High Data Rate Applications of ACTS Technology

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ABSTRACT

The telephony environment is evolving into the Integrated Services Digital Network (ISDN) which will provide a variety of new services to its customers. High data rate services and transmission methods are currently being defined that will be realized with the deployment of the Broadband ISDN (BISDN). The National Aeronautics and Space Administration (NASA) Advanced Communications Technology Satellite (ACTS) Program will conduct High Data Rate (HDR) experiments that will be applicable to the emerging broadband services of the telephony market.

The deployment of the BISDN may require a period of time extending over one, or more, decade(s) as operators seek to find the most economic means of evolving current networks to the BISDN [1]. Satellites will find a role in this evolutionary process as a transition service, alternate service and service of choice. The extent of satellites' role in the deployment of the BISDN will depend on the development of standards, market use of the services, and the capability of satellite systems to provide the desired services.

The text below will discuss the existing BISDN services and delivery method as defined by the International Consultative Committee for Telephone and Telegraph (CCITT) and satellites' role in provisioning those services. The NASA HDR ACTS experiment efforts are also summarized.

CCITT BISDN DEVELOPMENTS

International standardization of the BISDN is a process within the CCITT Study Groups (SG). The BISDN Recommendations were written, in part, to take into account the following:

- the emerging demand of broadband services;
- the availability of high speed transmission, switching and signal processing technologies; and
- the need to provide flexibility in satisfying the requirements of both user and operator [1].

CCITT SG XVIII commenced BISDN studies in January 1985. In 1988, the first CCITT approved BISDN Recommendation (I.121) provided guidelines on the principles of BISDN and its further refinement. At its November 1990 meeting in Japan, SG XVIII approved 13 new BISDN Recommendations and agreed to submit them to the rules of Resolution No. 2 (Accelerated Approval Procedures) [2-13]. The majority of these Recommendations are still in the draft form. SG XVIII's objectives for the 1992 BISDN Recommendations are to have a sufficiently detailed text allowing for the initial support of BISDN services using standardized procedures and interfaces [14].
SYNCHRONOUS DIGITAL HIERARCHY

The Synchronous Digital Hierarchy (SDH) has been agreed upon as the international standard for BISDN bit rates. The associated line bit rate is 155.520 Mbps of which 149.760 Mbps are available as transfer capability for subscribers [15]. The framing structure at this rate is referred to as the Synchronous Transport Module 1 (STM-1). This capacity is expected to be adequate for interactive service requirements in the foreseeable future. In the longer term, a bit rate of 622.080 Mbps, corresponding to the second level of the SDH, is also being standardized. The frame structure for the STM-1 is shown in Fig. 1.

The frame is byte-oriented and contains 9 rows and 270 columns broken into three main areas. Rows 1-3 and 5-9 of columns 1-9 of the STM-1 are dedicated to Section Overhead (SOH). The tenth column contains the Path Overhead (POH). The remainder of the frame is designated as the Administration Unit (AU-4). AU-4 also includes a pointer which resides in row 4 of columns 1-9. In generating the frame, the payload is first mapped into a specific sized envelop for the STM-1; i.e., Container (C-4). C-4 is mapped into Virtual Channel 4 (VC-4) along with the POH and VC-4 is then mapped into AU-4. The AU-4 pointer is fixed in location within the frame but the VC-4 payload is not. The VC-4 payload can be moved within the AU-4, and the AU-4 pointer is used for finding the first byte of the VC-4. The end result of this technique of packaging and allowing the payload to move within the frame is that it obviates the need for buffers and avoids associated slips at equipment interfaces [16].

The structure of the SDH permits byte interleaving to form an STM-n frame. The pulse frame has the same structure as in Fig. 1, but the number of octets per row is n-times larger. The frame repetition rate is 8 kHz for any integer n that can be employed.

ASYNCHRONOUS TRANSFER MODE

Asynchronous Transfer Mode (ATM) is the selected mode for implementing BISDN services. The ATM cell is the unit which carries information and is switched through the BISDN. ATM provides some specific advantageous facilities:

- high flexibility of network access to users;
- dynamic bandwidth allocation on demand with a fine degree of granularity;
- flexible bearer capability allocation and easy provision of semipermanent connections; and
- independence of the means of transport at the physical layer [1].

