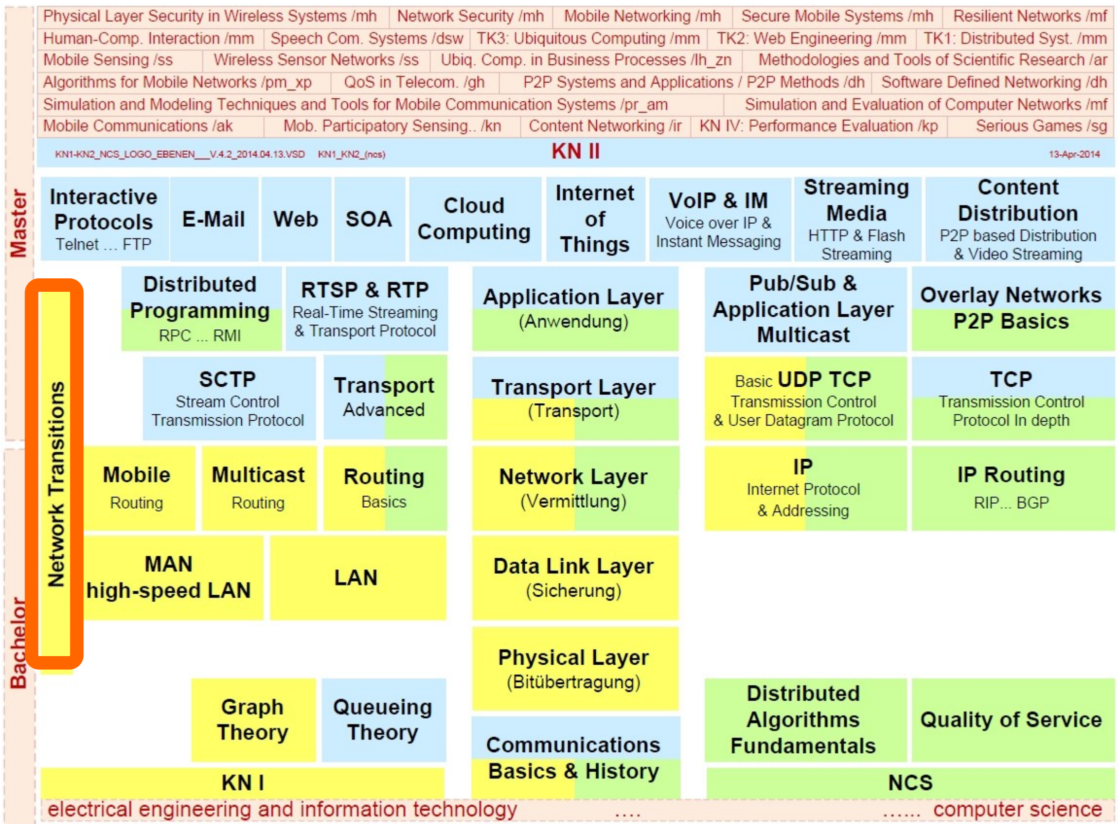
Communication Networks I

Network Transitions



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Overview

1 Motivation

Many heterogeneous networks

- past, nowadays, in future

Heterogeneous network technologies (data link):

- WAN: telephone networks, ISDN, ATM, ...
  mobile comm.: GSM, UMTS, DECT, Bluetooth, Zigbee, ...
- LAN: 802.3, 802.4, 802.5, 802.11, 802.16, ...
- MAN: FDDI, ...

Heterogeneous protocol architectures:

- former SNA (> 20 000 networks), DECNET (> 2000)
- OSI, ...
- Novell NCP/IPX, Appletalk (world of PCs in former times)
- TCP/IP (world of Unix, also world of PCs)

Heterogeneous application architectures (with same overall purpose):

- Email, Peer-to-Peer protocols
- Information access (WWW, WAP)

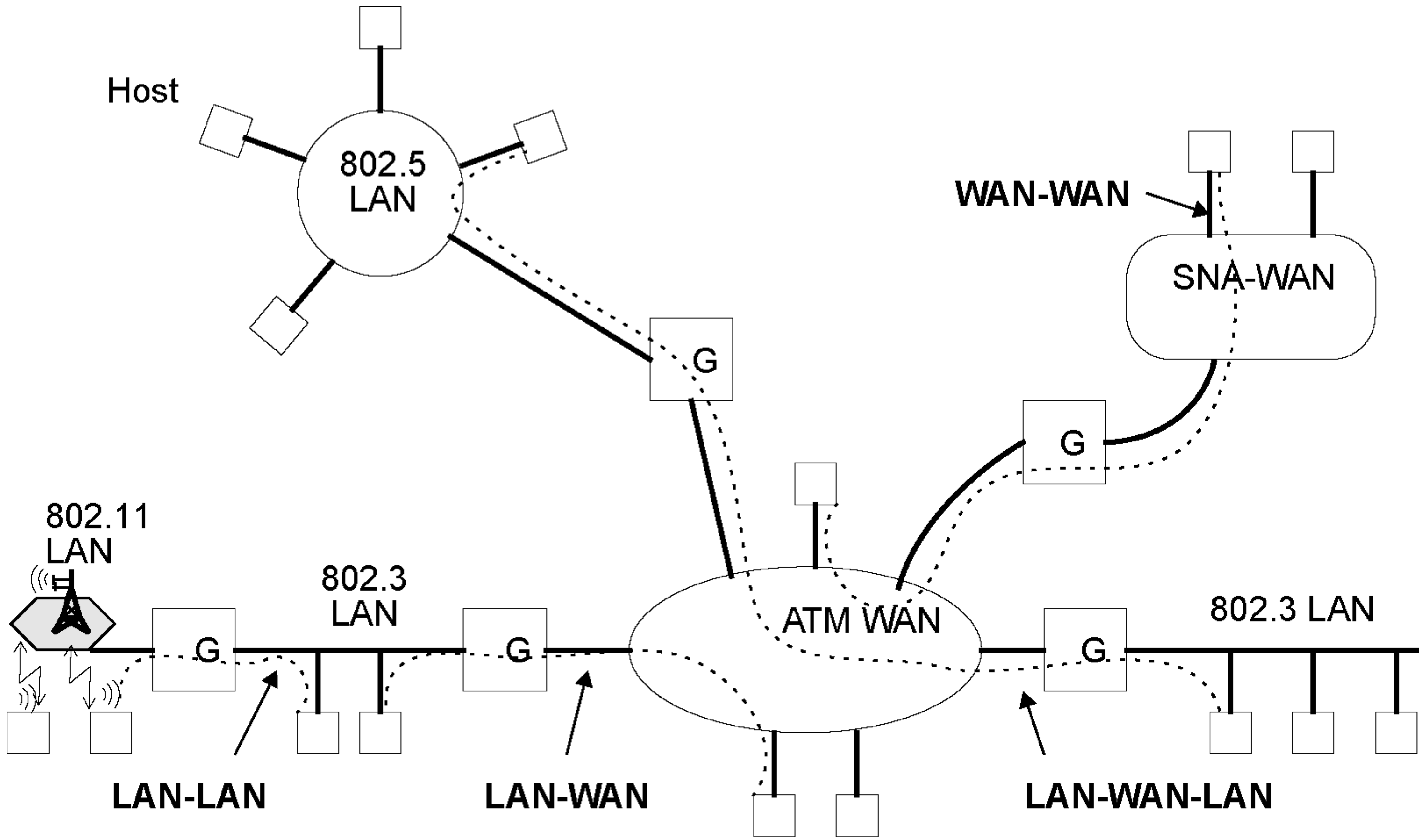
Changes in the near future vs. new technology & demands

