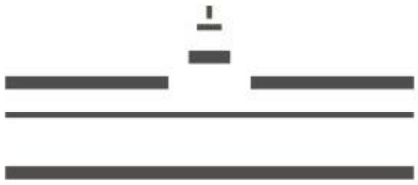


Westfälische
Wilhelms-Universität
Münster

Computer Networks, Winter Term 2009/2010

Overview

wissen.leben
WWU Münster

Jens Lechtenbörger

Outline

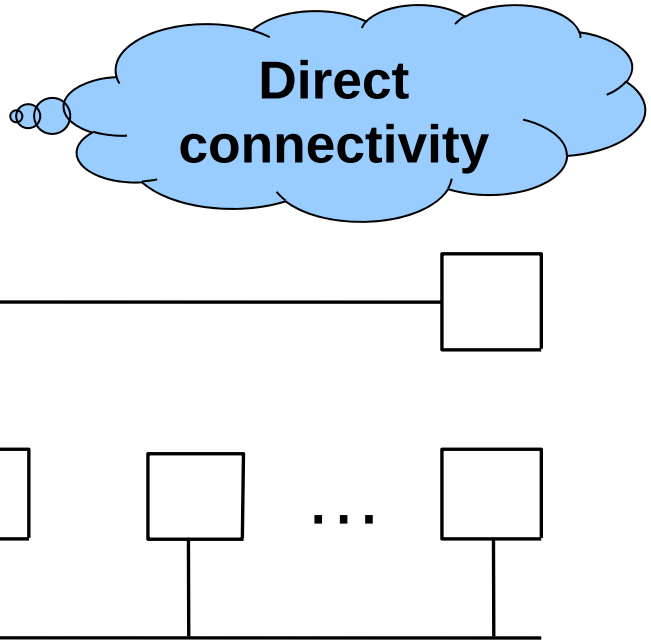
- Basics of Computer Networks
  - Building Blocks
  - Addressing and Forwarding
- Network Architecture
  - Layering and Protocols
  - Internet Architecture
  - OSI Architecture

Today's Core Questions

- What is a computer network?
- How to provide global connectivity in view of heterogeneous network technologies, diverse devices, and novel (and forthcoming) applications?
- How to cope with complexity?

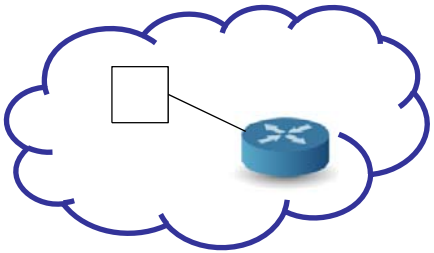
Building Blocks

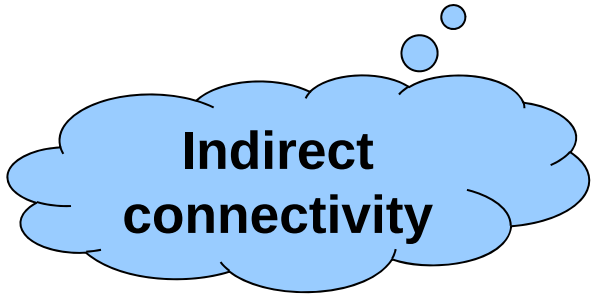
- Nodes: PC, special-purpose hardware …
  - Hosts
  - Bridges, switches, router 
- Links: air, cable, optical fiber …
  - Point-to-point
  - Multiple access (Ethernet, WLAN)

