Chapter 2: Hierarchical Structure of Network Functionality

2. Hierarchical Structure of Network Functionality

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Protocol: Description, how multiple parties (peer entities) interact when they are jointly working on a single job.

Problems:

- Communication protocols are mainly implemented in software. Protocol implementations are complex – like most other software.
- Communication systems often use many protocols in parallel.
- Many protocols have internal states. When several protocols interact the overall state-space is equal to the Cartesian product of the individual protocol state-spaces. Hence, the overall state-space may become extremely huge.

The key problem for network designers in protocol description is complexity.

Counter measure: divide and conquer approach

- Divide whole system into sub-systems, sub-systems into sub-sub-systems, …
- Define mutually independent protocol functions (see OSI model)
- Use protocol description languages
  - UML unified modeling language
  - SDL system description language (functional description)
  - ASN.1 abstract syntax notation 1 (data structures)


2.1 OSI Model

Design principles:
- Well-defined functions in each layer.
- Each function is completely handled in a single layer.
- Restricted inter-layer communication to avoid sides-effects (service primitives).
- Symmetry: Transmitter and receiver side of a function are always located in the same layer.

The OSI model is standardized by ISO. It is based on ideas similar to TCP/IP. In practice, the TCP/IP protocol suite is more important than the OSI model. Nevertheless, the OSI reference model and the underlying design methodology is frequently used in standardization and network design.

Hierarchical structure of the OSI model:
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Example:

American inventor has a patent

Formulation of the description

Writing a letter

Put in envelope, address and mail

Letter sorting process

Packaging the letter in a letter bag

Loading the letter bag on a plane

German engineer understands patent

Translation from English into German

Reading of the letter

Letter delivery and opening

Empty to letter bag

Empty to letter bag

Unload the letter bag from the plane

Unload the letter bag from the truck

Letter sorting process

Packaging the letter in a letter bag

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2.1.1 Physical Layer

Main goal:
- Mapping of information onto a signal, i.e., change the state of a physical object according to the information.
- Transport the physical object.
- Recover information from the state of the received physical object.

Second goal: physical channel multiplexing, i.e. a single physical medium is used by several independent links in parallel (divide a channel into several independent sub-channels).
Example: Frequency multiplex of TV channels.

2.1.2 Data Link Control Layer

The DLC has two sub-layers:

2.1.2a Medium access control
Medium access protocols avoid that several users disturb each other’s data transmission and assign transmission capacity in a fair way.
- Multiplex: separate sub-channels, independent usage
- Multiple access: single channel, shared usage
- Examples: Ethernet, Token Ring, ALOHA
2.1.2b Logical link control

Main goal: Provide reliable point-to-point link (no bit-errors)
Other goals: Link related ciphering and message integrity protection

Logical channel: Super imposed to physical channel, considers only information and no signal or physical objects.

Non-real time data transmission:
- Split data stream into frames (frame synchronization required)
- Add checksum (parity check bits, CRC)
- Verify correctness of checksum on receiver side
- Request transmitter to repeat frames with incorrect checksum
- Very low residual bit-error rate
- Memory required in transmitter and in some cases also in the receiver
- Delay and reduced throughput, when frames have to be repeated

Transparent data transmission (real time services like voice or video):
- No delay permitted
- Error-detection by checksum
- Error-concealment: muting in speech transmission, repetition of previous, already correctly received image in video transmission

2.1.3 Network Layer

Main goal:
- Routing: Find a way from sender to receiver which satisfies the requested Quality of Service (QoS), i.e. data rate, error-rate, packet loss, delay, …
- Switching: Forwarding of traffic according to a route determined before by the routing procedure. (Note: Switching differs for connection-oriented and connectionless services)
- Flow control: Protect network links from overload; otherwise risk of deadlock or break down of parts or even complete network. (methods: clever routing, queuing of incoming traffic, discarding/blocking low-priority traffic)

For mobile radio networks: Extended routing and flow control mechanisms

Mobility management:
- Handles changing user location
- Central location data base: HLR
- Actual location data base: VLR
- Paging: notify user in unknown location of incoming call
Radio resource management:
- Optimize usage of radio resources
- Admission control - long term
- Load control - intermediate
- Congestion control - short term