- high investments, migration becomes difficult
- decentralized investment decisions
  - departments install different networks
- constantly new technologies

Networks differ …

Item	Some Possibilities
Service offered	Connection oriented vs. connectionless
Protocols	IP, IPX, SNA, ATM, MPLS, AppleTalk, etc.
Addressing	Flat (802) vs hierarchical (IP)
Multicasting	Present or absent (same for broadcasting)
Packet size	Maximum different among nearly any two networks
Quality of service	Present or absent; many different flavors
Error handling	Reliable, ordered, unreliable, or unordered delivery
Flow control	Sliding window, rate control, other, or none
Congestion control	Leaky bucket, token bucket, RED, choke packets
Security, Trust	Privacy rules, encryption, etc.
Parameters	Different timeouts, flow specifications, etc.
Accounting	By connect time, by packet, by byte, or not at all

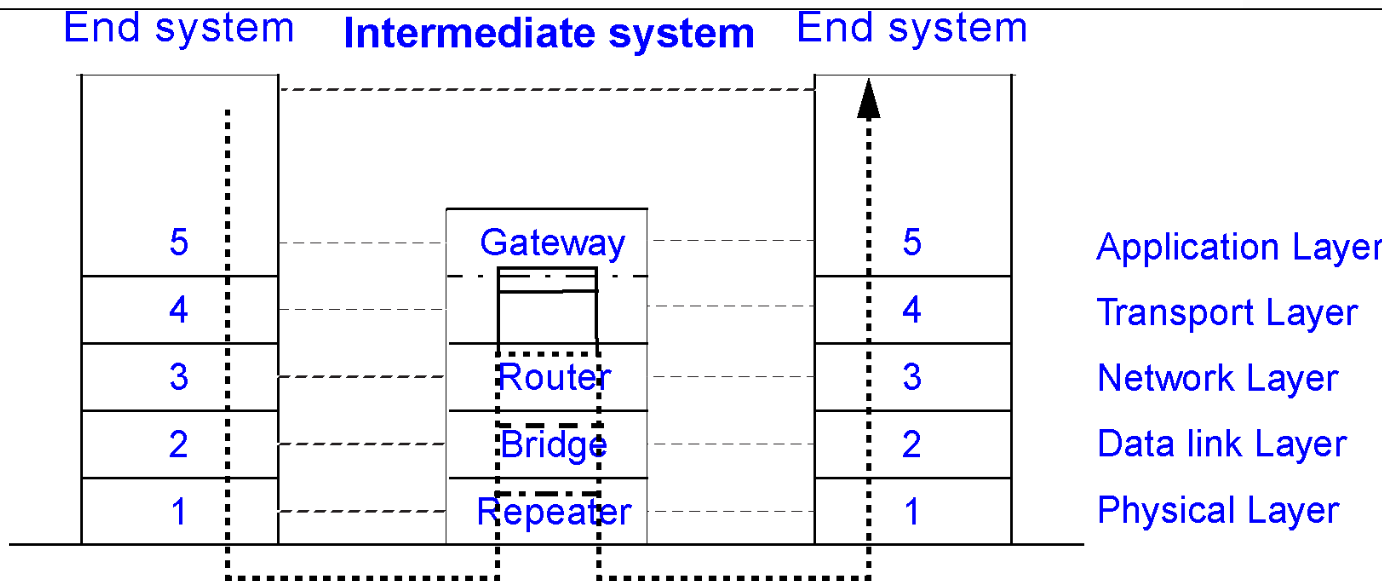
Interconnecting Different Networks



Why is it desirable to connect (heterogeneous) networks?

- resource sharing (CPU, data bases, programs, mailboxes, ...)
- increased availability
- ...

