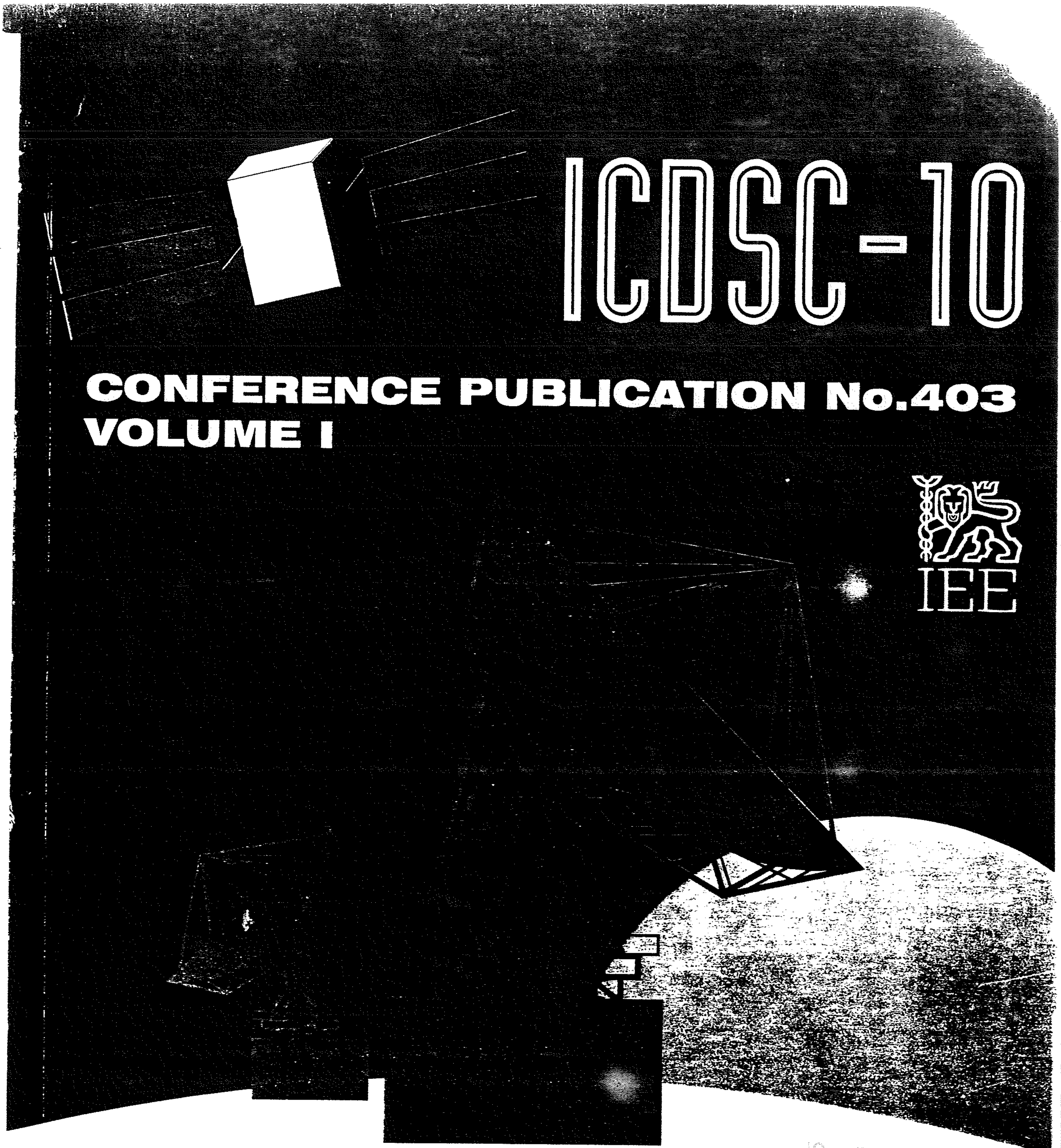

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THE PERFORMANCE OF THE FODA/IBEA SATELLITE ACCESS SCHEME MEASURED ON THE ITALSAT SATELLITE

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ABSTRACT

This paper briefly describes the FODA/IBEA satellite access scheme and presents part of the experimental results of two studies carried out both on real-time and non real-time traffic crossing a satellite network accessed with the FODA/IBEA access scheme. The jitter affecting the real time data is studied and a solution indicated, while for non real-time data the performance of the capacity assignment algorithm is shown. Tests were carried on the ITALSAT satellite, by using the Multi-application Traffic Generator system [Celandroni et al (2)] to generate a traffic load according to the characteristics required.

