Advanced Networking Seminar

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Seminar Goal

- Telecommunication Networks established 40+ years go
- Common architecture: layered protocol stack
- Technology keeps progressing
  - Wireless communication
  - Satellite communication/interplanetary communications
    - Vint Cerf predicted that in 2000 for 2010 ☺
  - OC 192/dark fibre: VERY HIGH data rates
  - Plethora of expected services from our networks
    - Mobility support
    - Secure communications
    - VPNs
    - ……

→ are "old" solutions and approaches still appropriate?

Seminar Goals, cont.

- 1st session: some comments on layered architecture
- Future sessions: looks at some new trend/challenge and discuss how this impacts networking
  - Maybe the answer is: it doesn't, really….
- http://kunz-pc.sce.carleton.ca/ECNUSeminar2015/
- For each topic
  - One survey paper
  - One "technical"paper
- Suggested set of topics/schedule: on website
- Other topics welcome

- Caveat: I have an opinion, but that is not necessarily more correct than yours

Layered Network Architecture

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Protocol Design

- Networking is complex, requires one to address many different challenges
  - Flow Control
  - Addressing
  - Routing
  - Data Representation
  - Media Access
  - And many more….
- "Traditionally", network protocols are implemented as a "stack", or layered:
  - OSI Reference Model
  - TCP/IP Protocol Stack
  - But also POTS, Cellular Networks, etc.

OSI Communications Model

7	Application	Application 7
6	Presentation	Presentation 6
5	Session	Session 5
4	Transport	Transport 4
3	Network	Network 3
2	Data Link	Data Link 2
1	Physical	Physical 1

Requirements for Layered Protocol Stack

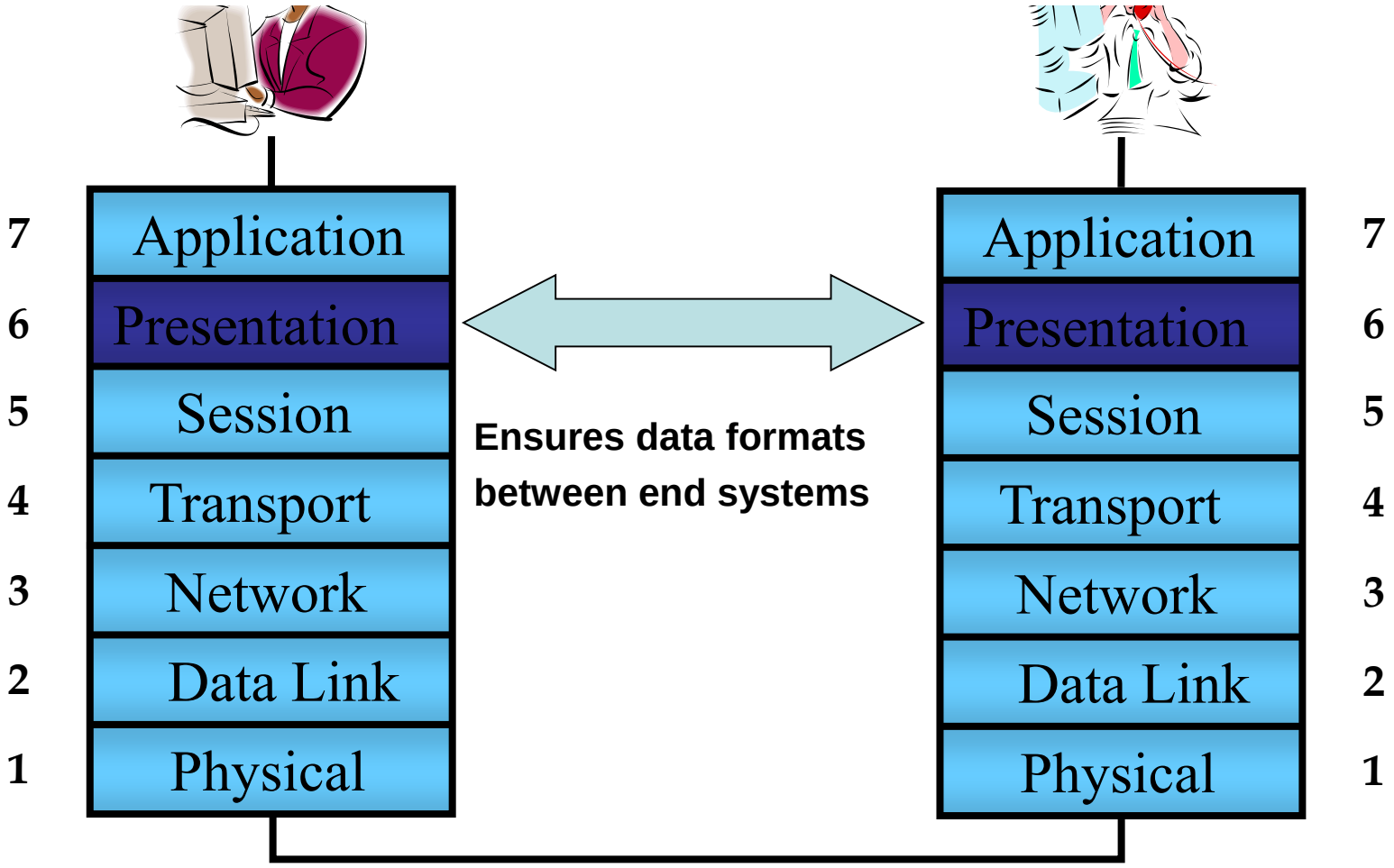
- Assign specific functions to each layer
- Specify interfaces between layers
  - Allows to replace implementation X of layer A to be replaced by implementation Y (may add new functionality, more efficiency)
  - Example: Internet used RIP as routing protocol, eventually replaced by OSPF (at least intra-domain). Does not impact the addressing scheme, or flow control or ….
- Software that realizes the functionality of a specific layer has to cooperate with software at other nodes, exchanging messages
  - Defines a layer-specific protocol
  - Information exchanged is either communicated through control messages (which adds quite a bit of overhead) or "in-band" through headers and trailers added to data packets being exchanged

