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Today's Computer Netwoks

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What are the Requirements of Today's Network

- Better Control of the flow of messages
- Faster Decision Making
- Meet the demands placed by Big Data, cloud Computing and mobile traffic
- Handle Quality of Service for different traffic

The Internet: a "nuts and bolts" view

Billions of connected computing *devices*:

- *hosts = end systems*
- running *network apps* at Internet's "edge"

Packet switches: forward packets (chunks of data)

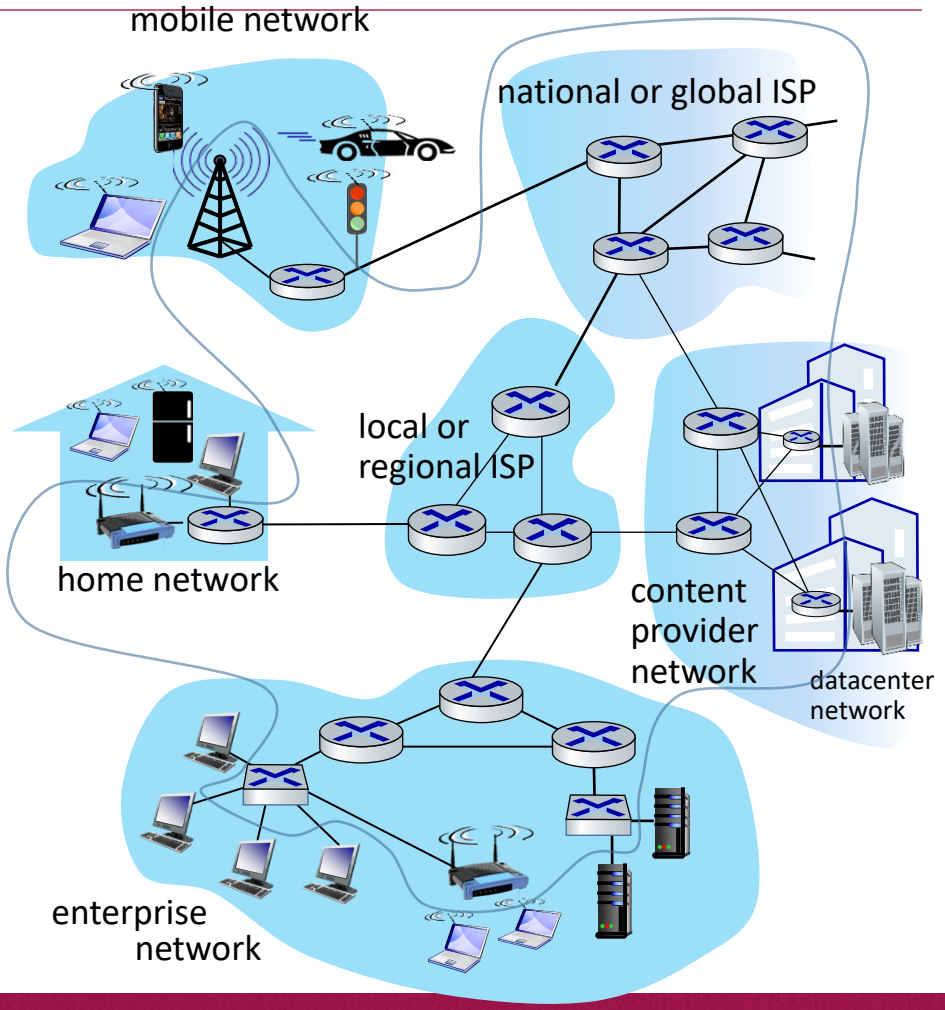
- *routers, switches*

Communication links

- fiber, copper, radio, satellite
- transmission rate: *bandwidth*

Networks

- collection of devices, routers, links: managed by an organization



A closer look at Internet structure

Network edge:

hosts: clients and servers

servers often in data centers

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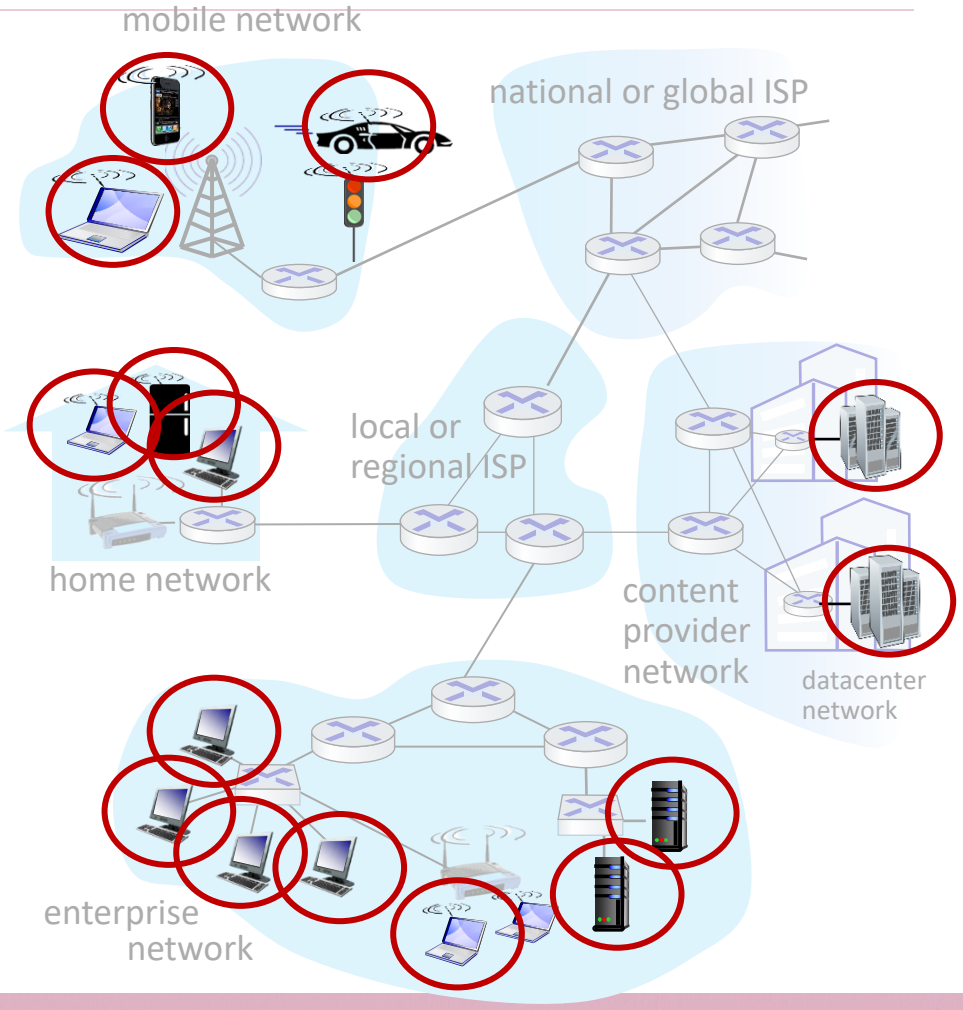

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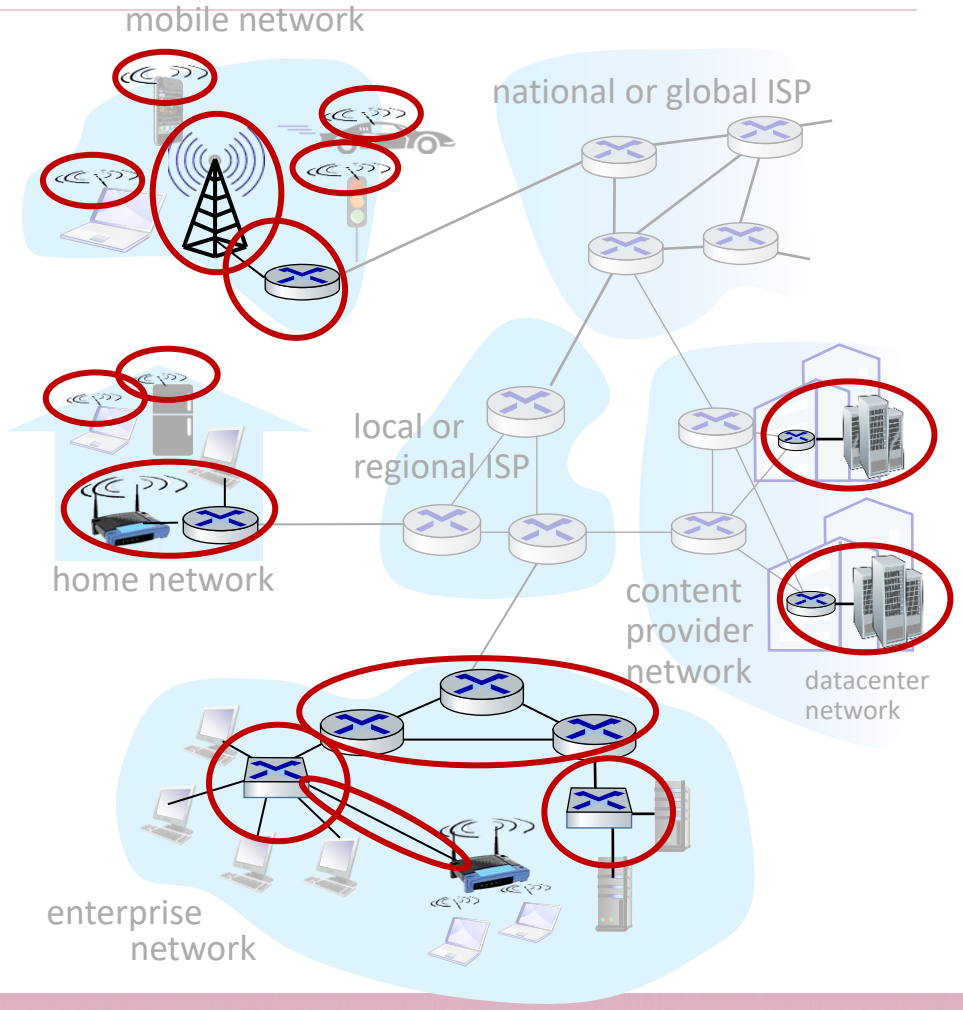
Access networks, physical media:

- wired, wireless communication links



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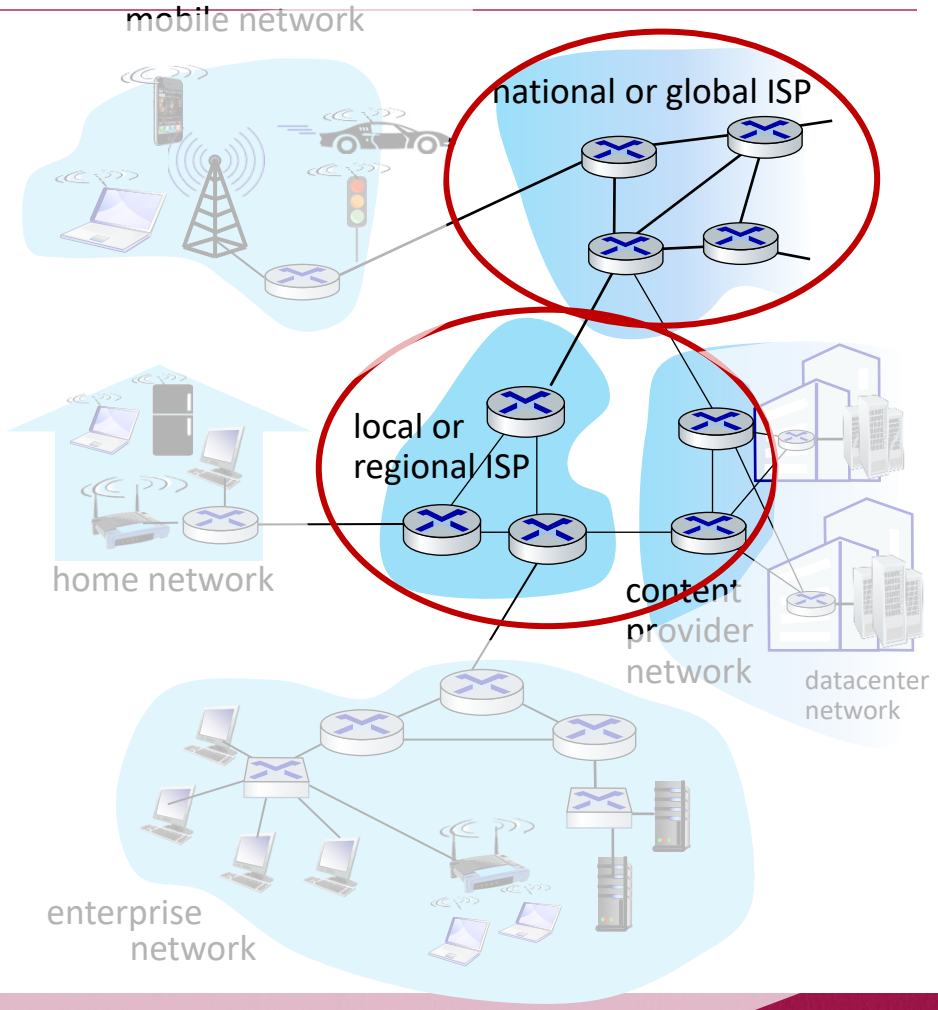
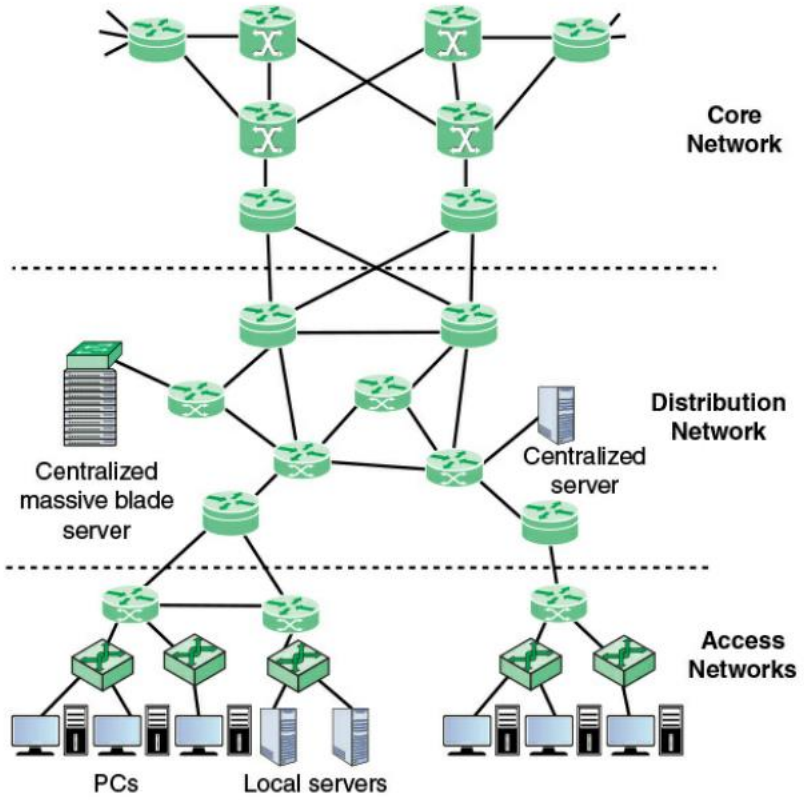
Network core:

- interconnected routers
- network of networks



Network Hierarchy adopted in a Typical Enterprise



3 Layers of hierarchy:

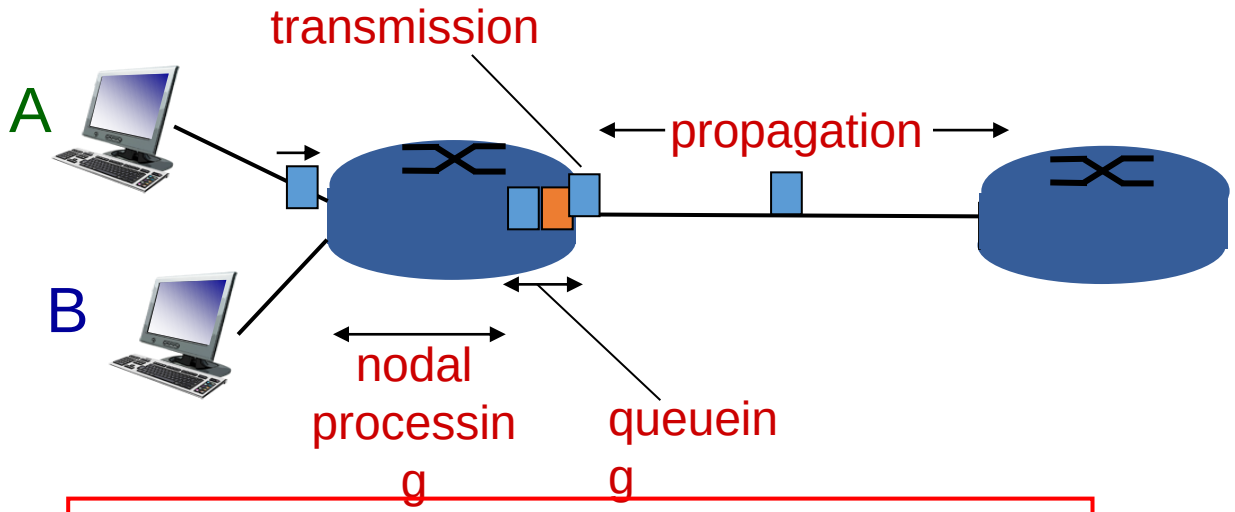
- LAN is used in Access networks
- Access Routers connect the local assets to next level
- Edge Routers connect Distribution network to access networks
- Core Networks connects geographically dispersed distribution networks and provides access to other networks

Network Hierarchy adopted in a Typical Enterprise

Edge Routers in Access Networks and Distribution Networks - the two routers are configured to recognize each other and will generally exchange routing and connectivity information and, typically, some traffic-related information. This cooperation between routers is referred to as peering.

The distribution network also serves to aggregate traffic destined for the core router, which protects the core from high-density peering.

