**Today’s Topic**

- This part of the lecture is about Differentiated Services architecture.

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**Internet today**

- Current Internet:
  - ‘Best Effort’-service
    - Equal opportunities (competitive resource sharing)
    - Equal missouries (uncontrolled delays and packet losses)
  - Trend:
    - Internet is becoming commercial network with services leveling the commercial incentives

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**Best Effort Service**

- Ideological background
  - Network is used only with good intent and need
- Turned to battle field
  - As fast and soon as possible
- Customer model
  - Access to the ‘Internet’
    - Possibility to use shared information resources
- Basis
  - Connectionless packet forwarding
Best Effort Router

- Packets are forwarded based on their destination address
- Scheduling and queueing
  - FCFS
- Equal treatment

![Best Effort Router Diagram](image)

Differentiated Services

- Identification of which parallel best effort network packet is destined, is coded in each packet
  - IPv4 ToS field is reformatted
    - No routing nor precedence
    - Generic class identifier

![Differentiated Services Diagram](image)

DiffServ Router

- Packets are forwarded based on the destination address and class information
- Scheduling and queueing is done based on the class information

![DiffServ Router Diagram](image)
**DiffServ Router**

- DiffServ router has one additional element in datapath compared to basic Best Effort router:
  - Conditioner
- Control plane of a DiffServ router has one extra element ie policy controller, which is responsible of internal management and configuration of conditioner and scheduler.

**DiffServ Conditioner**

- Traffic Conditioner is constructed a set of:
  - Classifiers
    - Responsible of logical separation of packet streams
  - Meters
    - Responsible of rate metering of logical streams
  - Markers
    - Responsible of actions based on metering results and predefined thresholds

**DiffServ PHB**

- Per hop behavior is block which contains queue management methods required to implement desired service
  - Queues
  - Queue space management algorithms
  - Schedulers

**DiffServ terminology**

- Workload in DiffServ is divided between two inherently different types of routers
  - Edge routers
  - Core routers
- Edge routers are on the domain edge interfacing
  - Customer
  - Other ISP
- Edge routers are responsible of conditioning actions which eventually determine the logical network where packet is to be forwarded.
**DiffServ terminology**

- Logical network is concatenation of PHBs which interact together.
- These logical networks have target service called per domain behavior (PDB).
- Target service is loose definition for the goal of the logical network when it is provisioned and configured in a predefined way.
- Edge router chooses PDB for each packet which comes from the customer
  - Marks packet with DSCP of PHB used to implement PDB.

**DiffServ**

- Service decision in edge router can be based on:
  - **Metering result**
    - Rate based
  - **Predefined set of filters**
    - IP address is customer
    - TCP/UDP port is application
  - **User request**
    - Precoded DSCP
    - RSVP signaling

- Core routers do nothing but forwarding of packets based on the extra information in DSCP field of packets.
- Requires
  - Classifier to detect DSCP fields
  - PHB to implement forwarding behaviors

**Service classes**

- Differentiated Services is aligned between Best Effort and IntServ
- There is a counterpart for each IntServ service class in DiffServ
  - Guaranteed Service <-> Expedited Service
  - Controlled Load <-> Assured Forwarding

**Expedited Forwarding (EF)** [RFC2598]

- Leased line emulation
  - From destined ingress point to destined egress point
  - End-to-end service with
    - Low loss
    - Low latency
    - Low jitter
    - Assured bandwidth
**EF**

- Service commitment is **only** assured
  - Resources inside EF class are shared
    - Amount of other EF traffic influences to the value of delay, jitter and loss
  - Path is freely chosen
    - Delay constraint can not be held as the delay of paths are inherently different
  - No reservation is done
    - Provisioning is in the key role

**EF**

- **Leased Line**
  - Dedicated resources
    - Full isolation
    - No room for overflow
- **Virtual Leased Line**
  - Shared resources
    - Partial isolation
      - From other than leased line traffic
    - Can accommodate overflow
      - Vague service guarantee

- Control of service guarantee
  - Access control
    - Rate control
    - User control
  - Provisioning
    - At least sum of contracted rates is allocated to EF traffic
    - High priority in the network
      - Scheduled ahead of other traffic
      - Starvation of lower priorities?
      - Only small fraction of total link capacity (10−30%)?