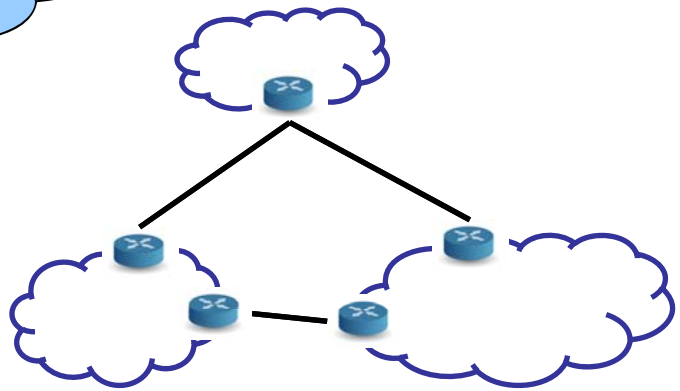


Switched Networks

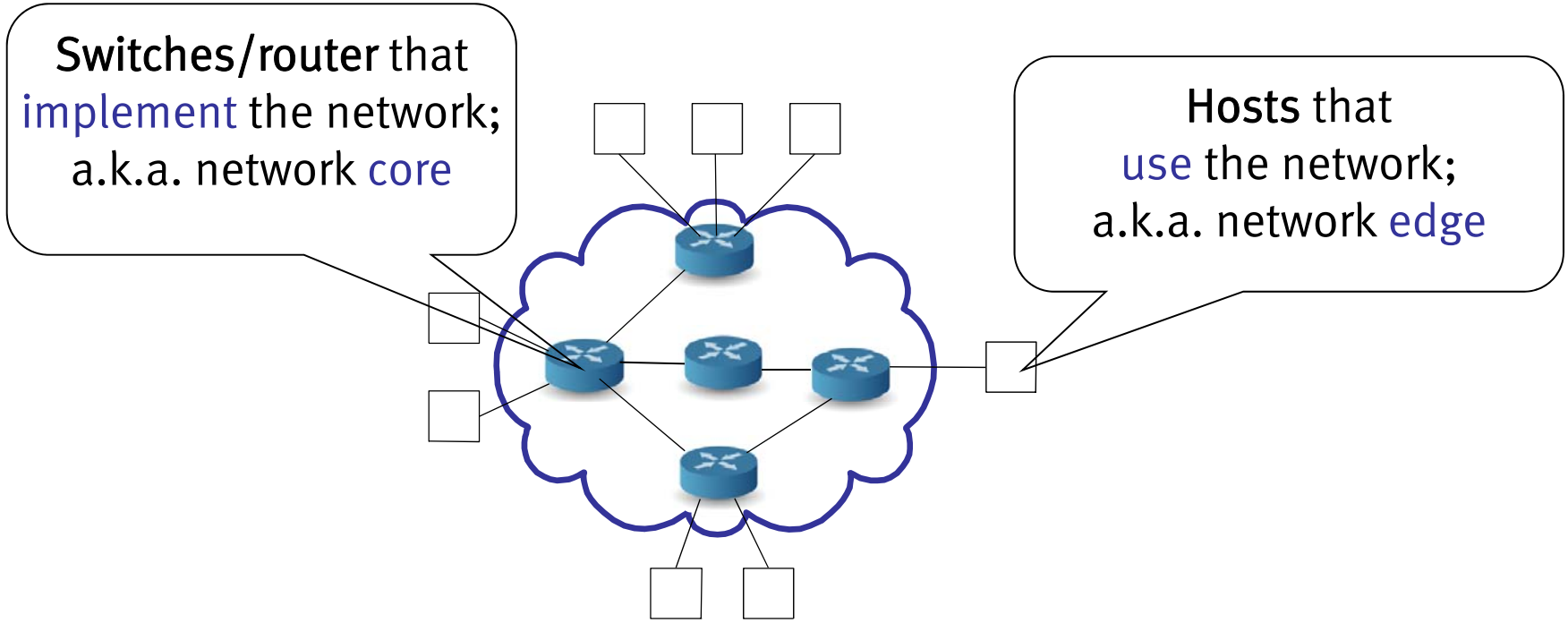
- A network can be defined recursively as...
- two or more nodes connected by a link
- or two or more networks connected by one or more nodes