FODA/IBEA

The FODA/IBEA(*) access scheme is designed to share in TDMA a multi-megabit-per-second satellite channel among many earth stations attached to fast LANs, maintaining the quality of the service required by the various applications even in faded conditions [Celandroni et al (1)].
A master station is responsible for system synchronisation and capacity allocation on request from the traffic stations. These tasks are accomplished by sending a reference burst. Data generated by both real-time (stream) and non-real-time (datagram) applications are simultaneously transmitted. The bit and the coding rates of the single transmitted packet are adapted to the variation in the channel quality due to bad weather conditions (fade countermeasure technique). This is possible thanks to a prototype of a variable-burst rate modem [GEC-Marconi (8)], which can dynamically change the data bit rate according to bit rate values selected by the FODA/IBEA system on the basis of the fade level of both the sending and receiving stations. The data bit rates are changed on a sub-burst basis, i.e. only the faded transmissions are made redunded. The possible range of bit rate values is from 1 to 8 Mbit/s. Before reducing the data bit rate, the system tries to counter the detected fade level by increasing the data coding rate. If this is not sufficient to guarantee the BER requested by the sending application, the data bit rate is reduced too.

(*) Fifo Ordered Demand Assignment / Information Bit Energy Adapter

When both stream and datagram data have to be simultaneously transmitted on the same channel and the characteristics of both the types of traffic maintained, there are two main problems: a) the inter-arrival time of the stream packets must be maintained constant, therefore a solution has to be found for the time jitter that generally affects the data; b) the channel assignment algorithm of the datagram data must be as fair as possible, avoiding the congestion due to an abnormal increase in traffic.
A stream application receives an assignment for a transmission window of a size sufficient for the requested capacity. The assignment is thus guaranteed, with the correct frequency, even in faded conditions. The assignment for the datagram data is not guaranteed in each frame and the assigned capacity is only a percentage of the one requested. To save channel overheads, the stream data and the datagram data sent by a station must be transmitted in the same transmission window. This is only possible if the transmission characteristics of the two types of data are compatible with the requirements of the fade countermeasure technique. Whether the transmission window is the same or two different windows are allocated, the variability of the datagram assignment affects the data jitter. In fact, when a stream of packets crosses the satellite network, each packet may experience a different delay which induces a jitter [Celandroni (7)] on the packet arrival times. While this jitter is almost irrelevant for non-real time applications, it may cause problems for the real-time traffic because the regularity of the packet generation time intervals is no longer respected. On the other hand, the variability in the datagram assignment is a consequence of the assignment algorithm used. The efficiency of this algorithm has proved in Celandroni et al (4), and the results are outlined below.

We used the ITALSAT satellite to test the FODA/IBEA system. A first set of tests were made among four stations by using an ad-hoc developed Multi-application Traffic Generator (MTG) able to load the system with any type and any amount of traffic, according to the designer's specifications [Celandroni et al (2)]. The system was then tested in a real environment, connecting different LANs situated in Pisa and in Florence [Celandroni et al (9)]. The experimental results presented in this paper were obtained by using the MTG system to load the satellite channel. Both Poissonian and fixed rate generators were used. The delay of the datagram data packets was studied in stationary and in transient cases. In the first case, the runs were performed over an interval of 30 s and data were collected after a

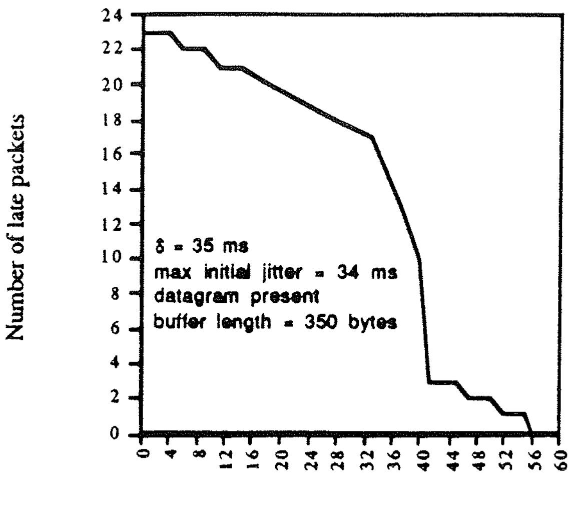

Fig. 4. Late packets versus delay offset: δ = 35 ms; datagram present on the channel; initial jitter span = 34 ms.

