Course on Computer Communication and Networks

Lecture 16
Synthesis, Summary/flashback and Projection (related topics – continuation of study)

EDA344/DIT 420, CTH/GU

Based on the book Computer Networking: A Top Down Approach, Jim Kurose, Keith Ross, Addison-Wesley.

Important for the exam

When/where: wednesday March 15, 14.00-18.00, SB-building

You may have with you:

- English-X dictionary
- no calculators, PDAs, etc (if/where numbers matter, do rounding)

Grading

- 30-40, 41-50, 51-60 (out of 60)= 3, 4, 5 (CTH)
- 30-44, 45-60 (out of 60) = G, VG (GU)

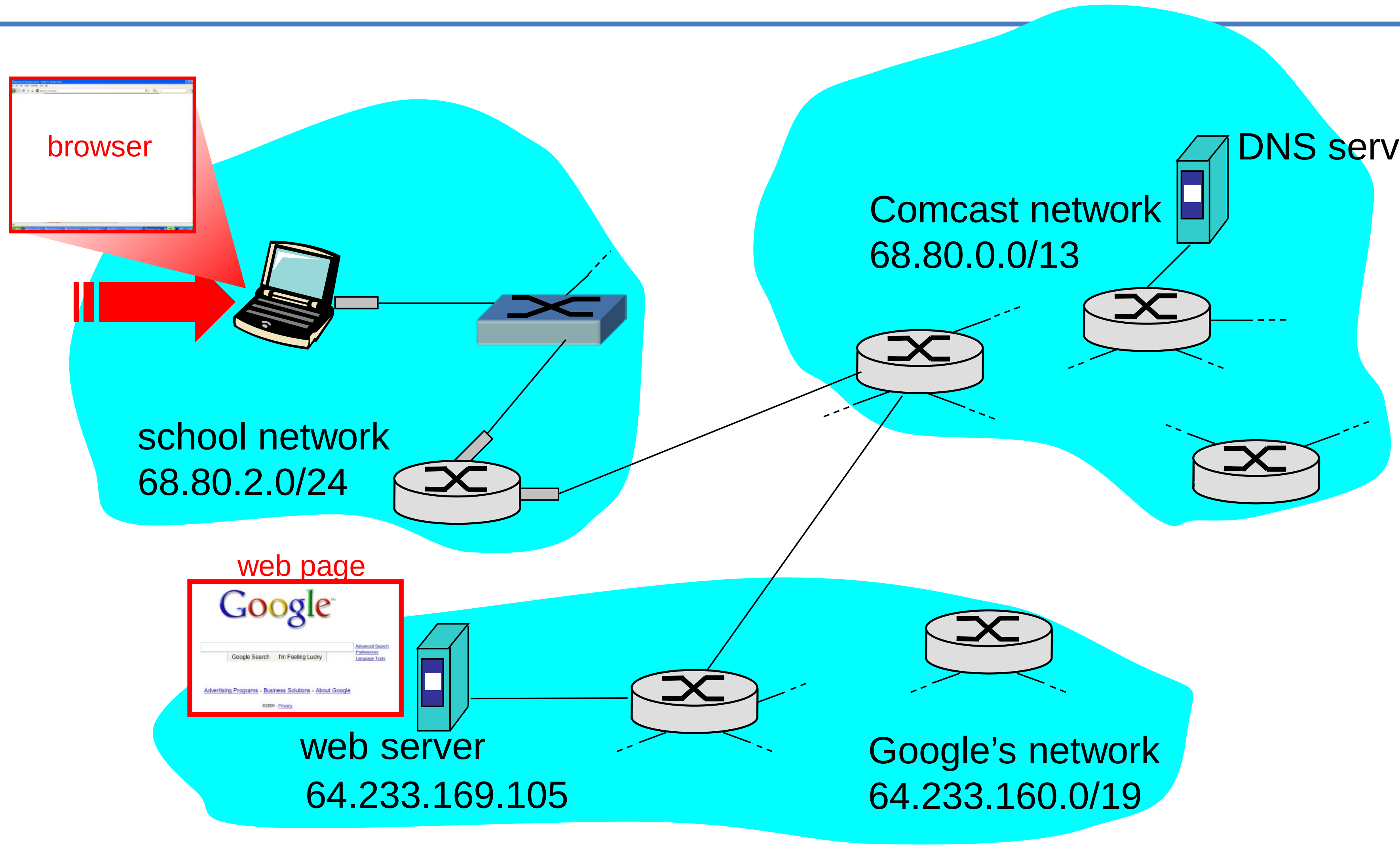
To think during summary-study

Have overview, critical eye; explain; ask yourselves: why is this so? / how does it work (or not work)?

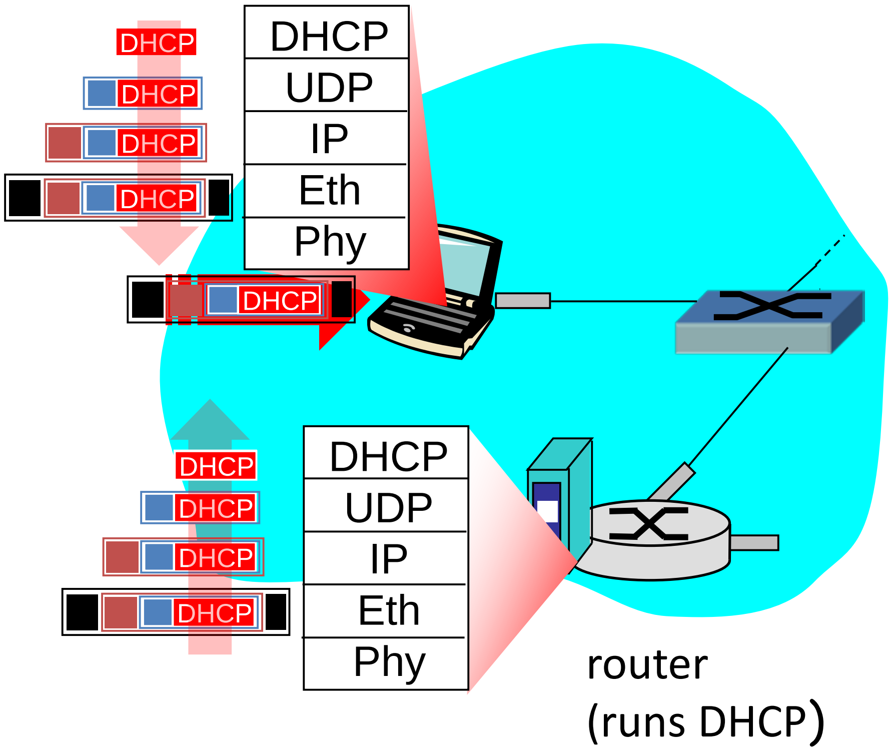
Synthesis: a day in the life of a web request

- Putting lots-of-what-we-learned together: synthesis!
  - *goal:* identify, review protocols (at all layers) involved in seemingly simple scenario: requesting www page
  - *scenario:* student attaches laptop to campus network, requests/receives www.google.com

A day in the life …. : scenario



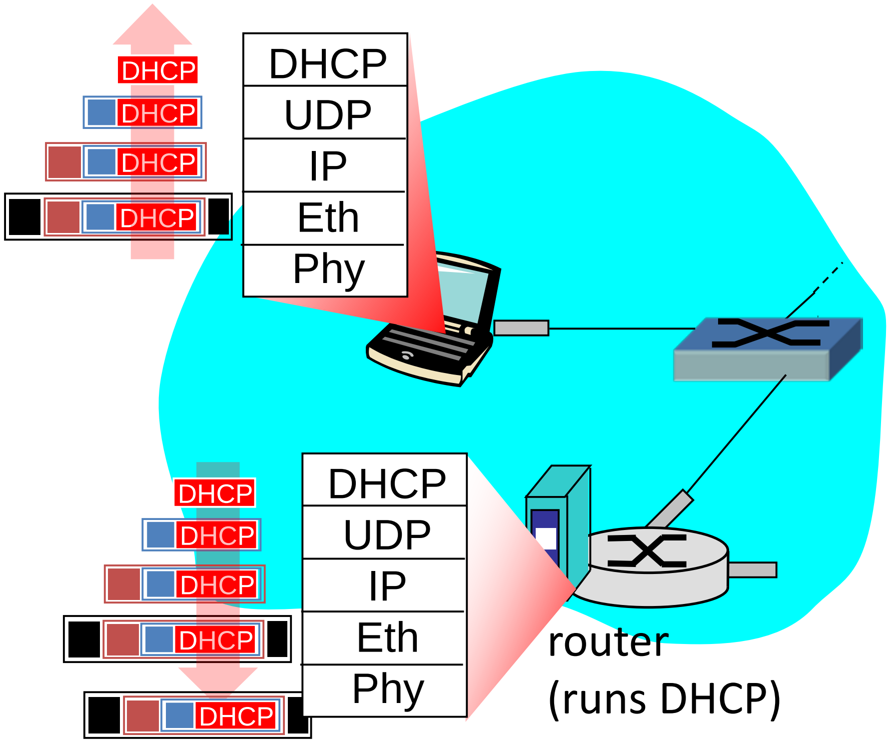
A day in the life… connecting to the Internet



connecting laptop needs to get its own IP address: use ***DHCP***

- DHCP request encapsulated in UDP, encapsulated in IP, encapsulated in Ethernet
- Ethernet frame broadcast (dest: FFFFFFFFFFFF) on LAN, received at router running DHCP server
- Ethernet demux'ed to IP demux'ed to UDP demux'ed to DHCP

A day in the life… connecting to the Internet

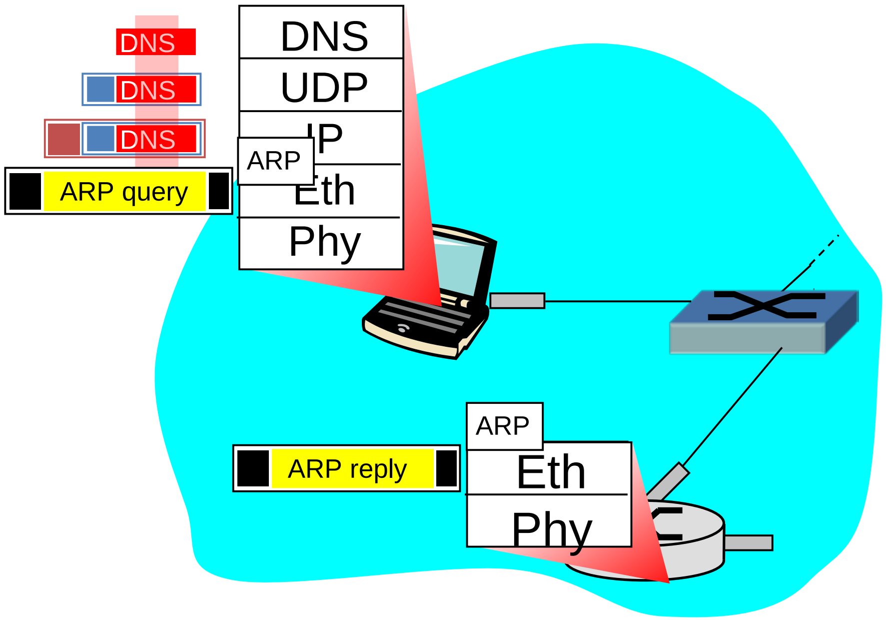


DHCP server formulates ***DHCP ACK*** containing client's IP address (**and also IP address of first-hop router for client, name & IP address of DNS server**)

- frame forwarded (switch learning) through LAN, demultiplexing at client
- DHCP client receives DHCP ACK reply

Client now has IP address, knows name & addr of DNS server, IP address of its first-hop router

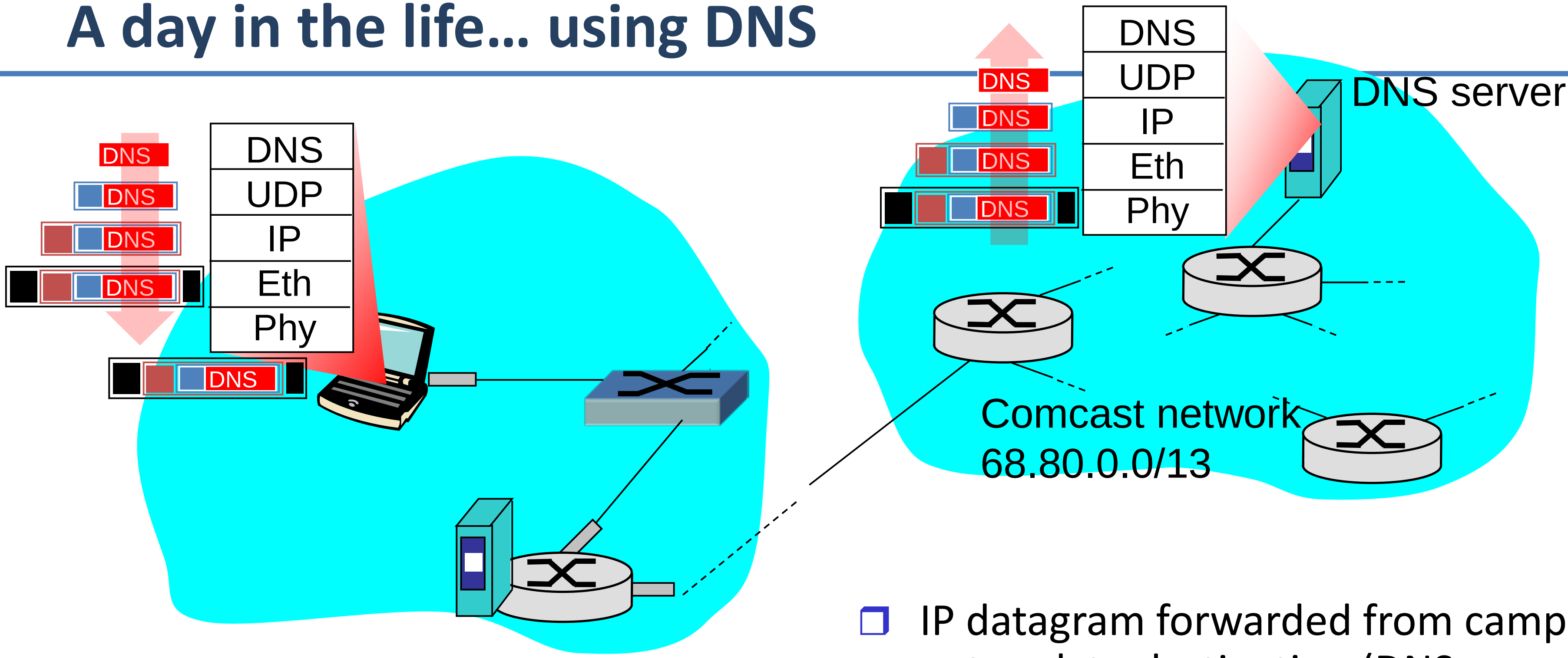
A day in the life… ARP (before DNS, before HTTP)



before sending ***HTTP*** request, need IP address of www.google.com: ***DNS***

- DNS query created, encapsulated in UDP, encapsulated in IP, encasulated in Eth. In order to send frame to router, need MAC address of router interface: ARP
- ARP query broadcast, received by router, which replies with ARP reply giving MAC address of router interface
- client now knows MAC address of first hop router, so can now send frame containing DNS query

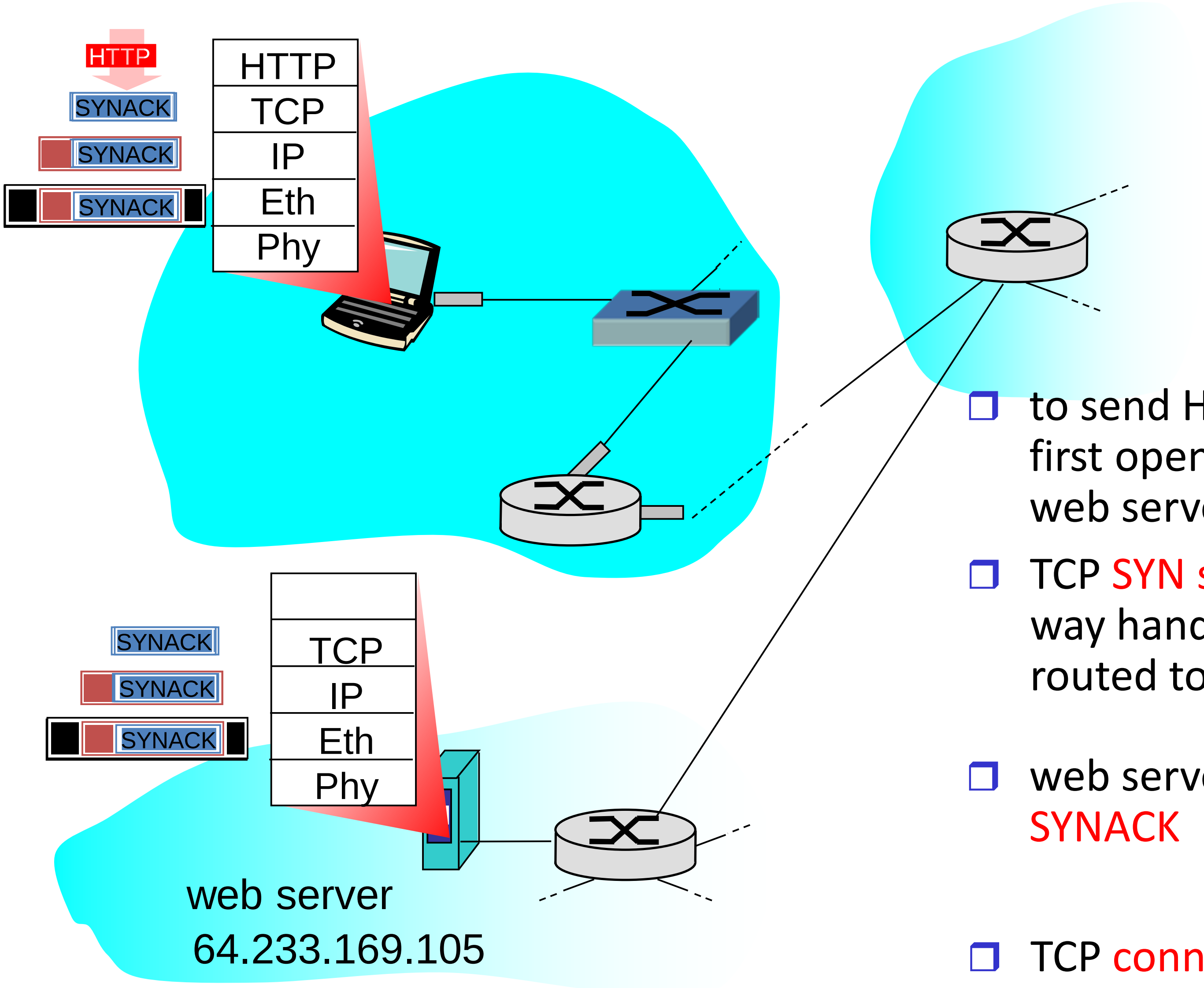
A day in the life... using DNS



- IP datagram containing DNS query forwarded via LAN switch from client to 1st hop router

