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DRIFS-TDMA: A PROPOSAL FOR A SATELLITE ACCESS DISTRIBUTED-CONTROL ALGORITHM FOR MULTIMEDIA TRAFFIC IN A FADED ENVIRONMENT

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SUMMARY

Most demand assignment time division multiple access (TDMA) satellite access protocols use centralized-control access schemes, rather than distributed ones, because their simplicity and robustness usually compensates for the longer allocation delay. Starting from the fifo ordered demand assignment/information bit energy adapter (FODA/IBEA) centralized-control protocol, we studied two distributed-control protocols, named distributed allocation with request in fixed slots (DRIFS) and faded environments effective distributed engineering redundant signalling (FEEDERS) respectively, for accessing a geostationary satellite channel. Multimedia traffic and faded environments were considered in the study of both access schemes. This paper presents the DRIFS proposal, together with the recovery procedures from critical events, the handling of which is central to the discussion of a distributed satellite access protocol. Probabilities of such events are also estimated. © 1997 John Wiley & Sons, Ltd.

KEY WORDS: satellite access scheme; distributed control; capacity allocation on demand; fading; multimedia traffic

1. INTRODUCTION

Allocation on demand protocols are based on the assumption that each station in the network receives a share of the global network capacity, depending on its needs. For time division multiple access (TDMA) satellite access, the share of each station corresponds to a time slice in the time frame. Some sort of control is needed to take into account the requests and to assign each station its transmission time. If a master station listens to all the requests and then computes and broadcasts the resulting allocations, the system has centralized control. If all the stations independently listen to every other station request and then compute the transmission time positions and lengths using a common algorithm, the system has distributed control.

Centralized control is more robust, because every station only needs to listen to the master in order to know when to transmit, whereas distributed control entails each station listening to all the requests. In a faded environment, where some stations may receive a low power level because of bad atmospheric conditions, a station may not be able to correctly receive the faded stations' requests. In this case, the burst time plan (BTP), i.e. the layout of the transmission allocations, cannot be computed, and the station cannot transmit without risking a collision, with a consequent loss of throughput. Some method of recovery from this and other possible scenarios must be devised to make the system reliable. This explains why distributed control protocols are more complex than centralized ones, when a comparable robustness level has to be achieved. However, even if robustness needs are satisfied, distributed control overheads are usually higher than those needed by centralized control. On the other hand, a distributed scheme is advantageous from a delay point of view, because each station can compute the BTP only one round trip time (RTT) after it has made a request for bandwidth, i.e. about a quarter of second for geostationary satellites.

In this paper we describe the distributed allocation with request in fixed slots (DRIFS) scheduling algorithm, together with the relevant recovery procedures. The access scheme presented allows the simultaneous transmission of both connection-oriented real-time data (stream data) and connectionless data (bursty data), i.e. it supports multimedia traffic. Because different names are adopted to define concepts that are very similar in purpose, in the text we use the ATM Forum TM4.0 ('ATM Service Category') classification for the traffic categories, while in the footnotes the corresponding ITU-T I.371 ('ATM Transfer Capability') classification is given. The traffic deriving from constant bit rate (CBR)* and variable bit rate (VBR)† applications, such as video-conferencing, interactive audio, audio/video distribution, audio/video retrieval, native ATM voice, etc., belongs to the stream type

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*Deterministic bit rate (DBR).
†Statistical bit rate (SBR).

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of traffic, together with data generated by applications that have the ability to reduce or increase their information rate if the network requires them to do so (available bit rate (ABR) applications)‡.

Applications for text/data/image transfer, messaging, distribution, retrieval and remote terminals, typically generate traffic belonging to the unspecified bit rate (UBR)§ service category, generally called bursty data.

Rain is a dominant factor in satellite communication at frequencies above 10 GHz. A transmission signal fading due to bad atmospheric conditions is countered in DRIFS by making the data redundant through the use of a variable coding and a variable symbol rate modem, as in the fifo ordered demand assignment/information bit energy adapter (FODA/IBEA) system.[1–3] The redundancy of the data transmitted by a station in its data bursts, depends on the fade levels of both the sending station up-link and the receiving station down-link. The DRIFS system stability is studied under faded signal conditions, and the relevant recovery procedures are reported.