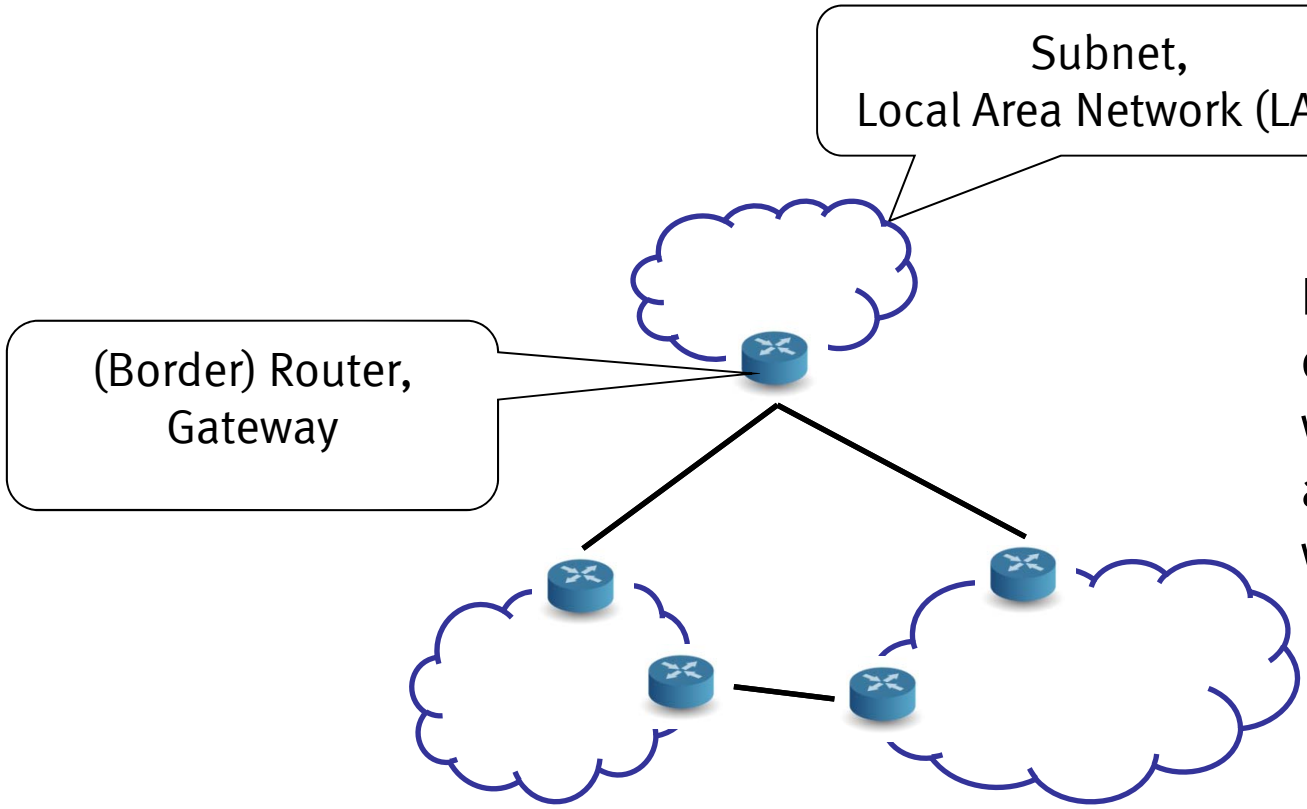




Inside vs. Outside the "Cloud"



Internet[work[ing]]



How can a host in one subnet tell to which host in another subnet it wants to talk?

Addressing, Forwarding, Routing

- Address
  - Byte-string that identifies a node (more precisely one of its network interfaces)
  - Usually unique (e.g., IP addresses, Lect. 7)
    - Scope?
    - Exception: Private IP addresses, NAT
- Forwarding
  - Process of forwarding messages to the destination node based on addresses
  - Based on forwarding tables
    - Routing: process of setting up forwarding tables (Lect. 8-9)

Forwarding Paradigms

- Datagram switching (connection-less)
  - Analogy: Postal system
  - Each message carries full destination address
  - Immediate, independent hop-by-hop forwarding by network devices based on destination address
  - May route around failures
    - Reliability increases with network size
- (Circuit switching (connection-oriented))
  - Analogy: Telephone network
  - Explicit connection setup prior to first message
  - All messages take same path to destination
  - Path breaks on failure
    - Reliability decreases with network size

Source: Van Jacobsen: A New Way to look at Networking.
http://video.google.com/videoplay?docid=-6972678839686672840

Outline

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  - Layering and Protocols
  - Internet Architecture
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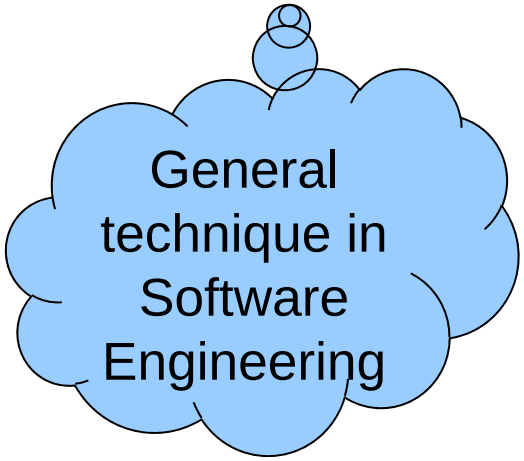
Layering

