate is

(500 - 16) / (500 * 6) = 0.16

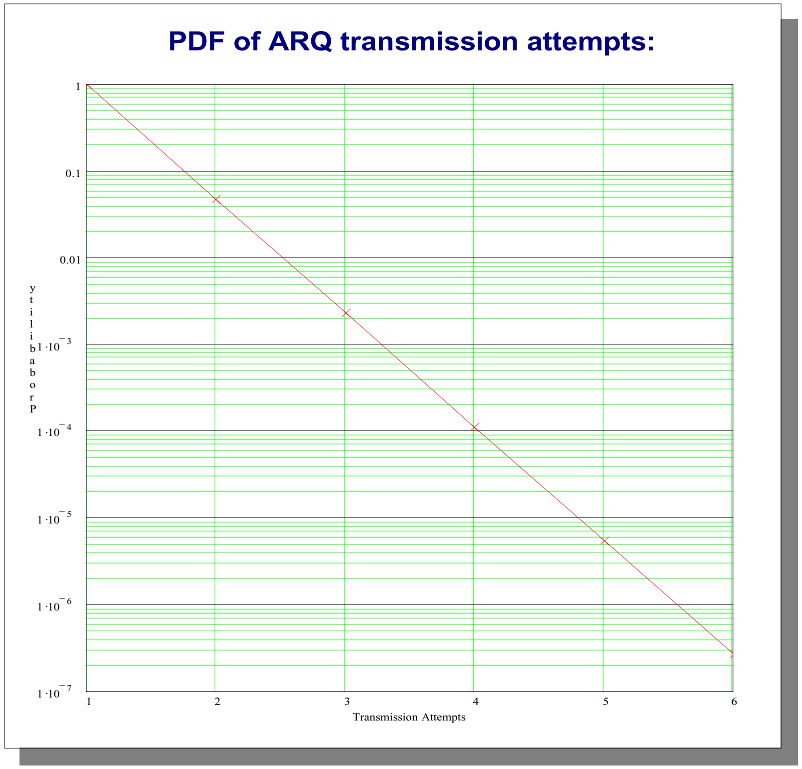
An ARQ Performance Example



An ARQ system has a packet size of 500 bits and a packet lifetime of 6 transmission attempts.

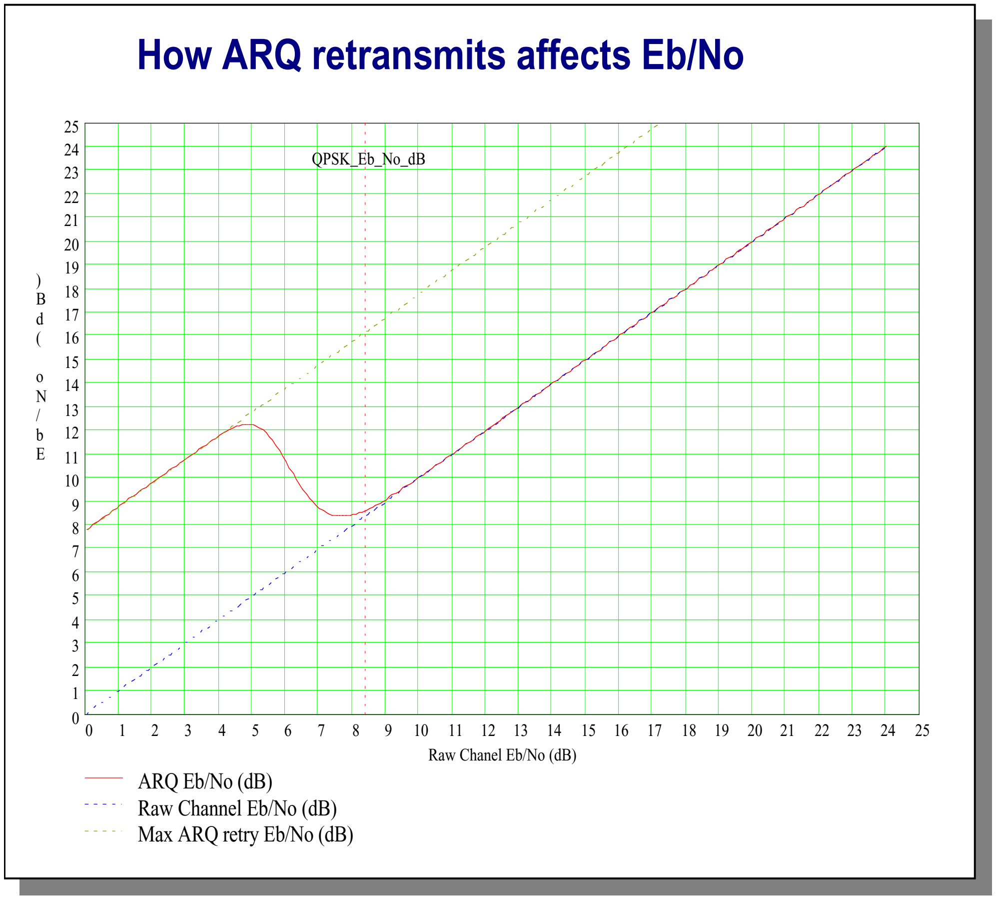
With the chosen operating point of 8.4 dB Eb/No or 11.4 dB CNR, this yields a corrected BER of $10^{\wedge-10}$, giving an order or magnitude margin over the target BER of 10^{-9}.

