OSSS with initial first transmission for medium access control in a WCDMA channel

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Abstract: The *initial first transmission* (IFT) technique is introduced in the OSSS medium access control protocol of [1] as a means to improve the throughput behaviour of non-delayed traffic. Contrary to what has been observed for the stabilisation of the slotted ALOHA protocol, the IFT technique is best suited for the OSSS protocol. The portion of non-delayed traffic remains higher than 90% for all levels of offered load less or equal to 1.0. This offers the potential for a high spectral efficiency in the CDMA channel, and finds applicability in a number of channel access interfaces, like WCDMA for UMTS.

1. Introduction

The OSSS (Overload Signal Spread Spectrum) protocol was first presented in [1]. It consists of a medium access control mechanism applicable to a WCDMA wireless channel, in which the base station broadcasts a congestion signal whenever the channel is likely to experience multiple access interference (MAI). This requires the channel to be divided into time slots of a certain duration t_s, at the beginning of which there is an access window time of duration t_{aw} where the mobile terminals schedule the start of their transmissions – see Fig. 1.

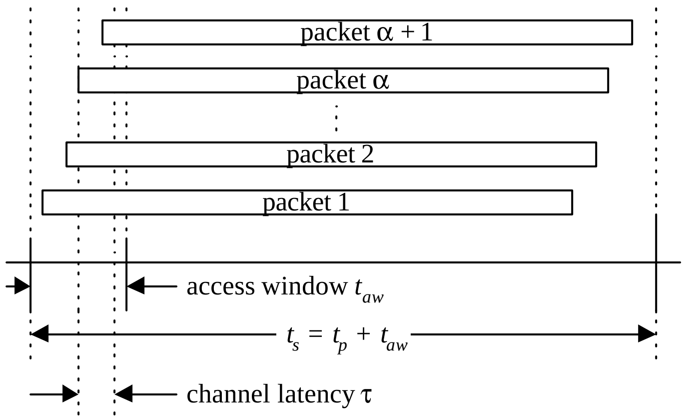

Fig. 1: A time slot in the OSSS protocol

At the start of such an access window, the base station listens to the channel for incoming transmissions, and when the channel capacity c is likely to be exceeded (at a given channel load threshold α, at time t'), the base station turns on a congestion signal that is broadcast throughout its coverage area. The mobile terminals, before attempting any transmission, listen to the channel and, if the congestion signal is sensed, defer their transmissions for a future time slot – see Fig. 2.

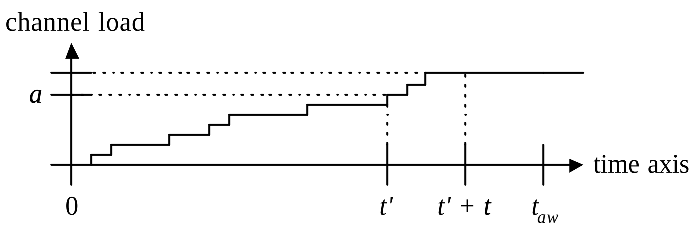

Fig. 2: The events during the access window

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A modified version of OSSS was presented recently in [2], where the negative effect of retransmissions following delayed or noisy packets was considered. In that work the OSSS protocol incorporated a preventive method to control the load in the system, in addition to the reactive control based on the congestion signal. The mobile terminals, before attempting any transmission, listen to the channel not only for the congestion signal, but also for a transmission probability parameter (p - which is also radiated by the base station). They perform a Bernoulli experiment in order to transmit their packets or defer them for a future time slot. The work in [2] presented a simple methodology to update the p parameter from time slot to time slot – see Eq. 1 below, and showed that the overall efficiency of OSSS remained higher than that of slotted ALOHA, when the two protocols were compared, both using the *deferred first transmission* (DFT) technique. The maximum level of offered load for bounded levels of access delay was found to be 0.75 and 0.55 for OSSS and slotted ALOHA respectively.

