Lecture 3: End-to-End Argument

CS 234 / NetSys 210: Advanced Computer Networks

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Parts of this lecture were adapted from ECE/CS598HPN by Radhika Mittal

Recap: Design Goals

0. Connect existing networks

1. Survivability
2. Support multiple types of services
3. Must accommodate a variety of networks
4. Allow distributed management
5. Must be cost effective
6. Allow host attachment with a low level of effort
7. Allow resource accountability

Recap: Architecture Highlights

- Packet Switching
- Layered Architecture
- Datagrams

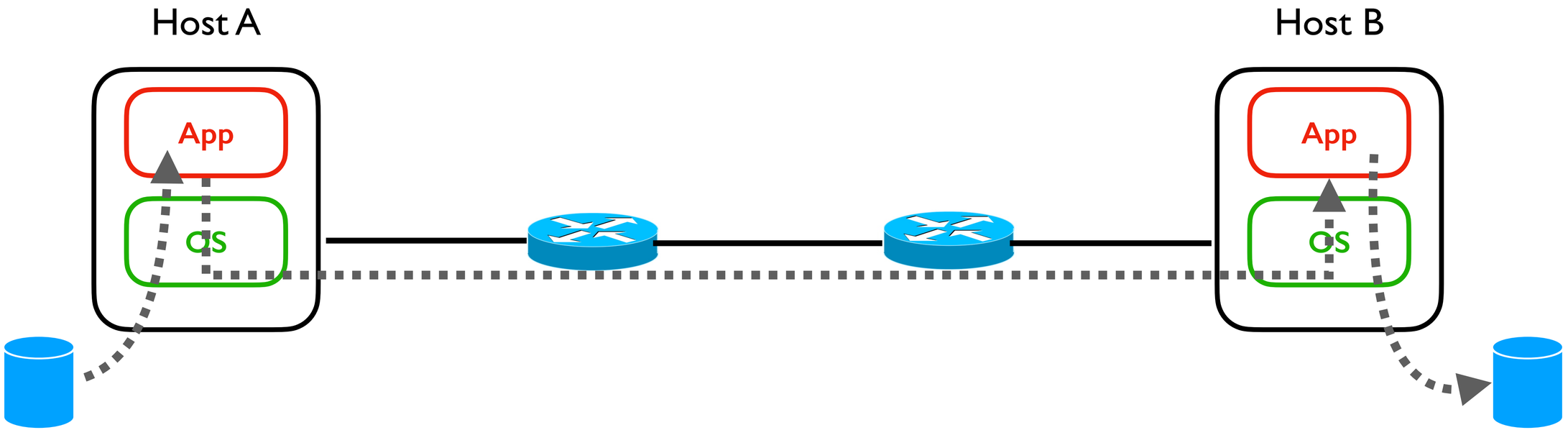
Today's Lecture

Where should functionality be placed?

End-to-End Arguments in System Design

- The most influential paper about placing functionality.
- The "Sacred Text" of the Internet
    - endless disputes about what it means
    - everyone cites it as supporting their position

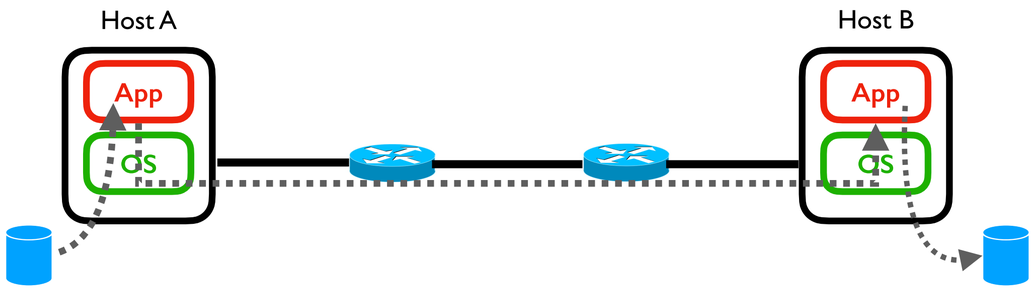
Example Application: File Transfer



Example Application: Reliable File Transfer

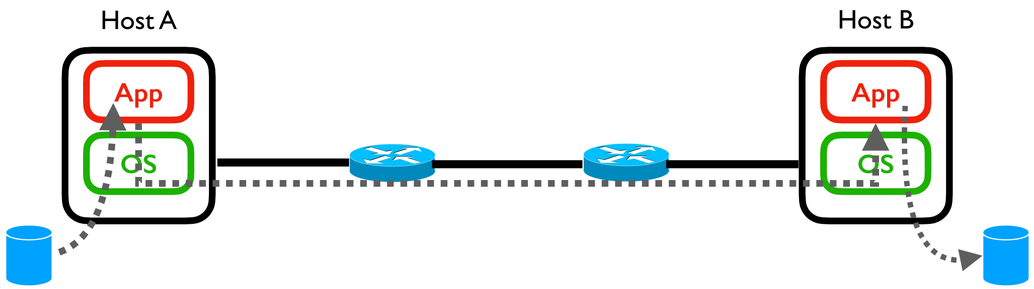
- Solution 1: make each step reliable, and then concatenate them