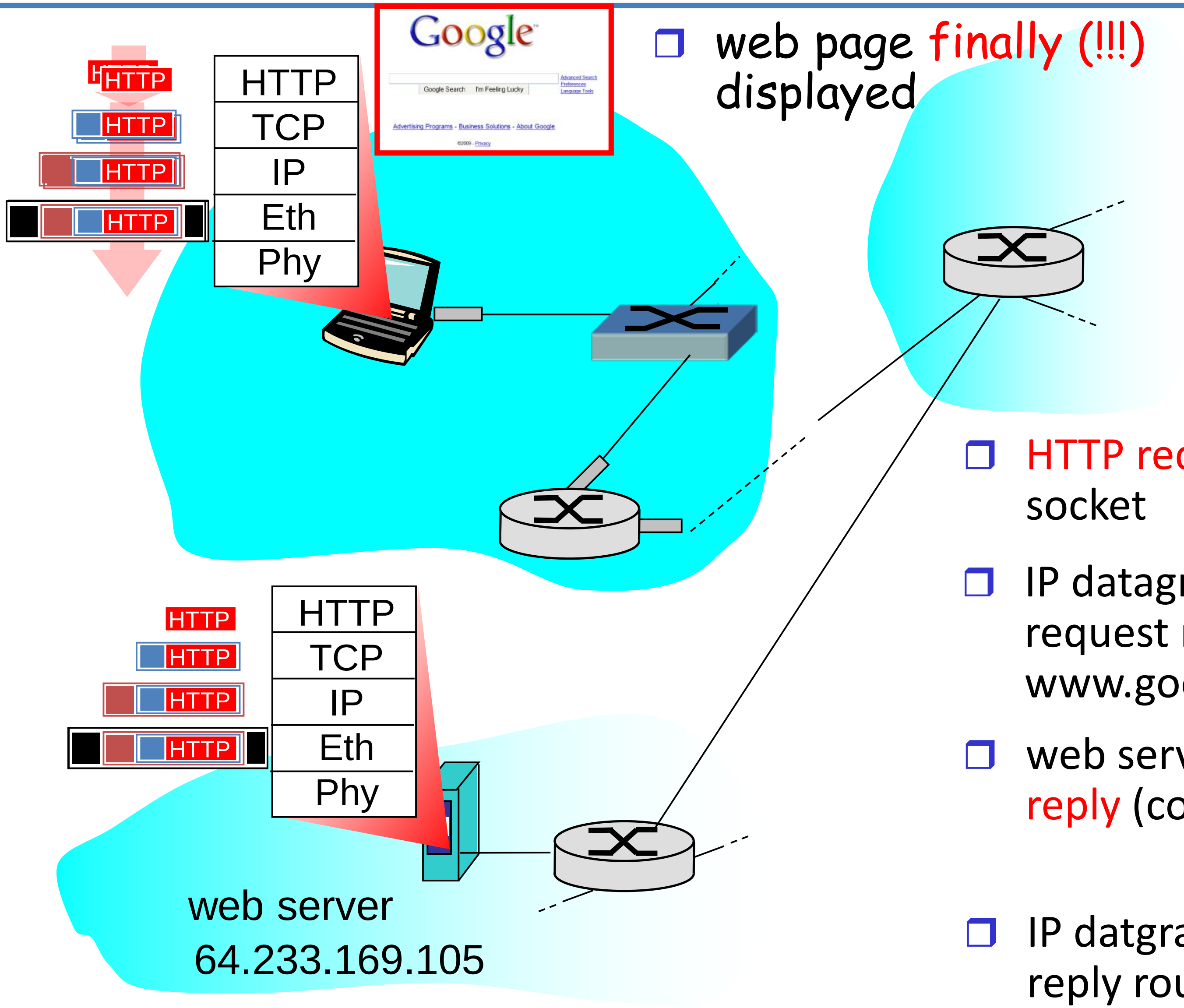
- IP datagram forwarded from campus network to destination (DNS-server) network, routed (tables created by RIP, OSPF and BGP routing protocols) to DNS server
- demux'ed to DNS server
- DNS server replies to client with IP address of www.google.com

A day in the life… TCP connection carrying HTTP



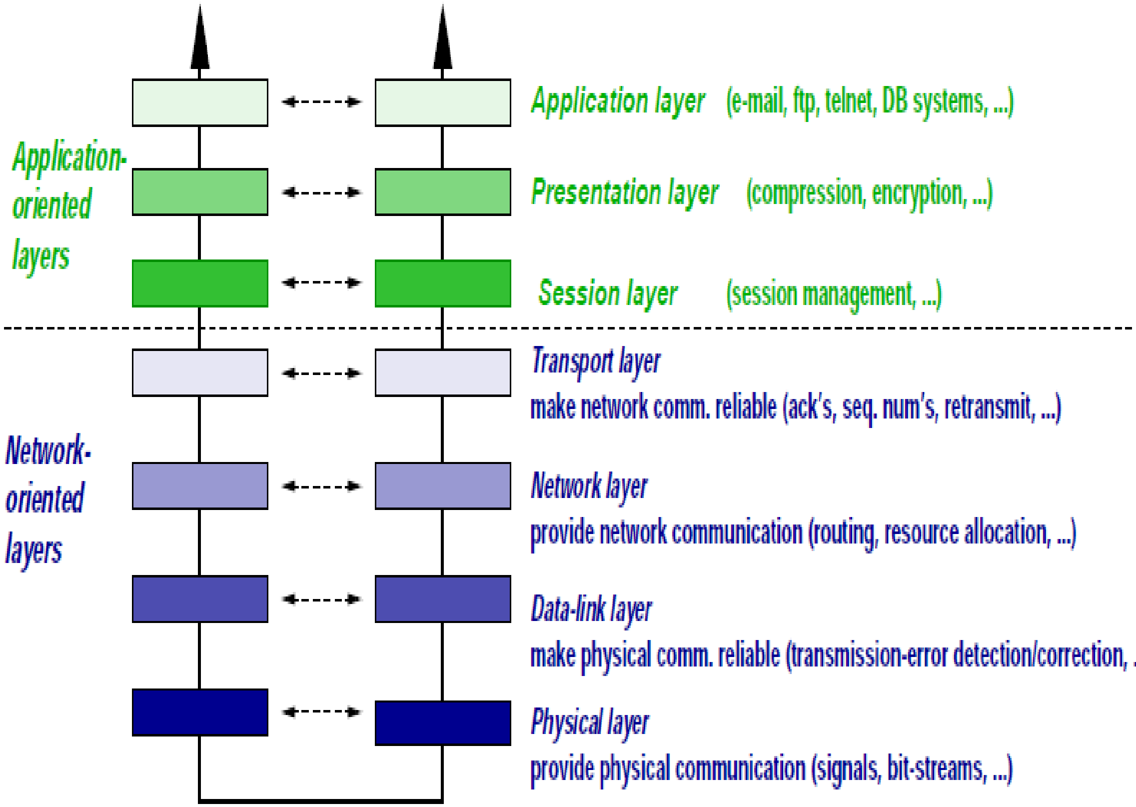
- to send HTTP request, client first opens TCP socket to web server
- TCP SYN segment (step 1 in 3-way handshake) inter-domain routed to web server
- web server responds with TCP SYNACK
- TCP connection established!

A day in the life... HTTP request/reply



- web page finally (!!!) displayed
- HTTP request sent into TCP socket
- IP datagram containing HTTP request routed to www.google.com
- web server responds with HTTP reply (containing web page)
- IP datgram containing HTTP reply routed back to client

Principles, Organisation

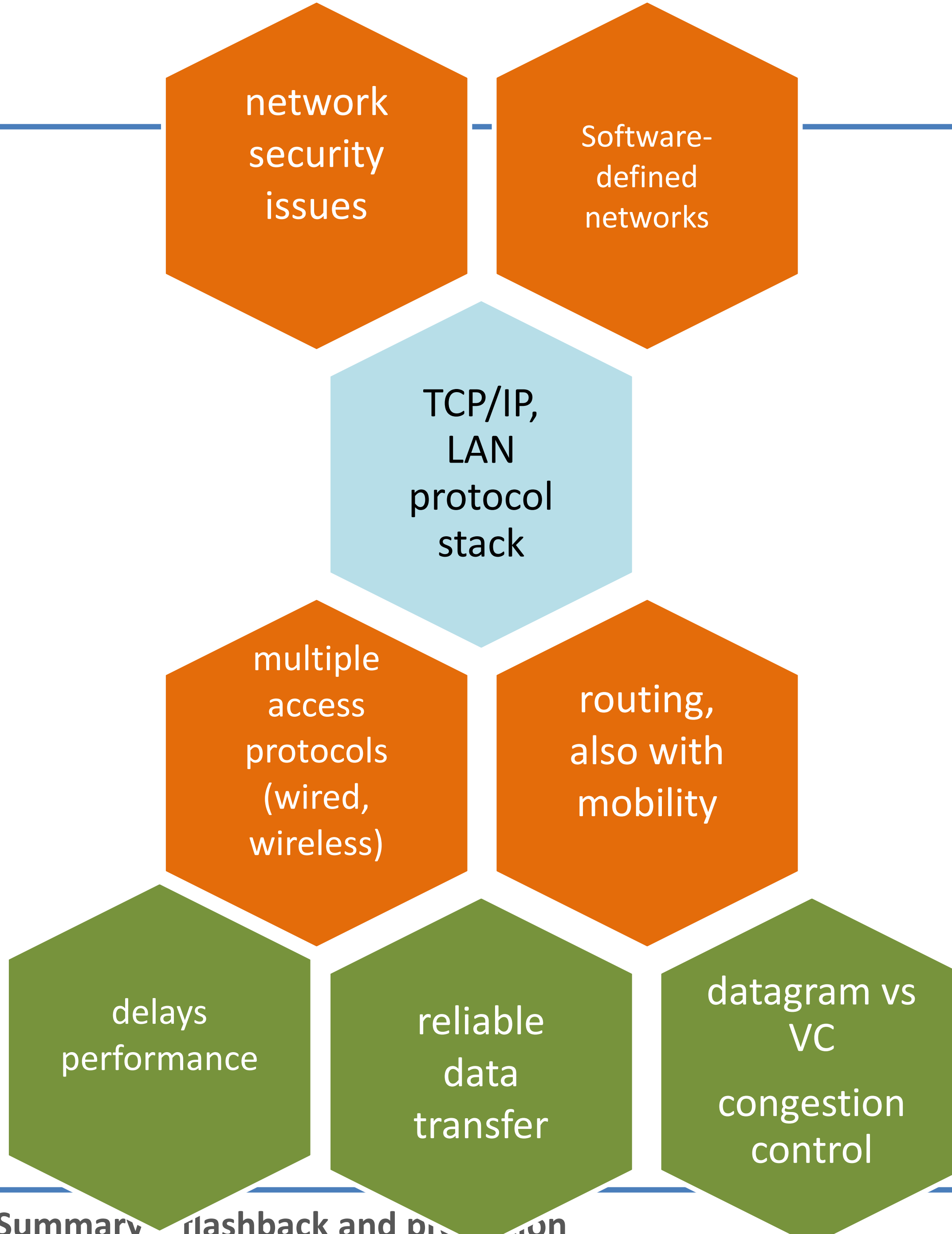


Network Problems

- Mobility, performance, security, …, …
- serving different types of traffic,
- connecting transparently different networks,
- routing, congestion control,
- access to shared (broadcast) transmission medium
- producer-consumer problems, flow and error control

Layering : principle, why

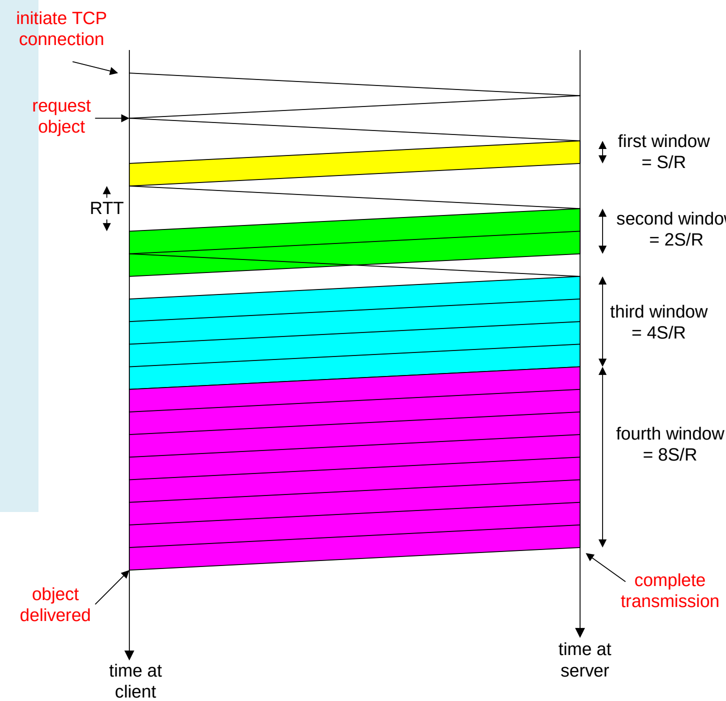
Highlights

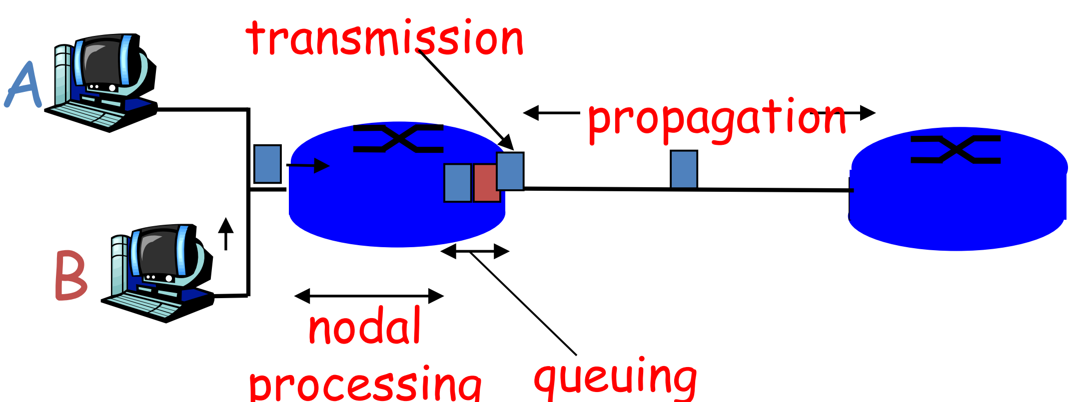

network security issues
Software-defined networks
TCP/IP, LAN protocol stack
multiple access protocols (wired, wireless)
routing, also with mobility
delays performance
reliable data transfer
datagram vs VC
congestion control

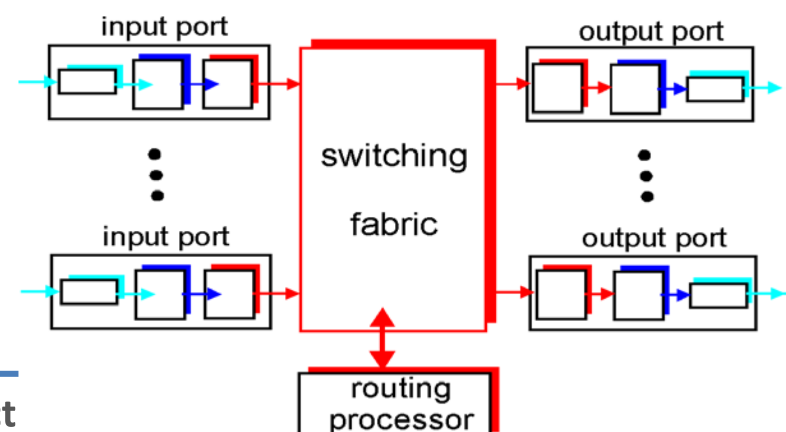
Types of delay; performance

delays
performance

- Propagation, transmission, queueing, processing
- Throughput (effective bandwidth), Utilization -- efficiency
- Packet-switching: impact of store&forward, pipelines, space-time diagrams
- Sliding windows performance
- Relation between delays-losses





