EE 122: Quality of Service and Resource Allocation

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Limitations of IP Architecture in Supporting Resource Management

- IP provides only best effort service
- IP does not participate in resource management
  - Cannot provide service guarantees on a per flow basis
  - Cannot provide service differentiation among traffic aggregates
- Early efforts
  - Tenet group at Berkeley (Ferraria and Verma)
  - Asynchronous Transfer Mode (ATM)
- IETF (Internet Engineering Task Force) efforts
  - Integrated services initiative
  - Differentiated services initiative

Service Classes

- Multiple service classes
- Service can be viewed as a contract between network and communication client
  - End-to-end service (multicast and anycast)
  - Other service scopes possible, e.g.,
    - Aggregates – all packets between to points (not necessary end-hosts) in the Internet
- Three common services
  - Best-effort (“elastic” applications)
  - Hard real-time (“real-time” applications)
  - Soft real-time (“tolerant” applications)

Example: Integrated Services

- Enhance IP’s service model
  - Old model: single best-effort service class
  - New model: multiple service classes, including best-effort and QoS classes
- Create protocols and algorithms to support new service models
  - Old model: no resource management at IP level
  - New model: explicit resource management at IP level
- Key architecture difference
  - Old model: stateless
  - New model: per flow state maintained at routers
    - Used for admission control and scheduling
    - Set up by signaling protocol
QoS Network

- Flow or session as QoS abstractions
- Each flow has a fixed or stable path
- Routers along the path maintain the state of the flow

QoS Network Operations

- Control plane: admission control
  - Reserve resources (i.e., link capacity and buffer space) at every router along the path
- Data plane: perform per flow
  - Classification: classify each packet to the flow it belongs to
  - Buffer management: decide when and which packet to drop
  - Packet scheduling: decide when and which packet to send

Control Plane: Admission Control

- Example: achieve per-flow bandwidth and delay guarantees
  - Example: guarantee 1Mbps and < 100 ms delay to a flow

Control Plane: Admission Control

- Allocate resources - perform per-flow admission control
Control Plane: Admission Control

- Install per-flow state

Data Plane

- Per-flow classification

Control Plane: Admission Control

- Install per-flow state

Data Plane

- Per-flow buffer management
Data Plane

- Per-flow scheduling

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Service Specification

- Loss: probability that a flow’s packet is lost
- Delay: time it takes a packet’s flow to get from source to destination
- Delay jitter: maximum difference between the delays experienced by two packets of the flow
- Bandwidth: maximum rate at which the source can send traffic

Hard Real Time: Guaranteed Services

- Service contract
  - Network to client: guarantee a deterministic upper bound on delay for each packet in a session
  - Client to network: the session does not send more than it specifies
- Algorithm support
  - Admission control based on worst-case analysis
  - Per flow classification/scheduling at routers
Soft Real Time: Controlled Load Service

- Service contract:
  - Network to client: similar performance as an unloaded best-effort network
  - Client to network: the session does not send more than it specifies
- Algorithm Support
  - Admission control based on measurement of aggregates
  - Scheduling for aggregate possible

Traffic and Service Characterization

- To quantify a service one has two know
  - Flow’s traffic arrival
  - Service provided by the router, i.e., resources reserved at each router
- Examples:
  - Traffic characterization: token bucket
  - Service provided by router: fix rate and fix buffer space

Token Bucket

- Characterized by three parameters \( (b, r, R) \)
  - \( b \) – token depth
  - \( r \) – average arrival rate
  - \( R \) – maximum arrival rate (e.g., R link capacity)
- A bit is transmitted only when there is an available token
  - When a bit is transmitted exactly one token is consumed

Characterizing a Source by Token Bucket

- Arrival curve – maximum amount of bits transmitted by time \( t \)
- Use token bucket to bound the arrival curve
**Example**

- Arrival curve – maximum amount of bits transmitted by time \( t \)
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**Per-hop Reservation**

- Given \( b, r, R \) and per-hop delay \( d \)
- Allocate bandwidth \( r_b \) and buffer space \( B_a \) such that to guarantee \( d \)

**End-to-End Reservation**

- Source S sends a message containing traffic characteristics
  - \( r, b, R \)
- Receiver R sends back this information + worst-case delay \( D \)
- Each router along path provide a per-hop delay guarantee and forwards the message
  - In simplest case routers split the delay \( D \)

**Summary**

- Service: a contract between end-hosts and network
- QoS goal: provide better than best-effort services to support new applications with more stringent delay and bandwidth requirements, e.g., IP telephony, videoconferencing
- QoS requires to manage flows/aggregates both on data and control plane
- Two major proposals:
  - Integrated Services
  - Differentiated Services