THE GAFO PROTOCOL
THE PROTOCOL TO ACCESS THE FODA/IBEA SYSTEM
RELEASE 4.0

Internal Report C94-03

April 1994

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The protocol to access the FODA/IBEA system

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CNUCE REPORT C94-03 / Rel. 4.0

June 1994

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Nomenclature

CCM	Channel Control Message
COS	Class Of Service
GCM	Gateway Control Message
MSG	Message
MTG	Multi-applications Traffic Generator
0x	Hexadecimal Number

1. SOFTWARE/HARDWARE BACKGROUND

FODA/IBEA stands for Fifo Ordered Demand Assignment/Information Bit Energy Adapter. It is a satellite channel access scheme in TDMA (Time Division Multiple Access) allowing the sharing of a satellite channel among a number of earth stations on a reservation basis. It is designed to handle different types of traffic [1], [2].
The FODA/IBEA software is split in two parts: one for receiving data from satellite (DOWN process) and the other one for transmitting data to the satellite (UP process). Both the DOWN and the UP processes run on two separated "boxes", respectively called RX-TDMA terminal and TX-TDMA terminal. From here on, when not explicitly indicated, TDMA terminal indicates both the DOWN and the UP units.

The TDMA terminal comprises a burst-mode modem and a TDMA controller [1].
The burst-mode modem is digitally implemented and provides a variable bit rate from 1 up to 8 Mbit/s. 4 different coding rates are provided (2/3, 4/5, 1/2, 1), to match the requirements (in terms of bit error rates) of the various applications.
The transmit unit of the TDMA controller consists of 3 boards: the user interface card, the control processor (Motorola 68030 running at 25 MHz) and the modem interface card, including the FEC encoder.
The receive unit of the TDMA controller consists of 3 corresponding boards plus the FEC decoder. The two (receive and transmit) units are interconnected via an SCSI link.
The user interface boards of the TDMA controller support the following:

a) two input 64Kbit/s ports to CCITT G703 standard;
b) two output 64Kbit/s ports to CCITT G703 standard;
c) eight asynchronous RS-232 ports (100-19.2Kbit/s);
d) synchronous input and output interface operating at 384 Kbit/s to CCITT RS-422 standard;
e) two Ethernet ports.

The term FODA/IBEA system indicates the FODA/IBEA software plus the TDMA terminal.

1.1 Access types

The FODA/IBEA system is required to work both as a transit network with attached inter-network gateway(s) and as a private network supporting directly attached users. Typical services for the outlined environment are, for instance, telephone, video-telephone, videoconference, file transfer, facsimile, document dissemination, information retrieval, etc. The various services have very different speeds and requirements. According to the tolerable delay, the traffic loading the network can be classified as either isochronous or non-isochronous. The first class is also referred to as *stream* traffic. A stream traffic generates a continuous flow of fixed length packets with fairly constant inter-arrival time. Type of traffic belonging to the second class is called *datagram* traffic. For this traffic type the delivery delay is not a critical constraint.

Reservations for isochronous services are performed on a per call basis and, where successful, generate a time slot assignment at regular intervals of time to each call (circuit mode).

Reservations for non-isochronous services are sent as frequently as possible (generally, at each data burst sending) to adapt the request to the updated needs. In this case, the assigned time slots are not guaranteed at regular interval of times (packet mode).

In the FODA/IBEA system, the access to the satellite is achieved through a centralised technique. Each earth station addresses its reservations, via the satellite channel itself, to a master station which schedules the sharing of the channel capacity among the requests and notifies each station about its slots assignments. The whole operation roughly takes half a second, i.e. a double-hop propagation delay.

Data error recovery is carried out on an end-to-end basis at the network edges. Data to be transferred to the satellite channel must be preceded by a satellite header added in transmission by the FODA/IBEA UP process and removed in reception by the DOWN process.

The main characteristics of the supportable traffic can be summarised in:

- acceptable quality of data (data error rate),
- acceptable data-loss probability,
- network-wide delay characteristics: standard deviation of the delay (jitter),
- data urgency.

Data is supposed to enter the TDMA controller from a gateway working as a concentrator of etherogeneous networks or from hosts directly connected to the TDMA controller. In both cases a protocol must be defined between the FODA/IBEA system

and the incoming data and requests. As from the protocol point of view the two different cases (gateway or host) are handled in the same way, we will always refer to the gateway solution.