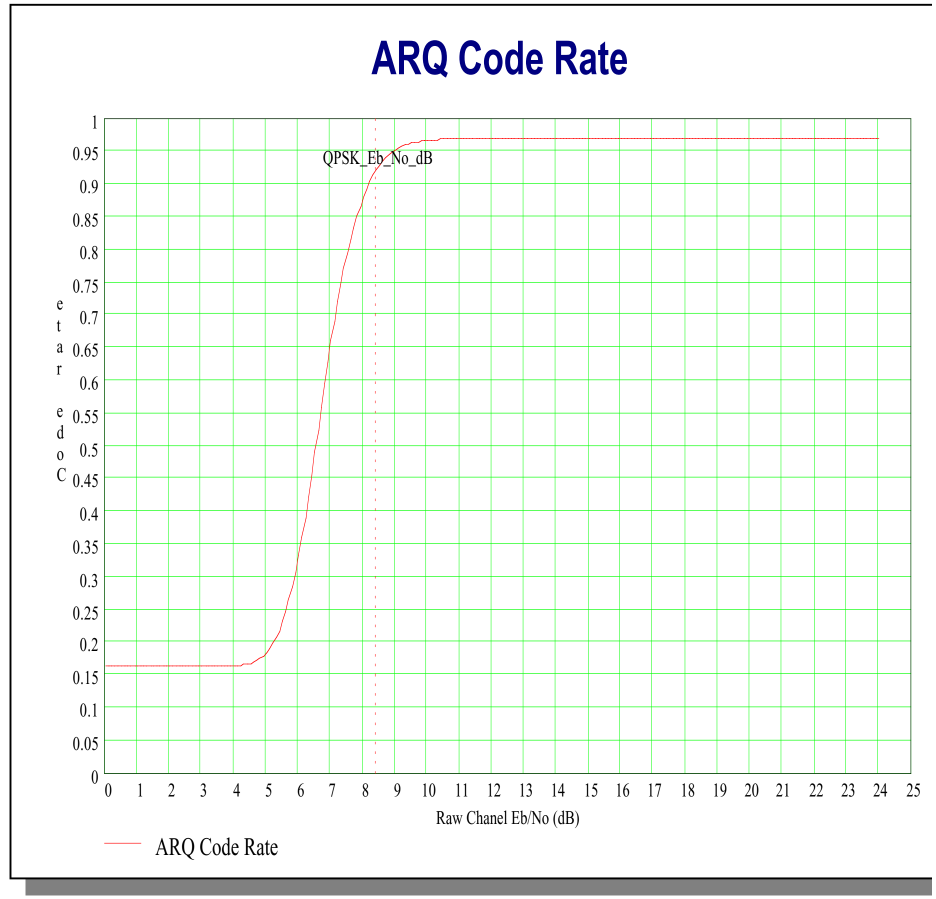
The individual Packet Error Rate is 5%. The plot below shows the PDF for the 6 ARQ attempts at 8.4 dB Eb/No.



