AUTOMATIC REPEAT REQUEST ASSISTED CORDLESS TELEPHONY

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ABSTRACT

A generic re-transmission scheme is proposed for packet reservation multiple access (PRMA) assisted indoors cordless voice communications. Its frame error rate (FER) versus channel signal-to-noise ratio (SNR) performance is assessed under various traffic loading conditions using the example of a re-configurable transceiver. A significant operating SNR reduction can be achieved, if the traffic load is not excessive. This effect is particularly pronounced, if the speech transceiver used can drop its transmission rate and accommodate this lower rate using a more robust modem, when attempting re-transmission. The key system features are summarised in Table 1.

Parameter	Low/High Quality Mode
Speech Codec	4.7/6.5 kbps ACELP
FEC	Twin-/Triple-class BCH
FEC-coded Rate	8.5/12.6 kbps
Modulation	Square 16-QAM/64-QAM
Demodulation	Coherent, Diversity- and PSAM-assisted
Equaliser	No
User's Signaling Rate	3.1 kBd
Voice Activity Det.	GSM-like [8]
Multiple Acess	32-slot PRMA
Speech Frame Length	30 ms
Slot Length	0.9375 ms
Channel rate	100 kBd
System Bandwidth	200 kHz
No. of Users	> 50
Equiv. User Bandwidth	4 kHz
Min. Channel SNR	15/25 dB

Table 1: Transceiver Parameters

1. INTRODUCTION

Automatic repeat request (ARQ) schemes have been successfully used in data transmission systems in order to render the bit and frame error rate over various channels arbitrarily low [1, 2, 3]. Due to their inherent delay and the requirement of a low-rate feed back channel used for acknowledging the successful or unsuccessful reception of a packet ARQ systems have not been used in speech communications. Quite recently Nanda, Goodman and Timor [4] have proposed packet reservation multiple access (PRMA) for microcellular mobile speech communications. In PRMA the slot status information is broadcast by the base station (BS) to the mobile stations (MS) instantaneously and with infinitesimal propagation delay in order to allow prompt contention for any time slot that is surrendered by users becoming temporarily inactive.

2. SYSTEM DESCRIPTION

In this contribution we propose a new PRMA-based speech re-transmission principle, where the slot status broadcast message is extended to include an acknowledgement flag indicating the erroneous or successful reception of an information packet. Should the received speech packet be corrupted by noise or interference after reservation was granted to the user, the acknowledgement flag is set accordingly and the user attempts to re-transmit this packet in an unallocated time slot during the current PRMA frame without reserving it. If collision- and error-free detection of this packet was accomplished during the current PRMA frame, unimpaired speech detection ensues, otherwise the decoder can invoke speech post-enhancement in an attempt to recover the speech packet from the two received packets. In theory the number of re-transmissions is not restricted, but in practice it is advantageous to re-transmit only once, in order to limit the packet dropping probability due to collisions. This method is applicable to any PRMA-assisted small-cell speech communications system and here we evaluate its performance in terms of frame error rate (FER) reduction using the example of a bandwidth-efficient 3.1 kBd cordless indoors speech transceiver scheme portrayed in reference [5].

The transceiver incorporated a dual-rate 4.7/6.5 kbps

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algebraic code excited linear predictive (ACELP) speech codec [6]. The ACELP codec was designed to drop its source encoding rate and speech quality under network control in order to allow the employment of a more error resilient but less bandwidth efficient modem amongst less favourable channel conditions if, for example, the first transmission of a speech packet was unsuccessful. However, the 'memory continuity' of both the low- and high-quality ACELP modes of operation must be maintained. Source-matched binary Bose-Chaudhuri-Hocquenghem (BCH) codecs [7] combined with un-equal protection diversity- and pilot-assisted 16- and 64-level quadrature amplitude modulation (16-QAM, 64-QAM) [9] are employed in order to accommodate both the 4.7 and the 6.5 kbits/s coded speech bits at a signalling rate of 3.1 kBd. Then, assuming a modem excess bandwidth of 100% and a bandwidth of 200 kHz, which corresponds to that of the Pan-European GSM system [8], at a signalling rate of 100 kBd 32 time slots can be created. This allows us to support in excess of 60 users, when employing packet reservation multiple access (PRMA) with no re-transmissions, while maintaining a packet dropping probability of less than 1%. Hence the equivalent user bandwidth becomes less than 4 kHz. The transceiver parameters are summarised in Table 1.