Four Components of Packet Delays in Internet

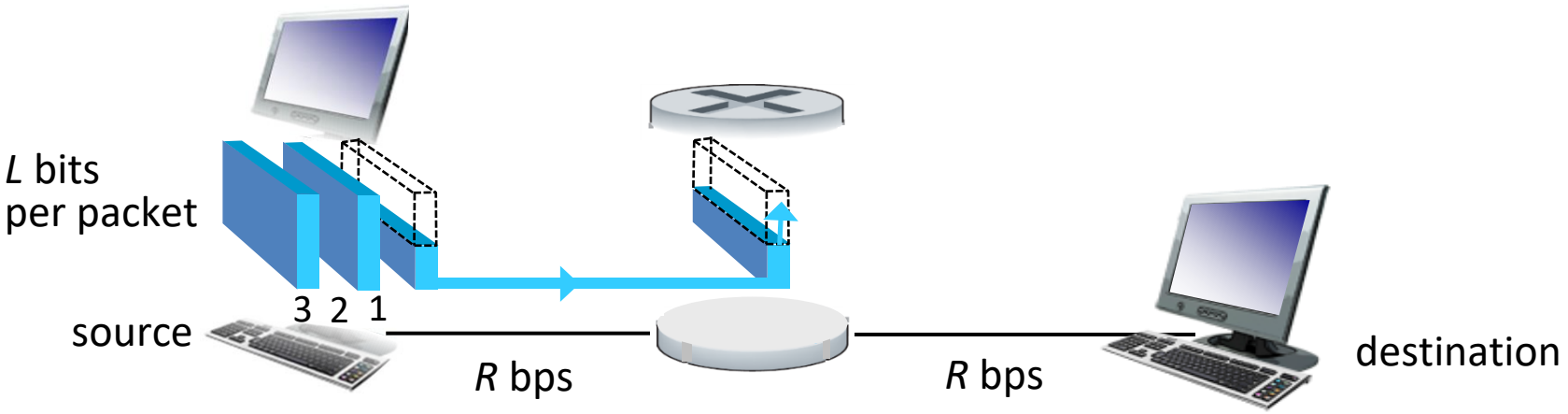


$$d_{nodal} = d_{proc} + d_{queue} + d_{trans} + d_{prop}$$

d_{proc}: nodal processing

- check bit errors
- determine output link
- typically < msec

Packet-switching: store-and-forward



- takes L/R seconds to transmit (push out) L-bit packet into link at R bps
- *store and forward:* entire packet must arrive at router before it can be transmitted on next link

one-hop numerical example:

- L = 7.5 Mbits
- R = 1.5 Mbps
- one-hop transmission delay = 5 sec

❖ end-end delay = $2L/R$ (assuming zero propagation delay)

more on delay shortly …

Example for Delay and Throughput Calculations

Queuing Delay, if 5 packets arrive simultaneously at the router?

- L = 7.5 Mbits
- R = 1.5 Mbps
- one-hop transmission delay = 5 sec

Nature of applications over Internet

- Sensitiveness to Delay and Throughput
  - Email – NO
  - FTP – throughput sensitive –size dependent
  - SNMP – requires to take min delay in case of congestion
  - Remote login –delay sensitive
- Per packet delay is not a concern
- Delay to transfer an element is the concern
- If failures in an internet are the cause of congestion, then the need for SNMP messages to get through with minimum delay increases with increased congestion.

Effect of Delay components

- Small elements delay is dominated by the Internet delay
- Large elements delay is dominated by the transfer time

WHY?

Types of Internet Traffic

- Elastic vs Non-elastic
- Elastic Traffic – can adjust to changes in delay and throughput
- Applications operating over TCP or UDP use as much capacity as possible (Elastic traffic)
  - In UDP, the limit is based on the rate at which data is generated
  - In TCP, the limit is based on the maximum rate that the end-to-end receiver can accept data.
- examples are applications that operate over TCP or UDP
  - file transfer (FTP)
  - electronic mail (Simple Mail Transport Protocol [SMTP])
  - remote login (Telnet, Secure Shell [SSH])
  - network management (Simple Network Management Protocol [SNMP])
  - web access (Hypertext Transfer Protocol / HTTP Secure [HTTP/HTTPS]).

Non-elastic Traffic

- multimedia transmission
- voice and video, and high-volume interactive traffic
- an interactive simulation application (for example, airline pilot simulation).
- May require
  - min throughput, bound on delay, bound on delay jitter
  - Real-time interactive applications, such as teleconferencing, may require a reasonable upper bound on jitter.
  - Bound on Packet loss

QoS of Application Class

Voice	One-way latency ≤ 150 ms
	One-way peak-to-peak jitter ≤ 30 ms
	Per-hop peak-to-peak jitter ≤ 10 ms
	Packet loss ≤ 1 percent
Broadcast video	Packet loss ≤ 0.1 percent
Real-time interactive video	One-way latency ≤ 200 ms
	One-way peak-to-peak jitter ≤ 50 ms
	Per-hop peak-to-peak jitter ≤ 10 ms
	Packet loss ≤ 0.1 percent
Multimedia conferencing	One-way latency ≤ 200 ms
	Packet loss ≤ 1 percent
Multimedia streaming	One-way latency ≤ 400 ms
	Packet loss ≤ 1 percent