Application Layer

7	Application	Application	7
6	Presentation	Presentation	6
5	Session	Session	5
4	Transport	Transport	4
3	Network	Network	3
2	Data Link	Data Link	2
1	Physical	Physical	1

Interface between the user and the software

Presentation Layer



Session Layer

7	Application		Application	7
6	Presentation		Presentation	6
5	Session	Establishes, manages and terminates communication between presentations	Session	5
4	Transport		Transport	4
3	Network		Network	3
2	Data Link		Data Link	2
1	Physical		Physical	1

Transport Layer

7	Application	Application	7
6	Presentation	Presentation	6
5	Session	Session	5
4	Transport	Transport	4
3	Network	Network	3
2	Data Link	Data Link	2
1	Physical	Physical	1

Ensures reliable transport

Network Layer

7	Application	Application	7
6	Presentation	Presentation	6
5	Session	Session	5
4	Transport	Transport	4
3	Network	Network	3
2	Data Link	Data Link	2
1	Physical	Physical	1

Provides routing

Data Link Layer

7	Application	Application	7
6	Presentation	Presentation	6
5	Session	Session	5
4	Transport	Transport	4
3	Network	Network	3
2	Data Link	Data Link	2
1	Physical	Physical	1

Reliable transmission across physical links

Physical Layer

7	Application	Application	7
6	Presentation	Presentation	6
5	Session	Session	5
4	Transport	Transport	4
3	Network	Network	3
2	Data Link	Data Link	2
1	Physical	Physical	1

Defines electrical, mechanical and functional specifications

TCP/IP Communications Model

4	Application	Application
3	Transport	Transport
2	Internetwork	Internetwork
1	Network Access	Network Access

Application Layer

4	Application	Interface between the user and the software.
3	Transport	Ensures data formats between end systems.
2	Internetwork	Establishes, manages and terminates communication between presentations
1	Network Access	

Application	4	
Transport	3	
Internetwork	2	
Network Access	1	

Transport Layer

4	Application		Application	4
3	Transport		Transport	3
2	Internetwork	Provides communication between applications on different hosts	Internetwork	2
1	Network Access		Network Access	1