The protocol between the gateway and the FODA/IBEA system is referred to as the GAFO protocol. The gateway which supports such a protocol is referred to as the GAFO gateway or, simply, gateway.

1.2 The gateway

The GAFO gateway must support both isochronous and non-isochronous applications, providing an appropriate protocol to support both the traffic types. In addition, gateways control messages (GCM) must be guaranteed to be delivered with the maximum protection and within a tolerable delay. Each GCM has the length fixed to 16 bytes. The FODA/IBEA system reserves a small amount of bandwidth to each active station, to be used in round-robin mode, to assure the transmission of GCMs.

The GAFO gateway is supposed to be able to set up a virtual connection with the destination GAFO gateway for each stream application.
Moreover, as the maximum length of a packet supported by the FODA/IBEA system is 2047 8-bit bytes, the GAFO gateway is supposed to be able to break into packets of 2047 bytes (as maximum) packets longer than the length supported by the FODA/IBEA system.

The gateway is also foreseen to support (but it is not mandatory) the Multi-applications Traffic Generator (MTG) software, to be used to simulate synchronous and asynchronous applications [3].

1.3 The protocol

The GAFO protocol supports the delivery of stream packets to either single or multiple destinations in applications requiring guaranteed data rates and controlled delay characteristics. It supports data coming from multi-user conferences, even if no attempt is here made to specify any multi-user conference protocol. This task is assigned to higher level layers.

The GAFO protocol provides a means of data exchanging among hosts, solving problems of bandwidth allocation and ensuring the data class of service maintenance. Moreover, due to fade conditions of the signal (especially when operating in Ka band in bad weather conditions), the delivery delay and the bandwidth characteristics of the stream traffic may be maintained with difficulty. In this case, in fact, the increased

coding rate and the eventual reduced bit rate of the data reduce sensibly the total information capacity of the stream sub-frame.

2. THE GAFO PROTOCOL

2.1 (GTW->UP) Channel control messages From the gateway toward the UP process (Gateway ---- ccm ------> UP process)

The channels control messages addressed by the gateway to the UP process have the format as in Fig. 1. In most cases, they cause the transmission of control information from the FODA/IBEA system to the master station.

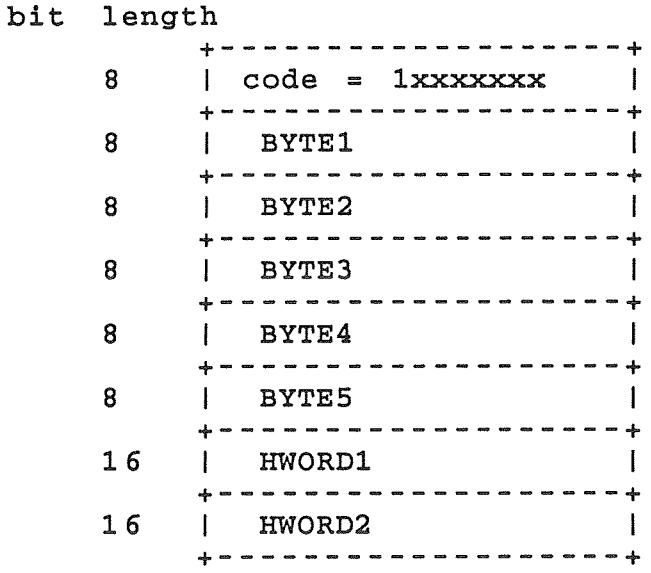

Fig. 1. Channel control messages format

2.1.1 CODE = 0x83. Stream channels request.

BYTE1 number of the destination station the stream data is addressed to.
BYTE1 = 0xFF and BYTE2 = 0 means broadcast.
BYTE1 = 0xFF and BYTE2 not zero means that the data is addressed to a group of destination stations. In such a case, BYTE2 identifies the group.

