INTEGRATION OF RANDOM ACCESS AND TDMA TECHNIQUES IN A MULTIBEAM SATELLITE SYSTEM

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ABSTRACT

In this paper,the utilization of random access techniques in multiple spot-beam switching satellites is described.The uplinks employ a slotted ALOHA protocol, while the downlinks use a TDMA structure. The number of satellite transponders is equal to the number of spot beams.The performance of this system is derived both through a theoretical approach and computer simulations.

1. INTRODUCTION

Satellites using multiple-beam antennas and on-board switching are very attractive since a frequency band can be reused in various spot beams [1] , [2] , [3] [4] . In Satellite-Switched Time-Division Multiple Access (SS/TDMA), a satellite has number of spot-beam antennas and a switching matrix which establishes the connections between the uplinks and downlinks according to the traffic demand.

The evaluation of the performance of an SS/TDMA satellite and, in particolar, of the algorithm which determines the slot assignment is largely studied in literature [2] ÷ [4]. Moreover, the TDMA structure is generally suitable when the traffic has a continuous flow and,therefore, the earth stations concetrate the traffic from many other stations.

When the traffic has a bursty behaviour the TDMA structure does not permit to achieve a high performance and efficiency.In these cases,it is convenient to use random access techniques such as ALOHA, so that each station can directly access the satellite. The utilization of ALOHA techniques in multibeam packet satellites was studied by Chang. This author has proved that a better performance can be obtained with respect to TDMA if suitable protocols are used [5]. In the scheme proposed by Chang, the transponders are connected to the different spot beams according to a switching strategy which varies each time with the traffic demand.

In this paper, a new method is described for the integration of ALOHA random access schemes and TDMA techniques in a packet satellite network.The uplink channels operate according to the slotted ALOHA protocol,while the downlink channels use a TDMA structure. The satellite transponders are permanently connected to a fixed spot beam and,therefore, the on-board swithching procedure is quite simple.

The toral performance of this system is derived through computer simulations.In particular, transmission delay and on-board system utilization are evaluated as a function of the traffic intensity.The occupancy of the on-board buffers is evaluated through an analytical approach,utilizing the queuing theory.

2. A MULTIBEAM SATELLITE SYSTEM USING RANDOM ACCESS TECHNIQUES.

The general structure of the multibeam satellite is shown in Fig.1.In this scheme N different spot-beam antennas cover spatially different areas and permit a complete interconnection between the earth stations.

A number of geographically dispersed users are joined into N groups,each comprised of N_s elements,which share a common transmission channel provided by a satellite spot beam.A slotted ALOHA protocol is used in uplink channels; successful packets are demodulated and buffered according to the destination zone.If they cannot receive immediate service,they are stored in the buffer assigned to the destination zone and queued until a slot in the TDMA downlink channel is available.

TDMA service provided by each transpon

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der uses a FIFO strategy to fill the slots of the frame (if packets are present in the buffer).

The TDMA periodic frame is divided into two parts; the first is compromised of N_S informative slots, each of a packet duration (1024 bits); the second part presents N_S mini-slots (of 120 bits each), devoted to sending positive acknowledgments back to those earth stations of the beam zone that sent successful packets on-board the satellite. The mini-slots are organized in a fixed assignement TDMA. The earth stations under a coverage area receive all the packets of their common zone : by inspecting the packet header at each terminal it is possible to determine the particular station the packet is destined to; packet addressed to other terminals are ignored.

In the system described in this paper, the number of transponders is assumed equal to the number N of spot beams; in this way a transponder is permanently devoted to a particular spot-beam. On the contrary, Chang considers a number M of transponders lower than N; moreover, this solution requires the application of a certain switching strategy and, therefore a more complex implementation. The solution considered in this paper semplifies the on-board equipment of the satellite.

3. EVALUATION OF THE MEAN ON-BOARD QUEUE LENGTH

In this section, some theoretical formulas are developed for the evaluation of the mean on-board queue length in each buffer, by utilizing the M/G/1 queue results [6] . The probability distribution of the service time x, the mean service time $\bar{x}$ and its variance σ_x^2 have been analized .

