MetroNet: An Overview of a CATV Regional Data Network

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Abstract

MetroNet is a low cost, high performance data communications network which is based on a synergistic combination of broadband analog, digital and packet switching communication technologies. MetroNet is seen as a means of providing a cost effective, data communications link to the small business and residential consumer market over currently deployed cable systems.

A description of the marketing and network communication requirements for MetroNet, along with general architectural considerations - both hardware and software, are discussed.

1. Introduction

The evolution of new services offered by cable operators is being driven by the demands of users and franchise authorities for additional value added services and the need of MSOs to generate new revenue streams. An area of active investigation by many MSOs is the provisioning of a two way data communication link over the cable network. This data link is the backbone over which many of the contemplated services will be provided.

Two market segments would appear to have significant need (in terms of traffic volume) for a data communications backbone; the business market and the residential consumer market. The business market contains users having a substantial data communication need and who would welcome the capacity, topology and cost saving potential of a CATV network as an alternative to the Public Switched Telephone Network (PSN). This market is being driven by the attempts of many companies to improve white collar worker productivity by deploying "Office of the Future" enhancements. The second market segment is that of the residential consumer. Unlike the business market, the residential consumer market does not yet exist and will have to be developed.

The telecommunication services which are being developed for the home consumer environment are usually consolidated under the umbrella of Videotex Services. It would appear safe to assume that the cost of providing network access and transport will have a strong bearing on the ultimate penetration of Videotex services in the residential market. This paper will describe a network which directly addresses the needs of the residential marketplace and will focus on describing a general architectural overview of MetroNet, a CATV regional data network.

It is projected that the consumer market will provide combinations of audio, textual and graphical information to the home subscriber. To many experts, the emergence of this market during the decade of the 80's is a certainty. The only question which remains is whether the market will evolve as an extension of plain old telephone service (POTS) or whether it will be provided by an alternate local distribution system, the cable. [1] It is our contention that the nature of the service (data), the traffic characteristics of the service (bursty transmission and long holding times), the type of plant the service is provided on (circuit switched, analog) and the recent movement of local telephone companies to cost based pricing (designated Universal Measured Service) will make the provision of Videotex services over the currently deployed Public Switched Network (PSN) a costly and unattractive offering. As a cost effective alternative, Videotex Service could be provided by local CATV franchises.

MetroNet is a low cost, high performance, data communication network and is a synergistic combination of broadband analog, digital and packet switching technologies. Utilizing standard cable TV facilities, MetroNet will provide a transparent, high performance, communication system incorporating distributed network intelligence. For the residential consumer market, MetroNet will be compatible with all existing (subsplit and midsplit) cable systems. Unlike other proposed CATV data networks, MetroNet makes no assumption as to where in the network control and service nodes are located. As such, MetroNet is completely generalized as to service node deployment. The MetroNet system architecture will provide the interconnection of a wide range of subscriber and service nodes, configuration flexibility, and the ability for a low cost phased introduction of service.

One of the underlying design goals of MetroNet is that it must provide today's Videotex services inexpensively yet still have the flexibility required for future network growth and applications. The generality of the system enables it to effectively service a wide range of user applications - from control and security monitoring systems to packetized LPC voice and data.

This paper will provide an overview of the MetroNet System. Among the areas discussed will be:

- Residential Market Requirements
- Network Requirements
- MetroNet's Network Architecture

2. Residential Market Requirements

This section begins by addressing the home telecommunication market and extrapolating the consumer network requirements by examining the range and types of service which will be deployed. The intention here was not to study all possible future services in great detail, but rather to forecast general trends in the development of this market and to estimate their impact on the telecommunications network that will transport these services. These projections were used to create a network traffic model in an effort to evaluate the network performance.

Forecasting service demands for the residential marketplace is not a straightforward undertaking. Indeed, many studies conducted during the last decade have predicted rapid development of this market. [2] Generally, these forecasts came as a result of anticipation of the results of the integration of new computer technology and advances in both telephone and cable television communication service. It was expected that this integration would make possible and, indeed, substantially lower the cost of a wide variety of services that previously were not handled electronically.

However, in many cases changes have been slower than expected. Except for a broader variety of television programming, increased use of video games, and some custom calling features, the home telecommunications market is not appreciably different from that of ten years ago.

