Networks and Communications

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Lectures, Books and Other Things

Course format:

- Tutorial material will be mixed into lectures
- Two course work exercises will be set

Books and other material:

- Tanenbaum *Computer Networks* (4th Edition)
- Stallings *Data & Computer Communications* (8th Edition)
- http://www.doc.ic.ac.uk/~pjm/nac/

For those interested in the hardware:

- Halsall *Computer Networking and the Internet* (5th Edition)

Applications (1): Terminal Networks

- Terminals attached to mainframes
- Terminal emulators on workstations
- Protocols
  - telnet
  - rlogin
  - ssh

Data rate	Utilisation
Low	Bursty

Applications (2): File transfer

- Move whole files from one host to another
- Protocols
  - ftp
  - rcp
  - http
  - scp

Data rate	Utilisation
High	Bursty

Applications (3): File access

- Access remote file system like it was a local file system
- Protocols
  - Netware
  - NFS
  - LanManager, SMB/CIFS, Samba

Data rate	Utilisation
Medium/High	Bursty

Applications (4): Email

- Electronic version of post
- store-and-forward
- Protocols
  - SMTP
  - X.500

Data rate	Utilisation
Variable	Constant/Bursty

Applications (5): Multimedia

- Sound and video are often viewed as they are received
- Protocols
  - RTP with SIP, H.225, H.245, . . .

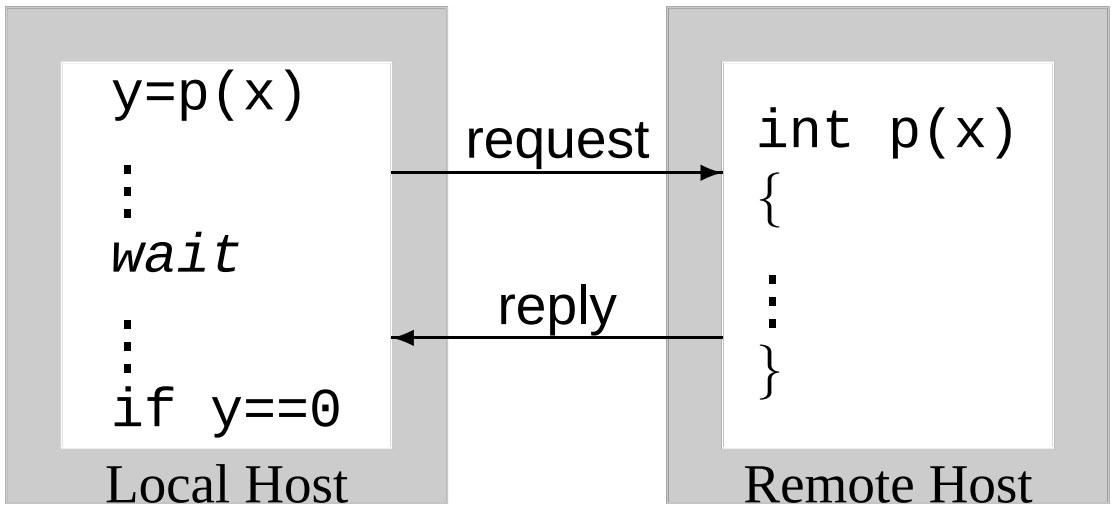
Type	Data rate	Utilisation
Sound	Medium	Constant
Video	Medium/High	Bursty

Applications (6): Teletext

- Broadcasting of text/images pages with TV
- One way data transfer
- Protocols
  - teletext
  - MHEG-5

Data rate	Utilisation
Medium	Constant

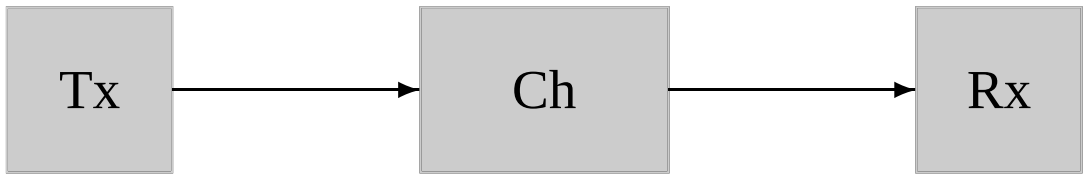
Applications (7): Remote Operations



- Java Remote Method Invocation (RMI)
- SUN Remote Procedure Call (RPC)