- Solution 2: end-to-end check and retry



Example Application: Reliable File Transfer

- Solution 1: make each step reliable, and then concatenate them
    - Not complete
    - What happens if any element misbehaves? The receiver has to do the check anyway!



- Solution 2: end-to-end check and retry
    - complete
    - Full functionality can be entirely implemented at application layer with no need for reliability from lower layer

Discussion

What is your interpretation?

Conservative Interpretation

- “Don’t implement a function at the lower levels of the system unless it can be completely implemented at this level” (Peterson and Davie)

- Unless you can relieve the burden from hosts, then don’t bother

Radical Interpretations

- Don’t implement anything in the network that can be implemented correctly by the hosts
    - Makes network layer absolutely minimal
    - Ignores performance issues

Moderate Interpretation

- Think twice before implementing functionality in the network
- If hosts can implement functionality correctly, implement it a lower layer only as a performance enhancement
- But do so only if it does not impose burden on applications that do not require that functionality

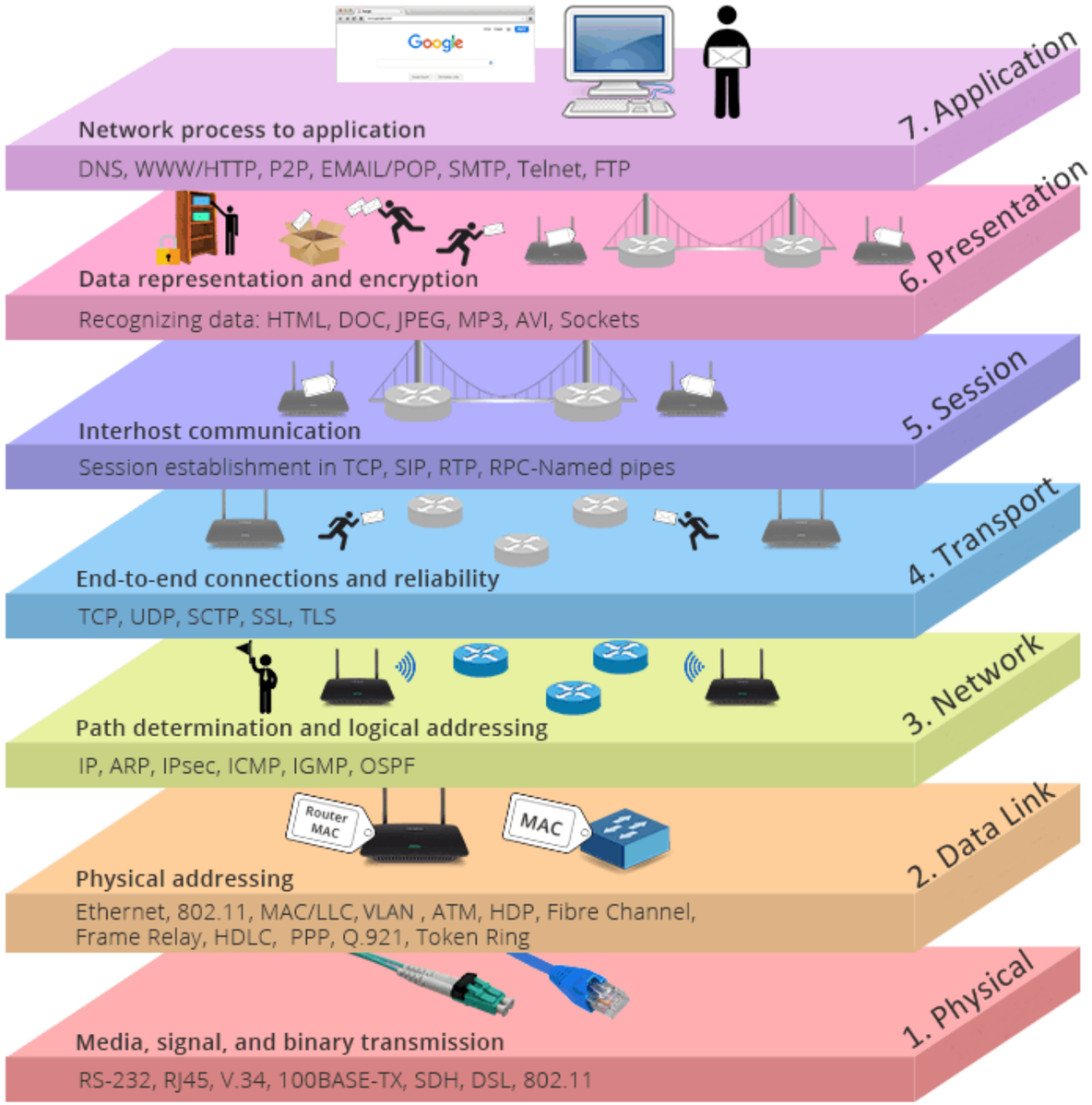
Challenge

- Install functions in network that aid application performance….

- …without limiting the application flexibility of the network

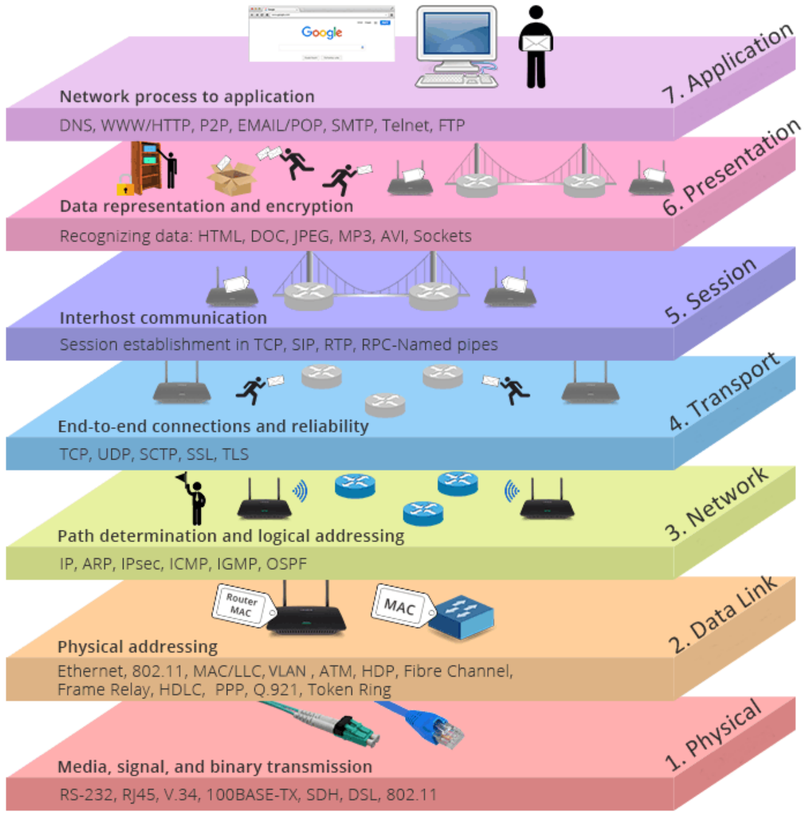
Layered Model

OSI Model	TCP/IP Model
Application Layer	Application Layer
Presentation Layer	
Session Layer	
Transport Layer	Transport Layer
