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Section II WAN Physical and Data Link Circuits

Internet Access and Internetworking Remote Sites

Each site to be internetworked over the public Internet will require a physical connection to the Internet through an Internet Service Provider (ISP). This section deals with the equipment, connection types and services offered. Setting up access will require that you choose an Internet service provider and obtain a circuit for network access that connects to your provider. In most cases, some equipment will need to be procured for each site.

The typical components to internetworking are:

Customer Premises Equipment (CPE)

CPE devices include a router, firewall, and depending on the circuit, a bridge, multiplexer (MUX) or Channel Service Unit/Digital Service Unit (CSU/DSU). Typically the customer owns, installs and maintains the equipment at the customer site, though often the telecommunications carrier will lease the equipment to the customer as an option. CPE is located where the provider service enters the location and is termed the ‘Demarcation Point’.

Telecommunications Company (Telecom Carrier)

A Telecom Carrier may offer a variety of choices to the customer that suits different price and performance levels. The simplest is of course, dial-up analog. Most WAN circuit choices are digital such as DS-X, ATM, T-1, T-3, Frame Relay, ISDN-BRI, ISDN-PRI, DSL and Wireless. This circuit can either connect to another of your sites directly in a private network configuration, or it can connect through the Internet via an Internet Service Provider (ISP). The installed circuit is terminated at the customer site demarcation point and connects to the CPE.

Internet Service Provider (ISP)

The ISP is an Internet Registry agent, and hosting provider that manages your connection to the Internet. Services such as electronic mail, Internet newsgroups, website hosting and Co-Location (hosting your servers in their Network Operations Center NOC), monitoring an administration may also be available. The ISP is your connection to the Internet backbone. Depending on the offerings, the ISP may also act like a Telecom Carrier by providing the circuit, as is typical with xDSL.

The specific requirements may vary with each installation as Telecom Carriers are providing Internet service, and ISP’s are partnering, acquiring, or merging with Telecom Carriers. It would not be unusual to have a single provider provide both the connection and the Internet hosting service.

Setting up access to the public Internet requires the following steps. Note that these steps must be repeated for each site to be connected. It may be worth considering having the same Telecom Carrier and ISP that can service all sites for a single source for technical support and multi-site discount programs.

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- Order an Internet connection

  Find out what your choices are by contacting an ISP or Telecom Carrier that is available in the area and selecting a circuit that matches your price and performance criteria. Regardless of the choice in circuit or provider, it is recommended to have a static IP for wide area networking and remote access. Major service provider examples are AT&T, Sprint, Verizon, SBC, British Telecom, Level 3, NTT, France Télécom, China Telecom, and Qwest.

- Choose an ISP

  Your ISP may offer simply a connection from a Point-of-Presence (POP) to their NOC for accessing the Internet, or may be more involved in setting up, managing and securing your access point. If you plan to connect across the public Internet, an ISP is essential for hosting your public address and domain name. Examples of major ISP's are UUNet/MCI, Level 3, Sprint, Verio and Qwest.

For a simple Internet connection where there is only one link between the customer site and the ISP, a static route or routing protocol is optional. This is because all traffic bound for remote networks must pass through the default gateway of the routers external interface. The gateway and IP address parameters are furnished by your ISP.

Note that regardless of your choice, if you are managing the equipment, it is a recommended option to additionally install a modem and POTS line with a RS-232 serial cable attached to the router at remote sites for out-of-band management. This will allow you to have dial up access to the router should the configuration become corrupted, or the primary connection to the site become unavailable.

This section provides an overview and comparison of the various choices available to provide access to an ISP. Aside from cost, the decision on choosing the method is largely a combination of:

Availability	What circuits and services are available at the site to be connected. Note that there may be distance limitations or performance limitations for connecting to the nearest POP (Point of Presence) depending on the service desired, or charges for the distance to the nearest POP that may increase the cost.
Speed	What bandwidth is desired/required for all users, including burst rate activity
Quality	Is the connectivity critical in nature such that it would require redundant or back-up lines. Is the quality of the line rate such that a Quality of Service QoS guarantee must be contracted in an Service Level Agreement (SLA) with your providers?
Management	Do you want the provider to manage and monitor your network access? Do you need 24x7 support monitoring from the NOC? Some providers offer more services and staffing than others. It may be best to select a single provider for all sites if possible to simplify support and bundle discounts.

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When packets are transmitted from one medium and format to another, the packet must be reformatted to conform to the Message Transfer Unit (MTU), and carrier frame format of the next network. Some platforms handle larger MTU's that afford better performance and reduce IP fragmentation.

Exterior WAN Circuit types and Signaling

External circuits when a packet leaves a facility for the public network, supported by a telecommunications provider.

There are two basic types of WAN circuits, circuit switched and packet switched.

- Circuit Switching provides a dedicated path for a connection that is not specifically shared with other users. An example of a circuit switched connection is a voice telephone call. The path is provided throughout the 'conversation' and terminated at the end of the data transfer. Circuit switch paths can also be permanent.

- Packet Switching allows individual packets from a variety of sources to share the same medium. As the packets enter routers, they are redirected according to destination. Whereas circuit switching is considered connection oriented, packet switching is regarded as connectionless (not to be confused with higher layer protocols that maintain connections such as TCP). The Internet is considered a packet switched network.

Packet Switching vs. Circuit Switching

While packet switching is good for burst data that uses larger packets, it can become congested. Packet switching must also read in the entire packet before forwarding as a 'store-and-forward' mechanism, because the packets sizes are variable. However, with circuit switching, there may be a call setup process to create a circuit before the transfer can take place. The exception may be a permanent virtual circuit described below.

- Circuit Types over the Internet are Virtual Circuits (VC) can be grouped into two categories, Permanent (PVC) and Switched (SVC).

- A PVC, sometimes called is a permanent, dedicated path between two Internet nodes. This is commonly a method for connecting a customer site to an Internet Service Provider (ISP). Since the PVC may be the only connection to the ISP, and all traffic bound for the Internet must travel through this circuit, it is a logical choice. Overall latency in this circuit configuration is fairly fixed.

- An SVC on the other hand can create, terminate and recreate circuits as necessary. This is typical when there are multiple or alternate paths that can interconnect nodes. An SVC requires a call setup or handshaking process between the two nodes and can introduce some overhead latency as this occurs.

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Physical Network Access Connections

Installing Internet access, similar to installing a LAN, requires choosing a physical layer (OSI Layer 1), connection to an ISP, and a Data Link Transport (OSI Layer 2) method. The choice of the layer 1 and layer 2 WAN circuit is based upon availability, speed required and cost. Physical layer media and data link formats are not mix and match. Certain data link layers require only certain physical media connections and vice versa. Below are details on the physical layer circuits and data link layer formats. Following on are example combinations of the two. The physical layer connection serves to carry the data from the provider POP to the termination point at the customer site.

