Local Area Networks (LANs)

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

Agenda

- **Introduction**
- **IEEE 802**
- **Logical Link Control**

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

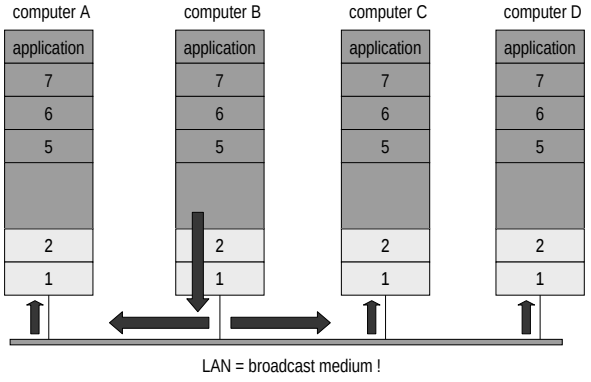
LAN History

- **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 fulfil communication aspects on LAN

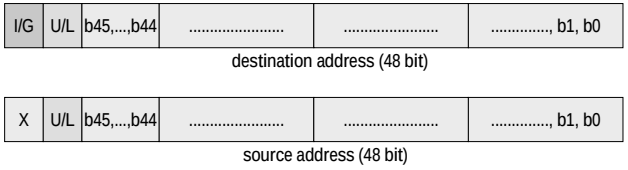
LAN Communication



MAC Addresses

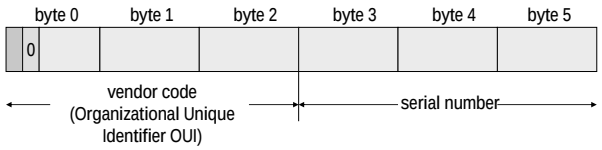
- **every station**
  - is identified by unique MAC-address used as source MAC-address in frames
    - so called “Burn-In” Address (BIA) in case address is administered universally by IEEE
- **MAC address**
  - 6 Byte (48 bit)
  - I/G (Individual/Group) bit
    - 0 … individual address
    - 1 … group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

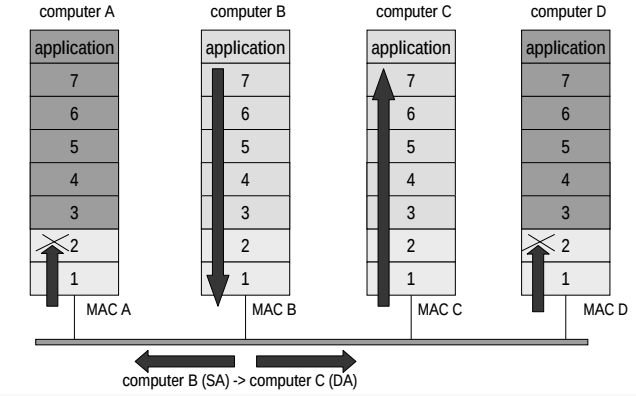
Receipt of frames (1)

- **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

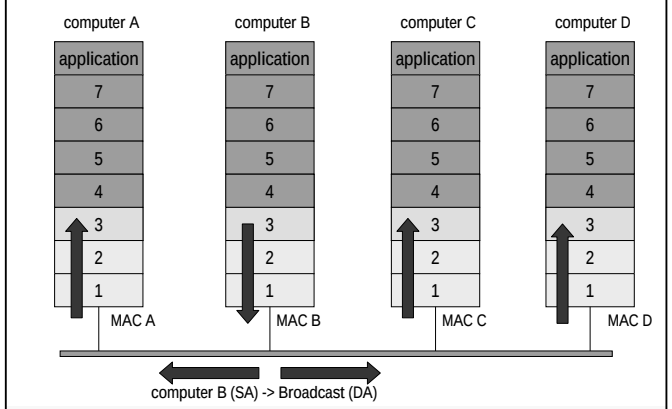
Receipt of frames (2)

- **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

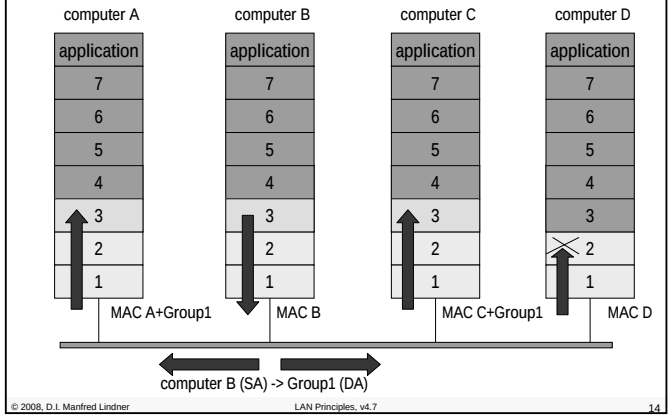
Direct Communication



Broadcast



Multicast



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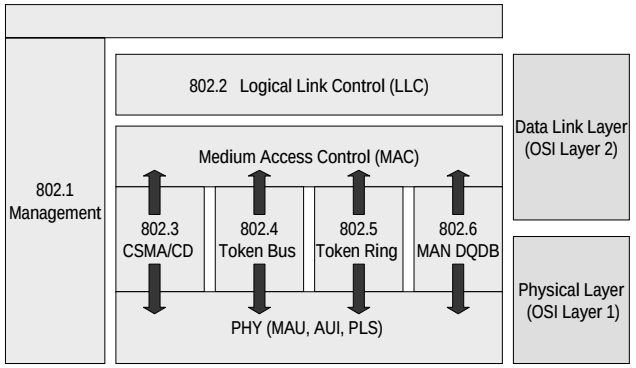
IEEE 802

