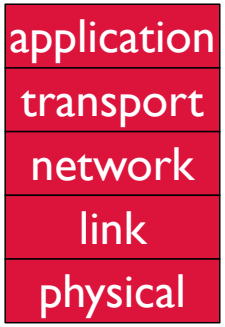
Layers



Firefox, `ping` , ...

TCP, UDP, ...

IP

ethernet, WiFi, ...

electrons, photons, ...

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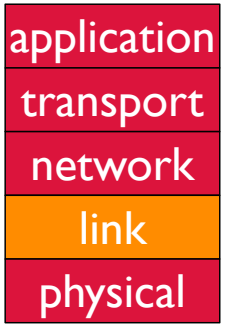

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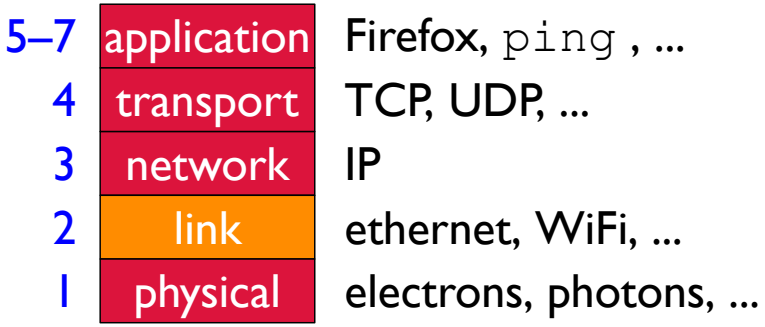
5–7
application
Firefox, ping , ...
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transport
TCP, UDP, ...
3
network
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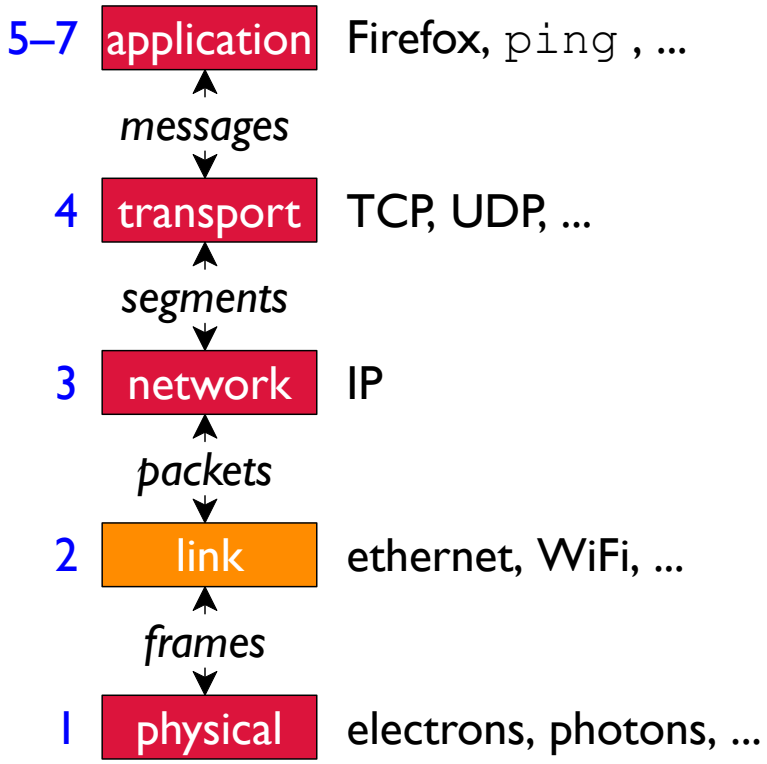
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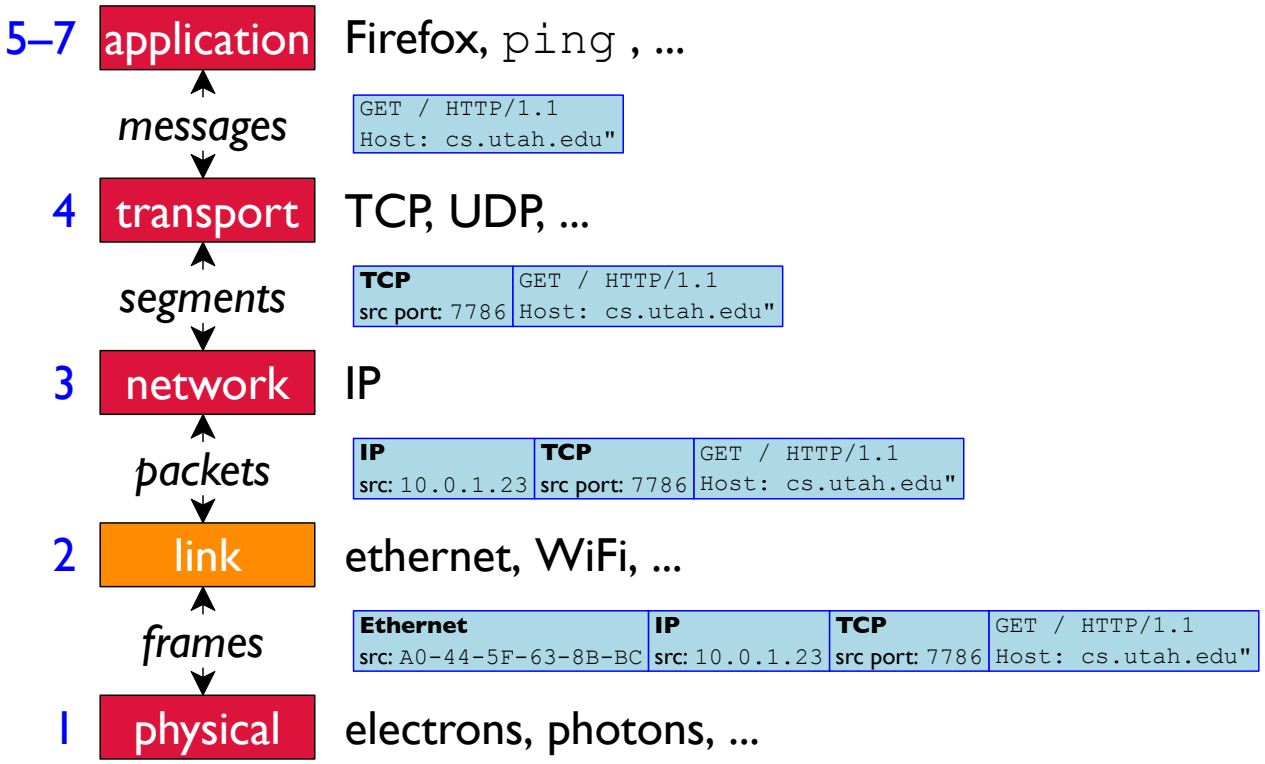
5–7
application
Firefox, ping , ...
messages
GET / HTTP/1.1
Host: cs.utah.edu"
4
transport
TCP, UDP, ...