- Use abstractions to hide complexity
- Abstractions naturally lead to layering
- Alternative abstractions at each layer
  - Abstractions specified by standards/protocols/APIs



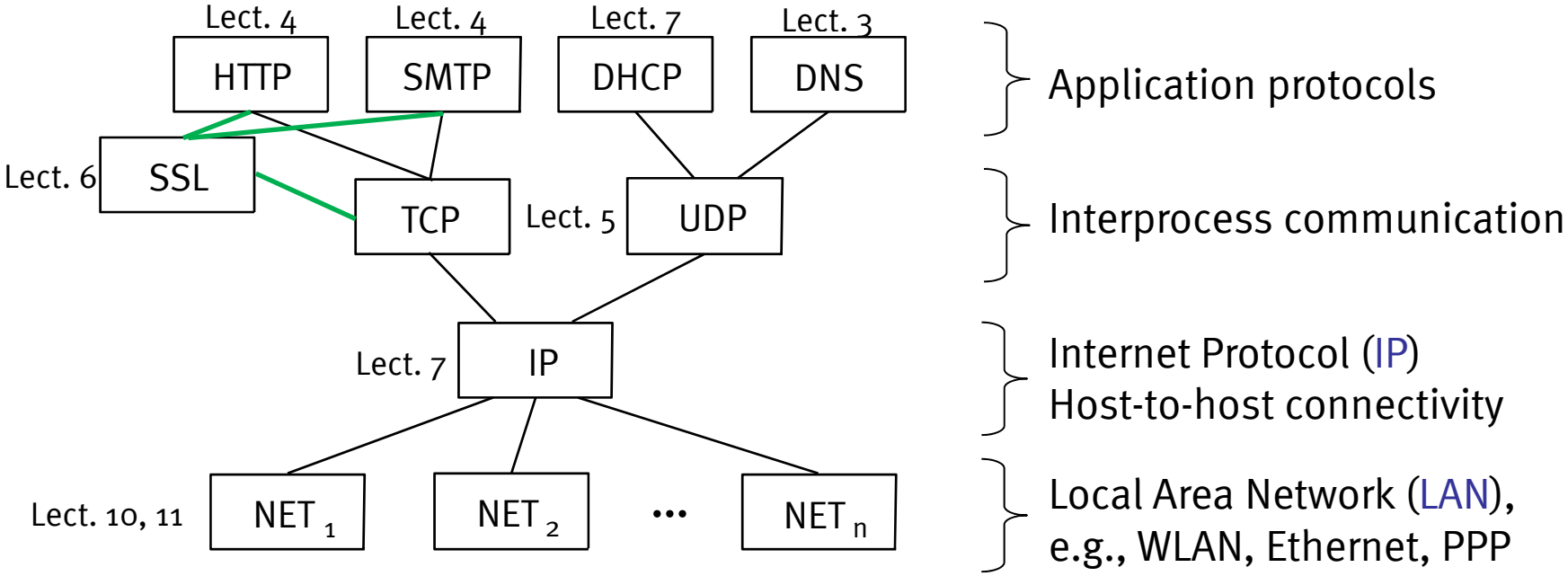
- Thus, problem at hand is decomposed into manageable components
- Design becomes (more) modular

Internet Standards

- Defined by Internet Engineering Task Force (IETF)
  - http://www.ietf.org/
  - Current list: http://tools.ietf.org/html/rfc5000
- Each standard specified by set of RFCs (Requests For Comments)
  - But not every RFC is a standard
    - http://en.wikipedia.org/wiki/April_Fools%27_Day_RFC
  - Stati: Informational, Experimental, Best Current Practice, Standards Track, Historic
- Community process
  - Everyone may submit Internet Draft
    - Typically produced by IETF working groups
  - Afterwards peer reviewing
    - Eventually, publication as RFC
  - David Clark: “We reject kings, presidents and voting. We believe in rough consensus and running code.” (http://www.ietf.org/tao.html)

Internet Architecture (Class Structure)

- Defined by Internet Engineering Task Force (IETF)

