Internet Architecture I
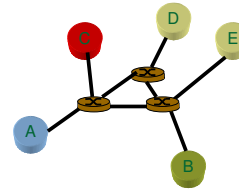
EECS 122: Lecture 2

Department of Electrical Engineering and Computer Sciences
University of California
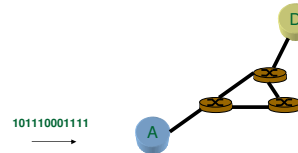Berkeley

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Today's Outline

- Last lecture was a "lean back" overview of networks
- Today, let's begin "leaning forward"
  - How the functions of the internet are organized into layers
  - How these functions lead to a protocol stack
  - The End-to-End Principle
  - Packet Sniffing

What's a protocol?

a human protocol and a computer network protocol:

protocols define format, order of msgs sent and received among network entities, and actions taken on msg transmission, receipt

Hi, Over

Sure! Over and out

TCP connection request

TCP connection response

Get http://www.berkeley.edu

<file>

time

Back to a simple network…

Review:
Hosts connect to specialized devices called Routers.
Routers are built (HW and Software) to discover the topology, select good paths and forward messages
quickly. They also respond to changing network conditions.

"Hey, David!"

101110001111

Digitize the message

"Hey, David!"

Need a host address!

| 1011 | 1000 | 1111 |

Packetize the message…
Assume equal packet sizes for simplicity although this isn't true in IP

Slide 7

"Hey, David!"

D

| D1011 | D1000 | D1111 |

A

Fix address width
Need an address field!

Add a destination label

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Slide 10

"Hey, David!"

Unreliable link

D

| D | 1 | 1011 | D | 2 | 1000 | D | 3 | 1111 |

R

A

Packets are mostly lost over the unreliable link.

Now there are <u>two</u> data recovery protocols running simultaneously

Retransmitting all the way from A adds load to the network
A protocol between R and D which recovers packets
lost over the link could get the message to D much
faster than having all retransmissions sent from A

January 19, 2006   EECS122 Lecture 2 (AKP)   10

Slide 8

"Hey, David!"

| D | 1011 | D | 1000 | D | 1111 |

D

A

What if packets arrive out of order?
What if packets are lost?

Add Sequence Numbers!

Now the routers can look for a fixed width address
How many bits wide should it be if our network can be at most 1000 nodes?
In IP the address is 32 bits wide

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Slide 11

"Hey, David!"

Unreliable link

D

| D | 1 | 1011 | D | 2 | 1000 | D | 3 | 1111 |

R

A

Packets are mostly lost over the unreliable link.
No need to retransmit all the way from A

Add field for link sequence numbers…

Why not just use the host sequence numbers?

January 19, 2006   EECS122 Lecture 2 (AKP)   11

Slide 9

"Hey, David!"

D

| D | 1 | 1011 | D | 2 | 1000 | D | 3 | 1111 |

A

What if packets arrive out of order?
What if packets are lost?

Add Sequence Numbers!

•Node D can reorder packets by sequence number
•Can run a protocol between the hosts that will cause A to retransmit lost packets

January 19, 2006   EECS122 Lecture 2 (AKP)   9

Slide 12

"Hey, David!"

Unreliable link

D

| D | 1 | 1011 | D | 2 | 1011 | D | 3 | 1011 |

R

A

What if packet 2 is lost before reaching router, R…?

If the link device at D is using the purple seq numbers it will keep asking for 2

The link sequence number field is filled out/rewritten at each hop.

January 19, 2006   EECS122 Lecture 2 (AKP)   12
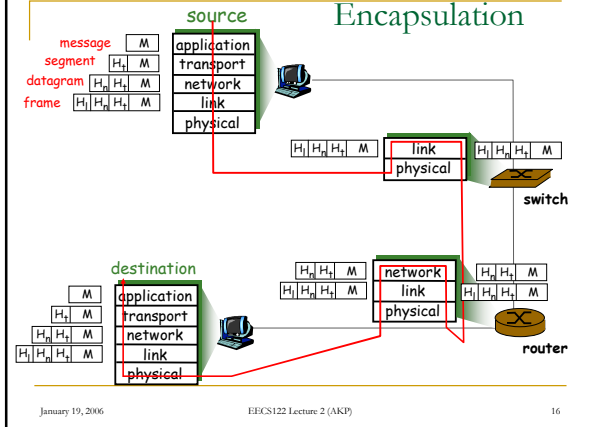
2

What's an Application Protocol?

- Examples
  - The IM protocol
  - HTTP
  - Mail
  - Bittorrent
- What about a protocol that routers use to learn the network topology?

Encapsulation

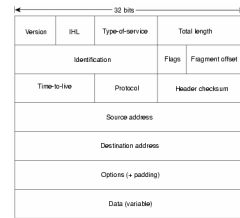## What did we learn?

- Need separate headers for:
  - Link level reliable transmission
  - Network routing
  - Host-Host Reliable transmission: Transport
  - Application protocols
- Different devices look at different headers
  - Link Level: Data Link Control (DLC)
  - Network Level: Router
  - Transport Level: Hosts
- Two devices that look at the same header are "**peers**"
- Each set of peers runs its own protocols
- Protocols at one "level" can be improved/changed without affecting the correctness of protocols at another level

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The IP Packet Format

Version	IHL	Type-of-service	Total length
Identification		Flags	Fragment offset
Time-to-live	Protocol	Header checksum	
Source address			
Destination address			
Options (+ padding)			
Data (variable)			

What about a broadcast system?