If, however, re-transmissions are used in order to reduce the frame error rate (FER), the number of users accommodated is expected to fall due to the increased collision probability at a concomitant speech quality improvement. In order to portray the underlying trade-offs in practical terms we have evaluated the frame error rate performance of our prototype system as a function of the channel signal to noise ratio (SNR) for 32, 50 and 60 speech users. These results are displayed in Figures 4-6 respectively and will be discussed in depth in Section 3.

In order to achieve the best possible speech quality and exploit the prevalent high SNR and high signal to interference ratio (SIR) of the cordless indoors environment, the transceiver initially attempted to transmit speech in the 6.5 kbps/64-QAM mode of operation. As a benchmarker we have used this system with no re-transmissions. The top curve of each of Figures 4-6 is denoted by 64QAM, NO ARQ, DROP, which represents the scenario, when 64-QAM transmissions are used without re-transmissions, but packets can be dropped due to PRMA collisions. Throughout our experiments a frame is deemed erroneous, if it is either dropped by the PRMA scheme or corrupted by the channel. Observe that the bold lines in Figures 6 and 7 indicate the frame error rate (FER) corresponding to the packet dropping probability for the specific number of users supported. This FER floor represents the lowest possible FER value in case of perfect channel conditions.

Another benchmarker scheme is constituted by the case, when every packet can be re-transmitted once using 64-QAM, but the traffic load is low, corresponding to a low number of users. Hence no packets are dropped and for perfect channel conditions the FER tends to zero. This situation is denoted by the legend 64/64QAM, NO DROP.

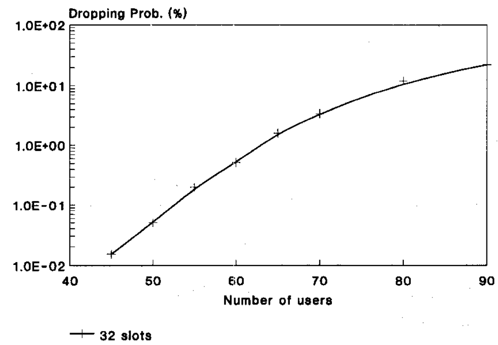

Figure 1: Packet dropping probability versus number of users for the re-configurable 3.1 kBd transceiver used in the prototype system

Two practical re-transmission schemes have been evaluated in our experiments. In order to maintain as high a speech quality as possible, we have initially attempted re-transmissions using the 6.5kbps/64-QAM scheme. The rationale behind this re-transmission policy was that due to the bursty channel error distribution the received signal is likely to have emerged from a deep fade, by the time re-transmission is permitted by the PRMA multiplexer. This arrangement was denoted by 64/64QAM, DROP.

Another practical re-transmission principle conceived was to drop the speech encoding rate to 4.7 kbps and invoke the more robust 16-QAM modem, when re-transmission was attempted. This system was denoted by the legend 64/16QAM, DROP.

3. PERFORMANCE AND DISCUSSION

During our investigations the signalling rate was 100 kBd, the pedestrian speed was 3 mph and the propagation frequency was 1.9 GHz. The packet dropping probability versus number of users supported is displayed in Figure 1. Observe that assuming a packet dropping probability of 1% approximately 62 users can be serviced. This curve represents the best possible FER performance under perfect channel conditions, when naturally no re-transmissions are necessary.