Many reasons could be offered for this belated development. Primary among these is the requirement that many actors in the marketplace have to undertake activities simultaneously. Generally, there is not one driving force but many. The offering of a service such as electronic funds transfer necessities significant resource allocation on the part of banks, communication companies, information processing firms, and residents. Market signals have to be very clear before this investment will be forthcoming. Individuals or firms that may lose market share should conditions change, e.g. sellers of paper, may delay through legislative or judicial means. Finally, regulatory uncertainty has also resulted in reluctance on the part of market participants to make the required investments.

Many of the forces which would tend to expand the home telecommunications market still exist today , but counter forces are also present. Thus, one of the fundamental design criteria for MetroNet was that the network architecture had to be modular and allow for either rapid or slow development of the consumer marketplace.

The potential range of these new services encompass such diverse areas as energy management, home security, bank and shop at home, video games, electronic directories and personal data storage, to name a few. While the projected market for these services is expected to be significant, the most difficult issue at this time is identifying those services which form the base or "critical mass" for the development of this marketplace. Unlike the Business Marketplace, which is being driven by a need for greater productivity in the office market, the residential consumer is motivated by a different set of needs. Most consumers acceptance of a new service (or set of services) will be based on the savings or perceived savings that the service offers to the subscriber. Table I summarizes the key services, their traffic characteristics, and their market penetration by 1990. The peak traffic was developed from a model of each prospective service. It should be emphasized that these services were used as an indication of the core or critical mass of services and formed a baseline for the network traffic model.

TABLE I

SERVICE	Peak Traffic Bits/Sec/ Residence	Penetration (Total) Households
1) Home Banking	2.6	30%
2) Home Shopping	11.35	25%
-Comparison Shopping	7.1	50%
-Reservations	.12	20%
3) Electronic Mail	2.66	2%
4) Electronic Newspaper		
- News	15.5	20%
- Public Notices	.16	30%
- Classified	1.6	30%
- Financial	1.75	10%
5) Information Services		
- References	15.5	30%
- Traffic Conditions	6.5	20%
- Software Packages	.77	10%
6) Security Services	.3	5%
7) Energy Management	.14	10%
8) Education Program	37.	5%
9) Medical Monitoring	.3	1%
10) Entertainment Services		
- Video Games	1.68	30%
- Gaming	.20	15%

3. Network Requirements

MetroNet will act as the integrated data communications backbone for all value added services to the home. This role places some rather unique requirements on the network implementation. MetroNet must support a wide range of applications, many of which have not been identified (in Table I above) or developed. In the design of MetroNet, it was realized that the network should provide a wide range of performance, customized to the needs of each application. Wideband, low delay applications should coexist with narrowband, delay tolerant applications without requiring the latter to pay the cost of the former. Furthermore, as more data traffic, users and applications are migrated to an integrated, regional data communications network, an increasing number of them will require privacy and security features to safeguard their data from other users. These features should be modularly included so that users not requiring these services do not pay for them and, further, that the full interconnectivity of the network is not compromised. Stated another way, a secure user should be able to optionally invoke the security and privacy services of the network.

A summary of the network design assumptions and requirements is shown in Table II. These assumptions and requirements were used to define the MetroNet system architecture and discuss such issues as Network topology, bandwidth, connectivity and control.

The choice of a network architecture was most strongly affected by the following network requirements:

- The network would have to support bursty, data type traffic.
- Network bandwidth is assumed to be a scarce and valuable resource.
- The network will be deployed in a hostile environment.

The first two requirements could be met by a network similar in design to SYTEK's System 20 LocalNet product line, that is, a distributed intelligence, packet switched network. However, the third requirement mandated that some form of centralized network administrative control be provided to prevent fraud (both of the network and of other users).

In the development of the MetroNet architecture, it became apparent that consideration must be given as to how the services depicted in Table I are provided. Specific issues considered with respect to service provisioning, included: who provides the service, the location of the service node, the size of the service node - among others.

