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Managed IP Services from Dial Access to Gigabit Routers

Technical barriers and Future trends for IP Differentiated Services

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This talk contemplates current trends as perceived by the author/speaker

Talk Structure

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- **Who cares about IP service**
- **What causes the IP QoS problem**
- **Gigabit router connections: IP/ATM and IP/SDH**
- **What does the future hold**

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Who cares about IP service?

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Typical IP provider categories

- **ISPs**
  - **Consumer & commercial access to the Internet**
  - **Value-added services (email, news groups, Web site hosting, IP Telephony, VPN etc.)**
  - **May be Local, Regional, National, International**
- **IP Backbone Providers**
  - **Provide interconnection: of ISPs to each other; between ISP sites; between Enterprise sites.**
- **Corporate intra-nets**
  - **Similar internal network structure to public service providers (backbones, regional subnetworks or mid-level backbones)**

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Evolving Internet requirements

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- **The growth of Internet is demanding:**
  - **Ever increasing bandwidth**
  - **Differentiated service capability**
  - **Mechanisms for provisioning and managing bandwidth**
  - **Isolation and protection against misbehaving users**
  - **Security/Filtering capabilities**
  - **Policy based routing**
  - **VPNs**
  - **Inter-operability**

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A Typical Service Goal

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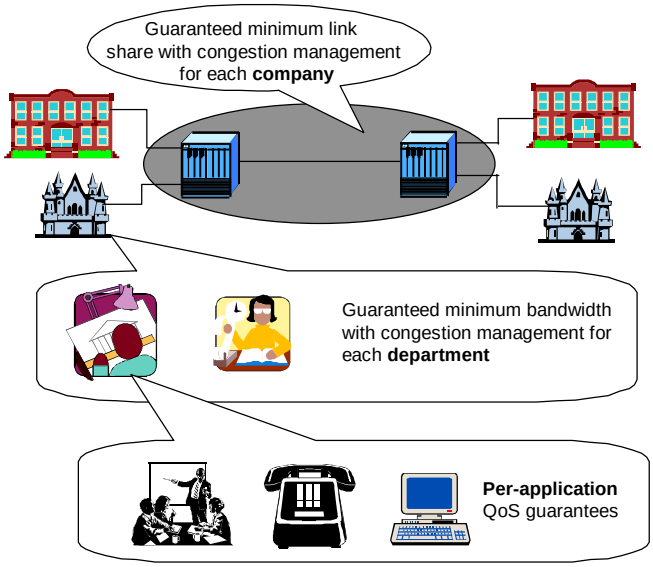

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What causes the IP QoS problem?

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A typical topology

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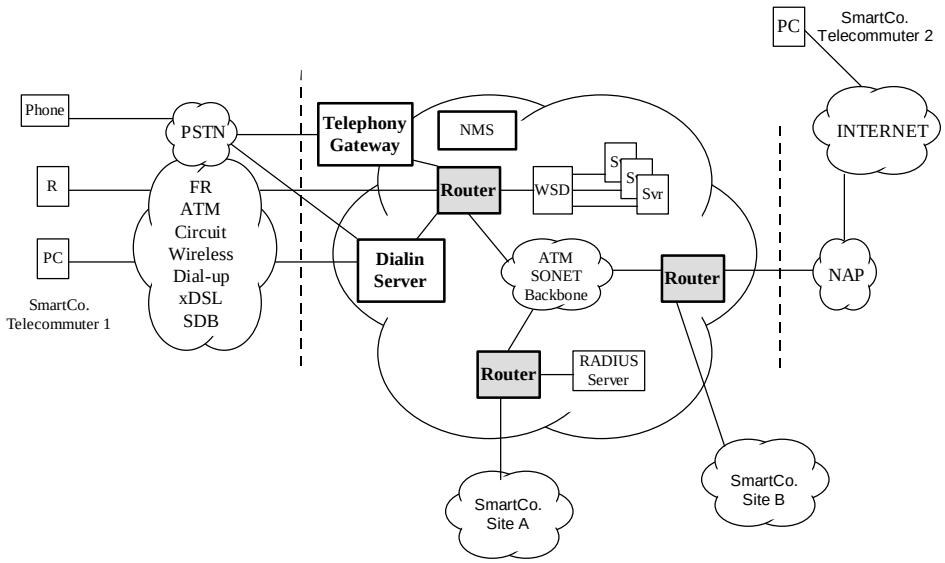

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What's the problem ?