2 Connecting Networks by “Relays”



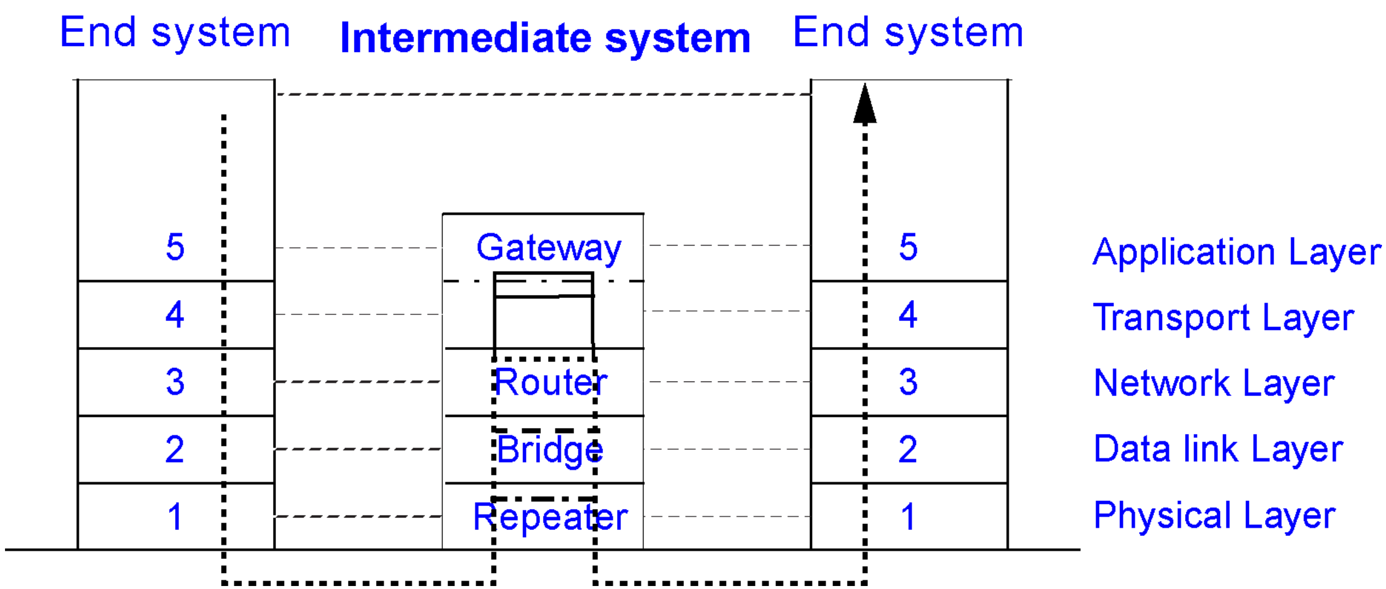
Layer 1: Repeater / Hub

- copies bits between cable segments
- works solely as a repeater (does not modify the information)
- does not influence the traffic between networks
- example: connecting 802.3 cable segments (larger range)

Layer 2: Bridge / Switch

- relays frames between LANs (MAC level)
- minor frame modifications, increases the number of stations
- example: 802.x to 802.y

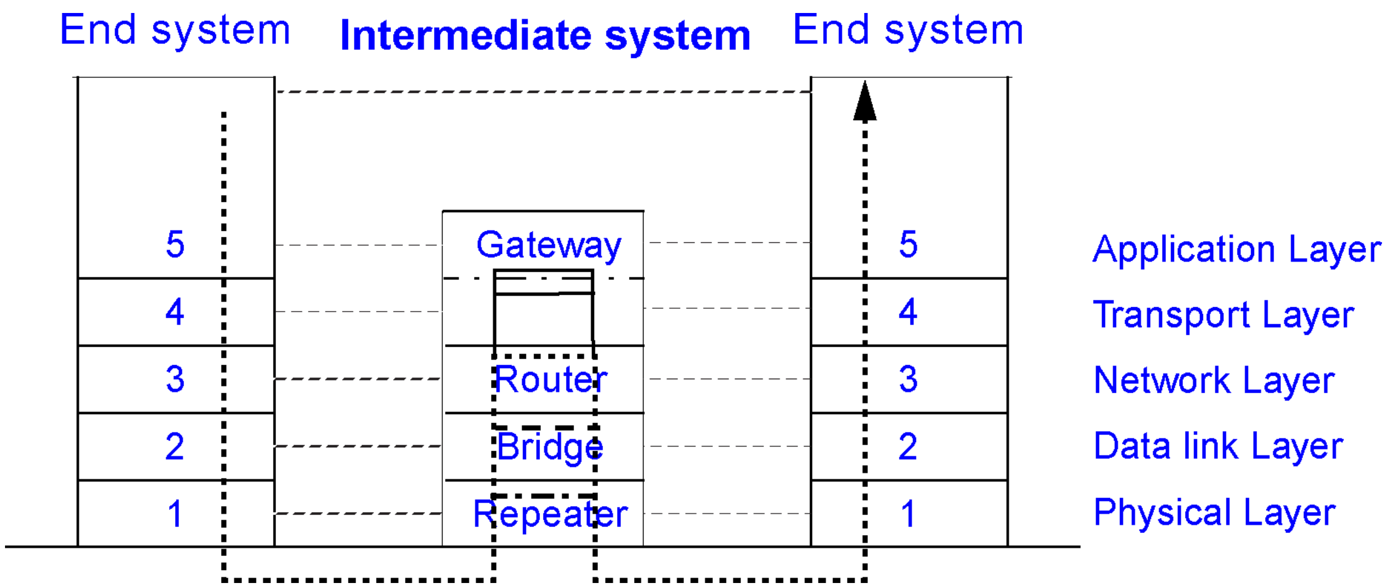
Connecting Networks by "Relays"



Layer 3: Router (or Layer 3 Gateway)

- relays packets between different networks
- modifies packets
- converts different addressing concepts
- example: X.25 to SNA

Connecting Networks by “Relays”



Layer 4 - 5: Gateway (or Protocol Converter)

- converts one protocol into another
  - (usually no1-to-1 mapping of functions)
- examples:
  - TCP in ISO Transport Protocol
  - OSI Mail (MOTIS) in ARPA Internet Mail (RFC 822)
  - change of media encoding (transcoding)
  - SIP to H.232 signaling for IP Telephony