Analog Service

Connecting to an ISP or remote site can be accomplished simply with a pair of routers and modems. This has the advantage of low installation cost, ubiquitous service in terms of analog coverage area, and can have a low monthly service fee depending on the calling plan. The downside is the call setup time and low data rate. If you are simply polling a device hourly, DDR may be a good choice. If however, you have more frequent polling, are programming over this connection, or have large file transfers, an 'always on' digital circuit may be a better choice.

DDR Demand Dial Routing uses a POTS (Plain Old Telephone Service) line and PPP (Point-to-Point Protocol) for connecting two sites. Dial-on-Demand routers will bring up the link when there is a packet bound for the remote network. Some DDR router solutions will allow packets to accumulate to a certain threshold before dialing. For Automation purposes, it is recommended that the router forward on one packet with broadcasts and multicasts not forwarded. Dial on Demand Routing (DDR) is also a good idea for any WAN solution for out-of-band management, and for backup access in case the primary link is down. PAP or CHAP authentication is recommended for remote user accounts. Of the two, CHAP is preferred, because it is bi-directional.

Point-to-Point Protocol

PPP is a serial, Data Link layer (OSI Layer 2) protocol that can be used on some digital circuits such as ISDN, though it is most often used on dial-up analog circuits. PPP can be over a single line, or multiple lines as in Multilink PPP (RFC 1990). Multilink allows several PPP lines to be from the same source and terminated at the same destination for increased bandwidth. PPP can also multiplex different protocols on the same link (IP, IPX, etc).

PPP encapsulates packets that share Link Control Protocol information such as compression and Network Control Protocol information such as addressing, along with of course data. The PPP frame fields are:

Protocol	1 or 2 bytes	Link Control Protocol, Password Authentication Protocol (PAP) Challenge Handshake Authentication Protocol (CHAP)

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Information	0-1500 bytes	Datagram to be transmitted, up to the Maximum Receive Unit (MRU).
Padding	As required	

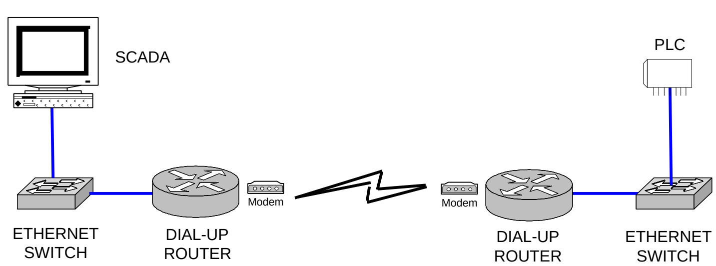
To establish a PPP connection, each end of the connection must do the following:

- Transmit Link Control Protocol information to agree on a configuration and verify the link
- Optionally authenticate each end to the other
- Exchange Network Control Protocol information

Dial Up Comparison

CPE	Low end router with serial interface and external V.90 modem
Data Circuits	Analog telephone line
Speed	v.90 (56 Kbs)
Cost	Low
Reliability	Fair. Can step down in speed over lower quality links

DDR Example



In this example, a unicast packet outbound for the PLC will be queued at the router, the router will examine the routing table to see which interface to bring up (number to call), connect, authenticate and transmit the packet. The obvious drawback is the latency required to setup the call and connection.

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Digital Service

Common choices for Internet access include Digital Signal ‘X’ service, T-Carrier service (North America) and E-Carrier (Europe) service. While they share similarities in terms of bandwidth, the signaling and choices vary somewhat. The following section describes each, but first there is a comparison chart between the different systems.

Bandwidth	DS-X	T-Carrier	E-Carrier
64 kbs	DS0	N/A	N/A
1.544 Mbs	DS1	T-1	N/A
2.048 Mbs	N/A	N/A	E-1
3.152 Mbs	DS1c	N/A	N/A
6.312 Mbs	DS2	T-2	N/A
8.448 Mbs	N/A	N/A	E-2
34.368 Mbs	N/A	N/A	E-3
44.736 Mbs	DS3	T-3	N/A
139.264 Mbs	N/A	N/A	E-4

The advantage to digital service is that compared to analog service, the signal does not degrade to the point (as with analog), where a 1 and 0 is indistinguishable. Therefore, digital service can be extended further, has greater bandwidth, and is more immune to external noise.

xDSL

For a small group of users or devices, a DSL line may be a good, low cost choice for network edge service. Note that DSL is limited to 18,000 from the DSLAM (Digital Subscriber Line Access Multiplexer). The DSLAM is a concentrator that brings back the customers line to the Telecom Carrier Central Office (CO), and then typically connects the DSLAM to an ATM backbone. The two options DSL provider offer is ADSL, and SDSL. Asymmetric DSL (ADSL) is less expensive that Symmetric DSL (SDSL) because the upstream speed is a fraction of the downstream speed. SDSL has equal speed in both directions and is useful if you are uploading larger amounts of data to either a web server or remote site over the Internet, or terminate remote/mobile users over the Internet (VPN users). Though DSL performance can vary based on distance and have some fluctuations in line rate, some providers have very high quality ATM backbones behind the DSL. Compared to a T-Carrier T-1 circuit, SDSL is less expensive and roughly equivalent in bandwidth. DSL service is gaining quickly in popularity as providers build out network access.

To install DSL service, a CLEC (Competitive Local Exchange Carrier), must install a ‘Local Loop’ to your location. This loop is telephone wire but within the distance reach of the DSLAM. The wiring then terminates in the DSLAM at the CLEC CO. At your location, the connection uses a filter to separate the DSL signal from the analog POTS signal. A filter must be installed on the termination point, or can be installed on individual analog devices such as non-digital telephones, FAX machines and modems.

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xDSL Summary

CPE	DSL Bridge and Dual Ethernet Router
Speed	384 Kbs to 7 Mbs depending on availability. Actual speed decreases with distance from the DSLAM. Up to 18,000 feet from DSLAM
Cost	Low hardware cost ranging from $100 - $200. Monthly recurring charges are typically under $200 per month
Reliability	Varies. May experience interruption or line rate fluctuation.

G.SHDSL Also known as G.991.2, it is an ITU global standard for DSL edge service. Among the improvements are increased synchronous speed to 2.3 Mbs, (in 64 Kbs increments), and it can be deployed 24,000 ft from the telecom carrier Central Office DSLAM. G.SHDSL also uses a handshake mechanism to negotiate the highest possible data rate over the link. Similar to other DSL formats, it is handed off to other network formats at the Telecom Carrier CO such as ATM, DS-X or OC-X service or POS (Packet over SONET). As G.SHDSL evolves, it is expected to replace other DSL types, T-1, DS-1 and ISDN for many worldwide users because of extended reach, rate adaptation (negotiating the highest bandwidth), and support for native IP framing to the edge (end device).