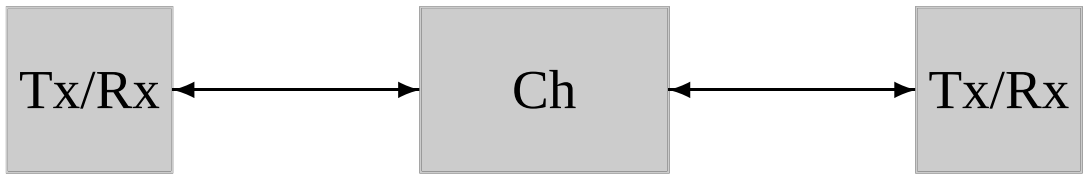
Data rate	Utilisation
Variable	Bursty

General Model (1): Simplex



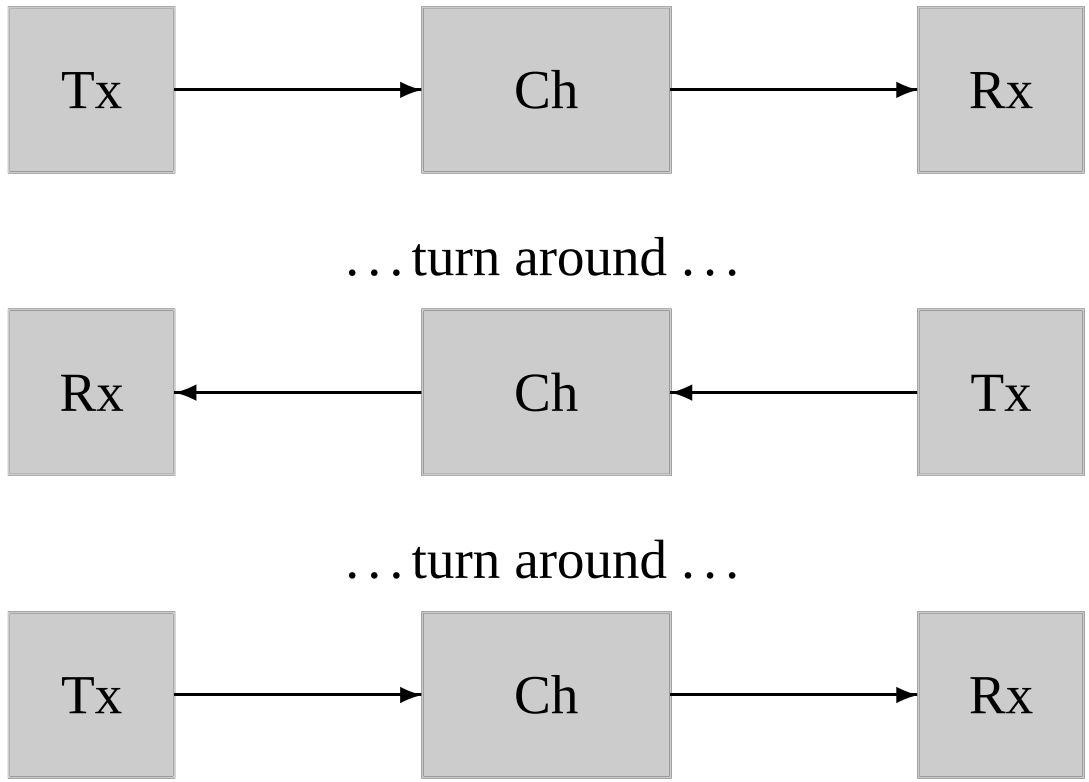
- Rare for data transfer to be truly one way

General Model (2): Duplex



- Often wastes capacity since data transfer not balanced

General Model (3): Half-Duplex



Error Rate

- No real channel is error free
- One measure is the **bit error rate** (**BER**)

Network	BER
Telephone network	10^{-5}
Digital telephone network (‘ISDN’)	10^{-7}
Ethernet networks	10^{-9}

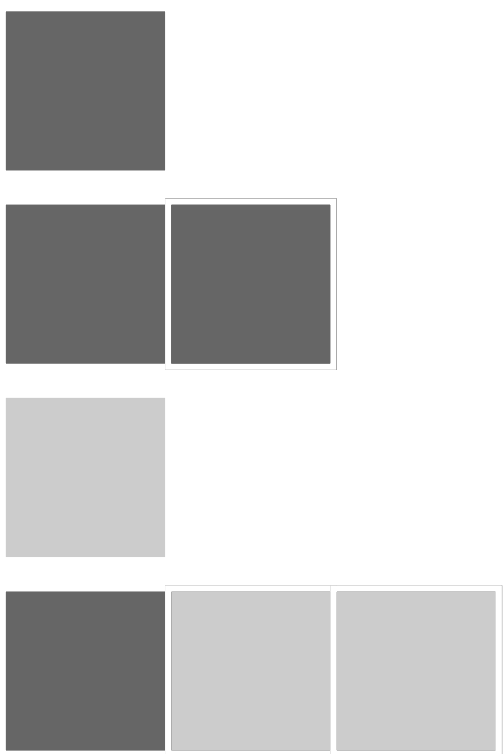
- Probability one bit in error= BER
- Probability two bits in error= BER^2
- Probability one bit error free =$1 - BER$
- Probability two bits error free =$(1 - BER)^2$

Worksheet: Errors

dark shaded box = bit containing an error

light shaded box = error free bit

$BER = 0.01$



Worksheet: Errors

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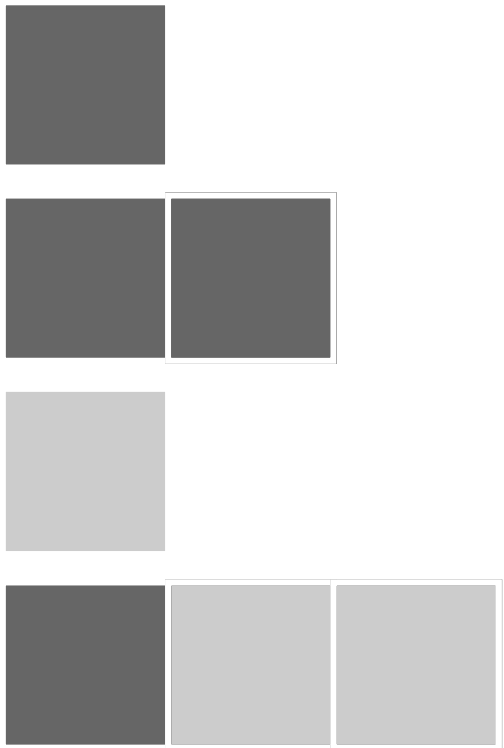
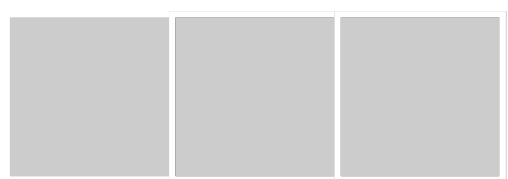
$BER = 0.01$



BER	0.01
BER^2	$0.0001 = 0.1 \times 10^{-3}$
$(1 - BER)$	0.99
$BER \times (1 - BER)^2$	$0.0098 = 9.8 \times 10^{-3}$

Worksheet: Errors



Any 3 bit but

$BER \times (1 - BER)^2$	$0.0098 = 9.8 \times \times 10^{-3}$
$BER^2 \times (1 - BER)$	$0.000099 = 99 \times 10^{-6}$
BER^3	$0.000001 = 1 \times 10^{-6}$
$(1 - BER)^3$	0.97
$1 - (1 - BER)^3$	0.03

