Internet
Network and Service Management
ISCC 2004

- Tutorial # 3 -

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Internet Network and Service Management

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Internet Network and Service Management

PURPOSE

To analyze Internet network and service management concept, models, architectures, the criteria and attributes associated with Quality of Services, Classes of Services, and Service Level Specifications/ Agreements, and the state of management products to provide solutions and applications focused on Internet network and service management.

TUTORIAL LEVEL

Intermediate/Advanced. It assumes basic understanding of networking and management concepts as applied to major networking technologies, including the Internet network environment.

WHO WILL BENEFIT BY ATTENDING

Management information systems, data communications and telecommunications staff, software developers, network and service providers, analysts, consultants, and managers seeking understanding of management services and management applications and management platforms associated with service management layer.

OUTLINE

1. Internet Network Management Architectures and Applications

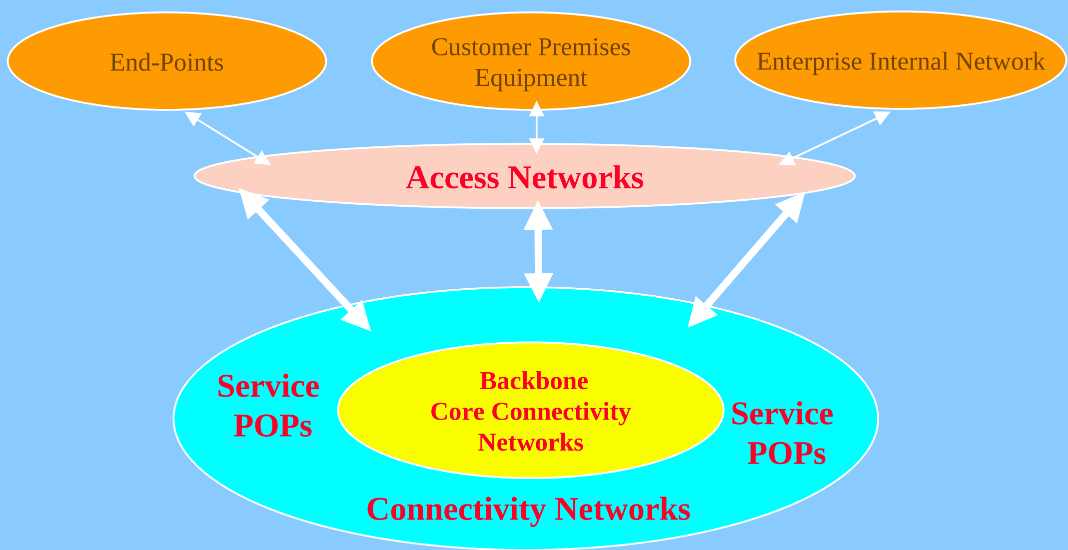
1.1 Internet network architectures and protocols
- Internet TCP/IP-based network architecture
- New Internet network architecture
- Internet TCP/UDP/IP protocol data framing

1.2 Internet network management architecture
- Internet network management conceptual model
- Internet SNMP protocol data framing and operations
- Internet network management

1.3 Internet network management products and applications
- Internet management evolution
- Internet management domains
- Major commercial management platforms

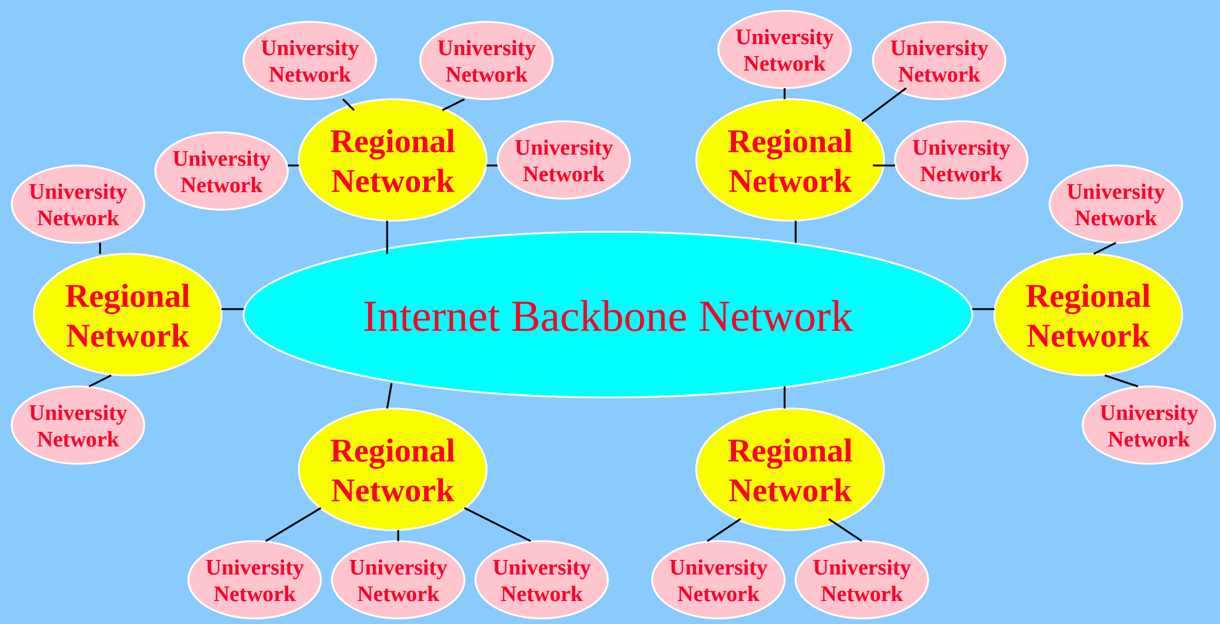
Traditional Public/Private Communication Network Model

• Any traditional service-oriented public/private network can be described as a mesh of network structures consisting of access networks, connectivity networks where services are offered, and core connectivity backbone networks. These networks may belong to multiple national and international jurisdictions. Individual end-points or whole enterprise internal networks are considered Customer Premises Equipment/Network and represent the source and destination of information.



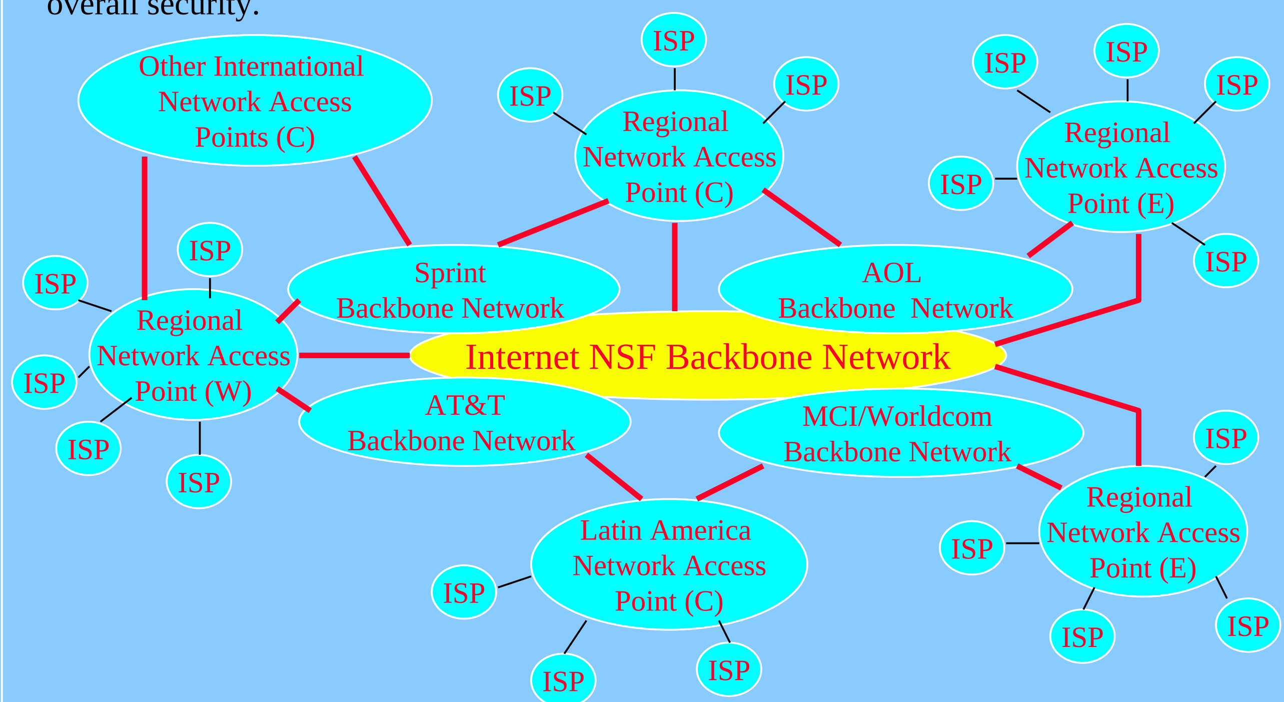
Traditional Internet

• For more than a decade, Internet has grown as a hierarchical structure having at the core a high speed backbone network accessed by major regional networks each of them consisting of a constellation of connected university networks, all of them representing autonomous systems.



New Internet Network Architecture

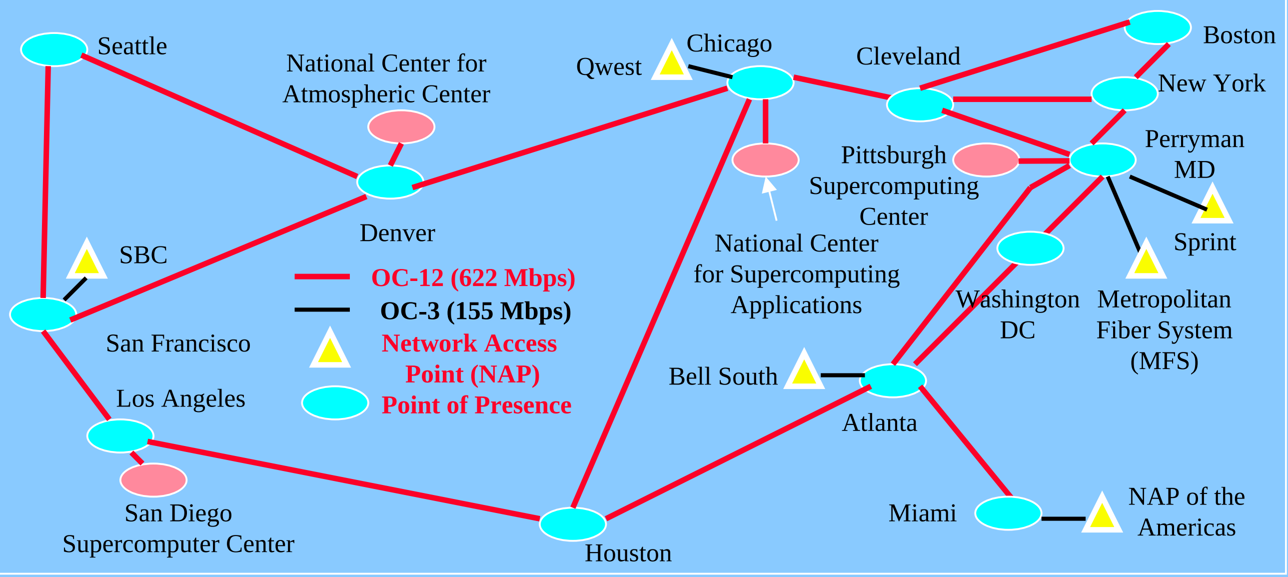
- Internet has also evolved from a research/education to a commercial service-based network.
- The tremendous growth of the past 5 years is stressing its limits in addressing capacity and overall security.



USA NSFnet vBNS Internet Layout

• The early **National Science Foundation (NSF)** network that played a crucial role in Internet development has evolved into NSF **Very-high-performance Backbone Network Service** (vBNS), essentially a combination of OC-3/STS-1 (155 Mbps) and OC-12/STS-4 (622 Mbps) with later migration toward OC- 48 and OC-192 (2.5 Gbps -10 Gbps) based infrastructure.

