Hierarchical Protocol Architecture

Youki Kadobayashi
Nara Institute of Science and Technology
Graduate School of Information Science

Why protocol architecture?

- Hierarchical protocol architecture
  - We'll learn the concept and structure of “ISO 7 layer reference model”
  - Just a **conceptual** model. But this reference model provides common basis of the computer network.

- A quick tour of history…
  - Gives answers to “why this architecture?”

- Important:
  - Standard concepts, interfaces, definitions and terminology are most **time-consuming aspects** of building interworking technologies
Historical Background (1): 1920s～1950s

Development of Communication Theory
- Two fundamental theories formed base of communication theory. Especially, you should understand Shannon theory.
- Harry Nyquist (1924)
  - Sampling theorem
  - Maximum data rate = 2H \log_2 V \text{ (bits/s)}
    - H: low pass filter bandwidth
    - V: discrete level of signal
- Claude Shannon (1948)
  - Shannon-Hartley theorem
  - Enhanced to noisy channel
  - Maximum data rate = H \log_2 (1+S/N)
    - S/N: signal-to-noise ratio

Historical Background (2): 1960s

Mainframe computers (e.g. IBM370…) were widely used, and there was a strong demand to access the computers.
- Connection between user terminals and host computer
- The major problem was its communication channel implementation for simple character-based information.

Independent development between communication service technology (e.g. telephone) and computer communication technology.
- transmission and exchange (telegram, telephone)
- computer networks

“Modem” era
- digital information had been slowly transmitted by analog channel
  - 300bit/sec etc.
- Major challenge: how to convert bit sequence into electronic signal
  - modulation technology (differential Manchester coding etc.)
Historical Background (3)

- the late 1960s ~ the early 1970s
- First deployment of data communication services, but only provided primitive services.
  - X.25
    - Derived from IBM HDLC and standardized
    - First step for the computer network

- Birth of “LAN” - Metcalfe’s Ethernet
  - Ethernet (IEEE 802.3), Token Ring (IEEE 802.5)
  - Dawn of high-speed data communication technology
  - Completely different technology from the “modem”
    - In 1200bit/sec era, Ethernet proposed 1Mbps technology.

Historical Background (4): 1970s

- the mid-1970s and the late 1970s
- Demand for the standard procedure of system interconnections
  - Various computer networks
    - Generalized digital leased line as a long-distance communication
    - Data exchange network: X.25
    - LAN System
  - Customized for vendors, systems and clients
    - Huge operation cost and development cost
    - “cost” except application
  - Emerging large scale online system, e.g. banking systems.
  - Standardization. Why not!?
    - Strong fear on the vendor centric architecture in the market.
    - Fear on “big blue”.

Historical Background (5): 1970s

- the mid-1970s and the late 1970s
- Complicated development of communication systems
  - functional separation and packaging
    - Much in the same way as structured programming
    - Modular development, verification of implementation
  - Origin of modern hierarchical protocols
    - Synchronous link / HDLC / X.25
    - Coax / Ethernet / XNS
    - Digital leased line / ARPAnet

Historical Background (6): 1980s

- the late 1970s and the early 1980s
- Beginning of standardization efforts
  - Three streams of standardization
  - as an international standard: ISO/OSI
  - as a research achievement: TCP/IP
  - Standardization by individual vendors
    - IBM/SNA, Digital/DECnet, Xerox/XNS, ....
OSI 7 Layer Reference Model

- Fundamental model of the hierarchical computer network protocol architecture
  - 7 Layers
    - Physical / Data Link / Network / Transport / Session / Presentation / Application
  - established as an ISO/OSI standard
    - Define the concept of the hierarchical protocols.
    - This model was widely accepted by many people, in the end.

- Work done in late 1970s to early 1980s.
  - This reference model contributed to the clear discussion on details of communication protocols.
OSI 7 Layer Reference Model

We’ll revisit this later.

Development of hierarchical protocol

- **1980s**
  - Vendor proprietary standards
    - IBM SNA, DECNET, Xerox XNS
    - AppleTalk, Novell Netware, NetBIOS
  - OSI
    - CLNP, TP4, IS-IS, X.400, X.500, X.509 …

- **TCP/IP**
  - RIP, EGP/BGP, OSPF
  - TELNET, SMTP, DNS, FTP, SNMP, NTP, …
  - DARPA adapted TCP/IP as a standard.
    - ARPAnet, MILnet
Development of hierarchical protocol

- We knew the market winner of computer communication protocols in 1990’s – “TCP/IP”

- Mistakes of OSI
  - Slow ISO standardization process by national delegates
  - Complex specifications
  - Only “7 Layer Reference Model” and X.500 are still widely used.