Calculations Using BER

Telephone line has BER= 10^{-5}

Calculate p(4K bytes contains an error)

- p(one bit is error free) = $1 - BER = 1 - 10^{-5} = 0.99999$
- p(4K is error free) = $0.99999^{4\times1024\times8} = 0.72$
- p= $1 - 0.72 = 0.28$

Calculate p(10 consecutive blocks sent error free)

- p= $0.72^{10} = 0.037$

Data Transfer Rates

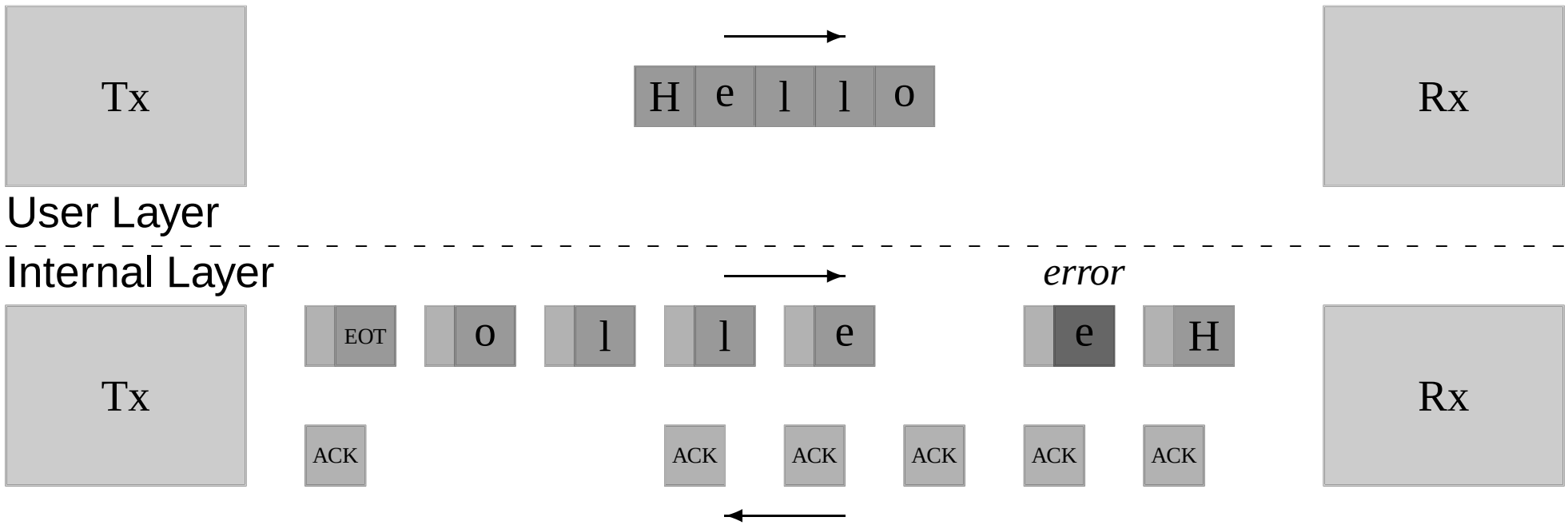
Any channel will have certain maximum data transfer rate

- **bit rate**: rate of bits passing through a channel
  measured in bits per second
- **throughput** rate of *usable* data passing through a channel
  measured in bits per second

Throughput lower because:

- errors → some of the data is retransmitted
- errors → acknowledgements
- control information → **framing** of data

Layers in a Communication System



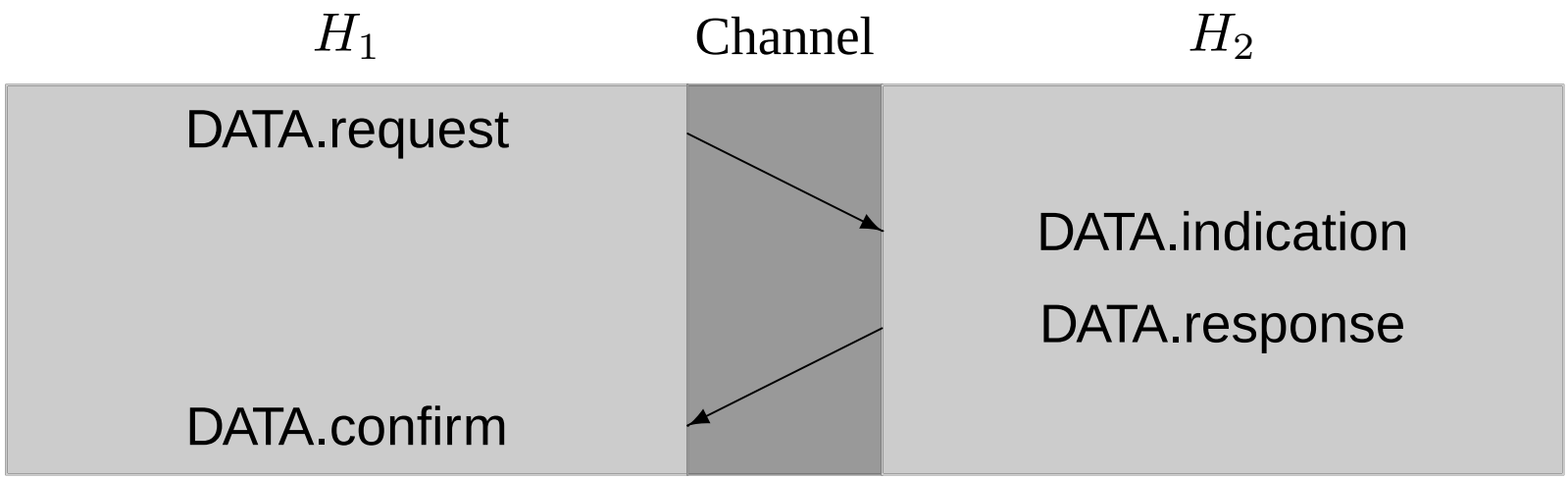
Quality of Service

What happens when Tx sends $m_1, m_2, \ldots$?