G.SHDSL Summary

CPE	G.HSDSL/Ethernet Router or G.HSDSL module for exiting router.
Speed	192 Kbs to 2.312 Mbs over 2 wires, up to 4.6 Mbs over 4 wires. Performance varies with distance, but can extend up to 24,000 feet from DSLAM.
Cost	Low hardware cost ranging from $500 - $1,000. Monthly recurring charges are typically under $200 per month
Reliability	Emerging standard - expected to be good.

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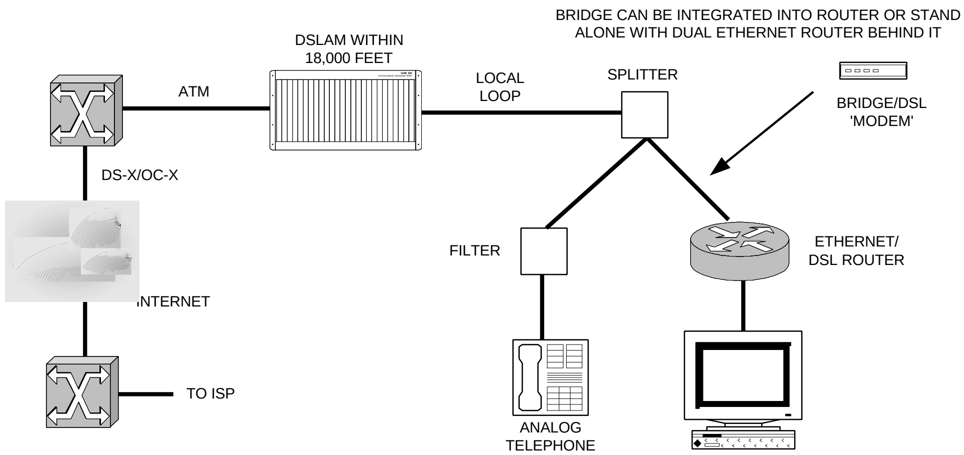
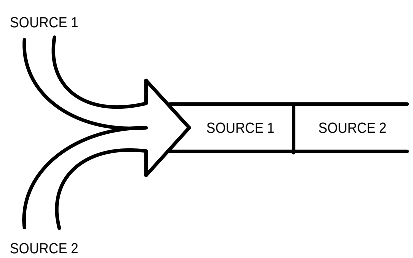
DSL Example



DS-X A DS0 is based on the leased line Digital Signal X system using 64 Kbs as the base unit. Connections using DS-X, T-Carrier, and E-Carrier use this base unit, and multiples of the base unit for circuits. This serves as the base multiple for T-Carrier and E-Carrier service and is defined by ANSI T1-107.

Digital Signal X uses Time Division Multiplexing to combine different data streams, including analog sources such as voice with Pulse Code Modulation (PCM). DS-X can be ordered in the following formats besides DS-O, DS-1 at 1.544 Mbs, (equivalent in speed to T-carrier T-1), DS-3 at 45 Mbs (equivalent to T-3). DS-X service can be used to connect multiple sites with DS0's for example, to a central site by multiplexing the smaller DS0's into a DS1 or greater.



DS-X Time Division Multiplexing

T-1/T-3 T-Carrier service is common throughout North America for dedicated, digital voice and data service. A T-1 is therefore a channelized version of a DS-X operating over 24 AWG wire and can

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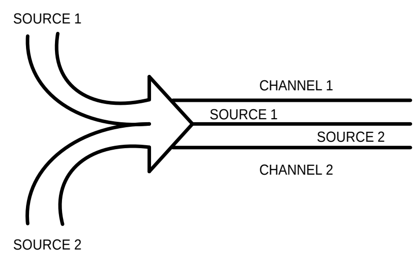
extend approximately 3,000 ft. A T-1 is equivalent in bandwidth to a DS-1 The conventional T-1 operates at 1.544 Mbits/sec using the concept of ‘robbed bits’ for signaling. Bit robbing is a mechanism where the circuit actually uses some of the bits, in band, for signaling, versus having a separate signaling channel like an ISDN BRI. A T-1 has 24 DS0 channels formatted as single DS-1 digital channel. A T-1 can also be partitioned into voice and data channels (ex. 12 voice channels and 12 data channels), or it can be ordered as a portion of a T-1 called a Fractional T-1 (FT-1). T-1 utilizes a CSU/DSU, which can be external from the router, or integrated on the WAN interface. External CSU/DSU’s usually connect to a router serial interface with a V.35 connector. T-1 service can be ordered from your telephone company and a RJ-48x ‘smart-jack’ will be installed that utilizes 4 of the 8 conductors for transmission.

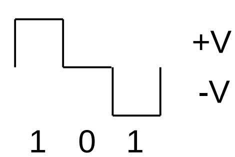


‘Channelized’ T-Carrier

When setting up a CSU/DSU you will need to match the settings provided by the Telephone Company. Below are some of the details on a T-1 circuit and what the settings do.

The T-1 frame is 192 bits (8 bits per channel X 24 channels + 1 bit for framing) and can digitize voice for transmission as well as data by sampling analog voice data at 8,000 sample per second. The most common framing is D-4 or ESF (Extended Superframe). Much of the difference between the two frame formats focuses on the use of the 193rd bit. T-1 circuits are limited in length to 3,000 feet with out a repeater and typically terminate at a telephone company CO (Central Office) switching center. Common coding for T-1 circuits is Alternate Mark Inversion (AMI) and must be matched in the configuration at both ends. AMI states that signals are transmitted with an alternating positive and negative voltage, with no voltage encoding 0’s. AMI is considered a bipolar signal. The timing is kept by a master clock that propagates the timing to other T-1’s.

AMI Encoding



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There is a setting for maximum successive 0's that you can see is necessary from the previous 'AMI Encoding' graphic. If a large number of 0's were sent in a data stream, there would be no voltage and the timing could drift. A method of encoding, also settable on many CSU'DSU's is B8ZS encoding (Binary 8 Zero Substitution). Essentially when a stream of eight 0's are received, they are replaced with a B8ZS 'code word'. This operates to inject 1's onto the line, and thus voltage as a keep-alive mechanism to retain timing with the line clock.