segments
TCP
src port: 7786
GET / HTTP/1.1
Host: cs.utah.edu"
3
network
IP
packets
IP
src: 10.0.1.23
TCP
src port: 7786
GET / HTTP/1.1
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2
link
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Ethernet
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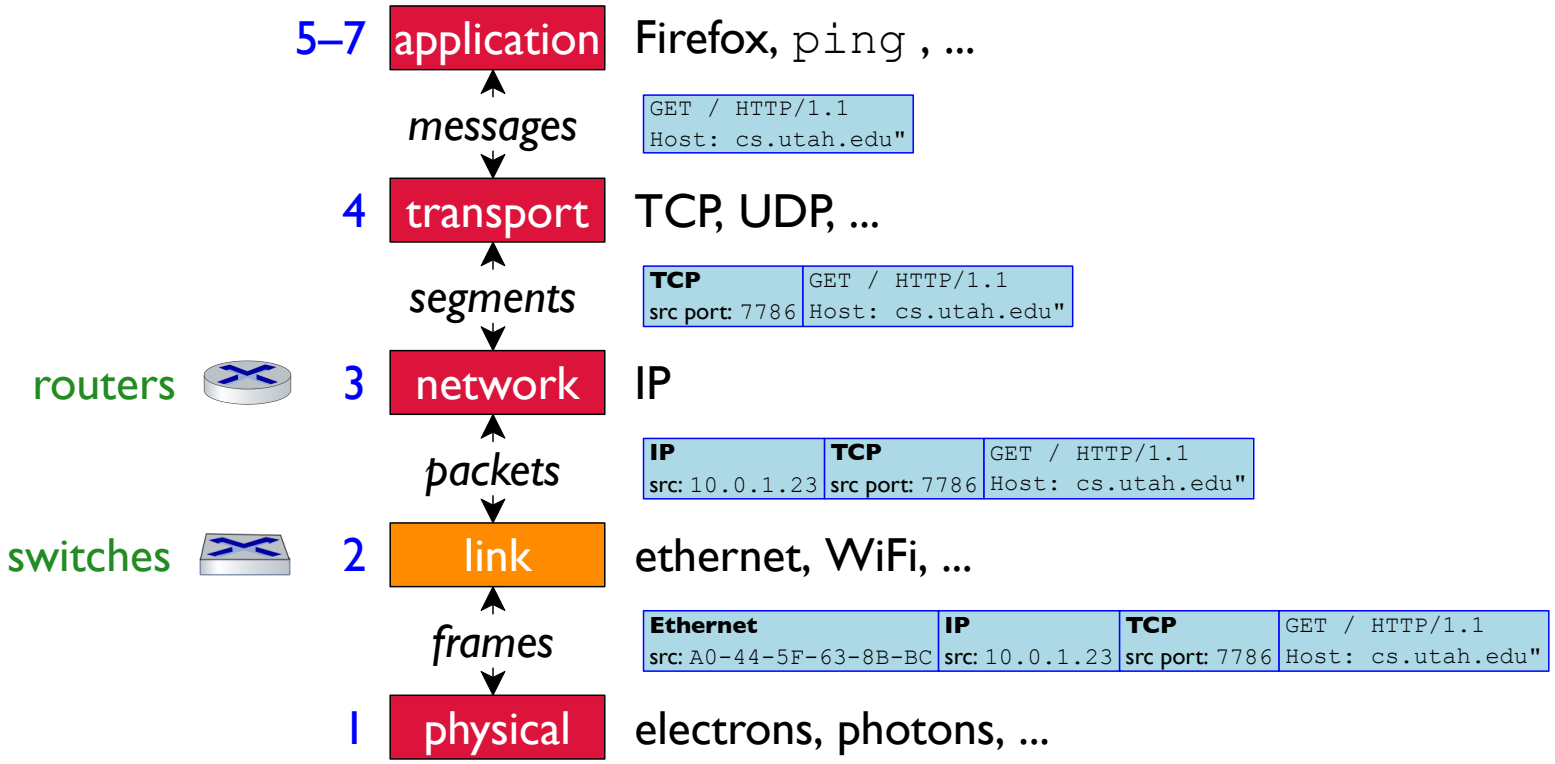
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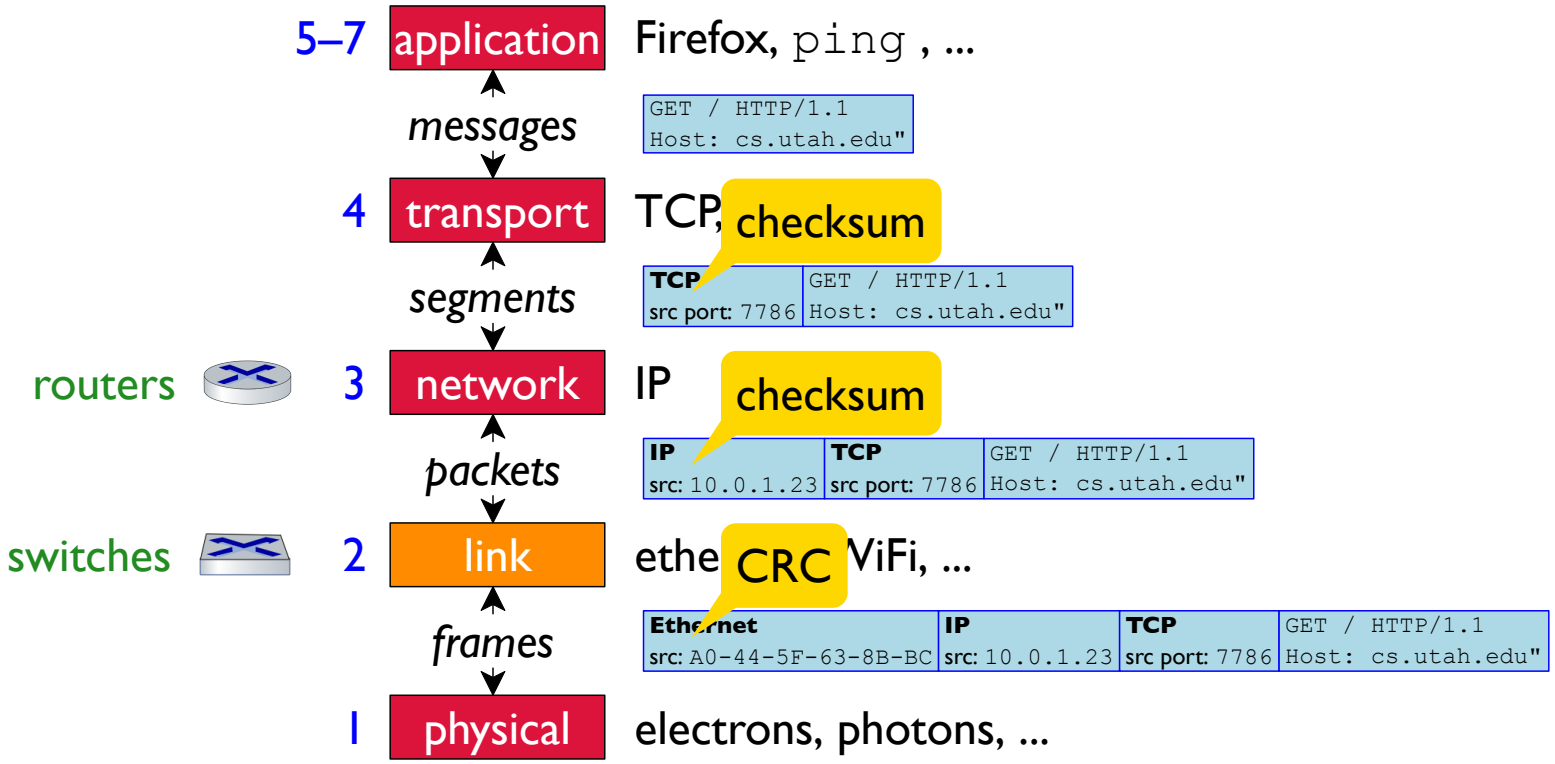
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application
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Weak Checksum: Parity

A 1-bit checksum is a **parity** check

... since that 1 bit is either on/odd or off/even

```
10001010  →  1
10011010  →  0
10111010  →  1
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Fast, but two corrupt bits cancel, which is especially bad when corruption is bursty