ATM achieves this by employing a multiplexed, packet-oriented technique which organizes cells of fixed length cells for inclusion into a multiplexed stream. At the User-Network Interface (UNI), the interface structure can be implemented in one of two ways. The UNI can be a continuous stream of ATM cells clocked at a bit rate of 155.520 Mbps or 622.080 Mbps or an SDH frame into which the ATM cells are mapped [12].

ATM is a connection-oriented technique requiring end-to-end call establishment procedures. Each ATM cell is 53 bytes in length and consists of a header and information field. The header size is 5 bytes in length while the information field is 48 bytes in length. The header and information field sizes remain constant at all reference points where the ATM technique is applied. Figure 2 shows the structure of the ATM header at the UNI and the Network Node Interface (NNI) [8].

ATM Header Fields

The Generic Flow Control (GFC) field exists in the ATM cell at the UNI but not at the NNI. The GFC function is implemented at the UNI to alleviate short term overload conditions that may occur. The GFC function is expected to restrict cells from the user and not the network. The GFC mechanism must allow a terminal to achieve an assured capacity or bandwidth allocated by the network to both Continuous Bit Rate (CBR) and Variable Bit Rate (VBR) calls. In the case of VBR calls, the GFC mechanism must be able to partition the capacity, above that guaranteed, among all the active connections.

The Virtual Path Identifier (VPI) and Virtual Channel Identifier (VCI) fields are used for connection identification within the BISDN. At the UNI, 24 bits are available for this purpose while 28 bits are used at the NNI.

The Payload Type (PT) field is used to provide an indication of whether the information field of the ATM cell contains user information or network information. Network information cells are not part of the user’s information transfer, and when they are used; further information concerning the type of network control will be found in the information field of the cell.

The Reserved (RES) field (1 bit) is to be used for further enhancement of cell header functions or for other functions. The Cell Loss Priority (CLP) field (1 bit) used to indicate which cells are subject to discard depending on network conditions. Cells that do not have the bit set have higher priority, as network capacity for them has been allocated. This bit may be set by the user or service provider.
The Header Error Control (HEC) field (8 bits) is used to detect or correct errors within the cell header. The error protection function provided by HEC provides both recovery from single-bit header errors and a low probability of the delivery of cells with errored headers under bursty error conditions. For some transmission systems the error correction capability might not be invoked.

ATM Connections

The ATM cells are hierarchically arranged into Virtual Channels (VCs) and Virtual Paths (VPs) within the BISDN. The header of the ATM cell contains the common unique identifier value of the VC and VP which the cell is associated with. A VC is a generic term used to describe a unidirectional communication capability for the transport of ATM cells. Within the BISDN network, VCs are aggregated into VPs through the use of a common identifier value in the ATM cell header [10].

In general, signalling and user information are carried on separate layer connections. A meta-signalling virtual channel is used to create signalling channels to establish and remove Virtual Channel Connections (VCCs). The meta-signalling virtual channel is a permanent virtual channel connection differentiated via a unique header value.

ATM ADAPTATION LAYER

The ATM Adaptation Layer (AAL) can provide services to the service-user layer that are not provided by ATM. It is not required, however, that the AAL be invoked by all applications. Implementation of the AAL takes place within the 48 octet information field of the ATM cell as shown in Fig. 3. The AAL receives information from the ATM layer in the form of an ATM Service Data Unit (ATM-SDU). The AAL also passes information to the ATM layer using an ATM-SDU [10].

Example services handled by the AAL are transmission errors, lost and misinserted cells, quantization effect due to cell information field size, transmission errors, flow control, and timing information. The AAL is further divided into a SAR (Segmentation and Reassembly) sublayer and CS (Convergence Sublayer). The prime function of the SAR sublayer is to segment higher-layer information into a size suitable for the information field of an ATM cell (at the source) and reassemble the contents of the ATM cell information fields in higher layer information (at the destination). The function of the CS is to provide AAL services at the AAL Service Access Point (SAP). Some example services of the CS include forward error correction, clock recovery, and time stamping of cells or information fields. Depending on the application, the SAR sublayer and/or the CS may be empty.