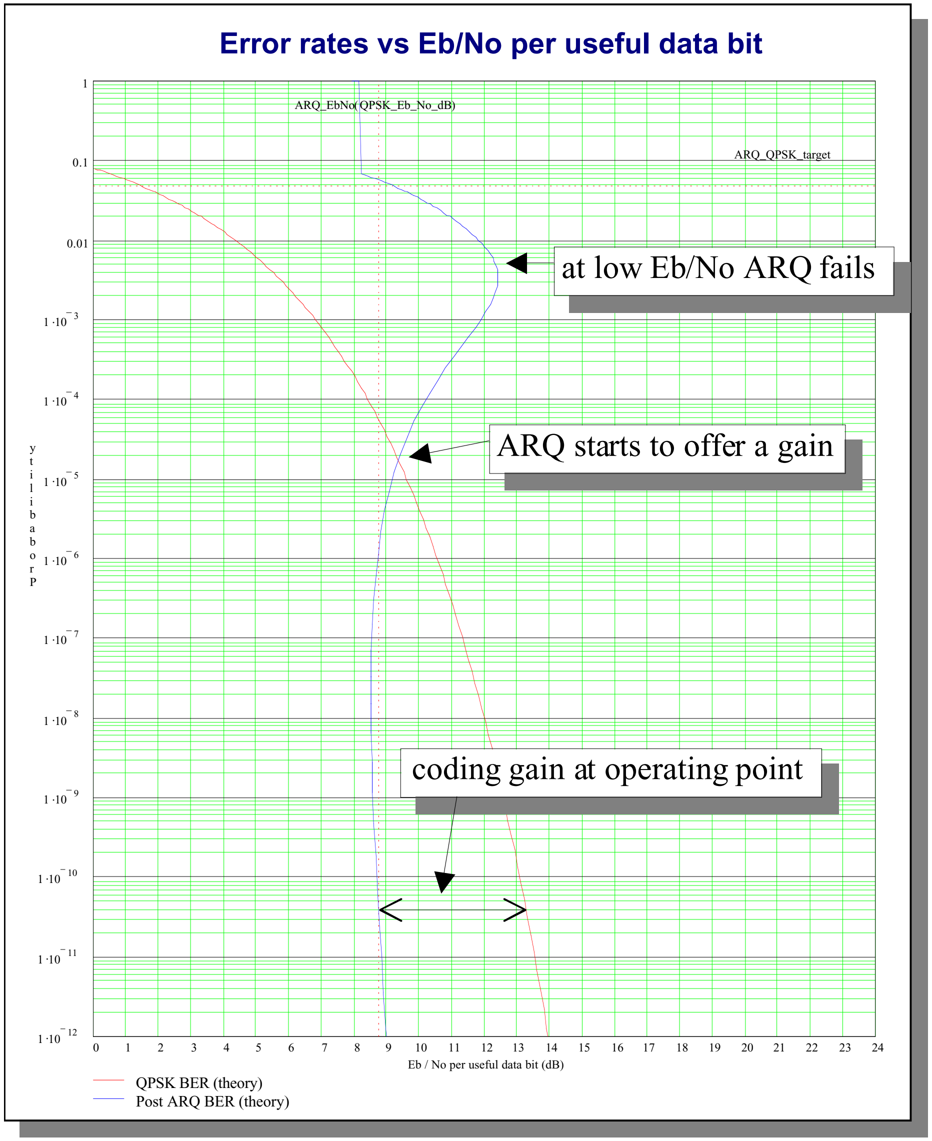
How does ARQ affect Eb/No?

With a standard FEC scheme, e.g. Reed Solomon, there is a fixed bandwidth penalty associated with the code rate. With ARQ the bandwidth taken by the retransmissions is dependant upon the channel BER and hence channel Eb/No.

