PRMA and MPRMA are a multiple access protocols for packet wireless cellular networks where fixed BSs communicate with a number of UTs. Due to the reflection, refraction and scattering of radio waves, the transmitted signal (downlink) often reaches UTs by more than one path, resulting in a phenomenon known as multipath fading [14],[15]. A detailed modeling of radio propagation channels is a major requirement in deriving the performance of any wireless packet network. The radio channel exhibits the typical characteristics of a time-varying channel [13]-[15]. However, the statistical parameters typical of the radio channel vary slowly with respect to the transmission time of a data packet [14],[15]. According to previous papers on this subject, the transmission medium has been modeled as a discrete Markov chain with a finite number of states [13]-[16]. Independent Markov channels are assumed for UTs. In each possible state the channel is modeled as discrete, memoryless, and characterized by a particular bit error rate (BER) value. In particular, we consider here the limit case of an uplink (i.e., from mobile UTs to BS) channel modeled by a two-state Markov chain, first introduced by Gilbert [16]. The states are termed "*GOOD*" (quiet) and "*BAD*" (noisy)[3]. A Forward Error Correction (FEC) code is assumed in order to control transmission errors in speech packets (i.e., no speech packet retransmission is allowed). It follows that the performance of the voice subsystem is independent of the channel state. Conversely, an error control by a suitable error detection-retransmission method has been considered for data packets. An ideal error detection code has been assumed, i.e, a code able to detect any error pattern. Under this assumption, we have that a data packet transmitted when the channel is in the *GOOD* state is always accepted by the BS (i.e., error free). Conversely, any data packet transmitted when the channel is in the *BAD* state is discarded and a new transmission is requested to the sending UT.

Channel state transitions are assumed to occur at the beginning of slots with probability $p_{B,G}$ ($p_{G,B}$) from the *BAD* (*GOOD*) state to the *GOOD* (*BAD*) state. Starting from these considerations, it is possible to show that:

1) The average sojourn time of the radio channel in the *BAD* state (burst length) is:

$$T_B = \frac{1}{p_{B,G}} \text{ (slots)} \tag{4}$$

2) The average sojourn time of the radio channel in the *GOOD* state is:

$$T_G = \frac{1}{p_{G,B}} \text{(slots)} \tag{5}$$

3) The cycle time is:

$$T_c = T_B + T_G \text{(slots)} \tag{6}$$

4) The duty cycle of the noisy burst, or the probability of being in the *BAD* state, is:

$$\delta = \frac{T_B}{T_c} \tag{7}$$

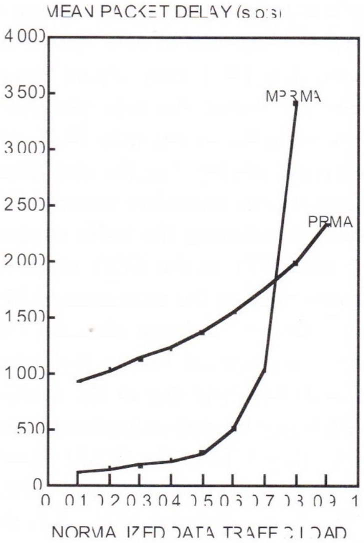

Figure 4: Mean data delay comparison (p_d=0.15, p_v=0.3, L_d=50 pkts, p_a=0.8).

Parameters T_B and δ characterize the burstiness of the radio channel while parameter T_c characterizes its time variations. Indoor wireless channels usually exhibit slow time variations (i.e., high values of T_c) [14]. Conversely, outdoor wireless channels are characterized by faster time variations (i.e., low values of T_c) [15].

A performance loss affects the standard PRMA protocol in the presence of a non-ideal, non-stationary radio channel propagation conditions (figures 5-6). In particular, we have an increase of P_{drop}. Caused by the need of retransmitting NAKed data packets.

