2. Data Networking

2.1 Inter-Networks: Networks of Networks

connection of disparate networks → scale, heterogeneity → universal connectivity

Concepts:
– Translation, overlays, address & name resolution, fragmentation: to handle heterogeneity
– Hierarchical addressing, routing, naming, address allocation, congestion control: to handle scaling

2.2 IP Protocol

Defines packet,address format and data forwarding procedures

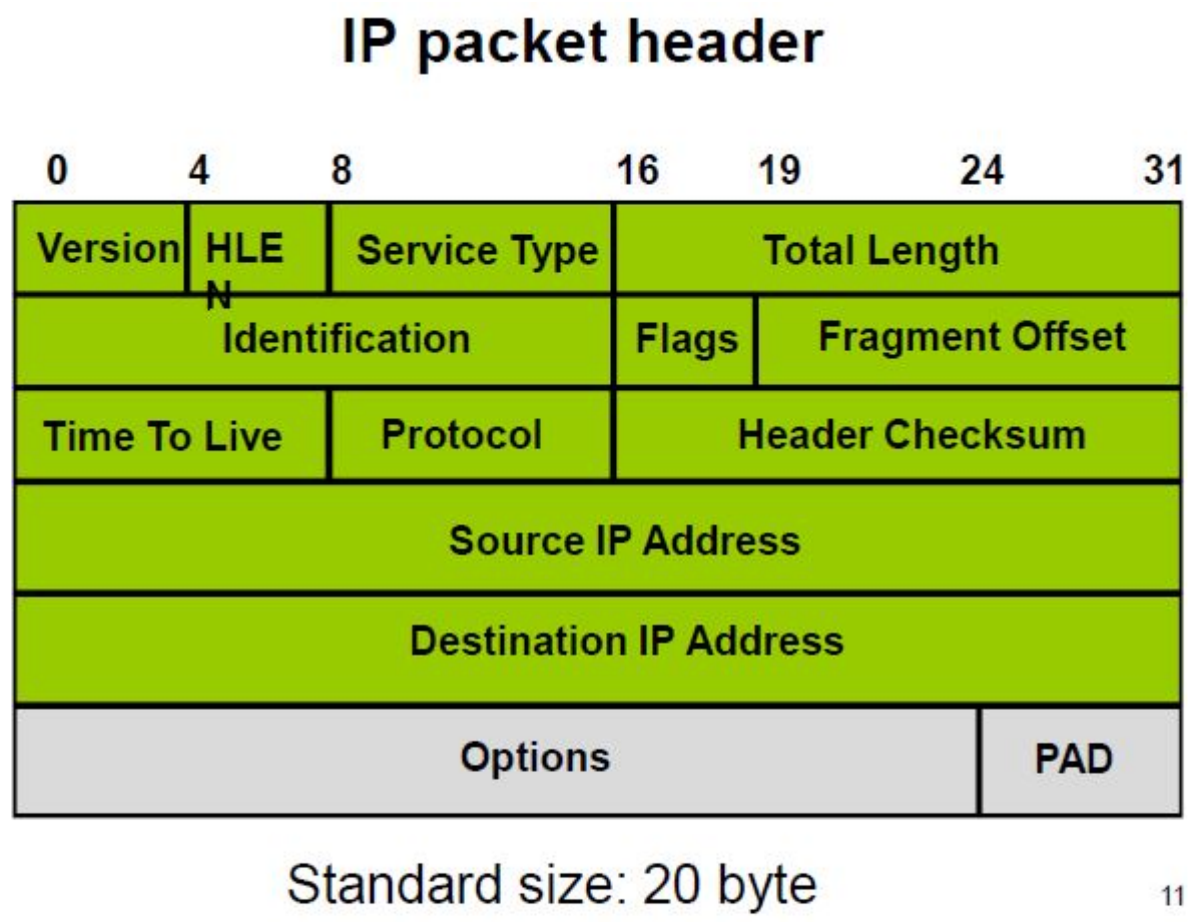
Best-effort service → connectionless, unreliable

Connectionless delivery: Stateless approach, each datagram routed independently, no QoS guarantees

Unreliable delivery: in case of:

- failure: drop and error message sent
- buffer shortage: drop and error message not sent cause cannot be store
- Checksum error: drop and error message not sent cause address may be wrong

CARENZA



2.3 Scalable Forwarding, Structured Addresses

Address assignment is done such that nodes which can be reached without resorting to L3 forwarding have the same prefix (network ID).