A comparison was made between centralized vs decentralized service node deployment. A centralized service node was characterized as being located at (or trunked to) the cable system headend. In this scenario, all services are provided by the MSO. A decentralized network architecture would allow service nodes to be physically located anywhere in the network. Services may or may not be provided by the MSO - that is, many service nodes would be provided by outside vendors or entrepenuers. The non- MSO service nodes would still generate a revenue stream for

TABLE II

Network Requirements

Assumptions

♦ Market – The network will be designed to suport the small business/ residential market

♦ Traffic – The network will be designed to support digital data type traffic

♦ Topology – The network will be implemented over a broadband CATV network which exhibits a "tree" type physical topology

♦ Bandwidth – Network bandwidth is assumed to be a scarce and valuable resource. It is assumed that the network will be implemented in a subsplit cable system with a maximum of 25 MHz (one way) allocated for data services

♦ Environment – The network will be deployed in a hostile environment and be subjected to both accidental and premeditated attacks.

♦ Standards – The network architecture will not necessarily conform with IEEE (or other standard organizations defined standard network. The network, however, will conform with the ISO seven level protocol architecture and will present standard interfaces to connecting nodes and networks.

General Requirements

♦ Capacity – The network will be capable of supporting a subscriber base of at least 50,000 subscribers. More complex systems of multiply interconnected networks may be deployed.

♦ Cost – The network will be cost effective for the consumer marketplace.

♦ Planning Cycle – The network should not exceed allocated RF spectrum capacity for at least a 10 year period after initial deployment and provisions for expanded growth must be included in the basic architecture.

♦ Adaptability – The network will be flexible extensible and will support current and future services

♦ Access Time – Under maximum loading conditions, the network will accept and transmit 99% of the packets it receives within 100 milliseconds.

♦ Geographical Extent – The network will be able to support traffic within a 20 mile radius of the network head end or some other centralized network node collection point. Provisions for expanded geographic coverage must be included in the basic architecture.

Connectivity

♦ Connectivity – The network will allow for the logical interconnection of any two nodes.

♦ Node Location – Nodes, both subscriber and server, may be physically located anywhere in the network.

♦ Communication Services – The network will provide a full range of communication services

♦ Connection Throughput – Subscriber nodes will have a throughput of at least 19.6 Kb/s

♦ Internetworking – The network will allow for the connection to and from off network nodes provided the proper interfaces and connections exist.

Network Control

♦ Access and Authorization – The network will be able to identify, authenticate and grant or deny access of any node to the transport services of the network. This implies that the network will posses an enforcement mechanism which can deny network access to unauthorized nodes.

♦ Security – The network will be able to protect itself against vandalism (both physical and electrical) theft (both from the network and authorized users) and attacks against user data privacy

♦ Monitoring – The network will posses digital and analog monitoring capability for maintenance, traffic allocation, and accounting purposes

Reliability

♦ Reliability – The network will be reliable such that the entire system downtime is less than three minutes per month

♦ Network Control Nodes – The network control nodes will be configured in such a fashion so as to meet the network reliability requirements.

the MSO in the form of traffic on the network, more services for the consumer, node access charges, etc. Furthermore, the MSO could provide billing support for these service nodes so that the consumer receives just one bill, not multiple bills, for Videotex Services.

Another area which was investigated was the issue of service node reliability, complexity and size. The last area to be considered was the regulatory impact on a centralized vs decentralized serving arrangement. For regulatory reasons alone, it is projected that a centralized service node architecture will leave the MSO open to long term legal entanglements and regulation. This reasoning is based on a projection of "creeping" regulation. Noteworthy examples which come to mind are recent mandates requiring the CATV industry to provide two way capability (FCC), interconnection of franchises (various state PUCs), and some censorship of CATV offerings (various franchises). This concern appears to be substantiated by a recent M.I.T. report on regulation of the CATV Industry [4].

To further pursue the issue of centralized vs decentralized service node deployment an examination of the effort and time needed to add new services and features to a system was performed .A summary of these findings are shown in Table III and clearly favor decentralized serving arrangements.

Based on the assumptions and network requirements from Table II and the requirement that service nodes be distributed throughout the network, it is apparent that the needs of the regional area data network could be provided by a distributed intelligence, packet switched network. However, it was decided that a centralized network control function which allowed the network administrator to control network access, subscriber node deployment, and distribute traffic was also necessary. The resultant hybrid network is MetroNet. It is felt that MetroNet provides an optimum mixture of decentralized network intelligence and reliability with centralized control. Additional flexibility is provided in that MetroNet will allow for the deployment of either centralized or decentralized service nodes.