The performance of the MPRMA protocol is shown in figures 7,8 in terms of P_{drop} and $\overline{x}$, respectively. As for the PRMA case, these figures highlight that the MPRMA performance is dependent on the dynamic of the radio channel. In particular, lower P_{drop} values are achieved in the case of a fast radio channel (low T_c) with respect to the case of slow radio channel (high T_c). A justification of this behavior is that a fast transmission channel exhibits a shorter sojourn time in the *BAD* state than slow transmission channels. This leads to a reduction of the time during which voice (and data) UTs remain in the *CON* state, therefore lowering P_{drop} (and $\overline{x}$). Figures 7, 8 clearly point out that the MPRMA protocol outperforms the standard

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[3] The downlink channel (i.e., from BS to mobile UTs) has been assumed ideal [13] so as feedback packets can be always considered error free.

PRMA protocol (figures 5, 6) also in the case of non-ideal, non-stationary transmission channel conditions.

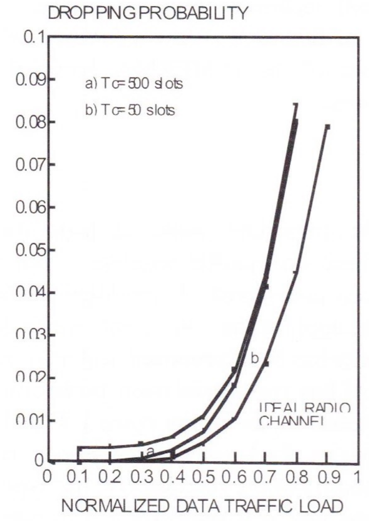

Figure 5 : Packet dropping probability comparison for the PRMA protocol (p_d=0.15, p_v=0.3, L_d=50 pkts, δ=0.1).

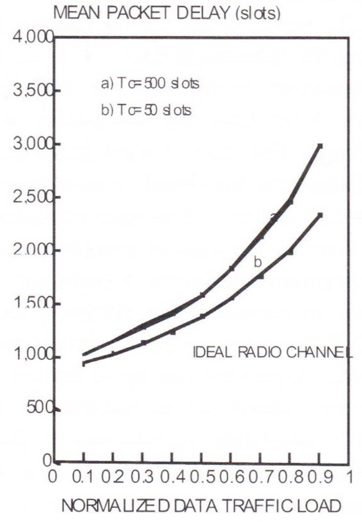

Figure 6: Mean data packet delay comparison for the PRMA protocol (p_d=0.15, p_v=0.3, L_d=50 pkts, δ=0.1).

A better performance for the MPRMA protocol in the case of slow radio channel can be achieved by breaking off the possibility to transmit a packet by the data HUT under poor radio channel propagation conditions (i.e., the radio channel is in the *BAD* state). This permits to avoid unsuccessful transmission attempts. In indoor or outdoor radio communications, time periods may occur in which a data UT is unable to correctly transmit data packets to the BS. Under such circumstances, the medium-access protocol plays a vital role in reducing losses in the network performance. Assuming independent radio channels for UTs, it may happen that, while one data UT runs into poor radio channel propagation conditions, another is able to correctly transmit data.

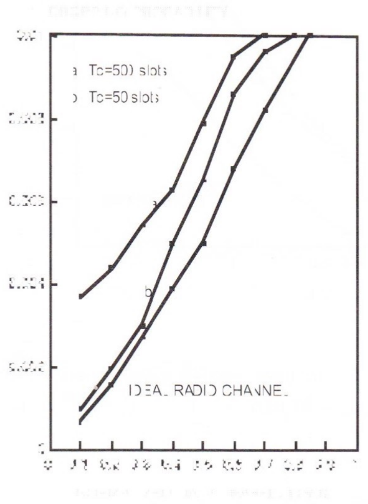

Figure 7 : Packet dropping probability comparison for the MPRMA protocol (p_d=0.15, p_v=0.3, L_d=50 pkts, p_a=0.75, δ=0.1).

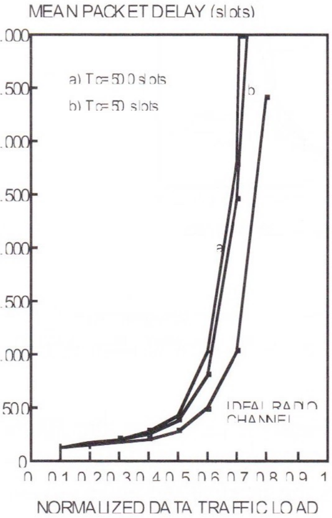

Figure 8: Mean data packet delay comparison for the MPRMA protocol (p_d=0.15, p_v=0.3, L_d=50 pkts, p_a=0.75, δ=0.1).