A comparison of Net ID identifies whether the destination is directly connected (reachable through L2 forwarding only)

Within L3 forwarding another structure can help hierarchical organization in routing.

2.4 Internet routing

Drivers

Tech and economy aspects:

- Internet is built of cheap and unreliable components → dynamic routing
- Components had computation capabilities → dist alg. can be implemented

- Cheap overlaid inter-networks → inter-networks create clouds that have to be connected globally

Model

Dynamic and intra/inter routing.

Internet organized as autonomous systems (AS)

Interior Gateway Protocols (IGPs) within AS

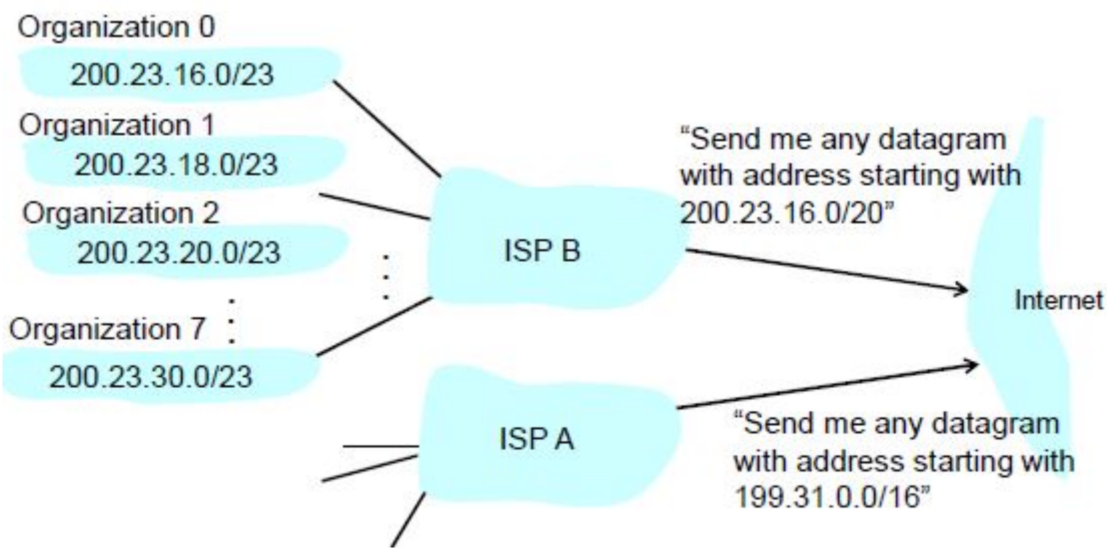
Exterior Gateway Protocols (EGPs) for AS to AS routing

2.5 Hierarchical routing

The ideal case is that all routers are identical, flat network, no hierarchy → not applicable in practice, cause we should have a routing table of more than 100 million destinations, and also for administrative reasons.