$$\begin{aligned} &a)\text{ underloaded time slot:} \qquad p(k+1) = \frac{c}{MeasuredLoad(k)}\,p(k) \\ &b)\text{ overloaded time slot:} \qquad p(k+1) = \frac{t'(k)}{t_{aw}}\,p(k) \end{aligned} \tag{1}$$

The IFT and DFT techniques were compared in [3] for the stabilisation of the slotted ALOHA protocol. While using IFT the transmission of newly arriving packets is attempted immediately, in the next available time slot following their arrival, but with DFT, the newly arriving packets immediately go into the backlogged state. That is, their transmission is attempted only after a random number of time slots, receiving the same treatment as the packets that have been backlogged for some previous reason. The work of [3] showed the different scenarios under which the IFT and DFT techniques were applicable to the slotted ALOHA protocol, and found slight advantages in the DFT case. For that reason, subsequent work on the stabilisation of the slotted ALOHA protocol have continued to use this technique (see for example [4]), and so the authors of this paper did the same in [2].

Following the work in [2], we tested the OSSS mechanism but now using the IFT technique, as a means of giving priority to the newly arriving traffic, and taking advantage of the fact that priorities can be easily applied in the OSSS protocol. We expect that by so doing, the percentage of traffic with no access delay would increase, at the expense of further delay to the already delayed traffic.

In the following section we describe in detail our proposed mechanism. Then, the simulation scenario is described in section 3, followed by the results and conclusions in sections 4 and 5 respectively.

2. OSSS with initial first transmission

This mechanism is similar to the one presented in [2]. That is, the OSSS protocol working as described in the introductory section of this paper, with the additional use of the transmission probability parameter as a preventive control mechanism of the load in the channel, and the estimation of the backlogged load from time slot to time slot. The key difference is that the newly generated traffic is given priority over the backlogged load. To do so we have split the access window into two portions. Newly arriving packets must schedule their transmission during the first portion, and furthermore, they are not subject to the preventive congestion control mechanism, hence their p parameter equals 1.0. Then the backlogged load is scheduled for transmission during the second portion of the access window, and its p parameter is estimated by using Eq. 1 - see Fig. 3.

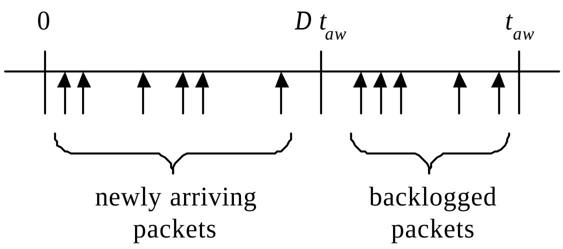


Fig. 3: Scheduling of the packets along the access window

In Fig. 3 the Δ parameter represents the proportion of the access window assigned to new arrivals. Of course, the monitoring of the load in the channel continues to be done at the base station, and the congestion signal is broadcast whenever the threshold level of congestion is reached. This means that the backlogged packets get a higher possibility of being deferred, for being scheduled when the congestion signal is more likely to be turned on.

3. Simulation scenario

We tested the aforementioned mechanism, essentially using the same network model as in [2] for comparison purposes. In that work, a one-cell wireless communication system was modelled, with the assumption that the mobile terminals are physically located at the same distance from the base station, experiencing equal channel conditions (latency, power reception, etc.). This implies that the system is assumed to be operating under perfect power control.

The parameter values used in the experiment are listed below in table I.

Channel capacity (c)	16 packets
Time slot duration (t_s)	10 ms
Latency to packet time ratio ($t\ / t_p$)	0.001
Packet length	424 bits
Spreading factor (N)	64
Proportion of the access window assigned to new arrivals (Δ)	0.5

Table I: Parameter values used during the experiments

As in [2], the t_{aw} / t ratio is considered as a parameter that refers to a low, medium or high latency in the channel. Thus we let t_{aw} / t = 50, 10 and 5 respectively.

The offered load in the system is produced by a number of on/off traffic sources, which on the average produce a mean value λ that varies between 0 and 1.0 in this simulation.