BYTE2 meaningful only if BYTE1 = 0xFF.
BYTE1 = 0xFF and BYTE2 = 0 means broadcast.
BYTE1 = 0xFF and BYTE2 not zero means that the data is addressed to a group of destination stations. In such a case, BYTE2 contains the identifier as assigned by the FODA/IBEA system (FODA_ug_id). Stream data generated by the application requesting the stream channels

is sent to all the stations belonging to the group of users. The control message 0xA0 must be sent before sending this control message. The stream data to be transferred is passed by the GAFO gateway to the FODA/IBEA system via one of the message codes in 2.3.3. The fields DB2 and DB3 in 2.3.3 must be equal to the value in BYTE4 of the present control message and to the field BYTE5 of the control message 0x81, respectively.

BYTE3 requested class of service for the data (see section 3).

BYTE4 identifier assigned by the GAFO gateway to this channel request. It results to be the identifier assigned by the GAFO gateway to the stream application requesting the stream channels (GTW_appl_id).

BYTE5 maximum number of packets pending in the queue before flushing.

HWORD1 number of requested stream channels expressed in number of 32-bit words per frame (1 frame = 20 ms).

HWORD2 minimum acceptable number of stream channels. It must be less or equal to HWORD1. If equal to HWORD1, the application cannot be compressed (even if it were necessary for fade reasons).

The FODA/IBEA system sends to the master station a request for a number of stream channels sum of all the single requests received from the GAFO gateway. Any further request, arriving to the FODA/IBEA system from the GAFO gateway when a certain number of stream channels have already been granted to this earth station, causes the sending to the master station of an updating request.

2.1.2 CODE = 0x87. Stream channels modification reply

BYTE1 ----

BYTE2 ----

BYTE3 maximum number of packets pending in the queue before flushing.

BYTE4 identifier assigned by the GAFO gateway to this stream application (GTW_appl_id).

BYTE5 identifier assigned by the FODA/IBEA system to this stream application (FODA_appl_id).

HWORD1 number of the stream channels granted by the master station (and accepted by the application).

HWORD2 minimum acceptable number of stream channels. It must be less or equal to HWORD1.

This control message is sent in reply to the control message 0x85.

2.1.3 CODE = 0xA0. Build a group of users

BYTE1 identifier assigned by the GAFO gateway to this users group (GTW_ug_id). The group must consists of at least 2 stations, in addition to the requesting station. A maximum of 8 stations per group (in addition to the requesting station) is allowed. Groups larger than 8 stations are handled as *broadcast*.

BYTE2 first station address.

BYTE3 second station address.

BYTE4 third station address or zero.

BYTE5 4th station address or zero.

HWORD1 5th (low byte) and 6th (high byte) station addresses or zero.

HWORD2 7th (low byte) and 8th station (high byte) addresses or zero.

The local earth station decides whether or not the users group can be built (earth stations active, dead, in too deep fade, etc.). If yes, by means of the reply message 0xC2 the GAFO gateway is granted about the users group creation and the local earth station assigns to the users group an identifier (FODA_ug_id) got from the map of the available users group identifiers available in the station (up to 15 users groups). Once a users group is created, data is sent to all the stations belonging to that group. The transmission characteristics (data bit and coding rates) are those ones of the station in the worst fade condition.

2.1.4 CODE = 0xB0. Cancel a group of users

BYTE1 identifier assigned by the GAFO gateway to this users group (GTW_ug_id).

BYTE2 identifier assigned by the FODA/IBEA system to this group of users (FODA_ug_id). This field must be zero if the control message aims to cancel a request for building a users group not yet granted.

BYTE3 ----

BYTE4 ----

BYTE5 ----

HWORD1 ----

HWORD2 ----

2.1.5 CODE = 0x89. Stream channels relinquish

BYTE1 number of the destination station the stream data was addressed to.
BYTE1 = 0xFF and BYTE2 = 0 means broadcast.
BYTE1 = 0xFF and BYTE2 not zero means that the data is addressed to a group of destination stations. In such a case, BYTE2 identifies the group.

BYTE2 meaningful only if BYTE1 = 0xFF.
BYTE1 = 0xFF and BYTE2 = 0 means broadcast.
BYTE1 = 0xFF and BYTE2 not zero means that the data is addressed to a group of destination stations. In such a case, BYTE2 contains the identifier as assigned by the FODA/IBEA system (FODA_ug_id).

BYTE3 requested class of service for the data (see section 3).

BYTE4 identifier assigned by the GAFO gateway to this channel request (GTW_appl_id). As BYTE4 in message code 0x83.

