Review of Important Networking Concepts

- Review: Layered communication architecture
- The TCP/IP protocol suite

Recall the Example from last lecture

- Ellington.cs.virginia.edu establishes an FTP connection to neon.cs.virginia:
  
  `ftp neon.cs.virginia.edu`

- We will use the example to illustrate some important networking concepts
The example: Passing a simple packet from neon.cs.virginia.edu (128.143.71.21) to ellington.cs.virginia.edu (128.143.137.144).

DNS: What is the IP address of "neon.cs.virginia.edu"?

- The IP address of "neon.cs.virginia.edu" is 128.143.71.21.

ARP: What is the MAC address of 128.143.137.1?

- The MAC address of 128.143.137.1 is 00:e0:f9:23:a8:20.

ARP: What is the MAC address of 128.143.71.21?

- The MAC address of 128.143.71.21 is 00:e0:f9:23:a8:20.

128.143.71.21 is not on my local network. Therefore, I need to send the packet to my default gateway with address 128.143.137.1.

128.143.71.21 is on my local network. Therefore, I can send the packet directly.

Communications Architecture

- The complexity of the communication task is reduced by using multiple protocol layers:
  - Each protocol is implemented independently
  - Each protocol is responsible for a specific subtask
  - Protocols are grouped in a hierarchy
- A structured set of protocols is called a communications architecture or protocol suite.
TCP/IP Protocol Suite

- In this course, we will be mostly concerned with the TCP/IP protocol suite.
- The TCP/IP protocol suite is the main characteristic for the networks that we call the Internet.
- The TCP/IP suite has four layers: Application, Transport, Network, and (Data) Link Layer.
- Computers (hosts) implement all four layers. Gateways (Routers) only have the bottom two layers.

<table>
<thead>
<tr>
<th>Layer</th>
<th>Services/Protocols</th>
</tr>
</thead>
<tbody>
<tr>
<td>Application Layer</td>
<td>telnet, ftp, email</td>
</tr>
<tr>
<td>Transport Layer</td>
<td>TCP, UDP</td>
</tr>
<tr>
<td>Network Layer</td>
<td>IP, ICMP, IGMP</td>
</tr>
<tr>
<td>(Data) Link Layer</td>
<td>Device Drivers</td>
</tr>
</tbody>
</table>

Functions of the Layers

- **Data Link Layer:**
  - Service: Reliable transfer of frames over a link
  - Functions: Synchronization, error control, flow control
- **Network Layer:**
  - Service: Moves packets inside the network
  - Functions: Routing, addressing, congestion control
- **Transport Layer:**
  - Service: Controls delivery of data between hosts
  - Functions: Connection establishment/termination, error control, flow control
- **Application Layer:**
  - Service: Handles details of application programs
  - Functions: Everything is application specific
TCP/IP Suite and OSI Reference Model

- You know about the OSI Reference protocol

- The TCP/IP protocol stack does not define the lower layers of a complete protocol stack

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More Information on Layers

- An entity of a particular layer can only communicate with:
  1. a peer layer entity using a common protocol (**Peer Protocol**)
  2. adjacent layers to provide services and to receive services
Layers in the Example

Open ftp session to neon

Establish a connection to 128.143.71.21

Send IP datagram to 128.143.71.21

Send the datagram to 128.143.137.1

Send IP datagram to 128.143.71.21

Send Ethernet frame to 00:e0:f9:23:a8:20

Send Ethernet frame to 00:20:af:03:98:28

Send Ethernet frame to 128.143.7.21

Frame is an IP datagram

Frame is an IP datagram

Frame is an IP datagram

Encapsulation

- As data is moving down the protocol stack, each protocol is adding layer-specific control information
Encapsulation in our Example

- Let us look in detail at the first Ethernet frame between ellington and router71.cs.
- This is the output of `tcpdump -exn host 128.143.71.21`

```
18:32:05.664412
0:a0:24:71:e4:44 0:e0:f9:23:a8:20 0800 60:
128.143.137.144.1627 > 128.143.71.21.21:
S 607835:607835(0) win 8192 <mss 1460> (DF)
   4500 002c 9d08 4000 8006 8bff 808f 8990
   808f 4715 065b 0015 0009 465b 0000 0000
   6002 2000 598e 0000 0204 05b4 b4b4
```
Encapsulation: Ethernet Header

Encapsulation: IP Header
Encapsulation: IP Header

32 bits

```
0x4  0x5  0x00  4A
9d08  010  000000000000
12B0  0x06  8bff
```

128.143.137.144
128.143.71.21

Encapsulation: TCP Header

32 bits

```
Source Port Number  Destination Port Number
Sequence number (32 bits)
Acknowledgement number (32 bits)
header length 0  Flags  window size
TCP checksum  urgent pointer
kind=2 length Max. segment size
```

Option: maximum segment size
Encapsulation: TCP Header

32 bits

<table>
<thead>
<tr>
<th>1627_{10}</th>
<th>21_{10}</th>
</tr>
</thead>
<tbody>
<tr>
<td>607835_{10}</td>
<td></td>
</tr>
<tr>
<td>0_{10}</td>
<td></td>
</tr>
<tr>
<td>6_{10}</td>
<td>000000_{2}</td>
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<td>0x598e</td>
<td>0000_{2}</td>
</tr>
<tr>
<td>2_{10}</td>
<td>4_{10}</td>
</tr>
</tbody>
</table>

Encapsulation: Application data

No Application Data in this frame
Different Views of Networking

- Different Layers of the protocol stack have a different view of the network. This is FTP’s and TCP’s view of the network.

Network View of IP Protocol
View of Network Hardware

ellington → Olsson Hall
- 100 Mbps Ethernet
- 155 Mbps ATM

Olsson Hall → neon
- 10 Mbps Ethernet
- 622 Mbps ATM

Gilmer Hall
- 155 Mbps ATM
- router71 / router137

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