Network Architecture and the OSI Reference Model
Architecture Outline

- The Internet and IP
- Network Architecture
  - Protocols and Layers
  - Encapsulation
- The OSI Reference Model
  - The Seven OSI Layers
- The TCP/IP Internet Stack
- Layering Example
- Tiered Internet Architecture
An internet :: involves the interconnection of multiple networks into a single large networks. [LG&W]

The Internet :: refers to the successor to ARPANET. The modern Internet is multi-tiered and includes commercial participation.

IP (the Internet Protocol) :: provides connectionless transfer of packets across an internet.
The Internet

- Provides a *name space* to refer to machines connected to the Internet *(e.g. chablis.cs.wpi.edu)*.
- The name space is hierarchical, but it is only administrative and not used in network routing operations.
- **DNS (Domain Name Service)** provides automatic translation of names to addresses.
Currently IP provides best-effort service.

- Packets may be lost (i.e., IP is unreliable).

General IP design philosophy

- Keep internal operations simple by relegating complex functions to the edge of the subnet.
- IP can operate over any network.
- This design allows IP to scale!!
- The end-to-end mechanisms are responsible for recovery of packet losses and congestion control.
- Uses 32 bit *hierarchical address space* with location information embedded in the structure.

- IPv4 address is usually expressed in *dotted-decimal notation*

  e.g.,

  128.100.11.56
IPv6 addresses are 128 bits long. 16 bytes of IPv6 address are represented as a group of hexadecimal digits, separated by colons. e.g.

[D&C]

\[2000:0000:0000:0000:0001:00ab:853c:39a1\]

Shorthand – leave out groups of zeros and leading zeros.

\[2000:0000::1:ab:853c:39a1\]
Layering and Abstraction

- Layering accommodates incremental changes.
- It is possible to have alternative abstractions at each layer.

Figure 1.9 Layered system with alternate abstractions available at a given layer.
In the 1970's vendor companies (IBM and DEC) developed proprietary networks with the common feature of grouping communication functions into related and manageable sets called layers.

**network architecture** :: a set of protocols that specify how every layer is to function and the defined interfaces between the layers.  

[LG&W]
Protocols

- Protocols are the building blocks of a network architecture.
- Each protocol object has two different interfaces:
  - service interface :: operations on this protocol
  - peer-to-peer interface :: messages exchanged with peer
Figure 1.10 Service interfaces and peer interfaces
**What’s a protocol?**

**human protocols:**
- “what’s the time?”
- “I have a question”
- introductions

... specific msgs sent

... specific actions taken when msgs received, or other events

**network protocols:**
- machines rather than humans
- All communication activity in the Internet is governed by protocols.

Protocols define: the format, the order of msgs sent and received among network entities, and the actions taken on message transmission and receipt.
What's a protocol?

A human protocol and a computer network protocol:

Hi

Got the time?

2:00

TCP connection request

TCP connection response

Get http://www.awl.com/kurose-ross

<file>
International Standards Organization
Open Systems Interconnect (OSI) Reference Model
Figure 1.13 The OSI seven-layer model
The OSI Model

Application A

Application Layer
Presentation Layer
Session Layer
Transport Layer
Network Layer
Data Link Layer
Physical Layer

Communication Network

Application B

Application Layer
Presentation Layer
Session Layer
Transport Layer
Network Layer
Data Link Layer
Physical Layer

Electrical and/or Optical Signals

Leon-Garcia & Widjaja: Communication Networks
OSI Layer Encapsulation

Application A

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

Application B

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

Leon-Garcia & Widjaja: Communication Networks

Advanced Computer Networks Network Architecture
<table>
<thead>
<tr>
<th>Layer</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Application Layer</td>
<td>Provides users access to the OSI environment and distributed information services.</td>
</tr>
<tr>
<td>Presentation Layer</td>
<td>Provides application processes independence from differences in data representations.</td>
</tr>
<tr>
<td>Session Layer</td>
<td>Provides the control structure for communicating between applications. Establishes, manages and terminates session connections between cooperating applications.</td>
</tr>
<tr>
<td>Transport Layer</td>
<td>Provides reliable transparent transfer of data between end points. Provides end-to-end flow control and error recovery.</td>
</tr>
<tr>
<td>Network Layer</td>
<td>Provides independence from the data transmission, routing/switching technologies used to connect systems. Responsible for establishing, managing and terminating connections.</td>
</tr>
<tr>
<td>Data Link Layer</td>
<td>Provides for reliable transfer of information across the physical layer. Sends and receives frames with the necessary synchronization, flow control and error control.</td>
</tr>
<tr>
<td>Physical Layer</td>
<td>Concerned with transmission of unstructured bit stream over a physical medium. Deals with mechanical, electrical, functional and procedural characteristics to access the physical medium.</td>
</tr>
</tbody>
</table>
ISO/OSI Reference Model