Connecting Networks by “Relays”

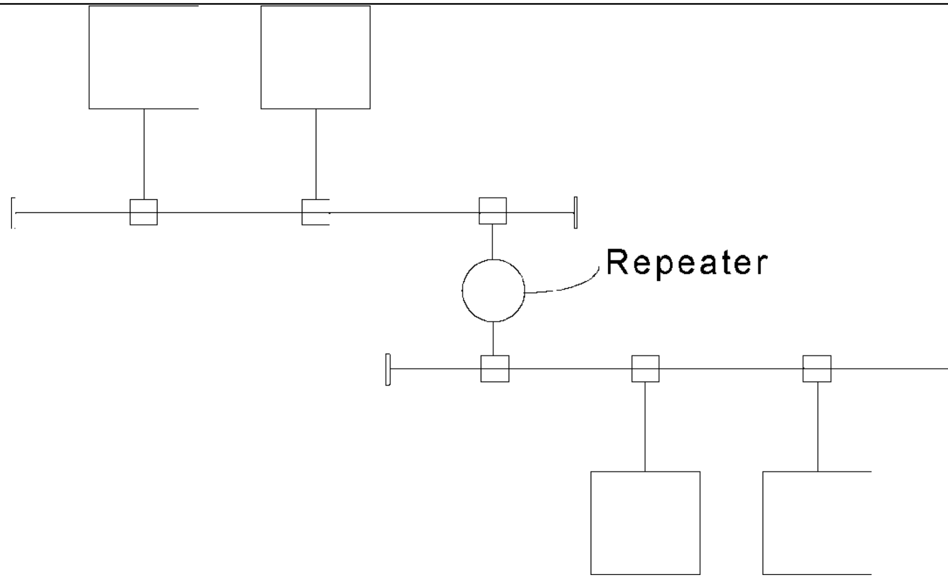
Note:

- names (in products) are often confusing
  - e. g. bridge and switch

Basic components

- 2 or more interconnected networks
- with
  - control path
  - data path

2.1 Repeater (Physical Layer)

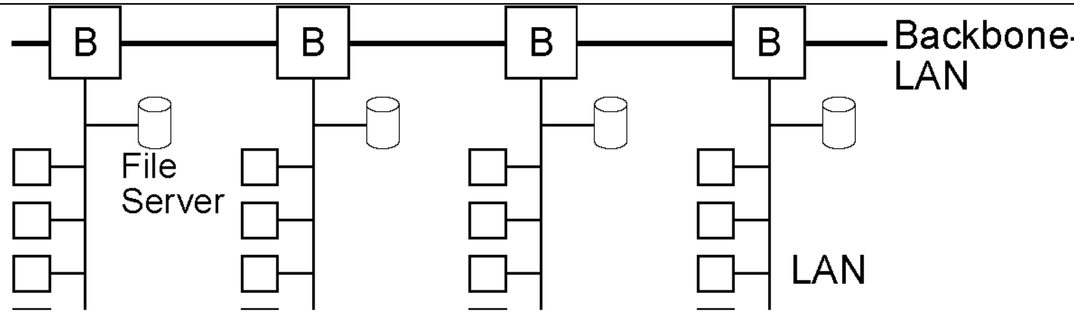


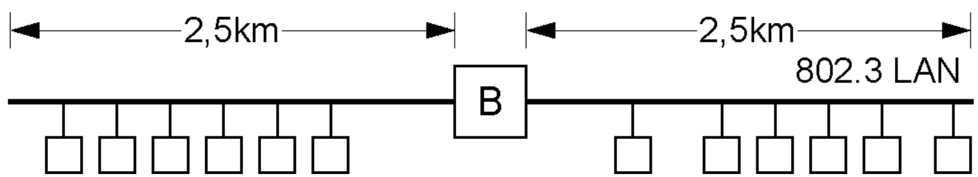
example: IEEE 802.3 configuration

Function

- to amplify the electrical signals
- to increase the range

2.2 Bridge (Data Link Layer)



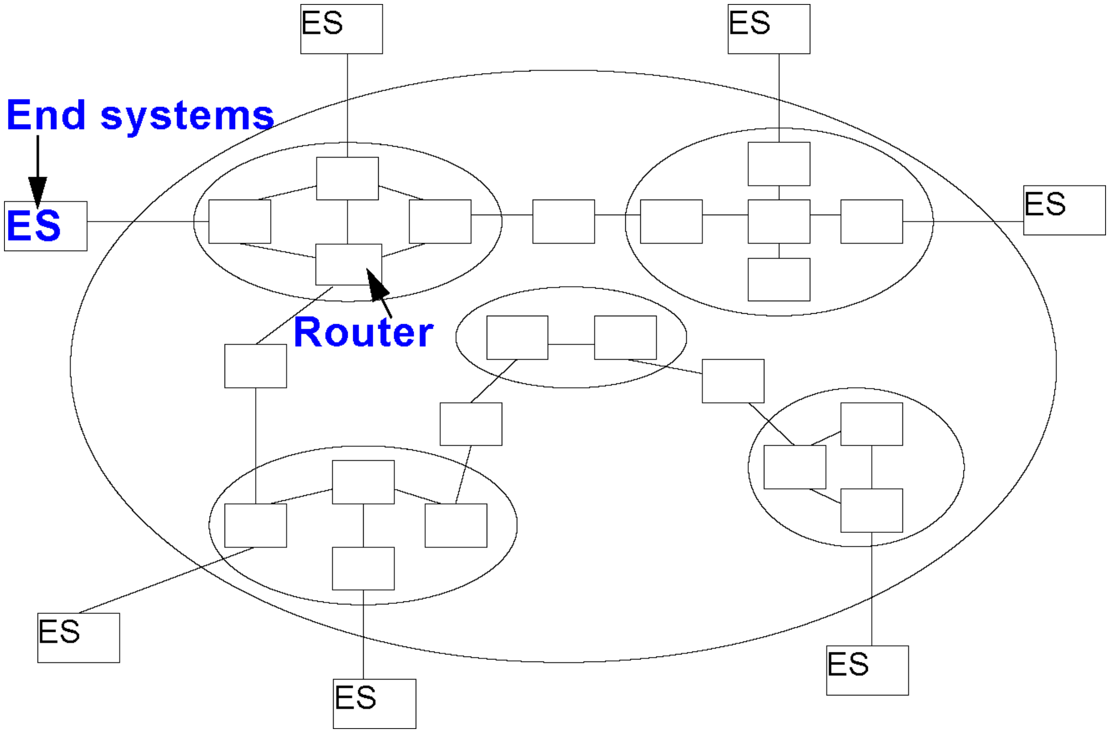


Tasks:

- to couple different LANs
- to provide scalability of networks
- to increase capacity
- to cover larger distances
- to increase reliability
- to improve security
- to offer independence from protocols (IP, OSI, ...)

important goal: to achieve TRANSPARENCY

2.3 Router (Network Layer)



Data transfer from end system to end system

- several hops, (heterogeneous) subnetworks
- compensate for differences between end systems during data transmission

2.4 Gateway (Application Layer)

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Task

- data format adaptation
- control protocol adaptation

Example media

- audio database with CD audio encoding and MIDI output at the system
- different audio data formats are converted in real time

Example signaling

- telephone connection establishment
  - From ordinary telephone (POTS)
  - to audio conferencing system (computer)
- adaptation by functional transformation and stubs

2.5 Repeaters, Hubs, Bridges, Switches

Repeaters & Hubs (L1):

- one collision domain

Bridges (L2):

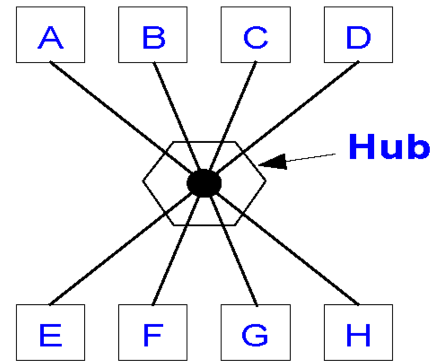
- connects two or more LANs
  - (potentially of different types)
- each line is its own collision domain
- typically store-and-forward

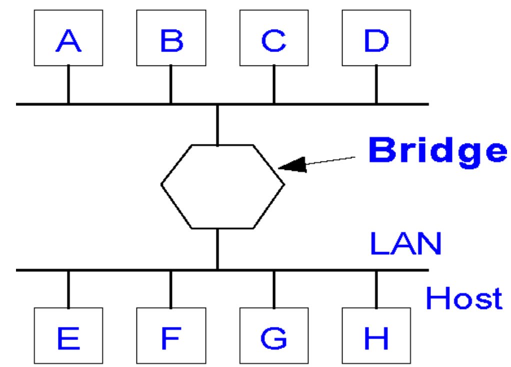
Switches (L2)

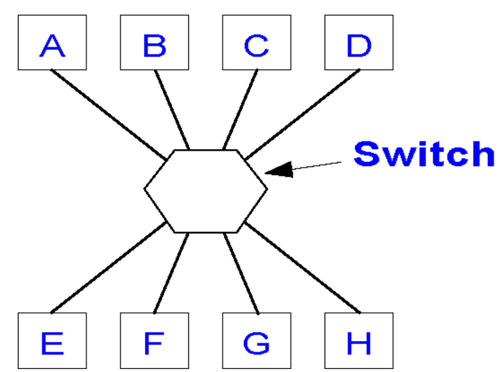
- typically connects two or more computers
- each port / line is its own collision domain (no collisions)
- typically cut-through switching devices
  - begin forwarding as soon as possible
  - when destination header has been detected, before rest of frame arrived
- hardware-based