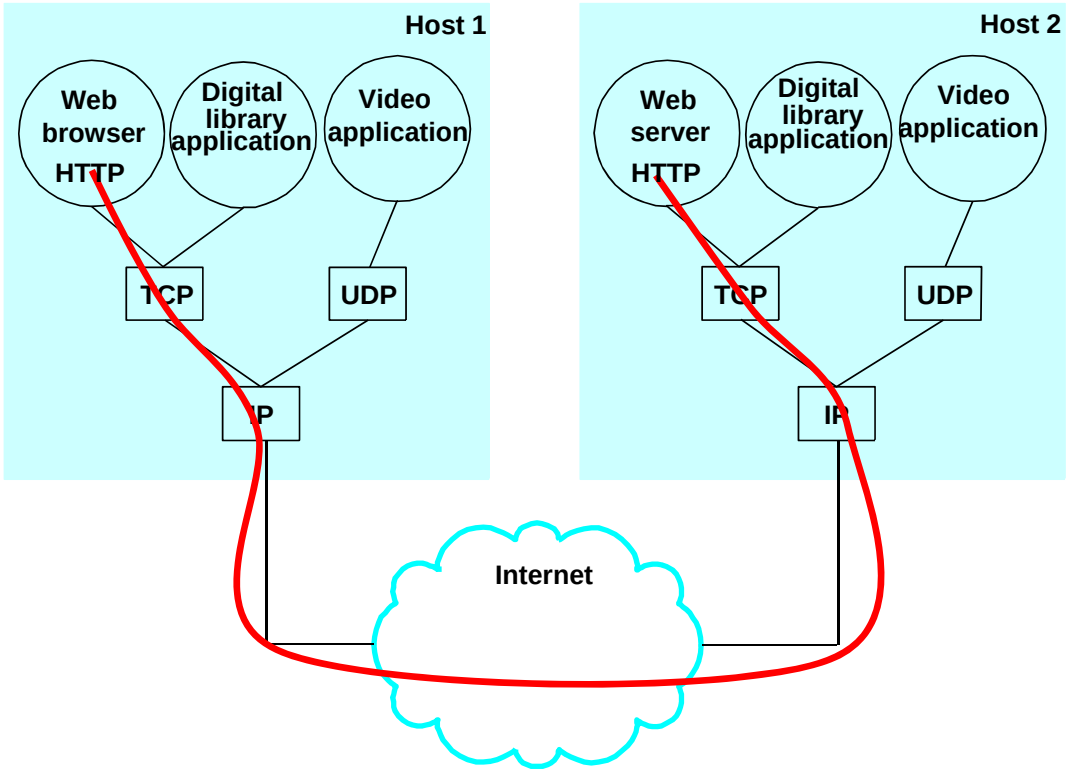


- Note:
  - "Hourglass design"
  - IP is focal point
    - Application independent!
    - Network independent!

IP, UDP, and TCP

- IP (Internet protocol)
  - Offers best-effort host-to-host connectivity
    - Connection-less delivery of datagrams
    - No effort to recover from transmission errors
- UDP (User Datagram Protocol
  - Extends IP towards best-effort process-to-process connectivity
    - Ports identify processes
    - Connection-less
- TCP (Transmission Control Protocol)
  - Offers reliable process-to-process connectivity
    - Ports identify processes
    - Full-duplex byte stream
    - Three-way handshake to establish connection
      - Initial round-trip time for setup
    - Acknowledgements and timeouts for retransmissions