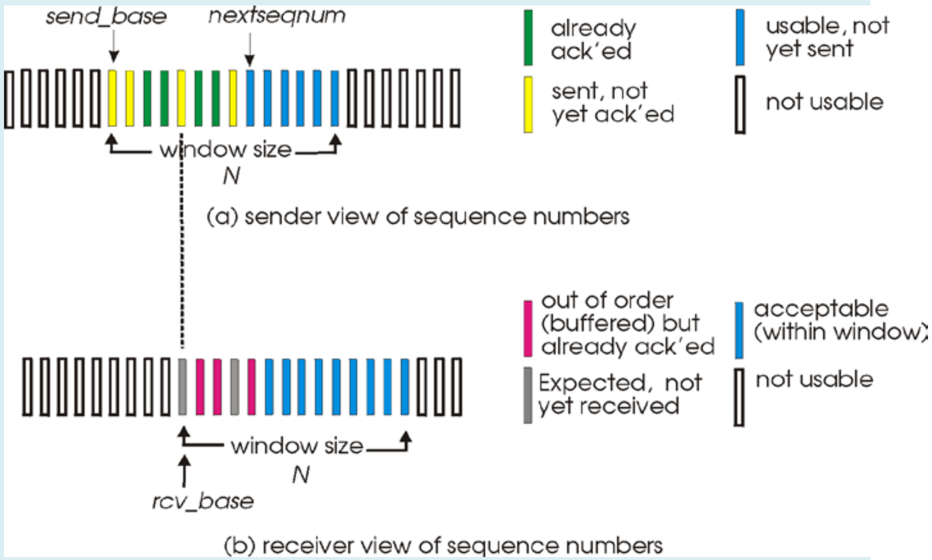


Reliable data transfer

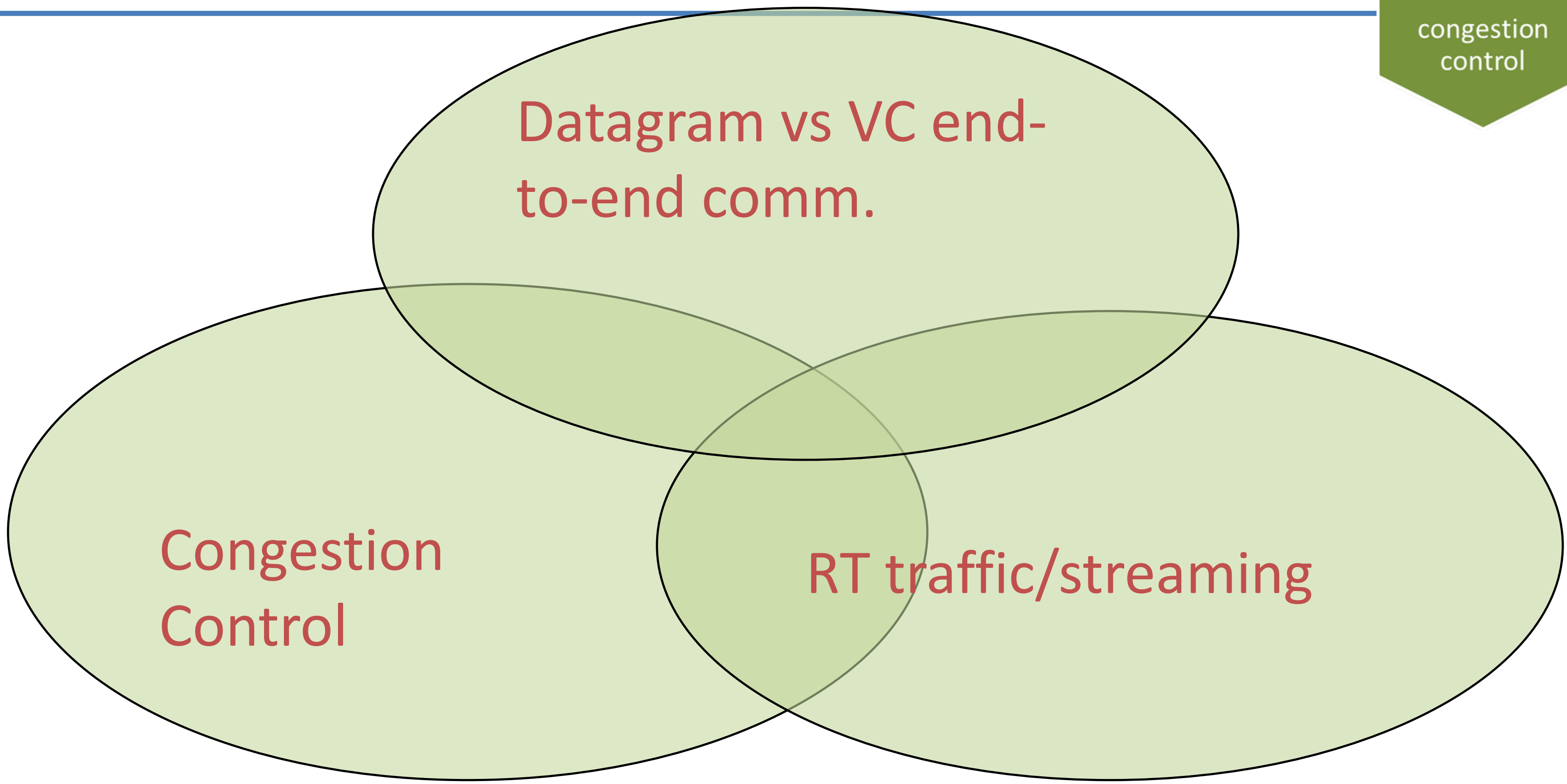
reliable data transfer

Guaranteed, in-order, correct delivery:

- stop&wait
- sliding windows
- sequence numbers
- window sizes
- dynamic windows (TCP)
- performance
- flow control



- **Error detection**: checksums
- **Error control**: go-back-n, selective repeat, FEC methods

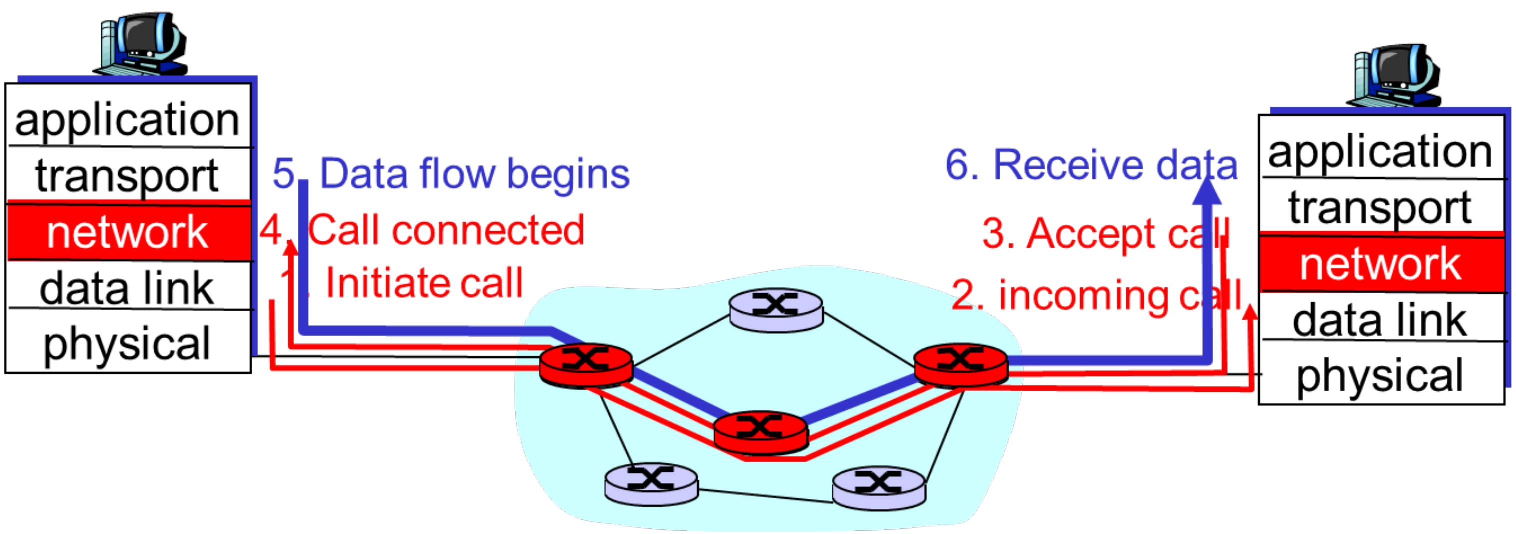


datagram vs VC

congestion control

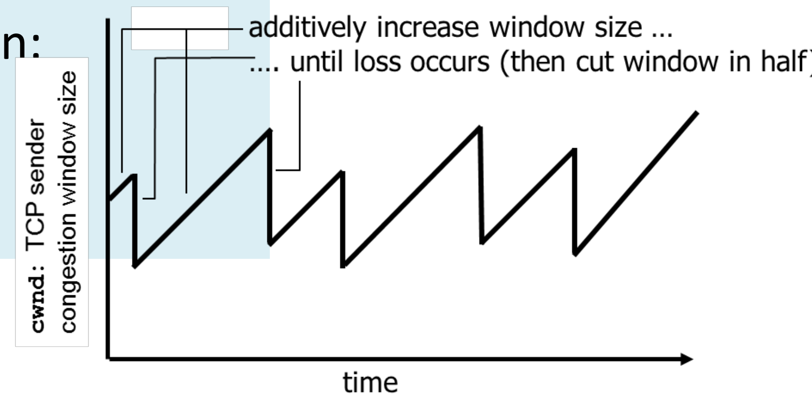
Datagram vs VC end-to-end communication

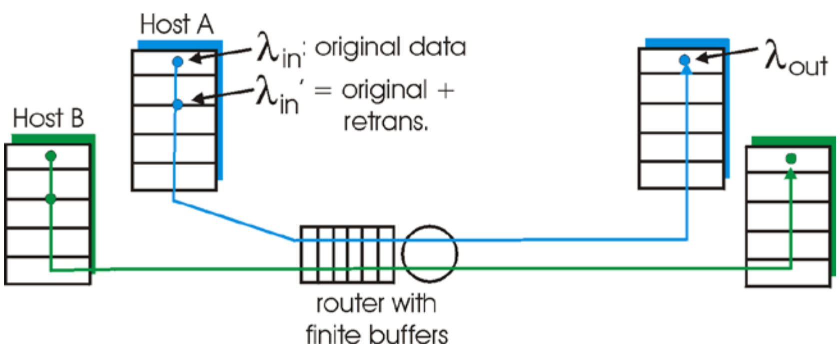
- Conceptual differences
- Decisions, comparison

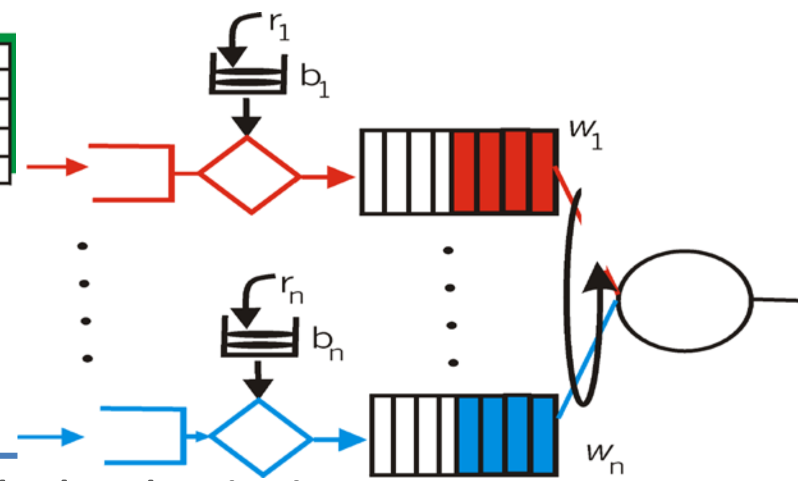


Congestion control (CC)

- why, how congestion occurs
- CC in TCP and performance; implied weaknesses
- CC in other ways, e.g. VC-based networks
  - Real-time (RT)-traffic resource reservation: traffic shaping and policing
  - rate-based







RT/streaming traffic

datagram vs VC

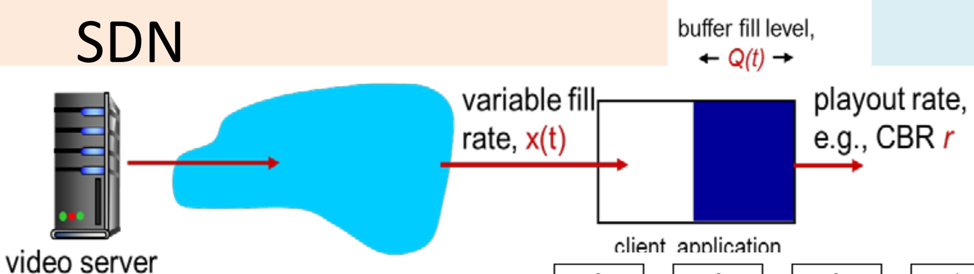
congestion control

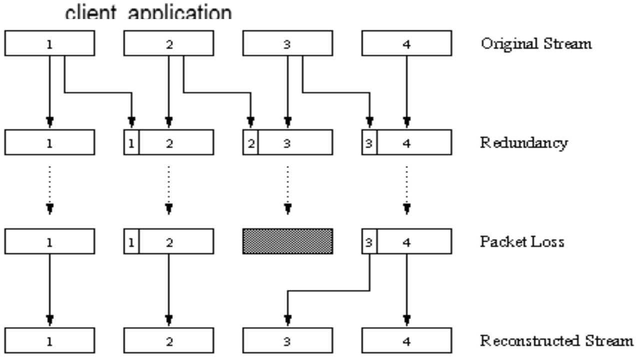
Internet context

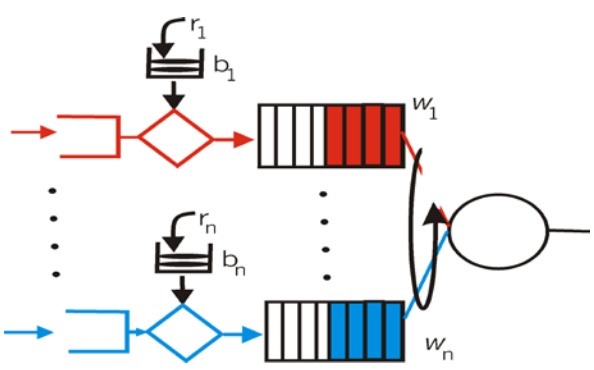
- Application-level solutions (playout delay, forward-error-control, caching-CDN)
- Intserv, Diffserv, traffic engineering, SDN

Conceptual needs:

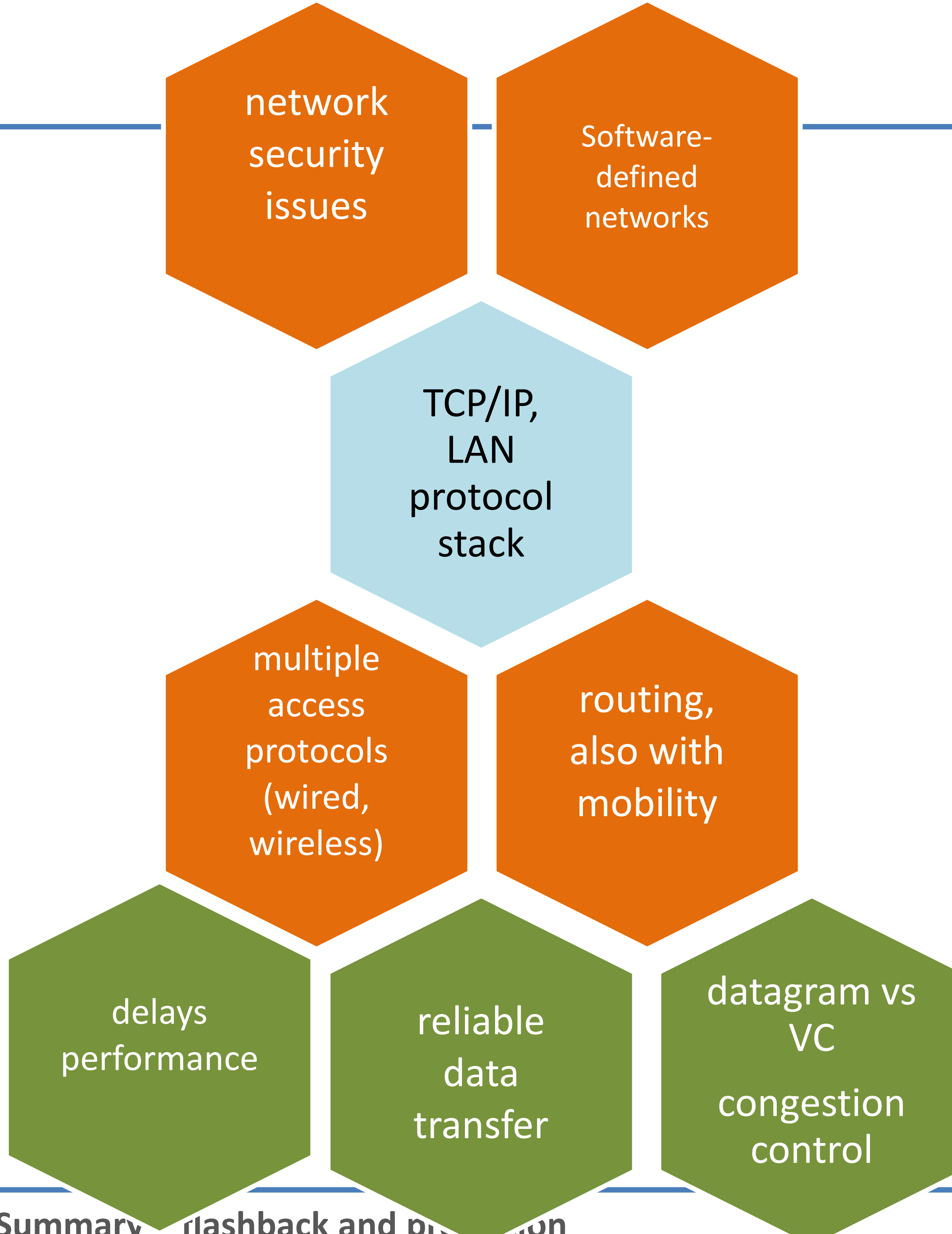
- packet/flow marking
- Admission control
- Traffic shaping & policing
- Packet scheduling