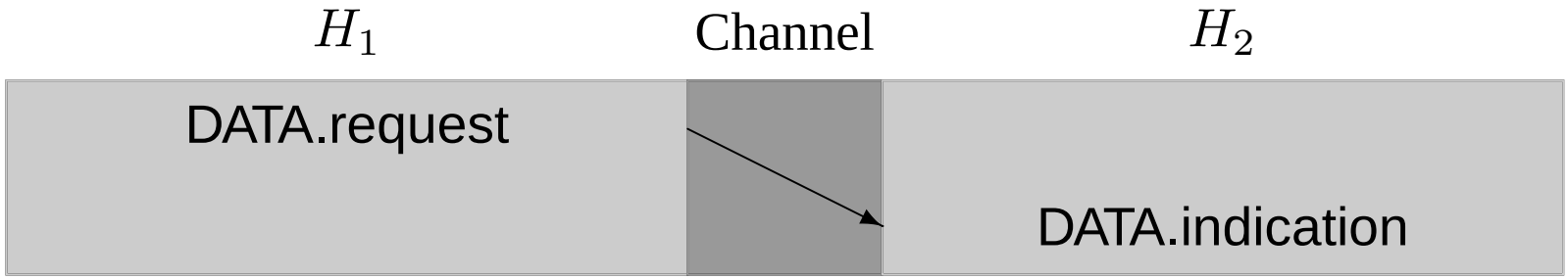
Property	High QoS	Low QoS
Sequencing of packets	Arrive in order	Any order
Guaranteed delivery	All arrive	Some go missing
Error free	All correct	Some contain errors
Duplication of messages	Arrive once	Duplicated
Channel capacity	Limited delay	Unlimited delay

Connectionless Channel (CL)

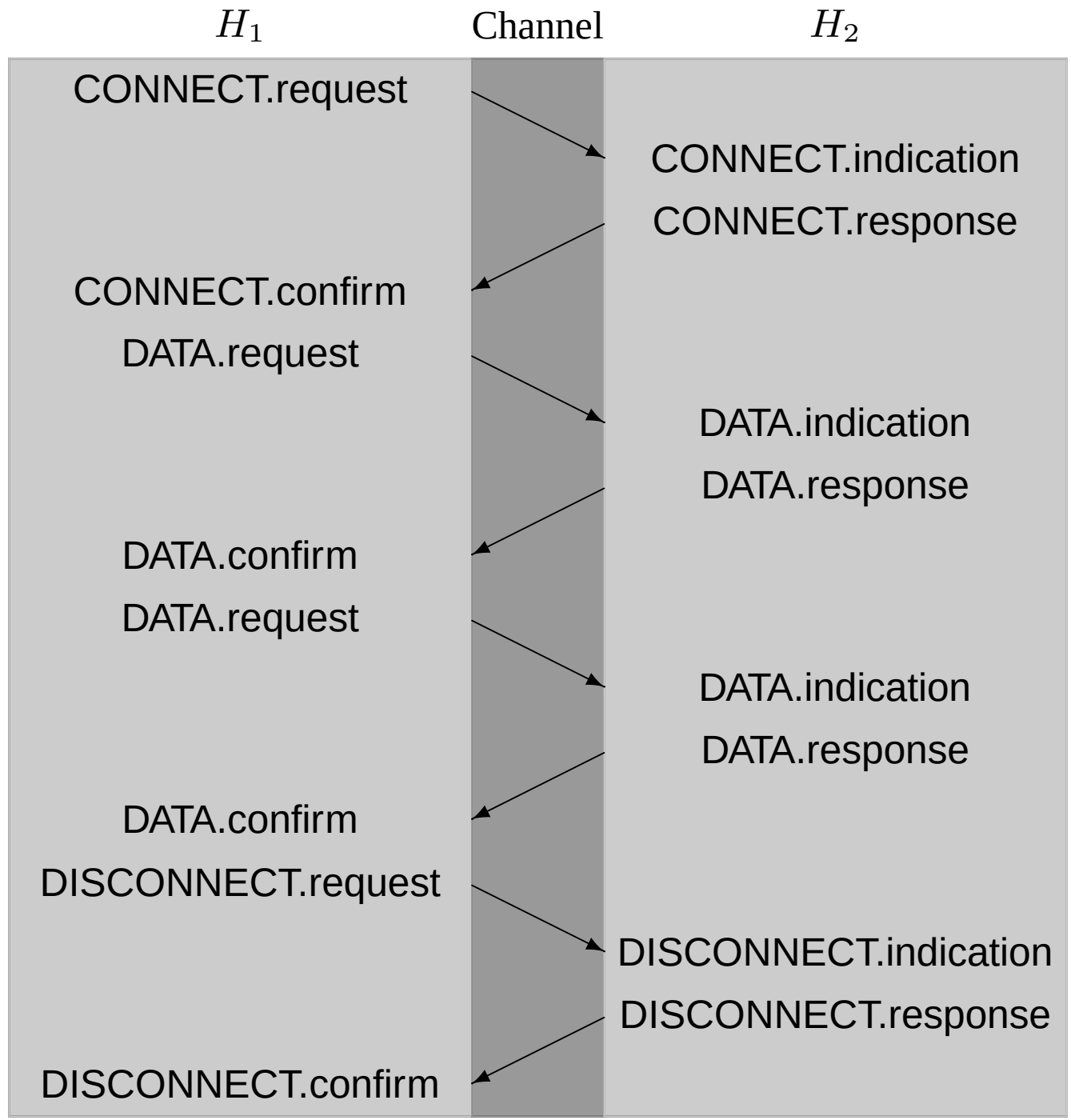
Confirmed data transfer



Unconfirmed data transfer



Connection Oriented (CO)



Typical behaviour of CO and CL services

- CO tends to imply high QoS
- CL tends to imply low QoS

e.g. Send $[m_1, m_2, m_3, m_4, m_5]$:

- CO service will always deliver $[m_1, m_2, m_3, m_4, m_5]$
- CL service may deliver
  $[m_1, m_2, m_3, m_4, m_5], [m_5, m_4, m_1, m_3, m_2], [m_5, m_5, m_1, m_2], [], \ldots$

Which is best?