TABLE III

NETWORK ARCHITECTURE - CENTRALIZED VS DECENTRALIZED
-SERVICE RELATED ISSUES-

	Central	Decentral
Effort to add new services	Harder	Easier
Effort to increase service capability	Harder	Easier
Effort to develop service	Harder	Easier
Time to develop new service	Longer	Shorter

4. MetroNet Architecture

MetroNet is a packet switched data network which provides communication via the CATV distribution network. The network consists of three generic types of nodes - network control and monitoring nodes, user nodes, and network interface nodes. The network architecture for MetroNet is outlined in Figure 1. A network consists of the following elements:

Cable Distribution Systems
- o Data Channel Access Monitor (DCAM)

Network Control Nodes
- o Network Access Controller (NAC)
- o Network Traffic Monitor (NTM)
- o Network Resource Manager (NRM)

User Nodes
- o Subscriber Node
- o Server Node

Network Interface Nodes
- o Intranetwork Links (optional)
- o Internetwork Gateways (optional)

The core network consists of the cable distribution system, the Data Channel Access Monitor, the Network Access Controller, the Network Resource Manager, the Network Traffic Monitor, and two nodes which want to communicate with each other.

A typical session in MetroNet is initiated when a subscriber node signals the Network Access Controller (NAC) and is allocated channal bandwidth. The subscriber then initiates a session with the Network Resource Manager which authenticates the session request and assigns a specific network channel for the subsequent session.

Information flow in the network would be from each node toward the head end. The headend receives each upstream transmission and rebroadcasts it on a specific downstream channel. The headend contains the enforcement mechanism which prevents network access (that is - it prevents network packet retransmission) of unauthorized packets. Authorized packets are rebroadcast downstream toward the network nodes. All session transmissions are monitored by the Network Traffic Monitor (NTM) which gathers network usage statistics for load management and accounting purposes. If MetroNet extends beyond the local geographical area, the network can be connected through either an Intranetwork Link or an Internetwork Gateway. The function of these components are summarized in the following sections.

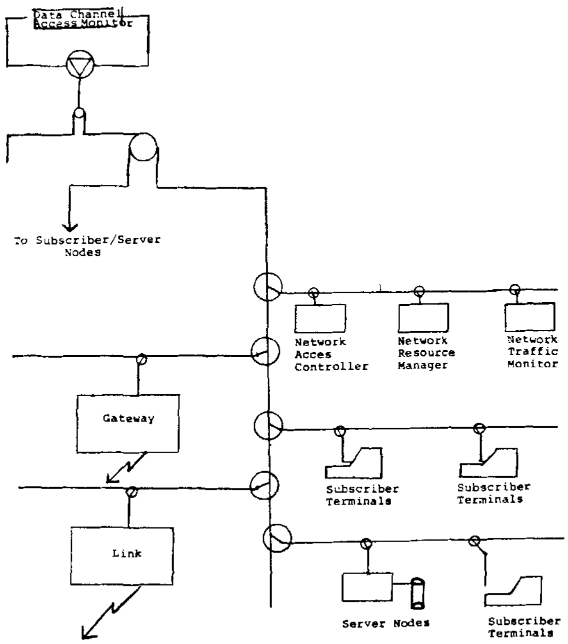

Figure 1

4.1 Cable Distribution Network

MetroNet utilizes broadband coaxial CATV cable as its physical communication medium. Analog video applications can share the same cable as the MetroNet data network. Since broadband CATV is a directional broadcast transmission system based on a single, rooted tree, physical topology, each network node can broadcast their transmission in one direction, up the tree towards the CATV head-end. The head-end contains a frequency translation device (DCAM) which rebroadcasts the transmission from the root of the tree downstream to all attached nodes. MetroNet exploits the directional aspects of the CATV transmission system to achieve full connectivity. MetroNet transmissions are contained in two frequency bands: an upstream (low frequency) and a downstream band (high frequency) and are compatible with either subsplit or midsplit cable systems. In a subsplit CATV system the band from 5 to 30 MHz is typically used for transmissions towards the cable head end. The outbound directory will be contained in a 25 MHz band somewhere in the 54-400 MHz region. It should be pointed out that the actual frequency allocations of the inbound and outbound bands are unimportant in the MetroNet architecture.

The MetroNet architecture divides the upstream and downstream bandwidth into multiple logical channels through the use of Frequency Division Multiplexing (FDM). Frequency Shift Keying (FSK) is used to modulate RF carriers to create individual data channels. Each MetroNet data channel will have a throughput of 128 Kb/s and is capable of supporting hundreds of users because of both the CSMA/CD access mechanism and the packet switched format.