- Victory of TCP/IP
  - Simple, open and fast process of standardization: victory of IETF standardization process.
  - The United States continued using TCP/IP.
  - Simple specification, implementation oriented

Decline of vendor protocols

- Once standardized, but abandoned the game.
  - DECNET → converged to OSI Protocol
  - AppleTalk → one of TCP/IP applications
  - Netware, NetBIOS → one of TCP/IP applications
  - Xerox XNS: declined and lost

- Only IBM / SNA has survived
  - Large scale general-purpose system known as “legacy system”
  - Difficult to migrate “mission-critical” system to the other open platform
Development of hierarchical protocol

- 21\textsuperscript{st} century
- Development of upper layer protocol
  - Session layer: SSL etc.
  - Presentation layer: XML etc.
  - Application layer: HTTP etc.
- “Demise of protocols” – processing platform
  - Web people said this
  - Lack of protocol design led to many consequences

- Layer segmentation and sophistication
  - Sub-layering in datalink layer: MPLS, VLAN etc.
  - Sub-layering in application layer: Web

Noteworthy technologies

- Interoperable protocol architecture
  - Separation of Interface and Implementation

- Data Link
  - Ethernet: LAN technology
  - HDLC: classical packet switching technology

- TCP/IP Protocol Suite
  - TCP/IP protocol is most used in the world.

- Network Management
- Application Technology
### Roles of layers

<table>
<thead>
<tr>
<th>Layer</th>
<th>Role</th>
</tr>
</thead>
<tbody>
<tr>
<td>Application</td>
<td>Protocols of Applications</td>
</tr>
<tr>
<td>Presentation</td>
<td>Machine independent but application specific expression of data.</td>
</tr>
<tr>
<td>Session</td>
<td>Application specific of “form” of communication.</td>
</tr>
<tr>
<td>Transport</td>
<td>Communication between the processes running on the nodes in the network, but as a common platform. Connection is the major concept in this layer.</td>
</tr>
<tr>
<td>Network</td>
<td>Data exchange functions, which is independent from some specific data links. End-to-end communication mechanism over networks interconnected. The “packet” is a container for data to be exchanged.</td>
</tr>
<tr>
<td>Datalink</td>
<td>Transmission procedure for data chunk (“frame”) over a single communication media. Define this layer tightly with Physical layer (L1)</td>
</tr>
<tr>
<td>Physical</td>
<td>Fundamental Transmission procedures for “bits” over communication media.</td>
</tr>
</tbody>
</table>

### Layer Structure

![Layer Structure Diagram]
Encapsulation

- Lower-level protocol encapsulates a packet of upper-level protocol
- \((n-1)\) PDU = \((n-1)\) header + \((n)\)PDU
- stores upper layer packet in the data area

Multiplexing

- layer N is multiplexing layer N+1 protocols
  - e.g. Ethernet can use IP and Apple Talk as a upper layer protocol.
Demultiplexing

- layer N is demultiplexing layer N+1 protocols
  - e.g. receiver delivers Ethernet frame to IP and AppleTalk

Pros & Cons

- **Pro.**
  - Simple
  - easily understandable
  - Separate, parallel implementations
  - concealment function and independent version up
  - interconnection between different networks

- **Con.**
  - hierarchical implementation can not improve quality and its performance.
  - memory and data managements are difficult by encapsulation process
    - flexible length of data is difficult to be handled.
Internetworking across different protocols

Network Layer Gateway:
essential to build networks over different datalinks

ES (End System)
Application
Presentation
Session
Transport
Network
Data Link
Physical

ES (End System)
Application
Presentation
Session
Transport
Network
Data Link
Physical

Network layer gateway
IPv4

Physical connection
Accommodates: heterogeneity in materials (optical / metal / wireless), intended scale, distance, speed, cost…
Transport Layer Gateway

ES (End System)  
Application  
Presentation  
Session  
Transport  
Network  
Data Link  
Physical  

Transport layer gateway

ES (End System)  
Application  
Presentation  
Session  
Transport  
Network  
Data Link  
Physical  

4/6 mapping
IPv4  
IPv6  

Physical connection

Accommodates: different Network-layer protocols

Application Layer Gateway:
let’s face it, it’s common…

ES (End System)  
Application  
Presentation  
Session  
Transport  
Network  
Data Link  
Physical  

Application layer gateway

ES (End System)  
Application  
Presentation  
Session  
Transport  
Network  
Data Link  
Physical  

Translation etc.
TCP  
IPv4  
IPv6  

Physical connection

Accommodates: diverse presentation formats, languages, transport protocols etc.
Any other protocol architectures?

The B-ISDN protocol reference model

The B-ISDN protocol reference model is a representation of the information flows in ATM networks. The model is a series of planes, each of which contain a layered architecture. The model is shown schematically below:

Fig. 2.0. The B-ISDN protocol reference model

The function and associated information of the planes is as follows:

<table>
<thead>
<tr>
<th>Plane</th>
<th>Function</th>
<th>Information flow</th>
</tr>
</thead>
<tbody>
<tr>
<td>User</td>
<td>Transfer of user application data</td>
<td>User application</td>
</tr>
<tr>
<td>Control</td>
<td>Call and connection control</td>
<td>Signalling related to calls and connections</td>
</tr>
<tr>
<td>Management (layer / plane management)</td>
<td>Network supervision</td>
<td>Network status and performance</td>
</tr>
</tbody>
</table>
An Overview of 7 Layers
Physical Layer

- Physical Layer (Layer 1)
- Transmission procedures for “bits” over communication media
  - procedure of bit transmission between nodes
  - e.g.
    - electrical signal level (e.g. 0: < +0.5v, 1 > 3.7v)
    - procedure of bit transmission (e.g. synchronization, error detection…)
- Defined and bound with each communication media
  - Fit to their characteristics and attributes.
  - Normally, treated as a set of physical and data link layers.

