WIRELESS LAN TECHNOLOGY

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***Abstract*----We present an experiment in interconnecting LANs via a satellite link and describe the individual components involved in the experiment. The project was developed in two phases: a) design and realisation of a satellite access scheme that supports real-time and non real-time traffic with a signal fading countermeasure, called FODA/IBEA-TDMA1; b) interconnection of LANs where real-time and non real-time applications run. The experiment was presented the first time in June 1994 as a demo in**

Which the Outlast satellite was used (in the 12/14 GHz band) to exchange data between two LANs in

Pisa and Florence, while video and audio applications running on PCs connected the two sites. The demo was repeated a few weeks later and the Intelsat satellite was used in the 20/30 GHz band.

Keywords: ---satellite, TDMA fade countermeasure, satellite LAN interconnection, satellite Videoconference

1. INTRODUCTION

Much work is in progress in the field of communication systems for real-time multimedia applications over local area networks (LANs). The goal of our research was to design and develop a heterogeneous network capable of simultaneously handling video, voice and data. The network is

heterogeneous in many senses: it is composed of various types of transmission media (LANs and satellite links); it carries different types of traffic (video, voice and computer generated data); and it uses several protocols, such as TCP/IP over Ethernet for the connection to external LANs, an internal Token Ring LAN used for data, audio and video applications, FODA/IBEA for the satellite network, and GAFO2 for the communications between the terrestrial gateway (where the data coming from the various LANs converge) and the satellite network.

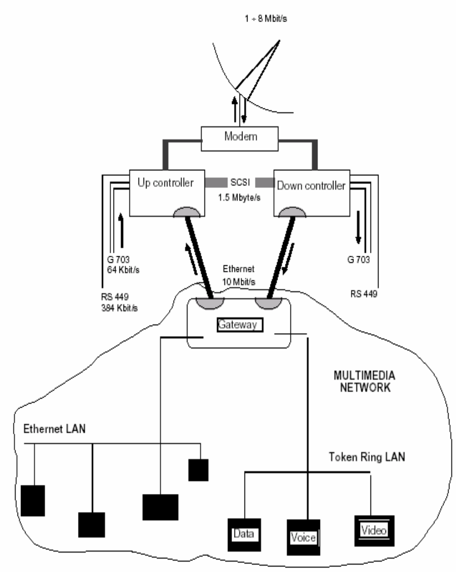

Fig. 1. The network scenario

Satellite links are more problematic than terrestrial links for two main reasons. The satellite round trip delay is quite significant when transmitting real-time data (stream data). Moreover, the HF signal may be considerably attenuated by bad atmospheric conditions, with a consequent degradation in the quality of the data transmitted. The latter is currently one of the major problems for communication satellites operating at frequencies above 10 GHz. As the Ku band (12/14 GHz) is shortly going to be saturated, we considered the Ka band (20/30 GHz) for the satellite network design. FODA/IBEA [11], the satellite access scheme we have developed, operates in TDMA. It allows the simultaneous transmission of real-time and non real-time (datagram) data, while maintaining the BER3 required by applications, even in conditions of signal fading, by varying the information bit energy (fade countermeasure technique). At the same time, the

University of Florence developed a gateway which takes data coming from both Ethernet and Token Ring LANs and sends them to the satellite network using GAFO, a protocol developed to communicate with the satellite earth stations.

The paper is organised as follows. In Section 2 the network scenario is presented, while in Section 3 the earth station hardware is briefly described. Section 4 describes the satellite access scheme, and Section 5 highlights the features of the GAFO protocol. Section 6 describes the LAN interconnection and outlines the demonstration of the whole interconnected network.

2. THE NETWORK SCENARIO

Figure 1 depicts the network scenario used in the demo of the project. The three earth stations had the same configuration; two of them were located in Pisa, while the third one was located in Florence (about 100Km away). Although for practical reasons the demo only involved three stations, this configuration can easily be extended to a larger number of stations, up to the hardware limit of 112. Each station needs a gateway that connects it to an Ethernet LAN and to stream applications (data, voice, video), or else the stations can themselves be Ethernet LAN hosts, provided that the applications that use the satellite link are equipped with the GAFO protocol interface.