As was previously specified, one of the requirements of MetroNet will be to provide access to network transport facilities and user accountability. Both of these requirements will be met through the use of a semi-intelligent head end - the Data Channel Access Monitor (DCAM)

The DCAM at the CATV system headend will perform two functions:

- It will receive the upstream channel transmission (data packets) and rebroadcast these transmissions from the headend in a specified downstream channel to all attached user devices, and

- It will, under direction of the Network Access Controller (NAC), examine every data packet passing through each headend channel. Packets from unauthorized network users will not be rebroadcast to the network. This strategy will prohibit unauthorized network access and misdirected billings by "spoofing" of the Network Traffic Monitor.

The network headend will be organized on a per channel basis. Each network data channel consists of a (low band) demodulator, a packet verification unit, and a (high band) modulator. Each group (~10) of DCAM modules (one module per channel) will have a "hot" stand by in case of failure of the online unit. Reliability is provided through 1 for N redundancy in DCAM units. It should be noted that even if there were a failure in both a front line and back up DCAM module, the remainder of the network would be unaffected and continue to operate. The network protocol architecture will be configured in such a way that if a DCAM module were to fail, the user nodes would default to their home channel and the Network Resource Manager would then reassign nodes to other data channels. The majority of users probably could recover and be reassigned to other data channels without detection of a network fault. (It is anticipated that the only discernible effect to a user would be a short delay or dead time before the network would reconfigure and it is suggested that such a delay might be difficult to discern from a server node slowdown).

Network growth would proceed on a channel by channel basis. Cable systems which require more data channels would be outfitted with more channels while smaller systems could be sized appropriately.

It should be pointed out that the network is organized so that nodes can be located anywhere in the network. Network control nodes, subscriber nodes or server nodes may be located physically anywhere within the network. The only centralized network component will be the DCAM located at the headend which is under the NAC's control, and except for monitoring of packet verifiers, its operation is passive.

4.2 Network_Control_Nodes

There will be three types of network control nodes in MetroNet- the Network Access Controller, the Network Traffic Monitor and Maintenance Node, and the Network Resource Manager.

The Network Access Controller (NAC) is under control of the network administration and will allow it to restrict unauthorized users access to network resources. The major resource protected is that of network transport services.

The basic function performed by the NAC is to provide network channel access. The Network Access Controller will maintain one or more data bases containing a list of valid user addresses, and user node ID's. The Network Access Controller can be located anywhere in the network but will be connected by a set of out of band channels to the head end. The use of out of band channels between the NAC and DCAM will prevent attacks on the DCAM by malicious network users that would prevent the DCAM from being out of communications with the NAC. The major purpose of the NAC is to give the MSO control of the network. This "centralized" control function though, may be located anywhere in the network.

The next major network control node is the Network Traffic Monitor and Maintenance Node. A Network Traffic Monitor (NTM) will be assigned to each network data channel. The network traffic monitor will collect information on:

- source/destination node traffic statistics - these statistics will be used for accounting purposes

- data channel throughput and utilization. This information will be transmitted as necessary to the NAC for traffic load leveling.

Furthermore, it is expected that the NTM will be able to monitor individual node status and collect information about:

- node up/down status
- node throughput
- node response time distribution

The actions of the NTM will be passive (except for its interactions with the NRM). It is anticipated that during non peak business hours the NTM could consolidate user usage and generate network billing information. A second function of the NTM will be to perform analog measurements of individual channels, cable and amplifier quality. Network Monitoring probes will be situated throughout the network and interrogated as necessary (over the data channels) by the NTM. This should allow the network administrator to detect network system faults both before and after occurrance. It should be noted that these network probes could be used to detect acts of vandalism (both physical and electrical) against the network. The centralization of network status will permit cost effective, implementation of network maintenance policies.

The last function to be performed by the NTM node will be diagnostics of network equipment - both network control nodes and user nodes. If administration costs are to be minimized, automatic remote diagnostic checks of equipment attached to the network will be necessary. In some cases, the NTM will only be responsible for interrogating other network components or generating test signals. However, the NTM will be charged with the responsibility of accumulating network diagnostic information, cataloging it, disabling faulty network equipment as required, and reconfiguring the network to minimize the effect of failures or damage caused by vandals. Like all MetroNet control nodes the NTM can be located anywhere within the network.