- CO makes applications easy to write
- CL demands less resources; and might be ‘faster’

Worksheet: CL and CO Networks

first field is the data, and the second field a sequence number

E	8	E	11	E	8	A	1		2	B	3	G	5
T	12	E	8	T	12	R	10	S	7	S	7		6

1. Reconstruct as much of the message as you can
2. List which packets are missing
3. List which packets you may pass on to the user
4. If CO obtains missing packets, how can a user still tell CL layer below?

Worksheet: CL and CO Networks

E	8	E	11	E	8	A	1		2	B	3	G	5
T	12	E	8	T	12	R	10	S	7	S	7		6

1. Reconstruct as much of the message as you can

A	1		2	B	3	G	5		6	S	7	E	8	R	10	E	11	T	12

2. List which packets are missing

   4, 9

3. List which packets the CO layer may pass on to the user

   1, 2, 3

4. If CO obtains missing packets, how can a user still tell CL layer below?

   Delays

Implementing CO using CL service

- Add sequence number to messages
- Buffer messages at Rx
- If buffer missing any messages, ask for retransmission

If Rx receives $[m_5, m_5, m_1, m_2]$

- Rx may deliver $[m_1, m_2]$ to the user
- Rx keeps $[m_5]$ in a buffer
- Rx requests Tx for $[m_3, m_4]$ be resent.

Synchronous v Asynchronous

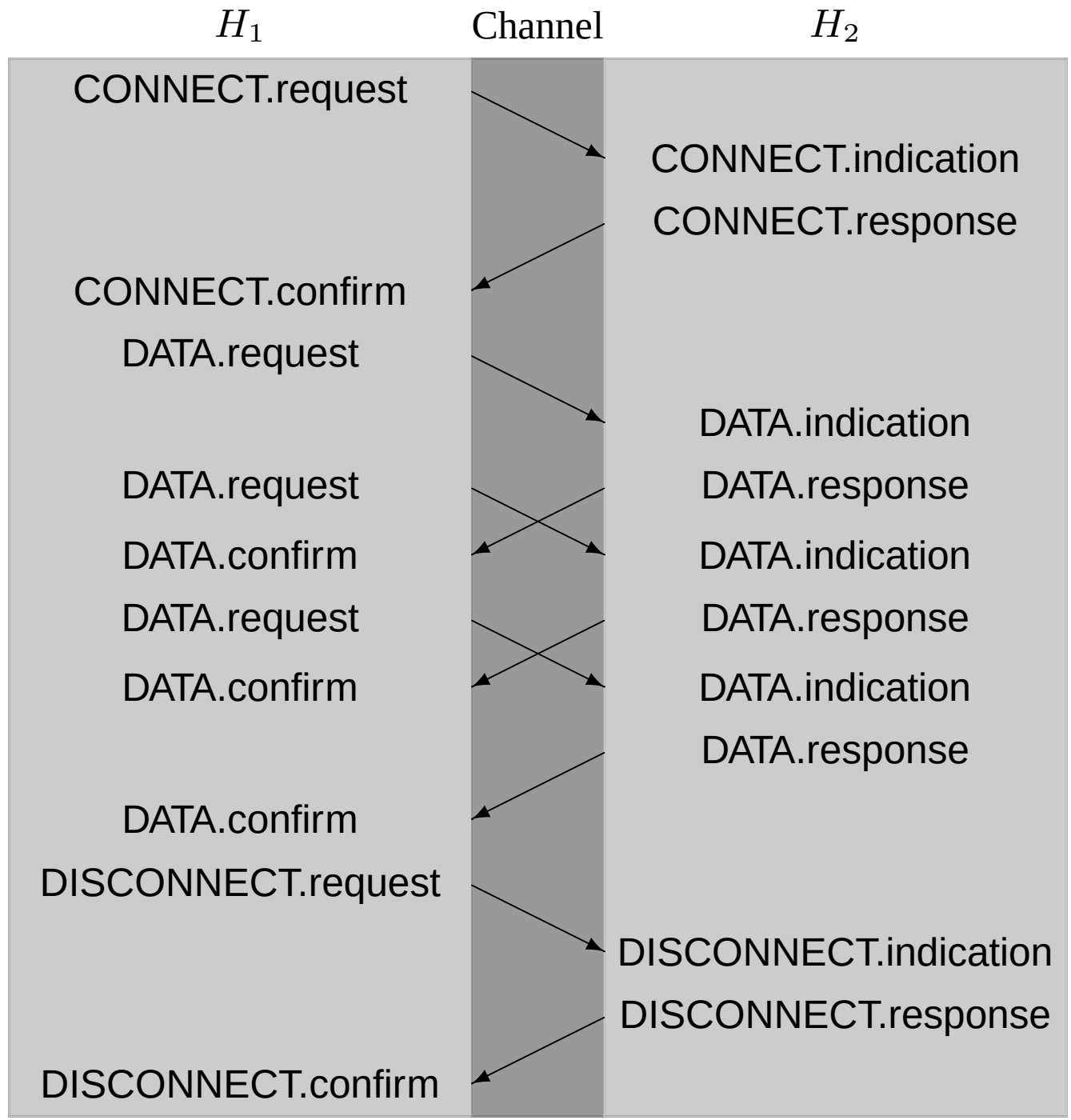
Synchronous communication

- always wait for a reply — **stop and wait**
- delays caused by
  - Transmission time between Rx and Tx
  - Response time at Rx