Strong: Cyclic Redundancy Check

A checksum based on adding numbers and keeping only low bits
is a kind of hash function... but not an especially good hash function

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A **cyclic redundancy check (CRC)** is a much better hash function:

d = number of bits to check
D = d bits of data
r = bits for hash result (typically 8, 12, 16, or 32)
R = the hash of D
G = a carefully chosen, agreed-on $r+1$-bit number

$$R = \text{remainder of } \frac{D \times 2^r}{G}$$

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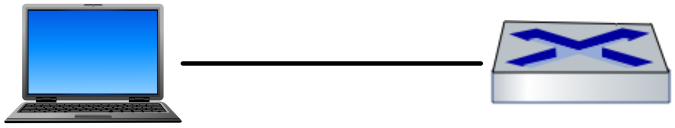
Detects any r -bit error burst

Coordinating Communication

Easy mode : point-to-point communication



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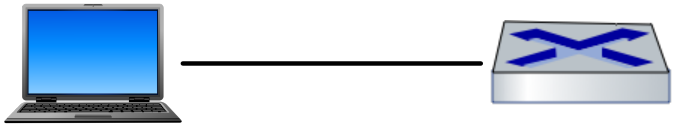
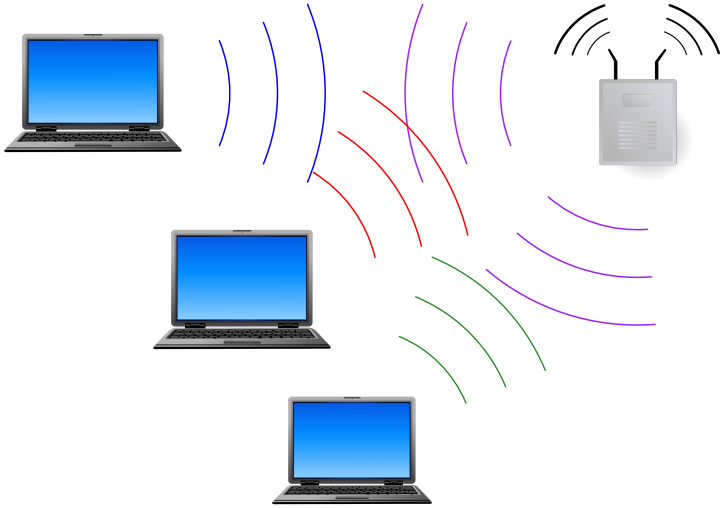


Hard mode : shared communication medium



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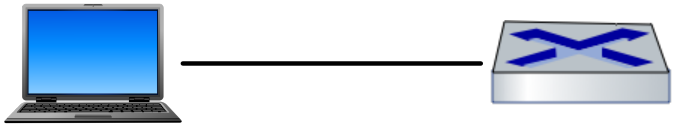

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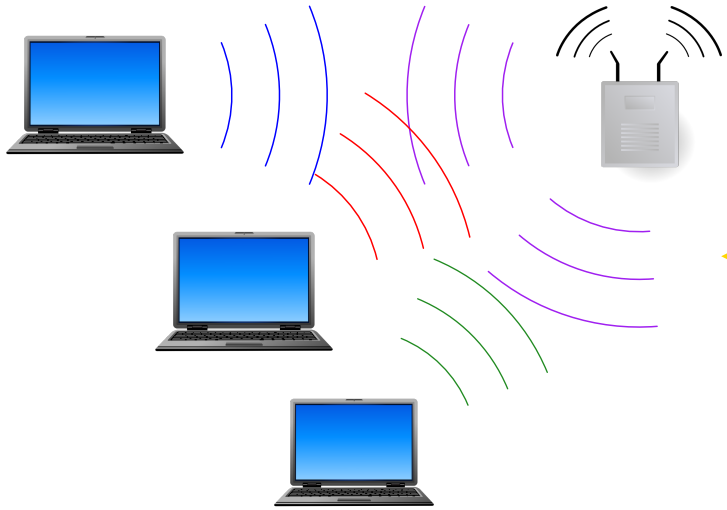
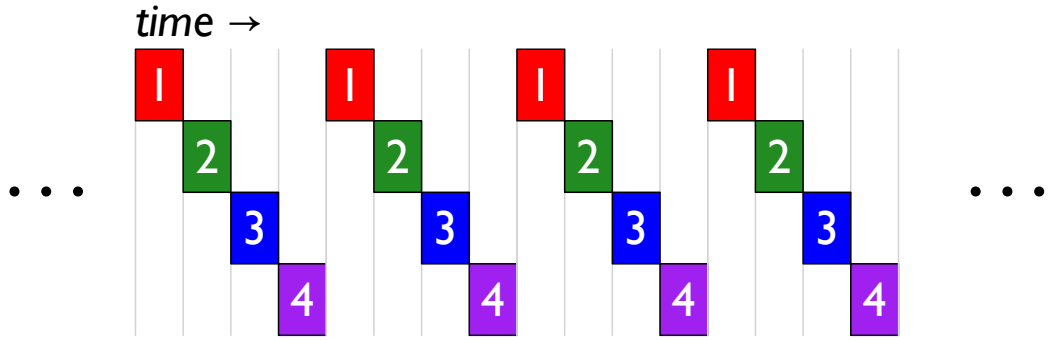


Goals:
- divide bandwidth fairly
- only one active

  ⇒ gets full bandwidth

Shared-Medium Strategy 1: Channel Partitioning

Time-devision multiplexing (TDM) :



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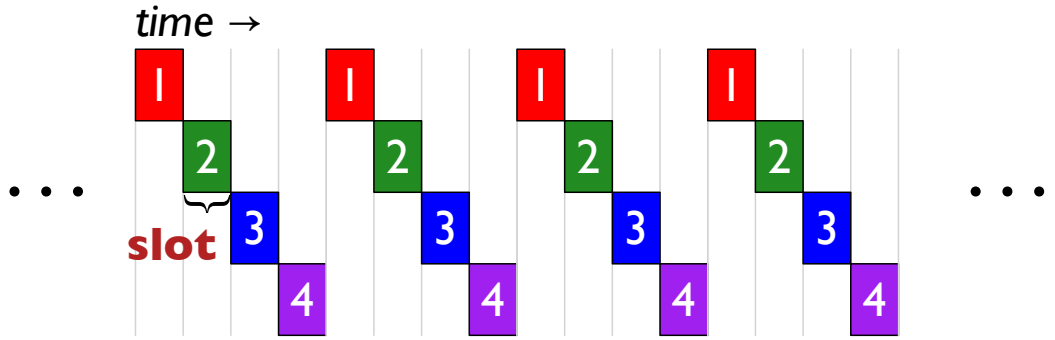

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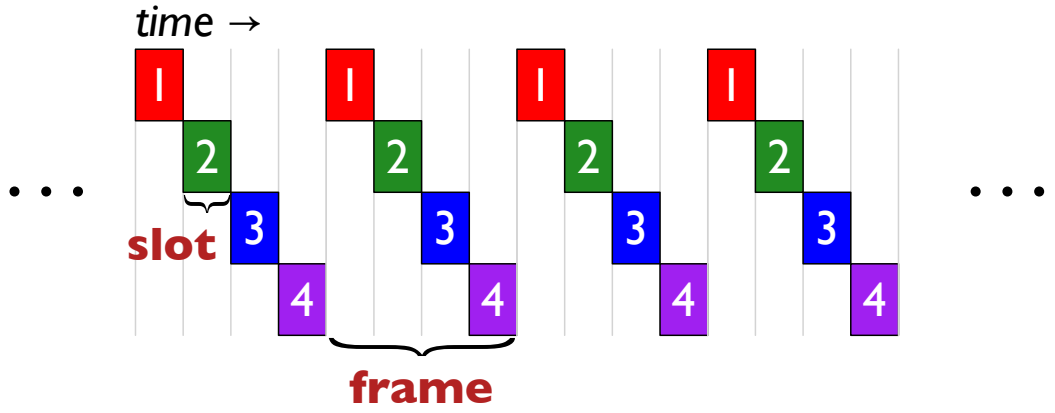

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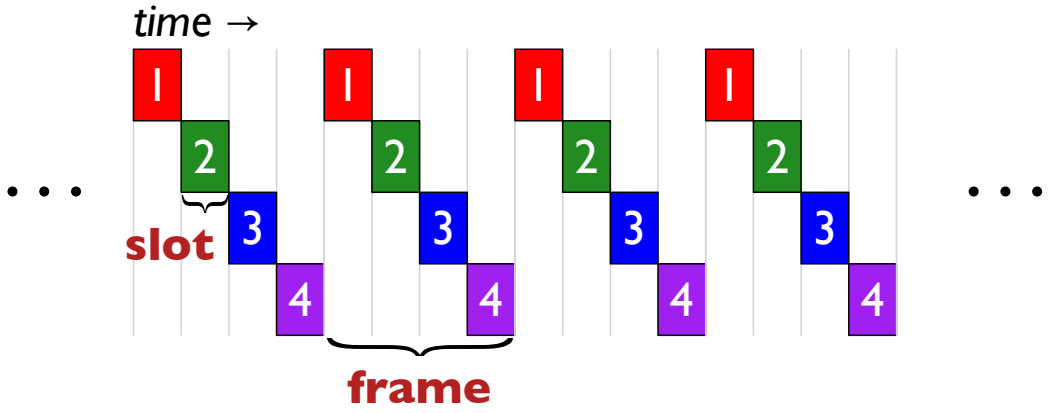
