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Source	David W. Jarrett Lucent Technologies 890 Tasman Drive Milpitas, CA 95035	Voice: Fax: E-mail:	+1-408-952-7452 +1-408-952-7456 djarrett@lucent.com
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Abstract	There was much discussion during IEEE 802.16 #0 on the target applications and services for our system requirements work, and therefore also for our MAC and PHY work. The following gives ITU-T definitions and Bearer Services and Teleservices, and proposes Bearer Services to be supported in the IEEE 802.16 System Reference Model.		
Purpose	The 802.16 Systems Requirements group should vote on which bearer services listed in this contribution should be covered in the System Reference Model, and therefore be addressed by the MAC and Phy work.		
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Definition of Bearer Service and Teleservice, and Services for Consideration by 802.16 Systems Requirements Task Group

David W. Jarrett
Lucent Technologies

Introduction

The following gives ITU-T definitions and Bearer Services and Teleservices, and proposes Bearer Services to be supported in the IEEE 802.16 System Reference Model. The 802.16 Systems Requirements group should vote on which bearer services listed in this contribution should be covered in the System Reference Model, and therefore be addressed by the MAC and Phy work.

Teleservices and Bearer Services

There was much discussion during IEEE 802.16 #0 on the target applications and services for our system requirements work, and therefore also for our MAC and PHY work. This contribution offers the following definitions from ITU-T I.210, "ISDN Service Capabilities – Principles of Telecommunications Services Supported by an ISDN and the Means to Describe Them" [1]:

Teleservice: "Teleservices provide the full capacity for communications by means of terminal and network functions and possibly functions provided by dedicated centers."

"A teleservice supported by an ISDN should use only one (or a small number of) bearer capability(ies) recommended by the CCITT. It should be noted that in the case where more than one of the recommended bearer capabilities is used for a given teleservice, network interworking functions may be required under the responsibility of the teleservice provider. However, a user operating a specific application is not prevented from using a terminal compatible with a given teleservice in association with a bearer capability not recommended for this teleservice. Examples of teleservices are telephony, teletex and videotex".

Bearer Service: "Bearer services supported by an ISDN provide the capability for information transfer between ISDN access points 1 or 2 and involve only low layer functions."

"The customer may choose any set of high layer (at least 4 to 7) protocols for his communication, and ISDN does not ascertain compatibility at these layers betweeb customers. An example of a bearer service is demand circuit-mode, 64 kbit/s unrestricted, 8 kHz structured bearer service."

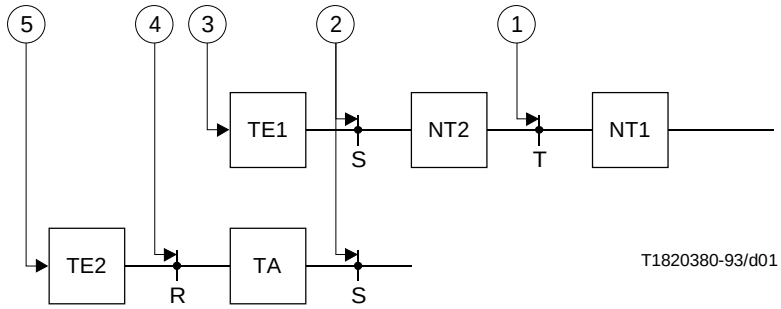

FIGURE 1/I.210

Customer access to services supported by an ISDN

"The definitions of the access points introduced in Figure 1 are as follows:

i) Access points 1 (reference point T) and 2 (reference point S) are the access points for bearer services supported by an ISDN. The choice between access point 1 (T) and 2 (S) depends on the ownership and form of provision (to the customer) of the communications equipment at the customer premises. The service classification and descriptions in the following are independent of different possible arrangements for such provision.

ii) At access point 4 (reference point R), depending on the type of terminal adaptors provided, other CCITT standardized services may be accessed, e.g. according to the X- and V-Series Recommendations.

iii) At access points 3 and 5 (user-to-terminal interface), teleservices are accessed – the teleservice concept includes the terminal capabilities."

"The following customer entities may be connected at access points 1 and 2:

– customer terminals;

– customer systems, e.g. PABXs, LANs, service vendor systems;

– private networks.

NOTE – Customer terminals and systems may be private or provided by Administrations."

Therefore to paraphrase, teleservices cover the full seven layers of the OSI protocol layer model and are seen at the terminal equipment, while bearer services cover the lower three layers of the OSI model are seen at the interface between the network and the terminal equipment. The bearer service interface is consistent with interface point A on the reference diagram from 802.16sc-99/3 [2], while teleservice interface cannot be seen on this diagram.

