Local Area Networks (LANs)

Principles, Standards IEEE 802,
Logical Link Control (LLC)

LAN History

- Local Area Network (LAN), invented late 70's
  - initially designed for a common transmission medium
  - shared media
  - high speed
    - 4 Mbit/s, 10 Mbit/s, 16 Mbit/s, 100 Mbit/s
    - nowadays up to 10 Gbit/s
  - limited distance
    - up to some km
    - hence local
  - because of high speed
    - no network elements with store and forward and no routing
    - originally no packet switching on layer 2 !!!
    - note: Ethernet bridging / Ethernet switching invented as L2 packet switching technology in the late 80's
  - therefore simple topologies
    - bus, ring, star

Agenda

- Introduction
- IEEE 802
- Logical Link Control

- Local Area Network (LAN)
  - all network stations share the same media
  - all stations have equal rights
    - no Master - Slave
  - a station can directly communicate with all other stations of the same LAN
  - basis for client - server computing
  - basis for distributed computing
  - high speed extension of internal computer bus
LAN Characteristics

- multipoint line
  - access control necessary
  - Media Access Control (MAC)
- addressing necessary
  - MAC-Address
  - unstructured addresses
  - note: there were initially no routing requirements because store and forward (packet switching) done by CPUs was too slow!
- broadcast behaviour
  - message sent out by one station reaches all other stations on same LAN
- layer 1 and layer 2 of the OSI model
  - are sufficient to fulfill communication aspects on LAN

MAC Addresses

- every station
  - is identified by unique MAC-address used as source MAC-address in frames
    - so called “Burn-In” Address (BIA) in case address is administered universally by IEEE
- MAC address
  - 6 Byte (48 bit)
    - I/G (Individual/Group) bit
      - 0 … individual address
      - 1 … group address
    - U/L (Universal/Local) bit
      - 0 … universal administered
      - 1 … local administered

IEEE-MAC-Address Format

- I/G Individual / Group (only for DA):
  - I/G = 0 individual address, I/G = 1 group broadcast
    - broadcast for a group is called multicast
      - address with all bits set to 1 ... Broadcast-address has FFFF FFFF FFFF (note: U/L is set to 1)
- U/L Universal / Local:
  - U/L = 0 global address, administered by IEEE
  - U/L = 1 local administered address
    - bit 47 (x) not used for source address
IEEE Administered Addresses (U/L = 0)

IEEE assigns each vendor of network components an unique vendor code (OUI, byte 0, 1, 2) vendors use byte 3, 4 and 5 for numbering their network components (serial number) called “Burned In” Address (BIA)

Receipt of frames (1)

• every frame is received by the Network Interface Card (NIC) of the station – because of the inherent broadcast behaviour of a LAN
• the NIC decides if a frame should be forwarded to the higher layers (3-7) of a station – depending on its BIA and the destination address of the frame – usually NIC interrupts the CPU of the station if frame is to be forwarded – otherwise frame is silently discarded by the NIC

Receipt of frames (2)

• higher layers (3-7) will see a received frame only – if destination MAC-address is equal to the station MAC-address – if destination MAC-address of the frame is the “all broadcast” address – if a multicast address was configured in the station and the destination MAC-address is equal to the configured
• to avoid interruption of all stations by broadcast frames – frames are destined to station specific MAC-addresses during normal operation – broadcast should be used in initialization phases of a network only

Direct Communication

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computer B

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computer C

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computer D

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MAC A

MAC B

MAC C

MAC D

computer B (SA) -> computer C (DA)
Broadcast application

computer A

7 6 5 4 3 2 1

MAC A

computer B

7 6 5 4 3 2 1

MAC B

computer C

7 6 5 4 3 2 1

MAC C

computer D

7 6 5 4 3 2 1

MAC D

computer B (SA) -> Broadcast (DA)

Multicast application

computer A

7 6 5 4 3 2 1

MAC A+Group1

computer B

7 6 5 4 3 2 1

MAC B

computer C

7 6 5 4 3 2 1

MAC C+Group1

computer D

4 3 4 3 4 3 4

MAC D

computer B (SA) -> Group1 (DA)

Agenda

- Introduction
- IEEE 802
- Logical Link Control

IEEE 802

- LAN Standardization is done
  - by IEEE (Institute of Electrical and Electronics Engineers)
  - workgroup 802 (February 1980)

- OSI Data Link Layer (Layer 2)
  - was originally designed for point-to-point line
  - but LAN = multipoint line, shared media