The last control node to be discussed here is the Network Resource Manager (NRM). The NRM, like both the NAC and NTM can be located anywhere in the network. The NRM is accessed directly by a network user node, and will allow:

* Network users to set up connections by symbolic names without knowing the destination address.

* Network users to interact directly with the NRM, ie - directory look up

It is expected that the network administrator will be responsible for the NRM data base. The NRM will provide the basic tools allowing network users the ability to build their own directory data bases for session set up through the use of symbolic address names.

4.3 Network User Nodes

The network user nodes will consist of two types, subscriber access and server nodes. The subscriber access nodes, (terminal), will be the most common in the network. The subscriber nodes will perform the following functions:

* Communication Interface to MetroNet

* Data terminal

It is expected that the display portion for the terminal will be the standard home television receiver. The attachment of the data terminal will transform its function from a simple TV receiver to that of a small personal computer which can call upon the data and information services attached to MetroNet.

The communication interface in the terminal will provide the following functions transparently to the user:

* Interact with the NAC for channel access

* Interact with the NRM for session initiation

* Interact and select, under network management control, a data channel on which to operate for this particular session

* Maintain and disconnect sessions as necessary

* Format and address packets using an internal MetroNet communications protocol suite

* Control access to assigned data channel band- width during a session using a CSMA/CD network access mechanism.

* Control the local and global flow of data over the MetroNet channel to prevent congestion and data loss during a session

* Detect errors through the use of Cyclic Redundancy Checks (CRC) and correct errors through retrans mission of lost or damaged packets.

It is anticipated that the terminal will be supplied by the cable MSO to the subscriber, just as current descramblers are provided. Each terminal will contain (either as a separate system, or integrated into the terminal node) a Network Access Unit (NAU). The NAU contains the RF modem and digital circuitry which implements the necessary protocols used to interface the user's terminal equipment to the network, The RF modem will be designed to be frequency agile over the entire data network spectrum. Each NAU contains a Network Access Unit Identification Number (NAU ID) which is in permanent storage within the unit. The NAU ID is unique for every network node and is the mechanism by which the NAC recognizes a particular billable user. It should be pointed out that the NAU ID is separate from the unit address and is never broadcast to the network. Tampering with the NAU ID is designed to give an attacker no real benefit. Theft of an NAU ID is roughly analogous to the theft of a credit card. Also, NAU ID space is very sparse. NAU ID's could be sixty four bits resulting in over 10 ** 19 different NAU ID's. Hence the probability of guessing a valid NAU ID would be very small. These precautions, together with the special equipment and knowledge needed to set a NAU ID into a unit make it relatively difficult for a user to falsify his identity to the NAC.

The subscriber node will be able to receive combinations of video, data, graphics, and audio. The specific format of the audio will be specified later but it is anticipated to require a throughput of $\leq$ 1.2-1.8 Kb/s. The subscriber terminal will be able to respond and transmit data and graphics. (It is not expected or required that the Terminal be able to formulate audio. If this capability were to exist, there is nothing to prevent its transmission over MetroNet, however.)

The second type of user node is the network server node. Like all other types of nodes it can be located anywhere in the network. In most all aspects, Server Nodes are identical to Subscriber Nodes in the communication services that are provided to the node. Service nodes will perform the following functions:

- Communication Interface to MetroNet
- Server applications

The communication interface to MetroNet will vary from looking similar to the subscriber node (for the smaller nodes) to being able to access multiple data channels concurrently (for the larger server nodes). Three generalized interfaces to MetroNet are envisioned at this time.

- A server node which has a single NAU and can support one session at a time.
- A server node which has two modems. In this node, one of the NAU's is always tuned to the home channel and the other NAU is (after the first session) tuned to a specific data channel. Subsequent sessions are transferred to this channel after the first session is initialized. The data channel modem and packet communication equipment is capable of handling multiple sessions on a single data channel. Ideally the limit of the server node to handle concurrent sessions should be the rate limiting step for the number of concurrent sessions the Network Access Unit can process. Further requests for sessions directed at this node by the NRM over the home signaling channel will be met with "node busy" response, or the NRM may provide call queuing services.
- A server node which has multiple modems. In this configuration, one NAU is always tuned to the home channel while other NAUs are distributed across various MetroNet data channels. Each separate NAU will be capable of handling multiple sessions.