THE EFFICIENCY OF THE ASSIGNMENT ALGORITHM FOR NON-REAL TIME DATA

A traffic station sends a request for a datagram transmission window that is proportional to the traffic coming into the station (i) plus the backlog (q), i.e. the volume of data already waiting for transmission to the satellite.
We have:

$$r = q + H\ i \qquad (5)$$

where H is a temporal constant of proportionality.
We chose a value of 0.4 s for the H parameter after getting simulation results by loading the channel with Poisson generators of datagram traffic for 10 stations.
Datagram requests must be issued as frequently as possible, to update the master station on the latest changes in the traffic situation. The requests are piggy-backed with the data, when an assignment already exists for the requesting station; otherwise they are sent in a control window whose assignment is guaranteed with a minimum frequency.
The requests are organised by the master into a circular queue, and cyclically scanned to compute the amount of time of each assignment. New datagram requests are put at the current beginning of the list so that they will be scanned first. This reduces the delay time between the first request and the assignment after a period of no transmissions. Any further datagram request received from the same station (besides the first one) is considered to be an update and it replaces the previous value. The length of the assigned transmission window (a) is proportional to the request in a range of values between a minimum (T_{min}) and a maximum (T_{max}) thresholds. We have:

$$T_{min} \leq a = f\ r \leq T_{max} \qquad (6)$$

where f is the coefficient of proportionality in the assignment. In the current implementation f is equal to the number of active stations N divided by 100, with 5% as minimum and 50% as maximum. T_{min} was introduced for efficiency purposes. It avoids allocations that are too small when the transmission overheads -due to preambles and headers- are too big in comparison with the information data. T_{max} prevents an over loaded station from removing too much capacity from the other stations.

After each assignment, the datagram request is decreased by the assignment itself and the next request is analysed, if space is still available in the frame. The first assignment that does not fit entirely the current frame will be analysed again as the first assignment in the next frame where the rest of the computed amount will finally be assigned. All the space up to the end of the frame (if insufficient for a minimum assignment) is given as an over-assignment to the last processed station.
If space is still available in the frame after an entire assignment cycle (i.e. the time between two consecutive assignments to the same station), the residual capacity C_r is shared among all the N active stations, even those stations which had no datagram assignment in that frame. The over-assigned capacity p results as a pre-assignment, and it is used by the station to absorb all or part of an abrupt traffic increment. Generally speaking, the system behaves like a sort of fixed TDMA (F-TDMA), called *pre-assignment mode*. The more this is accentuated the less the system is loaded. It migrates versus the pure FODA/IBEA assignment scheme when the channel load increases beyond a certain limit. The pre-assignment limit may be varied up to the entire channel capacity reserved for datagram, C_d, by varying the coefficient f.
The analysis carried out in Celandroni (7) studies the system behaviour during a transient of a load in one station, when all the other stations are in a steady state condition with a null backlog. The condition for the validity of the analysis is that the amplitude of the traffic step at the station considered is small enough to make negligible the relative increase in the assignment cycle. Under the above condition the assignment can be considered to be proportional to the request during the whole transient.
Some results of the analysis, reported in Fig. 5, show the utility of working in pre-assignment mode. The figure shows a comparison between the end-to-end delay as a function of the time during a transient, when the system is working in pre-assignment mode or not, respectively.

Two conditions are analysed: a) before the step of traffic, the station has a constant load of amplitude c equal to the amplitude of the traffic step i; b) before the step of traffic, the station has no previous load (case $c = 0$). The gain of the non pre-assignment mode in the case $c = i$ would appear to be lower than the gain in pre-assignment mode when $c = 0$. Celandroni (7) shows that this fact is more evident with lower loading conditions in the system.