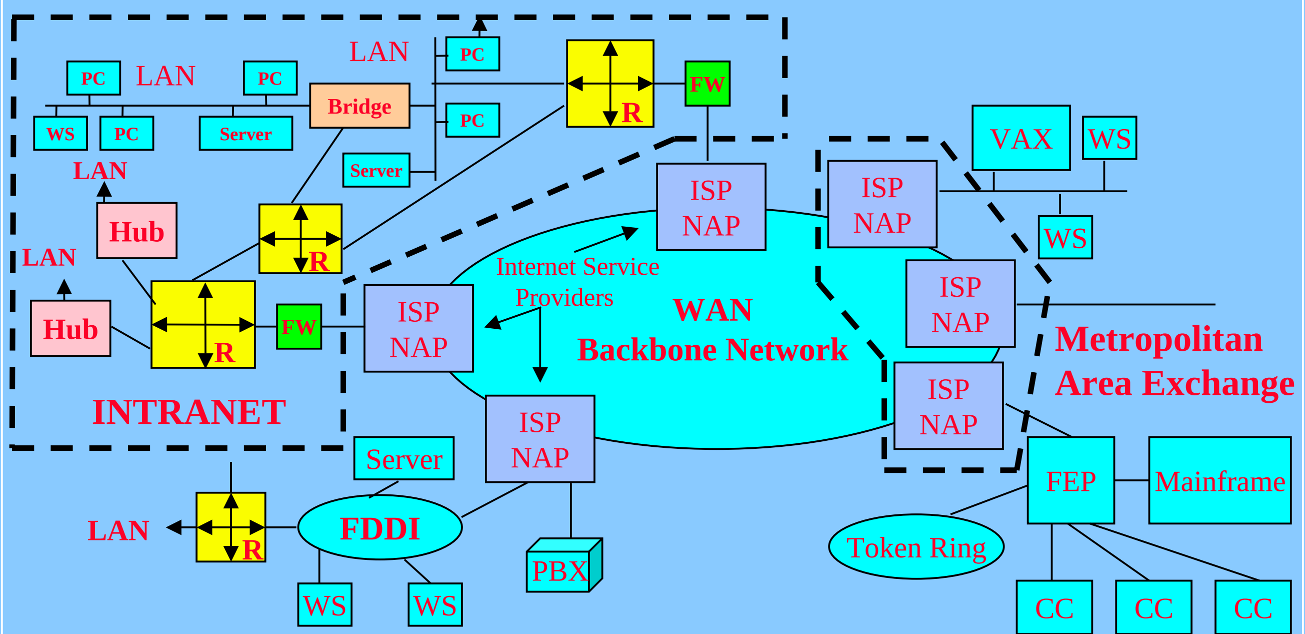
• There are 12 **Points of Presence** (POPs) in MCI Worldcom central offices and four POPs in dedicated Supercomputer Centers.



Internet TCP/IP-based Network Architecture

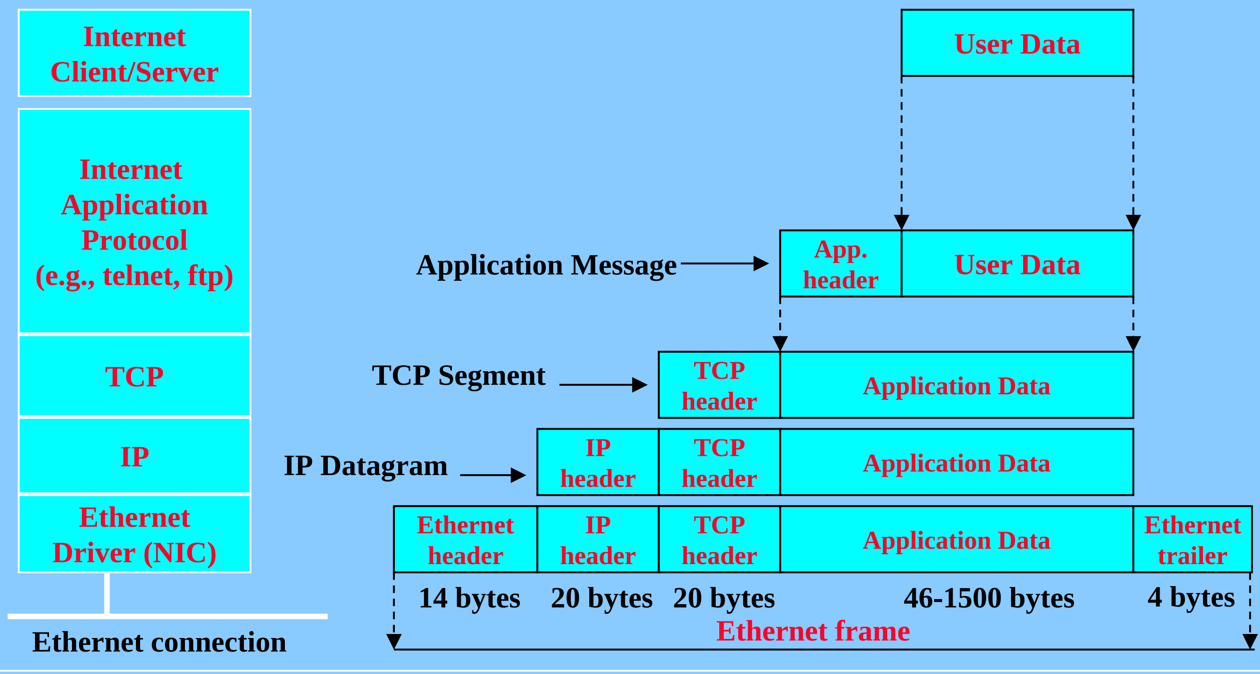
• Currently, the Internet is a three-tier router-based architecture that consists of a backbone network, connectivity networks, and the enterprise Intranet network environments.

• The connectivity network, built around **Internet Service Providers** (ISPs) **Network Access Points** (NAPs), interconnects Intranets/individual subscribers through the access networks to the backbone network, a high speed WAN using a combination of T3, FR, ATM, SONET, and WDM technologies.



Internet TCP/IP-based PDU Encapsulation

- The user data provided by communication software is **encapsulated** as it goes down the protocol stack by adding, in the form of headers, information pertinent to each layer.
- The opposite process, **decapsulation**, takes place at the reception of a PDU, where each layer strips the message and analyzes the corresponding header information.



Internet Protocol Version 4 Format

- Internet Protocol (IP) is the Internet Network Layer connectionless datagram protocol.
- IP routers may fragment datagrams while end-systems reconstruct fragmented datagrams.
- IP datagrams are delivered to the in-header IP destination addresses.

1 2 3 4 5 6 7 8 1 2 3 4 5 6 7 8 1 2 3 4 5 6 7 8 1 2 3 4 5 6 7 8 **Bits**

<table>
<tr><td>version
4 bits</td><td>IHL
4 bits</td><td colspan="2">Type of Service (TOS)
8 bits</td><td colspan="4">Total length
16 bits</td></tr>
<tr><td colspan="4">Identification (unequivocally)
16 bits</td><td>flag
3 bits</td><td colspan="3">Fragment offset
13 bits</td></tr>
<tr><td colspan="2">Time to Live (TTL)
8 bits (# of hops)</td><td colspan="2">Transport Protocol
8 bits</td><td colspan="4">Header Checksum
16 bits</td></tr>
<tr><td colspan="8">Source address
32 bits</td></tr>
<tr><td colspan="8">Destination address
32 bits</td></tr>
<tr><td colspan="3">Options
variable (less than 32 bits)</td><td colspan="5">Padding
variable (together with Options 32 bits)</td></tr>
<tr><td colspan="8">User Data
variable length(depends on the size of “Maximum Transmit Unit” accepted for a medium)
data field and header maximum 65,535 octets</td></tr>
</table>

Transmission Control Protocol and User Datagram Protocols

- Transmission Control Protocol (TCP) is the connection-oriented Transport Layer protocol.
- User Datagram Protocol (UDP) is the connectionless Transport Layer counterpart.
- Sockets (logical port number and IP address) are used to map applications into TCP/IP or UDP/IP protocols. Distinct port numbers are allocated for TCP and UDP-based applications.

1 2 3 4 5 6 7 8 1 2 3 4 5 6 7 8 1 2 3 4 5 6 7 8 1 2 3 4 5 6 7 8 **bits**

TCP

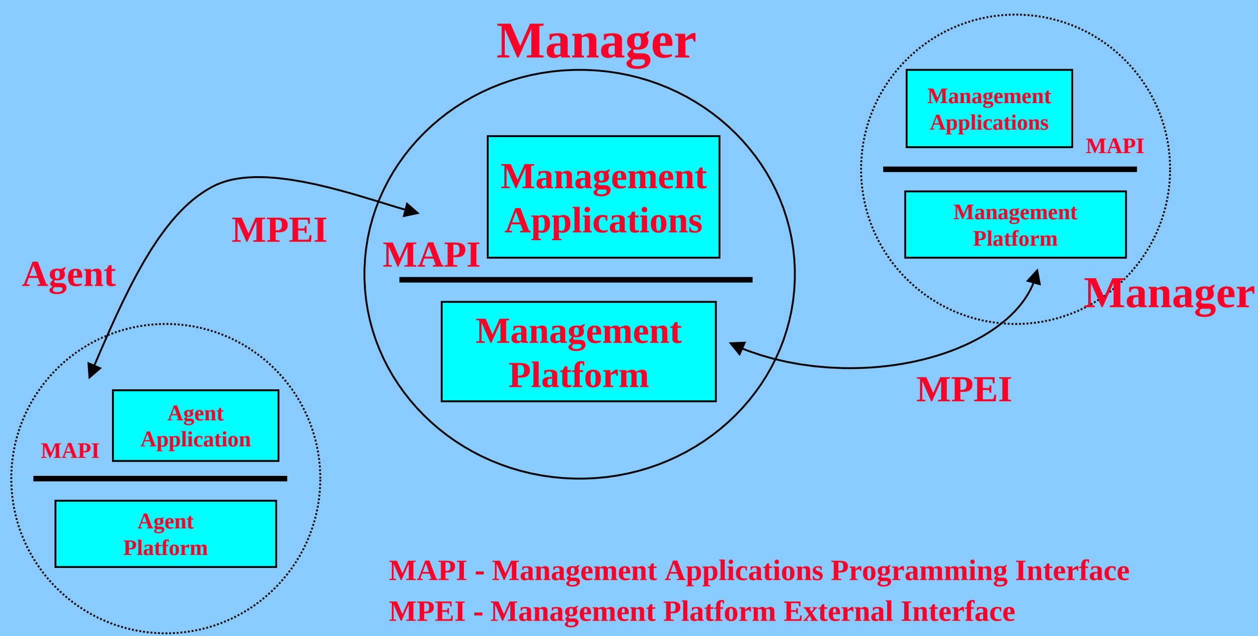
Source Port (e.g., 23 telnet, 21 ftp) 16 bits		Destination Port (e.g., 25 smtp, 69 tftp) 16 bits	
Sequence Number 32 bits			
Acknowledgment Number 32 bits			
Header Length 4 bits	Reserved 6 bits	Flags 6 different 1-bit	Window 16 bits
Checksum 16 bits		Urgent Pointer 16 bits	
Options variable (less than 32 bits)		Padding variable (together with Options 32 bits)	

UDP

Source Port (e.g., 23 telnet, 21 ftp) 16 bits	Destination Port (e.g. , 25 smtp, 69 tftp) 16 bits
Length 16 bits	Checksum 16 bits