Highlights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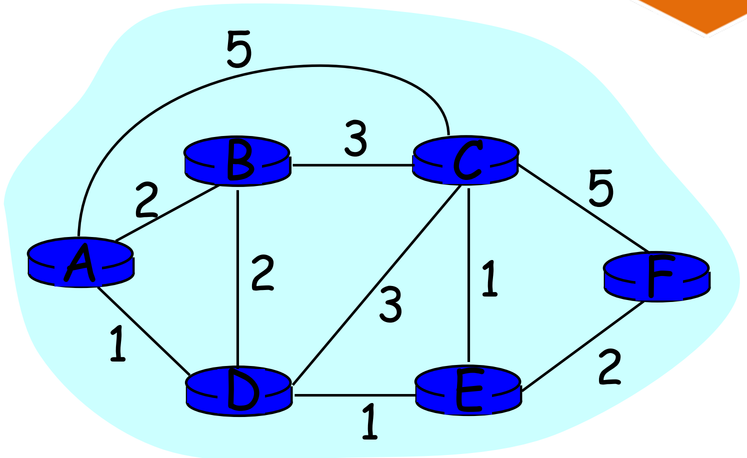
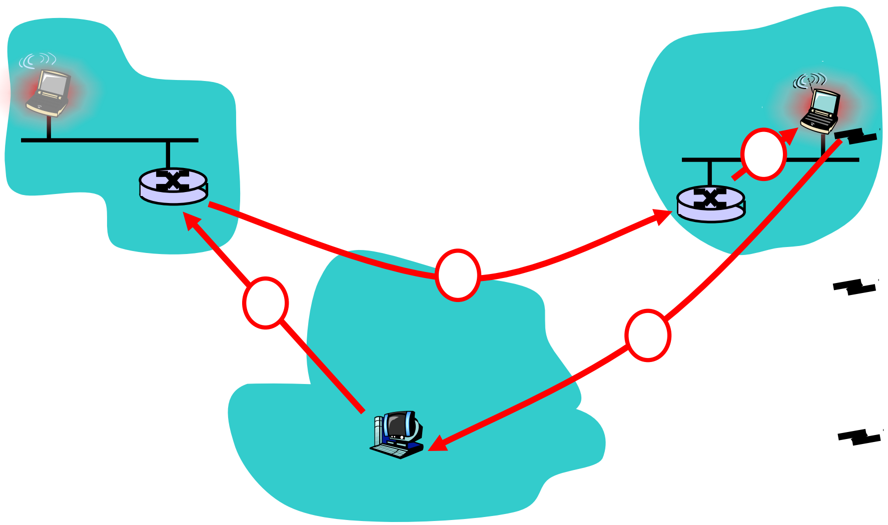
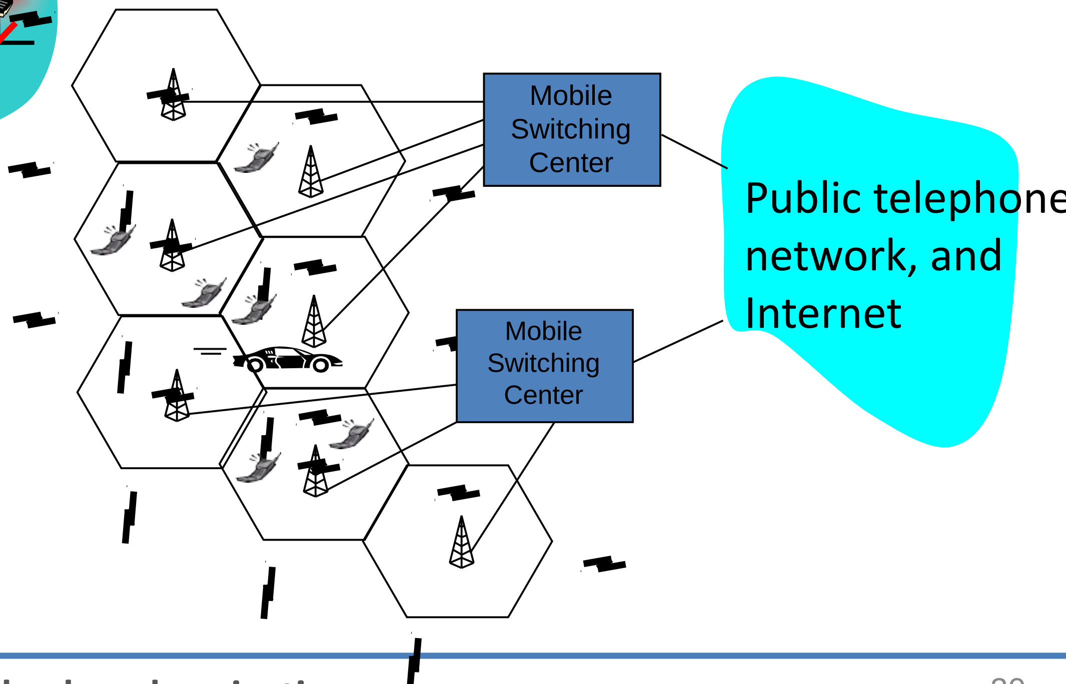
Routing, also with mobility

routing, also with mobility

- Routing algorithms, protocols
- Forwarding in routers
- Resource, policy issues
- Data plane and control plane in SDN
- Addressing mobility, tunneling





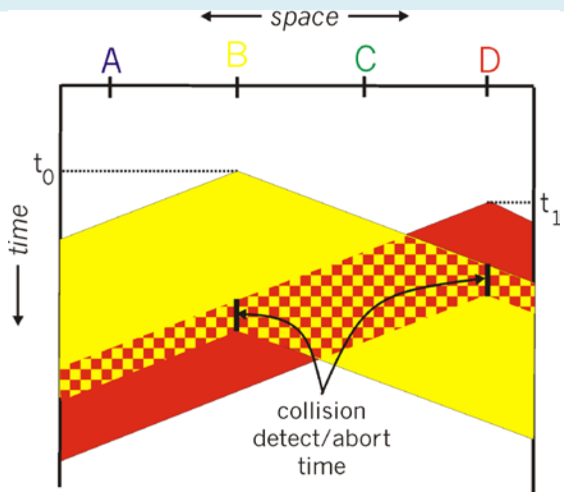


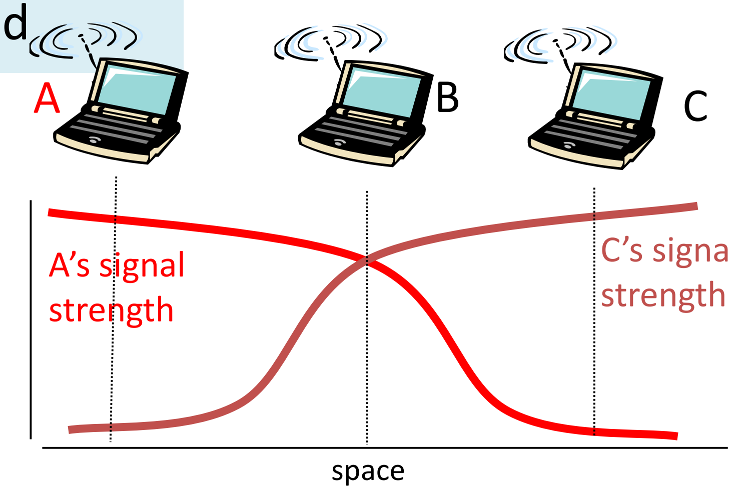
Medium access: multiple access methods

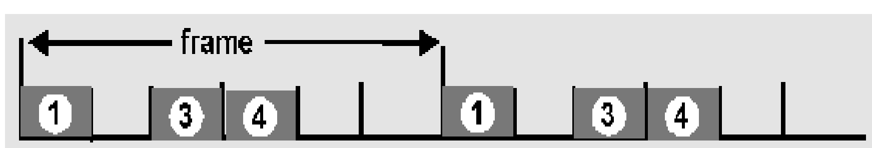
multiple access protocols (wired, wireless)

Strategies: (functionality, appropriateness)

- **Contention-based (random access), wired/wireless:**
  - Aloha, CSMA(CD/CA)
- **Collision-free:**
  - **Channel partitioning:** TDMA, FDMA, CDMA
  - **Taking turns:** e.g. tokens, reservation-based







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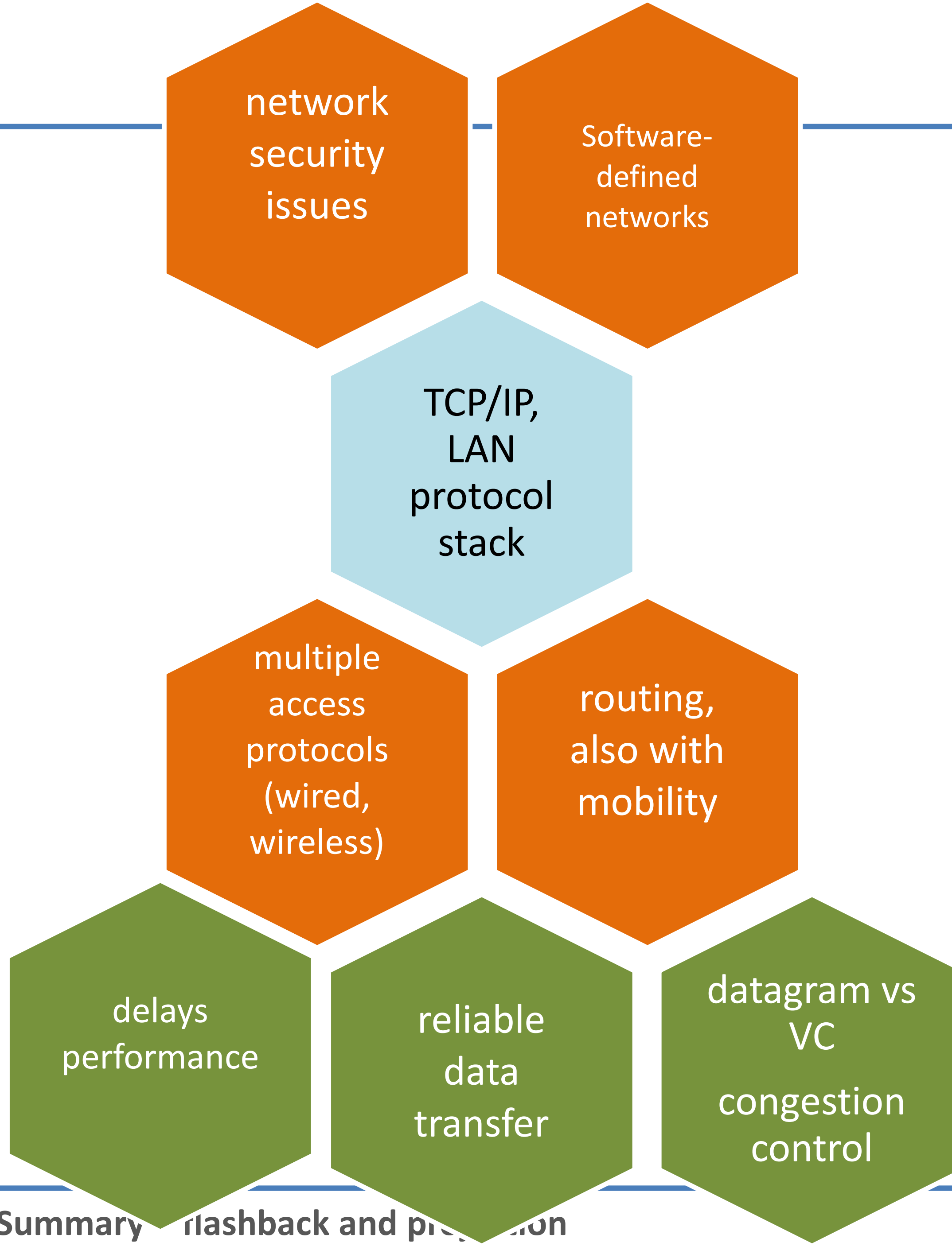
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TCP/IP protocol stack, applications, evolution

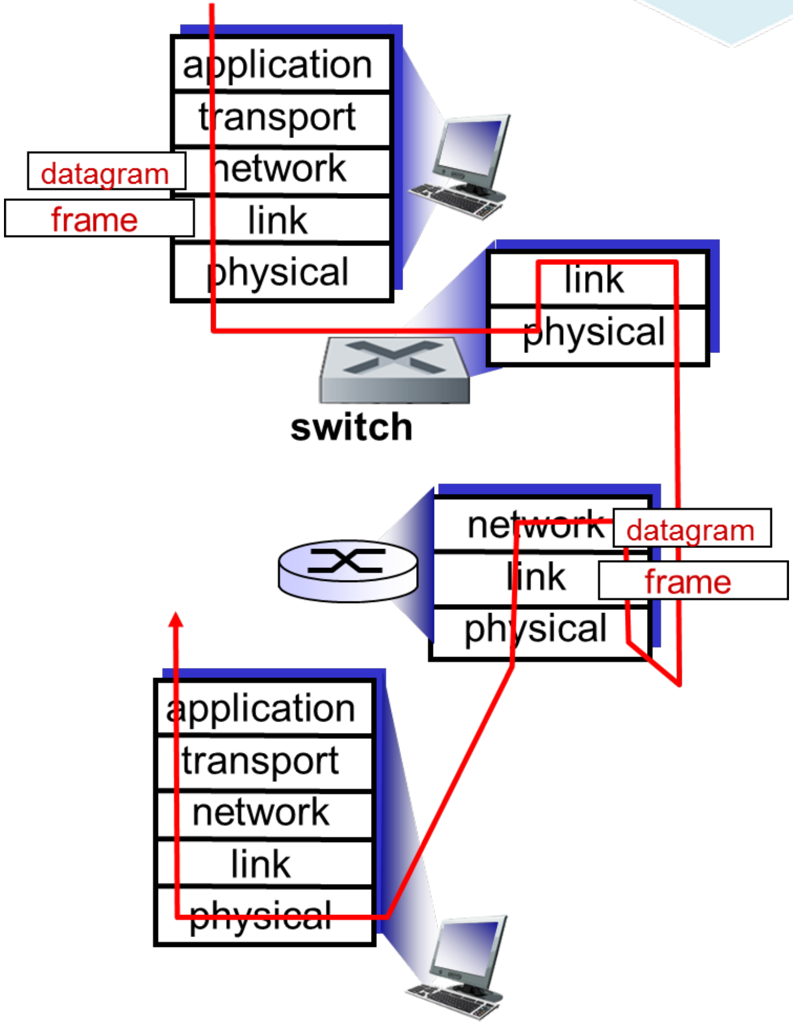
TCP/IP, LAN protocol stack

- Instantiation of network- solutions

(Routing, Congestion Control, Flow & error control, applications, link layer technologies)

- Advantages, limitations, updates

- New types of applications and how they function given the existing state of Internet



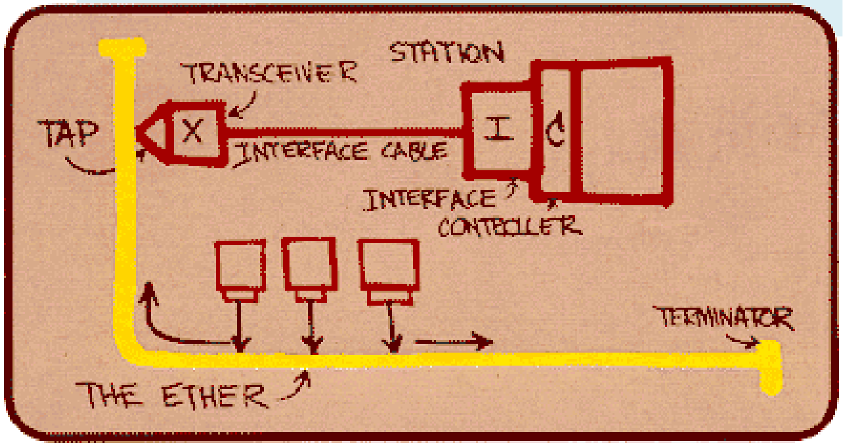
LANs & related link technologies

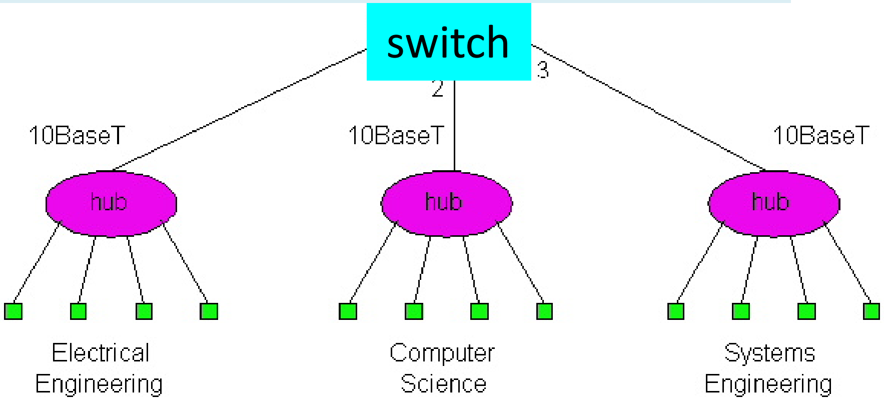
- **Protocol Examples: wired, wireless**

  Ethernet, 802.xy, GSM:

  Functionality, performance under low/high load

- **Connecting devices**;
  - functionalities and differences (Hubs, switches)
  - Algorithms for switch-"routing": learning& forwarding of packets
- **ARP**





