REAL-TIME SYSTEMS II
Real-Time Networking
Layers and impact on QoS

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Outline
- ISO Open Systems Interconnection (OSI) model
- Physical layer impact
- Data link layer impact
  - Medium access control
  - Logical link control
- Network and transport layers impact
- Application layer impact
  - Interaction models

ISO OSI Model
- ISO: International Standards Organization
- OSI: Open System Interconnection

Physical Layer
- Transport of bits
- Characteristics
  - Mechanical
  - Electrical (voltages, currents, impedance, baud rate, modulation, bit encoding, synchronisation, etc.)
  - Functional (topology, repeaters, etc.)
Data Link Layer

- Groups bits in frames
- Frame synchronization
- Detection (correction) of errors
- Flow control
- Management of access to medium
- Is often dependent on the physical layer

Network layer

- Routing of packets across links
- Flow congestion / control
- Gives a unique address over the network

Transport layer

- End to end reliable and transparent transport of information on a network
  - Checking and correcting errors
  - Flow regulation
- Establishment (release) of virtual circuits
- Multiplexing of virtual circuits

Session layer

- Management of dialog
  - Definition of synchronization points
  - Return to known state
Presentation layer

- Format conversion
  - To and from transfer syntax
- Ciphering
- Data compression

Application layer

- The only one visible to the application
- Add semantics to the information transfers
  - Defines concepts
  - Provides services
- Ex. FTP, SNMP, HTTP

Interconnections

- Repeaters
  - physical layer
- Bridges
  - data link layer
- Routers
  - network layer
- Gateways
  - application layer

See [Perlman, 2000]

Repeaters

- Used when the protocols on all layers are identical on both sides
- Connect two data circuits
- Expand the distance covered by (or the number of devices connected to) a data link whether wireless or wired.
- Regenerate the signals received on one side and transmit them on the other side and vice-versa.
- On some occasions, may also be used to interconnect a wireless cell to a wired link
  - Word repeaters
- Ethernet hubs are an example of repeaters.
Bridges

- Interconnect subnetworks using the same layer protocols above the data link layer
- Interconnect data links
- Both sides must also use compatible addressing information
- Examples:
  - IEEE 802.11 base stations interconnect an Ethernet based link and a wireless cell.
  - An Ethernet switch is used to interconnect two or more Ethernet links.

Routers

- Operate at the network layer level
- Their task is to find a route to convey a message from a source to a destination
  - Exchange information between themselves in order to find such a route
  - Can thus find an optimum path between two nodes whereas bridges only use a subset of the available topology.
- Difference with bridges
  - Bridges are transparent, routers are not
  - Routers modify the packets they forward in particular their address fields

Gateways

- Used when the protocols at the application layer are different on both sides
- Translate the messages from one protocol to the other one.
- Examples:
  - Connecting a Profibus or a CAN Open network to the Internet using HTTP over TCP/IP, requires a gateway because the protocols are different at all layers.
  - Sometimes called “proxies”

Impact of layers on QoS

- Observable properties of the network
  - Transfer delay bounds
  - Transfer delay variations (jitter)
  - Throughput
- All layers have an impact but some more than others
Physical layer

- Topology and physical limitations
  - How many nodes may be reached in one hop?
- Bit rate (not Baud rate)
- Signal to noise ratio
  - Bit error rate
- Resilience to interferences
  - Bit error rate
  - Bursts of errors on bits

Topologies in offices

- Topologies in offices

- Topologies in factories

- Medium Access Control
  - Access mechanism
    - May be influenced by priorities
  - Error detection scheme
    - Performance of error detection
  - Error correction scheme
    - Automatic Repeat reQuest (stop and wait, selective repeat, Go back N)
    - FEC
    - Hybrid FEC-ARQ
  - Packet delimitation
    - Packet error rate
Access mechanism

- How to isolate the emissions from different sources
- 3 basic choices
  - Use different frequency bands
    - Frequency Division Multiple Access (FDMA)
  - Emit at different instants
    - Time Division Multiple Access (TDMA)
  - Use a combination of both
    - Code Division Multiple Access (CDMA)
      - CDMA is also used to spread the spectrum of emission

FDMA

- Different transmitters use different channels
  - There is often some overlap between adjacent channels
    - Example: 802.11 (14 channels, but no more than 4 at any given place)
- Hardly used in wired LANs
- Used in some WLANs to mitigate interferences (for instance DECT, wirelessHART)

TDMA

- All nodes use the same frequency but at different instants
- Some temporal synchronisation is thus required
- Advantages
  - The bandwidth can be adapted according to the emitter
  - It is possible to power off the emitter in absence of emission
- Drawbacks
  - Additional load due to synchronisation
  - More problems (than with CDMA) with multiple paths

CDMA

- Separation in time and space
- Two principles
  - Direct sequence: each bit is converted into a sequence of chips
  - Frequency hopping: each transmission is performed at a different carrier frequency
- Advantages
  - Difficult to spy, rather insensitive to perturbations, no need for synchronisation, cells may use the same frequency band
- Drawbacks
  - Complex, requires control of emission power, requires a large frequency band
FDD and TDD

- 2 ways to handle full duplex operations
  - FDD (Frequency Division Duplexing)
    - Each direction uses a different band
  - TDD (Time Division Duplexing)
    - Both directions use the same band but at different instants

TDMA

- Predetermined
  - Each node has one (or more) slots in time
  - Usually called “TDMA” or “pure TDMA”
- Centralised access control
  - Polling, probing
- Decentralised techniques
  - Reservation