Internet Management Conceptual Model

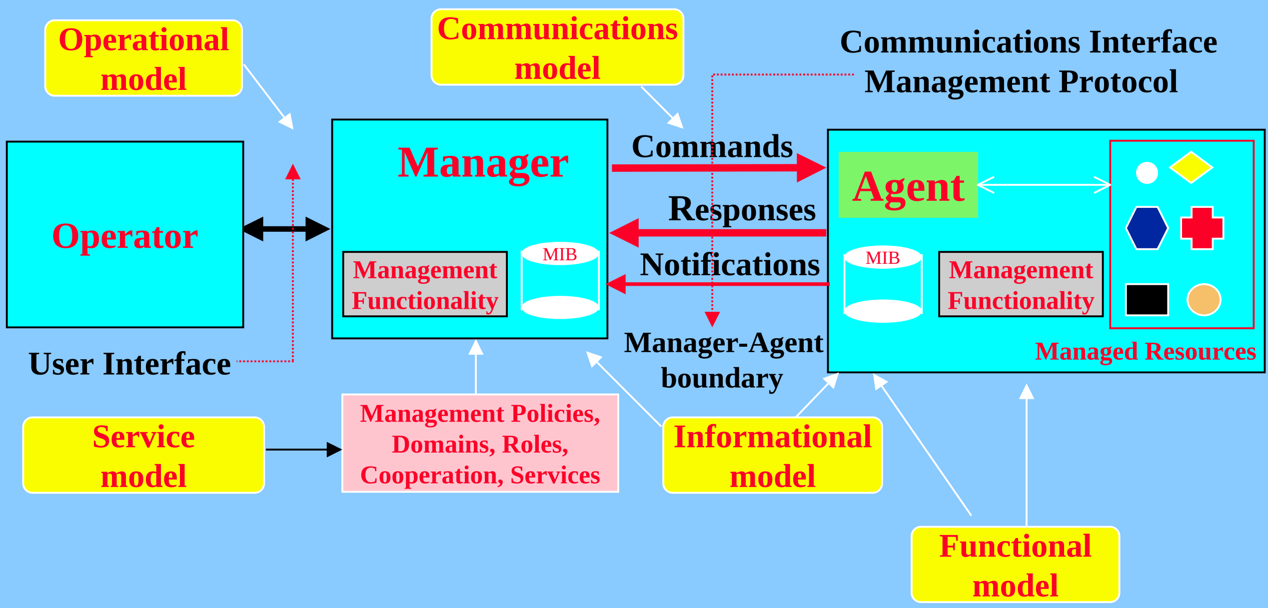
- Internet networks management is based on manager-agent paradigm and use of management platforms and open standardized external interfaces.



MAPI - Management Applications Programming Interface
MPEI - Management Platform External Interface

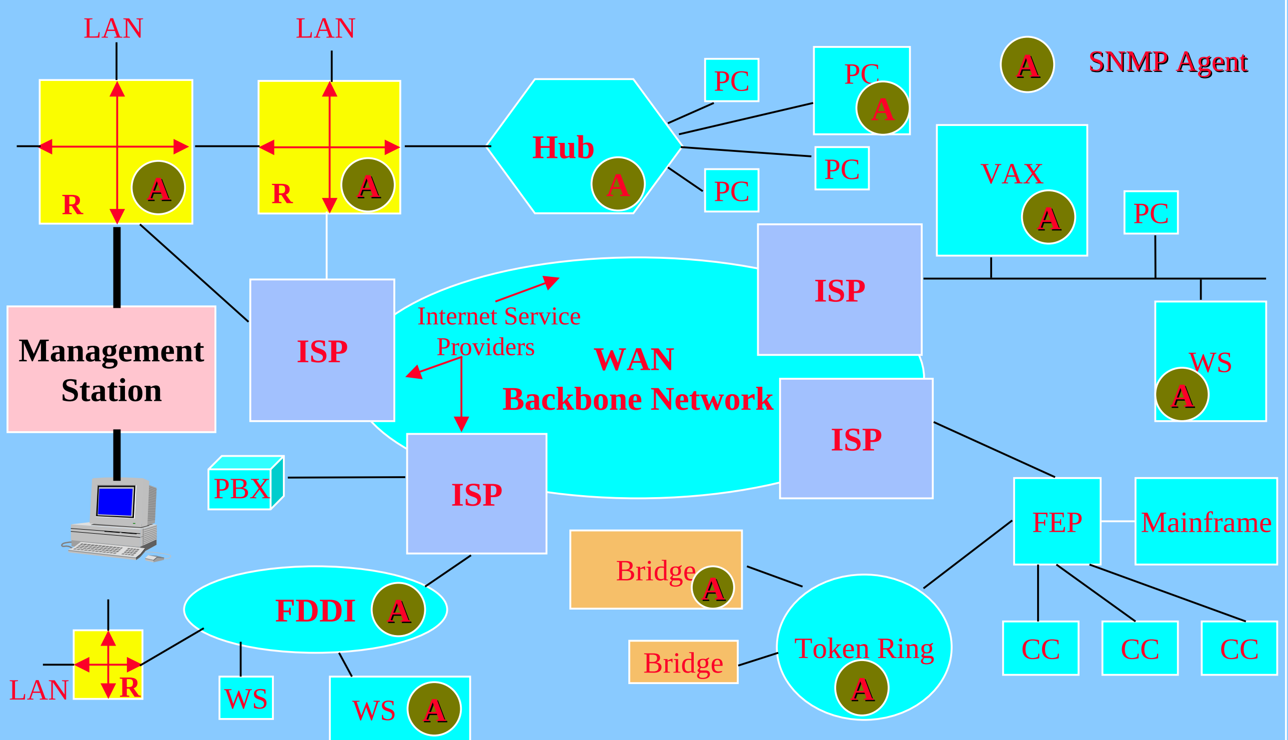
Models and Sub-models of the Manager-Agent Paradigm

- The Manager-Agent architectural relationship is detailed by several specific sub-models.
- There is a close relationship between communications, information, and functional models.



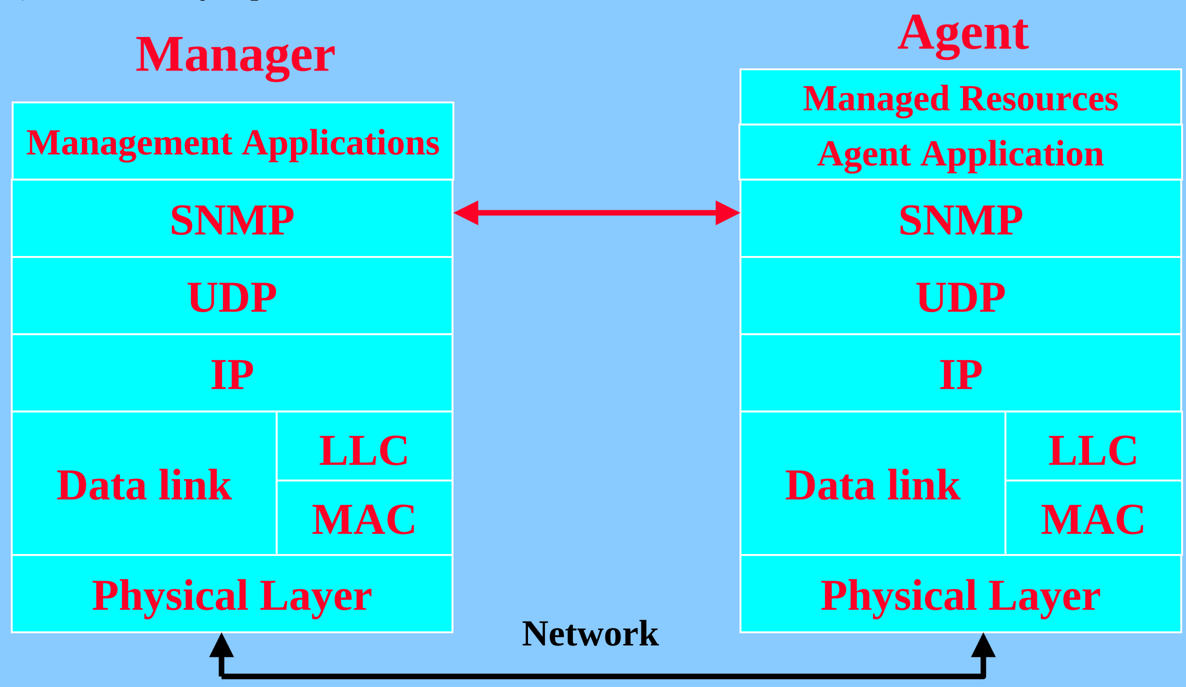
Internet Simple Network Management Protocol-based Diagram

- Internet SNMP-based management assumes that the managed agents are IP-addressable nodes.
- To manage network or systems resources, each managed node should include a SNMP agent.



Simple Network Management Protocol Stack

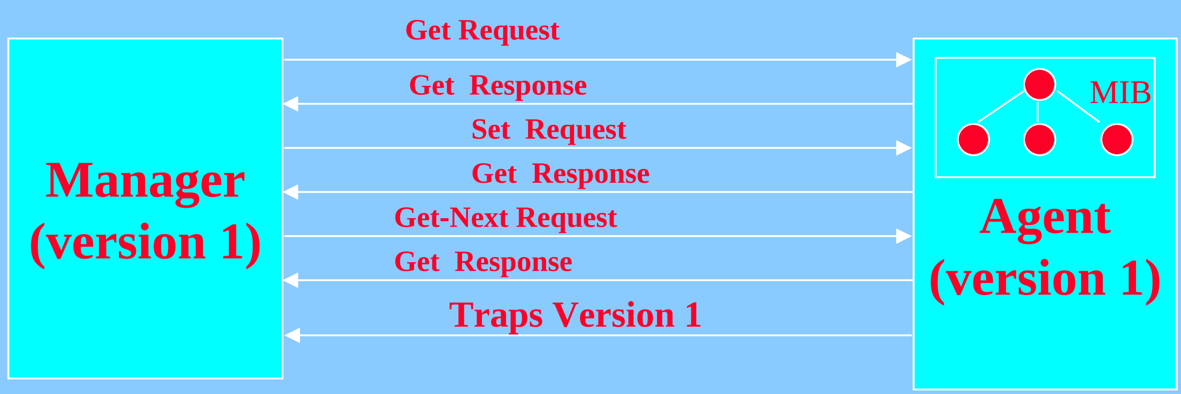
• Simple Network Management Protocol (SNMP) is an application layer protocol running on top of the User Datagram Protocol (UDP) Transport Layer protocol and the Internet Protocol (IP) Network Layer protocol.



SNMP-based Manager-Agent Services and Operations

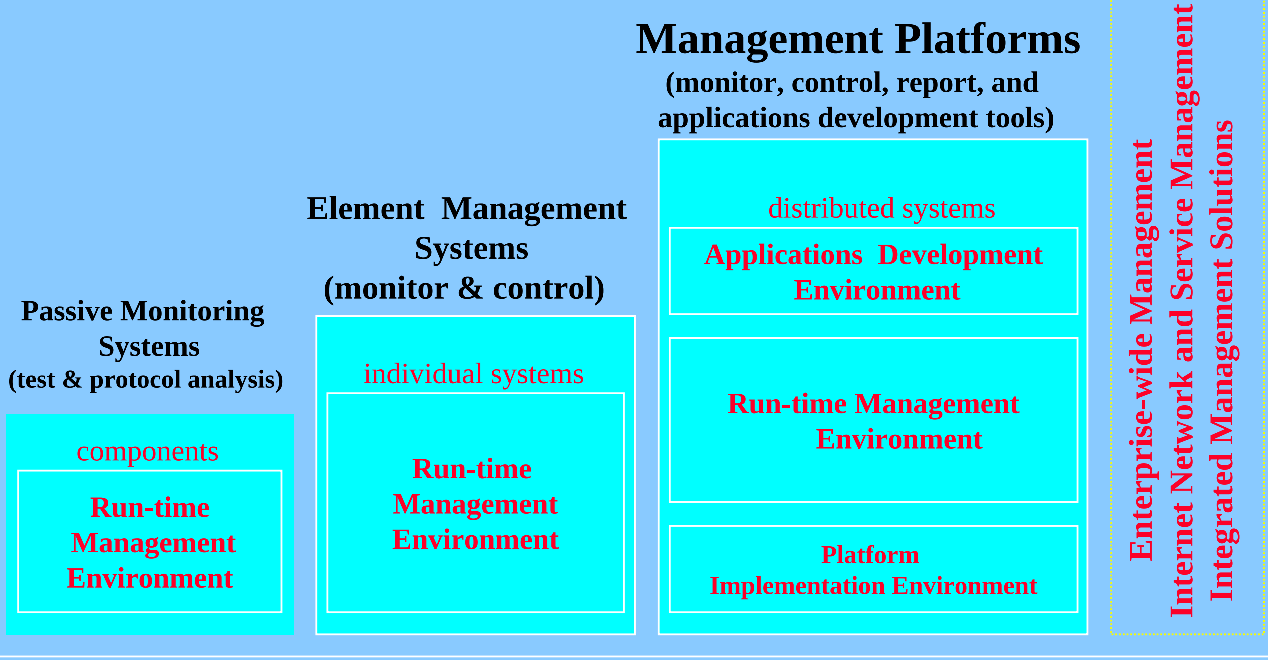
• SNMP Version 1-based network management uses four types of basic operations: Get, Get-Next, Set, and Traps.