This contribution's position is that the 802.16 Systems Requirements Task Group should discuss support for bearer services in the reference architecture. However, it is reasonable to also discuss teleservices, but only as a means to illustrate necessary aspects of the services that the 802.16 MAC and PHY will need to carry. The 802.16 Systems Requirements Task Group should not specify support for services between terminal equipment and the user.

Bearer Services for Consideration

The following sections will give qualitative descriptions of the bearer services this contribution requests the 802.16 System Requirements group to consider. Some information is given on the types of services, protocols used, QoS parameters, and other bearer service aspects. Full descriptions of the selected services can follow once the set of services has been selected. Note that this contribution intends that broadband wireless access networks only support the necessary user data, control and management protocols to enable these bearer services between reference points A and E of the reference model found in 802.16sc-99/3 [2].

This contribution asserts that 802.16 System Requirements work should cover services of interest to small, medium, and large business customers. These services may overlap with services of interest to other market segments (e.g., residential), but those other market segments should not be addressed explicitly.

This contribution does not provide any detailed market information or justification for the services listed below. However, this contribution asserts that these services are the most widely requested by service providers in the U.S. and every other region of the world (i.e., Latin America, the Caribbean, Western and Eastern Europe, Africa, and Asia and Pacific Rim countries) considering deployment of broadband wireless access systems. These services represent those most currently popular as well as those projected to be popular in the foreseeable future.

It is this contribution's position that the 802.16 Systems Requirements should remain agnostic to any particular implementation technology. If 802.16 determines its Systems Requirements based on a specific technology, it will not be useful in the long-term as an international standard. Rather, 802.16 should specify a system via MAC and Phy capabilities that will allow flexible support for all of the bearer services listed below. In this way 802.16 will produce a standard that will be useful now and extensible in the future.

Narrowband/Voice Frequency Telephony

This represents a general class of analog and digital telephone services that offer narrowband voice and data communication between users. The most widely known of these services is the so-called "Plain Old Telephone Service" (POTS). Here, circuits with voice frequency information (analog at the user interface, digital in the network) are requested from a central switching network and dedicated through the network while active. However, other services in this category include coin telephone service, ISDN BRI/BRA, and PC Telephony. These are all connection-oriented services, even though the lower layers supporting them are connection-oriented (as with POTS and ISDN BRI) or connectionless (as with PC Telephony). The basic bearer service needs of telephony services are the following:

- Supervision – monitoring the activity of a user's termination for the ability to accept new incoming calls, or requests from the user to make a new outgoing call.
- Call Signaling – sending messages from a user to request a new call, tear down an existing call, or modify an existing call with other end users.
- Alerting – informing a user of a new incoming call.

- Testing – initiating signals from the central network to troubleshoot possible problems with a user's termination.
- Coding – of user information (e.g., analog voice) to the transmission format (e.g., PCM).
- Power – basic POTS has traditionally provided power to the end user's terminal equipment (i.e., handset) so that telephone service will still work even when commercial power is interrupted. This allows POTS to support so-called lifeline service, where telephone service is always available to support calls to emergency service such as 911. However, not all services in this category provide network powering (e.g., ISDN BRI in the U.S., and PC telephony).
- Bandwidth - in general, the codings used in these services require bandwidths in the range of 64 kbps or less per call (one exception is ISDN BRI service with both B channels active, which uses 128 kbps). There are also some subjective quality metrics for the clarity of the encoded speech signals, that can vary based on the quality of the services sold to the end user (e.g., residential vs. business).
- Low delay – as apparent to the end users, the amount of delay between a user speaking and another user hearing the speech must be kept below a certain level to support two-way conversation. Again, the specific amount of delay can vary based on the quality of the service sold to the end user.
- Reliability – the network supporting service among end users can be engineered so that downtime (the time when a user cannot get network service due to a network fault) is limited to minutes a year on average. This is yet another metric that can be varied based on the service sold to the end user.

There are a number of supplementary services that can be added to the basic Bearer Service to enable capabilities such as Caller ID, Call Waiting, special dialing plans, three-way/conference calling, etc. These services require additional user-to-network signaling information above that required to request and terminate calls.

There are a number of existing protocols to carry signaling information for supervision, call signaling, alerting, and testing, as well as for supplementary services. These may be bit oriented (e.g., Bellcore TR-008), message based (V5.X, Q.931, H.225, H.245, MGCP), or a combination (Bellcore GR-303). The type of signaling used will vary based on the specific flavor of the bearer service and the types of network supporting it (e.g., POTS vs. PC Telephony), but the low network layers must support these for interoperation with legacy networks.