In the configuration used in the experiment, the stream applications run on hosts connected to a Token Ring network, while the datagram applications run on hosts connected via Ethernet. Data from both the LANs converges at the gateway which communicates with the FODA/IBEA satellite access system by using the GAFO protocol. The set of applications running on Ethernet plus those running on the Token Ring network plus the gateway are collectively called a Multimedia Network. This part was developed by the University of Florence.

FODA/IBEA runs on hardware designed by CNUCE, in collaboration with Telespazio and developed by Marconi R.C. (U.K.). It consists of a TDMA controller (which includes a variable coding rate codec), and a variable bit rate burst modem. The TDMA controller is split into two parts: the Up controller, for transmissions towards the satellite (uplink), and the Down controller, to receive data from the satellite (down-link). The communication between the Down and the Up controller is performed via an SCSI link at 1.5 Mbytes/s. Dedicated Ethernet lines connect the gateway to the Up controller and the Down controller, respectively.

Traffic type	Throughput	Packet Length	Tolerated Delay	BER Required	FODA/IBEA COS
interactive	low	small, variable	low	$< 3\cdot10^{-7}$	2
control	low	small, variable	medium	$< 10^{-8}$	1
mail	low/medium	medium, variable	high	$< 3\cdot10^{-7}$	2
bulk	high	medium/high, constant	medium/high	$< 10^{-8}$	1
fax	medium	big, constant	medium	$< 3\cdot10^{-5}$	3
VOICE special standard degraded	medium	small, constant	low, constant	 $< 3\cdot10^{-7}$ $< 3\cdot10^{-5}$ $< 10^{-3}$	 2 3 4
VIDEO slow scan TV	medium	big, constant	low, constant	$< 3\cdot10^{-5}$	3
video-conference	high	big, constant	low, constant	$< 10^{-8}$	1

Table 1. Traffic characteristics

Stream traffic, such as voice, slow-scan TV, videoconference, etc., is characterized by a constant packet arrival rate. Stream applications usually require short and fairly constant delays at the receiving end, Cannot tolerate out-of-order delivery of packets, but can tolerate occasional bit errors and dropped packets. In practice, stream traffic needs a fixed amount of bandwidth on a regular basis and the satellite network should not alter the inter-arrival time of the packets.

Datagram traffic is sub-divided into *bulk* and *interactive* types. Bulk traffic applications (typically file transfer protocols) usually transmit a large number of packets; however the delay caused by the network crossing is not critical, so this type of traffic does not have the rigid delay requirements of stream traffic. The satellite network can deliver the packets out of order, since higher level protocols take care of reordering them. However, corrupted or lost packets may severely impair the end-to-end throughput of such traffic, especially on a high delay medium like the satellite network. Interactive traffic (terminal access to computers, database enquiries, operator message exchanges, etc.) demands error free, reliable delivery of packets and short end-to-end delay to guarantee acceptable response times. It often consists of short packets (64 bytes on Ethernet is typical) with very irregular interracial times. Table 1 outlines different types of traffic in terms of the key parameters of delay, throughput and BER range which are commonly required. The last column in the table (FODA/IBEA Class of Service (COS))

Represents the mapping of the BER required by the associated type of traffic onto the satellite network. Four classes of service are envisaged, and COS number 1 is associated with the maximum protection from errors of the data transmitted. The COS number

Must be specified when using the GAFO protocol to pass data from the terrestrial to the satellite network. For stream data, the COS value is specified only once, when the virtual channel is set up; for datagram data the relevant COS value is associated with each packet.