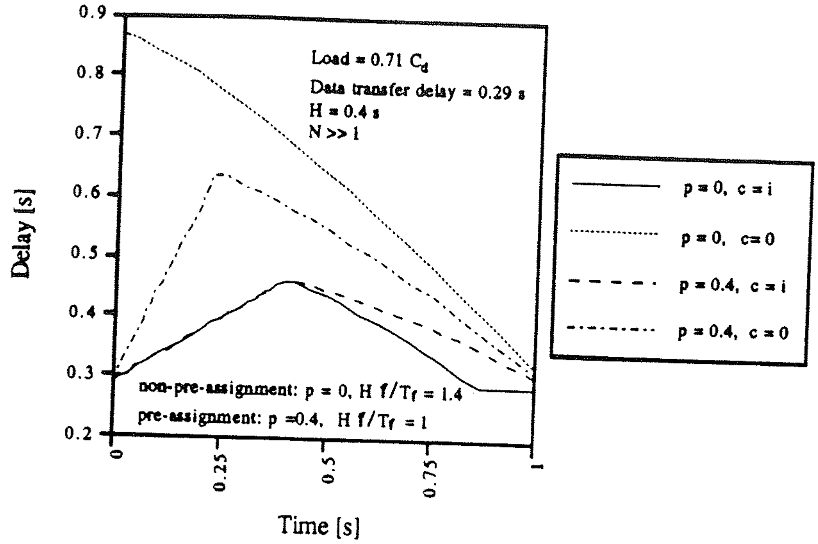

Fig. 5. End-to-end delay versus time during a transient due to a step of traffic at one station. A high number of stations is considered. Pre-assignment and non pre-assignment cases for pre-loaded and for non pre-loaded stations are reported.

EXPERIMENTAL RESULTS OF THE DATAGRAM ASSIGNMENT ALGORITHM

The net satellite round trip delay for the ITALSAT satellite at the Pisa station is 253 ms. For implementation reasons data is sent at an average of one frame later than its arrival at the TDMA controller. Including some processing overheads, the satellite round trip time is around 280 ms. The end-to-end delay shown in all the diagrams includes the satellite round-trip-time and the queuing time that data must wait for before being transmitted.

In all the tests data was sent uncoded, at 8 Mbit/s; the reference burst was sent 1/2 coded at 2 Mbit/s, and the control slots were assigned at 1 Mbit/s. Moreover, in all the figures the indicated traffic loads are information data loads, and no overheads due to preambles, headers, signalling bursts and guard times are included. Loads are expressed as a fraction of the total channel capacity (8,192 Kbit/s). The length of the packets is between 512 and 1024 bytes for the stationary cases, and 1024 bytes for all the transient cases.

Only the most significant diagrams are reported here, while the complete results set can be found in Celandroni et al (7).

Figures 6 and 7 refer to the stationary case. They show the transmission end-to-end delay experienced by each of the four active stations as a function of the traffic handled by the station, measured as a fraction of the channel capacity. The five dashed lines show different runs with different channel loading conditions, while the continuous lines show the behaviour of each individual station. The transmitted traffic was not distributed evenly among the stations so that behaviour could be compared among different loaded stations in different channel loading conditions.

The diagrams show the steady state behaviour of the system when the traffic sent by each station is fixed rate or Poisson, respectively. The delay values are averaged over a period of 30 s, starting 15 s after the beginning of the transmission to exclude transient effects.

The transient case was only tested with fixed rate traffic. A traffic step lasting about 6 s fed the station number 1 in all the three cases presented. These cases differ in terms of the load levels before the traffic step, and in the amplitude of the step itself.

While in the run in Fig. 8 the traffic step pushes the system into saturation, in the runs in Figs. 9 and 10 this traffic step does not saturate the system which is able to absorb, after a few seconds, the effect due to the increase in traffic. Before the traffic step, the system is scarcely loaded (64% in Figs. 8 and 9, 48% in Fig. 10). Each station receives the over allocation (pre-assignment) able to absorb, without any visible changes, any traffic step lower or equal to the over assigned capacity. Obviously, this case is not represented. In the other cases, after the beginning of the traffic step there is a rise in the queue length of the packets to send and, consequently, in the end-to-end delay, due to the system response.