BYTE5 identifier assigned by the FODA/IBEA system to this stream application (FODA_appl_id). As BYTE5 in message code 0x81.

HWORD1 ----

HWORD2 ----

This control message may be issued either on request of the stream application (which wants to stop its activity) or on decision of the GAFO gateway itself when no more data from the source application are detected for a certain amount of time. On receiving

this control message, the FODA/IBEA system sends to the master station a request for decrementing the number of stream channels globally assigned to this station or for cancelling the number of assigned stream channels (if just equal to the number of granted stream channels).

2.1.6 CODE = 8A. Modify a group of users

BYTE1 identifier assigned by the GAFO gateway to this group of users (GTW_ug_id).

BYTE2 identifier assigned by the FODA/IBEA system to this group of users (FODA_ug_id).

BYTE3 number of stations to be added.

BYTE4 station address.

BYTE5 station address.

HWORD1 station address(es).

HWORD2 station address(es).

The GAFO gateway requests the earth station to modify an already existing users group. As a group of users must consist of 2 stations as minimum and 8 stations as maximum, up to 6 additional stations may be specified in this control message. The reply control message 0xC3 must be waited for.

2.1.7 CODE = 0xF0. GTW introduces itself to UP Who are you?

BYTE1 GAFO gateway Ethernet address

BYTE2 GAFO gateway Ethernet address

BYTE3 GAFO gateway Ethernet address

BYTE4 GAFO gateway Ethernet address

BYTE5 GAFO gateway Ethernet address

HWORD1 GAFO gateway Ethernet address (high byte only).

HWORD2 -----

The gateway introduces itself to the UP process by passing to it the 6 bytes of its Ethernet address. A reply to this control message is waited for, i.e. the UP process Ethernet address (see 2.2.10).

2.2 (UP -> GTW) Channel control messages From the UP process toward the gateway (UP process -------ccm -------> Gateway)

The following channel control messages have the same format as in Fig. 1.

2.2.1 CODE = 0x81. Stream channels granted/refused

BYTE1 ----

BYTE2 ----

BYTE3 ----

BYTE4 identifier assigned by the GAFO gateway to the stream application (GTW_appl_id).

BYTE5 identifier assigned by the FODA/IBEA system to the stream application which requested the channels (FODA_appl_id). It is used when stream data is sent from the gateway to the FODA/IBEA system for transmission via satellite (DB3 field of 2.3.3). This field is used in the satellite header of the FODA/IBEA protocol.

HWORD1 number of stream channels granted by the master. This field must contain any acceptable number in the range of those specified by the application in the control message 0x83. If HWORD1=0, it must be interpreted by the application as a REFUSE control message, i.e. there is not enough space to allocate the requested number of stream channels. The source application may try later on.

HWORD2 ----

2.2.2 CODE = 0x85. Stream channels modification request

BYTE1 ----

BYTE2 ----

BYTE3 ----

BYTE4 identifier assigned by the GAFO gateway to the stream application (GTW_appl_id).

BYTE5 identifier assigned by the FODA/IBEA system to the stream application (FODA_appl_id).

HWORD1 new number of granted stream channels. This field must contain any acceptable number in the range of those specified by the application in the control message 0x83. HWORD1=0 is not allowed, because the application is already running and cannot be killed.

HWORD2 ----

This control message is sent when a stream application is requested by the FODA/IBEA system to reduce its bandwidth (if possible).

2.2.3 CODE = 0x98. Stop sending datagram packets (congestion detected)

BYTE1 ----

BYTE2 ---

BYTE3 ----

BYTE4 ----

BYTE5 ----

HWORD1 ----

HWORD2 ----

On receiving this control message, the GAFO gateway must stop sending datagram data to the FODA/IBEA system. The datagram applications must be alerted about the detected congestion.

2.2.4 CODE = 0x88. Resume sending datagram (congestion overcome)

BYTE1 ----

BYTE2 ----

BYTE3 ----

BYTE4 ----

BYTE5 ----

HWORD1 ----

HWORD2 ----

On receiving this control message, the GAFO gateway can resume sending datagram data to the FODA/IBEA system. The datagram applications must be alerted that the congestion has overcome.

2.2.5 CODE = 0xD0. Destination station(s) not reachable

BYTE1 number of the unreachable stations listed in the following. 8 is the maximum.

BYTE2 unreachable station address.