Table Legend:

Throughput (T):

low (T < 1 Kbit/s)

medium (1 Kbit/s < T < 100 Kbit/s)

high (T > 100 Kbit/s)

Packet length (L):

small (L < 128 bytes)

medium (128 bytes < L < 1 Kbit)

big (L > 1 Kbyte)

Delay (D):

low (D < 0.5s)

medium (0.5s < D < 2 s)

high (D > 2s)

3. THE EARTH STATION HARDWARE

Figure 2 shows the hardware of the TDMA controller and the variable bit rate burst modem. As some boards contained in the Down controller are the same as in the Up controller, some explanations are given for the Up controller alone. The Up controller consists of the following boards:

• Standard industrial board with a 25 MHz 68030 processor, 4 Mbyte DRAM memories, Bidirectional SCSI-1 interface, VMEbus interface, a LANCE chip for Ethernet, 4 RS-

232 ports (only one is actually used), timers, real-time clock, and a small non volatile RAM. It runs VMExec, a PSOS based real time operating system. The FODA/IBEA software— which controls and monitors the functions of the transmit control unit— uses the services offered by the real-time kernel, namely the priority pre-emptive task scheduler and inter process communication manager. Events, message queues, semaphores, task suspension and resumption are supported.

• Transmit serial interface this is a wire wrapped VMEbus double Euro card board. It

Acts as a buffer between the VMEbus and the three serial ports of the transmit controller: a high speed RS-449/RS-422 port (384 Kbit/s), and two CCITT G.703 ports (64 Kbit/s). This board is not currently used by FODA/IBEA, although the necessary software hooks to use it are in place. The processor interfaces to the controller via a number of VMEbus memory mapped ports which allow transmit data to be written and control and monitoring data to be exchanged. The interfacing function is performed by two boards: the transmit modem interface and the line interface.

• Transmit modem interface this is a wire wrapped VME double Euro card board. It contains all the channel coding, framing and symbol rate selection functions. It processes data presented to it through the 32-bit VME data bus and also provides status information for circuit and modem monitoring purposes. Transmit and control data are directed to a Data FIFO (First In First Out) which can store up to 512 bytes of data and control information at a time. The control information sets the channel coding hardware to the appropriate mode and the burst transmission timing. The burst format is depicted in Fig. 3. An interrupt is sent through the VME bus when the FIFO reaches less than half its capacity. Control data is also written to an event memory, which is used to synchronise burst transmissions to the transmit frame. This board is connected to the modem by a large shielded cable.

• Line interface board This board, which has no software interface with the VMEbus, contains the line drivers for interfacing to the modem and also provides the 16.384 MHz reference clock, derived from a 32.768 MHz oven controlled crystal oscillator situated on the line interface board. A coaxial cable carries the clock signal to the Down controller.

• Channel encoder this board has no software interface with the VME bus. It performs the data coding functions. The Down controller hardware consists of the following boards:

• Receive control processor same as in the Up controller.

• Receive serial interface same as in the Up controller. The interfacing function with the demodulator is performed by three boards: the receive modem interface, a line interface board, and the channel decoder.

• Receive modem interface this is a wire wrapped VME double Euro card board. It is controlled via a number of ports mapped onto the VME memory space which allow both reading and writing of status, control and data information by the processor. The circuit also provides the interface to the modem, for data reception and fault monitoring through a shielded cable. The decoded data stream is routed to the receive modem interface. This interface uses an event memory to perform real-time reception and decoding of the received bursts. The event memory is filled with information on the initial code rate and symbol rate of the bursts within the frame, together with their expected timing.

• Line interfaces same as the Up controller.

• Channel decoder same as the Up controller.