2. SOME ASSUMPTIONS

Before describing the DRIFS access scheme, let us make some assumptions and give some definitions.

- The frame is the fundamental time unit used for the allocation scheme. Each station transmits at most one allocation request and one data burst per frame. All data transmitted (control or user data) are preceded by a unique word, specific for the type of data. The frame duration time is T_f.
- The allocation requests are broadcast to all stations in the system and must be correctly received by all stations to create a correct BTP.
- Each station repeats its stream and bursty requests at each occurrence of its control slot.

Even if the access scheme is theoretically independent of the TDMA controller hardware used, the possible availability of a preambleless modem would have a heavy impact on the choices of some designs. Below, we refer to a modem with an acquisition preamble length that is not negligible as far as the channel overhead is concerned. We have four TDMA controllers and modems available that can support different coding rates (1/2, 2/3, 4/5 and uncoded), symbol rates (512, 1024, 2048 and 4096 Kbaud using either BPSK or QPSK modulation schemes), and output power levels ($-20 \div 0$ dBm), all variables at the sub-burst level.[4,5] This hardware was developed and used for implementing the FODA/IBEA centralized satellite access scheme. The protocol proposed in this paper can be used on the hardware presently available, but it would also benefit from the channel usage efficiency of a preambleless modem.

3. THE DRIFS-TDMA ACCESS SCHEME

Each frame consists of a control sub-frame (CSF), used in F-TDMA* mode, followed by a data sub-frame (DSF), used in DA-TDMA† mode, and finally by a first access slot (FAS), used in contention mode (Fig. 1).

Each station has a fixed size control slot (CS) in the CSF, and it uses its own CS to send control information, while the application data are sent in the DSF. The size of the CSF is then proportional to the number of active stations. The position of a CS inside the CSF is maintained fixed, but it is shifted back when a preceding station leaves the system. Control data sent in a CS are preceded by a control unique word (CUW). The first CS in a CSF is preceded by a reference unique word (RUW) which allows the synchronization of the system frame.

Each active station that has an allocation in the DSF sends application data in its data burst (DB). Each DB is identified by a data unique word (DUW) which precedes the user data. The DB can be divided into data sub-bursts (DSB), each addressed to a specific destination, with individual data bit and coding rates, according to the fade levels of both the sending and destination stations.

The FAS is used by those stations willing to enter the system.

3.1. *Station states*

A station can be in one of the following states:

- *Switched-off.*
- *Listening.* After a station is switched on, it begins listening to acquire the CUWs in order to read the allocation requests contained in each control slot, and to compute the BTP. No control slot is assigned to the listening station, so it cannot transmit. The station is only collecting information on the other stations and making dummy channel schedulings to be verified one round trip later. After a listening station has computed a certain number of correct BTPs, it is eligible to become active and it switches into *synchronized* state.
- *Synchronized.* To become active a synchronized station must declare its presence by sending a burst in the FAS, located at the end of each frame. Data transmitted in the FAS contain the first stream and bursty requests of the station; the format of the FAS data is therefore exactly equal to the CS data. The FAS is accessed in

‡Same name in ITU-T.
§No equivalent in ITU-T.

*Fixed-TDMA.
†Demand assignment-TDMA.

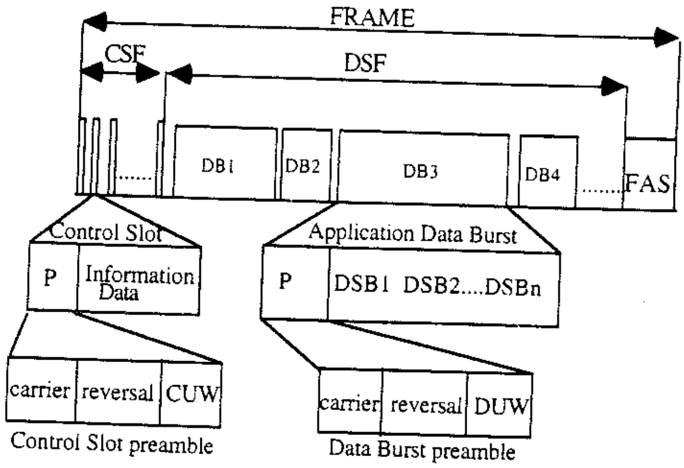

Figure 1. The DRIFS frame structure

contention with all the synchronized stations that want to become active. When a synchronized station has successfully used the FAS to enter the network, it becomes active and all the active stations update the channel scheduling in order to include one more CS (in the last position of the CSF) for the new active station.