DS-X / T-Carrier / E-Carrier Summary

CPE	Router with integrated or external CSU/DSU w/V.35 serial interface if external. Selected router performance should be proportional to the line rate selected for packet forwarding performance.
Speed	256-768 Kbs (FT-1), 1.544 Mbs (T-1), to 45 Mbs (T-3) and beyond.
Cost	Low to High CPE hardware cost depending on circuit choice and performance required. Recurring monthly charges range from a few hundred (FT-1), to $1,000 or more (T-1), to several thousand (T-3) dollars per month. Cost varies with mileage to the POP.
Reliability	High. The Telecom Carrier routinely monitors the circuit via diagnostic loopback to the routers external (WAN) interface or CSU/DSU.

SONET Synchronous Optical NETwork and Synchronous Digital Hierarchy (SDH), is an ANSI standard for optical communications. SONET also has an electrical equivalent, STS (Synchronous Transport Signals). SONET/SDH established a global standard for interconnecting fiber devices from different OEM's and different carriers in different countries. Prior to this, there were incompatible, proprietary systems, which made interconnection difficult. SONET is synchronous by design which means that the timing is derived from a single source. Consider systems that are asynchronous, each with different clocks, or plesiosynchronous where sources are similar and accurate, but nonetheless separate. SONET systems use the same cesium atomic source called a primary reference clock (PRC). The base unit of SONET is the Synchronous Transport Signal (STS), equivalent to the Optical Carrier Unit (OC-x). STS-1/OC-1 operates at 51.84 Mbs. Multiples of this base unit allow SONET to achieve speeds of up to STS-192/OC-192 at 9.95 Gbs. The big difference between other digital services such as DS-X and SONET is the clocking. DS-x services must use bit stuffing to multiply the DS0's (multiplex), into larger connection types like DS3. Where SONET is optical and the speed is derived from a standard reference, there is not need to bit stuff to increase the bandwidth on the link unless there is a phase shift between clocks, derived from a standard source, but operating independently. The hierarchical structure of SONET/SDH has to do with the clocks. There are multiple clocks, but they are all drawn from the same reference. The higher level clocks propagate the time down to lower level clocks. The hierarchy is a master/slave relationship. A

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SONET terminal derives its clocking from a Building Integrated Timing Supply (BITS), source which can supply slaves clocking from the actual OC-x incoming signal.

IP over SONET is typically referred to as POS (Packet Over SONET), and the SONET STS-1 frame contains two basic units:

- Transport overhead — 27 bytes contains section overhead and line overhead
- Synchronous Payload Envelope — 783 bytes PE contains payload data

The frame contains a total of 810 bytes. With the base rate of 51.84 Mbs, and a packet rate of 8,000 pps the duration of a single packet is 125 microseconds.

Synchronous Payload Envelope

Of the 783 bytes in the SPE, 27 bytes are reserved for transport overhead, leaving 756 bytes final payload capacity. As the connection type grows from OC-1/STS-1 to OC-3/STS-3 for example, the frame grows from 810 bytes to OC-n X 810. Therefore, an OC-3 frame is 2,430 bytes. Unlike ATM AAL5, SONET supports interleaving data from several STS-1 frames into an STS-3 frame. That means that the data does not have to be contiguous or even of the same type. A pointer indicates the alignment of each frame to accommodate different payload types. If a link has to be re-synchronized, the payload pointer can also be offset by a byte to re-time the synchronization.

Transport Overhead

Of the 27 bytes used for transport overhead, 9 bytes are for Section Overhead, and 18 bytes for line overhead. The section overhead carries information for performance monitoring, provisioning, management and alarming. The line overhead contains the payload pointer for the SPE, maintenance information, and performance monitoring, and other circuit features.

SONET Components

Terminal Multiplexer	Concentrator used as a Path Terminating Element (PTE)
Regenerator	Repeater that receives the incoming signal, sets it clocking to that signal and rewrites the section overhead only. Essentially a repeater.
Add/Drop Multiplexer	Used for combining different source connections for aggregation, or to put lower speed traffic collected, bundled with others, onto a higher speed connection.
Broadband Digital Cross-Connect	Interconnects SONET to DS-X

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Digital Loop Carrier	Aggregates lower speed services for deliver to Telecom Carrier

SONET Topology

SONET physical topology can be configured in a variety of topologies depending on the network applications. If necessary, the signal can be re-timed and transmitted greater distances by inserting a Regenerator between points. SONET physical topologies can be described as:

Point-to-Point	Terminated at each end by a Terminal Multiplexer
Point-to-Multipoint	Multiple Terminal Multiplexers connected to a common Add/Drop Multiplexer
Hub	For interconnecting multiple Point-to-Multipoint networks in a central location. The Add/Drop Multiplexers at each site are interconnected to a common Broadband Digital Cross Connect
Ring	Similar in a sense to a hub for interconnecting multiple SONET networks, except that it is distributed by interconnecting the Add/Drop Multiplexers at each site in a ring. The ring can be bi-directional, similar to FDDI that it provides fault tolerance.

<u>SONET Summary</u>

CPE	Varies with topology
Speed	51.84 Mbs (STS-1) to 9.95 Gbs (STS-192 / OC-192)
Cost	High CPE hardware cost depending on circuit choice and performance required. Recurring monthly charges of several thousand dollars per month.
Reliability	High. An excellent choice for cell switching ATM.

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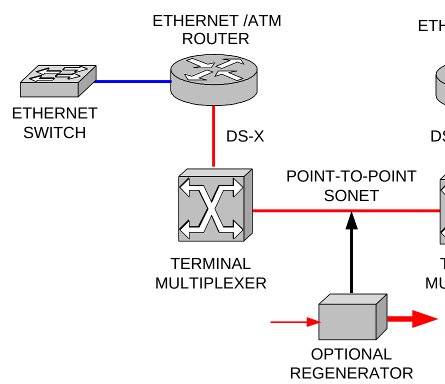
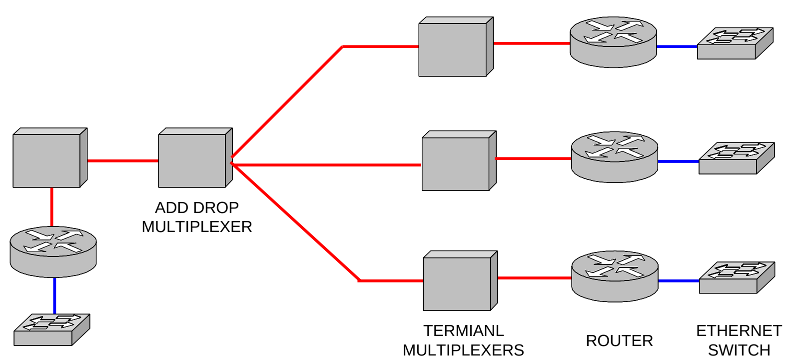
SONET Examples