We are modelling a system in which retransmissions are only attempted provided a maximum number of retransmission attempts has not been reached. When this happens, the packets are considered to be lost. This maximum number was chosen as 100 in our simulations.

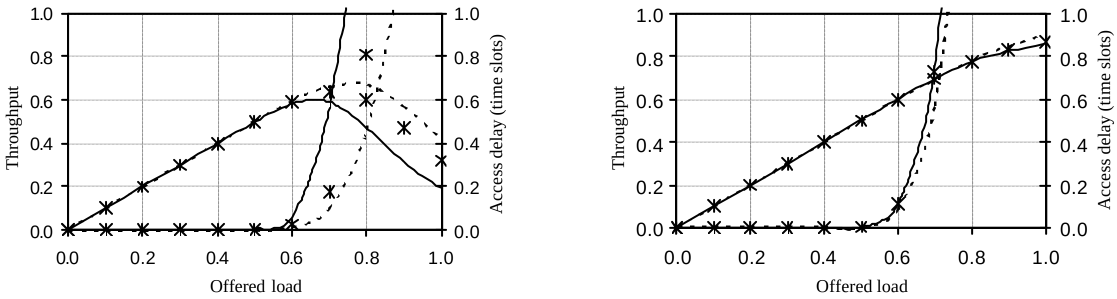
Finally, the congestion signal is only turned on after the maximum level of load is reached in the system, that is $c = a$.

4. Results

Results for the previously described simulation are presented in Fig. 4. We compare the throughput and access delay metrics for both, the OSSS approach of [2] (from now on referred as OSSS + DFT), and the new approach presented here (i.e. OSSS + IFT). Note that throughput means the amount of carried load that is received with no access delay.

There are three main findings from these results. The first one is that the new approach is almost independent of the latency in the channel. The three lines showing the low, medium and high latency cases follow almost the same behaviour, either on the throughput, or the access delay metric. This means that the protocol could be equally applied to different scenarios (i.e. from pico to macrocells).

The second finding, and most important, is regarding the amount of traffic that receives no access delay. While in the OSSS + DFT case the maximum is around 0.67, the same number is 0.9 for the OSSS + IFT case. This means that, despite the level of offered load, the MAC procedure is able to provide good access delay metrics, allowing excursions of the offered load up to the top capacity of the channel. This can be compared, not only to OSSS itself, but to slotted ALOHA as well, recalling that the maximum level of offered load is 0.52 (considering capture) for a stable operation of the MAC function - see either [2] or [5].



$- - : t_{aw}/t = 5$ $\quad$ $*** : t_{aw}/t = 10$ $\quad$ $--- : t_{aw}/t = 50$

Fig. 4: Results for the OSSS protocol with DFT (left) and IFT (right).

Finally, we see that the access delay metrics exhibit an unstable behaviour comparable to the worst latency case of OSSS + DFT. Although this might be seen as a negative effect of the new approach, in fact it is not. It only shows that, as the newly generated traffic is given precedence over the backlogged packets, the latest will observe a worst delay behaviour. The OSSS + IFT approach provides a worst level of access delay to the delayed traffic, but the amount of this traffic is kept to a minimum.

5. Conclusions

In this work new mechanisms that enhance the behaviour of the basic OSSS concept of [1] have been realised. The suggested approach deals with the contention between newly generated and backlogged traffic. This adds to other general mechanisms that deal with the same problem, e.g. the retransmission exponential backoff strategy.

We have obtained a highly efficient MAC mechanism, where utilisation of the channel is kept at a maximum. Despite the level of offered load, the portion of traffic that receives no access delay always remains higher than 85% (90% in the low latency case). This would be important for an all voice traffic system, where a high number of connections could be accepted (as for the high levels of offered load allowed) with the delay problem being converted into a lost traffic problem.

As a further development of this mechanism, we are reviewing the effect of changing the proportion of the access window assigned for new arrivals, and seeing if a dynamic strategy, based on the level of load in the system, can be obtained for the Δ parameter. We are looking also at the applicability of these concepts to the WCDMA access interface in UMTS.

References

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