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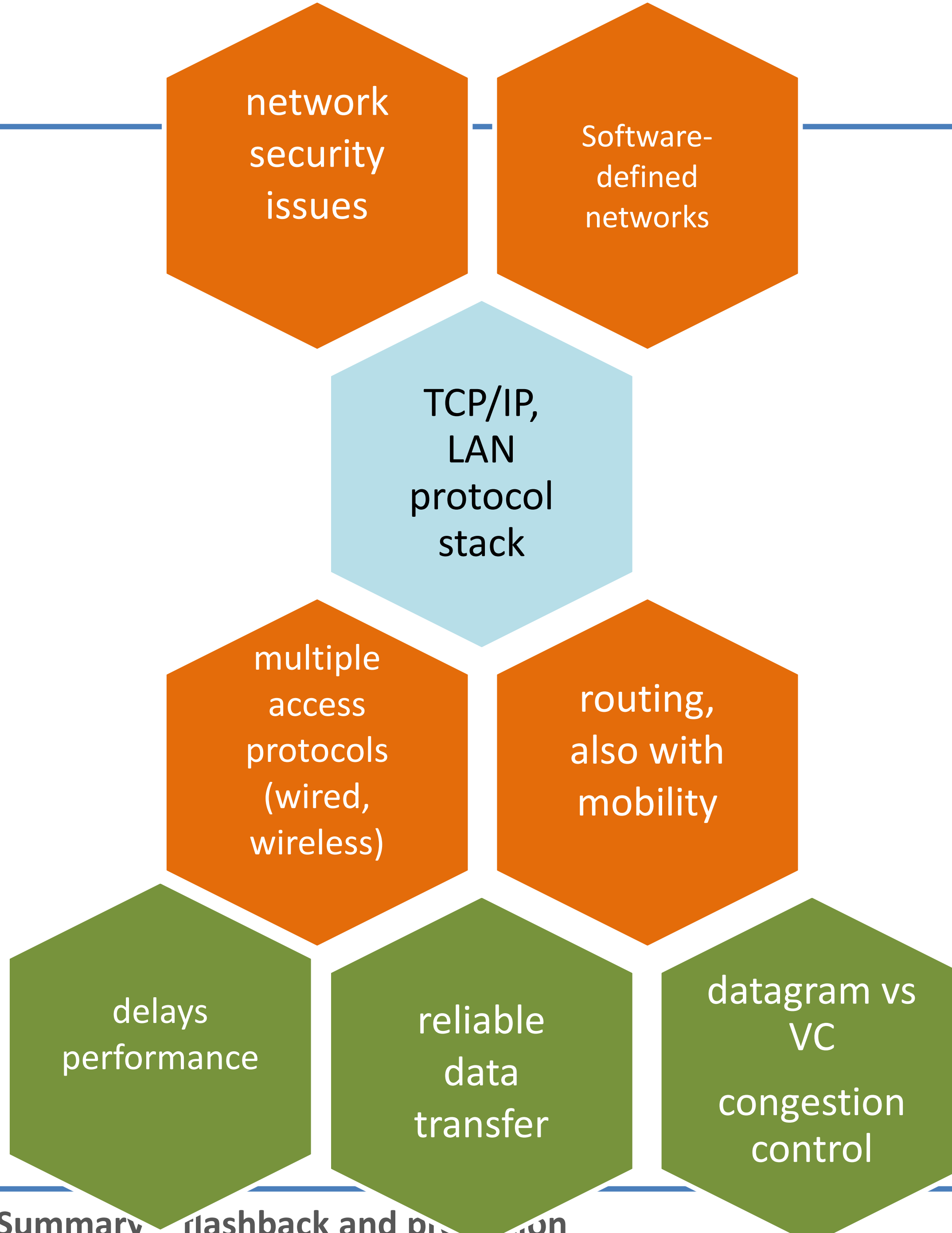
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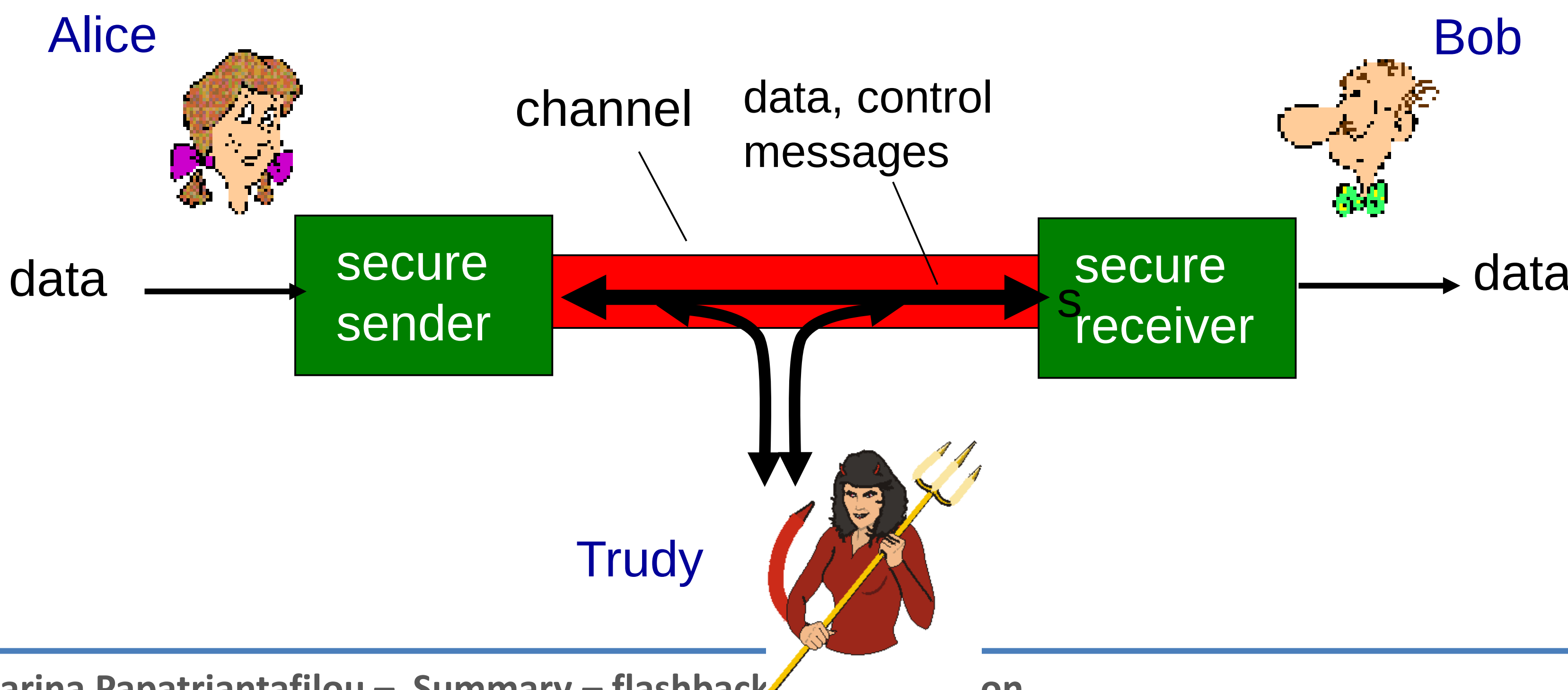
Security issues

network security issues

- **C, I, A** and methods to achieve them
  - The language of cryptography
  - Message integrity, signatures
- Instantiation in Internet: SSL, IPsec
- Firewalls

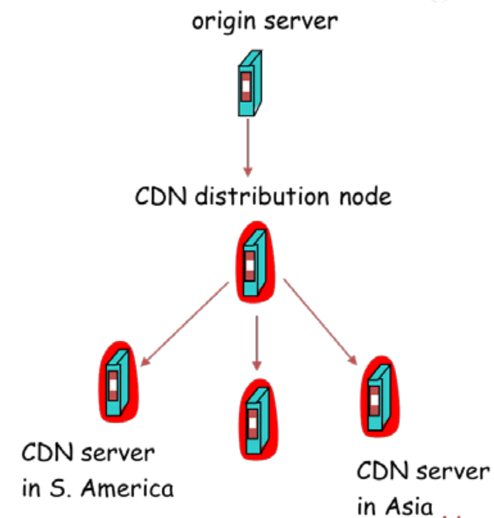


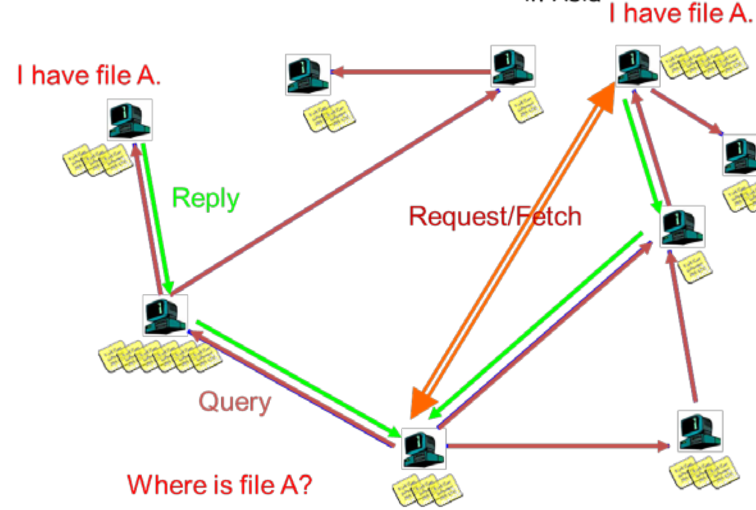
Overlays, CDN, SDN

Software-defined networks

- P2P/streaming applications-infrastructure (application-layer networking)
- traffic engineering, tunneling
- **Software-defined networks**: separation of control and execution planes; virtualization of ”network layer functionality”: eg. routing table updates implemented elsewhere (not in particular routers)
- (related to data centers, 5G; Internet of Things)

… complement the networking infrastructure …

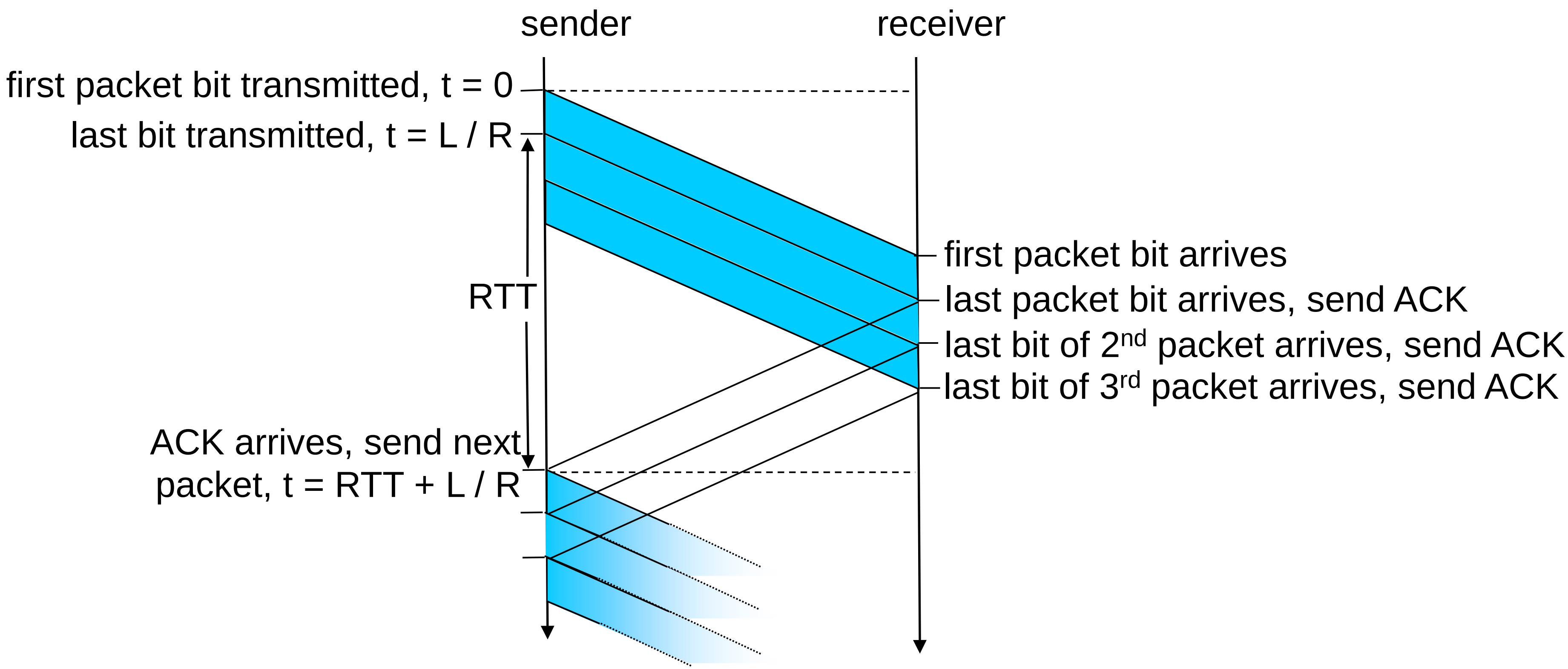




Main questions asked by you:

1. How can we have reliable data transfer on top of UDP
   – Implementation at app-layer
2. Difference between addressing in transport layer and in network layer? (e.g. TCP headers add source and destination IP addresses but these addresses are also added in the network layer: Is it redundant ?)
   – Some redundancy yes, TCP uses it for demux
3. ”special” IP address(mask) 192.168.0.0/16
   – Local, behind NAT; was standard global address in earlier, classful IP-addressing; preserved for historical & engineering reasons
4. Working with time-space diagrams
   – See next slide
5. Discuss exercise on slide 12 of *12.lectureNWcoreAndMediaSDN*
   – *Discussed in class*

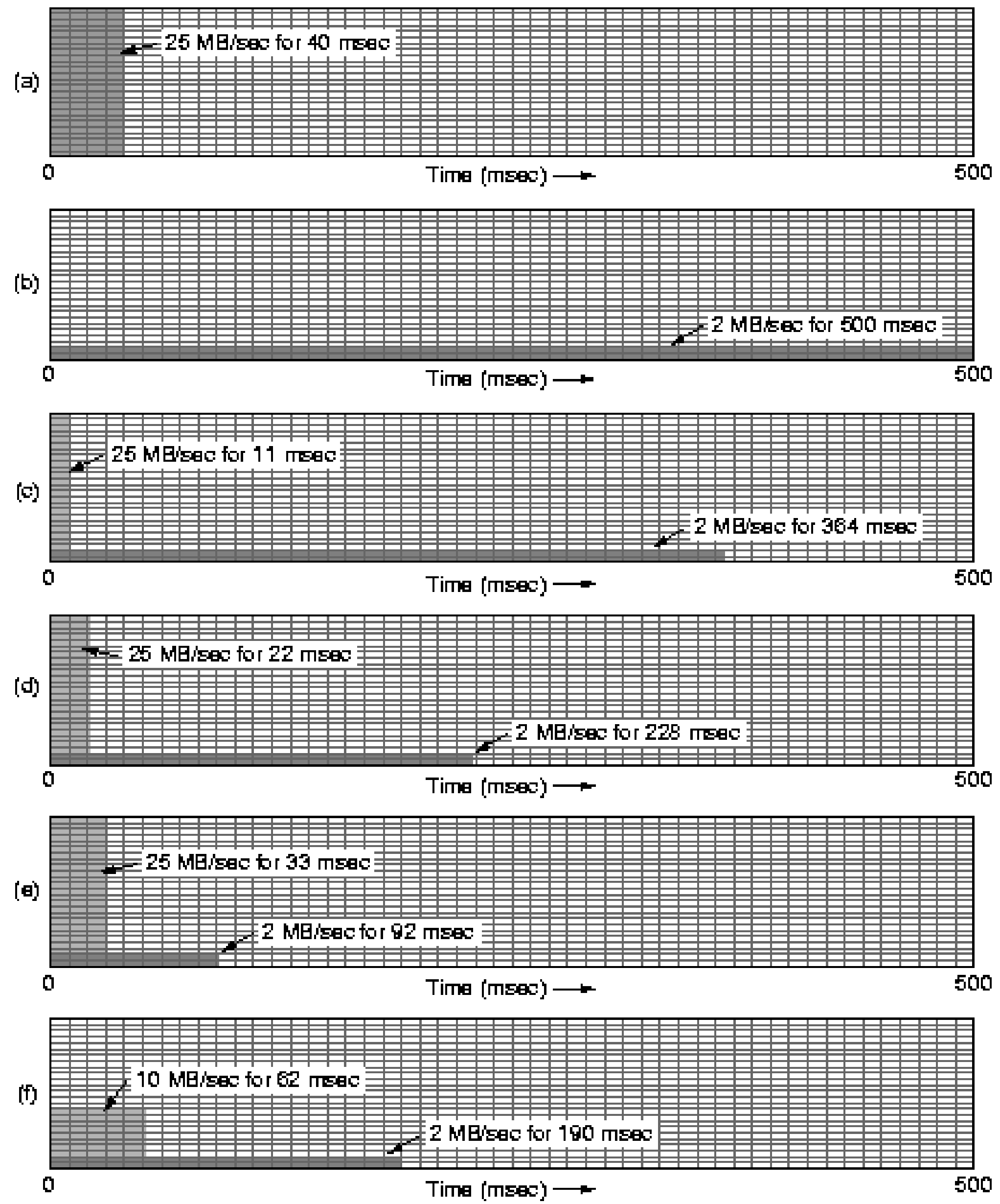
4: eg What is a full-utilization window?