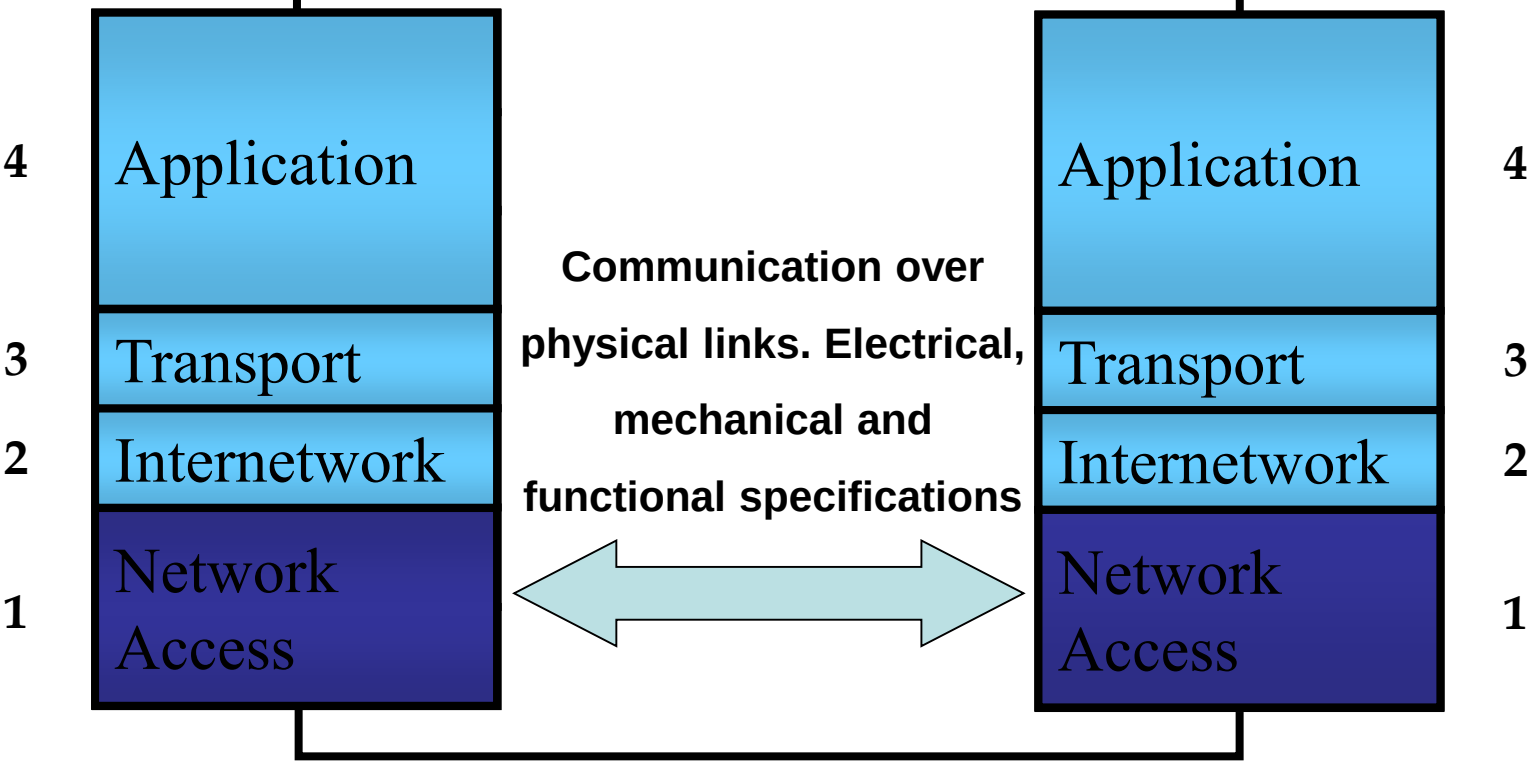
Internetwork Layer

4	Application		Application	4
3	Transport		Transport	3
2	Internetwork		Internetwork	2
1	Network Access		Network Access	1

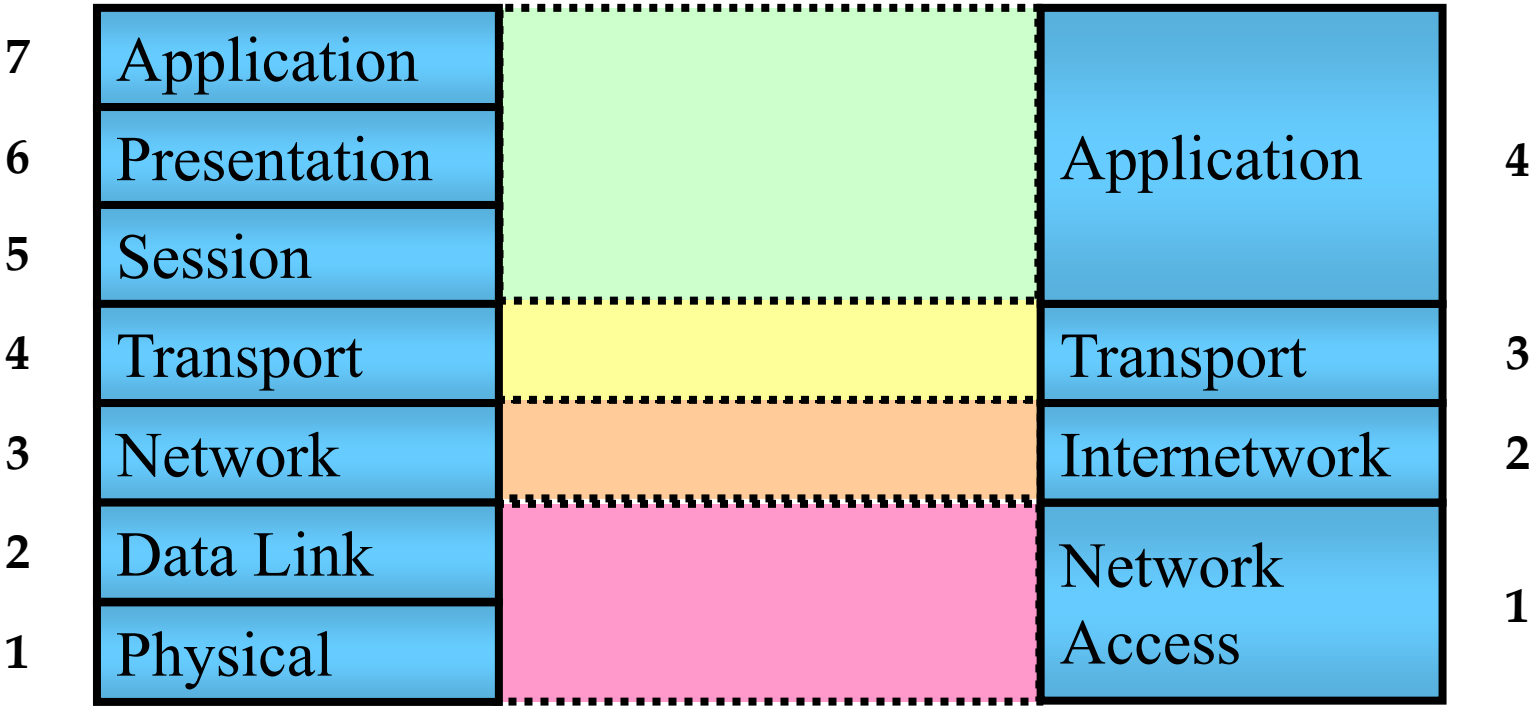
Host to host communication

routing of datagrams

Network Access Layer



OSI and Internet Models



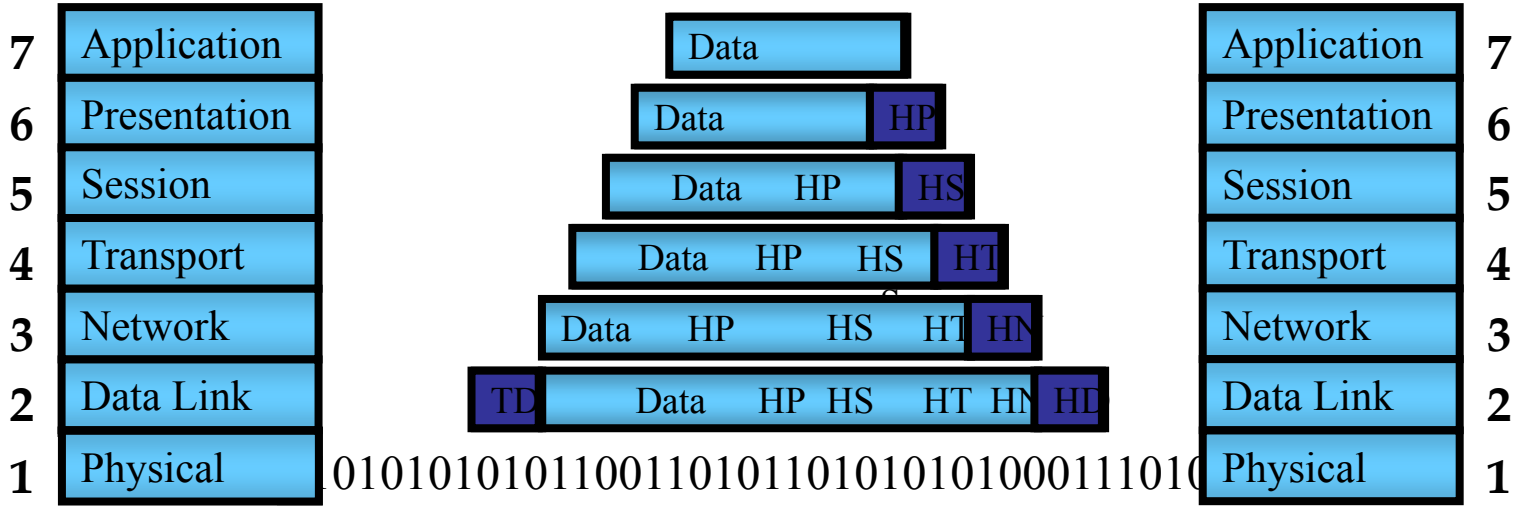
Internet Protocol Stack

- Some more insights into the reasoning underlying the Internet or TCP/IP protocol stack:
  - The Design Philosophy of the DARPA Internet Protocols
- Fundamental Goal: develop an effective technique for multiplexed utilization of existing interconnected networks
  - i.e.: no dedicated resources/lines/connections
- Second Level Goals:
  - Survive partial failures
  - Offer multiple communication services
  - Run over a number of networks
  - Support distributed management of its resources
  - Architecture must be cost-effective
  - Architecture must permit host attachment with low level of effort
  - Resource used in the Internet architecture must be accountable

Operation Through the Layers

Transmission of message

- Each layer adds pertinent information
  ısses the datagram to the next lower layer



Reception of message

- Each layer inspects the header information
- Datagram forwarded to the next appropriate higher layer

The Real Question