Hierarchical → more efficiency

Router aggregation

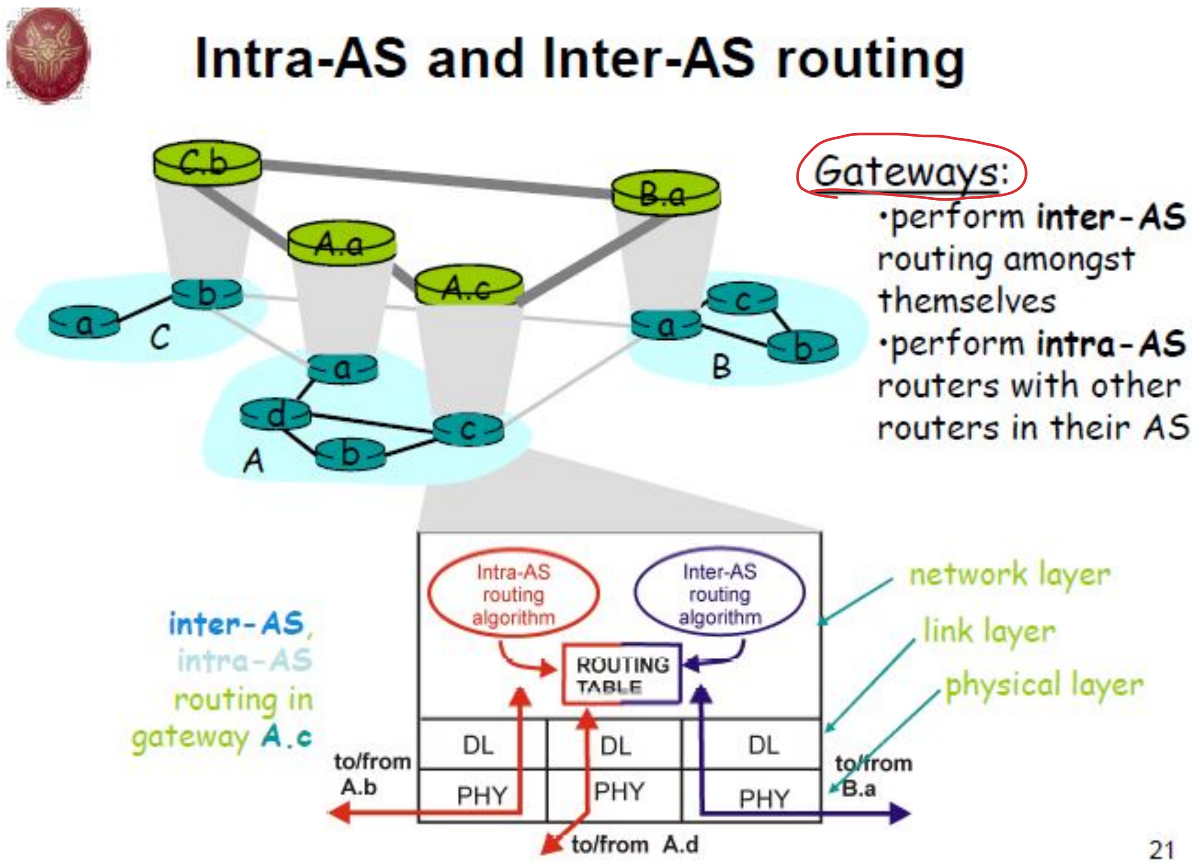


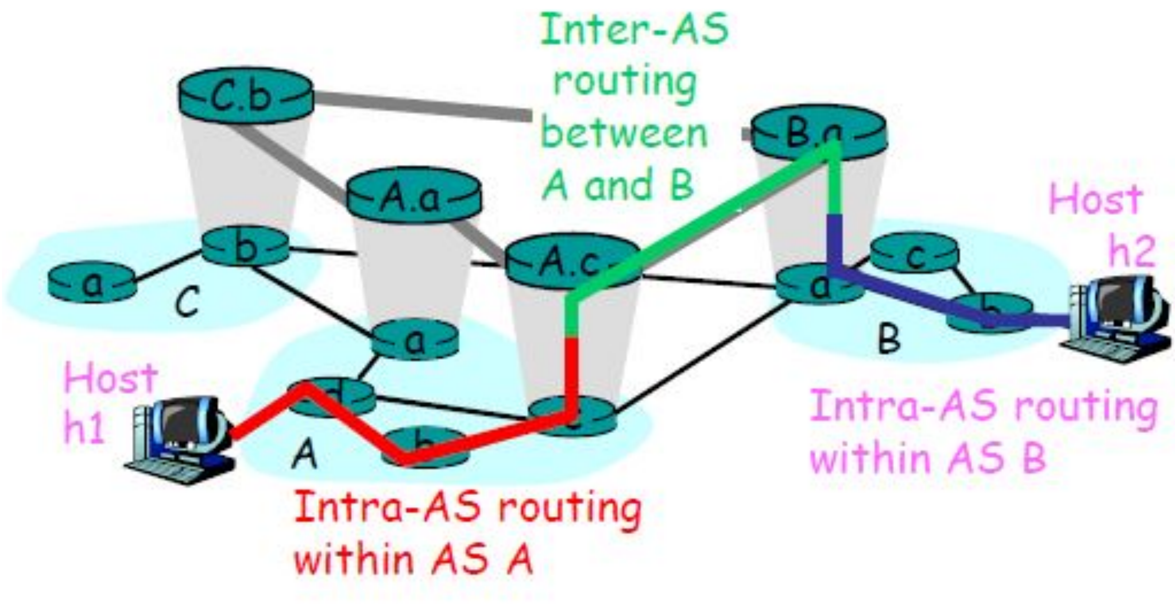
Router aggregated in AS:

- Networks with complex structure but same administrative authority
- Router within the same AS use same routing protocol
- Intra-AS routing protocols: routers of different AS may use different IGP

In each AS exist gateway routers:

- responsible to route out of the AS
- Run intra-AS protocols with the other ASs
- Run inter-AS protocols (EGP)





-Requirements

Intra:

- should scale for the size of an AS
- Diff. reqs on routing convergence after topology changes
- Operational/Admin/Management (OAM) Complexity
- Traffic engineering capabilities

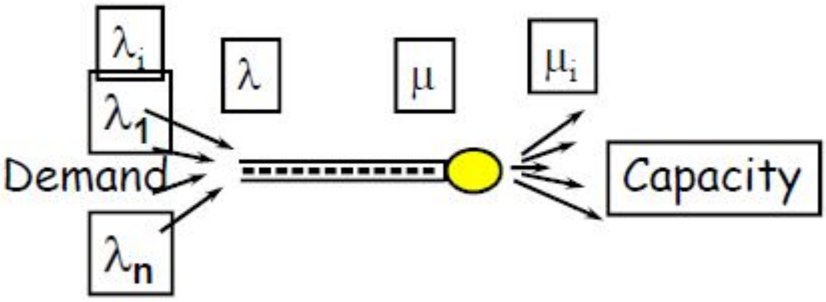
Inter:

- Should scale for the size of the global internet (focus on reachability, not optimality)
- Allow policy-based routing between AS

2.6 The congestion problem

"Demand outstrips available capacity"

It could be solved with complete info and zero delays

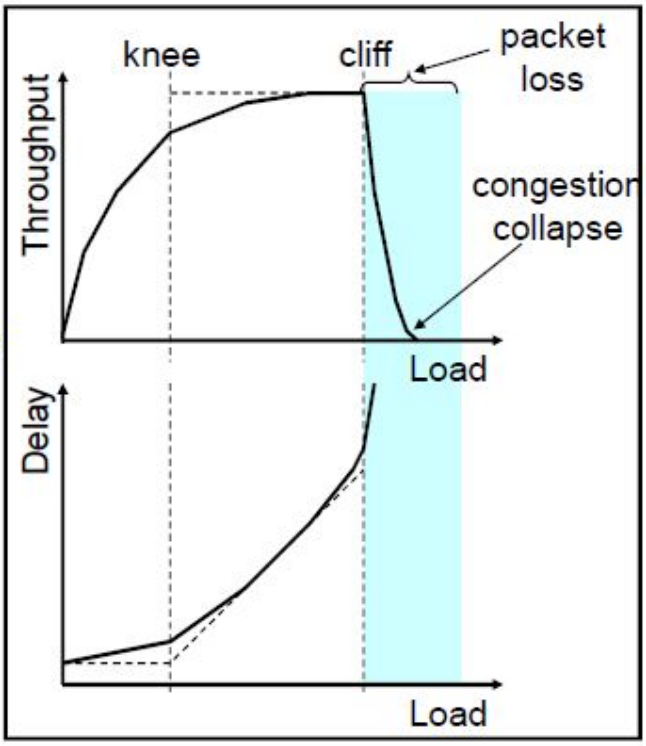


Close-up view

knee – point after which
- throughput increases very slowly
- delay increases fast

cliff – point after which
- throughput starts to decrease very fast to zero (congestion collapse)
- delay approaches infinity

Note (in an M/M/1 queue)
- delay = 1/(1 – utilization)



Congestion control goals

- stay left of cliff

- to guarantee stable operation, keep networks working in an efficient status and provide fair allocations of network bandwidth

Congestion avoidance goal

- stay left of knee

Right of cliff:

- congestion collapse

2.7 QoS

TCP/UDP/IP provides best-effort not reliability

Streaming delay of 5 to 10 seconds is typical, but deteriorate with congestion

Real-time is guaranteed by large bandwidth, but with congestion?