Example

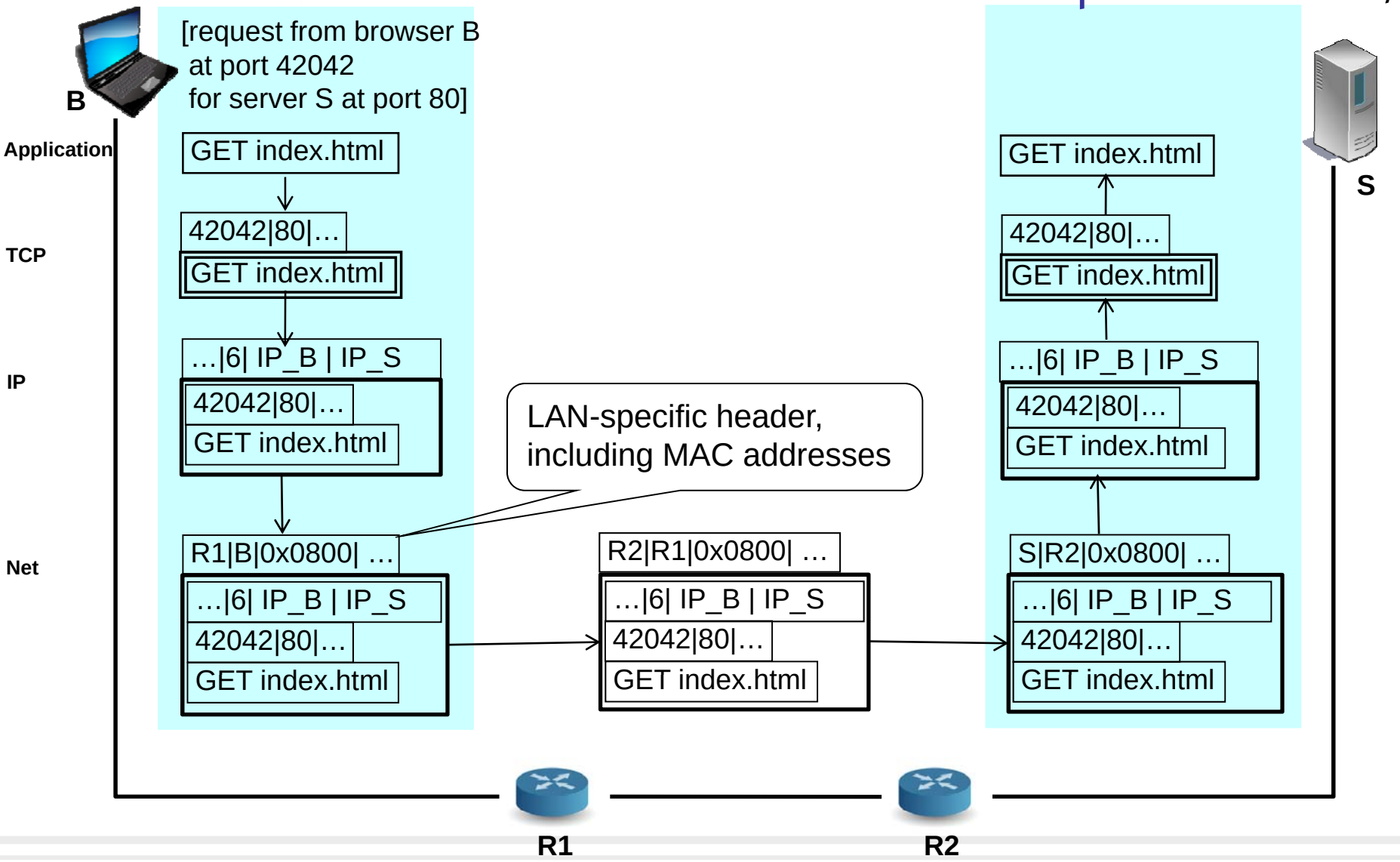


Web surfing employs "protocol stack" HTTP/TCP/IP

Typical Communication Steps

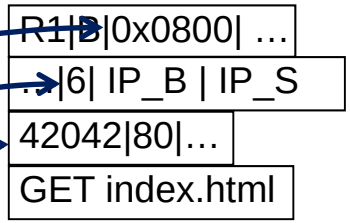
- Prerequisites
  - Internet communication requires numeric IP addresses
    - Bindings of human readable names and IP addresses via DNS
  - LAN communication requires MAC (media access control, hardware) addresses
    - Bindings of IP addresses and MAC addresses via ARP
- Ex.: Steps to send message M to host xlx.uni-muenster.de
  1. DNS lookup for "xlx.uni-muenster.de"
     - Returns 128.176.159.171
  2. Routing decision to determine IP address of next hop router
     - Returns IP address IP_R within sender's network
     - E.g., 128.176.4.1 at zivunix
  3. ARP lookup to determine MAC address for IP_R
     - E.g., 0:0:c:7:ac:0
  4. Send M via LAN to router
  5. Routers repeat steps (2) – (4) to forward M to final destination