4.4 Network Interface Nodes

Network Interface Nodes are units which either allow user devices to interface to the network or provide connectivity to other network channels, remote network sites (or subnetworks) and foreign networks.

User Network Access Nodes (UNAN) will provide access to the network to users who care to provide their own subscriber terminals or server nodes. The UNANs provide the same communication function as the subscriber/server nodes. The UNAN will contain a Network Access Unit ID (NAU ID) and at least one network address (server nodes will probably have multiple or rotary network addresses). The UNANs allow all the communication functionality of network provided server/subscriber nodes along with a range of standard interfaces.

The second class of network interface nodes provides connectivity between MetroNet "subnetworks". In the connotation to be discussed, MetroNet will be a group of subnets (and connecting nodes) which share a common address space, independent of their physical location. Separate cable systems are physically interconnected and this is accomplished through the use of a Link.

In its simplest form, the MetroNet Link will perform a one to one mapping of specific packets from MetroNet subnetwork channel to another MetroNet subnetwork channel. The link will be responsible for channel access at subnets and flow control of the transmitters if the destination channel is operating under heavy usage. The link channel size (that is the size of the channel between two links) will have to be sized to carry intranet packets with a minimum of delay. The size of this channel will be a function of the amount of traffic between subnetworks. The link channel could vary from a dedicated TDM or packet switched channel, but in all cases will be dependent upon the particular traffic patterns between subnets. It should be noted that subnets could be connected by links with low speed channels (possibly common carrier).

Since the MetroNet Link will be a network node, it will operate both automatically or under direction of the NAC and NRM. The last class of network interface node will be the Gateway. Gateways will provide interconnection between MetroNet and foreign networks. Foreign networks are meant to include MetroNet systems not under the control of the network administration, the PSN, public data networks (Telenet, Tymnet) and OCCs. Initially Gateways will be able to interface with the PSN and X.25 packet data networks. Gateways will be able to handle both incoming and outgoing sessions.

Gateways will be under the control of the NAC and NRM. Sessions addressed to nodes off of MetroNet will be directed to a Gateway. The gateway will serve the equivalent function of a tandem or class 4 office. Signalling to the remote nodes, session initiation, and, where possible, reliable data transmission via error detection and recovery protocols with foreign networks will be handled by the Gateway unit. Gateways will also be able to handle inbound session request from remote nodes. This will require that the portion of the session carried by MetroNet be negotiated through the NRM. It should be noted that sessions which are initiated offnet will probably be billed (for the MetroNet portion, at least) to the destination node, However, as metropolitan area networks proliferate this practice may revert to those currently governing telephone calls over the PSN.

4.5 Communication Protocols

MetroNet implements a common packet-switched protocol architecture throughout its component elements. The protocol suite is designed to be extensible, offering new:

- internal services,
- transmission media, and
- user device access methods.

with only localized changes to the architecture and implementation.

Transmission bandwidth on a channel is allocated in a distributed manner using a carrier-sense multiple-access with collision detection (CSMA/CD) access method. This technique permits each packet communications unit to contend independently for transmission access on one of the data channels. The minimization of centralized network control provides for high system reliability, low transmission delay, and high channel utilization. Each MetroNet channel is independent from all other channels with respect to transmission access, thus supporting simultaneous transmissions on each configured channel.

The protocol architecture for MetroNet is based on the ISO Open Systems Interconnection Reference Model [3] with modifications and extensions for the regional network environment. The seven protocol layers are:

- Application- Provides specific services to user devices
- Presentation- virtual terminal, format translation, end -to-end encryption services
- Session- name to address mapping, network monitor and control services
- Transport- flow and error controlled virtual circuit and transaction services
- Network- end-to-end addressing, routing and datagram services
- Link- per channel addressing, datagram services, error protection, transmission control (CSMA/CD) and Network Access Control
- Physical- multipoint, half-duplex communications with distributed access control.

It should be noted that the Applications layer is usually not provided by the network.

5. Summary

MetroNet will offer an integrated data communication system through the deployment of a sophisticated packet switched network. This network will allow the use of existing CATV systems to provide the residential consumer with a wide range of value added services in a cost effective manner. This network will not only meet the current projected communication needs of the residential market, but provide the extensibility and flexibility required to meet future growth and new services.

6. References

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