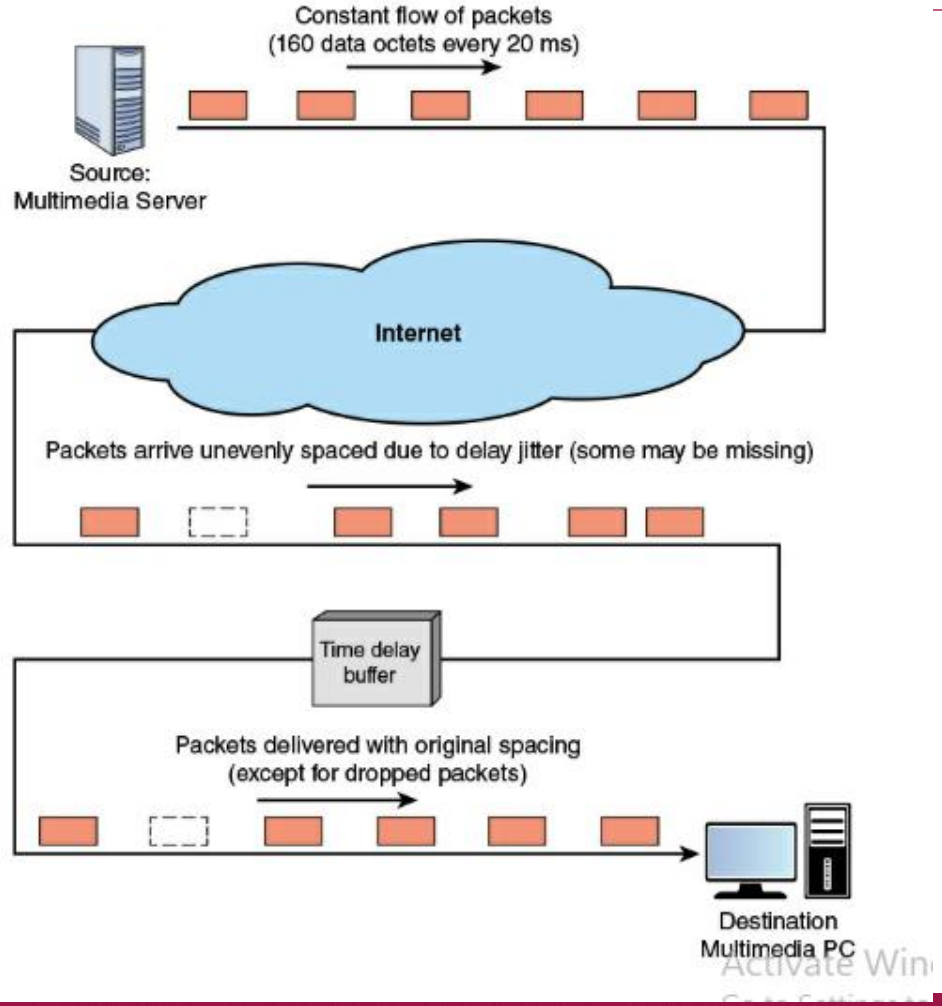
Table 2.2 QoS Requirements by Application Class

the video quality in streaming services might be directly affected by network parameters such as bandwidth, packet loss, and encoding parameters such as frame rate, resolution, and codec.

What happens if congestion occurs?

- Inelastic applications typically do not back off and reduce demand in the face of congestion
- TCP-based applications adjust its requirements in terms of demand for bandwidth.
- Therefore, in times of congestion, inelastic traffic will continue to supply a high load, and elastic traffic will be crowded off the Internet.