Asynchronous communication

- send multiple messages without waiting for reply
- less delay

Asynchronous CO



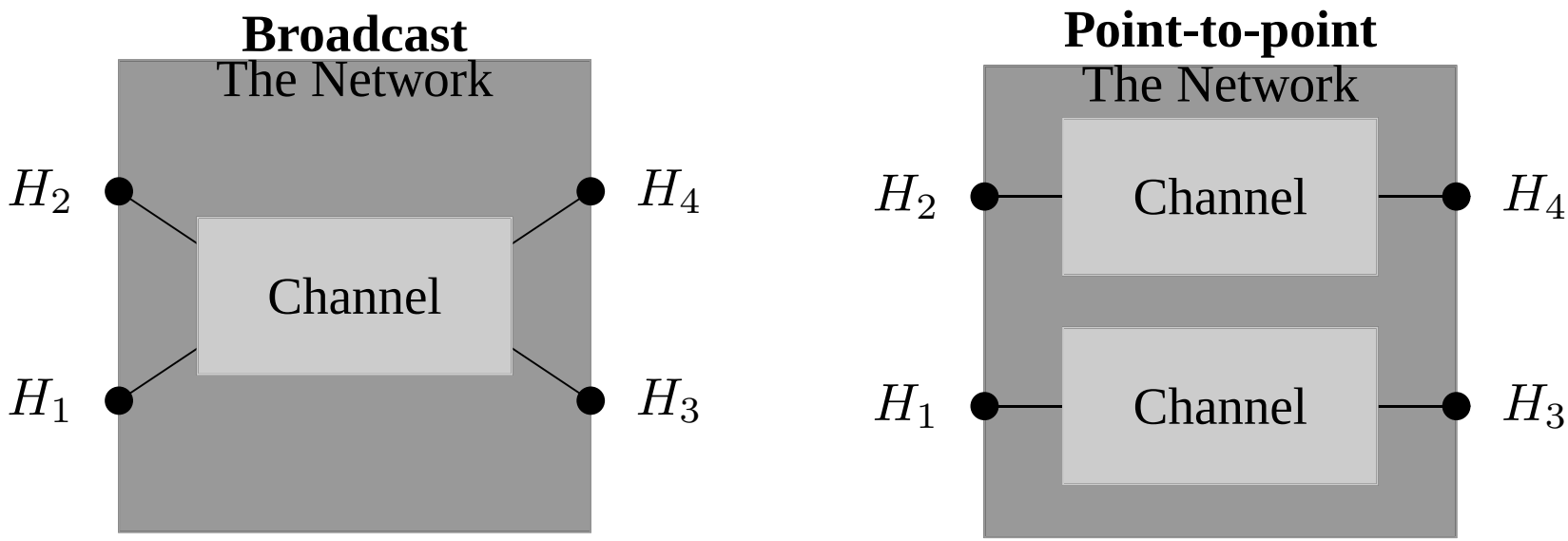
Networks

A network allows more than two hosts to communicate with each other

Scale of network falls into three sizes:

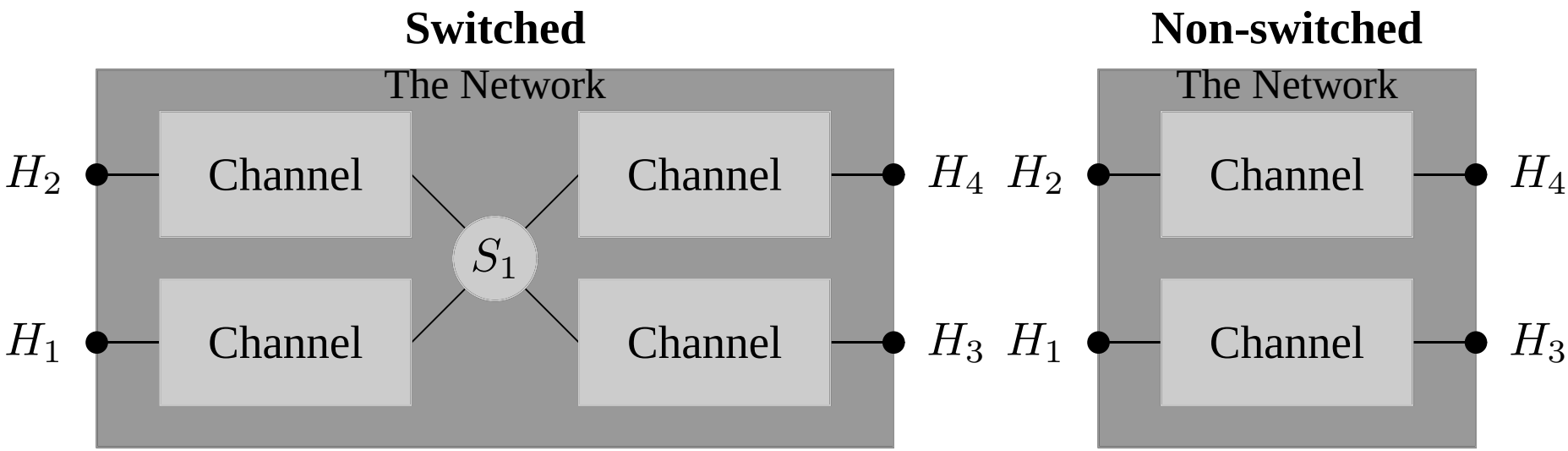
- **local area networks** (**LAN**)
  - Operate over 100’s of metres, 100’s of hosts, 1 owner
- **metropolitan area networks** (**MAN**)
  - LANs pretending to be WANs
- **wide area networks** (**WAN**)
  - Operate over 100’s of kilometres, 1000’s hosts, multiple owners