Given the packet dropping probability, the speech Segmental Signal-to-noise Ratio (SEGSNR) degrada-

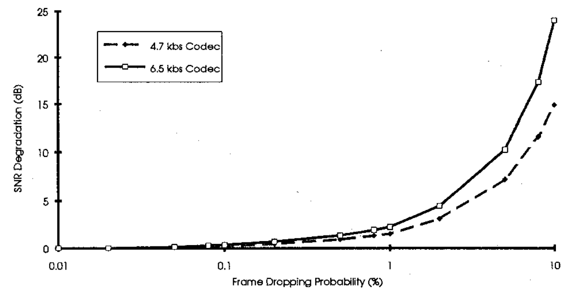

Figure 2: Speech SEGSNR degradation in both ACELP modes of operation due to random packet dropping

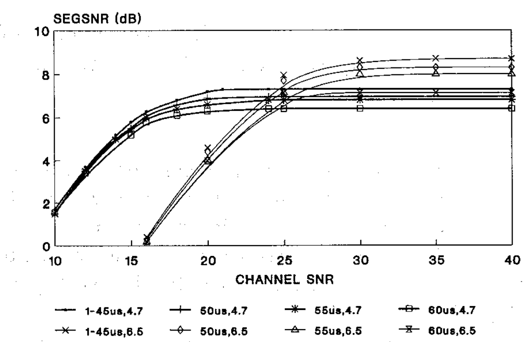

Figure 3: SEGSNR versus channel SNR performance of the re-configurable 100 kBd transceiver using 32-slot PRMA for different number of conversations

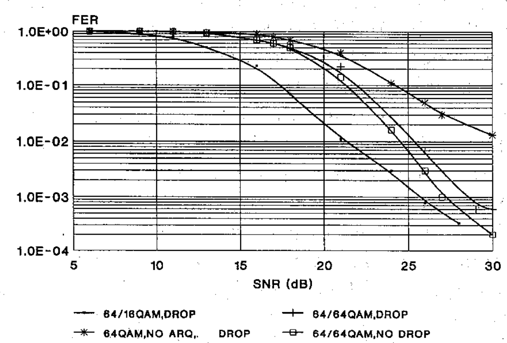

Figure 4: FER versus channel SNR performance of various speech re-transmission schemes when supporting 32 users

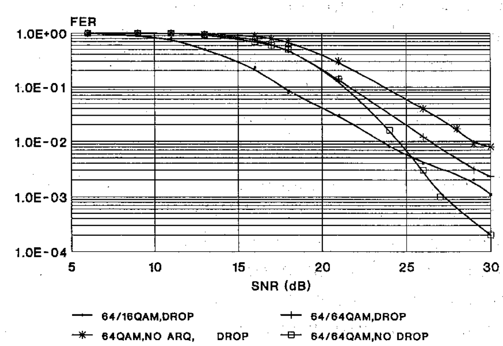

Figure 5: FER versus channel SNR performance of various speech re-transmission schemes when supporting 50 users

tion inflicted by random dropped packets in both modes of operation of the dual-rate ACELP codec is portrayed in Figure 2. Observe that the higher quality mode suffers a higher SEGSNR degradation at any packet dropping probability. In subjective terms the speech degradation due to PRMA packet dropping is less objectionable than that suggested by Figure 2, since the initial spurt clipping typically affects only the low-energy onset of the speech signal. The effects of PRMA packet dropping become explicit in Figure 3, where the overall SEGSNR versus channel SNR performance of our system is displayed without ARQ attempts.

As portrayed in Figures 4-6, irrespective of the number of users, the worst FER performance was achieved by the 64QAM, NO ARQ, DROP system, since no retransmission was invoked. In Figures 4-6 typically a channel signal to noise ratio (SNR) of 30 dB was required in order to maintain a FER of 1-2 %, which is associated with perceptually unimpaired speech quality. When the number of users was increased to 60, the FER contribution due to PRMA packet dropping further increased this FER value. If no packets were dropped and 64-QAM re-transmission was employed, the required channel SNR value was reduced to about 24 dB, an SNR reduction of about 6 dB.