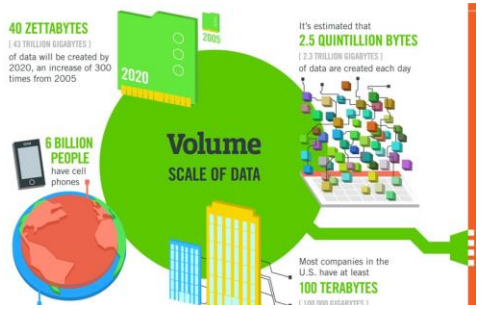
Real-time traffic – requires

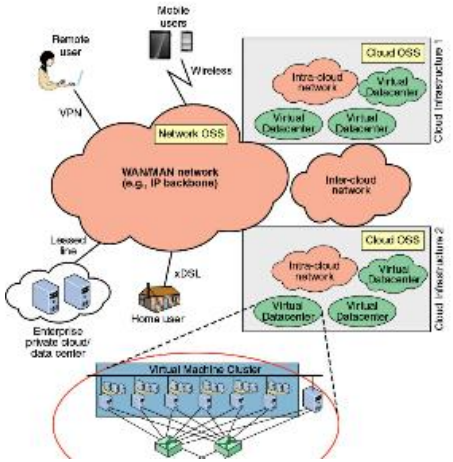


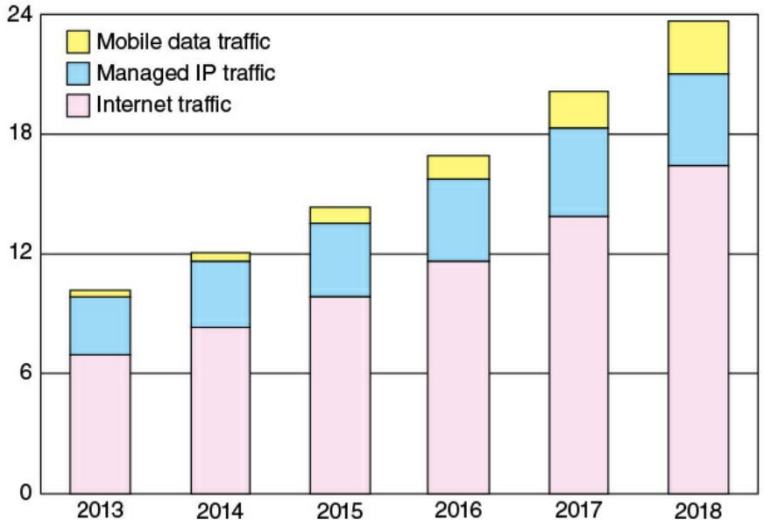
- Real-time traffic has a deadline associated with each block of data
- Data are not usable after the expiry
- Server is sending at 64kbps and delivered to multimedia PC
- the interarrival times between packets are not maintained at a fixed 20 ms at the destination.
- to maintain this, incoming packets are buffered and released at a constant rate.

Traffic Demand

- Applications that are creating stress on Internet
  - Big Data
  - Cloud Computing
  - Mobility







Big Data Sources

Social

User Tracking & Engagement

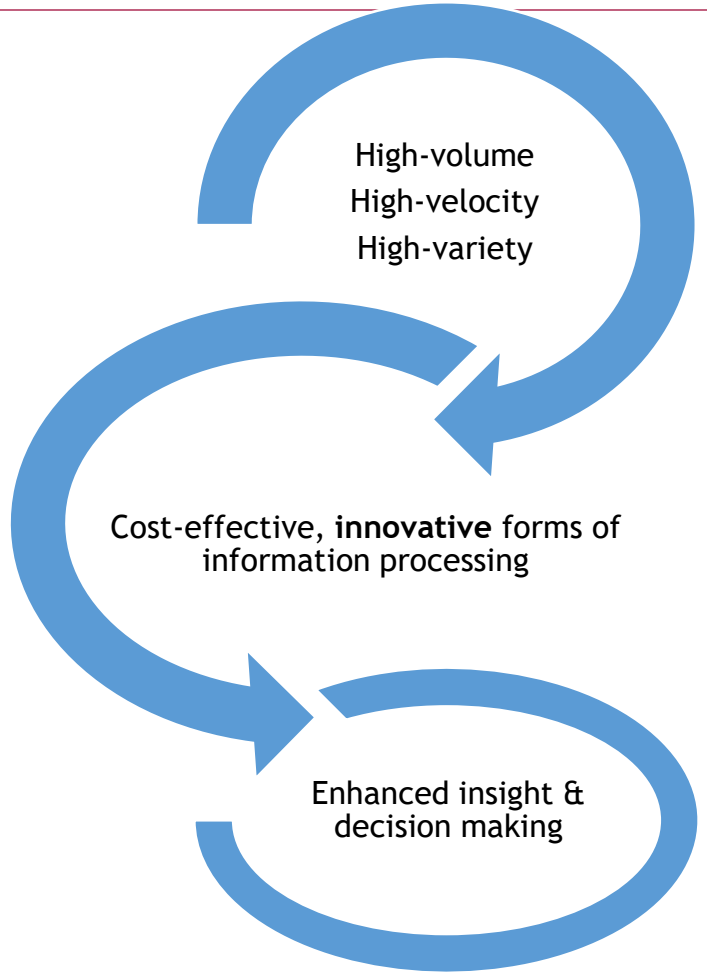
Homeland Security

eCommerce

Financial Services

Real Time Search

Characteristics of Big Data



Big Data is high-volume, high-velocity, and high-variety information assets that demand cost effective, innovative forms of information processing for enhanced insight and decision making.