Encapsulation

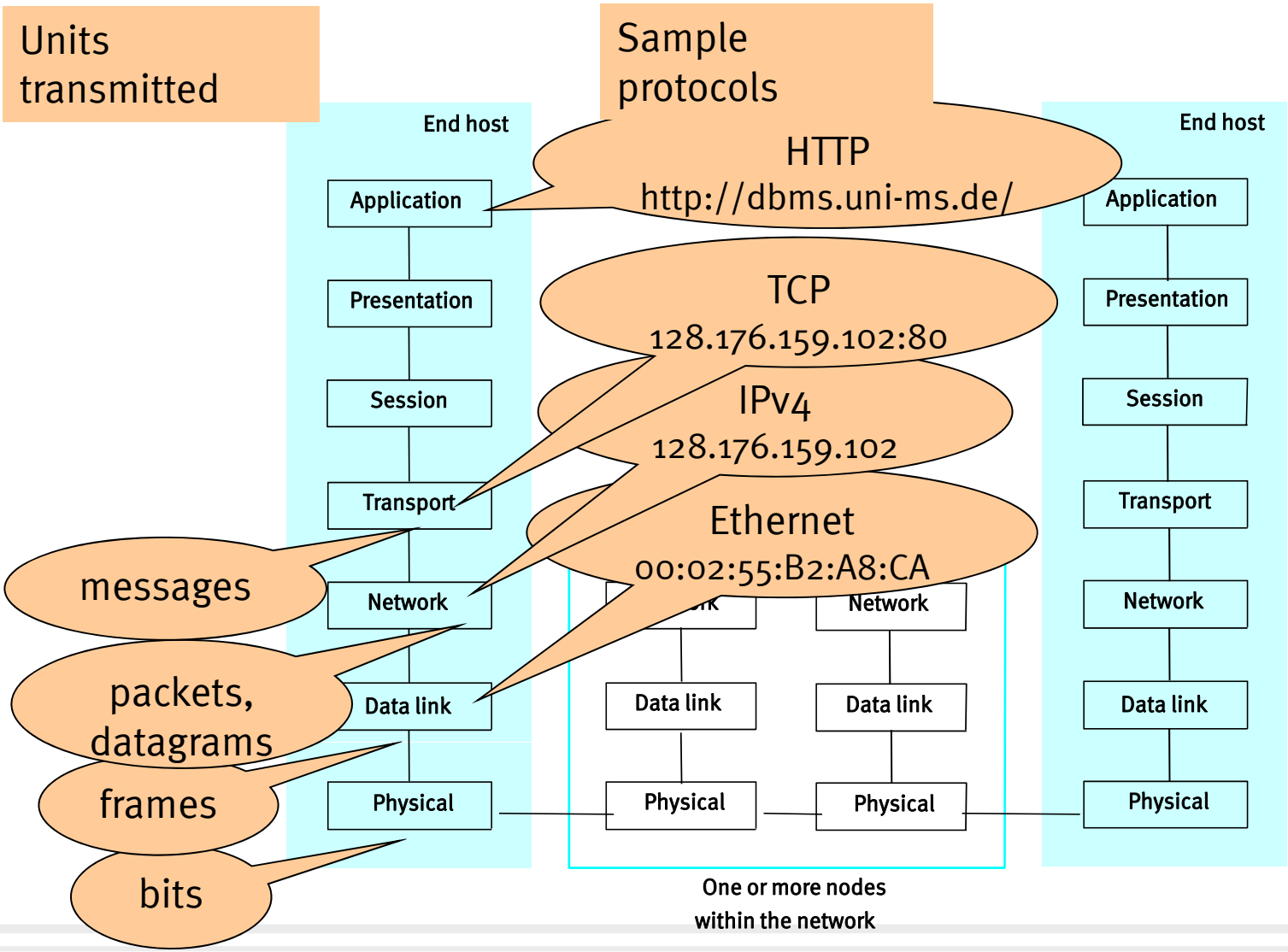


Encapsulation and Demux Keys

- Encapsulation
  - Protocol specific header added for each layer
    - "Pure" application message
    - Headers prepended when moving down the protocol stack
- Headers "unwrapped" when moving up again
- Demux key
  - Identifies recipient at next higher layer
  - Different protocols use different forms of demux keys
    - Ethernet header contains type field (IPv4 = 0x0800)
    - IP header contains protocol field (TCP = 6, UDP = 17)
    - TCP header contains app id (port) as demux key



OSI Architecture



Summary

- Computer networks are general purpose networks
  - Built from hosts, switches, routers, and links
  - Indirect connectivity via global addressing and forwarding
- Complexity reduced via layered architecture
  - Modular design
  - Internet vs OSI architecture
  - Encapsulation and demux keys

Learning Objectives

- Explain forwarding of Internet messages based on (IP and MAC) addresses and demux keys

Credits

- Several figures throughout this class are based on Powerpoint slides for Peterson/Davie: Computer Networks

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