- therefore OSI Layer 2 must be split into two sublayers
  - Logical Link Control
  - Media Access Control
IEEE 802 versus OSI

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<th>OSI Layer 2</th>
<th>OSI Layer 1</th>
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<tr>
<td>802.1 Management</td>
<td>Physical Layer (OSI Layer 1)</td>
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<tr>
<td>802.2 Logical Link Control (LLC)</td>
<td>PHY (MAU, AUI, PLS)</td>
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<td>802.3 CSMA/CD</td>
<td>802.4 Token Bus</td>
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<tr>
<td>802.5 Token Ring</td>
<td>802.6 MAN DQDB</td>
</tr>
<tr>
<td>MAC (Medium Access Control)</td>
<td>Data Link Layer (OSI Layer 2)</td>
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Tasks of LAN Layers

- **layer 1**
  - physical layer (PHY) specifies actual transmission technique
  - provides
    - electrical/optical and mechanical interface
    - encoding
    - bit synchronisation
  - consists of
    - MAU (Medium Attachment Unit)
    - AUI (Attachment Unit Interface)
    - PLS (Physical Layer Signalling)

- **layer 2**
  - MAC (Media Access Control) takes care for medium access algorithms, framing, addressing and error detection
    - avoid collisions
    - grant fairness
    - handle priority frames
  - LLC (Logical Link Control) provides original services of data link layer
    - connection-oriented services
    - connection-less service
    - SAPs (Service Access Points) for the higher layers

The IEEE Working Groups

- 802.1 Higher Layer LAN Protocols
- 802.2 Logical Link Control
- 802.3 Ethernet
- 802.4 Token Bus
- 802.5 Token Ring
- 802.6 Metropolitan Area Network (DQDB, MAN)
- 802.7 Broadband TAG
- 802.8 Fiber Optic TAG
- 802.9 Isochronous LAN (VGAnyLAN)
- 802.10 Security
- 802.11 Wireless LAN (WLAN)
- 802.12 Demand Priority
- 802.13 Not Used
- 802.14 Cable Modem
- 802.15 Wireless Personal Area Network (Bluetooth)
- 802.16 Broadband Wireless Access
- 802.17 Resilient Packet Ring
### IEEE 802.x Standards

- **IEEE 802.2**  
  - LLC (Logical Link Control)
- **IEEE 802.3**  
  - CSMA/CD, “Ethernet”
- **IEEE 802.4**  
  - Token-Bus
- **IEEE 802.5**  
  - Token-Ring
- **IEEE 802.6**  
  - DQDB (Distributed Queued Dual Bus) for MAN (Metropolitan Area Network)

### IEEE 802.1 Standards

- **IEEE 802.1**  
  - specifies a common framework for all 802.x LANs  
    - addressing rules, relations to the OSI model  
    - subnet addressing, Bridging Ethernetv2 to 802.2 LANs  
    - Management (802.1B)  
    - Bridging (802.1D) including STP (Spanning Tree Protocol)  
      - Single STP in case of VLANs  
    - System Load Protocol (802.1E)  
    - Virtual (V) LANs (802.1Q)  
      - Tagging  
    - STP Rapid Configuration (802.1w)  
    - Multiple STP (802.1w)  
      - Multiple STP instances in case of VLANs  
    - EAP Authentication (802.1x)  
      - Extensible Authentication Protocol

### Agenda

- **Introduction**
- **IEEE 802**
- **Logical Link Control**
LAN Framing with LLC

- Every data block is encapsulated in a L2 LAN frame.
- L2 LAN frame consists of:
  - MAC header
  - Followed by LLC in case of IEEE 802 LAN
  - MAC trailer
- MAC header and trailer are LAN type specific.

**MAC Header**

- LLC header is appended to higher layer data
- DSAP (Destination Service Access Point), 8 bit
- SSAP (Source Service Access Point), 8 bit
- Control Field, 8 or 16 bit

**LLC Header**

- DSAP and SSAP:
  - Used by different protocol families sharing the same communication media
  - E.g. TCP/IP parallel to Novell IPX, IBM SNA, NetBeui, Appletalk
  - Identify the higher level protocol family, which is the destination and the source of the given frame
  - Protocol type or protocol stack identifier