- *Active.* An active station computes the BTP at each frame. It uses its CS to send stream and bursty allocation requests, and has a bandwidth allocated for its data transmission in the frame following the reception of its allocation request.
- *Waiting-active.* In this state an active station has no bandwidth allocated for data transmissions but the CS must still be used to send its requests in order not to be declared dead.
- *Going down.* A station which explicitly declares that it will stop any activity is considered going down. This does not affect the other active stations. After completion of the going down procedure, the control slot associated with that station is deallocated. The control slots of all the following stations are then moved back in order to reduce in size the CSF, thus enlarging the DSF.
- *Disappeared.* A station which does not transmit in its CS for a certain number M of frames, is considered to have disappeared. This causes some problems for other stations which start the ending procedure (see below). After completion of this procedure, the CS associated with the disappeared station is deallocated, and the CSs of the following stations are moved back.

Appendix A contains the diagram of the state transitions of a station.

3.2. *Use of the control slot*

Each control slot has a fixed position in the CSF, as long as no station leaves the system. Every station knows which station is using which control slot, how many active stations there are and the control slot position of each one. When a station stops, all the stations must recompact the CSF, i.e. all the control slots following the stopped station must go back one position. An entering station is always assigned a control slot at the end of the CSF. In Figure 2 for example, N is the number of active stations, the addresses of the stations are i, j, … k, respectively; the INF_i field contains both the stream and bursty requests of station i, its fade level, and a space for one new born or one dead station (one at a time) that station i has detected.

Because the CS length is not negligible with respect to the frame length (at least using traditional modems that need a preamble), no more than U control slots are accommodated in a frame. If more than U active stations are present in the system, then the control slots are spread in C_c $]N/U[$ frames, where N is the number of stations and $]x[$ is the smallest integer not smaller than x. If U is equal to 8, up to 256 stations can be accommodated in 32 frames. C_c is the slot assignment cycle, and $F_c = 1/C_c$ is the assigment frequency.

The control slots must somehow be protected against transmission errors. Assuming a modem with a maximum bit rate of 8 Mbit/s, we devise a bit rate of 2 Mbit/s and a coding rate of 4/5 for the control slots.

3.3. *Leaving and entering the satellite network*

3.3.1. *Leaving the network.* A station may stop its transmissions either spontaneously or unwillingly,

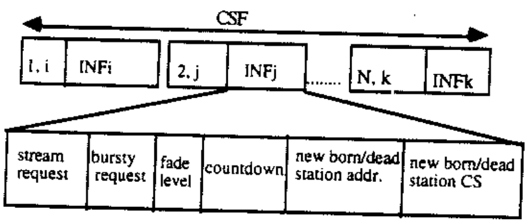

Figure 2. The CSF format

the centralized FODA/IBEA system from which it derives – of improving the system response to traffic transients and of reducing the connection set-up time. Moreover, the dynamic response accuracy to channel fading may be significantly improved. The only drawback is system efficiency for a large number of active stations and when the K_a band is used. This is principally due to the long preamble that traditional burst modems need, in order to keep the burst miss probability below an acceptable threshold, at low E_b/N_0 values. The use of a preambleless modem, which performs better from this point of view, would remove this inconvenience, thus allowing a higher number of active stations in the system.

The simulation results reported in Reference 10 highlight that with any type of traffic used (Poisson, two-states Markov-modulated Poisson, and fractal Gaussian noise), DRIFS performs better than FEEDERS (the other distributed- control access scheme that we studied) when the number of stations is over 32. This is because DRIFS can have an allocation cycle larger than the frame size, so the overhead for a large number of stations is lower than that of FEEDERS. The simulation results presented in Reference 10 also give suggestions for an improved distributed algorithm, which is a compromise between FEEDERS and DRIFS. This scheme should work like FEEDERS when the number of stations is less than 32, then, if the number of stations is increased, it should enlarge the allocation frame to C_c frames, as designed for DRIFS.

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APPENDIX A. STATE TRANSITIONS OF A STATION