Nomadic Computing and CDMA

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ABSTRACT

This paper shows how reliable data services can be provided in an error prone wireless environment using CDMA and a link layer retransmission protocol. A CDMA encoder using Walsh codes for 1.85 to 1.99 GHZ PCS applications is simulated under various error conditions with varying packet size to determine minimum acceptable QOS relative to error templates. The error templates and data rates of 16, 32, and 64 kb/s for mobile terminal units are then used with a link layer retransmission protocol to examine the overhead and its practical feasibility. Small packet sizes of about 50 bytes appear to provide promise for commercial implementations of such a protocol suite.

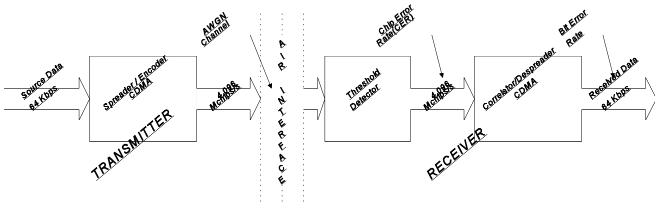
INTRODUCTION

In a previous work [1], we examined the impact of errors on the QOS that can be provided by the wideband CDMA air interface standard (1.85 to 1.99 GHZ PCS applications). We were able to determine upper bounds (error templates) on the simultaneous active channels that would preserve QOS without the use of a retransmission protocol. In this context, voice is the primary service and e-mail plus web services are simply value added with no guarantees to quality of data. In mobile computing and under the stringent conditions of spectrum availability, a retransmission protocol is essential to guarantee the quality of data services especially during the well known error bursts in the wireless medium. In addition to showing the resiliency of CDMA to the various wireless error profiles, this work demonstrates how a link layer retransmission protocol can be used over small packet (~ 50 bytes) link data transmissions to make CDMA a strong candidate for mobile computing. The simulation results provided here are for mechanisms between the mobile terminal and the base station not end-to-end protocols. The simulation demonstrates how the resistance of CDMA to errors improves with the reduction of packet size, thus make TCP/IP a less attractive protocol for such environment. In addition to the fact that link layer retransmission protocol are more efficient than transport layer "TCP" like retransmissions, the high overhead of 20 byte IP headers (44 bytes for IPv6) excaberates the performance problem especially for small 50 byte link layer transmitted packets. The link layer transmission protocol that we use here is based on SSCOP [2] and has a header of 8 bytes. A protocol that does retransmissions of only errored frames is quite appropriate when the wireless data rate is low and the round trip delay could potentially be long.

MOBILE TERMINAL TO BASE STATION PROTOCOL AND THE ENVIRONMENT SIMULATED

A mobile terminal (transmitter) and a base station (receiver) are linked via an air interface as shown in Figure 1 below. A CDMA spreader/encoder expands every bit of source information into 64 chips using one of 64 unique Walsh codes as defined in reference [3]. The receiver consists of a threshold detector and a CDMA correlator/despreader. Only one data stream is considered; therefore an interleaver is not required. Error is injected into the air medium as a Gaussian distribution with a varying number of mean errors to represent known wireless problems of interference, fading, propagation, power, and others. White Gaussian Noise is added to the baseband chips. We also injected bursty errors with a poisson distribution and a fixed one-millisecond duration as our best attempt to represent such a scenario. This simulation represent the transmitted signal in an aggregate noise environment surrounding the RF channel and receiver. Fading is not explicitly included. Data rates of 16, 32, and 64 kb/s were used with respecting Walsh codes of 256, 128, and 64 and a respective number of transmitters of 256, 128, and 64.

For such low data rates and potentially long round trip delay for acknowledgements, a protocol that performs retransmissions of only the errored packets is appropriate. It is necessary, therefore, to analyze performance for varying packet sizes at different SNR values. The receiver buffer size needed at those different SNRs is also calculated. The simulation program considered input file sizes of 1.024 Mbyte each of which was segmented into various size payloads that were encapsulated into SSCOP PDUs called Sequenced Data. These Sequenced Data were transmitted through the error environment described above. If the Sequenced Data frame (packet) contained an error, such packet was scheduled for retransmission. The retransmission is based on a round trip delay and packet size and represents the time it takes to cover the distance between the transmitter and receiver at a given data rate. If the Sequenced Data packet was error free and out of sequence, it was buffered until the previous packet(s) were received. If an error free and in sequence packet was delivered, no retransmission occurs. No timers, ACKS, or NAKS were used.