- **Presentation layer**: allow applications to interpret meaning of data, e.g., encryption, compression, machine-specific conventions
- **Session layer**: synchronization, check-pointing, recovery of data exchange
- The TCP/IP Internet stack is “missing” these two layers!
  - these services, *if needed*, must be implemented in an application.
  - needed?

K & R

Advanced Computer Networks  Network Architecture
Advantages of Layering Design

- An explicit structure for dealing with a complex system:
  - allows identification and structures the relationship of complex system’s pieces.
  - layered reference model for discussion.

- Provides an abstraction for functional locality.

- Simplifies the design process.
Advantages of Layering Design

- Modularity of layers eases maintenance and updating of system components:
  - change in implementation of a layer’s service is transparent to rest of the system.
  - Led to flexibility in modifying and developing network architectures.
  - Accommodates incremental changes.
TCP/IP Architectural Model

DCC 6th Ed., W. Stallings
OSI versus TCP/IP

Figure 1-21. [old] The TCP/IP reference model.

Tanenbaum
### Internet Protocol Stack

- **application**: supporting network applications
  - FTP, SMTP, HTTP

- **transport**: process–process 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” or in the air

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*Advanced Computer Networks*  
*Network Architecture*
TCP/IP Protocols

HTTP
SMTP
DNS
RTP

TCP
UDP

IP

Network
Interface 1

Network
Interface 2

Network
Interface 3

Leon-Garcia & Widjaja: Communication Networks
Figure 1.15 Alternate view of the Internet architecture
Layering Example

Client/server relationship

- Server process waits for incoming requests by listening to a port.
- Client process makes requests as required.
- Server process provides responses to these requests.
- The server process usually runs in the background as a daemon (e.g., httpd is the server daemon). for HTTP).
HTTP Example

- HTTP (HyperText Transfer Protocol) specifies rules by which the client and the server interact so as to retrieve a document.
- The protocol assumes the client and the server can exchange messages directly.
- The client software needs to set up a two-way connection prior to the HTTP request.
HTTP Client/Server Interaction

HTTP Client

Request

Response

HTTP Server
HTTP/TCP Layering Interface

HTTP client

HTTP server

Ephemeral

Port #

TCP

GET 80, #

#, 80 STATUS

Port 80

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HTTP Request

TCP Header

IP Header

Ethernet Header

Header contains source and destination port numbers

Header contains source and destination IP addresses; transport protocol type

Header contains source and destination physical addresses; network protocol type
Internet Structure: 
Network of Networks

- roughly hierarchical
- at center: “tier-1” ISPs (e.g., Verizon, Sprint, AT&T, Cable and Wireless), national/international coverage
  - treat each other as equals

![Diagram of Tier-1 ISPs interconnecting privately]
Tier-1 ISP: e.g., Sprint

POP: point-of-presence

to/from backbone

peering

to/from customers
“Tier-2” ISPs: smaller (often regional) ISPs
- Connect to one or more tier-1 ISPs, possibly other tier-2 ISPs

Tier-2 ISP pays tier-1 ISP for connectivity to rest of Internet
- tier-2 ISP is customer of tier-1 provider

Tier-2 ISPs also peer privately with each other.
“Tier-3” ISPs and local ISPs
- last hop (“access”) network (closest to end systems)

Local and tier-3 ISPs are customers of higher tier ISPs connecting them to rest of Internet
Internet Structure: Network of Networks

- a packet passes through many networks!
Internet Structure: Network of Networks

But if one global ISP is viable business, there will be competitors … which must be interconnected
... and regional networks may arise to connect access nets to ISPS.
… and content provider networks (e.g., Google, Microsoft, Akamai) may run their own network, to bring services, content close to end users.
at center: small # of well-connected large networks

- “tier-1” commercial ISPs (e.g., Level 3, Sprint, AT&T, NTT), national & international coverage
- content provider network (e.g., Google): private network that connects its data centers to Internet, often bypassing tier-1, regional ISPs
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