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- **Internet engineering philosophy to date:**
  - **"Best Effort" IP packet transport**
- **What does this mean?**
  - **Maybe I'll get your packets to their destination**
  - **Web access delays, degraded Voice/IP quality...**
- **Why does it exist?**
  - **IP Networks are engineered on statistical assumptions**
  - **Brief overloads (microseconds or milliseconds) somewhere in the network, and the congested router *might* randomly throw away packets**
- **How does it affect <u>your</u> customers?**
  - **Cannot protect *your* customers from packet loss**

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Congestion?

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- **Caused by traffic coming in temporarily exceeding output rate**
- **Some examples**
  - **People queuing for check-in an hour before the flight**
  - **People queuing to get on a plane immediately after the first boarding announcement**
  - **Highways during rush-hour**
  - **Exits from theatre immediately after credits start to roll**
  - **Output interface of a router when a burst of packets arrive simultaneously from a couple of other (or faster) interfaces**

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What's wrong with congestion?

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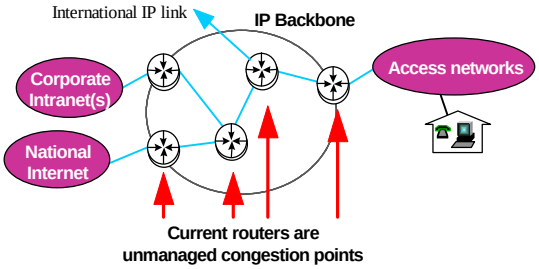

- **Random congestion**
  - **Bad for telephony, multimedia services, service quality...**
- **Typical solution - "faster routers and links"**
  - **Exponential traffic growth rapidly consumes new bandwidth**
  - **Still cannot protect one customer's traffic from anothers**

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Priorities during congestion

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- **Completely avoid congestion?**
  - **Usually impractical**
- **Protect the paying customer?**
  - **Provide priority handling for certain classes of customers (traffic)**
  - **e.g. separate First Class, "Frequent Flyer"/Business, and Economy/Coach queues at airport check-in**

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The ideal solution

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- **Routers that can**
  - **Identify the user or application to which a packet belongs**
  - **Identify sequences of packets belonging to the same user/application (FLOWS)**
  - **Isolate flows from each other**
  - **Provide minimum bandwidth guarantees to priority flows**
  - **Drop packets (during congestion) with fairness, intelligently target the flow(s) causing the congestion**

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A problem facing router designers

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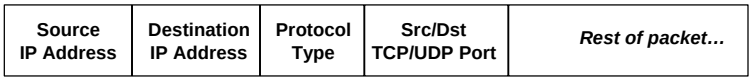
- **How much IP packet header processing can a poor router do per second?**

Forwarding decision is based solely on destination address (32 bits)

Classifying the Flow's type also requires the Protocol Type field to be inspected (another 8 bits)



Classifying the endpoints of a Flow also requires the source address to be inspected (another 32 bits)

Classifying the Flow's application also requires the TCP or UDP "ports" to be inspected (another 32 bits)

[NB. The above packet header has been simplified and rearranged for reasons of clarity]

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Another problem for router designers

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- **After classification, traffic must be placed in separate queues**
- **The number of queues dictates**
  - **Number of distinct priority/bandwidth levels**
    - **Each queue gets its own priority, applies to all packets that get placed into that queue**
  - **Level of isolation between flows**
    - **If multiple flows share a queue, they can still interfere with each other (steal bandwidth, etc)**
- **The more queues the better**

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Bandwidth Guarantees

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- **When traffic is isolated to distinct queues**
  - **Arrange for each queue to get distinct levels of average bandwidth**
  - **Various algorithms already exist (e.g. Weighted Fair Queueing - WFQ)**

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Things to watch out for...

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- **Simplified packet classification process**
  - **Use 1 or 2 "priority" bits in the packet header (easier to inspect at gigabit rates)**
  - **Allows only 2 or 4 priority levels and/or queue assignments**
- **Thousands of Flows exist per second**
  - **Get dumped into a handful of queues, which still allows large scale traffic interference**

This will be promoted as "QoS" support

<u>but it has many limitations</u>

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Gigabit router connections:
IP/ATM or IP/SONET

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Router interconnection

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- Two *religions* exist
- IP/SDH
  - Removes ATM layer
  - Limited to topology of raw SDH transport network
  - Routers are primary congestion points
- IP/ATM/SDH
  - ATM layer hides SDH topology
  - Provides managed bandwidth paths
  - Routers still congestion points

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How to do IP/ATM ?

