PART 2

IP Solution for layer 3
Agenda

• Introduction
• IP Solution for layer3
• IP Network implementation scenarios
• Operational services implementation
• Examples
Agenda Part 2

• Network Functionality
  – IP Protocol Stack
  – TCP / UDP as examples

• Basics
  – Routing basics
  – QoS Architectures
  – Traffic Engineering
OSI Vs IP stack

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<th>Layer</th>
<th>Protocol</th>
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<tbody>
<tr>
<td>1</td>
<td>Physical Layer</td>
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<tr>
<td>2</td>
<td>Data Link Layer</td>
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<tr>
<td>3</td>
<td>Network Layer</td>
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<td>4</td>
<td>Transport Layer</td>
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<td>5</td>
<td>Session Layer</td>
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<td>6</td>
<td>Presentation Layer</td>
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<tr>
<td>7</td>
<td>Application Layer</td>
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</tbody>
</table>

- MAC
- LLC
- IP
- TCP/UDP
TCP Reliable Transport Protocol

• Connection Oriented
  – End-to-End Virtual Circuit Connection over the IP Datagram service
  – Full Duplex operation

• Reliable transport
  – Retransmission of corrupted Frames
  – Stream oriented. Bit stream order guaranteed

• End-to-End Flow Control by Sliding Window

• Congestion Control
  – Slow Start
  – Congestion Window Limit
TCP Congestion Control

• TCP Tahoe
  – Detects losses using timeouts
  – On timeout, decreases the window to 1, sets the threshold to half the current window and starts slow-star

• TCP Reno
  – Detects losses using both timeout and the reception of three ack with the same sequence number
  – On losses, decrements the current window and the threshold to the half and continue with the linear phase

• TCP Las Vegas
  – The window size is dynamically adjusted to the measured throughput
**UDP**

- Connectionless service support
- Unreliable transport
  - No retransmission mechanism built-in
  - Corrupted datagrams are discarded
- No congestion control
- Used for connectionless oriented and non-elastic applications
  - Management
  - Voice over IP
  - Email
Routing and QoS Basics

- Routing
- QoS
Routing Components

- **Routing Protocol**
- **Topology Database**
- **Distance Function**
- **Routing Algorithm**
- **Forwarding Table**
- **Forwarding Function**

**Flow**
- **Incoming Packets** to **Routing Protocol**
- **Routing Protocol** to **Topology Database**
- **Topology Database** to **Distance Function**
- **Distance Function** to **Routing Algorithm**
- **Routing Algorithm** to **Forwarding Table**
- **Forwarding Table** to **Forwarding Function**
- **Forwarding Function** to **Outgoing Packets**
IP Routing Algorithms

- **Distance-Vector (RIP)**
  - Appropriated for small networks (less than 16 hops) with low capacity links
  - QoS and Multicast extensions

- **Link-State (OSPF)**
  - Appropriated for medium/large networks
  - QoS and Multicast extension
  - Security enhanced

- **Policy Routing. (Future trend)**
Real Routing Alternatives

• Simple Hop-Count Routing
  – Distance is a function of fixed parameters
    • Number of hops, administrative weight, etc.

• QoS Based Routing
  – Actual traffic load is considered
    • Residual capacity of the path
    • Actual delay, etc

• Constraint Based Routing
  – QoS considerations
  – Cost and profit considerations

• Policy Based Routing
  – Routing in function of the Application, the user, etc.
  – Policy rules such as right of use of network resources, etc.
Routing-Topology interaction
• Simple cost functions could produce congestion
  • Metric manipulation rarely solve the problem
• QoS aware routing distributes traffic load
QoS Routing is not Enough

F1 and F2 merge at node 3 both are routed together and form a single flow

- Layer 4 routing
- Constraint based routing
- Policy routing
Conclusions

• Network topology design should consider routing algorithm capabilities
  – Some links could be useless or only usable in extreme outage situations
• Traffic load sharing is not always possible
• Network capacity dimensioning has to be done considering routing capabilities.
• Network simulation is strongly recommended
QoS IP Architectures
QoS Alternatives Comparison

Performance vs Cost

- Best-Effort
- Diff-Serv
- Int-Serv
- Policy QoS
- Static Priority
- ATM QoS
- Over prov.
Technologies for QoS Service Provision

• ATM
• IP with QoS architecture
  – Integrated services
  – Differentiated services only for some applications
• DTM and DPT
  – Emerging technologies for QoS
QoS Components

• Flow specification
• Admission control
• Resource reservation
• Resource management
• QoS routing
QoS Architecture
QoS IP Architectures Alternatives

- **Integrated Services**
  - Suitable for Critical Services that require strong QoS commitments
  - Dynamic configuration