E.g. for 100% utilization, calculate how many packets can fill in RTT + L / R, ie (RTT + L / R)/ (L / R)

5: Policing: the effect of buckets

- input
- output pure leaky bucket, 2MBps
- output token bucket 250KB, 2MBps
- output token bucket 500KB, 2MBps
- output token bucket 750KB, 2MBps
- output token bucket 500KB, 2MBps, feeding 10MBps leaky bucket



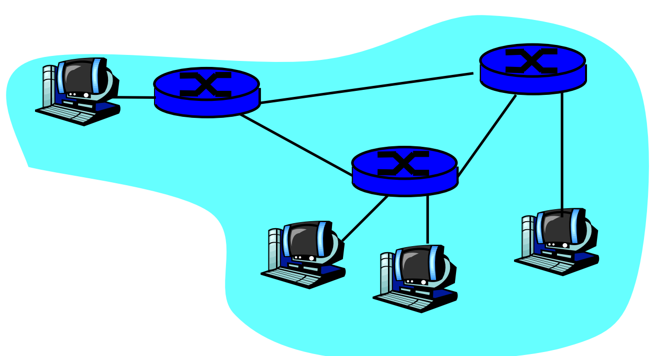
Synthesis cont.

1. Reflections, prespectives
2. Networking constantly evolving

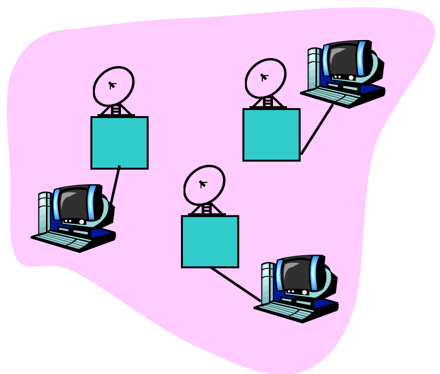
The Internet: virtualizing networks

1974: multiple unconnected nets
- ARPAnet
- data-over-cable networks
- packet satellite network (Aloha)
- packet radio network

… differing in:
- addressing conventions
- packet formats
- error recovery
- routing



ARPAnet



satellite net

"A Protocol for Packet Network Intercommunication",
V. Cerf, R. Kahn, IEEE Transactions on Communications,
May, 1974, pp. 637-648.

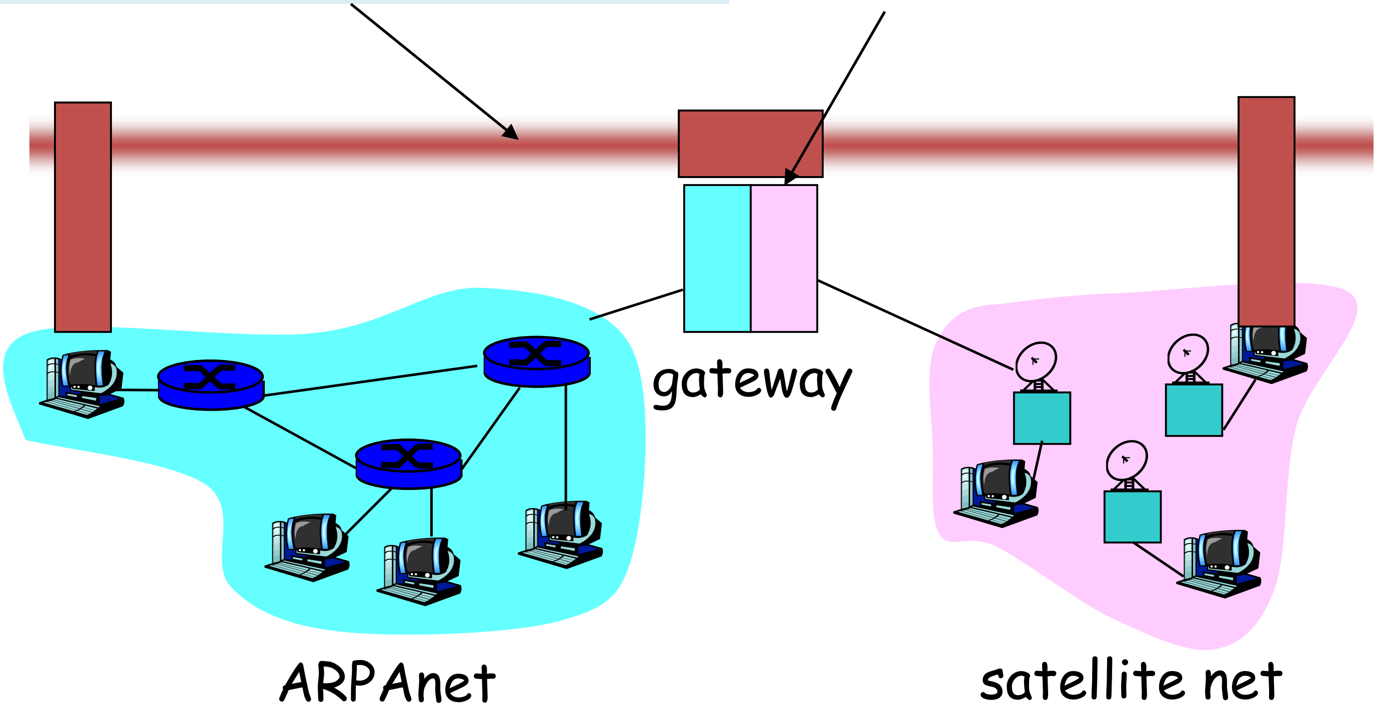
The Internet: virtualizing networks

Internetwork layer (IP):

- addressing: internetwork appears as single, uniform entity, despite underlying local network heterogeneity
- network of networks

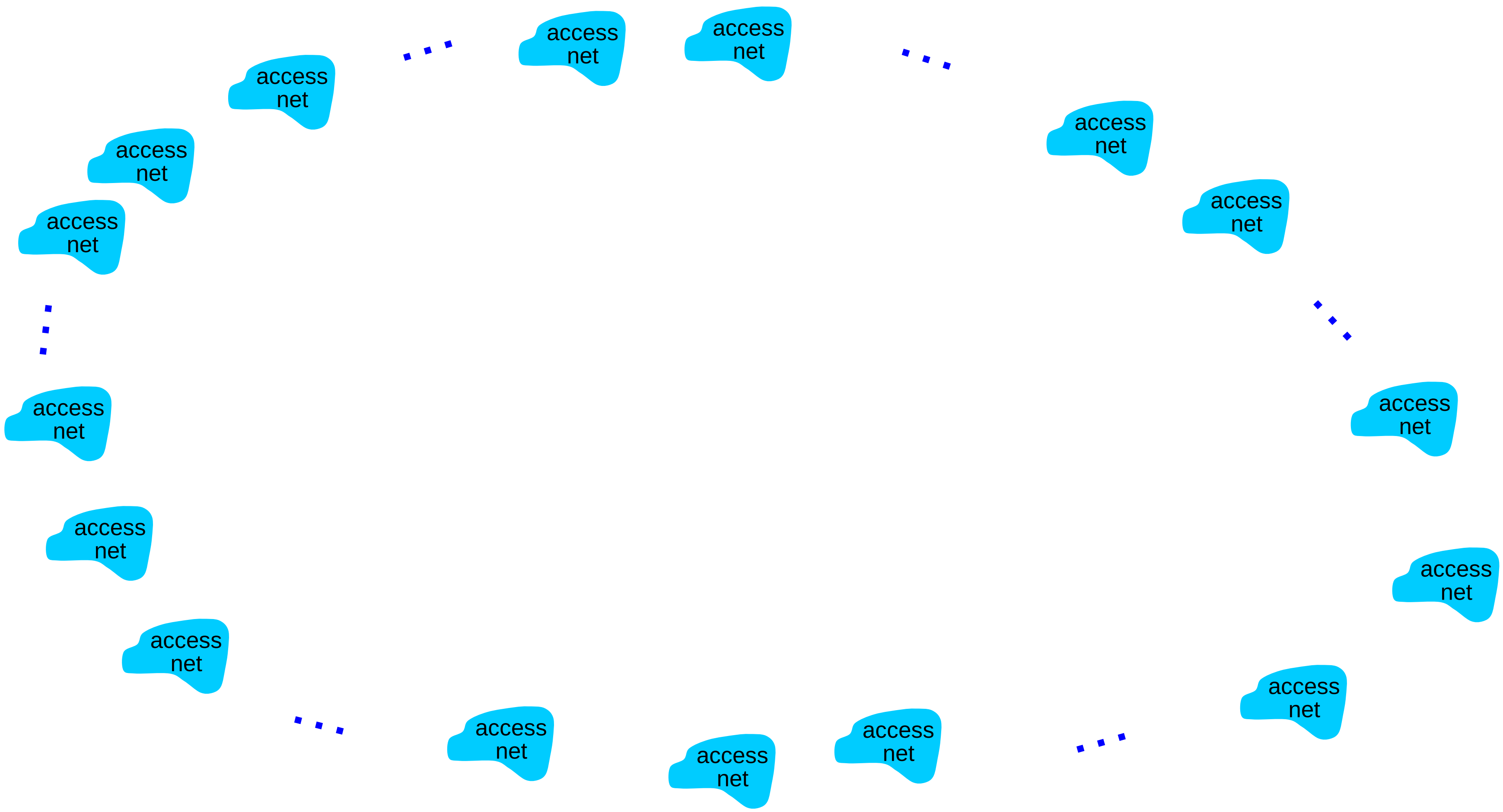
Gateway:

- "embed internetwork packets in local packet format"
- route (at internetwork level) to next gateway



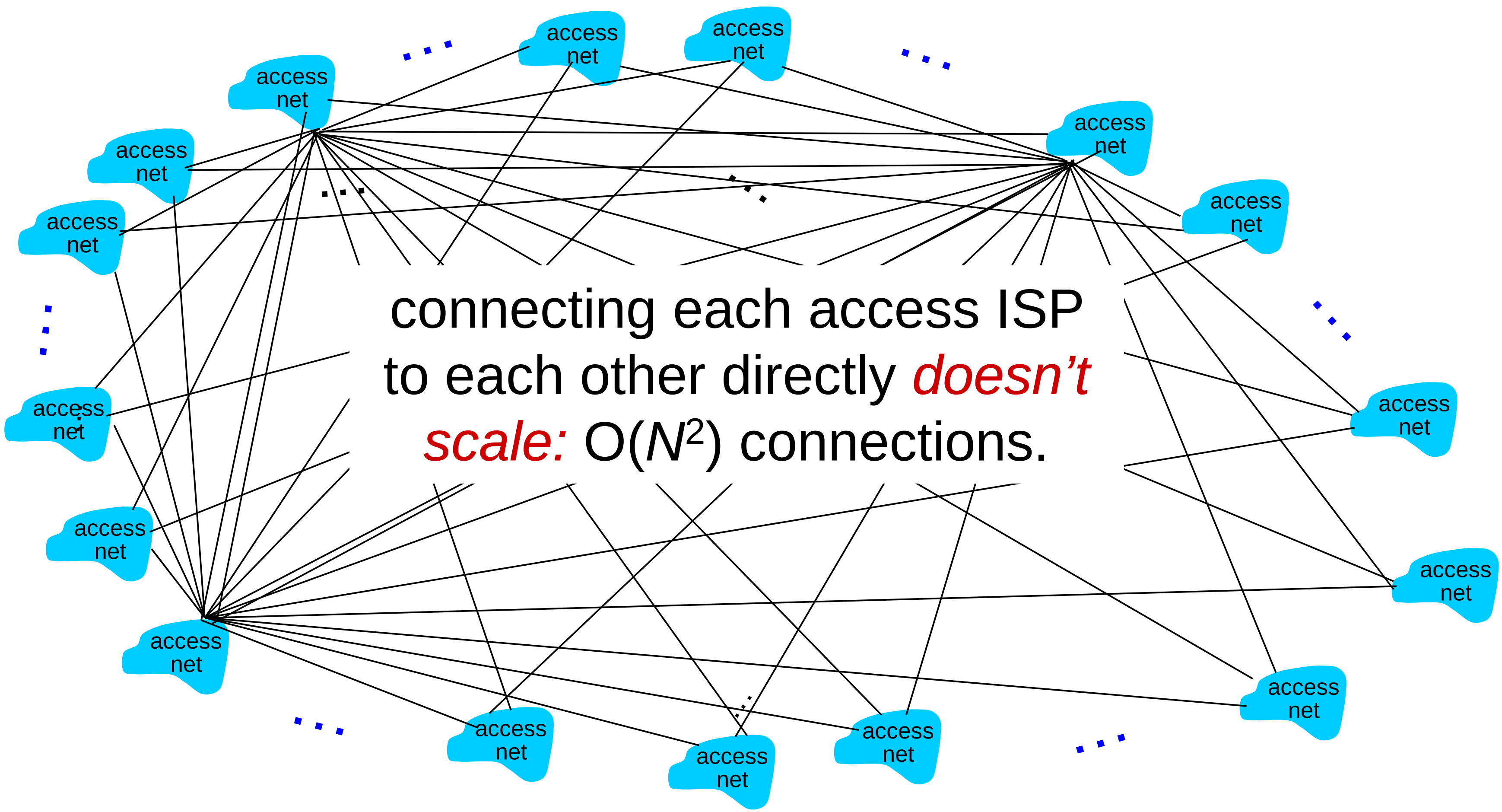
Internet structure: network of networks

Question: given *millions* of access ISPs, how to connect them together?



Internet structure: network of networks

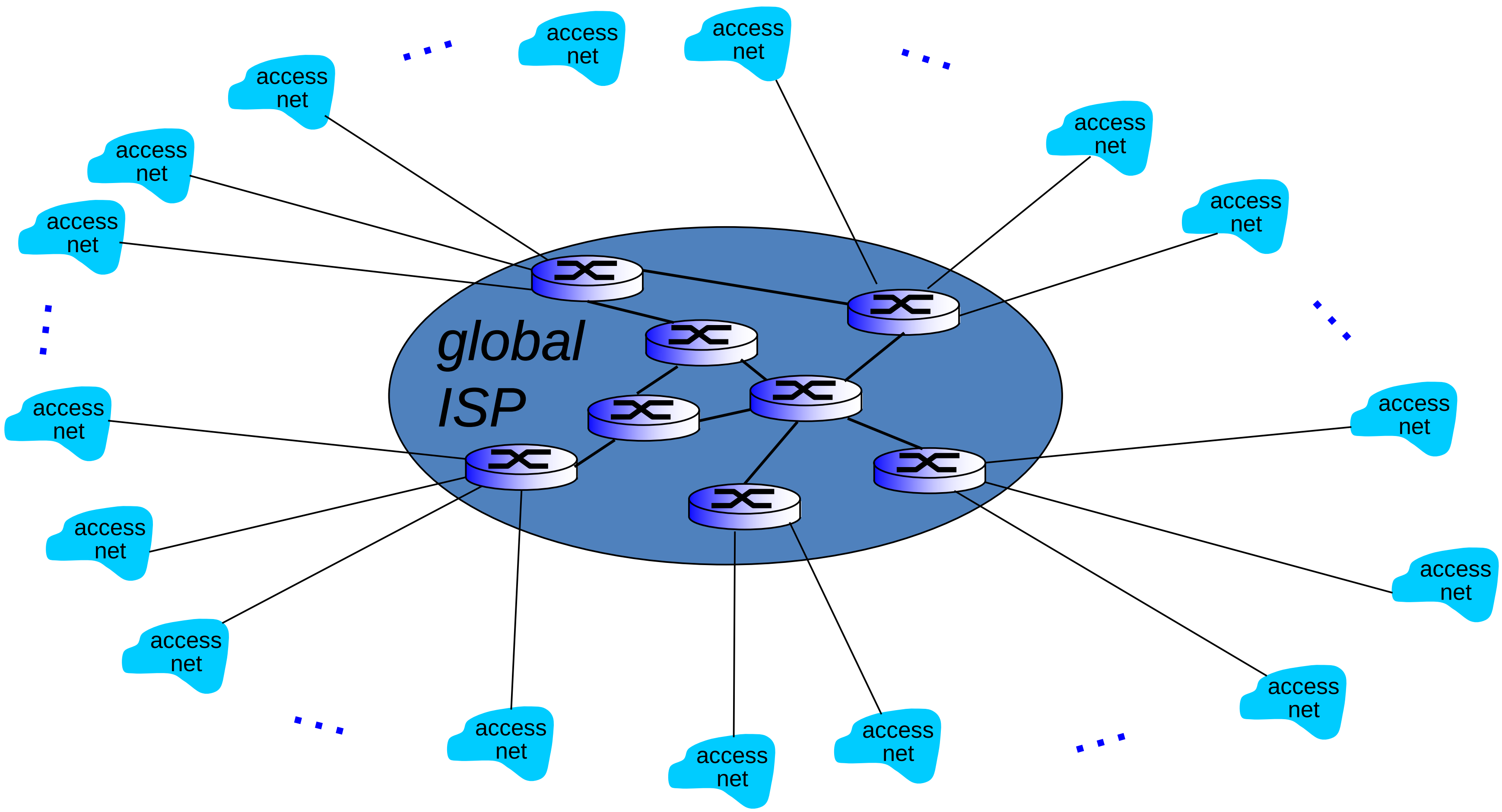
Option: connect each access ISP to every other access ISP?



connecting each access ISP to each other directly *doesn't scale:* $O(N^2)$ connections.