When allowing packet dropping and accommodating 32 users, which was associated with a low packet dropping probability, the system's performance was hardly degraded in comparison to the 64/64QAM, NO DROP scenario, as suggested by Figure 4. There was an approximately 5 dB SNR improvement due to ARQ. However, when supporting 50 users, the FER reduction due to ARQ eroded to about a factor four around an SNR of 26 dB, where the target FER of about 1% was maintained. This was the result of the accumulated effect of the increased PRMA packet dropping and packet corruption due to channel errors. This tendency became even more pronounced, when serving 60 users, which was associated with a packet dropping probability and

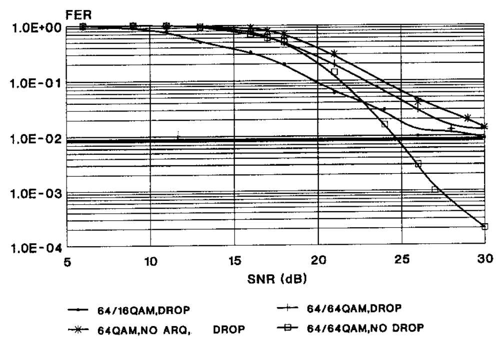

Figure 6: FER versus channel SNR performance of various speech re-transmission schemes when supporting 60 users

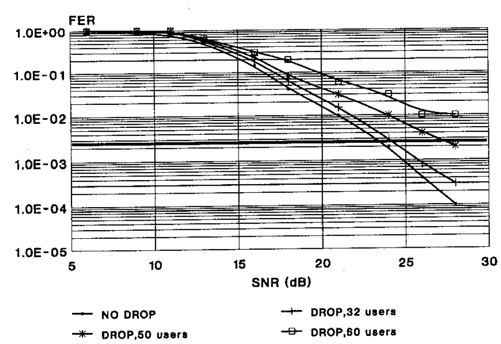

Figure 7: FER versus channel SNR performance of the 64/16QAM, DROP re-transmission scheme when supporting 32, 50 and 60 users in contrast to the NO DROP scenario

FER floor of about 0.7%.

The best performance was achieved by the 64/16-QAM, DROP scheme, which attempted re-transmission using the 4.7kbps/16-QAM arrangement. This system out-performed all other schemes in case of 32 users, achieving the target FER of 1% around an SNR value of 21 dB, almost 10 dB lower than the 64QAM, NO ARQ, DROP system. Even for 50 users it was sufficient to ensure an SNR of 23 dB for perceptually unimpaired speech quality, which was increased to above 25 dB in case of 60 users. Due to frame errors inflicted by PRMA packet dropping the FER curve flattened out around the packet dropping floor. The improved performance of the 64/16QAM, DROP arrangement in contrast to the 64/64QAM, DROP scheme was partially due to the fact that for a low pedestrian walking speed the assumption of emerging from deep fades quickly was rarely satisfied. Hence a frame error in case of 64-QAM transmissions was the pre-cursor of a deep fade and re-transmissions attempted using the more robust 16-QAM modem, rather than 64-QAM were more likely to be successful. The FER versus channel SNR performance of the 64/16QAM, DROP scheme is repeated in Figure 7 for 32, 50 and 60 users in contrast to the NO DROP scenario. It becomes explicit that as long as the traffic load does not become excessive, significant FER reductions can be achieved using ARQ. The FER performance curve for 32 users closely approximates the ideal NO DROP curve, which gradually erodes, as the system load exceeds 50 users.

4. CONCLUSIONS

A new speech packet re-transmission scheme was proposed for PRMA-assisted indoors cordless communications. The proposed scheme is suitable for any combination of source- and channel codecs, as well as modems. In order to prevent overloading the PRMA system with re-transmitted packets, it was advantageous to limit the number of packet re-transmissions to one, which predetermined the minimum required channel SNR value on a statistical basis, if the maximum acceptable FER was limited. If the number of users supported was high, the system operated in the packet dropping limited scenario, while for a low traffic load the performance limiting factors were the frame errors due to channel impairments. If a re-configurable transceiver is available, it is beneficial to invoke a lower speech quality, more robust mode of operation during packet re-transmission, since the first frame error is typically the pre-cursor of a deep fade, jeopardizing the success of the re-transmission, when using the same high quality/more vulnerable mode, as in the first instance.

5. ACKNOWLEDGEMENT

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6. REFERENCES

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