- **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



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)

Tasks of LAN Layers

- **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.x Standards

- **IEEE 802.10**
  - Interoperable LAN/MAN Security
- **IEEE 802.11**
  - Wireless LAN
- **IEEE 802.12**
  - Demand Priority Access Method, VGAnyLan
- **IEEE 802.15**
  - Wireless Personal Area Networks, “Bluetooth”
- **IEEE 802.16**
  - Fixed Broadband Wireless Access
- **IEEE 802.17**
  - Resilient Packet Ring

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

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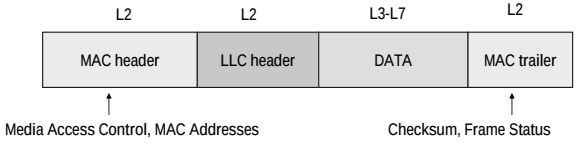
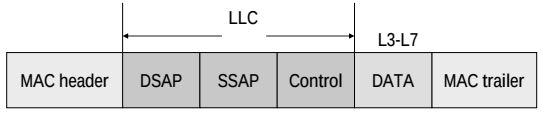
LAN Framing with LLC

- **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**



LLC Header

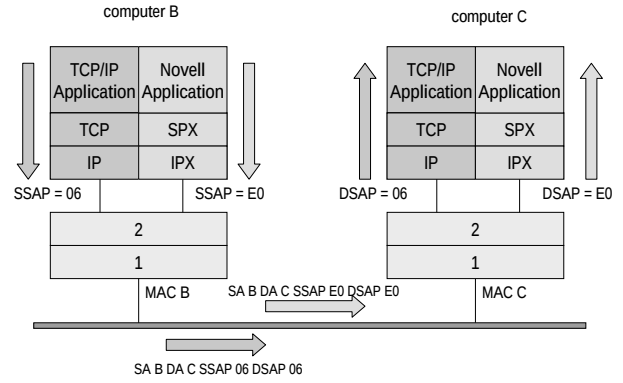
- **LLC header is appended to higher layer data**
  - DSAP (Destination Service Access Point), 8 bit
  - SSAP (Source Service Access Point), 8 bit
  - Control Field, 8 or 16 bit



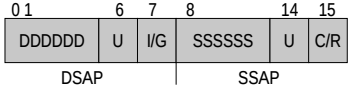
DSAP and SSAP

- **a IEEE 802 LAN**
  - can be used by different protocol families sharing the same communication media
    - e.g. TCP/IP parallel to Novell IPX, IBM SNA, NetBeui, Appletalk
- **DSAP and SSAP**
  - 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



DSAP and SSAP structure



I / G = 0 ... Individual DSAP
I / G = 1 ... Group DSAP

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

C/ R = 0 ... Command
C/ R = 1 ... Response

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)

Values for DSAP / SSAP

– 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

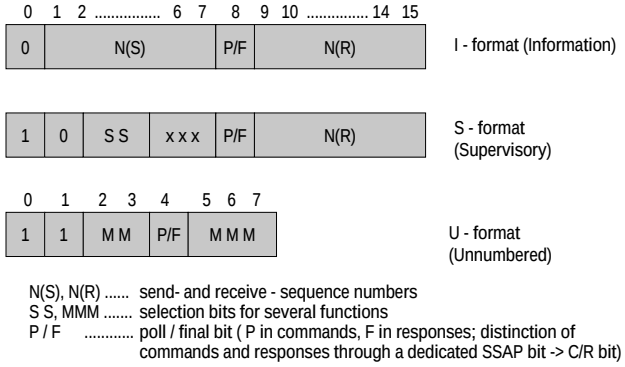
LLC Control Field

- **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

LLC Control Field



N(S), N(R) ..... send- and receive - sequence numbers
S S, MMM ..... selection bits for several functions
P / F ..... poll / final bit (P in commands, F in responses; distinction of commands and responses through a dedicated SSAP bit -> C/R bit)

Frame Types and Classes

	Cmd	Control	Resp	Control	Class 1	2	3	4
Type 1	UI	1100p000			x	x	x	x
	XID	1111p111	XID	1111f111	x	x	x	x
	TEST	1100p111	TEST	1100f111	x	x	x	x
Type 2	I	0 n(s) p n(r)	I	0 n(s) f n(r)		x		x
	RR	10000000 p n(r)	RR	10000000 f n(r)		x		x
	RNR	10100000 p n(r)	RNR	10100000 f n(r)		x		x
	REJ	10010000 p n(r)	REJ	10010000 f n(r)		x		x
	SABME	1111p110	UA	1100f110		x		x
	DISC	1100p010	DM	1111f001		x		x
			FRMR	1110f001		x		x
Type 3	AC0	1110p110	AC0	1110f110			x	x
	AC1	1110p111	AC1	1110f111			x	x

LLC Procedures and Service Types 1

- **Datagram Service**
  - UI (Unnumbered Information) -> Datagram Info
  - XID (Exchange Identification) -> LLC Ping
  - TEST -> Ping plus test data
- **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 2

- 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