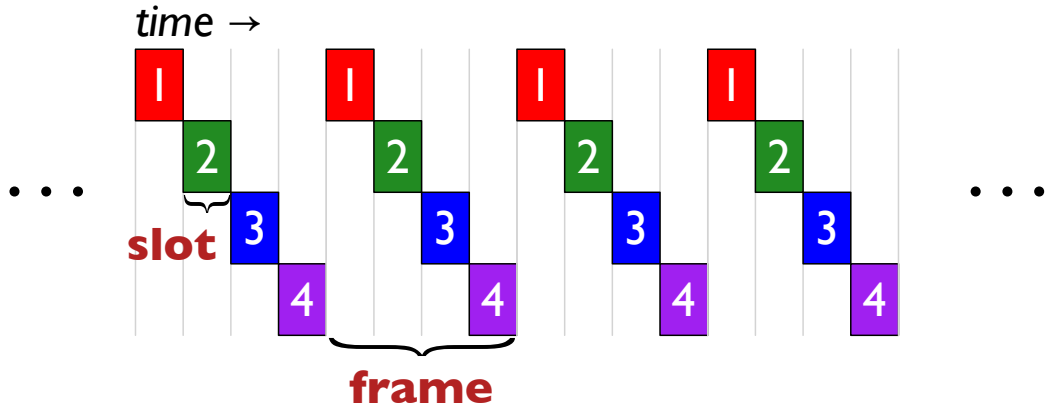


Frequency-devision multiplexing (FDM) :

same idea, but for simultaneous frequencies

Shared-Medium Strategy 1: Channel Partitioning

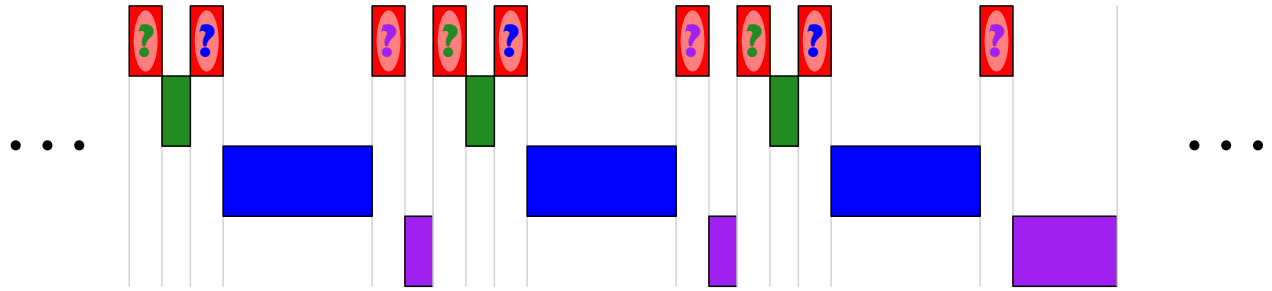
Time-devision multiplexing (TDM) :



+ No collisions
+ Perfectly fair
– Poor utilization when some are idle

Shared-Medium Strategy 2: Turn Taking

Polling :



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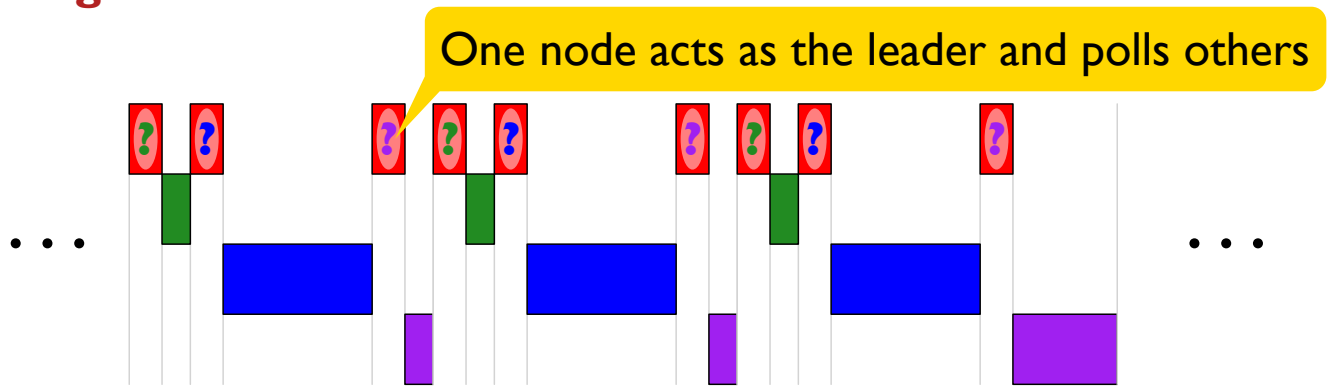

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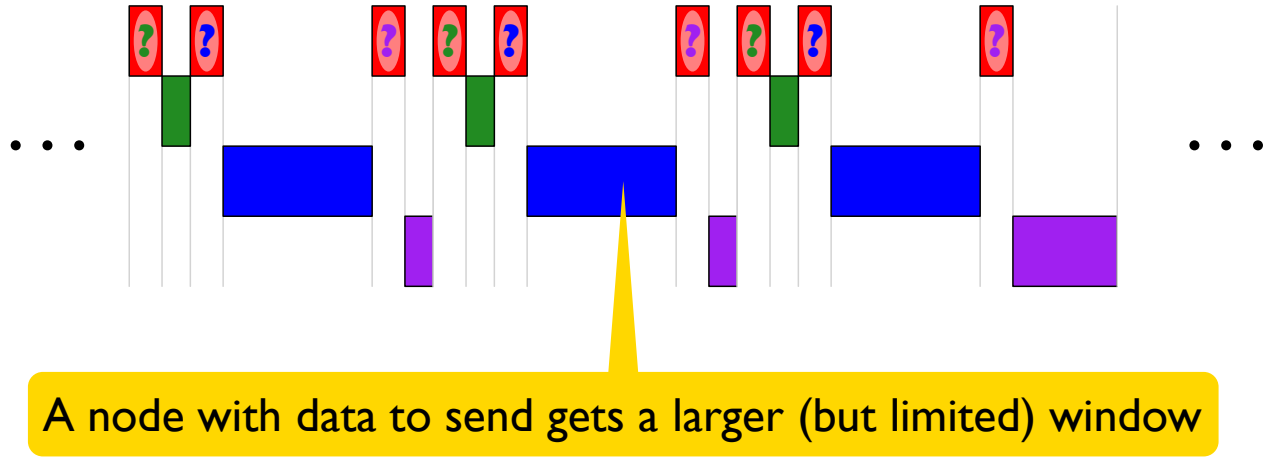

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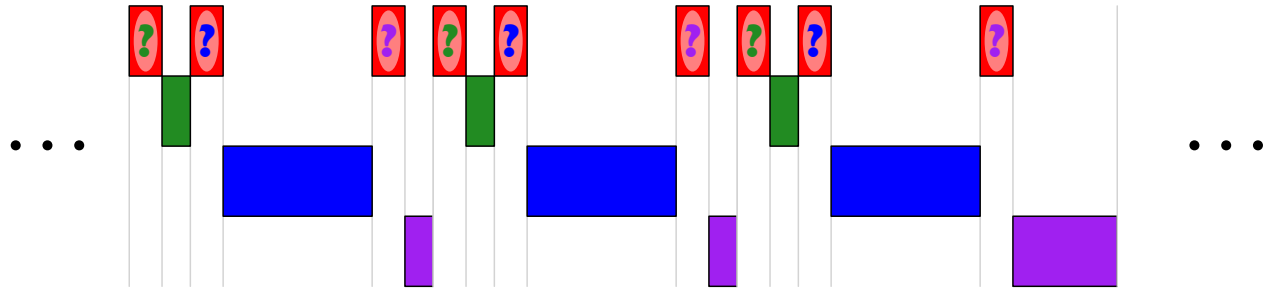
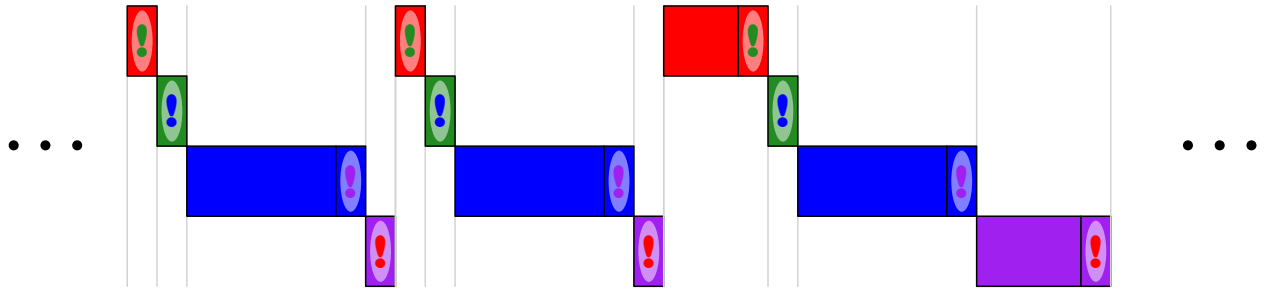


+ Better utilization
– Polling causes delays
– Recovery needed if the leader fails

Shared-Medium Strategy 2: Turn Taking