Networks: Broadcast or Point-to-Point



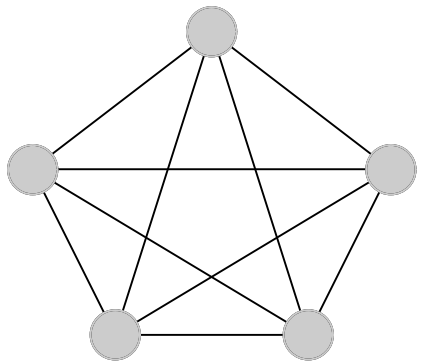
- LAN might be broadcast — one channel can support requirements of all hosts
- WAN might be point-to-point — too many hosts for one channel

Switching

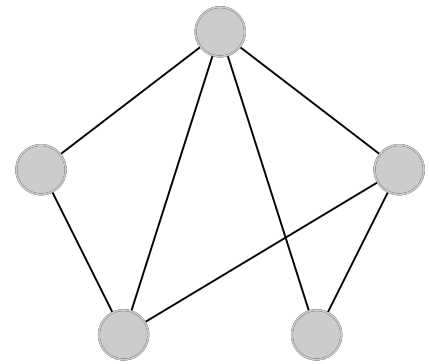

Switched
The Network
Channel
Channel
Channel
Channel
S_1
H_2
H_1
H_4
H_3
Non-switched
The Network
Channel
Channel
H_2
H_1
H_4
H_3

Network Topology (1): Mesh

Mesh (fully connected)

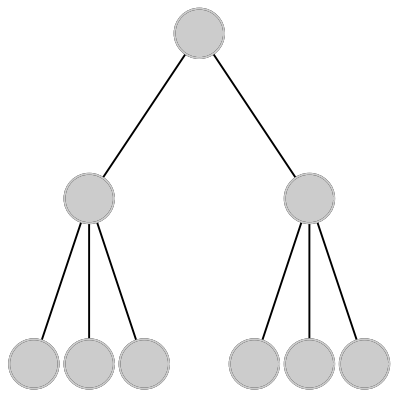


Mesh (partially connected)



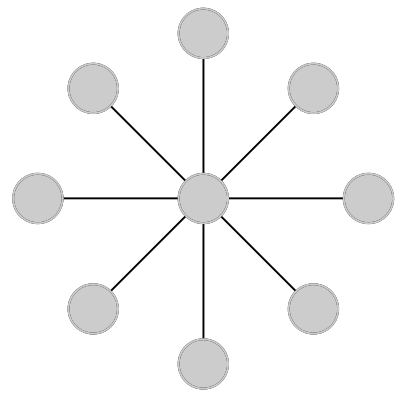
- Full mesh requires $\frac{n(n-1)}{2}$ links for n nodes
- Partial mesh requires routing

Network Topology (2): Tree



- Structured partial mesh
- Routing over network easy
- Single point of failure

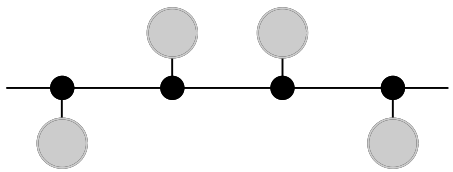
Network Topology (3): Star



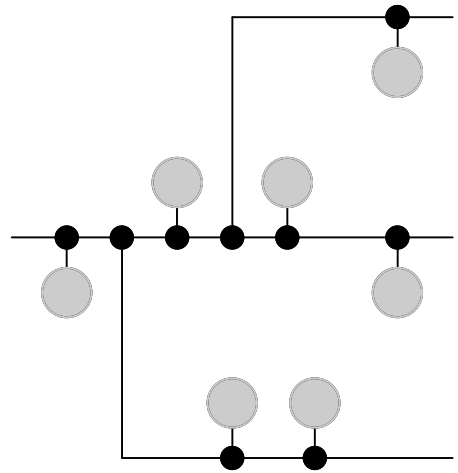
- Most nodes very simple — only have to contact hub
- Hub must be very reliable
- Basis of telephone system (hub is exchange)