- **Differentiated Services**
  - Few fix service classes
  - No end-to-end QoS control
  - Will be deployed by the Internet Service Providers

- **Policy Powered Networks**
  - Future trend in the QoS and policed service provision
IETF QoS Architectures

• Integrated Services (Int-Serv)
  – Based on the reservation paradigm
  – Application controlled

• Differentiated Services (Diff-Serv)
  – Based on a Service Level Agreement (SLA)
  – Controlled by an administrative contract
Int-Serv Architecture

Diagram showing the Int-Serv Architecture with layers such as RTP/UDP, RSVP, IP, LLC, and MAC, connected through QoS IP WAN.
Diff-Serv Architecture

Diagram showing the layers of the network stack:
- APPL.
  - SOCKET
  - TRANSPORT
  - IP
  - LLC
  - MAC

Two computer terminals connected through a QoS IP WAN cloud, with an SLA document between them.
Diff-Serv Services

• Better than Best-Effort (BBE)
  – Tailored for Web traffic no concrete QoS commitments

• Explicit Forwarding (EF)
  – Leased line emulation
  – Low delay but not assured delivery

• Assured Forwarding (AF)
  – Assured delivery. Variable but bounded latency
Diff-Serv Components

- Traffic Conditioning
- Traffic Classification
  - BE
  - BBE
  - EF
  - AF
- Flow aggregation

Per-Hope Behaviour

SALs Repository
QoS IP Evolving Architecture
Conclusions

- ISPs are going to use Diff-Serv to provide billable services
- Critical real-time application could only be provided by the Int-Serv architecture
- The Internet is evolving towards Directory Enabled Architectures
QoS Related Issues

• QoS means to satisfy application requirements

• Two main “Schools”
  – Over-provision
  – Traffic engineering
Over-Provision School

• Over-provision network capacity
• Do not worry about QoS
• Bandwidth is the “Solution”
  – The meaningless of “Throughput=Bandwidth”
  – Bandwidth is not the only factor on the application performance.
  – Application performance is limited by:
    • End-to-End delay
    • Protocol layering interactions
    • Network dynamics
Over-Provision is not the Solution

• Bandwidth is not a guarantee for QoS
  – It is needed but it is not enough

• End-to-End delay and buffering are limiting factors
  – When Sliding Window Transport Protocols (TCP) are used: \( T = \frac{W}{R_{tt}} \)
    • \( W \) Window Size (Buffer in end systems)
    • \( R_{tt} \) End-to-End Delay

• In a PSN E2E Delay depends on the traffic profile and many other factors
  – Only huge capacities can make the delay negligible
    • This is only true when capacity is not used
  – If all the traffic carried by the network is not profiled there is no guarantee on the E2E delay bound
Network Engineering School

- Network design and Traffic engineering to achieve firm guarantees on Network Performance
  - Bandwidth
  - Delay
  - Delay Variation
  - Losses
  - Service Availability
  - Service Priority
QoS Considerations

• Network Architecture
  – Components to assure QoS performance
  – Application-Network interaction support
    • IE Service definition

• Network Design
  – Capacity
  – Topology

• Network Dynamics
  – Flow and congestion control
  – Routing policy
Traffic Engineering Model

Traffic Engineering Model

- **Network Engineering**
  - Node & Transport planning

- **Capacity Management**
  - Routing & Capacity Design

- **Traffic Management**
  - Bandwidth broker, Routing Policy

- **Load Uncertainties**
  - Forecast Traffic Load
  - Actual Traffic Load

- **Capacity Changes**
  - Routing Update
  - Controls
  - Seconds to Minutes
  - Days to Weeks
  - Months to Years

- **Routing Tables**
  - Link Size
  - Traffic & Transport

- **Traffic & Transport**

- **Traffic Data**

- **Traffic Load**
  - Traffic Update
  - Forecast Traffic Load
Network Engineering

Topology Discovery

Traffic Engineering

Network Engineering

Topology & Traffic

Routes Updates

Network State

Traffic

Topology Updates

Topology & Triggers

Links Connection & Release

Operations

IP Layer

Underlaying Layers
The Role of the Internetworking Model

Packet data based services (IP, FR,..)

Voice (PSTN, cellular) and NB data services (64k & nx64k)

SDH lower order (LO=VC12/VC3) layer

SDH higher order (HO=VC4 path) layer

Optical (wavelength) layer

Fibre/transmission layer

Traffic Management

Capacity Management

Network Planning

Data/information and voice applications

ATM layer

λ- based connections

Capacity Management

Network Planning

Traffic Management
Traffic Control & Steering Functions

- Traffic Engineering
- Delivered Traffic
- Routing
- Topology
- Flow Control
- User Traffic