Introduction

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Protocol Reference Model - why need it?

- Necessary communication functions are complex in modern communication systems (networks)
  - e.g., addressing, routing, error handling, congestion control, access control or scheduling, and application specific requirements

- Layered approach has been widely adopted for organizing communication functions.
Protocol Reference Model – why need it? (cont’d)

- A protocol reference model (PRM) describes the functions of the layers and the relations of the layers with respect to each other.

- Each type of networks may have its own protocol reference model, e.g.,
  - ISO/OSI Seven Layer PRM
  - Internet TCP/IP protocol suite
  - Wireless network
  - Cable network
ISO/OSI Seven-Layer Protocol Reference Model

- Physical layer
- Data Link layer
- Network layer
- Transport layer
- Session layer
- Presentation layer
- Application layer
The OSI Reference Model.

- **User Space Layer**
  - Application
  - Presentation
  - Session
  - Transport
  - Network
  - Data link
  - Physical

- **Layer Interface**
  - 7: Application
  - 6: Presentation
  - 5: Session
  - 4: Transport
  - 3: Network
  - 2: Data link
  - 1: Physical

- **Host A**
  - Router
  - Network layer host-router protocol
  - Data link layer host-router protocol
  - Physical layer host-router

- **Host B**
  - Router
  - Network
  - Data link
  - Physical

- **Communication subnet boundary**
  - Internal subnet protocol
  - Packets
  - Frame
  - Bit

- **Name of unit exchanged**
  - APDU
  - PPDU
  - SPDU
  - TPDU

- **Kernel (OS)**
  - Network Interface Card (NIC)

- **Network Interface**

- **Interface**

- **The OSI Reference Model.**
Physical Layer

- To transmit raw bits over a communication channel

- Design issues
  - mechanical, electrical, and procedural interfaces and physical transmission medium

PC  RS-232  Modem
Data Link Layer

- **Reliable and efficient** transmission of raw bits *between two machines*

- **Design issues**
  - error detection and recovery, retransmission, frames in sequence, acknowledgment, etc.; frame boundaries; flow control.
Network Layer

- To control the operation of the subnet/interconnection of networks
- Host-to-host
- Design issues
  - routing, addressing, congestion control, accounting
Transport Layer

- To control and manage messages exchange between communicating processes on machines

- Design issues
  - reliability, connecting services, efficiency, naming, flow control
Session Layer

- Session Layer
  - To allow users on different machines to establish sessions between them.

- Design issues
  - dialogue control, token management, synchronization

SIP – Session Initiation Protocol
RTSP – Real-time Streaming Protocol
RSVP – ReSerVation Protocol
Presentation Layer

To manage the syntax and semantics (i.e. representation) of the information transmitted

Design issues

- abstract data types, encoding/decoding schemes, data compression, data encryption (security)

- e.g., ASN.1 (Abstract Syntax Notation One) and BER (Basic Encoding Rule), XML, etc.
Application Layer

- To support application specific functions for information transfer
  - It contains a variety of protocols, e.g., FTAM, RDA, CMISE, telnet, ftp, e-mail, etc.
Relation between Layers at an Interface

Layer n+1

Interface

Layer n

ICI

SDU

ICI

SDU

SAP

API

(Application Programming Interface)

SAP = Service Access Point
IDU = Interface Data Unit
SDU = Service Data Unit
PDU = Protocol Data Unit
ICI = Interface Control Information

Layer n entities exchange n-PDUs in their layer n protocol.

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Layers, Protocol, and Interfaces

Layer 5 protocol
Layer 4 protocol
Layer 3 protocol
Layer 2 protocol
Layer 1 protocol

Physical medium
The TCP/IP reference model

OSI

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<tr>
<th>7</th>
<th>Application</th>
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<tbody>
<tr>
<td>6</td>
<td>Presentation</td>
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<tr>
<td>5</td>
<td>Session</td>
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<tr>
<td>4</td>
<td>Transport</td>
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<tr>
<td>3</td>
<td>Network</td>
</tr>
<tr>
<td>2</td>
<td>Data link</td>
</tr>
<tr>
<td>1</td>
<td>Physical</td>
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</tbody>
</table>

TCP/IP

<table>
<thead>
<tr>
<th>Application</th>
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<tbody>
<tr>
<td>Transport</td>
</tr>
<tr>
<td>Internet</td>
</tr>
<tr>
<td>Host-to-network</td>
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</tbody>
</table>

Not present in the model
Internet Reference Model

5. Application layer
4. Transport layer
3. Network layer
2. Data Link layer
1. Physical layer
Access of the Future
Scalability is the key ...