Network Layer	Internet Layer
Data Link Layer	Network Access Layer
Physical Layer	



Discussion: Functionality at Each Layer

- What if these functions were placed in layers above or below? What are the costs and benefits?
  - Encryption (presentation layer)
  - Connection establishment (session/ transport layers)
  - Error recovery (transport)
  - Route determination (network layer)
  - Error checking (data link layer)



Discussion

- How is end-to-end principle violated in today's Internet?
  - ISP service differentiation (net neutrality rules are against this)
  - Deep packet inspection for spam filtering, advertisements, etc.
  - Web caches

Some comments from students

- “The trade offs between reliability and performance of end-to-end argument needs to be further explored” - Yurun Song
- “…further research will be required that investigate how to build systems that strike a compromise between the advantages of the end-to-end concept and the requirement for security and privacy measures.” - Rajath Ganapathi Hegde
- “Follow-up research could investigate the application of the end-to-end principle to current technologies, such as cloud computing, edge computing, and the Internet of Things (IoT)” - Rahul Jois
- “The end-to-end design may not make the most efficient use of network resources, as it requires all the processing and functionality to be performed at the end points. This can lead to inefficient use of network bandwidth and processing power.” - Maganth Seetharaman

Reminder

Project Title and Plan due in ONE week

Thanks!