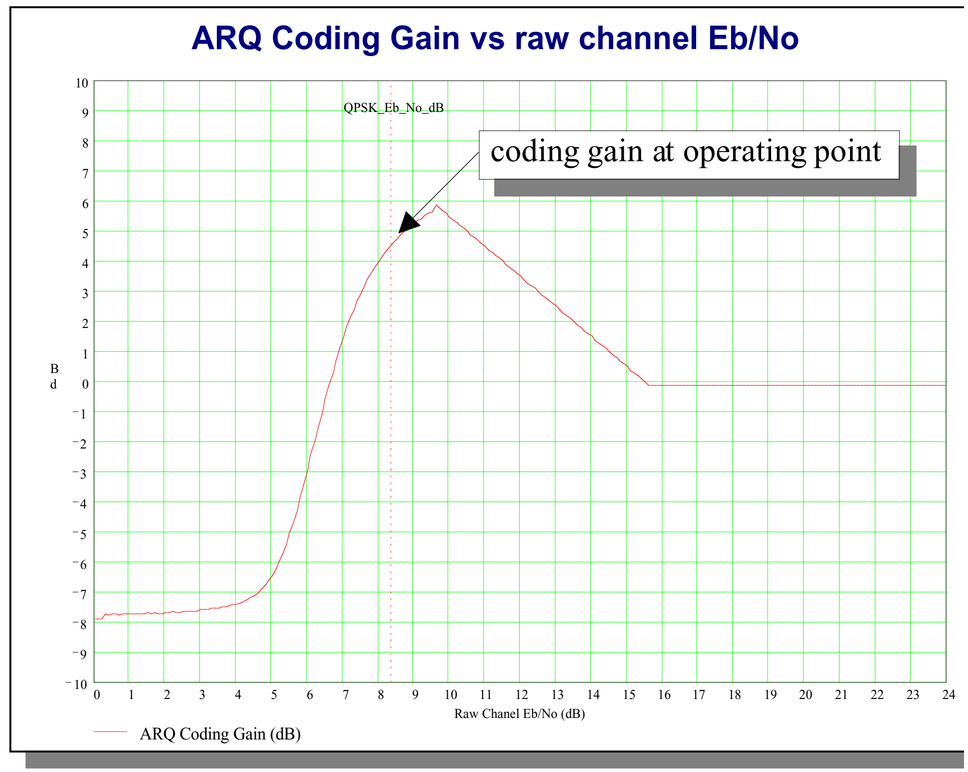




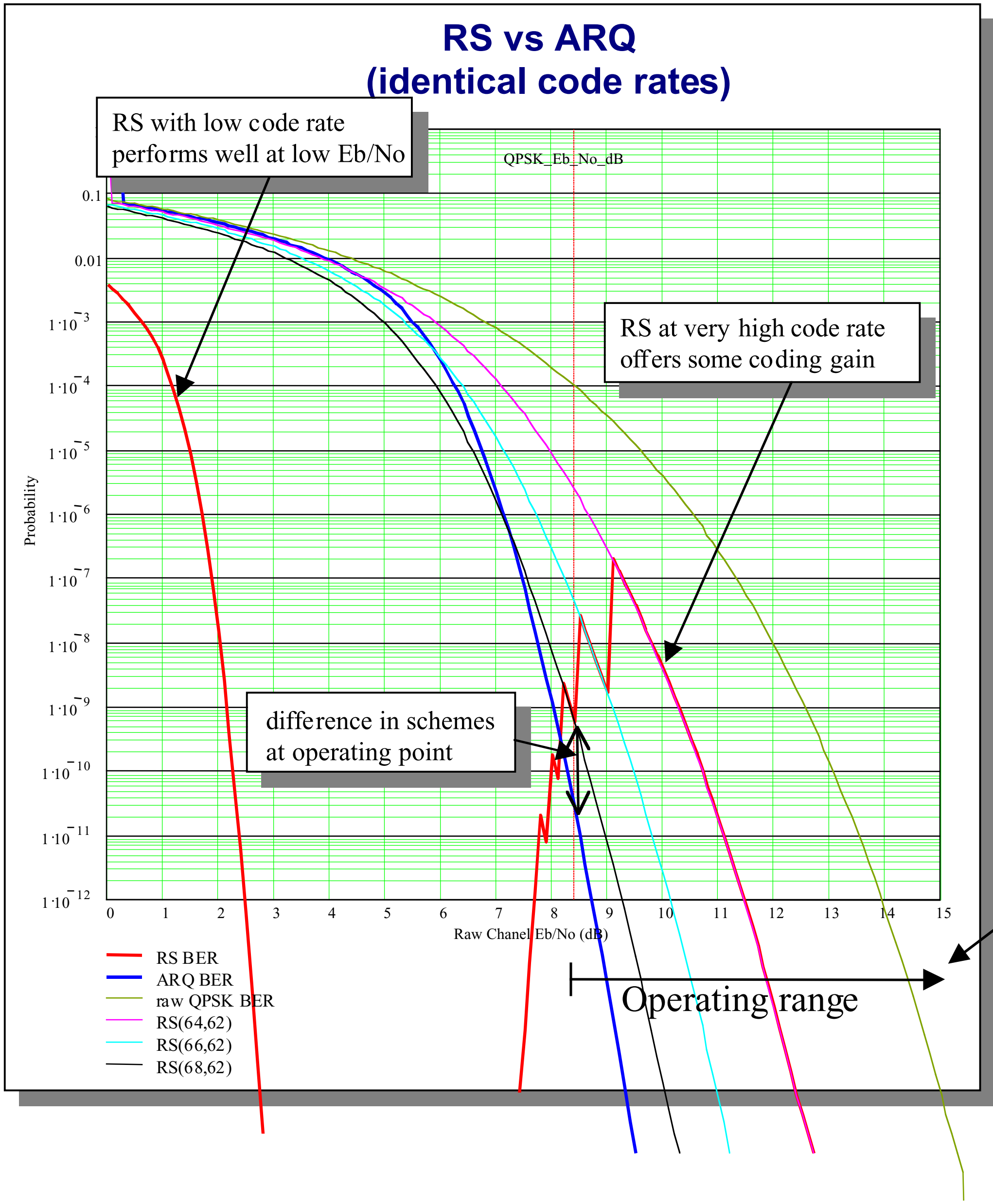
ARQ Coding Gain



In order to calculate coding gain, it is necessary to plot the post ARQ BER curve against Eb/No per useful data bit i.e. taking the ARQ bandwidth expansion into account. This is so that the ARQ scheme can be compared with raw QPSK on a like for like basis, i.e. each scheme has the same Eb/No per data bit. This yields a rather odd shaped graph which shows how ARQ copes badly at low Eb/No and then recovers at high Eb/No.



ARQ vs Reed Solomon



In order to make a fair comparison between ARQ and Reed Solomon, the BER performance has been plotted for both schemes using identical code rates at any given Eb/No. This is done by calculating the code rate of ARQ at a given Eb/No and then using a RS code with the same code rate (or as close as possible).

At very low Eb/No, RS out perfoms ARQ as it gets a code rate of 1/6. But at higher Eb/No and near our operating Point, ARQ outperforms RS at a code rate of 0.97.

The jagged RS graph is due to the fact that RS code rates are not continuous, and hence the code rate has discrete jumps. At very high Eb/No, the ARQ and RS code rate approach 0.97 and ARQ beats RS on coding gain.

All Subscriber Units should have an Eb/No in excess of the operating point, hence we are only concerned with the relative performance of the error correction schemes in this region.

ARQ Vs. RS FEC Conclusion

Proposed ARQ Error Correction with a code rate of 0.97 or greater (depending on Eb/No).

Reed Solomon FEC code cannot match the performance of ARQ at the same operating point.

Proposed ARQ does not perform well below a CNR of 11.4 dB.