The over assigned capacity is immediately used by station 1 which absorbs part of the traffic step. After a delay of more than two round trips, the bigger allocation is received from the master station and the maximum possible allocation is assigned to the station 1. This is sufficient to curb the queue growing and the delay. After that, in the case shown in Fig. 8, all the other stations see their queues growing and ask for more allocation.

This causes a smaller capacity assignment to station 1, thus causing a new rise in the queue up to the end of the traffic step. The capacity assigned to station 1 is equal to the maximum threshold but still insufficient to entirely compensate for the traffic step. This is why station 1 goes into saturation, thus affecting the other three stations for the whole traffic step duration.

In the case shown in Fig. 9, the traffic step of station 1 is not so consistent as to saturate the system. Thus, the bigger allocation to station 1 temporarily involves the other stations (only for the time required by station 1 to absorb the queue caused by the system response delay) which are affected by a short increase in their end-to-end delay. The station 1 transient also fades rather quickly. In the case in Fig. 10, stations 2, 3 and 4 have no knowledge of the traffic step in station 1. The capacity assigned to station 1 is, in any case, limited by the maximum threshold and is lower than the one requested. This is why the delay decreases more slowly than in the case in Fig. 9.

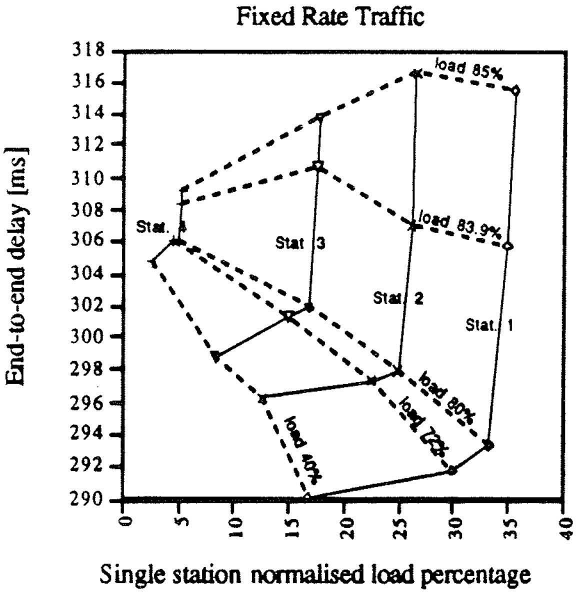

Fig. 6. Single station mean delay versus station load for fixed rate traffic.

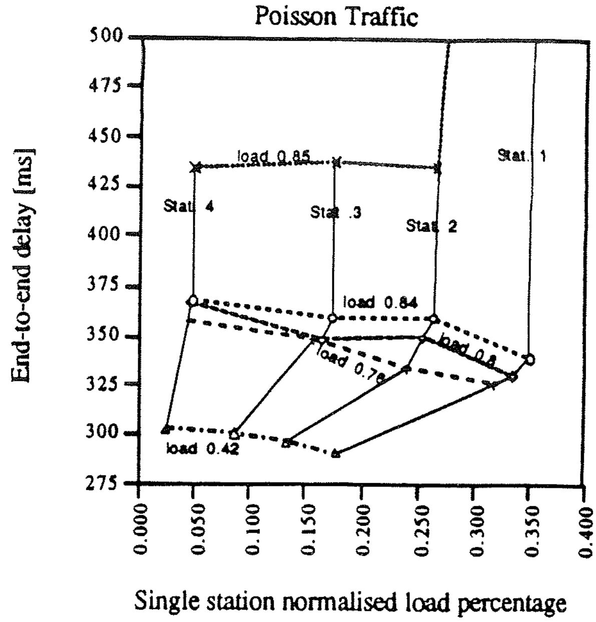

Fig. 7. Single station mean delay versus station load for Poisson traffic.