• Three types of Protocol Data Units (PDUs) are associated with manager-agent messages: Get/Set/Get-Next Request, Get response, and Traps.



Management Systems Evolution

• Management systems have evolved from passive monitoring to management platforms.
• Three environments are considered to be included in management platforms: run-time or operational environment, applications development environment, and implementation environment.



Internet Management Domains

• Internet management requires management of all structural and functional components that . make an Internet environment from networks to the actual protocols carrying information.

Physical Resources (Hardware)

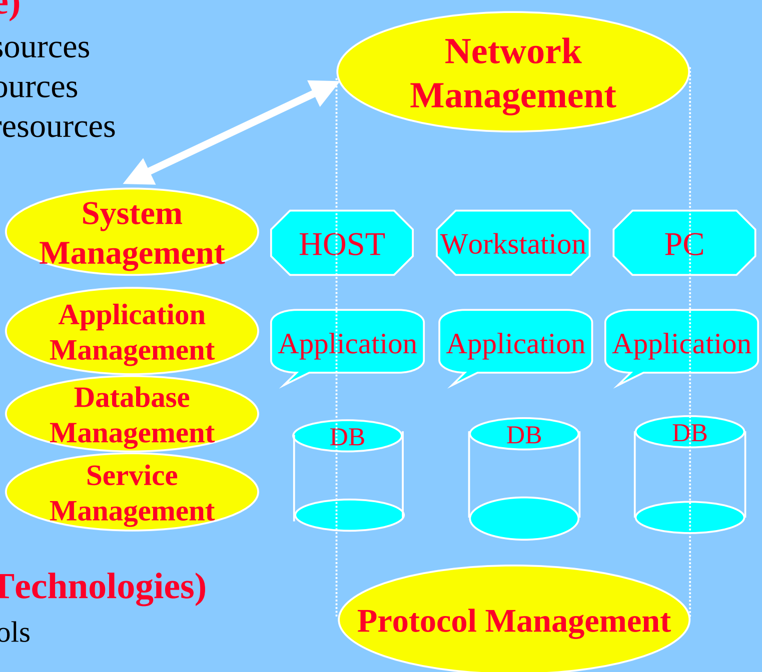
• Data communications network resources
• Telecommunications network resources
• Video Communications network resources
• Computing systems resources

Logical Resources (Software)

• Applications
• Databases
• Services
• User interactions
• Data flow/traffic
• Policies

Logical Resources (Protocols/Technologies)

• Layered communications protocols



Management Platforms Framework

MANAGEMENT PLATFORM

MANAGEMENT APPLICATIONS

Applications Programming Interfaces

MANAGEMENT PLATFORM FRAMEWORK
(MANAGEMENT SERVICES)

Hardware and Operating System

MANAGEMENT APPLICATIONS DEVELOPMENT TOOLS

Platform External Interface

Other Open Management Systems

Major Commercial Management Platforms

Network Management Platforms

- HP OpenView
- IBM /Tivoli SystemView
- SUN Solstice Enterprise Manager
- Aprisma (Cabletron) Spectrum
- Digital TeMIP
- Bull ISM/OpenMaster

Systems Management Platforms

- Tivoli Systems TME
- Computer Associates Unicenter TNG/TND

2. Service Management Concept, QOS, and SLA

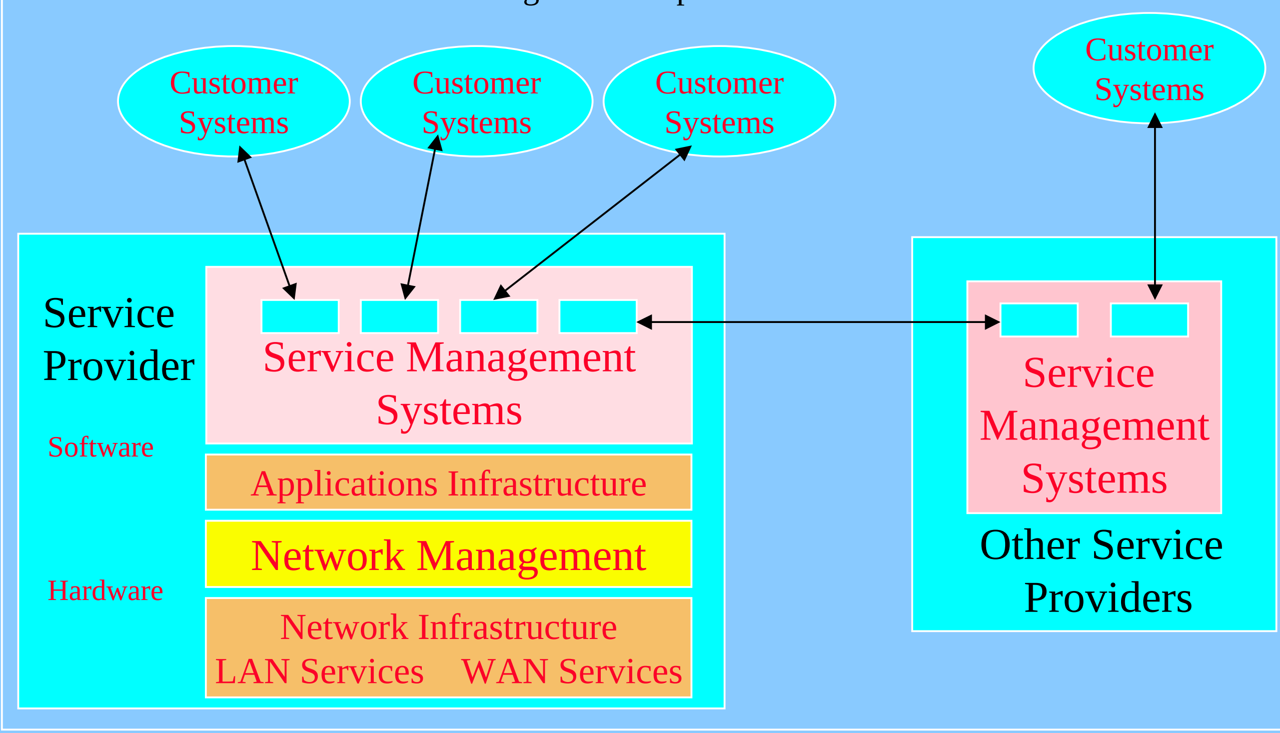
2.1 Service and service management concepts
- **Service and service management model**
- **Service domains/structures/qualifiers//criteria/providers**
- **Classes of services**

2.2 Quality of Service (QOS) model and metrics
- **QOS architectural model**
- **QOS metrics**
- **QOS measurement mechanisms and management**

2.3 Service Level Agreement (SLA) methodology and attributes
- **SLA management model**
- **Network SLA domains**
- **Applications SLA domains**

A Simplified Communications Service Model

- A communication service is a contract between **customers** (individual subscribers or organizations) and one or multiple **service providers** that assures exchange of information under well defined conditions and guaranteed performance.



Service Domains, Structures, Architectures, Models

- A quick introduction into the world of services and service management requires a basic set of terms, characteristics, and examples.

Service Domains	Service Structures	Service Architectures	Service Models
PSTN • Voice Communications • Value-added Voice Communications • Data Communications • Internet • Multimedia Communications • Internet 2 **CATV** • Video Communications • Multimedia or Converged Communications **PCS/PCN** • Cellular • Satellite	• Core Services • Value Added or • Extended Services • Management • Security • Time • Directory Services • Distributed Services	**Tier 1** **Access Services** • leased lines • dial-up lines • DSL • cable modem • wireless • satellite **Tier 2** **Connectivity Services** • aggregation • concentration • multiplexing **Tier 3** **Backbone Network Services**	• Generic Service Model and Functions • TeleManagement Forum Operations Model (TOM and eTOM) • Telecommunication Network Management (TMN) Service Model

Service Qualifiers, Criteria, Classes, Management, Providers

- A service, as a function of the network and supporting applications are characterized by a set of parameters which determine the service level.

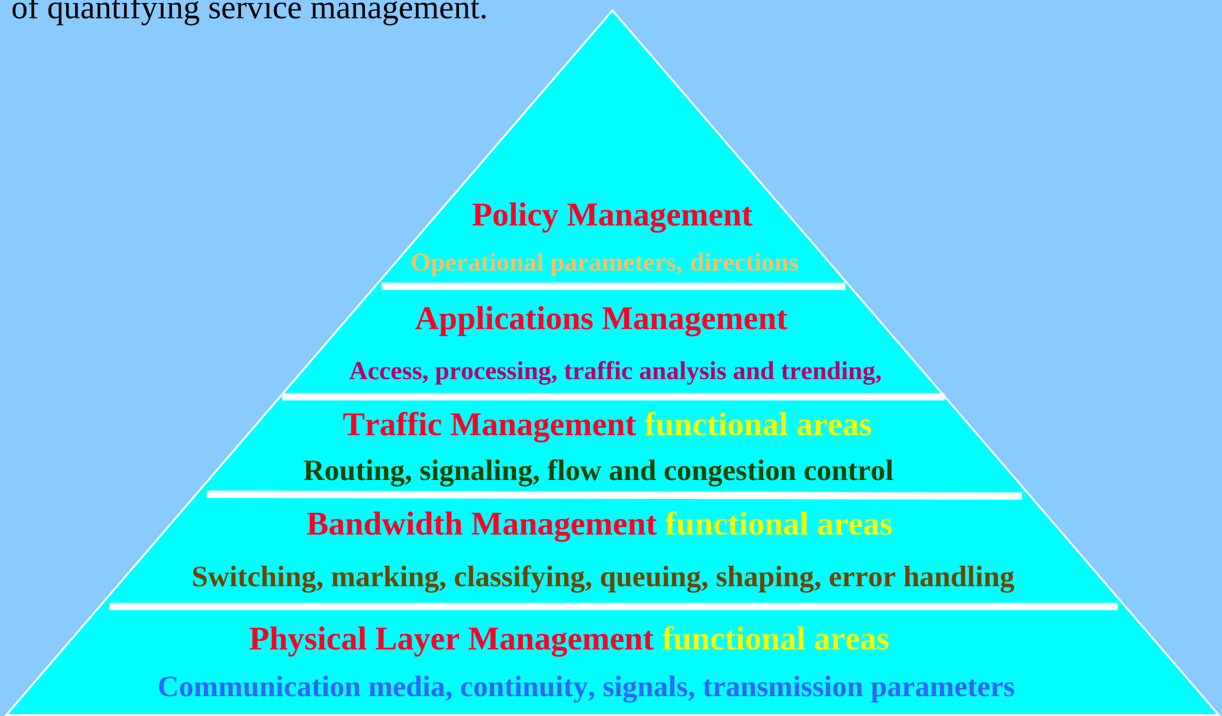
Service Qualifiers	Service Criteria	Service Classes	Service Management	Service Providers
• Availability • MTBF, MTTR • Bandwidth • Data Rate • Throughput • Response Time • Delay • Jitter • Packet Loss • CIR • CBR • Usage • Accounting • Cost • NQOS • AQOS	**Customer Perspective** • Feasibility • Accessibility • Availability • Scalability • Flexibility • Customer Service • Comprehensiveness • Personalization • Security/Privacy	• Carrier Class • Best Effort • Service Architectures - IntServ - DiffServ • Assured Forwarding • Expedited Forwarding	• Performance Management • Customer Service Management • Event Correlation System • Historic and Real-time Performance Data • Web-based Service Management	TSP ILEC/PTT LEC/IXC CLEC/CAP BLEC NSP ISP ASP MSP DCP MSO

Classes of Services (COS)

- **Class of Service (COS)** is an accepted grouping of common applications and users with similar service requirements into one of several broader services or priority classes.
- **Classes of Services** are used by service providers to differentiate services along cost and performance offered.
- The following functions and characteristics can be associated to COS:
  - Correlation between the sending and receiving applications.
  - Classification of traffic according to common fields and frame/packets headers.
  - Provides preferential treatment (minimum delay of certain traffic in congestion points).
    - Interactive voice, first priority
    - Financial transactions, second priority
    - E-mail, Web surfing, common applications, third priority
  - Bypasses queues on transmit interfaces.
  - Provides extra buffer space in network elements.
  - Provides extra bandwidth in network connections.