BYTE3 unreachable station address or zero.

BYTE4 unreachable station address or zero.

BYTE5 unreachable station address or zero.

HWORD1 unreachable station address or zero (hi and low bytes).

HWORD2 unreachable station address or zero (hi and low bytes).

The FODA/IBEA system alerts the GAFO gateway about the earth station(s) not reachable via satellite on the first attempt to send data to that station(s).

2.2.6 CODE = 0xC1. Destination station(s) now reachable

BYTE1 number of the stations, now reachable, listed in the following. 8 is the maximum.

BYTE2 now reachable station address.

BYTE3 now reachable station address or zero.

BYTE4 now reachable station address or zero.

BYTE5 now reachable station address or zero.

HWORD1 now reachable station address(es) or zero (high and low bytes).

HWORD2 now reachable station address(es) or zero (high and low bytes).

2.2.7 CODE = 0xC2. Build a group of users reply

BYTE1 reply code. The following codes are provided:

1 = ACK.
Users group built. The fields from BYTE4 (included) on are meaningless.

0x81 = NACK.
No more users group identifiers available in this station.

0x82 = NACK.
Users group not built because at least one station is unreachable. The fields from BYTE4 on must be checked. If not zero, they contain the addresses of the unreachable stations (6 as maximum).

BYTE2 users group identifier as assigned by the GAFO gateway (GTW_ug_id).

BYTE3 users group identifier as assigned by the FODA/IBEA system (FODA_ug_id) or zero (in case of NACK).

BYTE4 unreachable station address or zero.

BYTE5 same as the previous byte.

HWORD1 same as the previous byte(s) (high and low byte).

HWORD2 same as the previous field.

2.2.8 CODE = 0xC3. Extend a users group reply

BYTE1 reply code. The following codes are provided:

1 = ACK.
Request accepted. The earth stations listed in the command 0x8A have been included in the specified users group (ACK).

0x82 = NACK.
Request not accepted because at least one of the listed stations is unreachable. The unreachable stations (6 as maximum) are listed from BYTE4 (included) on.

0x83 = NACK.
Request not accepted because the specified users group does not exist.

0x84 = NACK.
Request not accepted because the specified users group is (more than) full (8 stations already active in the group).

0x85 = NACK.
At least one station is already a member of the specified users group.

BYTE2 users group identifier as assigned by the GAFO gateway (GTW_ug_id).

BYTE3 users group identifier as assigned by the FODA/IBEA system (FODA_ug_id).

BYTE4 meaningless or address of the unreachable station (if reply code = -3).

BYTE5 same as previous byte.

HWORD1 same as previous byte (high and low bytes).

HWORD2 same as previous field.

2.2.9 CODE = 0xC4. Error in request <error type>

BYTE1 message code of the wrong request.

BYTE2 error type. It is not yet completely defined. The following error codes are so far envisaged:

0x86 = invalid class of service;

0x87 = duplicated stream channels request;

0x88 = invalid destination address;

0x89 = an attempt is made to cancel a users group but some applications are still active.

BYTE3 ----

BYTE4 zero or identifier assigned by the GAFO gateway to the application (GTW_appl_id).

BYTE5 zero or identifier assigned by the FODA/IBEA system to the application (FODA_appl_id).

HWORD1 spare or dependent on the error type.

HWORD2 spare or dependent on the error type.

This control message is sent in reply to a request containing an error. The request is discarded.

2.2.10 CODE = 0xF1. UP introduces itself to GTW

BYTE1 UP process Ethernet address

BYTE2 UP process Ethernet address

BYTE3	UP process Ethernet address
BYTE4	UP process Ethernet address
BYTE5	UP process Ethernet address
HWORD1	UP process Ethernet address (high byte only).
HWORD2	-----

This control message is the UP process reply to the GAFO gateway presentation (2.1.7).

2.3 (GTW -> UP) Data messages
From the gateway toward the UP process
(Gateway -----data msg ------> UP process)

The control messages for sending data to the satellite (data messages) have the format shown in Fig. 2.