PBX Trunking

This is service to business users to connect their private, internal telephone switching equipment to the larger telephone network (PBX expands to "Private Branch EXchange"). As with telephony services, the most common current implementation is circuits switched through a central network, carrying voice and data traffic. Also, the most common physical layers are DS1 (North America) and E1, although there are other options using analog or digital technology. The individual circuits carried are commonly 64 kbps each, but with a maximum of 24 or 31 per physical connection (for DS1 or E1, respectively). Packet telephony technology (VOIP, VTOA, and VOFR) is being used to transform circuit-oriented voice to packet streams, with varying levels of compression, for more efficient multiplexing with packet data traffic over various physical layers.

The bearer service requirements are much the same as for telephony services, except that the terminal equipment (i.e., PC or telephone handset) does not communicate directly with the network. Therefore, requirements such as powering do not apply, and others are modified (e.g., the PBX performs supervision of terminal equipment, but the network performs separate supervision of the trunk to the PBX). In particular, the signaling used is still bit oriented and/or message oriented, but different standards as used (ISDN PRI, MFC R2, E&M, Q.sig).

Leased/Dedicated Circuit

Leased and Dedicated circuits are also used primarily by businesses, but to support voice and data transmission between two points with no switching by a central network. The network typically offers synchronous, bit-oriented service over standard WAN physical layer technology (i.e., 56/64 kbps lines to DS3/E3) or legacy serial interfaces (V.35, EIA-530, X.21, HSSI). A Leased and Dedicated Circuit Bearer Service would therefore offer (virtual) point-to-point service to transfer the user's bits transparently.

Such transfer of user information will require a continuous, low-delay, and low error transport service from the lower-layer network. Also, although leased circuits are available at rates as low as 9.6 kbps, this contribution advocates that the lowest rate considered by 802.16 be 56 kbps.

Routed IP

This is the bursty, connectionless transfer of variable length, Layer 3 IP packets from customer equipment (e.g., a router or IP switch) across the access network to other network or customer equipment. These IP packets may contain higher-layer protocol data such as UDP, TCP, ICMP control messages, etc. Many teleservices and applications can be enabled on this bearer service, such as internet access, remote (corporate) network access, IP VPN, etc. However, the Routed IP bearer service simply requires the transport network to encapsulate IP packets to the MAC/Phy layer format and send them to the next hop. Common encapsulation protocols include IEEE 802.2 LLC/SNAP and HDLC (and variants).

IP protocols and networks have historically been oriented to provide best effort service for traffic received from many users. There have been no standards covering priority, bandwidth guarantees, or any other aspects of traffic management across a network. Higher- (and in some instance, lower-) layer protocols have had the responsibility to ensure reliable delivery of packets across the network. However, various standards and specifications are emerging (IntServ, RSVP, DiffServ, etc.) to support different levels of priority for user packets, bounding of delay, and general traffic management through a heterogeneous network. In addition, some access network standards (e.g., DOCSIS 1.1 and later) guarantee bandwidth for IP traffic. Finally, other standards are emerging to support bearer services requiring better than best effort service (e.g., voice telephony) over IP.

There are no standards, but various practices that specify bearer service needs for IP such as bandwidth, latency or error/loss rates. Some of these are determined by the lower layers over which IP runs; e.g., Ethernet technology and topology determines the bandwidth available for IP in Ethernet LANs. Networks transporting IP may need to support multicast and broadcast communication in addition to the basic unicast service.

Bridged Ethernet (Remote Bridging)

This is the bursty, connectionless transfer of Layer 2 Ethernet frames from customer equipment (e.g., an Ethernet Switch, Hub, or Bridge) across the access network to other network or customer equipment (also known as Remote Bridging). These Ethernet frames may contain many Layer 3 protocols such as IP, IPX, Appletalk, DECnet, etc. IEEE 802.2 LLC/SNAP is the most common protocol used to encapsulate Ethernet before it is passed to the MAC/Phy layers. The most important Ethernet MAC/Phy layers for 802.16 to consider are IEEE 802.3 (10 Mbps Ethernet) and 802.3u (100 Mbps Ethernet). However, IEEE 802.5 (4/16 Mbps Token Ring) and ANSI FDDI (100 Mbps) could also be considered.