Bridges vs. Switches

- sometimes difference seems to be more a marketing issue than technical

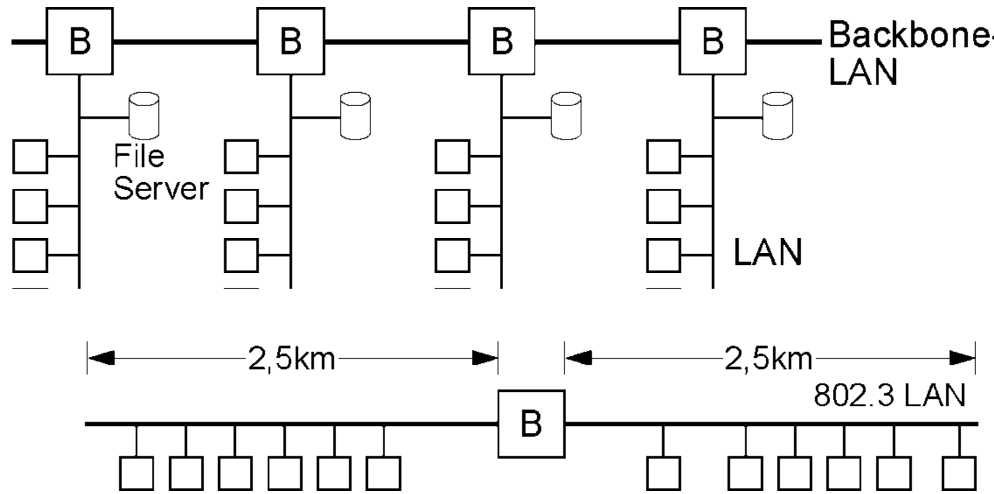






3 Bridge (Data Link Layer)

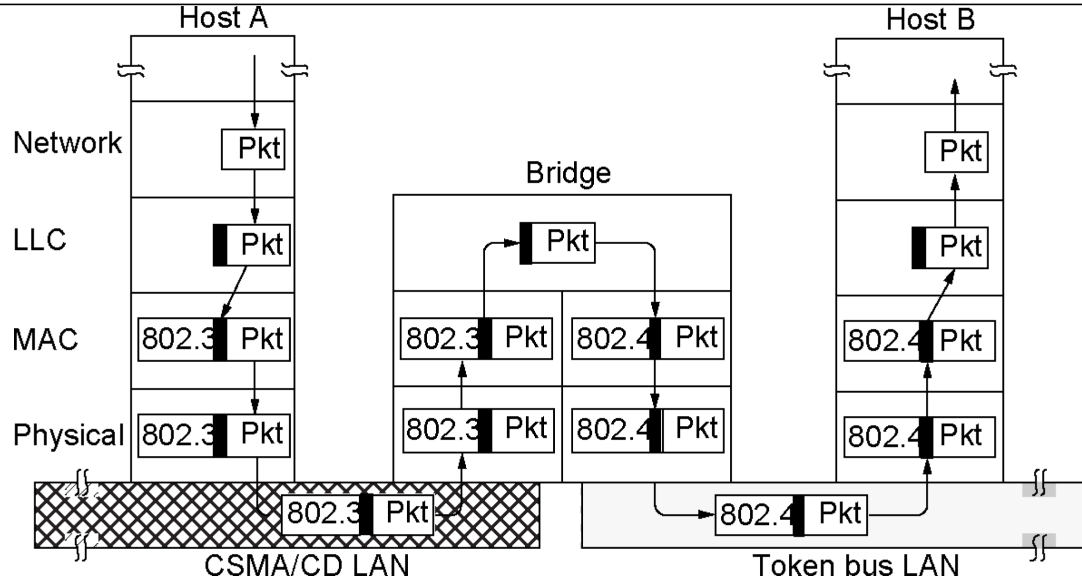
Tasks:



- coupling of different LANs
- scalability of networks
- to increase capacity
- to cover larger distances
- to increase reliability
  - bridge serves as "fire door"
- to improve security
  - stations can work in a promiscuous mode, i.e., read all frames on the network
  - bridge placement limits the spreading of information
- to offer independence from protocols
  - in opposite to routers

Important goal: to achieve TRANSPARENCY

- change attachment point without changes to HW, SW, configuration tables
- machines on any two segments should be able to communicate without regard to types of LANs used (directly or indirectly)



Example: 802.3 (Ethernet) and 802.4 (Token Bus)

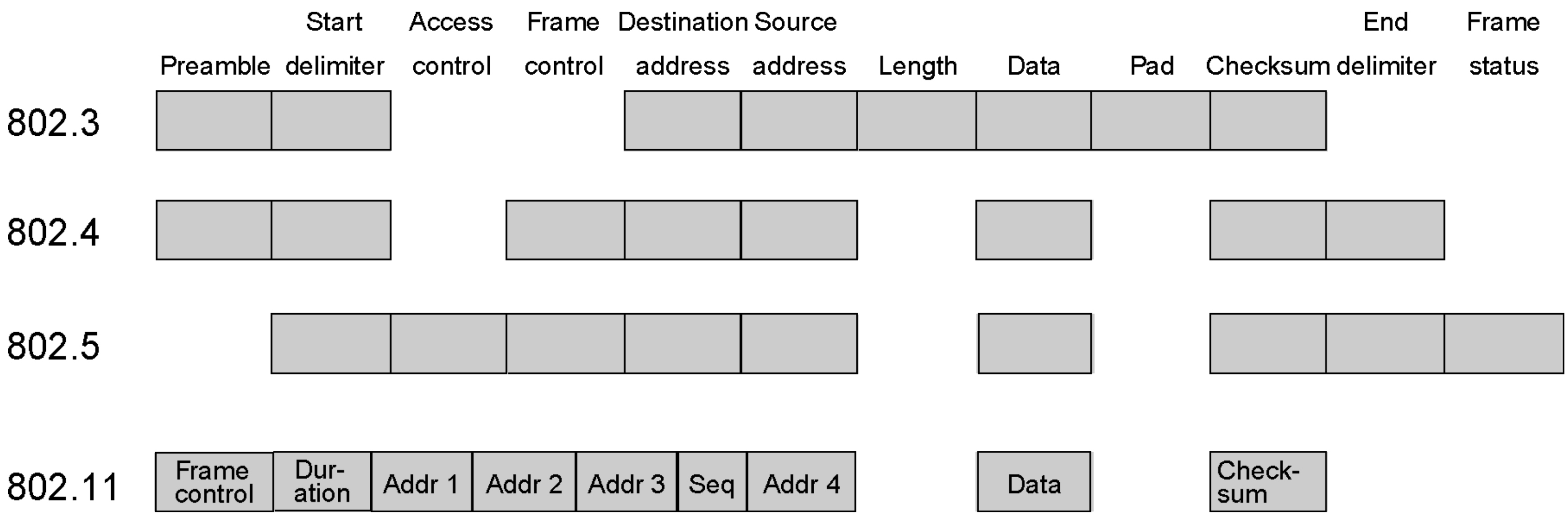
Approach

- LLC as common layer
- frames are routed to the respective MAC
- bridge contains
  - its own implementation for each MAC
  - for each to it belonging physical layer the corresponding implementation

802.x <-> 802.y: Tasks

Some different 802.x frame formats:

- there are even more different frame formats ...
- some fields are technically necessary in one case but useless in another
  - e.g. **DURATION** of 802.11



802.x <-> 802.y: Tasks

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Different transmission rates (4/10/11/16/100/1000/... Mbps)

- bridge between fast LAN and slow LAN (or several LANs to one)
  - link can be overloaded
- buffering frames which cannot be transmitted immediately
- potentially many frames must be buffered within bridge
- (end-to-end) retransmission timer (at higher level) tries n*retransmissions
  - but then reports that end system is not available