Quality of Service (QOS) Architectural Model

- **QOS** is a multidimensional combination of **performance attributes** applied to individual datagrams or complex data flows in data and telecommunications networks. QOS is one way of quantifying service management.



QOS Metrics (I)

- QOS results are achieved by managing functional areas covering physical layer, bandwidth, traffic, policy, and application management. In practice, only a few **global QOS attributes** are used: **availability**, data rate, **throughput**, **delay** (latency), delay variance (**jitter** or wander), and **packet loss**.

Availability

- Availability is the percentage of time when the network, applications, services are available when the user needs them. It is a ratio between the total time when the system is used in normal conditions and a given time interval (month, year). The traditional benchmark, inspired by PSTN known availability is **99.999% (five-nines)** that is 5.25 minutes per year.
- 99.99% assumes 51 minutes downtime, 99.9% 8 and a half hours, 99.5% 40 hours, and 99% 3 days and 8 hours downtime a year.

Data Rate

- The measure of how quickly data can be transmitted on a line, fiber optic cable, etc., and ultimately how much information can send be sent per unit of time. Measured in Kbps, Mbps, Gbps, or Tbps. A loose “interchangeable” term for date rate is **digital bandwidth**.

QOS Metrics (II)

Throughput

- The basic measurement of amount of actual user data/information transmitted in a unit of time. Throughput depends on the amount of accompanying redundant information, traffic queuing/ aggregation mechanisms, congestion conditions, and priority handling policies applied to particular data flows. It is related to data rate (always less) and it can be a fraction of the maximum available bandwidth.

Delay or Latency

- The measure of average transit time of packets and cells from the ingress to egress points of the network. There are end-to-end delays and delays along portions of the network.
- The **end-to-end delay** depends on the propagation rate of data in a particular communication medium (satellite or terrestrial), the distance, number and type of network elements (design, processing, switching, and buffering capabilities), routing schemas (dynamic, static, queuing, and forwarding mechanisms), **Bit Error Rate** (BER) in transmission, and policies regarding priority treatment of data flows.

QOS Metrics (III)

Jitter

- **Jitter** is one of the forms of **delay variation** caused by the difference in delay exhibited by different packets that are part of the same data flow. Jitter is caused primarily by differences in queuing delays for consecutive packets in the flow and by the possible alternate paths taken by packets because of routing decisions.

Packet Loss

- Typically measured as a percentage of the **ingress** and **egress traffic**. Packets can be lost because they are dropped at congestion points, traffic violations (synchronization, signaling, unrecoverable errors), excessive load, or natural loss included in compression/decompression mechanisms.
- Voice and video communications are tolerant to the loss of packets (often not noticed by users or by brief flickering on the screen) if they do not exceed 5%.
- TCP can handle dropped packets because it allows retransmission of information (absolutely necessary for pure data but unnecessary for voice or video).

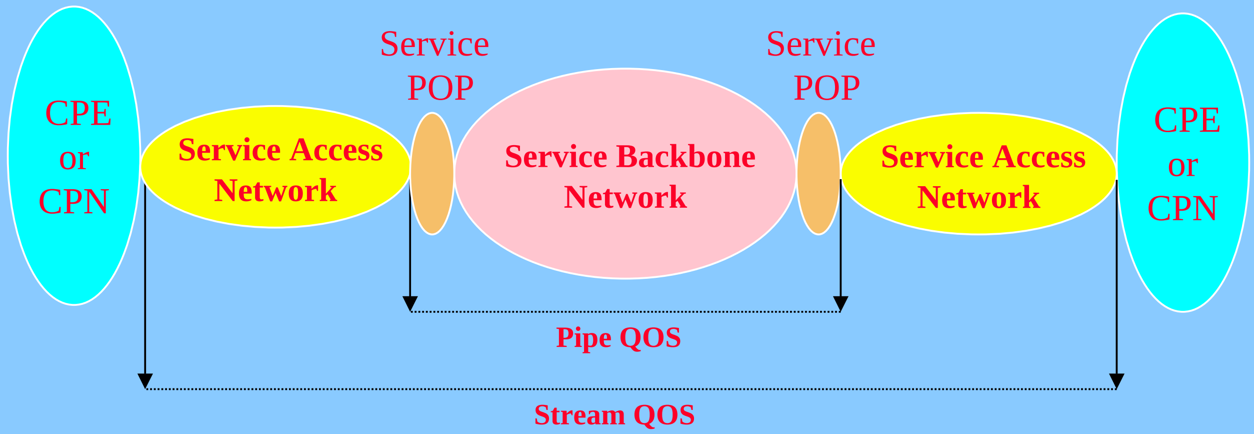
QOS Measurement Mechanisms

- Implementation of QOS/SLA requires, in addition to clearly defined QOS metrics, a set of cost effective QOS measurement mechanisms, as indicated below:

  - **Polling mechanisms** of counter-specific managed objects and associated MIBs.
    (Achieved via SNMP messages; typical MIB information related to traffic, error conditions, status of interfaces, but not delay and jitter values).
  - **RMON 1 and RMON2** proactive **remote monitoring**.
    (Local collection of statistics, off-line operation, sparing management bandwidth, multiple managers capabilities).
  - **Response Time Reporter** (RTR).
    (Cisco routers IOS extension in using trace routes commands to determine active ports and measure Round Trip Delay (RTD) between hops).
  - **Dedicated WAN Probes** in **CSU/DSUs** network components.
    (Dedicated CSU/DSU with embedded service analysis elements for FR, ATM, and IP level traffic statistics for individual applications such as telnet, ftp, ICMP, DNS, etc.).
  - **Advanced Network** and **Service Surveyor** (Internet Performance Measurement Project).
    (50+ customized PCs, dedicated surveyors, each synchronized using Global Positioning Satellite (GPS) systems, measuring transmission delays within 50 ms accuracy).

QOS Management

- **QOS** management means collection of QOS metrics using QOS measurement mechanisms and providing meaningful interpretation and reporting of the results to service providers and users as pertaining to service level agreements.
- QOS management can be differentiated along two major entities: data pipes and data streams.

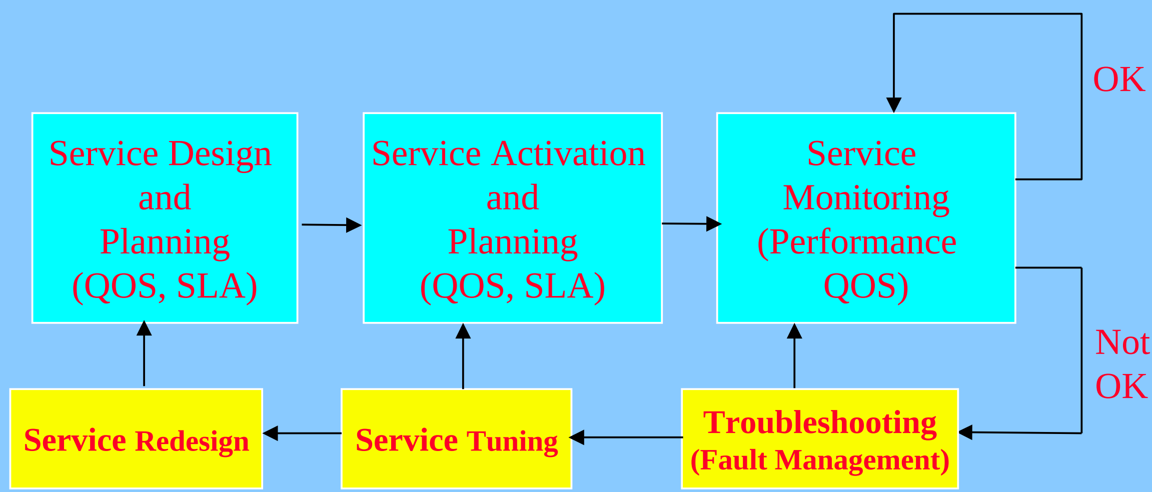


Pipe QOS
- Service Class
- Bandwidth
- MTU
- Packet size

Stream QOS
- Throughput
- Delay (Jitter)
- Packet loss
- Frame size

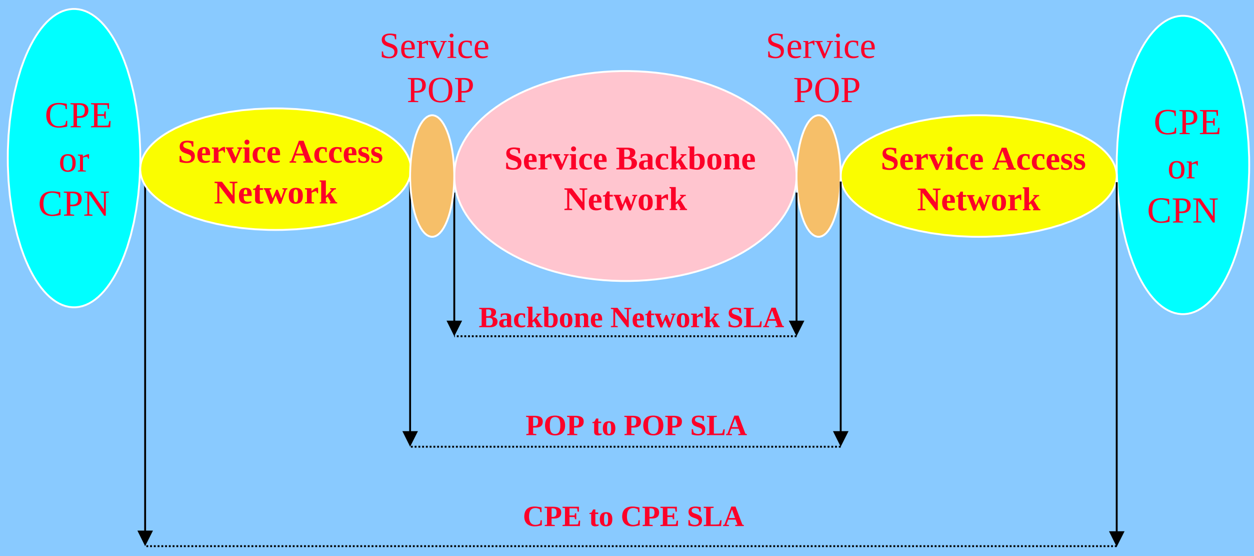
SLA Management Model

- Service Level Agreements (SLAs) are contracts between service providers and customers that specify the performance parameters (QOS) within which the services are provided.
- SLA management is a loop process targeting service activation and monitoring input and output QOS parameters.