Token passing :



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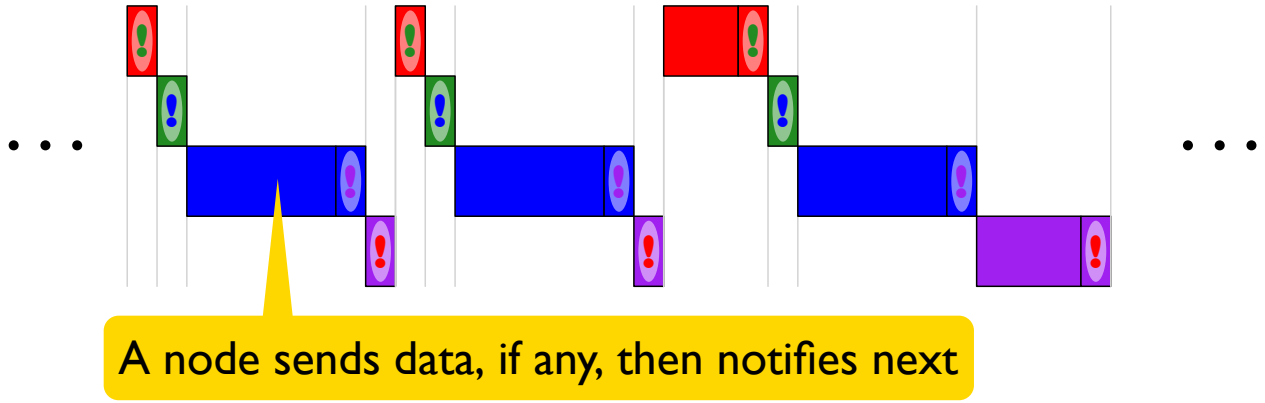

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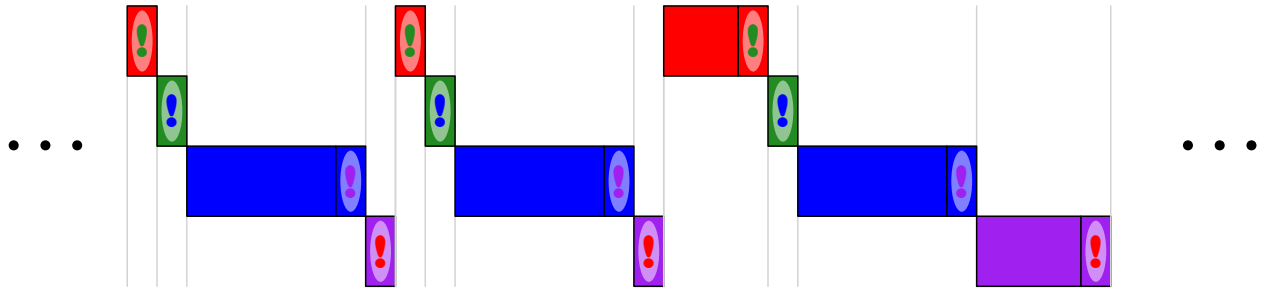

+ Better utilization
- Token-passing causes delays
- Recovery needed if any fails

Shared-Medium Strategy 3: Random Access

A **random access** strategy requires either

- detection of collisions by senders
- **carrier sense** to detect when someone is already sending

or both

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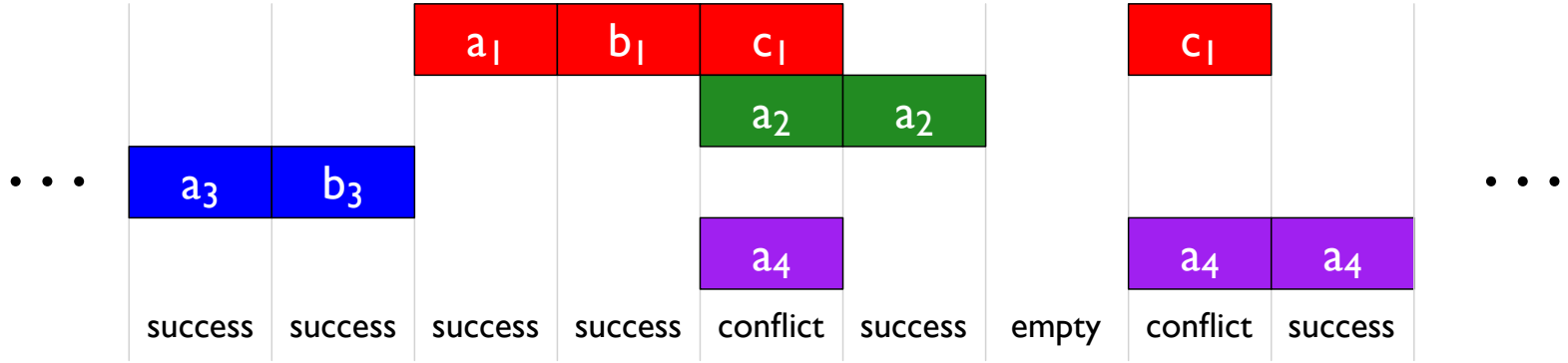
- detection of collisions by senders
- **carrier sense** to detect when someone is already sending

or both

A random delay is used when a collision is detected

Random Access: ALOHA