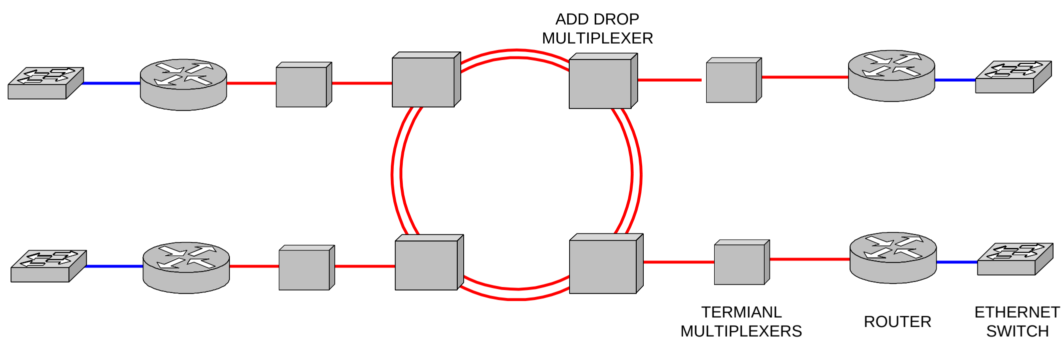
SONET Point-to-Point



SONET Point-to-Multi-point



SONET with Dual Counter-Rotating (Self Healing) Rings



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ATM Asynchronous Transfer Mode is well suited for larger installations, or applications that require a high degree of Quality of Service and level bandwidth allocation for converging services like voice and video. ATM is a high-speed ‘Cell Switching’ service for wide area networking that can also be extended to the internal Ethernet network using LANE (LAN Emulation) or serve as a campus backbone interconnecting several buildings. Though most ATM installations run over Multi-Mode Fiber or SDH/SONET, ATM can run over Unshielded/Shielded Twisted Pair (UTP or STP) copper. ATM packages IP Packets 48 bytes at a time, into 53 byte cells that include a 5 byte ATM header. The header details will be discussed a little further on.

ATM works at OSI layers 1 (physical), and 2 (Data Link) at increments of 155 Mbs (over OC-3 for example – 3 X 53.84 Mbs = ~155 Mbs). ATM is a switched protocol that uses either Permanent Virtual Circuits (PVC), or Switched Virtual Circuits (SVC) defined as:

PVC A circuit type which is like a dedicated line that is the default path. A PVC requires manual configuration and cannot easily adjust to network changes for redundancy.

SVC The more common type of ATM circuit, an SVC is like a telephone switch. Calls to open a path are setup, data transferred and then the circuit is ‘torn down’ or terminated. SVC’s do require a small amount of time for call setup, but are inherently better for adjusting to network changes.

The connections or ‘paths’ determine the interface to use to reach an endpoint. There are two types of endpoints in ATM:

UNI User Network Interface. When an ATM switch connects to a host or endpoint such as a server, router, LAN switch or CSU/DSU.

NNI Network Node Interface. When an ATM switch connects to another ATM switch.

VPI Virtual Path Identifier is a logical tunnel between two endpoints through which multiple VCI’s may pass. VPI’s are numbered 0-255.

VCI Virtual Channel Identifier is an numeric identifier for each channel of communication within a virtual path. Note that VCI’s 0-31 are used for network information and should not be used for user connections. VCI’s are numbered 0-65,535

ATM uses a layered approach for preparing the IP packet for the network, and removing the packet from the network to pass it up to the higher layer protocols. There are 3 ATM layers:

Physical layer Required to create the optical or electrical bitstream. This is subdivided into two sublayers:

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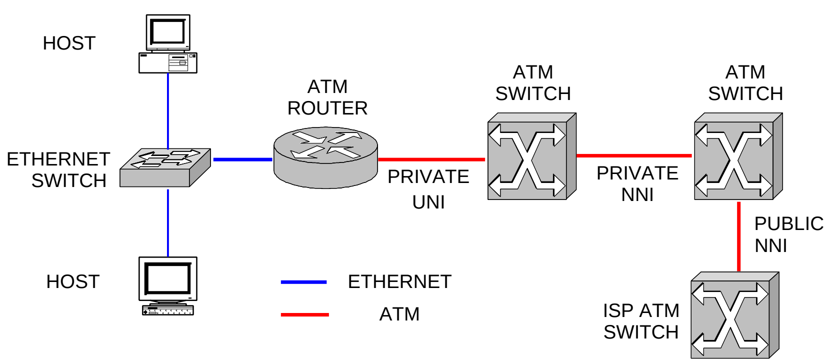
Physical Medium Dependant sublayer PMD is the physical SONET, DS-3, Fiber Channel media

Transmission Convergence sublayer Delineates cells
Header error control (HEC), checks header
Cell Rate Decoupling inserts cells on idle
Transmission Frame Adaptation packages cells into frames for the physical media
Transmission Frame Generation maintains the frame structure for the physical media

ATM Layer Manages the VPI and the VCI's within them by multiplexing and de-multiplexing, inserts and extracts the header and manages flow control

ATM Adaptation Layer (AAL) – There are 5 different iteration of the AAL with some well suited for services like voice or video, and other more suited for data. This paper will focus on the version most popular for data called AAL5. The AAL handles the conversion of the packet into 48 byte payloads for the cells and re-assembly after taking them off the network, much like the data length layer or MAC layer in Ethernet.

ATM Connection Types

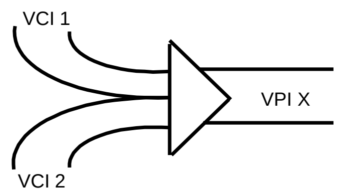


The 'ATM Connection Types' Figure illustrates the different connection types. The UNI (User to Network Interface), connects a host, in this case an ATM to Ethernet router, to the ATM switch. The NNI (Network Node or Network-Network Interface), connects one ATM switch to another ATM switch in a private network. When the private NNI connects a private ATM switch to the Public network (ISP) ATM switch, a public NNI is used.

The lower layers (ATM, AAL) receive the frame from the higher layer protocols (IP), and disassemble the frame into cells. In the header field of a private connection, the Virtual Path

Identifier (VPI 12 bits), Virtual Channel Identifier (VCI 16 bits), payload type (user data or control data 2 bits), cell loss priority (discard eligibility 2 bits), and Header Error Control (HEC 8 bits), make up the 5 byte Header.

The illustration below shows how multiple Virtual Channels are carried over a Virtual Path.