Network Topology (4): Bus

Bus

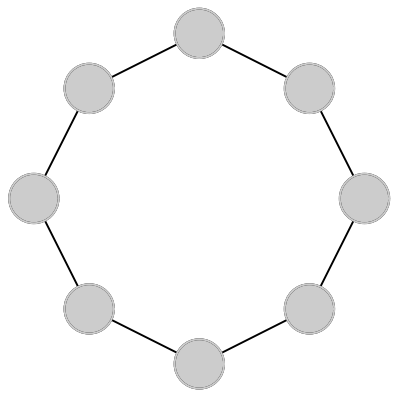


Bus/Tree



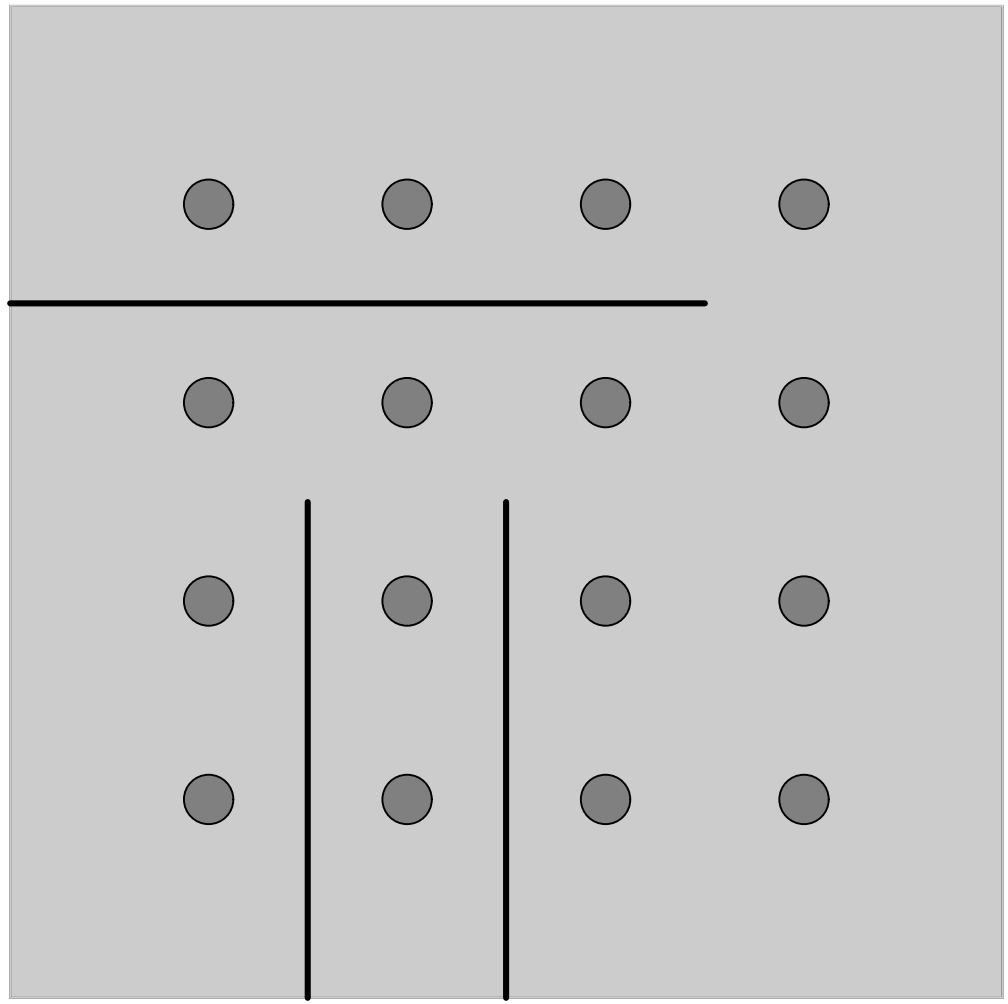
- Broadcast
- LANs only
- Connect buses together via repeaters

Network Topology (5): Ring

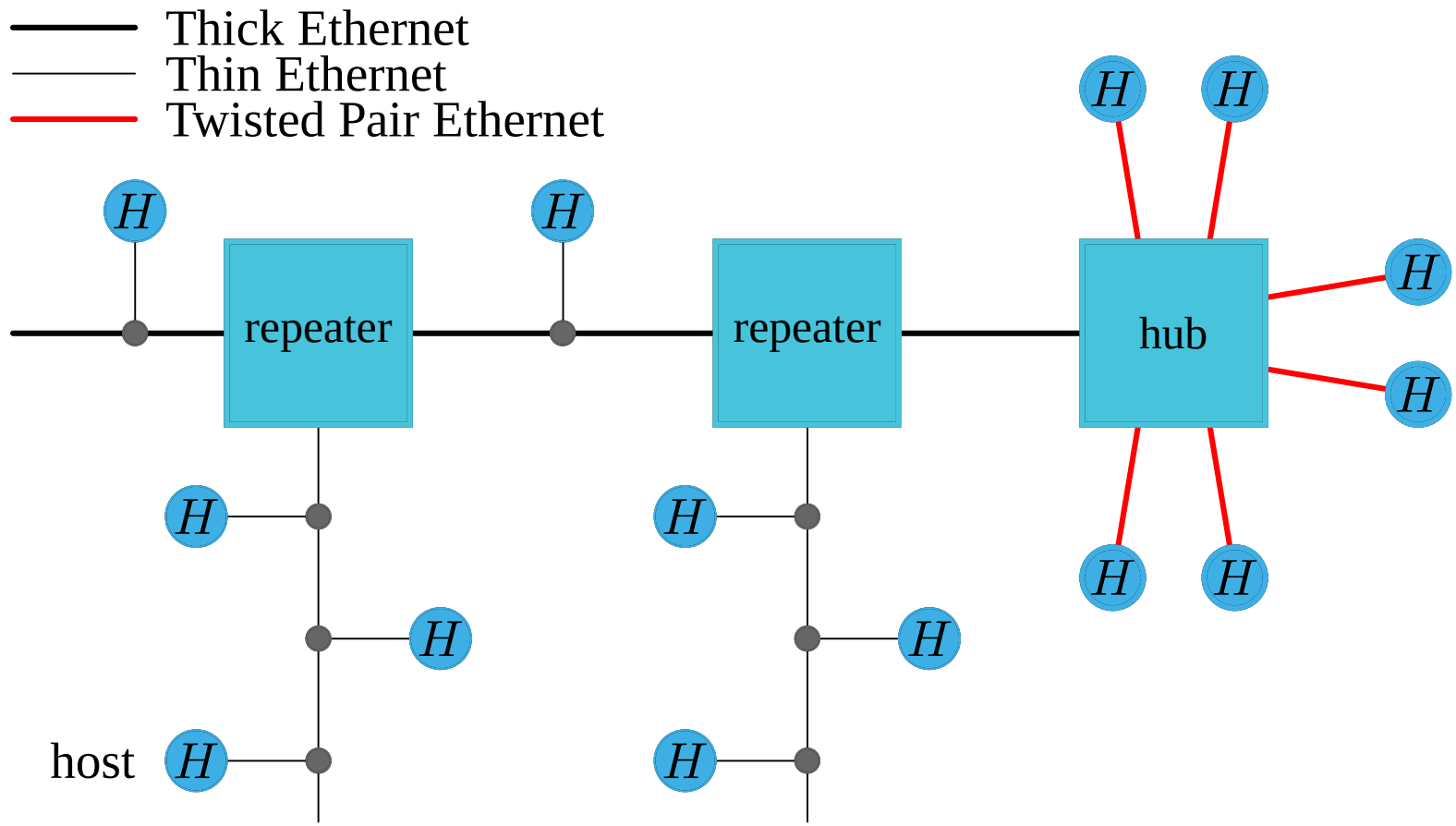


- Broadcast
- Data passed on from host to host around ring
- LANs only

Worksheet: Topology in Buildings



Example Topology: 10Mbs^{-1} Ethernet Bus/Tree



Example Topology: PSTN Partial Mesh