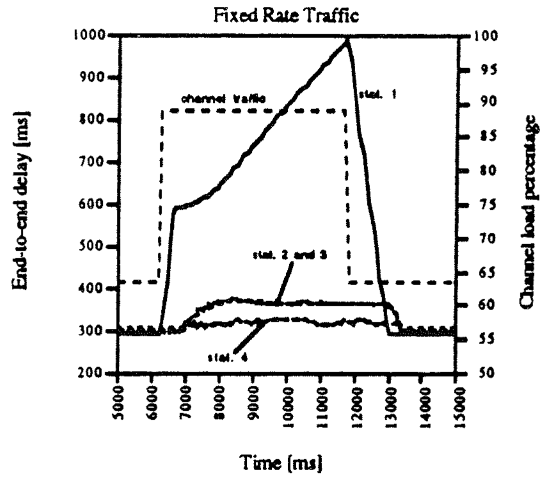

Fig. 8. Single station delay versus time when station 1 has a traffic step of 25% in the channel capacity (step duration = 5.5 s).

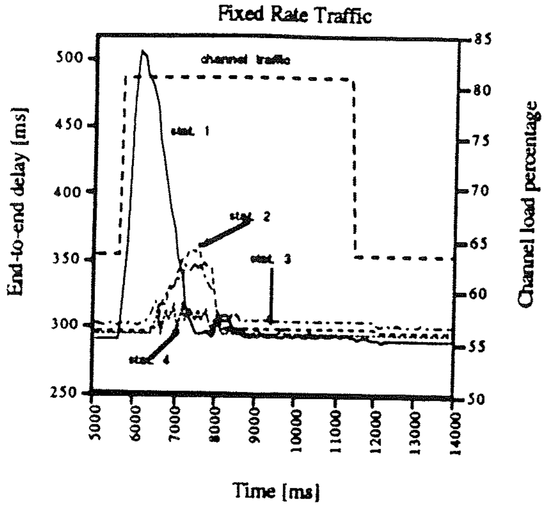

Fig. 9. Single station delay versus time when station 1 has a traffic step of 17% of the channel capacity (step duration = 5.5 s)

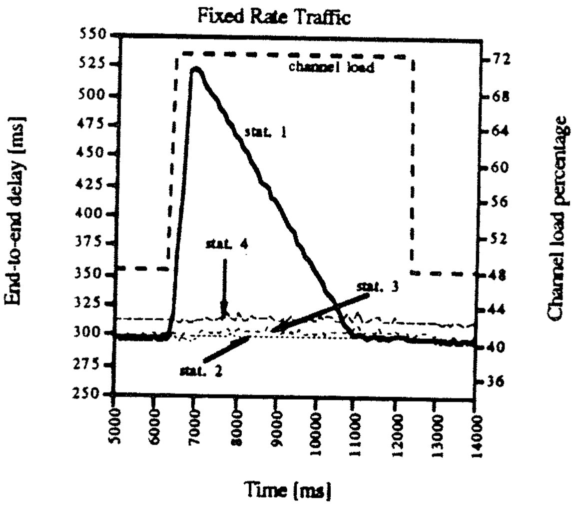

Fig. 10. Single station delay versus time when station 1 has a traffic step of 24% of the channel capacity (step duration = 5.5 s)

CONCLUSIONS

We have presented an overview of the performance of the FODA/IBEA access scheme, measured on the ITALSAT satellite. The jitter introduced by the FODA/IBEA system on the arrival times of packets generated by real-time applications can be removed by adopting the leaky bucket solution, even when the data enters the satellite network already affected by an initial jitter. Setting the size of the parameters according to the worst case may penalise system performance by increasing the end-to-end delay bejond an acceptable level. This may also occur with measured jitter distributions when the initial jitter span is very wide. In these cases the jitter distribution may in fact have very long tails, which give a negligible contribution to the cumulative distribution function. In these cases a sub-optimal sizing of the delay offset and of the buffer may be wise. As far as the datagram traffic is concerned, the efficacy of our assignment algorithm has been presented. The stationary cases show a limited average end-to-end delay in the data transferred by the satellite network, even in heavy loading conditions. The spread of the delay values is acceptable even when the system is loaded with Poissonian traffic generators. In the transient analysis, the important effect of the maximum allocation threshold is outlined. It shows how low the perturbation affecting the other stations is when a step of traffic of an amplitude prohibitive with respect to the above system loading conditions is applied to a station.

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