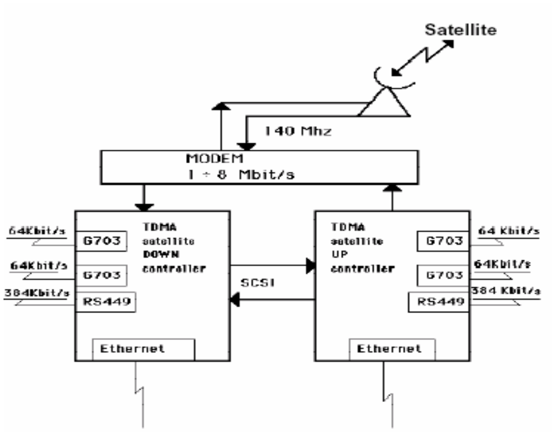

Fig. 2. The hardware configuration

The most interesting feature of the burst modem is that its symbol rate, coding rate and transmit power level can be dynamically adjusted within a data burst. The transmit power of the individual data sub-bursts (see Fig. 3) is tuneable in steps of 0.5 dB in a 20 dB range. Each sub-burst can be transmitted at a different symbol rate (and, hence, different symbol energy) as required. The available symbol rates are 512, 1024, 2048 and 4096 K Baud in either BPSK or QPSK modulation formats. In order to meet the dynamic rate requirements the modem is implemented using digital signal processing (DSP) techniques. The codec supports variable coding rates: uncoded PSK and 1/2, 2/3, 4/5 punctured codes, derived from a ½ convolution encoder, thus providing one more way to adapt the information bit energy to the channel quality. Coupled with the symbol rate agility, this allows an overall information rate of 512-8192 Kbit/s in QPSK or 256-4096 Kbit/s in BPSK.

4. THE SATELLITE ACCESS SCHEME

4.1 Master/slave functions

FODA/IBEA-TDMA control is centralised. Any station can be the control station (master), while concurrently acting as a slave station. If faults arise, the master station may be replaced by any other station. The issue of centralised versus distributed control is in constant debate. A centralised algorithm is more robust than a distributed one in most sorts of contingencies, because one station alone (the most powerful or the least faded one) is responsible for the consistency of the burst time plan. In the distributed case all stations are responsible, so all stations have to listen to each other, thus increasing the chances that some control information is lost or misinterpreted and the burst time plan corrupted. Distributed control, on the other hand, is more responsive to traffic variations, because only one round trip time is needed for the network to find out the traffic situation of its components, so highly burst traffic sources are more efficiently dealt with, thereby increasing the global channel utilisation. Distributed control systems may compensate for the lack of robustness with complex recovery algorithms, which usually impose some additional channel overhead. We chose centralised control because of its robustness, letting the complex datagram assignment algorithm (discussed below) compensate for the responsiveness deficiencies caused by the double round trip delay. The functions of the master and slave stations are reported below.

The master:

a) allocates time within the TDMA frame for the stream and the datagram transmissions of the slaves on the basis of their requests,

b) Broadcasts the fade level declared by each station,

c) Maintains the synchronisation of all the stations within the network,

d) Is responsible for maintaining the optimum transmit power level, which is used by all the slaves as a reference level,

e) Uses the frame space allocated to itself to send data over the network in the same way as any other slave station.

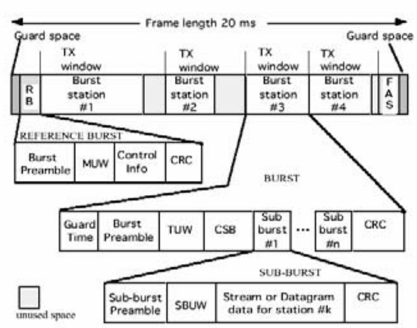

Fig. 3. Frame, Burst and Sub-burst Formats

The slave:

a) Sends allocation requests for stream and/or datagram transmissions to the master,

b) Communicates its fade level to the master station,

c) Adjusts the transmit power level keeping the master as a reference,

d) Uses its allocated frame space to send data throughout the satellite network,

e) Chooses the symbol rate and the code rate for the single data sub-burst to send inside its transmission window, depending on the fade level of each link.

4.2 THE FRAME FORMAT

The FODA/IBEA frame is 20 ms long; the format is shown in Fig. 3.

Picture legend:

Reference burst. Burst Preamble for modem acquisition. Sub-bursts preamble for modem acquisition. Shorter than the burst preamble. MUW Master Unique Word. For modem acquisition. Relevant to the reference burst only. TUW Traffic Unique word. For modem acquisition. Relevant to each data burst SBUW Sub-burst Unique Word. Half the length of the MUW or TUW. Control info This part of the RB contains the stream and datagram assignments of each station, the fade level measured by each station, the frame number, the address of the next master station (in case of master recovery procedure), etc. Control Sub-Burst. It describes the relevant data burst. It contains information describing the individual sub-bursts contained in the burst, such as the data destination, length, coding and bit rate, information relative to the disassembling and reassembling of the data, the datagram and/or the stream requests, the measured fade levels, etc.