- Scalable Bandwidth – optics
  - POPs: OC-192, 3/200; OC-768, 6/2003, 10G Ethernet

- Scalable Networks – IP (IPv4 and IPv6)

- Scalable Services – Content!
  - The more you know about what’s inside the packet, the more you can put smart things inside the switch/router.
Technology Advances/Evolution

Application layer
IP
ATM
SONET
Dark fiber

Application layer
IP
SONET
Dark fiber

Application layer
IP
SONET
Dark fiber
Terminology

■ **Services**

  ■ A service is a set of primitives (operations) that a layer provides to the layer above it.

  ■ Services are defined as part of a layer interface specification

■ **Protocols**

  ■ A protocol is a set of rules that governs the format and meaning of information exchanged by the peer entities within a layer
Terminology (cont’d)

- **Services vs. protocols** is like **abstract data types (ADTs)** vs. **Implementation**.
Communication Services

- **Connection-Oriented Services**
  - Three phases
    - connection establishment, data transfer and connection teardown
  - Example: telephone calls

- **Connectionless (datagram) Services**
  - Self-addressed messages
  - Messages are independent and may take different routes and may be out of sequence.
  - Examples: postal mail
Connection-Oriented and Datagram Services

- May be provided at the Link Layer, Network Layer, Transport Layer and above.

- Service characteristics
  - reliability - correctness and no data lost
  - examples
    - file transfer
    - electronic mail
    - voice
    - video
Network Standards

- Scope
  - architecture, services, interfaces, protocols, etc.

- Why need standards
  - To achieve *compatibility* and *interoperability* between networking systems
    - proprietary, isolated subnetworks
  - To call for *Open System Interconnection* or *Open Networking*
Two kinds of standards

- "de facto" standards
  - specifications that have happened without any formal plan.
  - examples: Internet protocols, IBM PC specifications, UNIX operating system

- "de jure" standards
  - formal, legal standards adopted by some authorized standardization body
  - examples: International Telecommunication Union (ITU) (formal CCITT), ISO, IEEE, ANSI, POSIX, etc.
International Standardization Authorities

- Two classes
  - established by treaty among nations
    - e.g., ITU
  - established by voluntary, nontreaty organizations
    - e.g., ISO

- Telecommunication service providers - a major player
International Standardization Authorities

- Telephone networks - the first worldwide communication network
  - aggressively involving
    - Data communications
    - Integrated Services Digital Networks (ISDN)
    - Mobile communications
    - Video communications (Cable TV)
International Standardization Authorities (cont’d)

- The legal status of the world telephone companies varies considerably from country to country
  - e.g., completely owned and run by government (a nationalized company or PTT) vs. complete open (free) market

- In USA
  - Federal Communications Commission (FCC) and State Public Utility Commissions
Internetworking Devices

- **Repeaters**
  - To connect two networks at the **Physical Layer**
  - To forward bits from one network to another

- **Bridges**
  - To connect two networks at the **Data Link Layer** (or Medium Access Control Layer)
  - To selectively forward data link layer frames (protocol data units).
  - **Transparent bridge** - plug-and-play, self learning network configuration
Internetworking Devices

- **Routers**
  - To connect two networks at the **Network Layer**, e.g., IP routers
Layer 2-3-4-5 Switching

- Traditional traffic transmission and switching is limited at layer 2, e.g., Ethernet switch, ATM switch, etc.

- Recently, definition of switching has been extended to include routing packets based on layer 3, layer 4 and layer 5 (such as URL and URI) information.
Remarks

- Implementation complexity - interoperability
  - mandatory, option, implementation compliance, implementation agreement, validation/testing laboratories, etc.
Remarks (cont’d)

- Layered structure, All-layer, vs. Layerless
  - Poor performance
  - Duplicate functions
## Six Different Types of Service

<table>
<thead>
<tr>
<th>Service</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reliable message stream</td>
<td>Sequence of pages</td>
</tr>
<tr>
<td>Reliable byte stream</td>
<td>Remote login</td>
</tr>
<tr>
<td>Unreliable connection</td>
<td>Digitized voice</td>
</tr>
<tr>
<td>Unreliable datagram</td>
<td>Electronic junk mail</td>
</tr>
<tr>
<td>Acknowledged datagram</td>
<td>Registered mail</td>
</tr>
<tr>
<td>Request-reply</td>
<td>Database query</td>
</tr>
</tbody>
</table>

**Connection-oriented**

**Connectionless**
## Four Classes of Service Primitives

<table>
<thead>
<tr>
<th>Primitive</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>Request</td>
<td>An entity wants the service to do some work</td>
</tr>
<tr>
<td>Indication</td>
<td>An entity to be informed about an event</td>
</tr>
<tr>
<td>Response</td>
<td>An entity wants to respond to event</td>
</tr>
<tr>
<td>Confirm</td>
<td>The response to an earlier request has come back</td>
</tr>
</tbody>
</table>