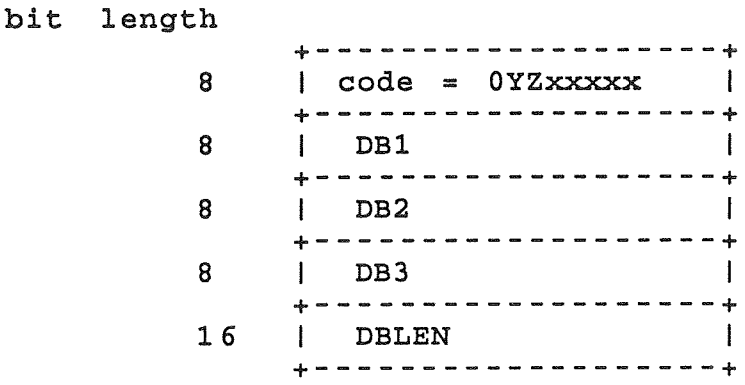

Fig. 2. Data messages format

Bit Y If set on, the data packet is used for measurement purposes. In this case, the data packet is generated by the Multi-applications Traffic Generator (MTG) running on the gateway. Real data is preceded by a MTG header, where some fields have to be filled by the FODA/IBEA system [3]. The code number corresponding to a measurement packet is indicated in parentheses.

Bit Z If set on, the CRC must be sent on satellite and checked on reception.

2.3.1 Send bulk data to satellite

2.3.1.1 CODE = 0x11. Without CRC check
2.3.1.2 CODE = 0x51. Generated by MTG, without CRC check
2.3.1.3 CODE = 0x31. With CRC check
2.3.1.4 CODE = 0x71. Generated by MTG, with CRC check

BYTE1 number of the destination station the bulk data is addressed to.
BYTE1 = 0xFF and BYTE2 = 0 means broadcast.

BYTE1 = 0xFF and BYTE2 not zero means that the data is addressed to a group of destination stations. In such a case, BYTE2 identifies the group.

BYTE2 meaningful only if BYTE1 = 0xFF.
BYTE1 = 0xFF and BYTE2 = 0 means broadcast.
BYTE1 = 0xFF and BYTE2 not zero means that the data is addressed to a group of destination stations. In such a case, BYTE2 contains the identifier as assigned by the FODA/IBEA system (FODA_ug_id).
Bulk data is sent to all the stations belonging to the group of users. The control message 0xA0 must be sent before sending this data message.

DB3 requested class of service for the data (see section 3).

DBLEN length in bytes of the following data.

2.3.2 Send interactive data to satellite

2.3.2.1 CODE = 0x12. Without CRC check
2.3.2.2 CODE = 0x52. Generated by MTG, without CRC check
2.3.2.3 CODE = 0x32. With CRC check
2.3.2.4 CODE = 0x72. Generated by MTG, with CRC check

BYTE1 number of the destination station the interactive data is addressed to.
BYTE1 = 0xFF and BYTE2 = 0 means broadcast.
BYTE1 = 0xFF and BYTE2 not zero means that the data is addressed to a group of destination stations. In such a case, BYTE2 identifies the group.

BYTE2 meaningful only if BYTE1 = 0xFF.
BYTE1 = 0xFF and BYTE2 = 0 means broadcast.
BYTE1 = 0xFF and BYTE2 not zero means that the data is addressed to a group of destination stations. In such a case, BYTE2 contains the identifier as assigned by the FODA/IBEA system (FODA_ug_id).
Bulk data is sent to all the stations belonging to the group of users. The control message 0xA0 must be sent before sending this data message.

DB3 requested class of service for the data (see section 3).

DBLEN length in bytes of the following data.

2.3.3 Send stream data to satellite

2.5 (DOWN -> GTW) Channel control messages From the DOWN process toward the gateway (DOWN process -------ccm -------> Gateway)

The following channel control message has the same format as in Fig. 1.

2.5.1 CODE = 0xF3. DOWN introduces itself to the gateway

BYTE1	DOWN process Ethernet address
BYTE2	DOWN process Ethernet address
BYTE3	DOWN process Ethernet address
BYTE4	DOWN process Ethernet address
BYTE5	DOWN process Ethernet address
HWORD1	DOWN process Ethernet address (high byte only).
HWORD2	-----

This control message is the DOWN process reply to the GAFO gateway presentation (2.4.1).

2.6 (DOWN -> GTW) Data messages From the DOWN process toward the gateway (DOWN process ------- data msg ------> Gateway)

The format of the following data messages is the same as in Fig. 2. The meaning of bits Y and Z in the code field is also the same as in 2.3.