Most router are FIFO and transmission scheduling, to mitigate impact of "best-effort", we can:

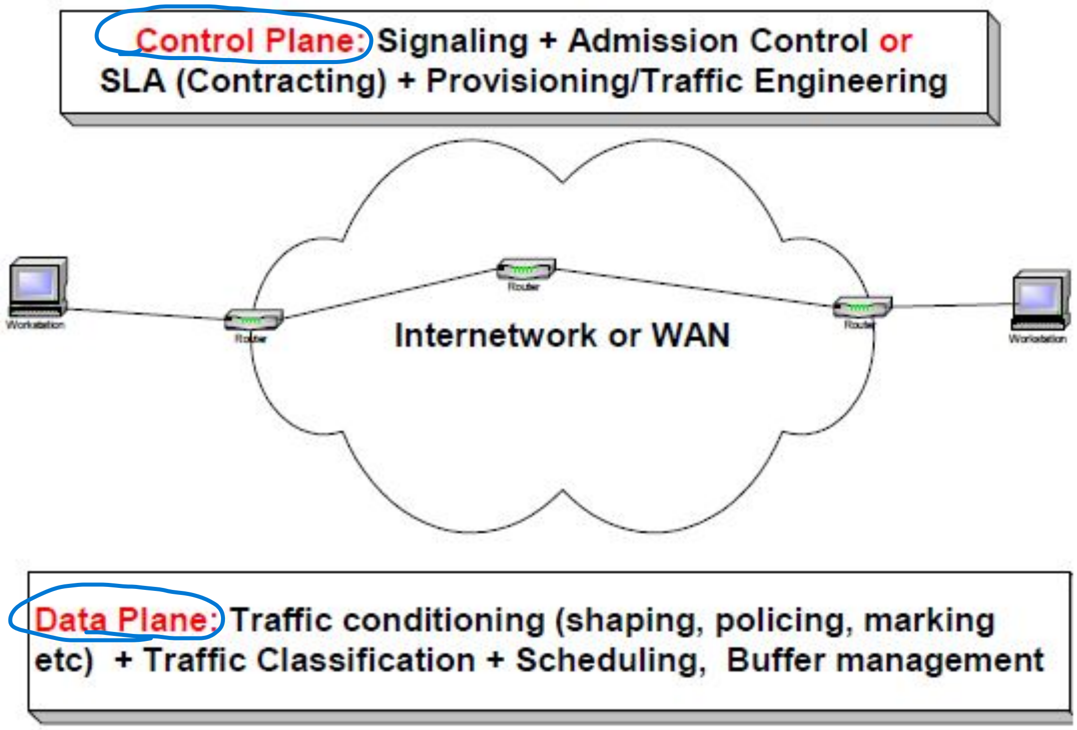
- UDP over TCP to avoid slow-start
- Buffer content and control playback
- adapt compression with bandwidth

Need to use new scheduling disciplines which provide “isolation” of performance from arrival rates of background traffic

Solutions in IP Networks

Add bandwidth and improve caching, new scheduling policy and set up SLAs.

Use of differentiate services for classes of packets



2.8 Internet transport layer

Mux/Demux → final destination of data is not the host but an application running in the host

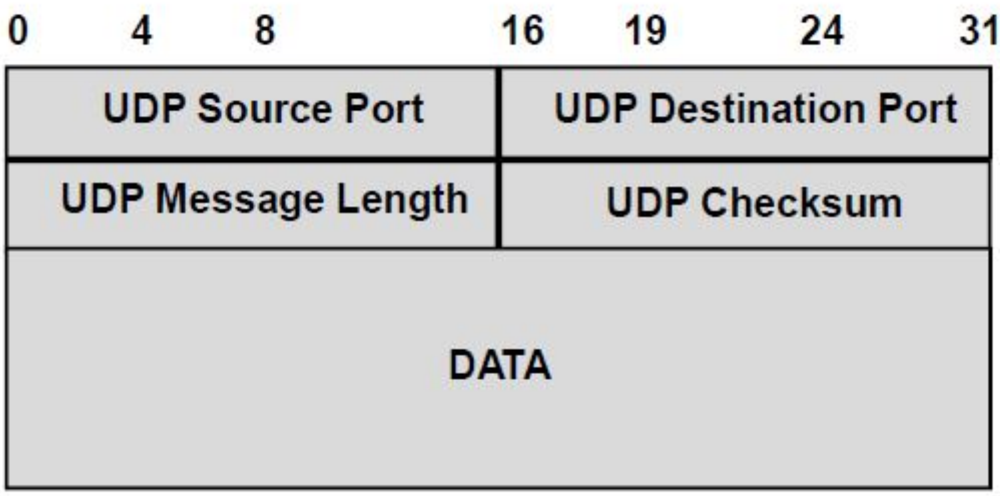
Port: interface between processes and net arch.; there is an association between ports and processes.