2.1.4 Transport Layer

Main goal:
- Provide a reliable end-to-end data transport
- ARQ protocols like in LLC layer to request retransmission of erroneous or missing packets

Second goal:
- Provide high-speed end-to-end connection by distributing traffic onto multiple network connections (downward multiplexing: multiple connections used by one user, in contrast to upward multiplexing: one connection shared among multiple users)

2.1.5 Session Layer

Main goal:
- Controls communication between processes (e.g. handling of interruptions) and access to services or system resources

2.1.6 Presentation Layer

Main goal:
- Handles syntax and semantics of data
- Conversion of data structures, e.g. character sets
- Source coding (speech compression, data compression)
- Cryptographic end-to-end ciphering, integrity protection of documents, authentication of communication parties

2.1.7 Application Layer

Services provided to the user:
- Telecommunications: phone, fax, SMS
- Broadcast: radio, TV
- Data communications: file transfer, remote login, e-mail, HTTP, …
2.1.8 Common issues of all layers

Addressing:
- Networking means that resources are shared and used jointly in parallel.
- Address headers describe where to deliver certain data.

Segmentation, fragmentation:
- Split long data streams into pieces which are more convenient to handle
- Add headers and sequence numbers to each piece.
- **Segments**: Add checksum for ARQ, i.e. each segment can be retransmitted individually
- **Fragments**: No individual checksum, hence no retransmission of pieces. Only retransmission of complete data stream after reassembly.

Connection setup, maintenance, release: (connection-oriented services only)
- **Setup**: Common understanding between peer entities on parameters (modulation alphabet, data rate, QoS, frame/packet size, …)
- **Maintenance, reconfiguration**: Check that connection is alive, adjust parameters
- **Release**: Declare resource as free again.

2.2 Communication in the OSI Model

Entity:
- Some parts of the OSI model have to be realized in hardware, while some parts are realized in software. However, all functional units are called *entities*.
- Hence, terminals, network nodes, processes, users, … are entities.
- In the OSI model direct communication is only allowed between entities of adjacent layers N,N-1
- Exchange of service primitives at a service access point (SAP) between the layers.
- A *service primitive* can be considered as a call of a subroutine, i.e. a message or parameter exchange between processes.
- Frequently used services/service primitives: connect (connection properties), data (transmission of data), disconnect
- Peer-to-peer communication (protocols) is realized indirectly between opposite entities of the same layer. Example: ARQ protocol (layer 2) sends ACK or NAK via PHY (layer 1), without PHY understanding these data.
2.3 **OSI Data Structure**

- We distinguish between packet data units (PDU) and service data units (SDU).
- The PDU of layer N becomes the SDU at layer N-1.
- At layer N-1 a header is added to the SDU and the resulting packet is the PDU of layer N-1.
- The header contains information such as address, segment number, PDU length.
- The contents of a SDU is transported without being evaluated in any way.
2.4 Switching Entities in TCP/IP and OSI

**Repeater:** signal regeneration
- Same signal on both sides
- Longer distances
- Mobil radio, e.g. in narrow valleys

**Bridge:** connection of LANs
- Handles (different) medium access protocols
- Promiscuous mode: copy all frames
- *Self-learning:* determine “who is where” by observation; copy frames selectively
- *Source-routing:* route description included in header by sender; copy frames accordingly.

**Router:** connection between LANs
- Exchange of network state information
- Ability to determine route through network

**Gateway:** Network connection on higher layers
2.5 Remarks

- Implementation of inter-layer communication (SAP) is not specified in OSI. Hence, highly vendor specific.
- Integration of complete physical entities of different vendors in a single network is possible.
- Building a protocol stack in a single physical entity from layers of multiple vendors is difficult!
- Inter-layer communication can be time consuming. This is critical in realtime applications, e.g. speech transmission.
- Shortcuts by management backplane
- Sometimes separate protocol stacks for user data and control data