The Ethernet Mac and Phy layer protocols used at the interface to the end customer's terminal equipment will also influence some aspects of the bearer service needs (e.g., bandwidth). Additionally, IEEE 802.1D (Transparent Bridging with the Spanning Tree Algorithm) describes QoS parameters for a local bridging service. These same parameters can be used to specify the performance of the remote bridged Ethernet Bearer Service to be offered by 802.16 specifications, with some changes to specific parameters. They include:

- Service Availability
- Frame Loss
- Frame Misordering
- Frame Duplication
- Transit delay experienced by frames
- Frame Lifetime
- Undetected frame error rate
- Maximum service data unit size supported
- User Priority
- Throughput

Frame Relay Service

Frame Relay Service (FRS) is a connection-oriented, bursty data service that allows for the transfer of variable length frames across standard WAN physical layer technology (i.e., 56/64 kbps lines to DS3/E3) and legacy serial interfaces (V.35, EIA-530, X.21, HSSI). ITU-T Q.922 defines the Frame Relay data link layer specifically as an ISDN bearer service. The frame structure defined there is analogous to HDLC, and includes some HDLC elements. This frame structure is used to directly map Frame Relay frames to the physical layers. However, this frame structure is altered somewhat when mapping to other physical layers, such as ATM.

Frames are relayed from a source to a destination by means of virtual connections, which can be established or torn down via administrative procedures (for PVCs) or via user-to-network signaling (for SVCs). Connections are identified by Data Link Connection Identifier (DLCI). The networks across which FRS is used are assumed to have very low error rates, such that reliable delivery is not explicitly included in the protocols. Traffic is assumed to be bursty, and some forms of bandwidth guarantees can be supported, via specification of Committed and Excess Information Rates and burst lengths. The bearer service attributes which quantify the quality of the offered service include:

- Delay
- Frame delivered ratio
- Data delivered ratio
- Service Availability
- Traffic/Bandwidth, described in terms of:
  - Committed Information Rate (CIR)
  - Committed Burst Size (Bc)
  - Excess Information Rate (EIR)
  - Excess Burst Size (Be)
  - Arrival Interval (T)

There are many features defined in Frame Relay Forum implementation agreements, including PVC Multicast (FRF.7). However, many of these are not widely implemented, and PVC service is the most popular offered by service providers.

ATM Cell Relay Service

ATM Cell Relay Service (CRS) is a bearer service involving the delivery of ATM cells across a network interface. It is itself a connection oriented service intended to carry both bursty and continuous streams of voice and data traffic, connectionless or connection-oriented, using fixed-length cells. The users of CRS must perform the task of adapting their native traffic to the cells. Standards and implementation agreements exist from the ITU-T, ATM Forum, IETF, and other bodies to adapt all the bearer services mentioned above, and others, to the CRS bearer service. However, the CRS must support the various traffic classes that have been defined to handle the traffic characteristics of the services adapted to ATM, specifically Constant Bit Rate (CBR), non-real-time and real-time Variable Bit Rate (nrt-VBR and rt-VBR, respectively), Unspecified Bit Rate (UBR), and Available Bit Rate (ABR). Other traffic classes are being defined. ATM Traffic Management standards specify the QoS parameters defining how ATM switches will supporting these traffic classes. ATM cells are themselves adapted to many physical layers (T1/E1, DS3/E3, OC-x/STMx, …) via transmission convergence sublayers defined in various standards and implementation agreements.

ATM's fixed-length cells allow traffic with different characteristics to be efficiently multiplexed onto a common physical network, while maintaining multiple priorities, bandwidth guarantees for continuous and bursty traffic, and other specific QoS attributes. Bearer service attributes defined in various ATM standards which quantify the quality of the offered service include:

- Cell Delay Variation
- Cell Transfer Delay
- Cell Loss Ratio
- Cell Error Ratio
- Severely Errored Cell Block Ratio
- Cell Mis-insertion Rate
- Mean Cell Transfer Delay
- Bandwidth, defined in terms of[1]:

[1] Note that different traffic classes use different sets of parameters.

- Peak Cell Rate (PCR)
- Sustained Cell Rate (SCR)
- Maximum Burst Size (MBS)
- Cell Delay Variation Tolerance (CDVT)
- Minimum Cell Rate (MCR)

Conclusions

This contribution has defined Bearer Service and Teleservices based on ITU-T standards. It asserts that the 802.16 Systems Requirements group should focus on describing Bearer Services to be covered on the System Reference Model.

Then, the contribution lists specific Bearer Services for consideration by the 802.16 Systems Requirements group. These services are the most widely requested by service providers worldwide considering deployment of broadband wireless access systems. These services represent those most currently popular as well as those projected to be popular in the foreseeable future. Therefore, support for these services will allow 802.16 to produce an international standard that will be useful now and in the future.

References

[1] ITU-T Recommendation I.210 (1993) - “ISDN Service Capabilities – Principles of Telecommunications Services Supported by an ISDN and the Means to Describe Them”

[2] 802.16sc-99/3 – “Broadband Wireless Access System Reference Diagram,” Margarete Ralston, Wytec