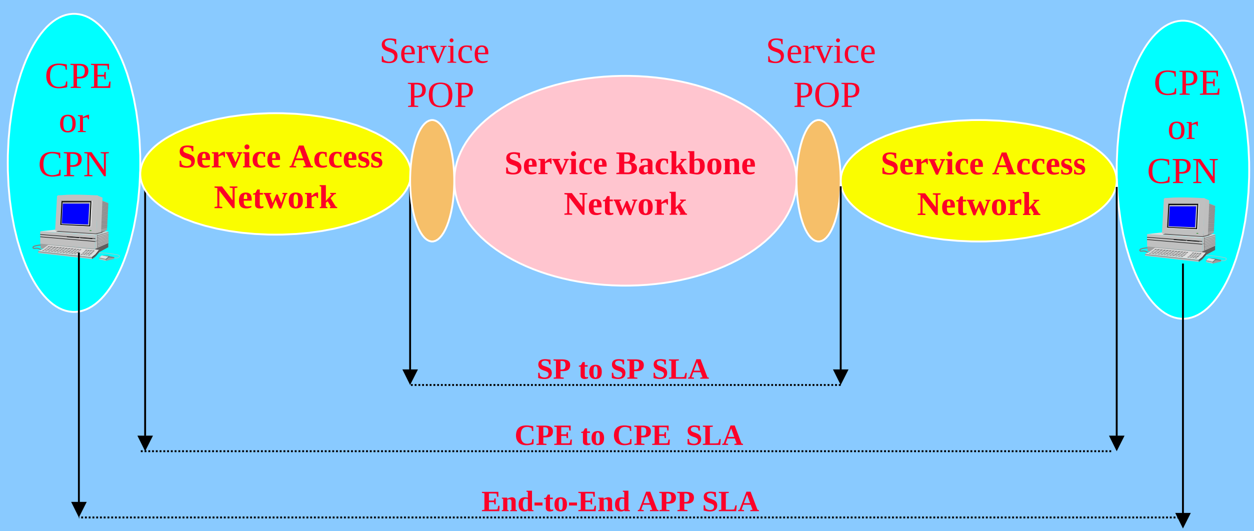
Network SLA Domains

• Network SLAs can be established at three major demarcation points covering the backbone network (hence backbone SLA), connectivity networks (hence POP to POP SLA) and access networks (hence CPE to CPE SLA).



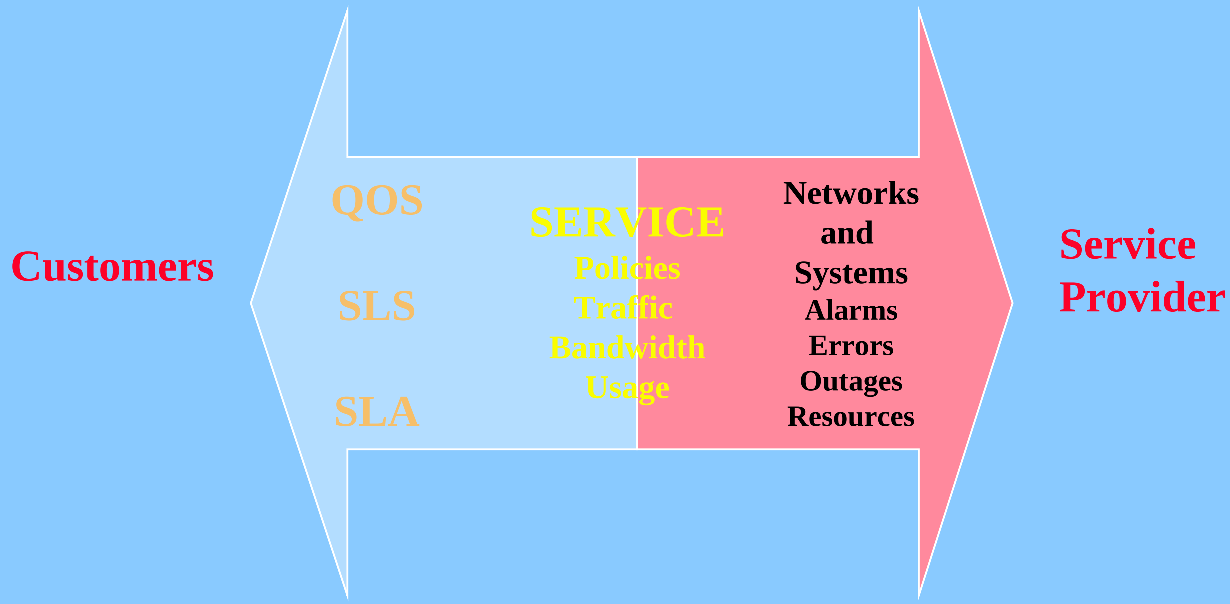
Applications SLA Domains

• Application SLAs can be established at three major demarcation points covering connectivity networks (SP to SP), access networks (CPE to CPE SLA), and end-to-end SLA between applications (APP SLA).



How QOS Data and SLA Are Used

- Establishing, collecting, reporting QOS data, and, ultimately comparing QOS data with Service Level Specifications (SLSs) is a joint effort of service providers and customers although they use different perspectives.



3. Internet Service Management Technologies

3.1 Internet services and classes of services
- Internet service providers characterization
- Internet Integrated Services
- Internet Differentiated Services
- Multi-Protocol Label Switching

3.2 Internet service level agreements
- SLA domains for Internet IP-based data services
- SLA components for Internet data services

3.3 Internet service management products and applications
- Standalone service management application suites
- Management platforms and service management
- Carrier service management application suites
- Micromuse Netcool/Omnibus Architecture and Application Suites

Internet Service Providers Characterization

- A quick introduction into the world of Internet Service Providers (ISPs) requires a basic set of service-related terms and service management characteristics.

Internet Service Providers	Service Qualifiers	Major Services	Service Mechanisms	Value-added Services
• UUNET **• Etherlink** **• AOL/Time Warner** **• AT&T** **• Sprint** **• Quest (US West)** **• Verizon (Bell Atlantic/GTE)** **• SBC** **• BellSouth** **• Cable and Wireless** **• IXC Communications**	• Connectivity •Availability • MTBF, MTTR • Bandwidth • Data Rate • Throughput • Response Time • Delay • Jitter • Packet Loss • Usage • Accounting • Cost/Payback • Denial of Service • Compensation for non-compliance	**• Internet Access** - dial-up - cable modem - xDSL - satellite - IAD **• Traditional Internet** - DNS - DHCP - NAT **• New Internet** - VoIP - VPN - RADIUS - Audio streaming - Video streaming - Web-cast video	**• Traditional Internet** - Best Effort **• Integrated Services** (IntServices) **• Differentiated Services** (DiffServ) - Assured Forwarding - Expedite Forwarding	• Policy-based Network Management (PBNM) • Historic and real-time Performance Management • User Management • Security Management • Trouble Reporting

Internet Integrated Services (IntServ)

- **Integrated Services,** as a QOS mechanism, are focused on individual packet flow between end systems (applications) using TCP/UDP/IP protocols. Interest into integrated services dates back to 1993 when the “best effort” Internet “quality”guarantee started to be questioned by the need to support audio/video cast across the Internet environment. However, the standardization of integrated services came later in the form of:
  - RFC 2211 “Specification of the Controlled-Load Network Element Service”
  - RFC 2212 “Specification of Guaranteed Services”, and
  - RFC 2215 “General Characterization Parameters for Integrated Service Network Elements”.

- There are three components recognized as part of the Integrated Services architecture:
  - **Admission Control Unit** (checks if the network can grant the server request).
  - **Packet Forwarding Mechanism** (performance packet classification, shaping, scheduling, and buffer management in the routers).
  - **Resource Reservation Protocol** (RSVP) (sets the flow states in the routers).

Internet Differentiated Services (DiffServ) (I)

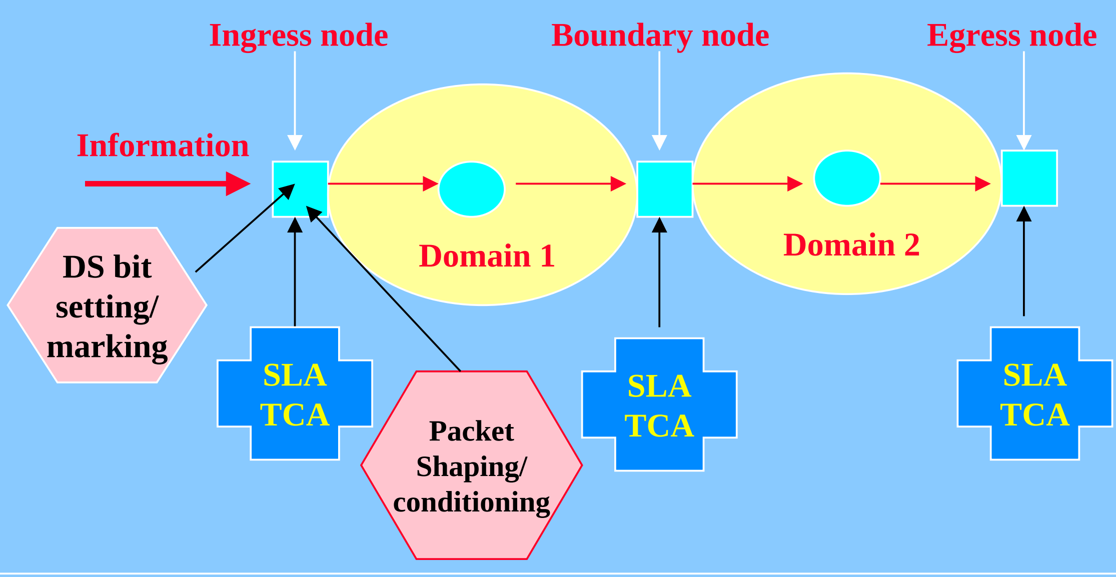
- **Differentiated Services,** as a QOS mechanism for aggregate traffic handling, are based on the former **Type-of-Service** (TOS) field specified in the IP V4 RFC 791 Internet standard. In the original specifications, the first three bits were described as **precedence bits** to be used as a selector of priority queued interfaces (largely ignored today). The higher the precedence number given, the greater is the chance that the packet will be transmitted before other packets.
- The use of other bits in the TOS field included:
  - 4 bits used as flags with the following functions:
    - minimize delay
    - maximize throughput
    - maximize reliability
    - minimize monetary cost

Note: All 4 bits set to "0" implies normal service. Only one of the 4 bits can be turned "ON".

  - 1 bit reserved for future use

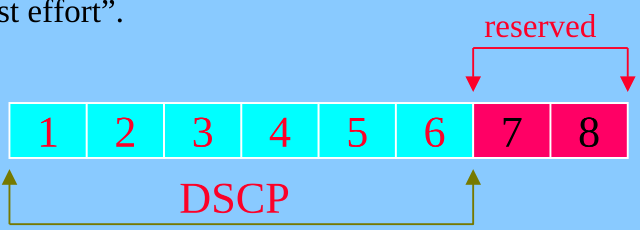
Differentiated Services Architectural Model (II)

- Although RFC 2474 and RFC 2475 do not provide service class guidance (it is outside the scope of the RFCs, there is a standard process of forwarding packets between ingress nodes, boundary nodes, and egress node, each of them subject to some Service Level Agreements (SLAs) and Traffic Conditioning Agreements (TCAs). In Differentiated Services every hop implements a **Per-Hop-Behavior** (PHB) adjustment.



Differentiated Services Fields Definition (III)

- RFC 2474 replaces the old IPV4 TOS field with a new IPV4/IPV6 Traffic Class definition. In the new layout, the first 6 bits represent the **Differentiated Services Code Point** (DSCP) while the last two bits are reserved for future use. DSCP is used to select the Per-Hop-Behavior (PHB) class. In case the DSCP is not a recognizable DSCP, the default PHB must be used which is the "best effort".



- Although, in principle, the DSCP field is not restricted, three major categories are considered:
  a. **xxxxx0** is for standard activities (allows 32 code points).
  b. **xxxx11** is for experimental activities and local use (allows 16 code points).
  b. **xxxx10** is initially for experimental activities but later can be used for standard PHB services (allows 16 code points).
- Currently, there are 5-6 service models built around some" standardized" differentiated services. All require interworking between QOS domains which may use different DSCPs.