AAL Service Classes and Protocols

In order to minimize the number of AAL protocols, a classification specific to AAL services has been defined based on the following parameters:

- timing relationship between source and destination (required or not required);
- bit rate (constant or variable); and
- connection mode (connection-oriented or connectionless) [9].

Some combinations of these parameters are not required; for example, a timing relationship for a connectionless bearer service. Four classes are distinguished as shown in Fig. 4.

To support the four service classes A-D, four types of AAL protocols are being standardized [17, 18]. The internal structure of the ATM-SDU for the four AAL types is under study within SG XVIII.

AAL type 1 supports constant bit rate services such as voice transport. Type 1 services include segmentation and reassembly of user information, handling of lost and misinserted cells, handling of cell delay variation, and source clock frequency recovery.

AAL type 2 provides services similar to those of AAL type 1; maintaining the timing relationship between source and destination while handling variable bit rate transmissions.

AAL type 3 supports connection-oriented data services such as X.25 and Frame Mode Bearer Service (FMBS). AAL type 3 also incorporates a Cyclic Redundancy Check (CRC) calculation.

AAL type 4 supports connectionless data services and would provide for the interconnection of Local Area Networks (LANs) or Metropolitan Area Networks (MANs).

BISDN SERVICES

CCITT draft I.211 defines the services provided by the BISDN [4]. These services are the functions that the BISDN
will provide in the support of applications. The BISDN services
are divided in two stages creating specific service definitions.
The first differentiation occurs between interactive and
distribution services. An interactive service provides for the
bidirectional exchange of information between users or between
users and hosts. A distribution service provides for the
unidirectional flow of information from a given point to other
(multiple) locations [2].

**Distribution Services**
Distribution services are further subdivided into distribution
services without user individual presentation control and
distribution services with user individual presentation control.
In distribution services without user presentation control, users
obtain service without having the ability to exercise control
over the start and order of the presentation of the distribution
information. This service class can be visualized as analogous
to current broadcast TV and radio services.
Distribution services with user presentation control provide
the information as a sequence of information entities, e.g., cells
with cyclical repetition. A short cycle may be used for
frequently referenced material. Examples of this type of service
are applications such as stock prices and commodity markets
and weather forecasts. In general, this service will provide
services to a specific limited user group with interest in an
information set that changes in real time [19].

**Interactive Services**
Interactive services are subdivided into the following:

*Conversational*:
Conversational service provides for
bidirectional communication via real-time, end-to-end
information transfer from user to user. The flow of information
may be bidirectional symmetric, bidirectional asymmetric or
even unidirectional (e.g., video surveillance). Example
applications for this service are video telephony, video
conference, distributed supercomputer data processing and
supercomputer supported visualizations.

*Messaging*:
Messaging service offers user-to-user
communications between individual users via intermediate data
bases. These data bases would provide functions such as store-
and-forward, mailbox and/or message handling (e.g.,
information editing, processing and conversion) functions. This
type of service could provide for the delivery of moving
pictures, high-resolution images and audio information.
Applications using this service would be variations of multi-
media electronic mail.

*Retrieval*:
Retrieval service provides for the retrieval of
information stored in databases by users upon demand. The
time at which information starts is under the user’s control.
In addition to being the “receive” counterpart of the “send”
messaging service, this service provides access into databases
intended for public use. Some applications using this service
are Home Shopping, Education/Training, Video on demand,
Computer Aided Design/Computer Aided Manufacturing
(CAD/CAM).

**BISDN SERVICES VIA SATELLITE**

Satellites are well-suited to support multipoint and broadcast
communications over a wide geographic area [20]. Two of the
inherent characteristics of satellites in this regard are:

1. All end points in a coverage area receive the same signal; and
2. The bandwidth occupancy is independent of the number of end
points in a coverage area; or conversely, the greater
the number of end points, the lower the amount of network
resources per end point.