ATM Addressing

Because ATM operates below the IP layer and is a circuit switched network model. ATM maps the higher layer IP addresses to the ATM addresses in a table. ATM is a connection-oriented protocol which will form a virtual connection between two endpoints. The addressing for private ATM networks is based upon a 20-byte Network Service Access Point (NSAP). Public networks use a different ITU (International Telecommunications Union) standard called E.164. There are 3 formats for ATM addressing DCC (Data Country Code), ICD (International Country Identifier), and E.164 for public UNI's. The 3 components of the addresses are:

IDI Initial Domain Identifier – Identifies address allocation and authority

AFI Authority and Format Identifier – determines the type and format of the IDI

DSP Domain Specific Part – ATM routing information

Then, depending on the format (DCC, ICD or E.164), there are other fields that identify a country code in Data Country Code (DCC) in the IDI. DCC's are assigned by ISO 3166. Another format, ICD (International Code Designator), identifies private organizations and is assigned by the British Standards Institute under ISO 6523.

When a packet has to be transmitted over an ATM network the AAL and ATM layers have divided the IP and higher layer bytes into the cell payloads that will be sent over the ATM physical layer. Because ATM is not a broadcast based network like Ethernet, and not all AAL types support multicasting, (AAL 5 in particular), ATM has other methods to locate endpoints and setup connections. They are:

Virtual Path Multicasting Virtual Path links are a multicast group, each with its own unique Virtual Connection Identifier (VCI)

Multicast Server	A multicast server is connected to all endpoints and packets are forwarded to the server, which checks that the packet is fully received before re-transmitting to the destination. The server acts like a proxy or intermediate device in this manner.
Overlaid point-to-multi-point	All nodes become members of a multicast group by making connections with each other.

To summarize how an ATM network sets up a connection and performs a data transfer, the following steps are processed:

- An ATM switch sends a connection request setup message containing the ATM address of the destination, to its neighboring, directly connected switch. This is repeated in turn to propagate the connection request across the ATM network.

- When the destination finally receives the connection request control frame, it determines whether the connection request will be accepted. It will then send a ‘Call Preceding’ and a ‘Connect’ message response back to the source.

- The source then sends a ‘Connect Acknowledge’ message back to the destination to establish the data connection.

How the connection requests are handled is done by the ATM PNNI connection routing protocol (Private Network to Network Interface). PNNI is similar to traditional link state routing protocols such as OSPF, in that is tracks certain metrics of each connection for bandwidth, availability, etc. PNNI has a dedicated VCI identifier (18), that allows PNNI messages to discover and build a topology table of the network that help the switches choose the best path. The list that the ATM switches build is called the ‘Designated Transit List’ (DTL), similar to a routing table. When setting up an ATM network, the use of ‘Integrated Local Management Interface (ILMI) is recommended. ILMI will monitor and share information such as interfaces, IP addresses and interface names automatically on VCI ID 16. Otherwise, this must be configured manually at each switch.

ATM service over SONET is commonly provided based upon a multiple of the Optical Carrier (OC) value. The basic unit of ATM has 53.84 Mbs. Therefore an OC-3 circuit is 3 x 53.84 rated at 155 Mbs. Service can be ordered ranging from OC-3 on up to OC-12.

ATM Media Choices

While ATM is commonly run over SONET/SDH at incremental OC-X values of 53.84 Mbs, it can also be run over DS-3, E-3 (European standard), 155 Mbs Multi-Mode Fiber), FDDI (Fiber Distributed Data Interface), STP (Shielded Twisted Pair) and UTP (Unshielded Twisted Pair).

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The OC (Optical Carrier) standard allows for high speed links such as OC-3, OC-12, OC-48 and OC-192 to provide multi-gigabit speeds.

ATM Bit Rates

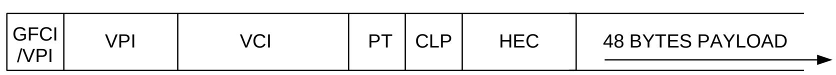
When choosing ATM service, there are several choices one can make in terms of bandwidth bit rate. The choices are:

CBR	Constant Bit Rate	Fixed Data Rate
UBR	Unspecified Bit Rate	Not for QoS. Does not guarantee bandwidth
VBR	Variable Bit Rate	Data rate can vary. Not for QoS
ABR	Available Bit Rate	Guaranteed minimum bit rate. Can burst above the ABR

ATM is a good choice for organizations where different types of traffic are converged. Examples include data, video and Voice over IP (VoIP). ATM allows all types of traffic on the line without contention. Depending on the type of traffic, some Adaptation layers are more suited than others. This paper has covered AAL5 for data, however, AAL5 does not support ‘interleaving’ cells. AAL 5 requires that the entire packet be sent as a group of cells, instead of interleaving VoIP, video cells on the same connection with the cells form an IP data packet. If using VoIP or video, consider one of the other adaptation mechanisms more suited to voice and video.

The ATM cell is formatted as:

ATM Header



GFCI/VPI	4 bits	Generic Flow Control Identifier for UNI, Virtual Path Identifier for UNI
VPI	8 bits	Virtual Path Identifier
VCI	16 bits	Virtual Channel Identifier
PT	4 bits	Payload Type (See Below)
CLP	4 bits	Cell Loss Priority, 0=Discard if Congested, 1=Priority cell,
HEC	8 bits	Header Error Check, Checksum

Payload Type Detail

PT	Bit 1	0=User Data, 1=Control Data
	Bit 2	0=No Congestion, 1=Congestion
	Bit 3	AAL5 Only, 0=Not End of Frame, 1=End of Frame

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ATM Comparison

CPE	ATM Switch or Router with selected router performance proportionate to the STS-X / OC-X circuit selected. ATM DSU (Data Service Unit)
Speed	1.544 Mbs, to 622 Mbs (OC-12) and beyond to multi-gigabit service
Cost	Moderate to High CPE hardware cost depending on circuit choice and performance required. Recurring monthly charges range from a few thousand (OC-3) to many of thousands (OC-48) dollars per month.
Reliability	High, though an excellent choice for sustained, high quality delivery.

Frame Relay Frame Relay is a packet switched network that can use PVC's (Permanent Virtual Circuits-similar to a dedicated leased line), or SVC's (Switched Virtual Circuits similar to making a call to another node to transfer data), to communicate at up to 45 Mbs over T-3.

Frame Relay Assembler / Dissemblers (FRAD's) and routers packetize data from other formats such as Ethernet and route frame relay packets to the destination VC. The FRAD is integrated as a function of the router, or in some cases, can stand alone for transmitting serial data. If using a T-1, a CSU is used to multiplex the data on to the frame relay circuit. The packets are variable in length and frame relay adds 2 bytes to the IP payload (which already contains the higher layer application data) and a 16 bit Frame Check Sequence (FCS). Of the 2 bytes in the IP datagram, 10 bits are the Data Link Connection Identifier (DLCI). The DLCI corresponds to the Virtual Circuit mapped to a destination address. The Fame Rlay switches called nodes, forward the packet to the appropriate destination based on the routing tables after examining the DLCI.