2.8.1 UDP: User Datagram Protocol

Connectionless, no delivery guarantee.

Functions: mux through port abstraction, checksum to verify data integrity

Using UDP should solve reliability and Flow and congestion control



Best applications:

- operating in local area
- all data contained in a single packet
- full reliability is not fundamental
- need to send data at rate independent from the network

2.8.2 TCP: Transmission Control Protocol

Connection oriented, reliable, flow and congestion control, used in: telnet, ftp, smtp, http

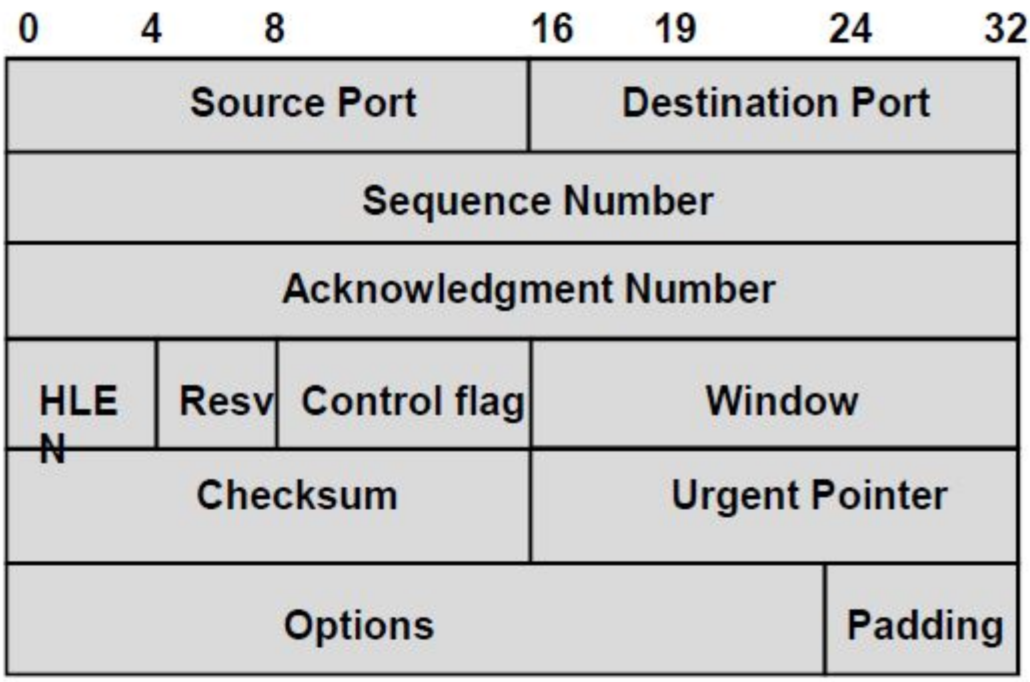
mux through ports; connection opened between two TCP entities, is more complex than UDP, requires more CPU and memory.

- TCP freely segments and reassembles data, a FIFO buffer is the interface between TCP and app processes
- Flow control and congestion operates on the transmitter window size

▼ **Connection identification**

By:

- src and dest IP
- src and dest ports
- TCP and UDP use of port numbers are independent



2.8.3 RTP: Real-Time Transport Protocol

Protocol that manage real-time transmission of multimedia data, is commonly used in Internet telephony apps; combines its data transport with a control protocol (RTPC)

Includes:

- sequence number (to detect lost packets)
- payload id (describes specific media encoding)
- frame indication (marks beginning and end)
- source identification (originator of the frame)

- intramedia synchronization (uses timestamps to detect different delay)

RTPC

Includes:

- QoS feedback
- Session control
- Id (include participant info)
- Intermedia synchro (enables synchro of audio and video streams)