The minimum overhead per frame (due to the reference burst and the guard times, in Fig. 3) is about 8.6% of the available bandwidth of 8 M bit/s with the timings of the current prototypal hardware and the parameters chosen for the reference burst. The rest of the channel is available for burst transmissions, where every burst and every sub-burst within a burst needs some overhead. Our prototypal software adds one more frame length delay, mainly because of CPU speed problems. The *reference burst* is sent by the master station in order to assign the time allocations (transmission window times) for the transmissions of the requesting slave stations. The reference burst is always sent at a bit rate of 2 M bit/s and a coding rate of 2/3, thus allowing a 10-5 probability of correct reception for down link fades up to 14 dB.

A station uses its assigned transmission window to send its stream and datagram data together. Data can be multiplexed inside a transmission window, allowing the datagram data to be transmitted in the portion of the stream assignment when possible, such as during the silence periods of the voice applications. Due to the assignment algorithms (described in 4.4), the part of a transmission window assigned to the stream data transmission maintains its size in every frame while the part for the datagram data may change size at each frame. Therefore, the transmission window sizes must be recalculated by the master at each frame. Space for a First Access Slot is reserved every 32 frames, by reducing the space available for data transmission, to allow a new station to enter the network. This slot is used in contention among all the new stations. The FAS is sized for sending requests, control information and a small amount of data, plus the uncertainty due to the current satellite position with respect to the nominal satellite position. This safety space is currently set to ±150ms. The FAS has a fixed position inside the frame (before the end of the frame). It must be accessed at 1 M bit/s, 2/3 coded. This bit rate is lower than the bit rate of the RB because even heavily faded stations must have the opportunity to enter the satellite network. In this case, the faded station receives the RB affected by the down link fade only, but it receives its own FAS affected by both up and down link fades. The lower FAS bit rate is intended to cope with this situation. The term stream sub-frame will be used hereafter to indicate the overall amount of frame devoted to the stream allocations. Likewise, datagram sub-frame indicates the amount of frame devoted to the datagram allocations.

5. THE PROTOCOL TO ACCESS THE SATELLITE NETWORK

An ad-hoc protocol (GAFO protocol [6]) has been developed to handle communications between the satellite network and the gateway interfacing it. The protocol provides for control messages and data messages. Specifically, the control messages allow the system to:

• Set • up/close a connection-oriented session for stream applications;

• Build/cancel/modify a sub-set of users allowed receiving data;

• Exchange control information about the network addresses of the gateway, the Up controller and the

Down controller;

• Stop/resume sending datagram data (congestion control);

• Exchange information about the status of other stations.

The data messages support:

• sending/receiving stream data with/without CRC;

• sending/receiving datagram data with/without CRC;

• sending/receiving test data with/without CRC.

The protocol was implemented in the C language on the Up controller, the Down controller and the gateway. The control packets are 12 bytes long, while the overhead for the data packets is 6 bytes. This information is not transmitted to the satellite link.

6. LANs INTERCONNECTION

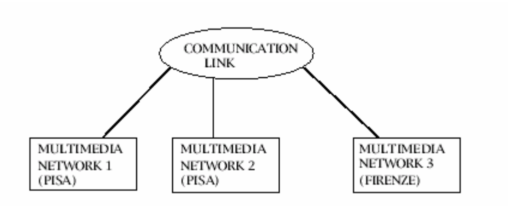

Fig. 5. MALAN Logical Structure

LANs can support voice, video and data transmissions [12]. This experiment, named MALAN (Multimedia Applications on LANs) was developed in a scenario characterised by two fundamental components:

• The communication link, consisting of earth stations and satellite,

• The local infrastructure, connected by the communication link and consisting of a collection of LANs (Ethernet and Token Ring). Two fundamental prerequisites had to be fulfilled:

• To develop a set of significant applications involving voice, video and data;

• To package those applications in a portable system. The logical configuration of the experiment is shown in Fig. 5, where each box labelled Multimedia Network represents a portable system together with the applications. A Multimedia Network consists of several elements

• The internal Token Ring *LAN*.