Centralised access

- One master station / N slave stations
  - A slave station may only transmit as a response to the master station
- Advantages
  - Simple, the master is the unique point of coordination
  - Easy to adapt polling to slaves needs
  - Worst case polling time can be calculated
    - Good point for real-time applications
- Drawbacks
  - The master is a hot point for reliability
  - The master is used in each transfer -> additional delays
  - Not very efficient when few slaves are active (or numerous slaves)
    - Can be improved by probing

Distributed access

- Appealing as compared to centralized techniques
  - More reliable
  - Access delays often shorter
  - Better use of the bandwidth
  - No need for planning (i.e. in case of multiple wireless cells)
- drawbacks
  - Often more complex
  - Not always easy to predict temporal properties
Distributed access techniques

- Static (predetermined)
- Distributed probing
- ALOHA
- Carrier Sense Multiple Access (CSMA)
- Ethernet
- CSMA/CA
- Token bus
- Token ring

Classification of some solutions

- Distributed
  - Deterministic
  - Contention
- Centralized
  - Periodic
  - Aperiodic

  - Periodic: FIP
  - Aperiodic: SDLC, PROFIBUS

Logical Link Control

- Connectionless services
  - QoS: priority
  - SDN (Send Data with No ack)
    - Unacknowledged connectionless-mode data transfer
      - DL-UNITDATA request - DL-UNITDATA indication
  - SDA (Send Data with Ack)
    - Acknowledged connectionless-mode data unit transmission service
  - RDR (Request Data with Reply) or SDR (Send Data with Reply)
    - Acknowledged connectionless-mode data unit exchange service
      - DL-REPLY-UPDATE request DL-REPLY-UPDATE-STATUS indication

Reservation

- When a node wants to transmit (for a long period)
  - Gets access and signals its request
  - Request is granted and resources are allocated
    - Resources may be slots or medium for a given duration
  - When the node no longer needs the resources, it releases them (may be automatic)
- There is no conflict on the resource use
- There might conflicts in the requests
- Widely used technique (cellular phones, 802.11, …)
- Interesting from the QoS perspective
Logical Link Control (2)

- Connection oriented service
  - QoS: priority
- Connection establishment
  - DL-CONNECT request -- DL-CONNECT indication -- DL-CONNECT response -- DL-CONNECT confirm
- Data transfer
  - DL-DATA request -- DL-DATA indication
- Termination
  - DL-DISCONNECT request -- DL-DISCONNECT indication
- Reset
  - DL-RESET request -- DL-RESET indication -- DL-RESET response -- DL-RESET confirm
- Flow control
  - DL-CONNECTION-FLOWCONTROL request -- DL-CONNECTION-FLOWCONTROL indication (parameter: amount of data allowed)

Send Data No acknowledge (SDN)

- No temporal problem (except access control)
- Possible response is separated (adds time)
- May be used to synchronise (multicast or broadcast)

Send Data with Ack. (SDA)

- No temporal problem (except access control)
- Possible response is separated (adds time)

Request Data with Response (RDR)

- Good to decouple requester from provider applications
- Requires quick response
  - Problem with some implementations (i.e. 802.11)
Send Data with Response (SDR)

- Good to decouple requester from provider applications
- Requires quick response

DL-REPLY request

Layer 2

data

channel

DL-REPLY STATUS indication

DL-REPLY-UPDATE request

Layer 2

data

DL-REPLY-UPDATE STATUS indication

DL-REPLY indication

Network Layer

- QoS negotiation and admission control
- Resource reservation
- Packet buffering and scheduling
- Resource management
- Routing table management
  - See [Pragyansmita]

- Metrics
  - Bandwidth, delay, delay variation (jitter)

Network Layer (2)

- Enabling QoS routing of data
  - Consider various metrics to select the best route
  - Provide a fair bandwidth to non QoS flows
  - Graceful performance degradation

- Approaches
  - Statefull: manage per flow state & perform per flow operations
    - Intserv + RSVP
  - Stateless:
    - DiffServ (different behavior between core and edge routers)

Transport Layer

- Connection establishment and release
- Flow control mechanisms
- Error control mechanisms
ISO transport layer QoS parameters

- Connection establishment delay: max. acceptable time between a transport connection being requested and its confirmation being received by the user
- Connection establishment failure probability: probability that a connection cannot be established within the max. delay
- Connection release delay: max. acceptable delay between a user initiating release of a connection and actual release at peer user
- Throughput: number of bytes of user data sent per unit of time
- Transit delay: elapsed time between submission and delivery
- Residual error rate: ratio of incorrect, lost and duplicate TSDUs to the total number sent
- Transfer failure probability: ratio of total transfer failures to total transfer samples during a given window

ISO transport layer QoS parameters

- Connection Release Failure Probability: fraction of connection release attempts that did not complete within the connection release delay interval (as agreed)
- Protection: used by the user sender to specify interest in having the transport protocol provide protection against unauthorized third parties reading or modifying the transmitted data.
- Priority: used to specify the relative importance of transport connections. In case of congestions or the need to recover resources, lower-priority connections are degraded or terminated before higher-priority ones.
- Resilience: probability that the transport protocol will spontaneously terminate a connection due to internal or network problems [Iren 99]

Session and Presentation Layers

- Session layer
  - Check points
    - Frequency of check pointing impact time lost for recovery
- Presentation layer
  - Compression
  - Transfer syntax compactness

Application Layer

- Interaction model [Thomesse 93]
  - Client-server
    - Need to wait until server responds
  - Publish-subscribe
    - Temporal decoupling between the publisher and the user
  - Producer-consumer
References

- ISO/IEC 8802.2: 1998. Information technology - Telecommunications and information exchange between systems - Local and metropolitan area networks - Specific requirements. Part 2: Logical link control

References (2)