2.6.1 Bulk data received from satellite

2.6.1.1 CODE = 0x01. Without CRC check
2.6.1.2 CODE = 0x41. Generated by MTG, without CRC check
2.6.1.3 CODE = 0x21. With CRC check
2.6.1.4 CODE = 0x61. Generated by MTG, with CRC check

DB1	number of the source station from where the data comes from.
DB2	user group identifier (as defined in the source station).
DB3	data status.
DBLEN	length in bytes of the following data.

2.6.2 Interactive data received from satellite

2.6.2.1 CODE = 0x02. Without CRC check
2.6.2.2 CODE = 0x42. Generated by MTG, without CRC check
2.6.2.3 CODE = 0x22. With CRC check
2.6.2.4 CODE = 0x62. Generated by MTG, without CRC check

DB1	number of the source station from where the data comes from.
DB2	user group identifier (as defined in the source station).
DB3	data status.
DBLEN	length in bytes of the following data.

2.6.3 Stream data received from satellite

2.6.3.1 CODE = 03. Without CRC check
2.6.3.2 CODE = 43. Generated by MTG, without CRC check
2.6.3.3 CODE = 23. With CRC check
2.6.3.4 CODE = 63. Generated by MTG, with CRC check

DB1 number of the source station from where the data comes from.

DB2 identifier of the stream application as assigned by the FODA/IBEA system (FODA_appl_id).
The values DB1 and DB2, together, are a unique identifier.

DB3 data status.

DBLEN length in bytes of the following data.

2.6.4 GCM received from satellite

2.6.4.1 CODE = 0x20. With CRC check
2.6.4.2 CODE = 0x60. Generated by MTG, with CRC check

DB1 number of the source station from where the message comes from.

DB2 user group identifier (as defined in the source station).

DB3 data status.The data status byte (DB3) has the format shown in Fig. 2.1.

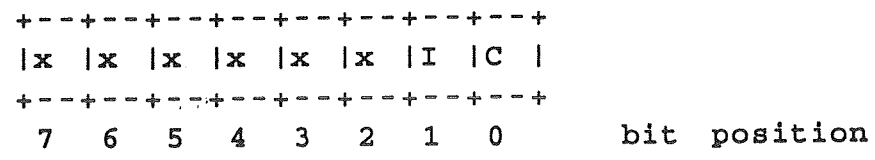

Fig. 2.1 The data status byte (DB3) format

where:

C CRC check (as far as the satellite link is concerned).
If ON, CRC is wrong.

I if ON, buffer is incomplete.

x spare bits.

DBLEN length in bytes of the following gateway control message. It is fixed to 16 bytes.

3. THE CLASS OF SERVICE

One of the major problems for communication satellites operating at frequencies above 10 GHz is the high level of rain attenuation encountered. This attenuation is not uniformly distributed: there are seasonal and diurnal variations which show that severe rain fall is an irregular and unavoidable phenomenon.
The basic principle, used by the FODA/IBEA system, to cope with different levels of the signal attenuation is the variation of the coding and bit rates. The effect on the system performances is, of course, a reduced overall channel capacity in those periods in which a bigger attenuation is experienced at one or more stations.

Operating conditions with the Eb/No ratio below a reference level are typically due to the fading caused by atmospheric conditions, but the same technique can also be employed, if anything, to support stations having marginal performances in terms of EIRP and G/T, working in the same system. The less powerful stations in this case are managed like stations in fading with the only difference that the fading conditions are events limited in time.

In the exchanging of data between two end-user applications in an internetworking system (satellite link included) the most significant parameters characterising the quality of the requested service are:

- the typical data delay
- the maximum jitter of the packet inter-arrival time
- the requested bit error rate.

In the FODA/IBEA system, the first two parameters are really not negotiable. In case of stream, the delay depends on the round trip time (which, in its turn, depends on the geographic position of the station) plus a fraction of the time frame, 20ms long. The maximum jitter can be assumed one time frame long. In case of datagram both the delay and the jitter depend strongly on the overall traffic conditions of the system and by the saturation control mechanism.
In no case, anyway, these parameters can be specified by the application.
The BER, on the contrary, must be specified by the application to choose the quality of the transfer. In the present system, a requested range of BER is specified by means of a class of service value, as shown in Table 1.