PROPOSED MAC LAYER ARQ MECHANISM CAPABILITY:

Typically, FWA Systems are designed in a layered manner, with ARQ implemented in a data link controller that is separate from the media access controller. Implementations of this type cause delays in transmission that make it difficult or impossible to support fixed latency guarantees.

This ARQ proposal integrates the traffic scheduling, channel access mediation, and ARQ all into a single media access controller, providing fast selective repeat ARQ of cell traffic while still supporting traffic latency requirements.

PROPOSED MAC LAYER ARQ MECHANISM CAPABILITIES:

- -BASED ON IN-SERVICE MAC/ARQ FBWA TDD SYSTEM
- -CAN BE USED IN TDM AND TDMA, AS WELL AS SYMMETRIC AND ASYMMETRIC FBWA CHANNELS
- -CAN BE USED ALONE, OR AS AN OPTION, CONCATANATED WITH PHY LAYER-FEC
- -CAN BE USED FOR UL AND/OR FOR DL EC
- -CAN BE USED WITH OFDM AND SC PHY
- -CAN BE USED WITH TDD AND/OR FDD SYSTEMS
- -CAN SUPPORT MANY REAL-TIME AND NON-REAL TIME SERVICES.

<u>THE SUBJECT CONTRIBUTION ON THE PROPOSED MAC-LAYER ARQ EC ONLY DESCRIBES</u>:

-THE SELECTIVE-ARQ DL MECHANISM FOR A TDD SYSTEM (UL DESCRIPTION IS IDENTICAL)

-ASSUMES NO PHY-LAYER FEC

- STATED FBWA SYSTEM PARAMETERS (E.G., BURSTS/FRAME, CELLS/BURST, CELL STORAGE, AND PRIORITY LEVELS) ASSUMED FOR DESCRIPTIVE PURPOSES

THE SUBJECT CONTRIBUTION FOCUSES ON IDENTIFYING THE FBWA SYSTEM S BASIC STRUCTURE AND FUNCTIONALITIES THAT THE PROPOSED MAC-LAYER ARQ CAN BE USED WITH.

DETAILS UNDER WHAT CONDITIONS, AND HOW THE MAC-LAYER ARQ AND THE PHY-LAYER FEC INTERACT TO OPTIMALLY ACHIEVE THE REQUIRED PERFORMANCE OF THE FBWA SYSTEM, NEED TO BE DECIDED BY THE MAC GROUP MEETING JOINTLY WITH THE PHY GROUP.