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- Multiple approaches for integrating IP and ATM networks
  - Classical IP/ATM
    - Gigabit routers will eliminate throughput issue
    - Logical IP Subnets (LIS) support complex logical topologies
  - Label Switching (MPLS)
    - Provides an alternative solution to traffic engineering.
    - Otherwise of limited value in the face of advanced gigabit router designs
  - LANE/MPOA
    - Acceptable for low/mid-range bridged LAN services

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What does the future hold?

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Emerging Trends

- **Classical "router" technology has been**
  - **CPU/software based**
  - **Unable to support sophisticated QoS and filters at high line rates**
- **Emerging switch-based gigabit architectures**
  - **Single-protocol, IPv4 routers**
  - **Data forwarding in hardware**
  - **Separate processor(s) for management and routing protocols**

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Next generation IP hierarchy

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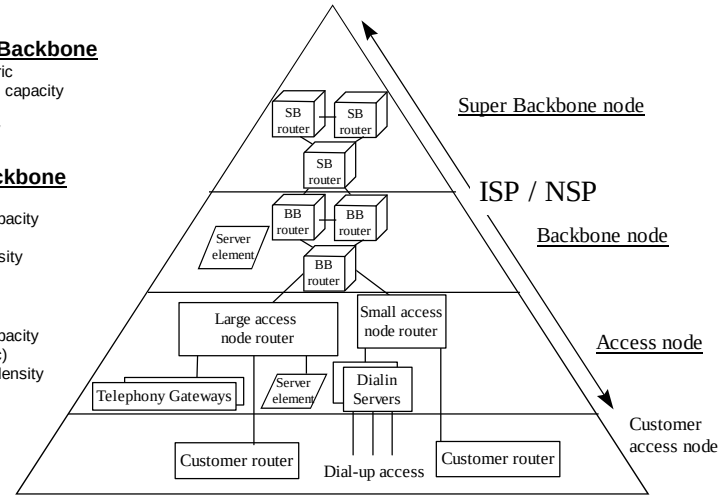
Backbone/Super Backbone
- >= 64 Gbps switch fabric
- >= 16 Mpps forwarding capacity
- >= 16 slots
- High nodal port density
- Optional Redundancy

Large Access/Backbone
- ~16 Gbps switch fabric
- ~4 Mpps forwarding capacity
- ~4 slots
- Medium nodal port density
- Optional Redundancy

Small Access
- ~1 Mpps forwarding capacity
- ~1 slot (no switch fabric)
- Entry Point nodal port density



BB - Backbone

SB - Super Backbone

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For real Differentiated Services

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- **Packet Filtering**
  - **Drop (firewall) policies, independent forwarding/routing tables, coarse assignment to traffic classes**
  - **Based on any combination of source/destination addresses, protocol, TCP/UDP port numbers, In/out interface**
- **Queue ('flow') Classification**
  - **Statistical assignment of IP flows to thousands of queues (*per-flow* queuing)**
  - **"Flow" is any combination of source/destination addresses, protocol and TCP/UDP port numbers**
- **Scheduling and Active Buffer Management**
  - **Hierarchical WFQ scheduling**
  - **Selectable "drop from front" or "drop from tail" congestion overload management mechanisms**

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Prediction: Innovations coming soon

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Service Requirement	*Emerging Innovations*
Large and scaleable bandwidth (STM-1, STM-4, STM-16+)	•Switch-based router architecture – hardware forwarding engines – wire-speed route table lookup – wire-speed packet filtering – wire-speed flow classification – large routing tables – 256K+ entries – Partitionable
Differentiated services	•Sophisticated QoS architecture – Wire-speed per-flow queue management – Hierarchical WFQ scheduling – Elastic, minimum bandwidth guarantees – No slow-down
Traffic management	•Flow isolation •Drop-from-front buffer management

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Conclusion

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- The key limit to earning revenue as an ISP is providing QoS to customers
- *More Bandwidth* is not a scalable solution
- *Managed Bandwidth* is the scalable solution
- Next generation Routers must
  - Classify customer traffic
  - Separately queue customer traffic
  - Protect customer traffic
- Sophisticated router technology is emerging and will filter into all levels of the IP network

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