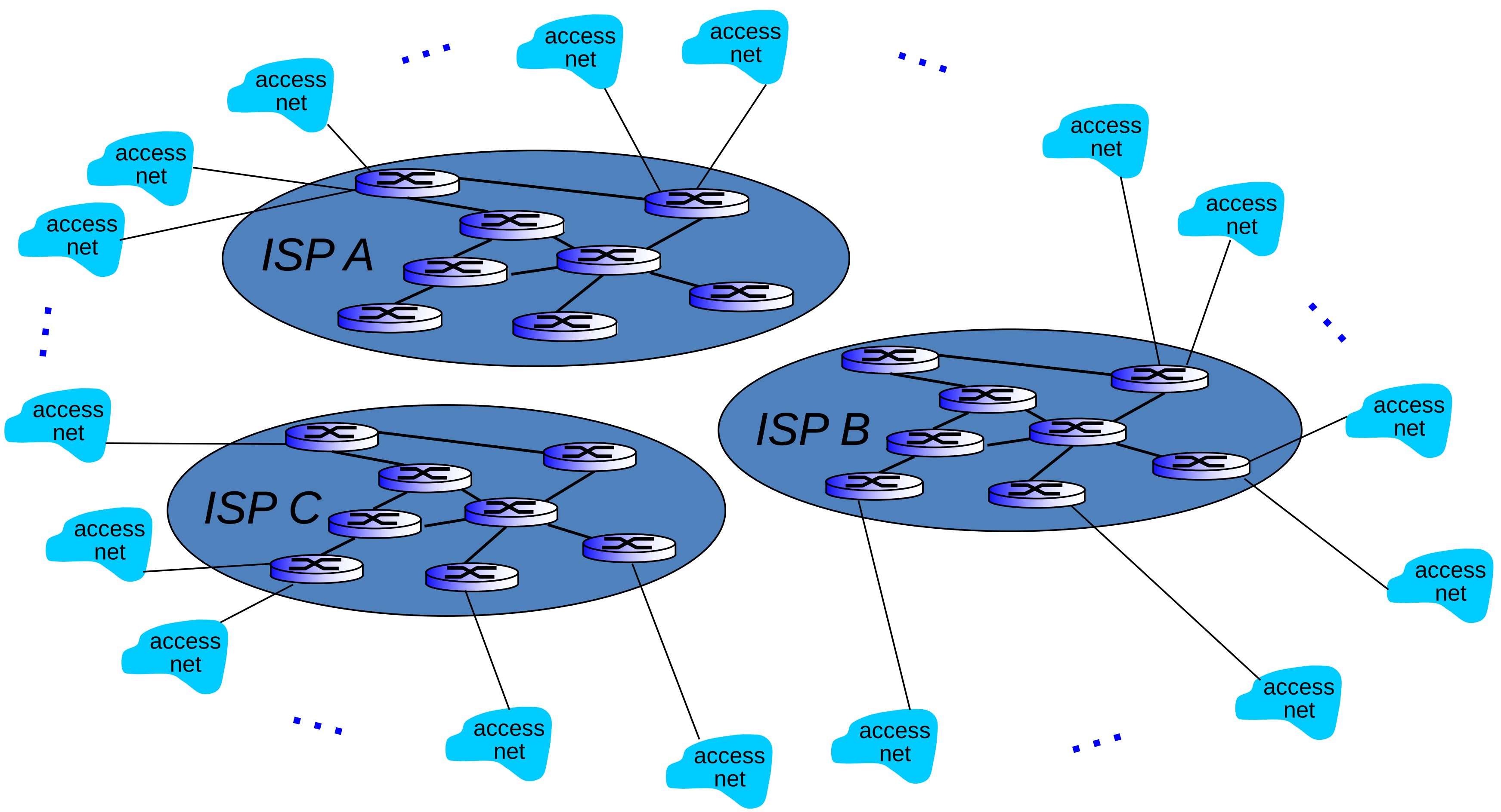
Internet structure: network of networks

Option: connect each access ISP to a global transit (imaginary) ISP?
Customer and provider ISPs have economic agreement.



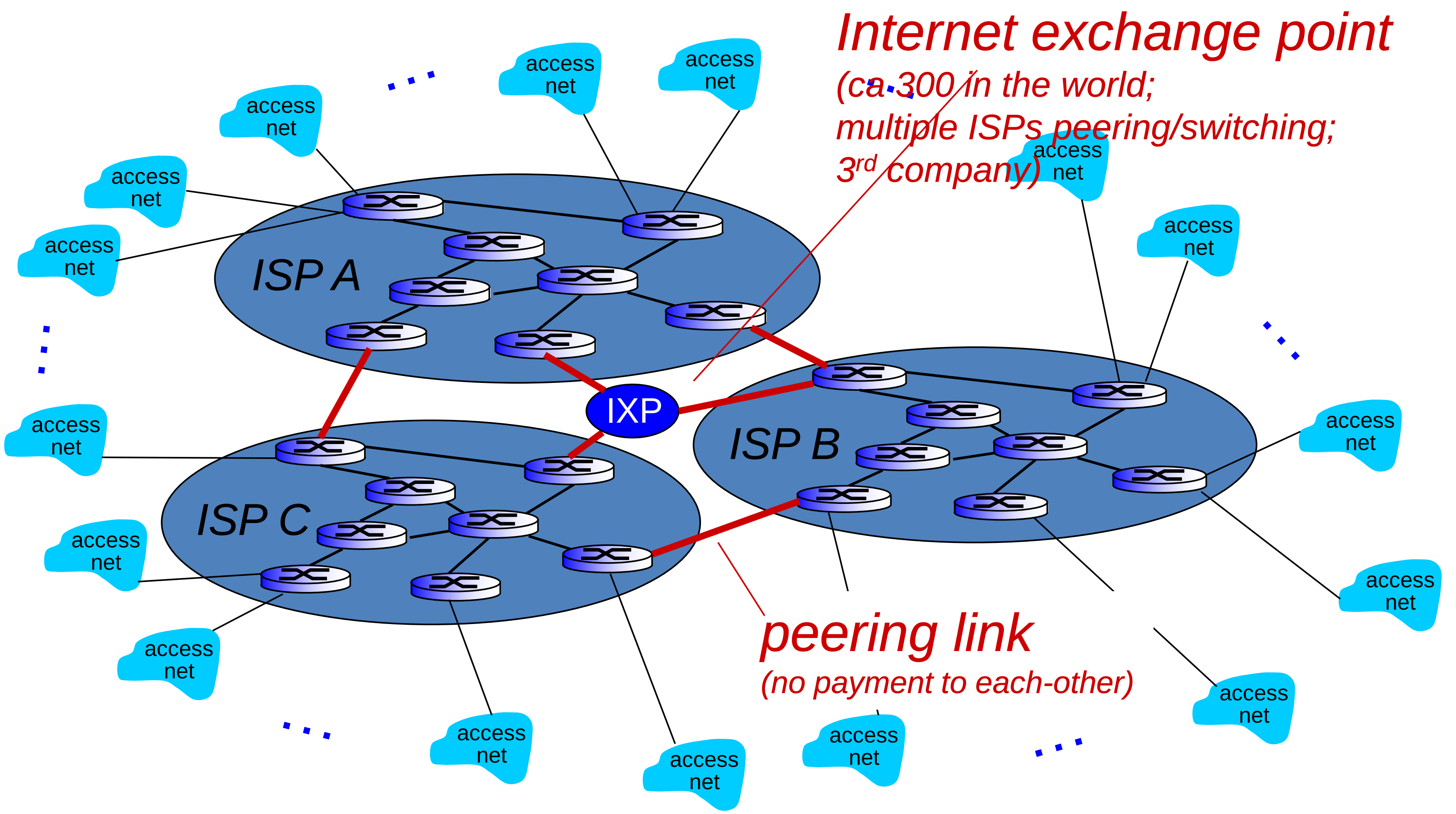
Internet structure: network of networks

But if one global ISP is viable business, there will be competitors
….



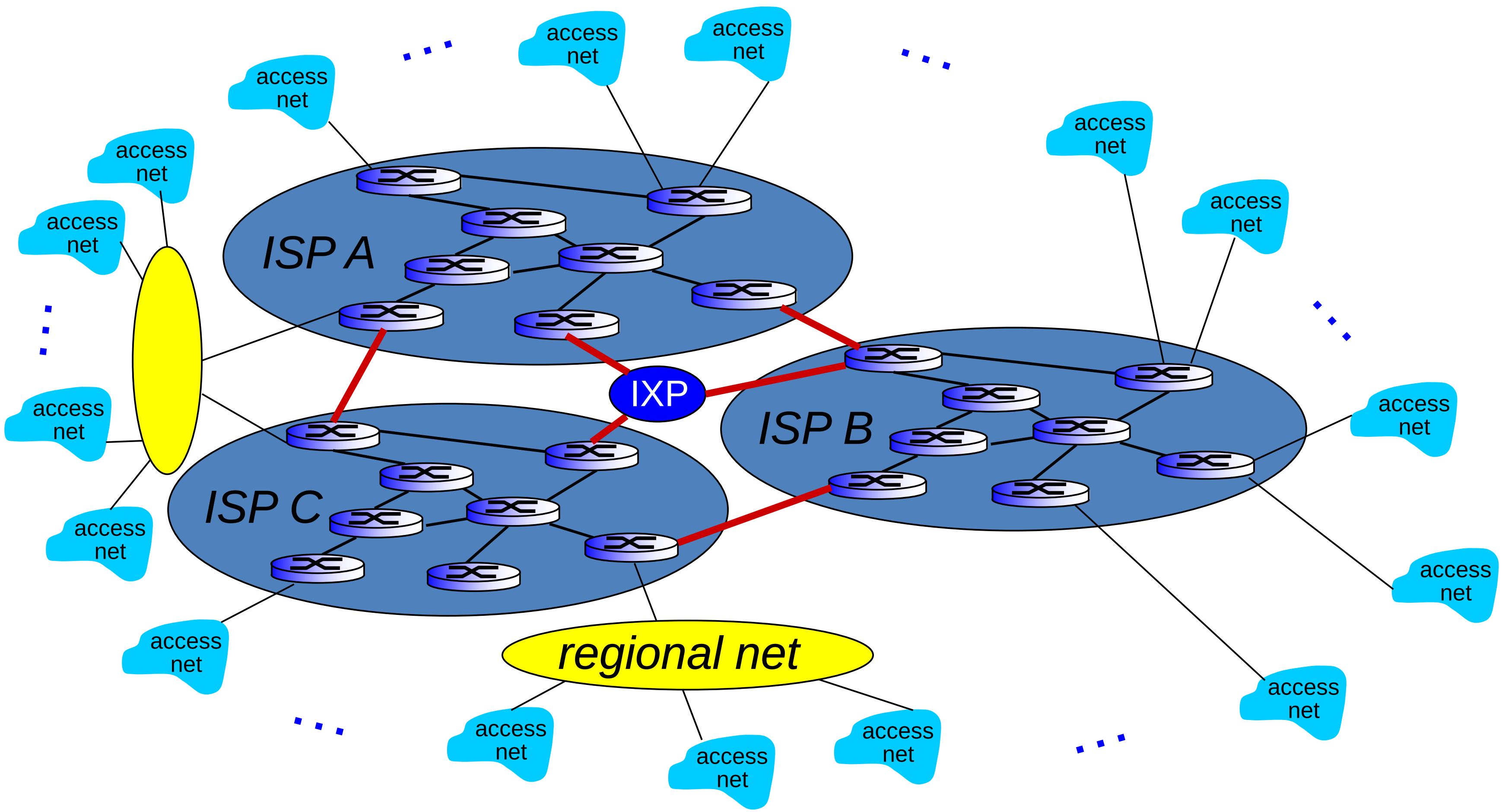
Internet structure: network of networks

But if one global ISP is viable business, there will be competitors …. which must be interconnected



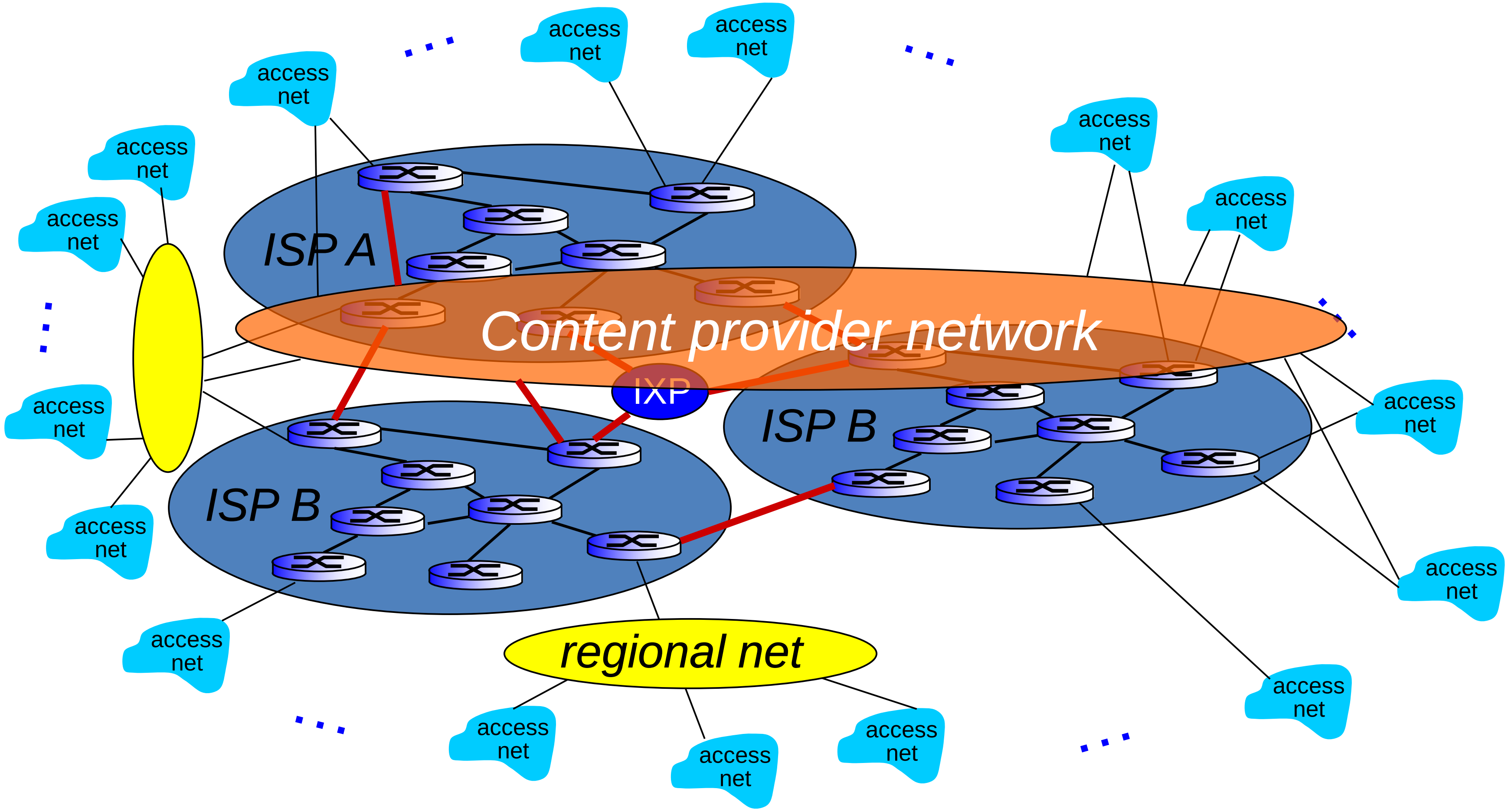
Internet structure: network of networks

… and regional networks may arise to connect access nets to ISPS

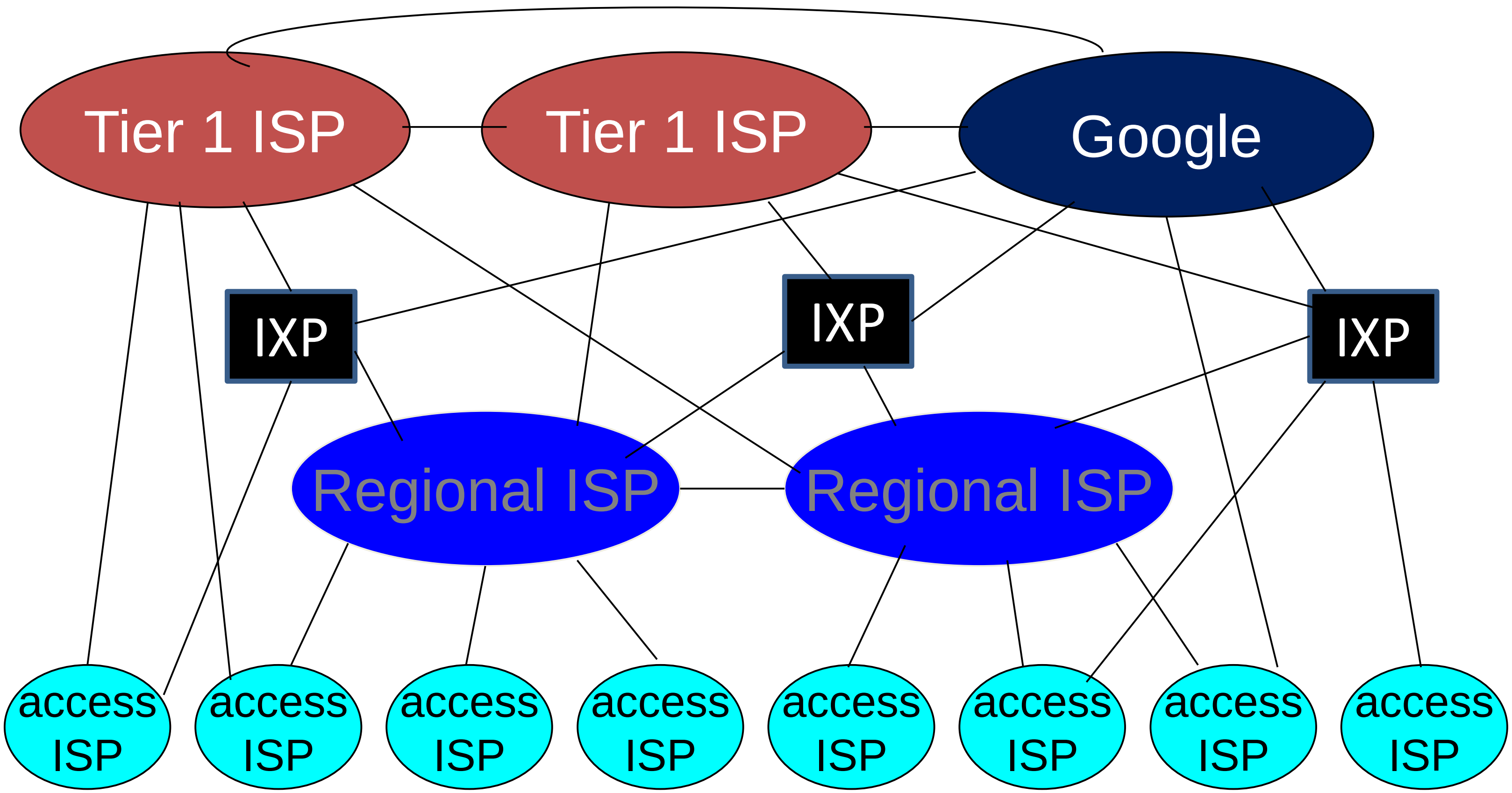


Internet structure: network of networks

… and content provider networks (e.g., Google, Microsoft, Akamai) may run their own network, to bring services, content close to end users



Internet structure: network of networks



- at center: small # of well-connected large networks
  - "tier-1" commercial ISPs (e.g., AT&T, NTT, TeliaSonera, DeutcheTelecom), national & international coverage
  - A new form of content provider network (e.g, Google): private network that connects it data centers to Internet, often bypassing tier-1, regional ISPs

Synthesis cont.