Two other characteristics of satellites that make them
particularly suited to support BISDN services in general, are
their ability to:

1. Dynamically allocate network resources to specific network
end points and effect temporary broadband connections;
2. Provide for early introduction of all BISDN services in areas
where customers are geographically dispersed or otherwise
unable to receive those services terrestrially.

In addition, the use of satellites may contribute to the
flexibility of the BISDN through its direct integration into the
network. For example, satellites can easily support network
connections for Distribution Services without user individual
presentation control through satellite links terminating at the
Service Access Points (SAPs). Similarly, satellites could also
support the messaging and retrieval services of a BISDN. The
systematic integration of satellites into the BISDN will also
enhance network redundancy, hence the BISDN’s disaster
recovery capability.

Although satellites are inherently capable of providing
BISDN services, satellites’ role in this regard is dependent, to
a large degree, on the documents that define the BISDN. The
majority of the BISDN documents are currently being
developed, and reasonable provision must be made within their
development process to allow for satellites to assist in achieving
the goals of the BISDN.

**ACTS HIGH DATA RATE PROGRAM**

State-of-the-art satellites employing high-power, wide-
bandwidth transponders are proving themselves capable of
supporting BISDN services. The ACTS will be used to conduct
High Data Rate (HDR) experiments. The ACTS is NASA’s
research and development flight program scheduled for launch
in the first quarter of 1993.

**ACTS High Data Rate Study**

A NASA-funded study by Comsat Laboratories
(Germantown, MD) examined possible HDR Earth terminal
and network concepts and their feasibility for satellite
communications through the ACTS microwave switch matrix
mode (MSM) of operation. The study, which began in
February, 1991, evaluated a number of items (e.g., Earth
terminal characteristics, network characteristics, standards,
critical hardware equipment costs, and technology) that would
influence the design, equipment selection, and cost of a HDR Earth terminal developed in the 1992-1996 time frame [21].

Comsat considered a system-level, satellite switched, time-division multiple access (SS-TDMA) network control design for a mesh network that used the ACTS MSM and scanning, isolated, and fixed beams. Potential Earth terminals were to use time-division multiplexing to communicate among themselves and with a terrestrial network. At the study’s final review, Comsat presented potential characteristics of a Earth terminal and its network. A hypothetical Earth terminal design was presented that had T1 (1.544 Mbps), T3 (44.736 Mbps) and OC-3 (155.53 Mbps) interfaces. The design anticipated use of 2.4- or 4.7-m-diameter antennas and 100- to 120-W transmitters to achieve availability of about 0.995 with a bit error rate of $10^{-11}$ in all ACTS coverage areas.

NAS/DARPA High Data Rate Activities

NASA in conjunction with the Defense Advanced Research Projects Agency (DARPA) is developing research prototypes of HDR Earth terminals to be used with the ACTS. The Earth terminals will be used for advanced applications and experiments involving satellite and satellite/terrestrial networks in support of the High Performance Computing and Communications (HPCC) Program, the DARPA Basic Research Program, and NASA ACTS Program objectives [22].

A minimum network of three Earth terminals will be created to demonstrate new capabilities and functionality that are possible using satellites in a network at very high data rates. Three overall goals are to achieve:

1. A very high data rate between two sites in a point-to-point configuration;
2. Flexibility in allocating capacity to multiple senders and receivers in a network configuration; and

Three of the terminals will be portable with the antenna diameter not to exceed 5 meters. The minimum system data rate is to be capable of supporting at least a Synchronous Optical Network (SONET) Optical Carrier 3 concatenated (OC-3c).

It is anticipated that the HDR system will be available for experimentation in the mid-1994 time frame. End-user application requirements have not yet been fully defined.

CONCLUSION

Satellites have the capability to extend BISDN services beyond the range of the terrestrial BISDN and will possibly provide certain BISDN services more cost effectively, either in a direct competitive or hybrid satellite-fiber implementation. In order to do so, satellites’ inherent flexibility must be used to address the wide range of services and lessen the network impact of future technology and market uncertainties.

REFERENCES