**Assured Forwarding (AF)** [RFC2597]

- **Four** independent service classes
  - All packets of a flow are destined to one of the classes
  - No association of service level between the classes
- **Three** precedences in each class
  - Flow can have packets with different precedences
  - Order of packets in a flow is not allowed to change
  - Precedence can not be used to scheduling decisions inside the class

<table>
<thead>
<tr>
<th>Class</th>
<th>Precedence</th>
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<tbody>
<tr>
<td>AF11</td>
<td>AF21 AF31 AF41</td>
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<tr>
<td>AF12</td>
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- No end-to-end semantics
  - Service can be deployed as any to any service
  - Like today
  - Uncontrollable resource usage inside the network
    - Very vague QoS
  - Class / precedence in contrast to service guarantee???
AF

- **Class differentiation**
  - Associate timing
    - Real-time to Bulk
  - Associate money
    - First class to cattle class
  - Associate user
    - CEO to laundry man
  - Associate protocol
    - TCP / UDP
  - Associate application
    - Clustering of similar application types

- **Precedence differentiation**
  - Associate rate
    - Under/over subscription
  - The rest same as class based except timing can not be used

Based on previous

- **Best-Effort Service**
  - Connectionless
  - Aggregated state
    - Local session state

- **Differentiated Service**
  - Connection-oriented
  - End2End session state
    - Session signaling [RSVP]
  - Admission control
    - Leaky-bucket traffic control
  - CoS
  - Per-flow WFQ

- **Integrated Service**
  - Per-class WFQ
  - Per-class and/or per-flow WFQ

1 Border routers may keep track individual sessions if required by policing or multifield classification.

2 Scheduling depends on per hop behavior [PHB]. Minimum requirement is FIFO with multilevel RED.

AF

- Construct services based on previous aspects
  - Many dimensions of freedom
  - How to make sure that system can not be manipulated
    - User control vs Network control

Based on previous

- Only way the DiffServ brings something new of valuable is that traffic within the network is well engineered i.e. traffic types sharing common buffer needs to be with similar requirements
- Only way to achieve this is to let the network to do classification and differentiation
  - Users are not, at large, well enough educated to make wise choices for the service classes
  - Or they try to exploit some resource with malicious intent
Best Effort semantics

- Best Effort service
  - All packets are treated equally
    - Forwarding is based on the destination address
    - Packets are queued into single FIFO queue
    - During the time of congestion packets are dropped
      - From the tail of the queue
        » When there is no space in the queue
        » When average queue length goes above threshold
  - Access to the network is sold to the customers

Differentiated Services semantics

- Differentiated Services
  - Packets are differentiated to $N$ parallel Best Effort networks
    - Each parallel network operates like basic Best Effort network with the exception that there can be priorities and other semantics associated to the service.
    - 'QoS' based network service is sold to the customer

EF semantics

- 'End–to–end' service
  - Single domain end–to–end
  - Quality is defined by two constrains:
    - Provisioning
      - Class should be provisioned with enough resources to handle worst case aggregate
    - Sharing
      - No resource reservation for individual flows.
      - Under and overflows possible
      - Timing and delays can not be held or guaranteed

AF semantics

- No end–to–end semantics
  - Service can be deployed
    - Point–to–point
    - Any–to–any
  - Uncontrollable resource usage inside the network
    - Problem of commons

Precedence -> drop probability

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What a customer wants ...

• Lets face the music
  – Customer is only interested in the perceived quality
  • How things are rolling compared
    – Minute ago
    – Year ago
  – Customer is not interested in the novel technology which is behind the service
  – This means end-to-end service quality

End-to-end service

• What prohibits ???
  – Structure of DiffServ is based on local control (policies)
    • Classification based on the policies at the edge of the network
    • Forwarding based on the policies in the core of the network
  – We can stretch through single domain (ISP) with EF
  – We may stretch through single domain (ISP) with AF
• End-to-end
  – Is not within single ISP
  – Is between source and destination