1. Reflections, prespectives
2. **Networking constantly evolving**

Data center networks

- 10's to 100's of thousands of hosts, often closely coupled, in close proximity:
  - e-business (e.g. Amazon)
  - content-servers (e.g., YouTube, Akamai, Apple, Microsoft)
  - search engines, data mining (e.g., Google)

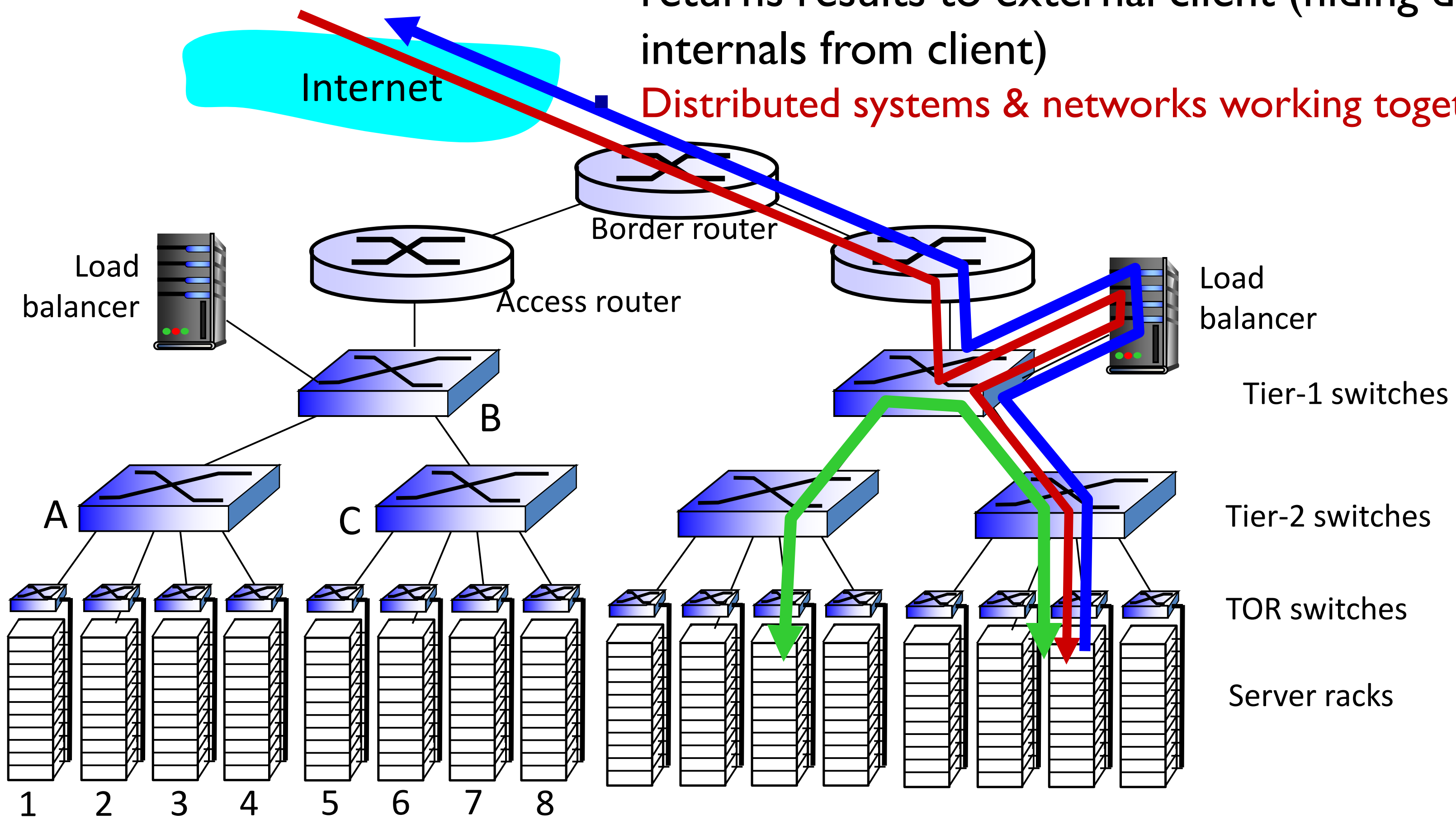
- challenges:
  - multiple applications, each serving massive numbers of clients
  - managing/balancing load, networking, data bottlenecks

Inside a 40-ft Microsoft container, Chicago data center

Data center networks(SDN-relevance)

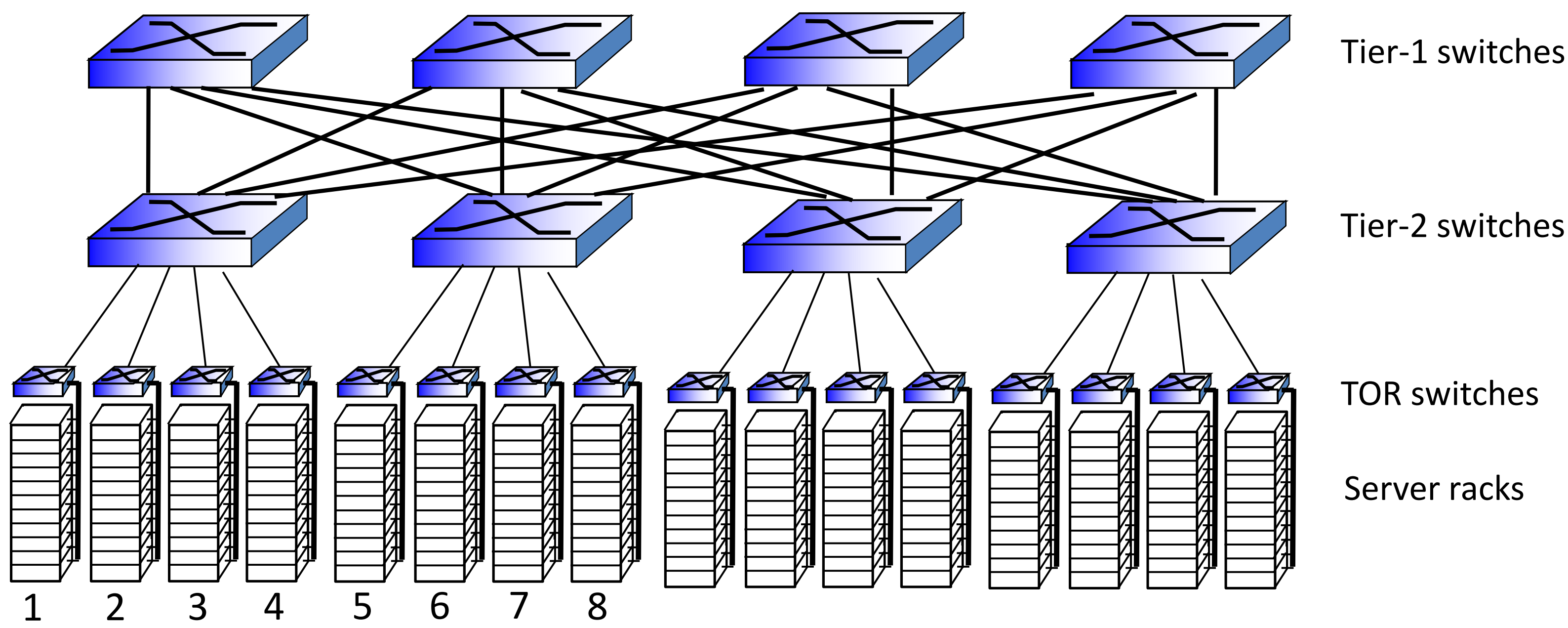
load balancer: application-layer routing

- receives external client requests
- directs workload within data center
- returns results to external client (hiding data cente internals from client)
- Distributed systems & networks working together



Data center networks (SDN-relevance)

- rich interconnection among switches, racks:
  - increased throughput between racks (multiple routing paths possible)
  - increased reliability via redundancy
  - Distributed systems & networks working together



guest lecture (joint with Adv. Distributed Systems course)

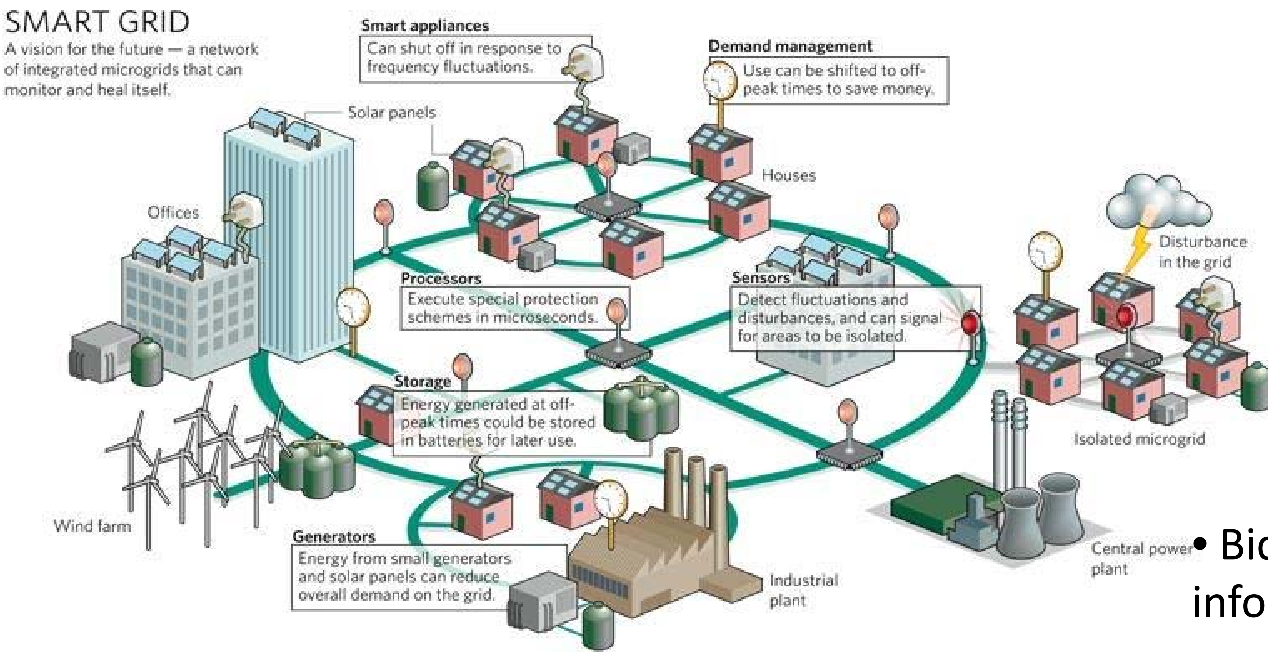
will be rescheduled outside the Study Period

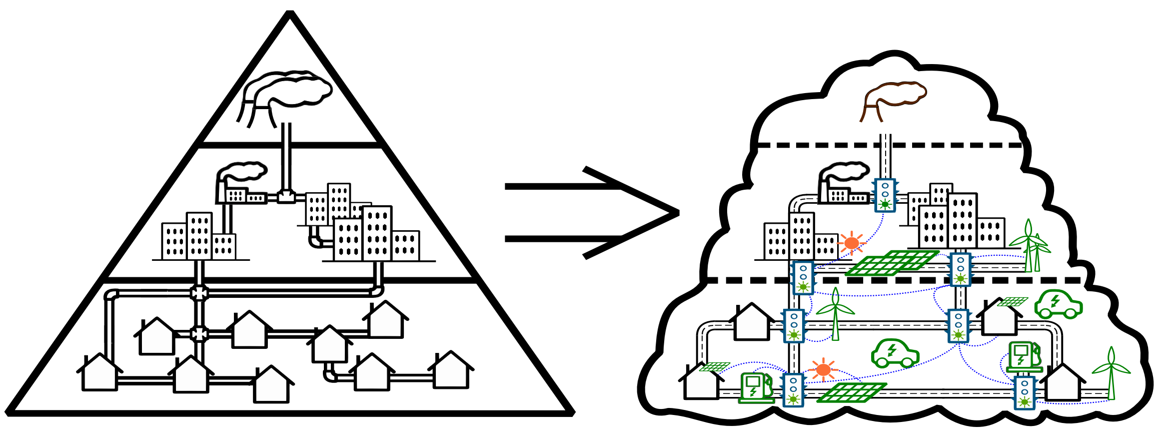
Niklas Gustavsson, engineering team leader at Spotify, Gothenburg

More examples: a story in progress + possible followup course...

Overlays useful here, too:

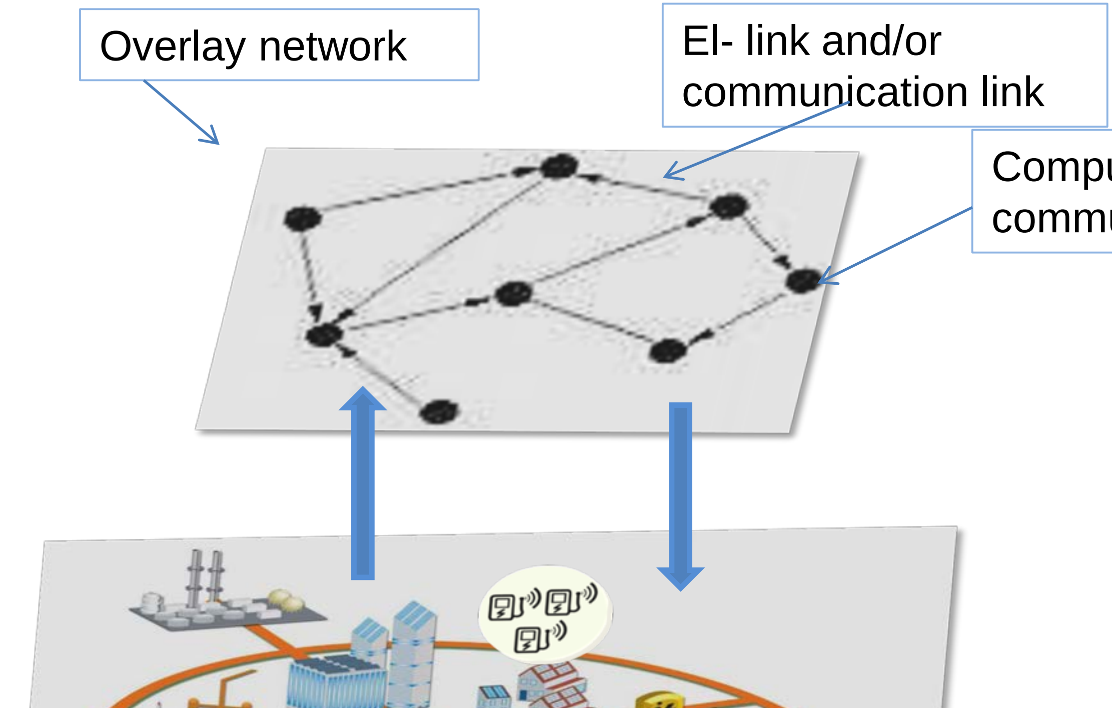
New power grids: be adaptive!

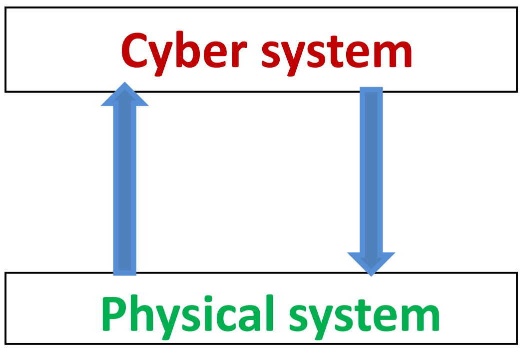




- Bidirectional power and information flow
  - Micro-producers or “prosumers”, can share resources
  - Distributed energy resources
- Communication + resource-administration (distributed system) layer: IoT

El-networks as distributed cyber-physical systems





Course (DAT300, LP1):
ICT Support Cyberphysical Systems
Connecting Distributed Systems, Networks, Data processing and Security in CPS

Thank you

Recall, important for the exam:

When/where: wednesday March 15, 14.00-18.00, SB

You may have with you:

- English-X dictionary
- no calculators, PDAs, etc (if/where numbers matter, do rounding)

To think during last, summary-study

Overview; critical eye; explain; ask yourselves: why is this so? / How does it work?

Good luck with all your efforts!!!

"If you hear a voice within you say 'you cannot paint,' then by all means paint, and that voice will be silenced." – Vincent Van Gogh