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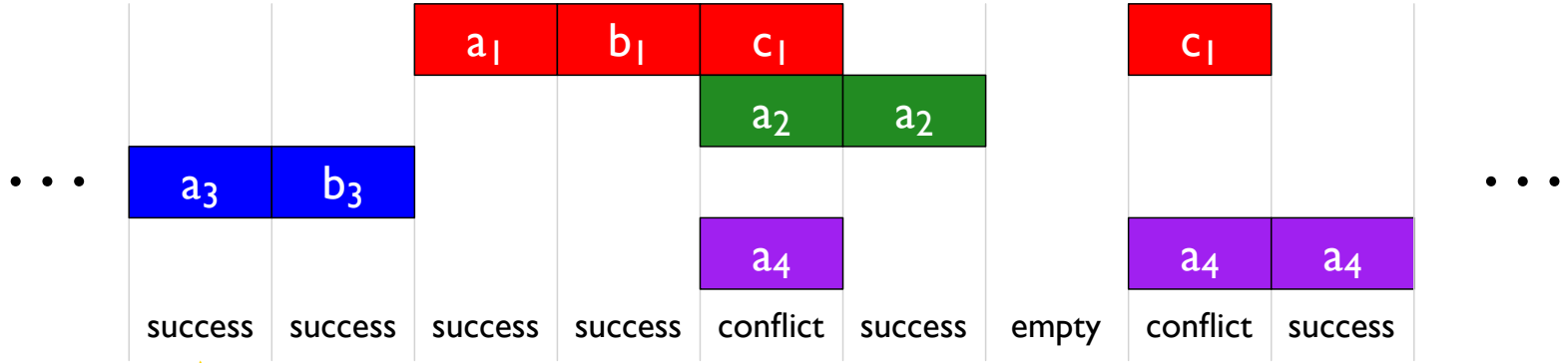
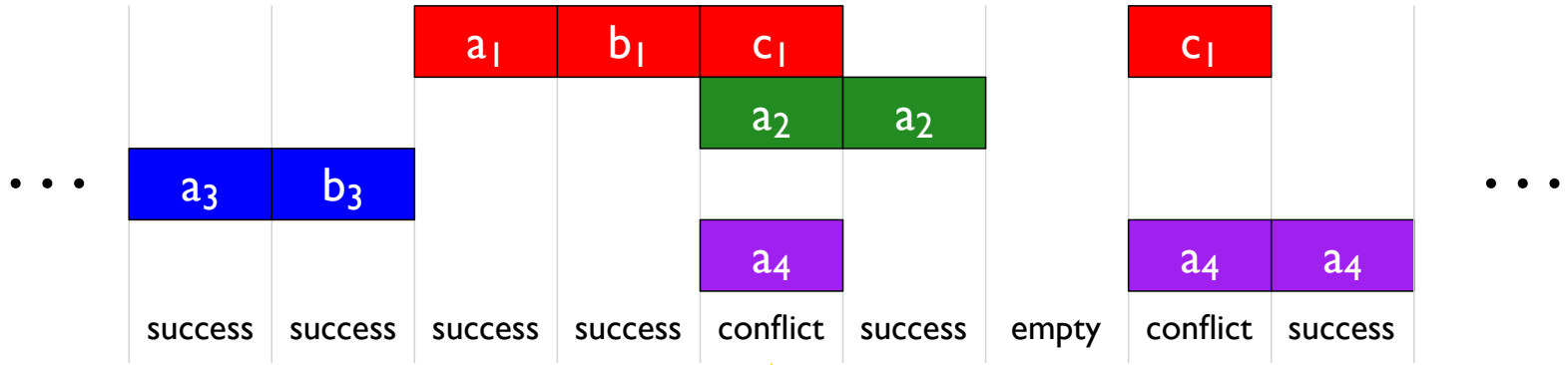


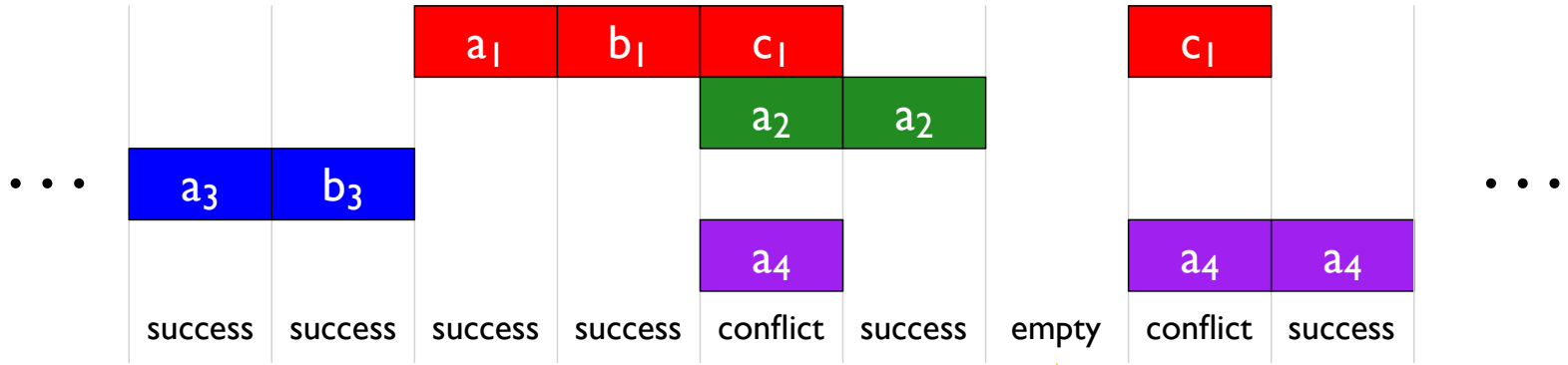
On success, a node can keep sending as long as it has data

Random Access: ALOHA



On conflict, each node retries on next slot probability P

Random Access: ALOHA



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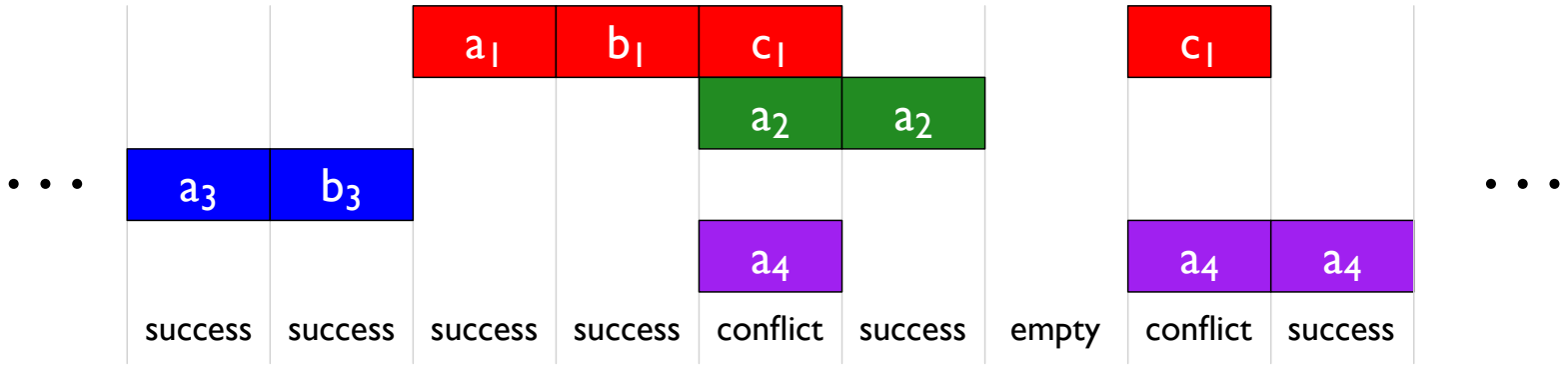
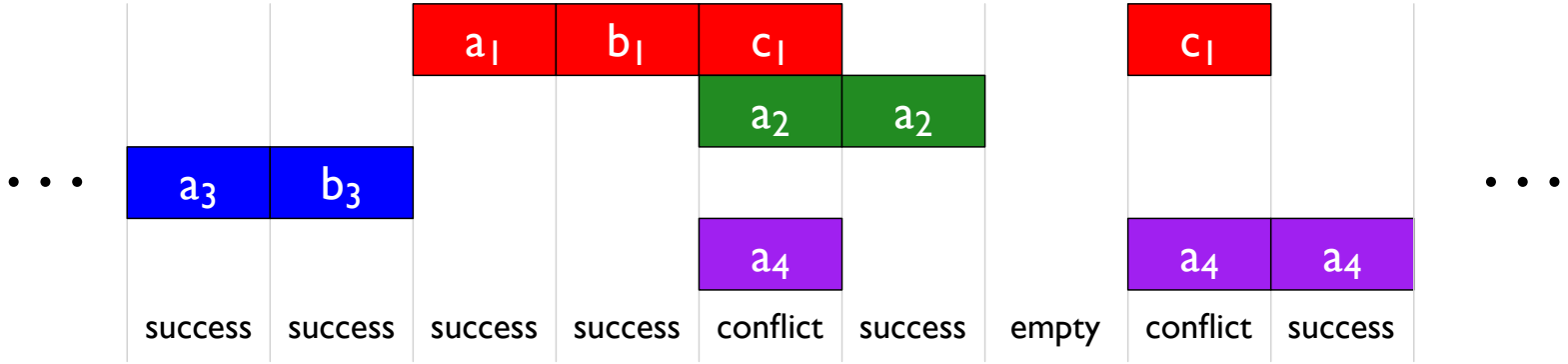


Slotted ALOHA , which needs synchronization:

+ Sole active nodes can use full bandwidth
+ Multiple active nodes get fair share
– Even after optimizing P, likely to get only 37% success

Random Access: ALOHA



Original **unslotted ALOHA** avoided synchronization:

- Success drop drops by half

  because each local slot likely overlaps two other peer slots