**Protocol Stack Distinction**

- TCP/IP
- Application
- Application
- TCP/IP
- Application

- Novell
- IPX
- SPX
- Novell
- IPX
- SPX

- DSAP = 06 SSAP = E0 DSAP = 06 SSAP = E0

- DSAP = 06 SSAP = ED DSAP = 06 SSAP = ED

- MAC B SA B DA C SSAP 06 DSAP 06

- MAC C MAC B SA B DA C SSAP 06 DSAP 06
DSAP and SSAP structure

<table>
<thead>
<tr>
<th>0</th>
<th>1</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>14</th>
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<td>U</td>
<td>I/G</td>
<td>SSAP</td>
<td>U</td>
<td>C/R</td>
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</table>

- I/G = 0 ... Individual DSAP
- I/G = 1 ... Group DSAP
- C/R = 0 ... Command
- C/R = 1 ... Response

U = 0 ... user defined
U = 1 ... IEEE defined

Values for DSAP / SSAP

- 128 values possible for I/G = 0
  - 63 are reserved for IEEE protocols (U = 1)
  - 63 for vendor specific protocols and for free application usage (U = 0)
  - examples:
    - Hex 00 .......... Null SAP
    - station with running LLC software always responds to a frame destined to the Null SAP -> LLC Ping can be implemented
    - Hex 03 .......... LLC sub-layer group management (U=1, I/G=1)
    - Hex 06 .......... DoD IP (U=1)
    - Hex 42 .......... 802.1d Spanning Tree Protocol (U=1)
    - Hex AA .......... TCP/IP SNAP (U=1)
    - Hex FE .......... ISO Network Layer (U=1)

- examples (cont.):
  - Hex E0 .......... Novell (U=0)
  - Hex Fy .......... reserved for IBM (U=0)
  - Hex F0 .......... NetBIOS (U=0)
  - Hex F4 .......... IBM LAN manager individual (U=0)
  - Hex F5 .......... IBM LAN manager group (U=0, I/G =1)
  - Hex F8 .......... remote program load (U=0)
  - Hex 04 .......... SNA path control individual (U=0)
  - Hex 05 .......... SNA path control group (U=0, I/G =1)

- range Hex 8y to 9C (with U=0)
  - is reserved for free usage
  - except y = xx1x (binary notation); U=1

Values for DSAP / SSAP

LLC Control Field

- LLC Control field and protocol procedures are very similar to HDLC
  - remember: HDLC procedures allow connection-less and connection-oriented services on a layer 2 link

- connection-less mode of LLC is used by
  - IP, IPX, AppleTalk, etc

- connection-oriented mode of LLC is used by
  - SNA over LLC Type 2
  - NetBIOS over LLC Type 2 (NetBeui)
    - e.g. Microsoft Network (old style – already obsoleted)
LLC Control Field

- **four service methods defined for LANs**
  - **Class 1:**
    - connectionless unacknowledged service (datagram)
    - type 1 - frames: UI,XID,TEST
  - **Class 2:**
    - connection oriented service plus Class 1
    - type 2 - frames: I,RR,RNR,REJ,SABME,UA,DM
  - **Class 3:**
    - Class 1 plus connectionless acknowledged service
    - type 1 - frames plus additional type 3 - frames: AC0, AC1
  - **Class 4:**
    - Class 2 plus connectionless acknowledged service
    - type 2 - frames plus additional type 3 - frames: AC0, AC1

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**LLC Procedures and Service Types**

1. **Datagram Service**
   - UI (Unnumbered Information) -> Datagram Info
   - XID (Exchange Identification) -> LLC Ping
   - TEST -> Ping plus test data

2. **Connection Oriented Service**
   - SABME (Set Asynchronous Balanced Mode Ext.)
     - connection establishment
   - UA (Unnumbered Acknowledgement)
     - connection establishment acknowledgement
   - DM (Disconnected Mode)
     - negative acknowledgement for connection establishment or connection abort
   - DISC (Disconnect)
     - connection tear down
LLC Procedures and Service Types

- I (Information)
  - data frame
- RR (Receiver Ready)
  - ACK plus station ready
- RNR (Rec. Not Ready)
  - ACK plus station not ready
- REJ (Reject)
  - NACK with GoBackN
- FRMR (Frame Reject)
  - for signalling error situations

Acknowledged Datagram-Service

- ACx command with data immediately acknowledged by ACx response, next ACy command only after arrival of ACx
- Idle RQ protocol (stop and wait)

LAN Framing with Ethernetv2

- every data block is encapsulated in an Ethernetv2 LAN frame
- most common framing used today
- only connectionless service possible on layer 2
- LAN frame consists of
  - Ethernet MAC header
  - Protocol stack identified by protocol type field in MAC header
  - Ethernet MAC trailer

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