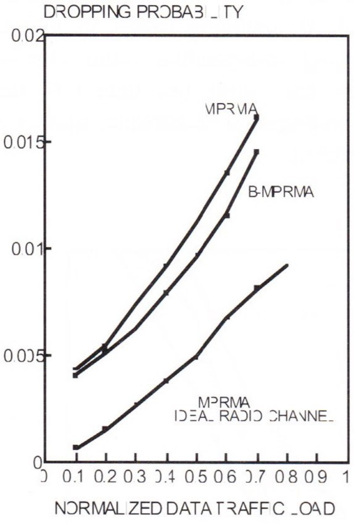

Figure 9 : Mean data packet delay comparison (p_d= 0.15, p_v= 0.3, L_d= 50 pkts, p_a= 0.75, T_c= 500 slots, δ= 0.1).

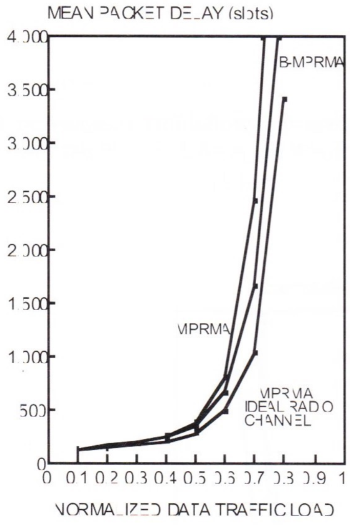

Figure 10: Mean data packet delay comparison (p_d= 0.15, p_v= 0.3, L_d= 50 pkts, p_a= 0.75, T_c= 500 slots, δ= 0.1).

With the proposed break-off technique, the BS is provided with an ACK/NACK counter which is reset to zero when a new ID reaches the head of the access queue. If a NACK message is sent out to the data HUT, the counter value is increased by one. Conversely, the counter value is reset to zero whenever an ACK message is sent out. If the counter value reaches a fixed threshold value H, i.e., the BS sends out H consecutive NACK packets, the ID of the data HUT is removed from the head of the access queue and shifted to the last position (bottom of the queue). Derivation of parameter H is dependent on the radio channel propagation conditions. In our case, it is straightforward to note that the most suitable choice is to set H to one. Parameter P_{drop} and $\overline{x}$ for the MPRMA protocol with the breakoff technique outlined above (B-MPRMA) are shown in figures 9, 10 as a function of ε. The better performance of the B-MPRMA protocol is highlighted in the figures.

5 CONCLUSION

In this paper, the important issue of performance evaluation of a joint voice, data packet wireless communication system has been considered. A modified PRMA protocol suitable for applications in joint voice,data packet wireless networks has been proposed and analyzed. The MPRMA protocol has two permission probabilities for UTs in the *CON* state, i.e., p_v for the voice UT and p_d for data UT, being $p_d < p_v$. Each transmitted packet contains specification of the ID of the sending UT, the type of message (voice or data) and if a reservation is required. Voice communications are handled by the MPRMA in the same way as the standard PRMA protocol. A different management technique has been introduced for data communications in order to achieve a better performance. When a data UT successfully transmits a packet on an idle slot, the BS stores its ID in the access queue and the data UT enters the *WAIT* state. When an ID reaches the head of the access queue, the associated data UT (i.e., the data HUT) attains permission to transmit on each idle slot with probability p_a. More than one slot can be allocated to the HUT per frame. The case of ideal radio channel propagation conditions and non-ideal, non-stationary radio channel propagation conditions has been considered and analyzed. In particular, in the case of non-ideal, non-stationary channel propagation conditions a technique to break off the possibility of accessing the common radio channel by the data HUT has been proposed for enhancement system performance. A performance optimization for the parameter p_a has been carried out as outlined at the end of Section III. The simulation results clearly show that the proposed MPRMA protocol outperforms the standard PRMA protocol, proving moderate values of $\overline{x}$ as well as satisfying the P_{drop} constraint for voice packets under different radio channel propagation conditions.

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