Source: Gartner IT Glossary

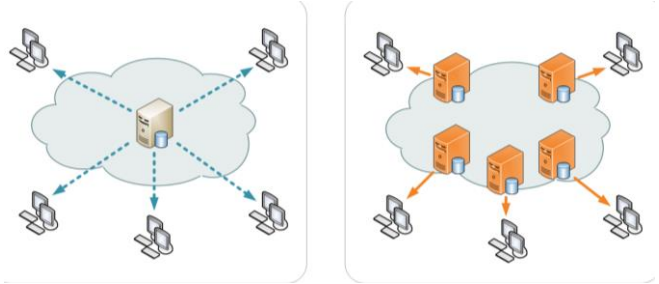
Mobile Traffic

Sources of Mobile Data

- Devices, with multimegabit Internet access
- Mobile apps
- High megapixel digital cameras
- Access to multiple types of wireless networks (for example, Wi-Fi, Bluetooth, 3G, 4G)
- Several onboard sensors

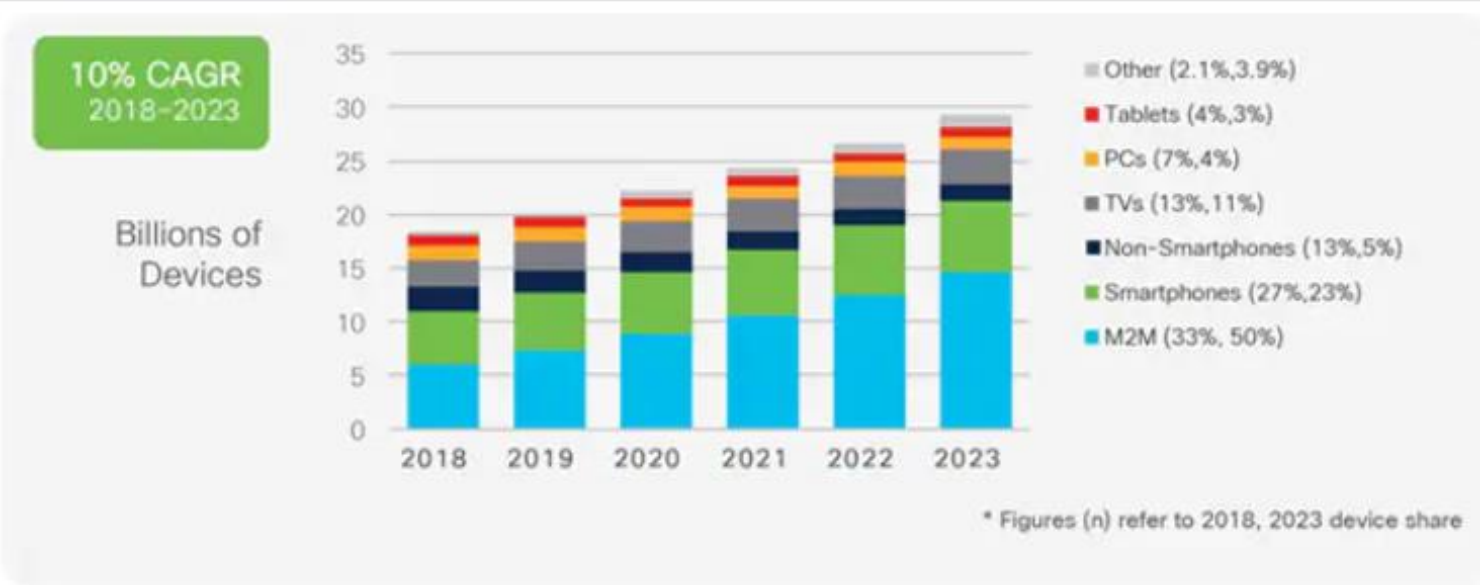
Content Distribution Network (CDN)

- A geographically distributed network of proxy servers and their data centers.
- The goal is to provide high availability and performance by distributing the service spatially relative to end users.
- CDNs emerged as a means for alleviating the performance bottlenecks of the Internet
- Is used to deliver contents including web objects (text, graphics and scripts), downloadable objects (media files, software, documents), applications (e-commerce, portals), live streaming media, on-demand streaming media, and social media sites.



Sources: wikipedia

Growth of Connected Devices



Cisco Annual Internet Report 2018-23

Quality of Service (QoS)

- Throughput: min or avg in bytes per sec or bits per sec
- Delay: avg or max delay. Also called latency.
- Packet jitter: max allowable jitter.
- Error rate: max error rate, in terms of fraction of bits delivered in error.
- Packet loss: Fraction of packets lost
- Priority: Assigned levels of priority for various traffic flows
- Availability – percentage of total time available
- Security – types of security offered

Routing Packets

- Routing of packets involve accepting the packets from the source and deliver them to the destination
- Routing algorithm finds a path or route through the network based on some function (Routing function)
- Routing algorithm – finds the min cost path between a source and a destination
- Routing decisions can be based on other criteria

Routing and Forwarding

- The key function of any router is to accept incoming packets and forward them.
- A router's forwarding table shows, for each destination, the identity of the next node on the router.

Book Chapters

- Kurose 1.2 – 1.3, 2.6
- Stallings 2.2,2.3