Differentiated Services PHB Classes (IV)

- Currently, there are seven PHB proposed classes that may have a chance to be adopted:

Group A (the focus is on minimum loss of packets)

- AF-1 **Assured Forwarding PHB** highest importance level
- AF-2 **Assured Forwarding PHB** middle importance level
- AF-3 **Assured Forwarding PHB** lowest importance level
- BE "**Best Effort**" (default PHB)

Group B (the focus is on flexibility and dynamic packet differentiation related to packet loss and bandwidth)

- DRTP **Dynamic Real-time** primary area
- DRTS **Dynamic Real-time** secondary area

Group C (the focus is on delivery with minimum delay)

- EF-1 **Expedite Forwarding PHB** primary area
- EF-2 **Expedite Forwarding PHB** secondary area

Internet Applications and DiffServ Class Attributes (V)

- Different applications require different Internet service classes as exemplified in this table:

Application	Internet Service Classes	Comments
Circuit Services	Expedited Forwarding EF-1	Since these are leased lines, it will provide the maximum QOS available.
Interactive Video (Video conferencing)	High-bandwidth Expedited Forwarding EF-1 or Assured Forwarding AF-1	The use of AF-1 depends on the compression applied and acceptance level of loss packets. May require jitter buffers. It is highly dependent on the EF traffic and it may require a scrupulous traffic management.
Voice Telephony	EF-1 or AF-1	The same as interactive video.
Broadcast Video	Assured Forwarding AF-1	In this case, the delay is not a significant issue so the use of jitter buffers can smooth the traffic.
IBM SNA over TCP/IP	Assured Forwarding AF-2	IBM SNA traffic requires a reasonable response time and low packet loss. It may require traffic management.
File Transfer	Best Effort BE or Assured Forwarding AF-2	In this case, the delay tolerance depends on the application; packet loss requires retransmission.
Electronic mail	Best Effort BE or Assured Forwarding AF-2	In this case, the delay tolerance depends on the application; packet loss requires retransmission.

Multi-Protocol Label Switching (MPLS) Header (I)

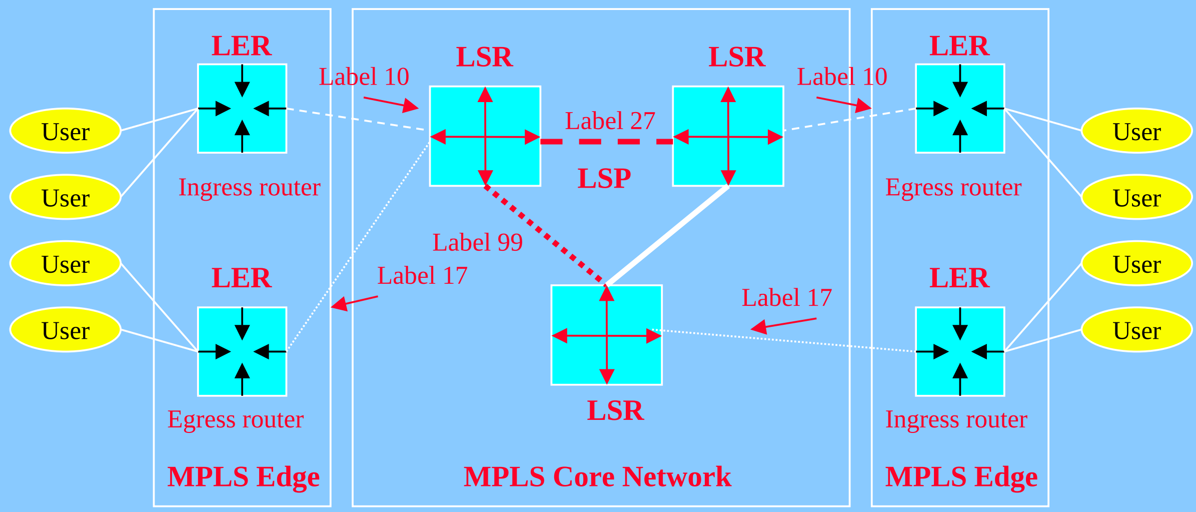
- **Multi-Protocol Label Switching** (MPLS) is an encapsulation protocol, characterized by a a new header that is located between layer 2 and layer 3 headers and which essentially is a label red by the **Label Switching Routers (LSRs)** and based on existing label information to switch the packet to the proper port according to a selected **Label Switching Path** (LSP).
- MPLS was created as a way of simplifying forwarding packets in an IP network (simpler and faster) as well as in ATM and FR networks. However, the today routers are fast enough, so the MPLS role has changed to traffic engineering and support of differentiated services.
- MPLS is both a packet forwarding and a path controlling schema and protocol taking the best of two worlds-the IP packet-based and ATM cell-based networks.
- A MPLS labeling packet (24 bits) contains a header which consists of: 20 bit label, a 3 bit experimental field, one 1 bit label stack indicator, and a Time To Live (TTL) field of 8 bits.
- Each LSR at the ingress point will insert a **MPLS header** in each packet and the header is removed as the packet will leave MPLS routing domain.

MPLS Header	Label 20 bit	Experimental use 3 bit	Label indicator 1 bit	TTL 8 bit	32 bits

DL Header	MPLS Header	IP Header	TCP Header	User Data

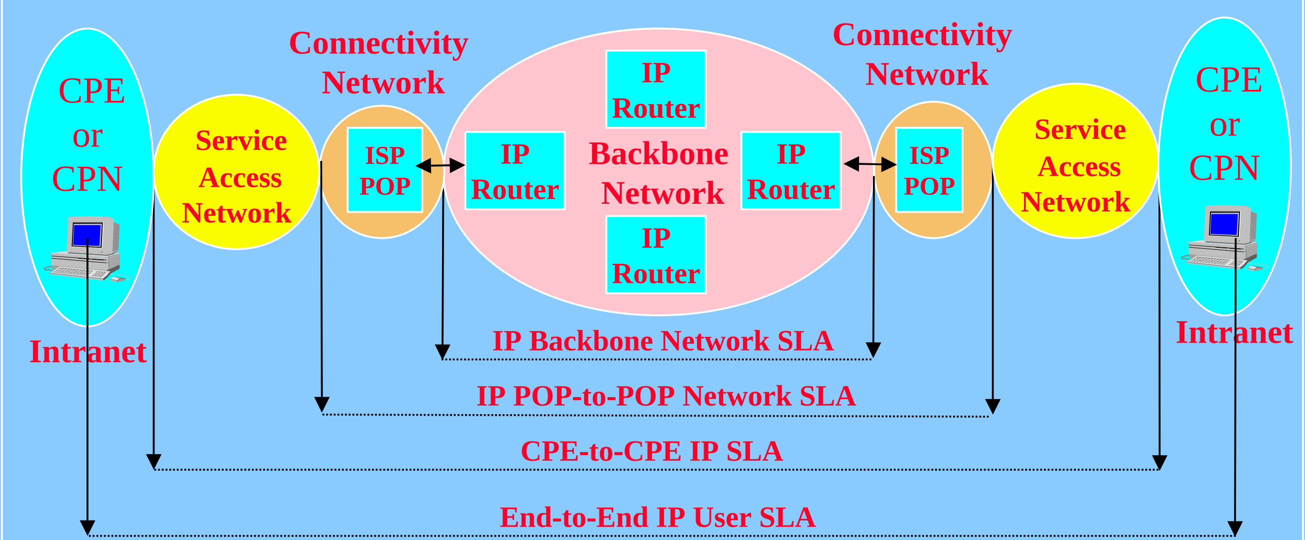
Multi-Protocol Label Switching Architecture (II)

- **Multi-Protocol Label Switching** (MPLS) networks consist of **Label Edge Routers** (LER) in the MPLS Edge domain, **Label Switching Routers** (LSR) in the MPLS Core domain, and **Label Switching Paths** (LSP). On each physical link, a LSP is represented by a particular label specific within the context of that link. The labels are distributed using either the specialized **Label Distribution Protocol** (LDP) or extensions of RSVP and BGP protocols.



SLA Domains for Internet IP-based Data Services

- The IP-based Internet is a public data communication router-based infrastructure linking major organizations and hundreds of millions of individual subscribers. It is capable of transporting not only data but also voice, streaming audio/video, and fax via variable length packets.
- Four types of SLAs can be implemented for IP services: IP backbone network SLA, ISP POP-to-POP connectivity network SLA, CPE-to-CPE access network SLA, and end-to-end user desktop SLA covering the Intranet environment (if implemented).



SLA Components for Internet Data Services

- Key network systems parameters suggested for Internet SLAs should cover both the service provider network (backbone, connectivity, access) and end-to-end user applications.
- SLAs monitoring requires primary tools and probes to collect QOS performance statistics according to QOS metrics for Internet services. The primary measurement tools are based on SNMP polling and use of RMON probes. Internet service level metrics may include:

1. **Network Availability** (measured over a month); calculated as follows:

$$\frac{\text{(Total hours in a month) x (Number of sites) - (Network Outage Time)}}{\text{(Total hours in a month) x (Number of sites)}}$$

2. **Access Availability** (percentage of time (%) a given service is operational)

$$\frac{\text{(Elapsed Time) - (Outage Time)}}{\text{(Elapsed Time)}}$$

3. **End-to-End Delay** (the amount of latency for packets carried through IP networks)

$$\frac{\text{(Total packets end-to-end) x (End-to-End delay for the packets)}}{\text{(Number of packets)}}$$

4. **Packet Loss Ratio (PLR)** (the percentage, %, of the total number of lost IP packets, end-to-end)

$$\frac{\text{(Ingress Packet Count) – (Egress Packet Count)}}{\text{(Ingress Packet Count)}}$$

(Packet loss may be caused by congestion, buffer overflows, or code violations).

Service Management Product List (I)

- Service Management products can be grouped into three major categories: standalone application suites, management platforms with specialized service management packages, and carrier-based set of products and policies targeting support for both service providers and customers in the field of service management.

Standalone Application Suites for Service Management

- **Micromuse Inc.** (www.micromuse.com)
  - NetCool/Omnibus
- **Concord Communications** (www.concord.com)
  - eHealth
- **Visual Networks** (www.visualnetworks.com)
  - Visual UpTime (WAN SML)
  - Visual Trinity (E-business service management) (formerly Avesta Technologies)
- **InfoVista** (www.infovista.com)
  - InfoVista System
- **Opticom** (www.opticominc.com)
  - iView Service Management

Service Management Product List (II)

- **Cisco Systems** (www.cisco.com)
  - NetSys Service Level Management Suite
  - Cisco QOS Policy Manager
- **Nortel** (www.nortel.com)
  - Preside Portfolio of Service Management Solutions (service providers)
  - Optivity Suite of Products for Unified Management (enterprises)
- **Network Associates** (www.networkassociates.com)
  - Intranet Management Suite with Service Level Manager components
- **NetScout Systems** (www.netscout.com)
  - nGenius Performance Management System
  - nGenius Application Service Manager
  - Next Point SML (formerly NextPoint Networks)
- **Quallaby** (www.quallaby.com)
  - PROVISO Service Level Management
- **Synch Research** (www.sync.com)
  - Circuit Management Solutions

Service Management Product List (III)

Management Platforms Packages for Service Management

- **Hewlett Packard** HP OpenView (www.hp.com)
  - IT Service Manager
  - Internet Service Management
  - Application Management
- **Aprisma Management Technologies** (formerly Cabletron) (www.aprisma.com).
  - SPECTRUM Solutions for Service Providers
  - SPECTRUM Response Time Management
  - SPECTRUM Application Management
- Combined with BMC PATROL, Metrix WinWatch, Concord Communications Network Health, Opticom iView, and Optimal Networks to provide a complete service management solution.
- **Tivoli Systems** (www.tivoli.com)
  - Performance, Availability, and Service Delivery Management

Service Management Product List (IV)

Carrier Packages for Data Service Management

AT&T (www.att.com)

- Managed Networks Solutions

Sprint (www.sprint.com/data 1)