One caveat with Frame Relay is that packets can be dropped due to errors and also network congestion. Because packets can be dropped due to congestion, a pair of bits in the Frame Relay header notify other nodes of a congestion condition. These bits are the Forward Explicit Congestion Notification (FECN) and Backward ECN (BECN) bits. Some frames may also have a 'Discard Eligibility' bit set to inform the switch that the packet may be discarded should network congestion reach such a point. However, not all devices may understand the FECN and BECN bits. It is recommended that the equipment, or the providers equipment, be able to recognize FECN and BECN bits to reduce lost packets.

The connections for Virtual Circuits in a frame relay network are managed by the Local Management Interface (LMI). The LMI tracks the availability of a Virtual Circuit (alive and/or congested), and DLCI assigned to that interface. LMI is a useful feature to be implemented in a Frame Relay network.

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Frame relay can also be connected to ATM by mapping the FECN to the ATM GFCI and the frame relay DLCI to the ATM VPI/VCI. Of course, it would be packetized into 53 byte cells for ATM. Performance on a frame relay network for automation may involve examining the CIR and AR, as will as measuring end-to-end latency because call setup on SVC's can increase latency.

Because Frame Relay uses virtual circuits in a multi-drop network, it can be an economical alternative to more expensive leased line, dedicated circuits. The following are the terms used by providers when subscribing to Frame Relay:

CIR The Committed Information Rate is the data rate subscribed to by a customer from a provider for steady state traffic. The CIR is averaged over a period of time.

EIR The Excess Information Rate is the available bandwidth for excessive or burst traffic above the CIR

AR Available Rate. The speed at which a frame can be inserted into the network. May require call setup before the frame can be injected.

FCS A Frame Check Sequence (similar to a CRC) is a checksum trailer value that is usually 2 bytes which can detect a single error in a value up to 65,535. Both IP and TCP use 16 bit FCS'.

VC A Virtual Circuit (VC) is a software defined path or virtual connection between two points.

PVC A Permanent Virtual Circuit is a point-to-point path defined by a network operator such as a telephone carrier or ISP. A PVC is essentially a dedicated circuit and simpler to setup than an SVC, but is available all of the time, possibly resulting in unused bandwidth which is billable regardless of usage.

SVC A Switched Virtual Circuit is dynamic, defined on a case by case basis depending on the destination address of the packet. SVC's are more complex to manage, but may be less expensive to operate as it is demand based. SVC's require call setup prior to data transfer, which can introduce some latency. PVC's maintain the same CIR regardless if the PVC is idle.

<u>Frame Relay Comparison</u>

CPE	Router/FRAD. A Terminal adapter is required if using ISDN, CSU/DSU if using T-1.
Data Circuits	DS-0 / FT-1, DS-1 / T-1, DS-3 / T-3, ISDN-BRI, ISDN-PRI
Speed	256 Kbs – 45 Mbs depending on subscribed line rate

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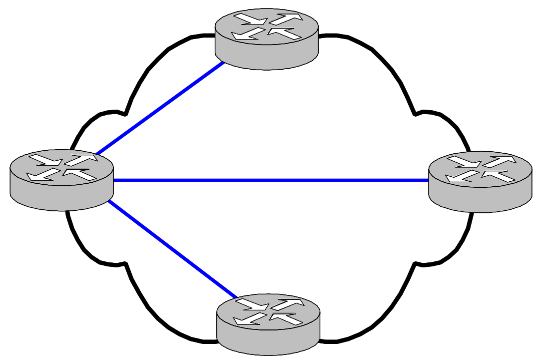
Cost — Low to Moderate. Cost varies by mileage from the POP.

Reliability — Good to excellent but can experience congestion. Use equipment that recognizes and responds to congestion flow control bits.

Frame Relay Example

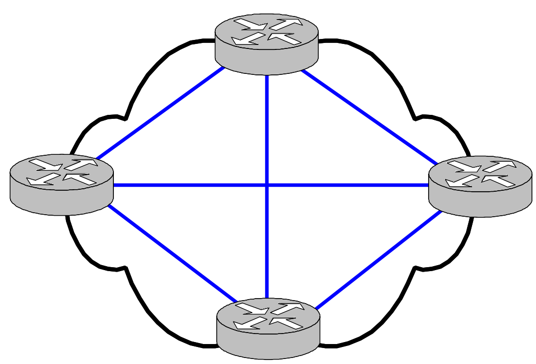
These topology examples show the virtual circuit DLCI mappings between sites using FRAD's or Frame Relay routers. Star topology is simpler to manage but has a single point of failure.

Star Topology



Fully meshed topology is harder to manage with multiple VC mappings but has greater resilience.

Fully Meshed Topology



ISDN-BRI Integrated Service Digital Network Basic Rate Interface is the second most popular method for business digital Internet access although ISDN BRI is being overshadowed by DSL for many users. ISDN BRI is becoming overshadowed in metropolitan areas as DSL gains favor due to its low cost and superior performance. The ITU standard has two synchronous 64 Kbs DS0 Full Duplex 'B' (Bearer) channels for data and 1 'D" 16 Kbs channel for signaling. ISDN is effective for WAN purposes and can 'turn' down one B channel when line utilization is low, leaving just a single B channel idling, and should data transfer request surge ISDN can bring up the second BRI. ISDN can be fairly inexpensive to install because ISDN BRI baseband operates over standard twisted pair telephone cabling supporting voice and data. The B channels cannot be further provisioned, therefore a 64 Kbs link is up and transmitting, or it is not. There used to be a fractional BRI that provided only a single B channel, but it is less common.

The ‘D’ channel uses the Link Access Protocol – D Channel (LAPD) for signaling the status of a link. While the B channels are used for transmitting data through the network, the D channels only communicate between the device (ISDN router), and the network. The D channel is not transmitted over the network to the other end. Protocols used for the B channels and the D channel differ. The choices for the B channel are PPP (Point-to-Point Protocol) or Multi-link PPP. The D channel protocol is ITU Q.931 or 5ESS in North America, and EuroISDN, ETS-1 or DSS1 in Europe.

ISDN routers are available with a choice of either S/T or U type interfaces. The U interface connects directly to the telephone jack, and the S/T interface connects to an external NT-1 (Network Termination 1). Whereas an ISDN Router enables you to connect PC’s to ISDN, It is possible to connect non-ISDN devices to ISDN using a Terminal Adapter. The Terminal Adapter essentially converts analog data (such as a FAX machine or Modem), to digital data before transmission over ISDN.

Each device is addressed using a Terminal Endpoint Identifier (TEI), or Service Profile Identifier (SPID). The SPID is 14 digits with 10 digits for telephone or ‘Directory Number’, and the last 4 digits for ISDN devices may that share that number.