• The external Ethernet *LAN*.

Each Multimedia Network is connected to the Communication Link through the gateway. It introduces a simple priority mechanism in favour of the stream traffic, as it can distinguish between information coming from the Data application and information from Voice and Video applications. The latter always has precedence over the former. In addition, the gateway measures the total traffic flowing back and forth from the LAN and the Communication Link. Applications were selected in order to represent the most significant media: data, voice and video. *Data* is a TCP/IP based application and transfers files. Each image is 153 Kbytes and the image format is VGA bitmap. *Data* could thus be defined as an image transfer application. In this way two goals are achieved:

• To significantly load the LAN,

• To visually control the results of the application.

Images are transferred iteratively, without any action by the user. Voice provides a real-time telephone-like connection. Using a simple interface, users call a remote destination and start a conversation. Two options are available: voice sampled at 8 bits and voice sampled at 14 bits extended to 16, without any encoding. In the first option, traffic of 64 Kbit/s is generated; in the second, traffic of 128 Kbit/s is generated. *Video* provides the core of a video-conference service, making use of the same interface applied in Voice, a remote user can be called and a remote conversation can start. Two communication options are available:

384 K bit/s and 1664 Kbit/s. The active elements in the Multimedia Network are

connected by means of two LANs: a 10 M bit/s Ethernet and a 16 M bit/s Token Ring. Ethernet and Token Ring are selected alternately, so as to get an empirical comparison.

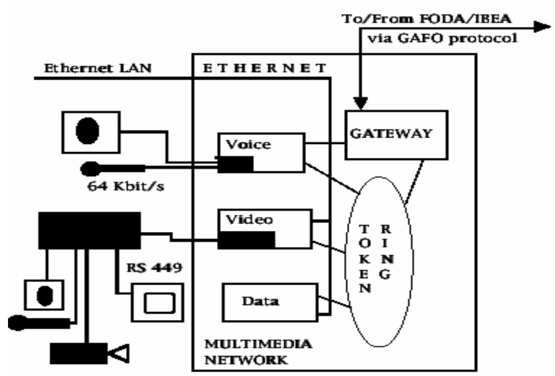

Fig. 6. The Multimedia Network structure

6.1 Physical description of the multimedia network

From a physical point of view, the Multimedia Network is a rack packaging four computers connected by two separate networks, an Ethernet and a Token Ring, plus a complex set of peripheral equipment for voice and video acquisition

Programmable Array (FPGA) and a Digital Signal Processor (DSP), memory and logic to interface to the external world. The programmability of both the FPGA and the DSP allows the same board to be used for both voice and video. Video-codec, made by Compression Labs Inc. (CLI), is connected through an RS-449 link to video. A monitor, a microphone, a loudspeaker and a camera are also connected to the video codec. Each computer can be connected to a monitor and a keyboard. An MS

DOS operating system is installed on each computer, and the driver for the communication adapter. Drivers for XIL-DSP were specially developed by DEE. C is used as the programming language, with a small Assembler portion.

CONCLUSIONS

In the first phase of the project the FODA/IBEA satellite network (software plus hardware) was developed which, up to now, is a prototype unique in the world of TDMA satellite networks which can adapt the robustness of the data transmission to the fade conditions of both the sending and the receiving stations. Inside the same transmission window data are addressed with different redundancy information values according to the atmospheric conditions of the stations. • the satellite link can be divided among many users, like any other terrestrial link;

• The already existing infrastructures (LANs) can be used for multimedia applications.

As far as the first point is concerned, only one satellite channel can interconnect several sites with a complete net. This is not easy to achieve with terrestrial links. Only one channel multiplexes stream and datagram data together, reserving the available bandwidth for the datagram after stream handling. It is possible to define high-level software protocols which reserve a minimum space for the datagram data and handle the stream sessions in an adaptive way

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