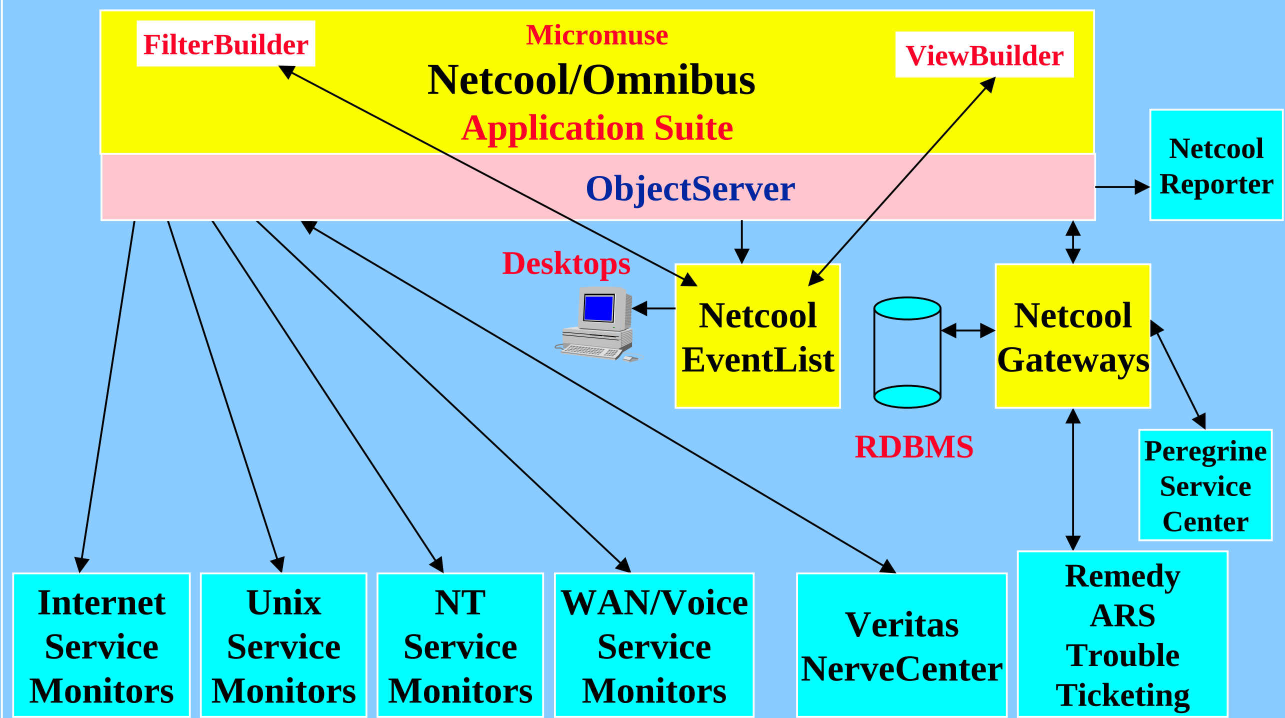
- Insite Network Management

MCI (www.mci.com)

- Enterprise Assurance

Micromuse Netcool/Omnibus Architecture

- Micromuse **Netcool/Omnibus** is the core application of the Netcool suite which allows carriers and service providers to interact with a wide array of management systems.



Micromuse NetCool SLM Application Suite

- Micromuse Netcool/Omnibus provides a comprehensive umbrella suite of processes and applications targeting real-time fault and Service-Level Management (SLM).
- More than 120 off-the-shelf probes and monitors are available to collect event data from management platforms, databases, metrics, application suites, including Internet monitors.

Service Providers ISP, MSP, TSP

Micromuse

Netcool/OMNIbus

Service Level Management Application Suite

Enterprise Systems

Carriers

Object Server

Network Management Platforms/Systems	Systems Management Platforms and Databases	Internet Service Monitors	WAN and Voice Monitors/Probes
- HP OpenView NNM - HP IT/OperationsCenter - IBM SystemView - Cabletron SPECTRUM - Sun Solstice EM - Seagate DiMONS - Cisco CiscoWorks - 3Com Transcend - Newbridge Networks - Cascade CascadeView - Bay Networks Optivity	- BMC PATROL - Digital Polycenter - Oracle Tables -Sybase Tables - Informix Tables - Microsoft NT Eventlog - Remedy ARS TT - Peregrine Service Center	- DNS, LDAP - FTP - HTTP - SMTP, POP3 - RADIUS, HTTPSSL - TCP Port - ICMP/Ping - HTTP-D Common Log - HTTP-D Error Log - Unix Syslogd	- Cisco StrataView - Newbridge MainStreet 46020 - Nortel INM - NET IDNX - Timeplex TimeView -Agile Networks ATMizer - Siemens GPT EM-OS - Ericsson ACP 1000

Micromuse NetCool Application Suite Overview

Description	**Netcool OMNIBUS** is a service management umbrella application suite for **Carriers** and **Service Providers** that collects, process, and stores enterprise-wide event messages from a variety of probes.
Major Components	**Object Server, Netcool Reporter, Netcool Event List Console, Internet Service Monitors, Netcool Desktop, local probes** to **SNMP-based managers, WAN ,Voice Systems,** and **DBMSs.**
Major Functions	- **Pooling probes**, filtering, correlating data according to an array of attributes and service views. - **Monitoring SLA compliance** of local LANs, WAN links, and end-to-end applications. - **Reporting** on **SLAs** (real-time performance, off-the shelf reports on uptime, downtime, outages).
Service Levels Metrics	**Physical port metrics** (port failure, recovery, count of occurrences, performance events), **server metrics** (node up/down, processes running, count of ping fails), **LAN** and **WAN segment metrics** (circuit failures, recovers, group of events, end-to-end availability, reliability of FR/ATM switches), **e-mail metrics** (state of processes, load average, messages delayed, message size, SMTP queue), **ftp metrics** (download/upload files, throughput, volume), **database transfer** (time/transfer rates).
Installations	**Major NOC:** BT, UUNET, MCI WorldCom, Deutsche Telecom, J.C. Penney, Cable and Wireless, Charles Schwab, AOL, US West, AirTouch, AT&T, GTE, PSINet, MindSpring Enterprises.
Example of Implementation	**NOC Operation:** HP OpenView NNM as a polling engine, CISCO Works, UNIX ASCII daemon. Components required: **Object Server, Netcool Reporter, OpenView NNM** probe**, ASCII** probes, **Netcool Service Monitors** (SMTP trap receiver, DNS, FTP), UNIX SysLog Daemon probe, **Netcool Gateways** (pass event messages to a historical data store, DBMS such as Oracle, Sybase).
Pricing	The list price for a hypothetical customer site is around $100,000 for the set of Netcool applications, $10,000 for annual software maintenance, and $3,000 for installation and training.
System Requirements	Runs on Windows NT and various Unix operating systems (HP-UX, Solaris, AIX). Java Event List allows operators to view events from a desktop browser and deliver list to JVM enabled systems.
Future Directions	Scalability, Linux Red Hat support, higher operator productivity: http://www.micromuse.com

4. Issues and Trends in Internet Service Management Implementation

4.1 Issues in Internet service management implementation

4.2 Trends in Internet service management development

4.1 Issues in Internet Service Management Implementation

- Lack of standards for QOS and SLAs covering all the communication layers.
- Lack of uniform management capabilities across networks/systems/applications.
- Lack of end-to-end QOS/SLA management across multiple service providers.
- Scalability of management solutions and service differentiation mechanisms.
- Lack of profitable business models and overall service management costs.
- Currently, poor credits and unverifiable terms, make SLA compensation a mockery.

4.2 Trends in Internet Service Management Development

- Internet service management, QOS, and SLAs are becoming the most important differentiators between Internet service providers.

- Dedicated measurement tools, mechanisms, and applications are planned and implemented to provide partial or end-to-end Internet service performance views.

- Some Internet service providers started inclusion of access portion of the network in the overall SLAs agreed with customers.

- Specialized QOS test network, Qbone was proposed within Internet 2 backbone network to oversee the quality of the network and to validate Internet QOS measurement techniques.

List of Acronyms

A	Agent
ADSL	Asymmetric Digital Subscriber Line
AF	Assured Forwarding
ANSI	American National Standards Institute
APP	Application
AQOS	Application Quality of Service
API	Applications Programming Interface
ASP	Application Service Provider
ATM	Asynchronous Transfer Mode
BE	Best Effort
BER	Bit Error Rate
BER	Basic Encoding Rules
BLEC	Broadband Local Exchange
BML	Business Management Layer
CAP	Competitive Access Provider
CATV	Cable Television
CBQ	Class-Based Queuing
CBR	Constant Bit Rate
CBR	Constraint Base Routing

CC	Cluster Controller
CIR	Committed Information Rate
CLEC	Competitive Local Exchange
COS	Class of Service
CPE	Customer Premises Equipment
CPN	Customer Premises Network
DBMS	Database Management System
DCP	Data Center Provider (e.g. Exodus)
DHCP	Dynamic Host Control Protocol
DiffServ	Differentiate Services
DL	Data Link
DNS	Domain Name Service
DRTP	Dynamic Real -Time Primary
DRTS	Dynamic Real -Time Secondary
DS	Differentiate Services
DS0, DS1, DS2, DS3	Digital Signal level 0, level 1
DSCP	Differentiated Services Code Point
DSL	Digital Subscriber Line
DWDM	Dense Wavelength Division Multiplexing
EF	Expedite Forwarding
EML	Element Management Layer
EMS	Element Management System

FCS	Frame Check Sequence
FDDI	Fiber Digital Data Interface
FEP	Front End Processor
FR	Frame Relay
FTP	File Transfer Protocol
FW	Firewall
GPS	Global Positioning Satellite
HTTP	Hyper Text Transfer Protocol
IAD	Integrated Access device
ICMP	Internet Control Message Protocol
IEC	Inter Exchange Carrier
ILEC	Incumbent Local Exchange Carrier
IntServ	Integrated Services
IP	Internet Protocol
ISM	Integrated System Management
ISP	Internet Service Provider
IT	Information Technology
ITU-T	International Telecommunications Union - Telecommunications Sector
IXC	Interchange Carrier

LAN	Local Area Network
LDAP	Lightweight Directory Access Protocol
LDP	Label Distribution Protocol
LEC	Local Exchange Carrier
LER	Label Edge Router
LLC	Logical Link Control
LSP	Label Switching Path
LSR	Label Switching Router
MAC	Media Access Control
MAPI	Management Applications Programming Interface
MAE	Metropolitan Area Exchange
MIB	Management Information Base
MP	Management Platform
MPEI	Management Platform External Interface
MSO	Multiple Services Operator
MSP	Management Service Provider
MPLS	Multi-Protocol Label Switching
MTBF	Mean Time Between Repairs
MTTR	Mean Time To Report/Repair
MTU	Maximum Transmission Unit
NAP	Network Access Point
NE	Network Element

NIC	Network Interface Card
NM	Network Management
NML	Network Management Layer
NMS	Network Management System
NMS	Network Management Station
NNM	Network Node Manager
NQOS	Network Quality of Service
NSF	National Science Foundation
NSP	Network Service Provider
OC	Optical Carrier
OS	Operating System
OSI	Open Systems Interconnection
PBNM	Policy-Based Network Management
PBX	Private Branch Exchange
PC	Personal Computer
PCN	Personal Communications Network
PCS	Personal Communications Services
PDU	Protocol Data Unit
PHB	Per-Hop-Behavior
PLR	Packet Loss Ratio
POP	Point of Presence
PSTN	Public Switch Telephone Network

QOS	Quality of Service
R	Router
RADIUS	Remote Authentication Dial-In System
RDBMS	Remote Data Base Management System
RFC	Request For Comment
RMON	Remote Monitoring
RSVP	Resource Reservation Protocol
RTD	
RTR	Response Time Reporter
SDH	Synchronous Digital Hierarchy
SLA	Service Level Agreement
SLM	Service Layer Management
SNA	System Network Architecture
SML	Service Management Layer
SNMP	Simple Network Management Protocol
SMTP	Simple Mail Transfer Protocol
SONET	Synchronous Optical Network
SP	Service Provider
STS	Synchronous Transport Signal
T1, T3	T1, T3 Carrier
TCA	Traffic Conditioning Agreement

TCP	Transmission Control Protocol
TeMIP	Telecommunications Management Information Platform
TMN	Telecommunications Management Network
TND	The Next Dimension
TNG	The Next Generation
TME	Tivoli Management Environment
TOM	TeleManagement Operations Model
TOS	Type of Service
TSP	Telecom Service Provider
TTL	Time to Live
UDP	User Datagram Protocol
vBNS	very-high-performance Backbone Network Service
VoIP	Voice over Internet Protocol
VPN	Virtual Private Network
WAN	Wide Area Network
WDM	Wavelength Division Multiplexing
WS	Workstation
WWW	World Wide Web