- Example: Satellite.

10Mbps or 100 Mbps

HUB

SWITCH

100Mbps or 1Gbps

1, 2, 5.5, 11Mbps

Burned into NICs
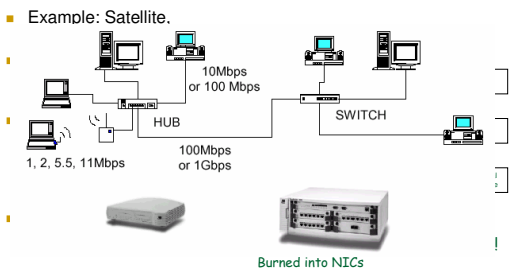
Layering of airline functionality

	ticket
	baggage
	gate
	takeoff/landing
	airplane routing

departure airport   intermediate air-traffic control centers   arrival airport
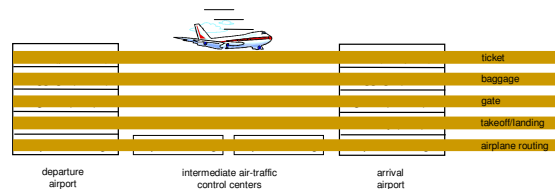
Layers: each layer implements a service
- via its own internal-layer actions
- relying on services provided by layer below

3

Internet protocol stack

- **application:** supporting network applications
  - FTP, SMTP, HTTP
- **transport:** host-host data transfer
  - TCP, UDP
- **network:** routing of datagrams from source to destination
  - IP, routing protocols
- **link:** data transfer between neighboring network elements
  - PPP, Ethernet
- **physical:** bits "on the wire"

| application |
| transport |
| network |
| link |
| physical |
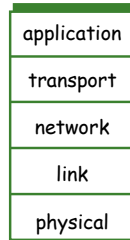
Internet End-to-End Argument
(Saltzer, Reed and Clark 1984)

- Implement a network function at the end hosts unless it cannot be implemented correctly in this manner.

OR

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

- This principle was a fundamental guiding principle for the first phase of the internet

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Question

- Can multiple _____ protocols co-exist on the internet?
  1. Transport
  2. Routing
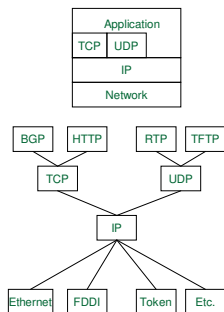 3. Link
- Yes to all three!

E2E Argument Applied

- Routing
  - Just doing it on the hosts would eliminate routers…and the internet would not scale
- Error Recovery
  - Can't just implement it at the lower layers since packets can be lost within the host as well
    - Must implement at the host so don't implement it at the link level
- Security
  - Similar argument as for error recovery
- E2E argument is a great principle, but it is violated a lot

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An Advanced View of Internet Layering

| Application |
| TCP | UDP |
| IP |
| Network |

BGP | HTTP | RTP | TFTP
TCP | UDP
IP
Ethernet | FDDI | Token | Etc.

- Almost Any kind of application can write directly on IP
  - Including new transport protocols
- IP cannot be avoided
- As long as the routers speak IP, any application that can make do with datagram service can be written and implemented on the end devices.
  - No co-ordination, standards activity etc. is required!!

The downside of layering

- Efficiency
  - Suboptimal network behavior
    - Transport layer can't get information from the routers
  - Added Overhead
    - Fragmentation and reassembly
- Confusion in actual networks
  - What layer does the function "security" belong to?
  - Is routing just a network layer function?
  - Layer 2 , Layer 4 and Layer 4-7 switches!

Example: Layer 4-7 switch

- For http://www.stocks.com
- What if we want many servers to appear as one?
  - Load balancing for server performance
    - Number of TCP connections
    - Server capacity
  - Load balance over different geographies
- All requests for that url go to a device called a Layer 4-7 switch
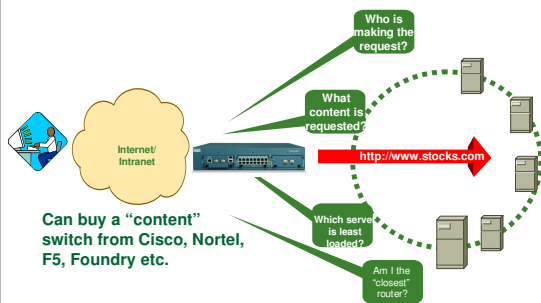
Be a protocol detective…

- Download a free packet sniffer, Ethereal from www.ethereal.com
- A packet sniffer allows you to examine the packets sent from and received at your host.
- Classified by protocol.
- This allows you to see how your host is communicating with other devices of the internet

A Layer 4-7 Switch

Who is making the request?

What content is requested?

Which server is least loaded?

Am I the "closest" router?

Internet/ Intranet

http://www.stocks.com

Can buy a "content" switch from Cisco, Nortel, F5, Foundry etc.

Summary/Questions

- How the functions of the internet are organized into layers
- How these functions lead to a protocol stack
- The End-to-End Principle
- Packet Sniffing

Next time we will study Delay Models and how to think about network performance

Where are internet protocols standardized?

- The Internet Engineering Task Force:
  - http://www.ietf.org
- IAB
- Areas
- Working Groups
- Drafts, RFC, Proposed Standards
- Being forced to evolve to deal with the total commercialization of the internet
  - Good: Output has immediate global impact
  - Bad:
    - Many more demands of the network
    - Weaknesses in the architecture have "immediate global impact"