In the evaluation of the service time of the protocol, it is necessary to take into account the presence of the rest periods at the output of the buffers for non-informative transmissions (synchronization and mini-slots in Fig. 2). Owing to the particular slot available for downlinks and the system state (idle or busy) the first element in the buffer queue gets a differerent service time.

Through some analytical computations it can be shown that the mean service time is :

$$\bar{x} = \frac{5\tau}{3+2\lambda\tau} \tag{1}$$

τ being the downlink time slot and λ the message rate for each station. The second moment of the service time distribution is given by :

$$\sigma_x^2 = \frac{\tau^2}{27} \left[1+122\,\lambda\,\bar{x} \right] \tag{2}$$

Since we joined N_S stations into one channel group, the traffic intensity ρ at the input of each buffer is given by:

$$\rho = N_S \lambda \bar{x} \tag{3}$$

By using these formulas, the following equation can be evaluated [6] :

$$\left\{ \begin{array}{l} E(n) = \rho + \rho^2 \dfrac{(1+\sigma_x^2/\bar{x}^2)}{2\,(1-\rho)} \\ T_i = 1/N_S\lambda \\ T_b = \bar{x}/(1-\rho) \end{array} \right. \tag{4}$$

where E(n) is the mean queue length in each buffer, T_i the idle period duration and T_b the busy period duration.

4. RESULTS

In this section, some results are shown for the performance of the system previously described. It is tha each station generates traffic according to a Poisson distribution probability with parameter . The packets are 1024 bits long. The uplink rate V_S may be different from V_D which is used in the downlinks. Extensive simulations were performed for different values of V_S , V_D and λ. The number N_S of stations for each zone is fixed to 16.

The overlapped packets are retrasmitted with a uniform probability on K_R time slots, according to a slotted ALOHA protocol.

Fig. 3 depicts the parameter E(n) in the case of V_S = 32768 b/s, V_D = 16384 b/s K_R = 10 as a function of the mean interarrival time $E_t = 1/\lambda$. The same parameter is shown in Fig. 4, for the case $V_S = V_D$ = 262144 b/s, K_R = 10 . The dotted lines represent the results obtained througt the queueing theory given in Sect. 3 .

Fig.5 depicts the mean idle duration T_i for the two cases shown in Figs.3 and 4.

In Fig.6 the mean transmission delay D is shown for three different cases.The delay D is the sum of the ALOHA delay,on-board system time and delay trip equal to 0.25 se.

Fig.7 depicts the transponder utilization U_t for the three cases previously considered.The utilization U_t takes into account both the informative traffice and the service traffic,which in our case is about 11% of the total traffic.

From these results it can be noted that the transmission delay is close to a minimum value when the transmission rate is high.Moreover,the transponder utilization decreases with the increase of the transmission rate.

5. CONCLUSIONS

In this paper,the performance of a multibeam satellite using a radom access technique in uplinks and a TDMA structure in downlinks is aanalyzed.Through some computer simulations,the main parameters of this system, such as the transmission delay and transponder utilization,were evaluated.

The system is studied for the connection of several bursty traffic useres, spread over a wide area.This system presents a simple structure,full interconnettivity and a good transmission performance.

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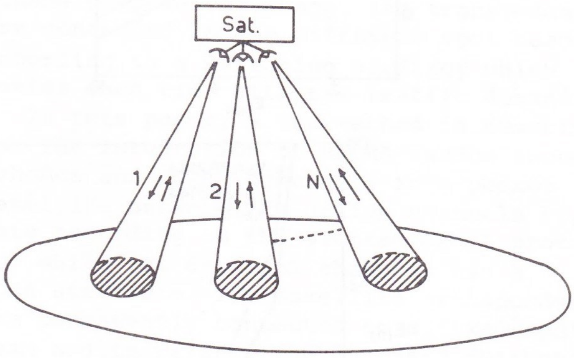