<u>ISDN BRI Comparison</u>

CPE	A lower end router with ISDN interface and Terminal Adapter (NT-1)
Data Circuits	Uses twisted pair telephone cabling
Speed	128 Kbs
Cost	Low
Reliability	Fair. DSL may be a better choice if available.

ISDN-PRI ISDN Primary Rate Interface uses 23 DS0 ‘B’ 64 Kbs channels in North America (30 in Europe), and 1 “D” channel for bandwidth similar to a T-1 at 1.544 Mbs. Where ISDN has signaling on a separate D channel, the T-1 has signaling embedded into all 24 channels by ‘robbing bits’ from each channel. As with an ISDN BRI, a terminal adapter is required.

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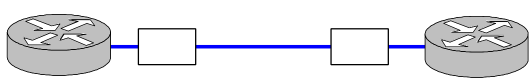
ISDN PRI Comparison

CPE	A mid-range router with ISDN interface with NT-1 or Terminal Adapter
Data Circuits	Uses twisted pair telephone cabling
Speed	1.544 Mbs
Cost	Low to Moderate
Reliability	Good

ISDN Example



Choosing an ISP

Internet Service providers can offer services including

- Registry Services — Registration of your Domain Name and IP address allocation
- Hosting — Hosting of web and FTP services with storage allocation
- Mail Service — Hosting of mail services and mailbox management
- Co Location Services — Placing of your servers in their NOC for management
- Connection Management — Monitoring and reporting of your connection

It may be helpful to select a single provider when choosing an ISP. Having multiple providers for different locations can complicate the troubleshooting process by having one ISP shift responsibility to another ISP. This also allows any managed services, hosting services and security policies to be integrated with one provider.

ISP Registry Services

To register your company or site domain, the application must be passed up to a Regional Internet Registry (RIR). Registry services and ISP's can help you expedite the registration process. There are 4 RIR's chartered by the Internet Assigned Numbers Authority (IANA):

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ARIN	American Registry for Internet Numbers
RIPE-NCC	Réseaux IP Européens Network Coordination Centre
APNIC	Asia Pacific Network Information Centre
AFRINIC	African Network Information Centre
LACNIC	Latin America – Caribbean Network Information Centre

The RIR's allocate address space to ISP's whom in turn assign addresses to end users. The registration form will require:

- Organization name and address
- Administrative point of contact
- Technical point of contact

You can search to see if the domain name you desire is available by using WHOIS at http://www.networksolutions.com Include the second level domain label (mycompany for example), along with the Top Level Domain label (TLD) .com, .net, .us. org. etc.

Once the registration process is approved and complete, the following items can be added to the root name servers (a Root server is an authoritative DNS server for the Internet. There are currently 13 root servers):

- A Record	Address Record, maps the IP address to the domain name
- MX Record	Mail Exchange Record, points to your mail server host SMTP gateway
- NS Record	Name Server record, either delegated or authoritative (usually the hosting ISP)

Once the record is entered, it will take approximately 24 hours to propagate the change to all resolvers. A Resolver is a DNS server that can do a recursive search of DNS records including root servers. Your ISP hosts DNS resolvers. Your ISP will have a Resolver DNS server that can query ancestral name servers or root servers.

There is a modest fee for registering your domain name, and for obtaining a block of address space that may be payable on a regular annual, or semi-annual basis.

When accepting address assignments from an ISP, be sure to get a static address, or block of addresses. Some DSL providers will assign addresses dynamically. This will disrupt your connection should the DHCP lease expire and you be assigned a new address, or if the ISP changes the address structure. When accessing a remote location, you will have to rely on a static address to establish that connection unless DNS is updated to reflect the address change.

ISP's are classified by a 3 tier delineation.

- Tier 1	Interconnect with each other and at Public Network Access Points

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- Tier 2 These are regional ISP’s that interconnect with one or more Tier 1 ISP’s
- Tier 3 These providers interconnect with Tier 2 ISP’s and smaller customers

If you are a large enterprise, you may consider a Tier 1 ISP for more direct Internet access (fewer hops). If you company is regional, a Tier 2 ISP may be a more cost effective choice.

When you request an Internet Domain name through an ISP, or AS (Autonomous System) number, the ISP or Registry service will process you application through ARIN for North American domain names.

For more information on DNS, CIDR (Classless Inter-Domain Routing), Private Addressing and NAT (Network Address Translation), see Section III ‘Routers’.

ISP Security Services

ISP’s can also offer other services that help prevent some threats such as DOS and DDOS attacks. ISP’s monitor the network 24x7 and will mitigate attacks sourced from routes where such attacks originate. Some ISP’s will also offer email scanning of attachments to filter embedded viruses.

Conclusion

There are two typical categories of Automation users considering WAN technology:

Larger organizations seeking to interconnect multiple plants for business intelligence

> For these organizations, discussing the strategy with your Information Technology group is the best place to start. You may find that leveraging existing WAN circuits and interfaces can be extended to include the Automation component. With security paramount, particularly where Automation is involved, be sure to review Section VI ‘Security’ as preparation for such a discussion.

Organizations seeking to poll remotely located devices for SCADA like pumping and substations

> Automation users looking to poll remote locations that usually contain small number of devices, should consider either DDR in this Section or ‘Wireless’ in Section V. Of equal importance is proper security, along with an understanding of your SCADA application manages connections, for the best performance and reliable transfers.

For additional information, or assistance with your network project, please call Schneider Electric Network Services at 800-468-5342, or visit us on the web at http://eclipse.modicon.com

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Trademarks

AT&T	is a registered trademark of AT&T Corporation
Sprint	is a registered trademark of Sprint Communications Company LP
Verizon	is a registered trademark of Verizon Communications
SBC	is a registered trademark of SBC Communications, Incorporated
British Telecom	is a registered trademark of BT Group PLC
Level 3	is a registered service mark of Level 3 Communications, Incorporated
NTT	is a registered trademark of NTT Communications
France Telecom	is a registered trademark of France Telecom SA
China Telecom	is a registered trademark of China Telecom
Qwest	is s registered trademark of Qwest Communications International, Incorporated
UUNet	is a registered trademark of MCI/WorldCom Incorporated
MCI	is a registered trademark of MCI/WorldCom Incorporated
Verio	is a registered trademark of NTT Communications
ITU	is a registered trademark of the International Telecommunication Union
ARIN	is a registered trademark of the American Registry for Internet Numbers
RIPE-NCC	is a registered trademark of the Reseaux IP Europeens Network Coordination Centre
APNIC	is a registered trademark of the Asia Pacific Network Information Centre
AFRINIC	is a registered trademark of the Africa Network Information Centre
LACNIC	is a registered trademark of the Latin America and Caribbean Network Information Centre