- Practically all networking solutions are based on a layered model
  - Advantages: ???
  - Disadvantages: ???
- Undeniably, the model has served us well
  - Developed and deployed in early 1970s, when the "Internet" had far fewer computer, much slower (and less variable) data links, etc
  - Still working reasonably well now, when Internet has billions of devices, and communication links with data rates that differ by 10 orders of magnitude or so
- Challenge: what layer to implement a specific network functionality at?
  - Data encryption: Wifi (Layer 2), IPSec (Layer 3), SSL (Layer 4), OSI Model says Layer 6, HTTPS (Layer 7)
  - Reliability: Wifi (Layer 2), TCP (Layer 4), DNS (Layer 7)
- What is the "right" layer?

Answer: Paper on "End-to-End Arguments in System Design"

- Paper published in 1984
- Is discussed on its own Wikipedia page, https://en.wikipedia.org/wiki/End-to-end_principle
  - Wikipedia page states that "The end-to-end principle is a classic design principle in computer networking"
- Has over 2500 citations
  - By comparison, my best paper has just over 400, and the second-best is somewhere around 170 or so, dropping fast
- So what does it say?

The End-to-End Argument (quoted from paper)

The function in question can completely and correctly be implemented only with the knowledge and help of the application standing at the endpoints of the communication system. Therefore, providing that questioned function as a feature of the communication system itself is not possible. (Sometimes an incomplete version of the function provided by the communication system may be useful as a performance enhancement.)

Answer

- There is no single "right" layer:
  - The lower in the protocol stack, the more efficient, BUT you may end up imposing a solution that is not appropriate for the higher layer
  - The higher in the protocol stack, the less efficient, but the more likely to be the "right" solution for the specific application
  - Examples: reconsider reliability and/or security again
  - Conclusion: it is a trade-off ☺, so different people can, quite reasonably, come to very different solutions.

Going Forward

- We have an architectural model that has stood the test of time
  - Layered protocol stack
- We have a well-established set of protocols that
  - Are well-tested
  - Have demonstrated how to scale
    - DNS is a single, global protocol
    - Routing/Address Assignment is done hierarchically
  - Run on a plethora of devices

- So is networking "done" and we should focus on new problems?
- Do we need new/different protocols and if so why?
- Do we need a different approach to designing, building, and running networks?
  - If so, what would that new model be?