Data Link Layer (1)

- Data Link Layer (Layer 2)
- Transmission procedure for data chunk over the communication media.
  - Working with the physical layer.
  - “frame”: bit sequence with its structure
    - data transmission unit
  - Contention and coordination with multiple nodes in a single communication media.
- Standard elements
  - identification in communication media
  - frame format
  - access procedure (MAC sub-layer)
Data Link Layer (2)

- Many standards
  - Data exchange procedure by digital leads lines (HDLC)
  - IEEE802.x series
    - Ethernet 802.3
    - Token Ring 802.5 (historic)
    - WiFi 802.11
  - Define as a DLL (e.g. ISDN…)
    - I.100 series includes call procedure and data frame definitions

- Each data link layer is normally defined with its specific physical layer.
  - physical channel and transmission procedure are tightly coupled.

Network Layer (1)

- Network Layer (Layer 3)
- Data exchange functions, which is **independent** from some specific data links.
  - define communication between ES’s (End Systems)
  - address assign for nodes
  - gateway function implement as an IS (Intermediate System)
  - definition of packet
    - Unit of data transmission in the network layer
Network Layer (2)

- Standard elements
  - Format of ES and IS addresses / identification.
  - Packet format
  - Routing mechanism of packet switching.
  - Broadcast / multicast / anycast

Transport Layer (1)

- Transport Layer (Layer 4)
- Communication between the processes in the network
  - Multiple processes exist in ES
  - Process = service provider and consumer
  - fundamental protocol for process
  - using common transport protocol in network
    - communication ES uses common transport protocol
Transport Layer (2)

- Functions of transport layer
  - provides more usable communication service than a packet switching done in Network layer.
  - Define End-to-End communications
  - Error and flow controls using retransmission of packets
  - error handling is embedded.

Upper Layer Protocols

- Protocols in session, presentation and application layers are called “Upper Layer Protocol”
  - Definition for each specific application / service
  - Implementation of the various requirements by network applications
Session Layer

- Define unit of communication
  - Transaction
  - Session

- Define process for communication unit
  - Transaction Logging & Roll-back operation
  - Session Termination

- Model definition for fundamental information processing.

Presentation Layer

- The expression of data
  - Provides a basis of expression of data properly in different platforms
  - Decimal number “1” can be encoded in multiple ways.
    - expression of “1”
      - How many byte use?
        » 1, 2, 4, less than 1 byte (6 bits), ....
      - How to go about byte order?
        » Little Endian / Big Endian
      - How to go about bit order before transmission?
        » MSB first, LSB first
Application Layer

- Protocols for applications
  - They do not define the applications; interface is defined.
  - e.g., SMTP (simple mail transfer protocol) for e-mail, with many e-mail applications that interoperate.
    - Server: sendmail, qmail, postfix, etc.
    - Client: Eudora, Mozilla Thunderbird, MS/Outlook, etc.

Hands-on...

- Have your VM ready
- See another slide-deck prepared by TAs
Conclusion

**Hierarchical Protocol**

- Step-by-step solution
- Abstraction of service in layer
  - Physical Layer: bit
  - Data Link Layer: frame
  - Network Layer: packet
  - Transport Layer: connection

- Division of interface and implementation

- Hierarchical protocol architecture can interconnect between different networks.

Assignment II
1. Please open dataset1.pcap using Wireshark or another preferred packet analysis tool. Elaborate on any particularities you identify.

2. Please open dataset2.pcap. Identify the starting frame of an attempt to access a Wikipedia page. Elaborate on what happened to that attempt.

Guidelines for submitting the assignment

- Deadline: Wednesday (04/29) 23:59
- File Naming: Name_StudentID
- Preferred file format: PDF
- Length: at most 2 pages
- Language: English / Japanese
- Send to: network1-2015@is.naist.jp
1. Wiresharkなどを使ってdataset1.pcapを解析してください。そして見つけた特徴などについて述べてください。
2. 同様にdataset2.pcapを解析してください。そしてWikipediaのページにアクセスしようとしている部分を特定してください。その部分で何が起こっているのか述べてください。

課題提出についての注意事項

- 締め切り: 水曜日（明日 4 月 29 日）23:59
- 提出ファイル名: 名前__学生ID
- ファイルフォーマット: PDF
- ページ数: 最大2ページ
- 言語: 英語 / 日本語
- Eメール: network1-2015@is.naist.jp