Distributed Systems
2. Quality of Service

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What factors matter for network performance?

- Bandwidth (bit rate)
  - Average number of bits per second through the network
- Delay (latency)
  - Average time for data to get from one endpoint to its destination
- Jitter
  - Variation in end-to-end delay
- Errors (packet loss)
  - Percentage of packets that don't reach their destination

Why do we care?

- We want to provide users with
  - Good interactive performance
  - Mostly glitch-free streaming video
  - Good quality IP telephony

Quality of Service Goal

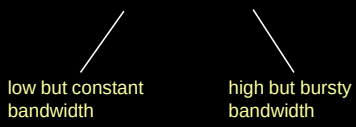
- Provide an applications with the data flow performance they need
- Examples
  - VoIP: low bandwidth, low latency (<150 ms), low jitter (<50 ms)
  - Video streaming: high bandwidth, longer latency OK
  - Remote login: low bandwidth, relatively low latency, high reliability
  - File transfer: high bandwidth, high latency OK, high jitter OK , high reliability

QoS Aware Networks

- A QoS-aware network will allow an application to specify its needs and will reserve sufficient capacity in the network to meet those goals
- Admission Control
  - Applications request a particular quality of service from the network
  - If the request is granted, the application has the contract
- Traffic Control
  - Classifies, queues, and schedules traffic within the network

ATM: Asynchronous Transfer Mode

- Late 1980's
- Goal: Merge voice & data networking



ATM

- Traditional voice networking
  - Circuit switching
    - Too costly
    - Poor use of resource
    - Does not lend to multicasting
- ATM
  - Based on fixed-size packets over virtual circuits
  - Fixed-size cells provide for predictive scheduling
  - Large cells will not hold up smaller ones
  - Rapid switching

ATM

- Current standard:
  - 53-byte cell: 48-byte data, 5-byte header
- Sender specifies traffic type upon connecting:

CBR	Constant bit rate	*Bandwidth*	Uncompressed video, voice
VBR	Variable bit rate	*Avg, peak bandwidth*	Compressed video, voice
ABR	Available bit rate	*Minimum bandwidth*	web access
UBR	Unspecified bit rate	–	ftp

ATM

- Small cells → lots of interrupts
  - >100,000/second
- ATM hardware supports an ATM Adaptation Layer (AAL)
  - Converts cells to variable-sized (larger) packets:
    - AAL 1: for CBR
    - AAL 2: for VBR
    - AAL 3/4: ABR data
    - AAL 5: ABR data, simplified
    - AAL 6: MPEG-2 video
- IP traffic: transmitted as data using AAL5

Quality of Service in IP

- IP was not designed with QoS controls in mind
- IP cannot take advantage of QoS controls offered by an underlying network
  - And you can't count on a specific underlying network for end-to-end service
- Some QoS mechanisms created as add-ons

Quality of Service Problems in IP

- Too much traffic
  - Leads to congestion
- Inefficient packet transmission (not really a QoS issue)
  - 59 bytes to send 1 byte in TCP/IP!
  - 20 bytes TCP + 20 bytes IP + 18 bytes ethernet
- Unreliable delivery
  - Software to the rescue – TCP/IP
- Unpredictable packet delivery
  - No controls on bit rate, delay, jitter
  - Packets may take different routes, resulting in different performance

Inefficient Packets

- Some software generates lots of tiny packets
  - Head-of-line blocking
  - Nagle's algorithm:
    - buffer new data if unacknowledged data outstanding
- Header/packet compression
  - Link-to-link
  - Header compression (RFC 3843)
  - Payload compression (RFC 2393)
  - Trade-off: $ delivery vs. $ compression

Approaches to QoS

- Best effort
  - Avoid congestion by overprovisioning the network
- Differentiated service
  - Identify one type of service (data flow) vs. another
  - Use this information to affect packet queuing and scheduling
- Guaranteed service
  - Have every device in a route commit to a level of service for a specific data flow

IP Flow Detection

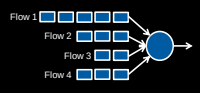
- Flow detection in routers:
  - Flow: set of packets from one *address:port* to another *address:port* with same protocol
  - Network controls flow rate by dropping or delaying packets
  - With flow detection
    - drop TCP packets over UDP
    - Discard specific UDP flows to ensure QoS for other flows

IP Flow Detection

- With flow detection:
  - Traffic Shaping
    - Identify traffic flows
    - Queue packets during surges and release later
    - High-bandwidth link to low-bandwidth link
  - Traffic Policing
    - Discard traffic that exceeds allotted bandwidth

Dealing with congestion: Scheduling

- Congestion
  - More incoming traffic than we can route
  - Pick what traffic to route, what to delay (buffer), and what to drop
- FIFO queuing
- Priority queues
- Flow-based weighted fair queuing
  - Group all packets from a flow together
- Class-based weighted fair queuing
  - Based on protocols, access control lists, interfaces, etc.
- Custom queues

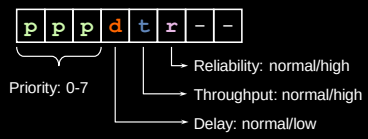


Differentiated Services (soft QoS)

- Treat some traffic as better than other
  - Statistical - no guarantees
- Identify class of service & priority
  - Router can use this data to make scheduling/dropping decisions
- Use on Internet (especially across ISPs) limited due to peering agreement complexities

Differentiated Services (DiffServ)

- ToS field in IP header (bits 9…16)
  - Differentiated Services Control Point (DSCP)



RFC 2475, December 1998

Guaranteed QoS (hard QoS)

- Guarantee via end-to-end reservation

Reservation & Delivery Protocol

- RSVP: ReSerVation Protocol
  - Each unidirectional data stream is a flow
  - Hosts request specific quality of service per flow
  - Routers reserve resources
  - RFC 2205
- Every device through which data flows must support RSVP

Other mechanisms

- Multi-Protocol Layer Switching (MPLS)
  - Make packet routing more efficient … more like layer 2
  - Each packet is assigned a routing label (based on destination & packet priority)
  - Routers make queuing and forwarding decisions based on this label
  - Similar problems to RSVP

Other mechanism

- 802.1p: control QoS at the MAC layer (layer 2)
  - Eight traffic classes defined in an ethernet frame
  - This is *not* an IP QoS mechanism

Priority	Traffic
0	Background
1	Best effort
2	Excellent effort
3	Critical
4	Video <100 ms latency
5	Voice <10 ms latency
6	Internetwork control
7	Network control

Media Delivery Protocols

- Real-Time Control Protocol (RTCP)
  - Provides feedback on QoS (jitter, loss, delay)
  - RFC 3550
- RTP: Real-Time Transport Protocol
  - Not a routing protocol
  - No service guarantees
  - Provides:
    - Payload identification
    - sequence #
    - time stamp
- RTP/RTCP do not provide QoS controls

The End