Different frame lengths

- 802.3: 1518 bytes, 802.4: 8191 bytes,
  802.5: unlimited, 802.11: 2346 bytes
- 802 does not support segmentation
  - not the task of this layer (at least typically seen this way)

→ frames that are too long are dropped

- loss of transparency

Priorities

- supported (in various forms) from both 802.4 and 802.5
- NOT supported by 802.3

802.x <-> 802.y: Tasks

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Different checksum calculations

- means conversion, delay, buffering

Security

- 802.11 provides some data link layer encryption
- 802.3 does not

Quality of Service / Priorities

- supported (in various forms) by
  - 802.4 and 802.5
- NOT supported by 802.3
- ’kind of’ in 802.11 (PCF / DCF)

Acknowledgements

- supported by 802.4 (temporary token handoff)
- supported by 802.5 (C+A bits)
- not supported by 802.3

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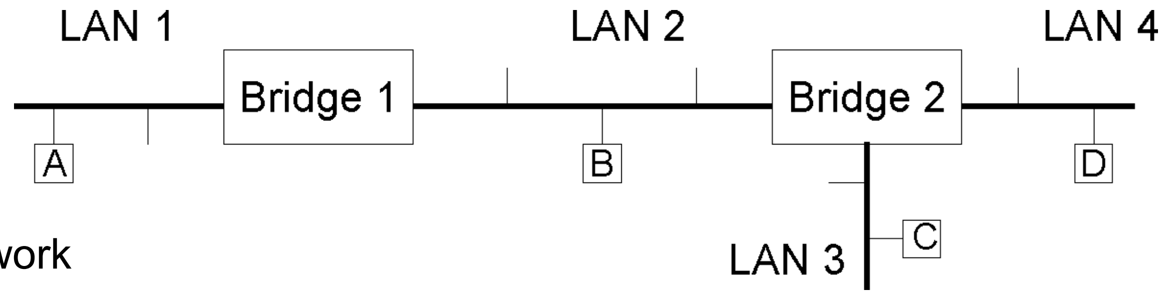
Example: 802.5 Token Ring to 802.3 CSMA/CD

- frame size Ra:
  if Ra(Token Ring) > Ra(CSMA/CD)
  - no overall solution
  - L2 does not offer segmentation
  - network knows a frame’s atomic unit only

- Priorities
  - Token Ring priorities are lost

- Acknowledgement
  - bridge has to confirm Token Ring frame,
    - even though it was not delivered to the CSMA/CD receiver

3.2 Connecting Several Networks: Transparent Bridges



Transparency:

- bridges not visible as such
  for other components of the network

→ simplifies other components

Principle: transparent bridge

- bridge works in PROMISCUOUS MODE
  - receives every frame of each connected LAN
- bridge manages table: station → LAN (output line)
  - Bridge1: A → LAN 1 B → LAN 2 C → LAN 2 D → LAN 2

Decision procedure

- source and destination LANs identical
  → frame dropped
- source and destination LANs differ
  → frame rerouted to destination LAN
- destination unknown
  → flooding

Bridge table initially empty

- use flooding for unknown destination

Learning process: backward learning

- bridge works in promiscuous mode:
  - receives any frame on any of its LANs
- bridge receives frames with source address Q on LAN L

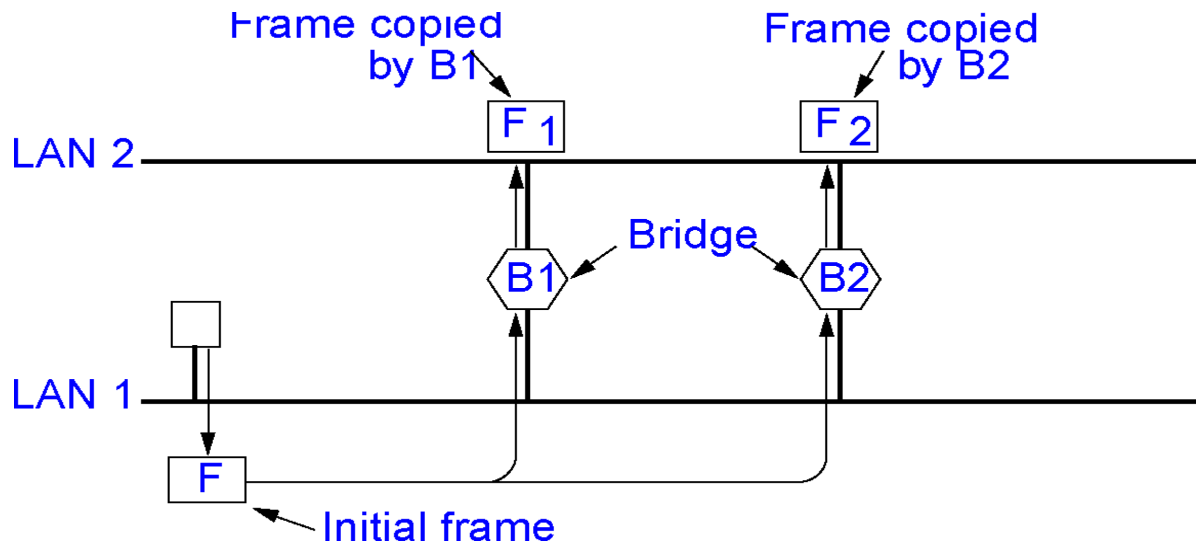
  → Q can be reached over L

  → create table entry accordingly

Adaptation to changes in topology

- entry associated with timestamp (frame arrival time)
- timestamp of an entry (Z, LAN, TS) is updated when frame received from Z
- table scanned periodically and old entries purged
  - if no update for some time, usually several minutes
    - e.g., because system moved and reinserted at different position
    - flooding is used if machine was quiet for some minutes

Transparent Bridges: Spanning Tree



Increase reliability:

- connect LANs
  via VARIOUS bridges
  in parallel

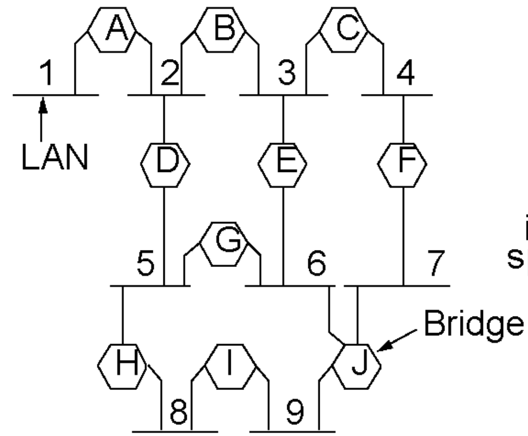
Problem

- this creates a loop in the topology
- frames with unknown destination are flooded
  - frame is copied again and again

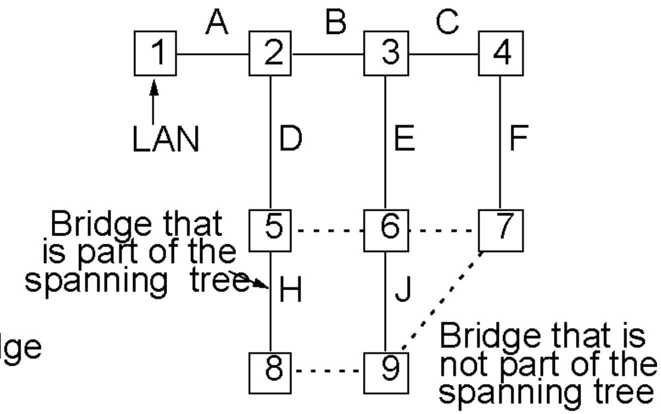
Solution:

- Communication among bridges
- Overlay actual topology by spanning tree reaching every LAN
  - exactly one path from any LAN to every other LAN

Transparent Bridges: Spanning Tree



Bridges between LANs



A Spanning Tree

Example: Algorithm

- root of tree selection
  - Bridge identified by unique identifiers
    - e.g. serial number
    - e.g. MAC address and a priority
  - all bridges broadcast their unique id, lowest chosen as root for all other bridges
- generation of spanning tree (from the root to every bridge and LAN)
  - configured with bridges representing the nodes within the tree
  - thereby avoiding loops
- adaptation if configuration is changed (bridge or LAN)

Drawback:

- ignores some potential connections between LANs
- i.e., not all bridges are necessarily present in the tree

3.3 Source Routing Bridges

Alternative to transparent bridges

Principle

- frames of the senders defines path
- bridge routes the frame

Prerequisite

- LAN has a unique address (12 bit)
- bridge at the respective LAN is also unique (4 bit)

then

- sender flags the frame
  (top bit of its own address = 1),
- if destination address is not reachable in LAN
  → bridge routes only frames
  that have been flagged in such a way

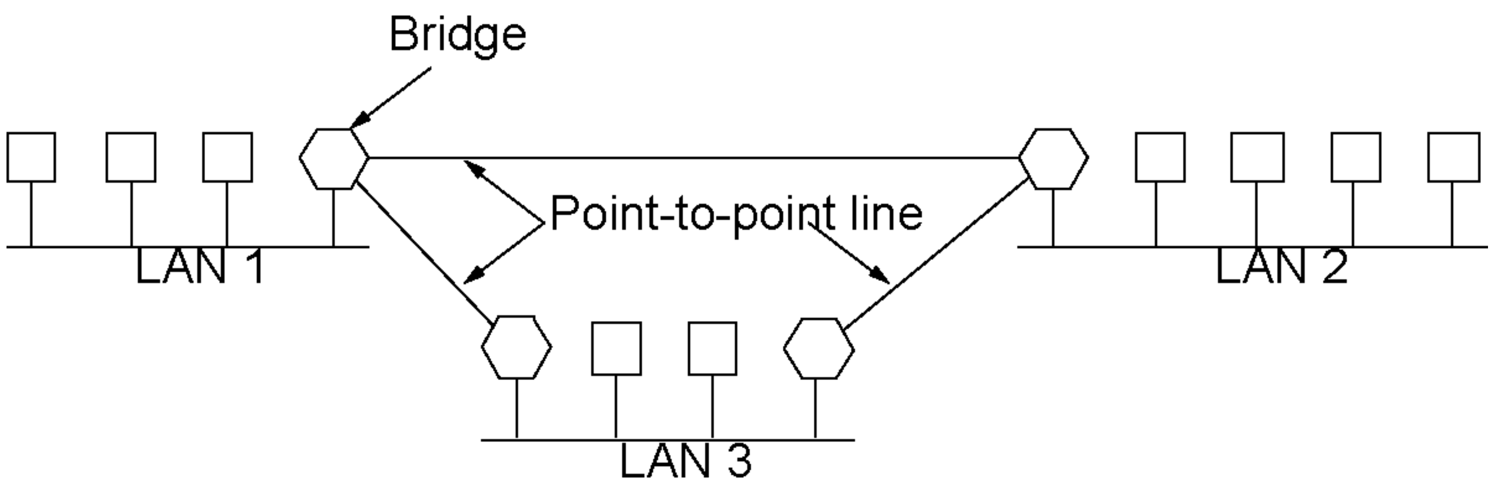
Determining Path

- sender sends discovery frames as broadcast
- each bridge reroutes these (reaches every LAN)
- during return (route)
  - the complete path is copied and
  - transmitted to sender
- problem: high traffic

Conclusion: usually transparent bridges are used

3.4 Connecting 2 Equal Networks: Encapsulation

Example: remote bridge



Principle

incoming data unit is

1. packaged as payload,
2. transmitted and
3. then fed into the destination network

Properties

- certain protocol on connecting route
  - e.g. PPP
  - i.e. e.g. MAC frame in PPP
- only station at the destination network can be reached
  - but for example not the network being bridged
- simple