Fig.1 -

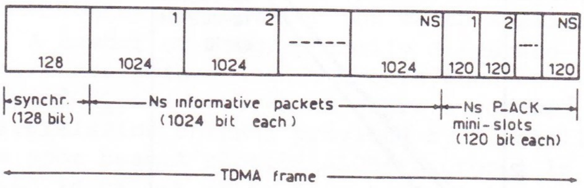

Fig. 2 -

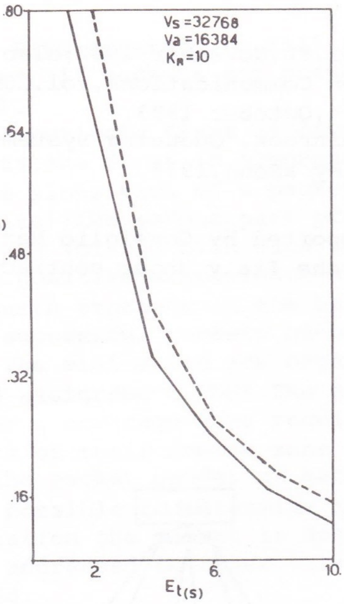

Fig.3

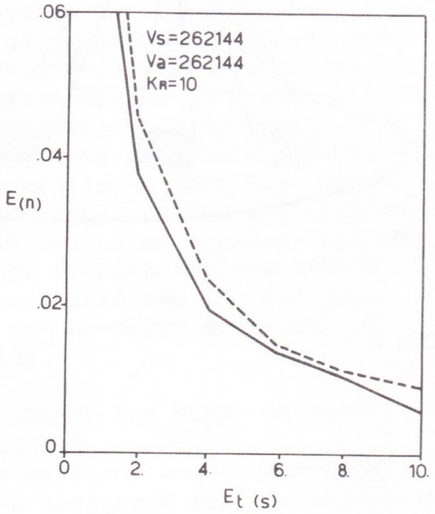

Fig.4

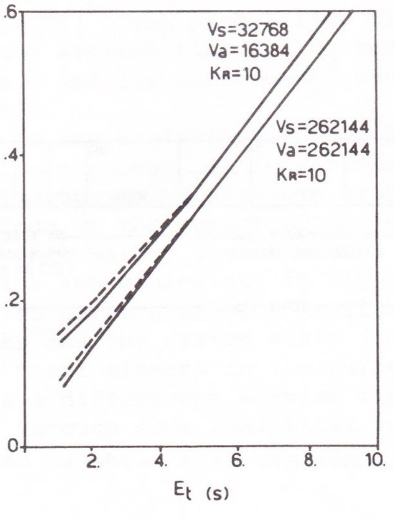

Fig.5

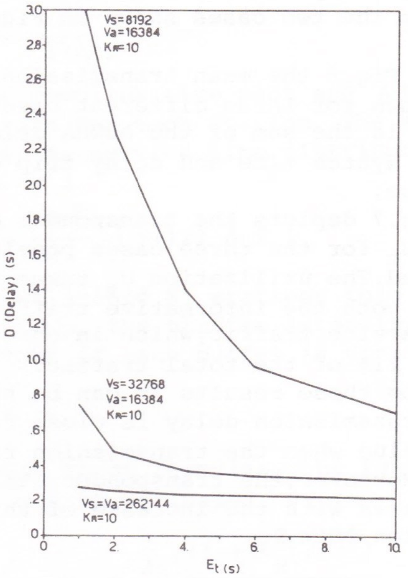

Fig.6

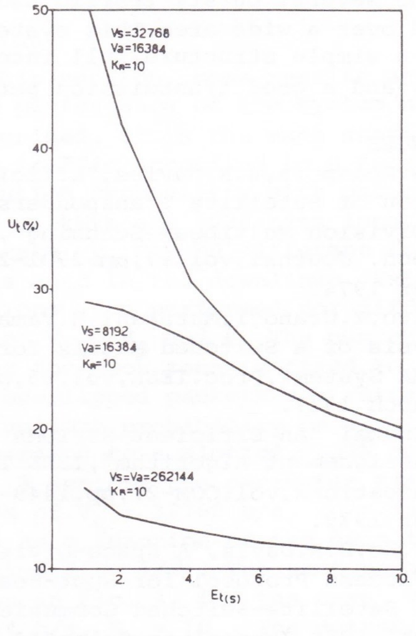

Fig.7