Each stream application must send a request to the FODA/IBEA system as the control message 0x83 (stream channels request). Each station of the FODA/IBEA system provides to assemble together all the HWORD1 values specified in the requests of different stream applications, sending to the master a global unique request, sum of all single HWORD1 values.
The master grants all the global requests, coming from the active stations, up to a fixed upper limit of the stream sub-frame. If the master grants exactly the requested number

of channels, the system provides to distribute the assigned channels among the applications according to the individual requests.
The master ignores the values specified in the HWORD2 and BYTE3 fields (of the message code 0x83) of the single applications; they are used by the requesting station when in fade. For datagram applications, the class of service parameter must be specified for each data packet.

COS	BER not >	BER not <	Example of type of data
1	10^{-8}	----	reference burst; broadcasted control inf.; control sub-bursts; headers
2	$3 * 10^{-7}$	10^{-8}	reliable data: bulk data; special voice/video; interactive data
3	$3 * 10^{-5}$	$3 * 10^{-7}$	standard voice/video
4	10^{-3}	$3 * 10^{-6}$	degraded voice

TABLE 1.

Let us fix the reference value of Eb/No as the ratio allowing the system to receive uncoded data with the highest class of service (1) at the maximum speed rate (8 Mbit/s/s). The resulting theoretic value is 12 dB. The fade level is defined as the degradation of the Eb/No ratio, expressed in dB, with respect to the reference value.

When the necessity arises to compensate an increased attenuation of the signal (i.e. keeping the same value of the BER), it is preferable to increase the coding rate of the data with respect to maintain the same coding rate and to reduce the bit rate. The speed must be reduced only when the signal to noise ratio (Eb/No) drops below a minimum value, necessary to allow the acquisition of the burst modem in a reasonable number of symbols.

The compensation of fade conditions is translated into a request for a wider bandwidth both by the station in fade and by all the other stations wishing to send data to the station in fade. The FODA/IBEA system reacts to the increased requests of bandwidth, due to fade conditions, in different ways according to whether the type of traffic is stream or datagram.

The stream traffic is privileged. The stream application needs a preliminary phase in which a certain bandwidth is negotiated between the master and the user. Once a stream link has been granted, the system attempts to keep unchanged the link characteristics even in presence of fade conditions. When a station, sending data to another one fallen in fade, requests more stream channels to support already set up applications, the master tries to grant the new request and the upper limit of the stream sub-frame is moved ahead, if necessary, squeezing the datagram sub-frame. The

moving of the stream sub-frame limit is only allowed in this case, not for granting channels requested by new applications. This new upper limit is moved back to the normal position when the fade conditions has overcome. While the stream sub-frame upper limit is moved ahead, new requests are rejected by the system.

If the enlarging of the stream sub-frame is not sufficient to satisfy the increased request, the system notifies to the application the necessity of reducing its bandwidth (up to the value specified in the HWORD2 field of the request). This is only possible if the value in HWORD2 is less than the value specified in HWORD1. After receiving the ack from the application (control message 0x87), the station begins sending data with reduced bit rate, while maintaining the BER specified by the requested class of service.
This procedure is only applicable, of course, to those applications compressible in bandwidth, if anything, such as voice and video with variable rate codec. Incompressible applications are not guaranteed to maintain the requested BER under heavy fade conditions, especially if experienced when the system is strongly loaded. It is up to the application itself the decision whether to continue the session with degraded performances or to give up, leaving the occupied channel bandwidth to other users.

As far as the datagram is concerned, fading conditions cause an increment of the real backlog and of the amount of instantaneous traffic. This automatically increases the station request, making the attempt to get more bandwidth. Due to the increasing of the request itself and/or to the eventual compression of the datagram sub-frame to grant more stream channels, the overall capacity of the datagram may result sensibly reduced and particularly under heavy load conditions of the system. An efficient action of the channel saturation control system is requested to avoid congestion.

A rather simple method to avoid saturation is to block the growth of the backlog for a while, exercising a backpressure on the remote users, when a dangerous situation is detected. Since data is collected from high speed networks (typically LANs provided with flow control mechanisms), the only effect of this procedure is to slow down the overall traffic coming from the remote hosts for a convenient interval of time.

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