RESULTS

Figures 2 and 3 provide relationships between BER, CER, and SNR while Figure 4 displays the number of mobile terminals versus bandwidth at a given data rate. These results, as provided in our other [1], allow us to compute the number of retransmissions and related overhead for various packet sizes and error environments described above.

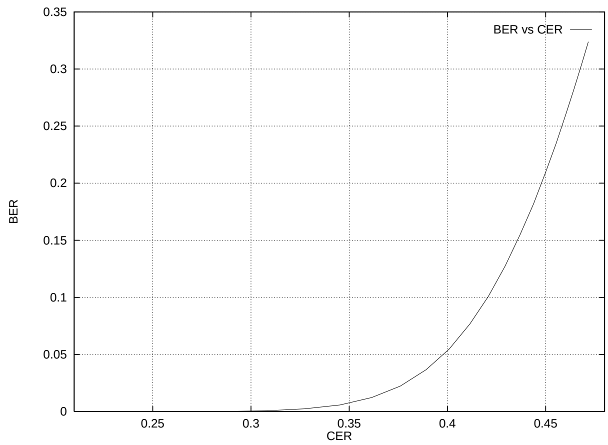


Figure 2. Bit error rate as a function of the chip error rate.

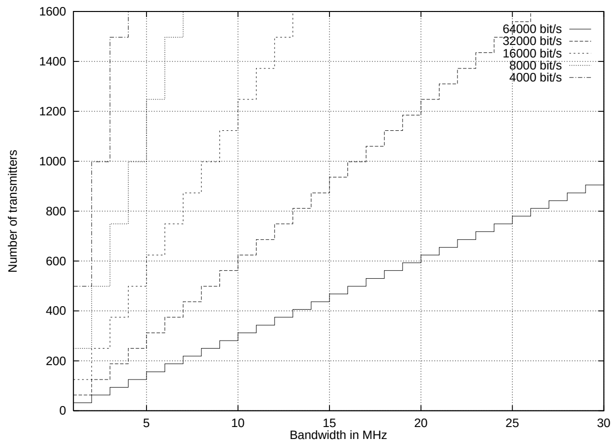


Figure 4. Number of transmitters as a function of bandwidth in MHz.

The input 1.024 Mbyte file was segmented into various packet sizes of 50, 60, 70, 80, 90, 100, 200, 500, 1000, 2000, 5000, and 10,000 bytes each of which was CDMA transmitted under various bit error rates.

The number of frames (payload packet plus headers) transmitted and the corresponding total transmission time in seconds are given in Figures 5 and 6 respectively. These values are provided for the very wide range of errors requested by an SNR ranging from 11dB = 6.1 x10 $^{-3}$ errors/sec. to above 16dB = 5 x 10^{-6} errors/sec. Note that the actual number of frames retransmitted would be less than what is shown in Figure 5. It is less by the total number of packets that make up the 1.024 Mbyte file. For example the actual number of transmitted 50 byte frames at SNR=11dB is 295,442 not 315,922 frames. Similar subtraction needs to be carried out for Figure 6. As seen, smaller frames require less retransmissions at high error rates (small SNR values). The buffer size of the receiver needed for the retransmission is small (1 to 2 frames when the distance between the transmitter and receiver is 50 Km). For a 50 byte frame, 20 480 packets were required to be transmitted. A total, of 238828 frames were transmitted in an SNR environment of 11dB. In this worst scenario the total number of errors was 586860 and the time it took to transmit the whole file was 24 minutes and 53 seconds. Note that these results shown in Figures 5 and 6 are for a confirmation of a total of 64 mobile terminals (users) operating at 64 kb/s with 64 Walsh codes encoding.

TRANSMISSION OVERHEAD

SSCOP requires payload to be a multiple of 4 bytes. In case of a 50 byte packet two additional bytes are added (stuffed). The SSCOP header that is concatenated to the payload is 4 bytes: sequence numbering, payload type indentifier, reserve byte, etc. Therefore, in the case of 50 byte packets the retransmission protocol overhead is 6/56 per frame. The retransmission itself is an overhead that can be easily computed by subtracting values in Figures 5 or 6 from the number of frames (or time taken) required to transmit the actual 1.024 Mbyte file. A third type of overhead is the number of frames stored in the buffer of the receiver. We show in Figures 7 and 8 two extreme cases (high and low error rates) which indicate a very reasonable number of frame buffers shown at SNR = 11.5 dB and SNR = 14 dB.

REFERENCES

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