Random Access: Carrier Sense

Carrier Sense Multiple Access (CSMA) means
"don't talk when someone else is talking"

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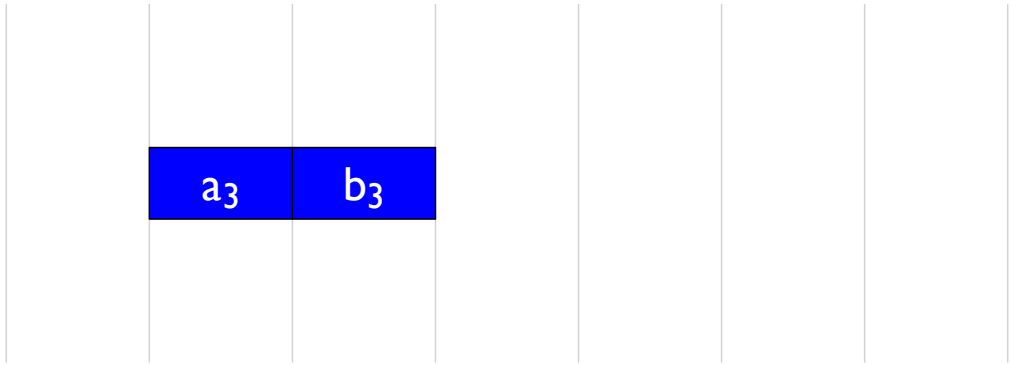
The catch: there's a delay between the time that one node sends and another node starts to sense it



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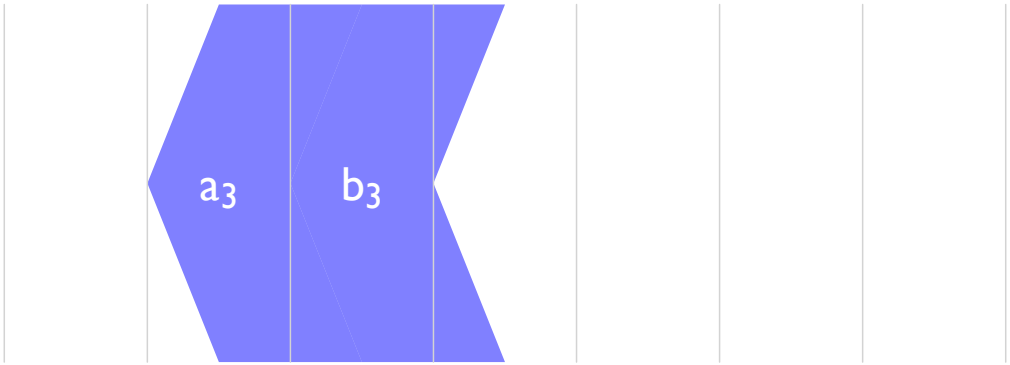

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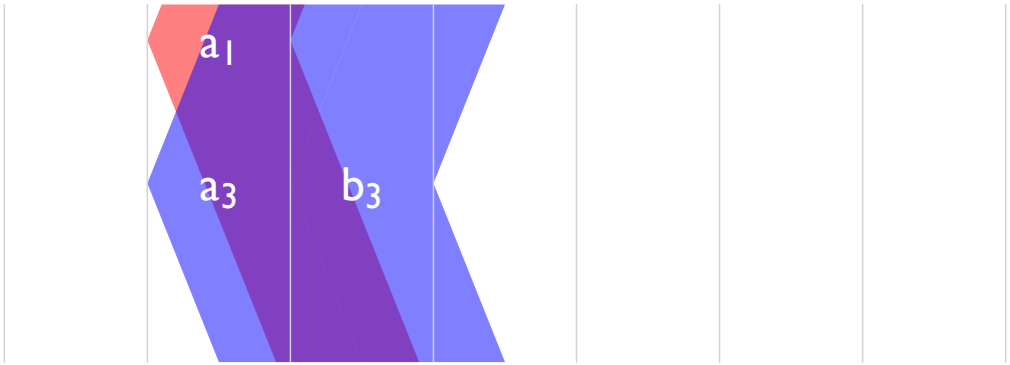
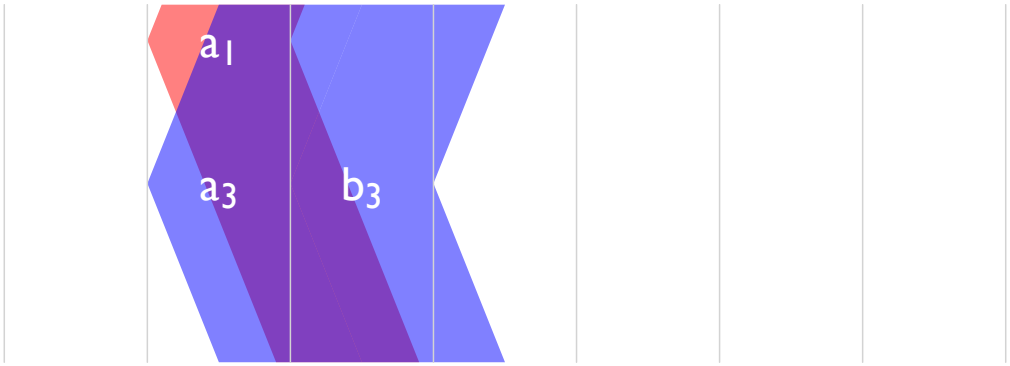


Handling Conflicts in CSMA



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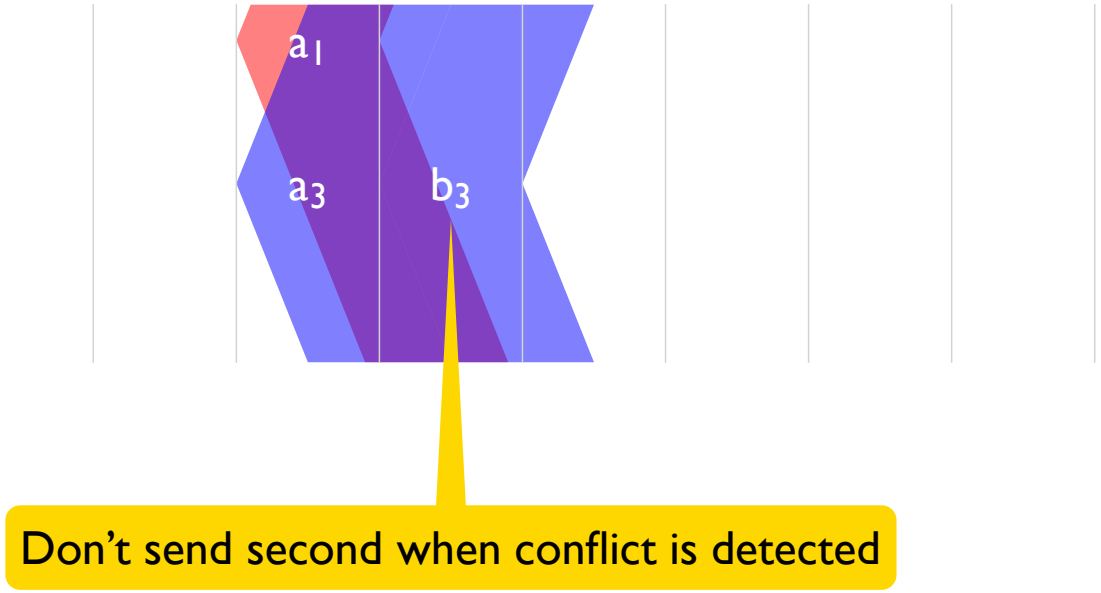

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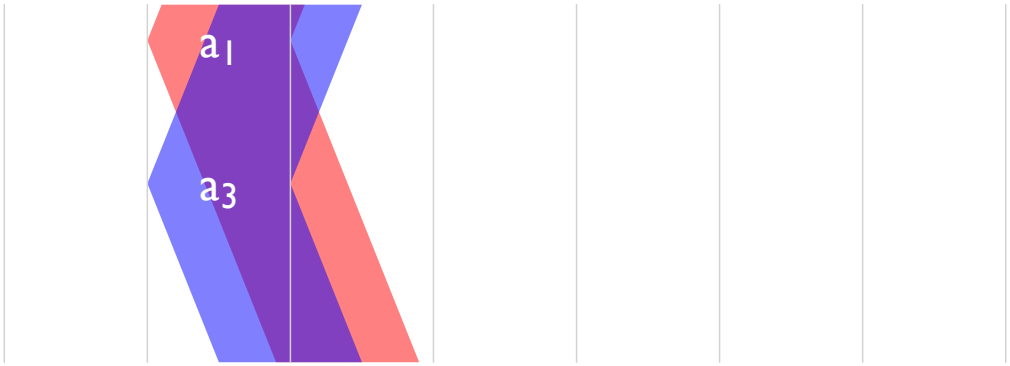

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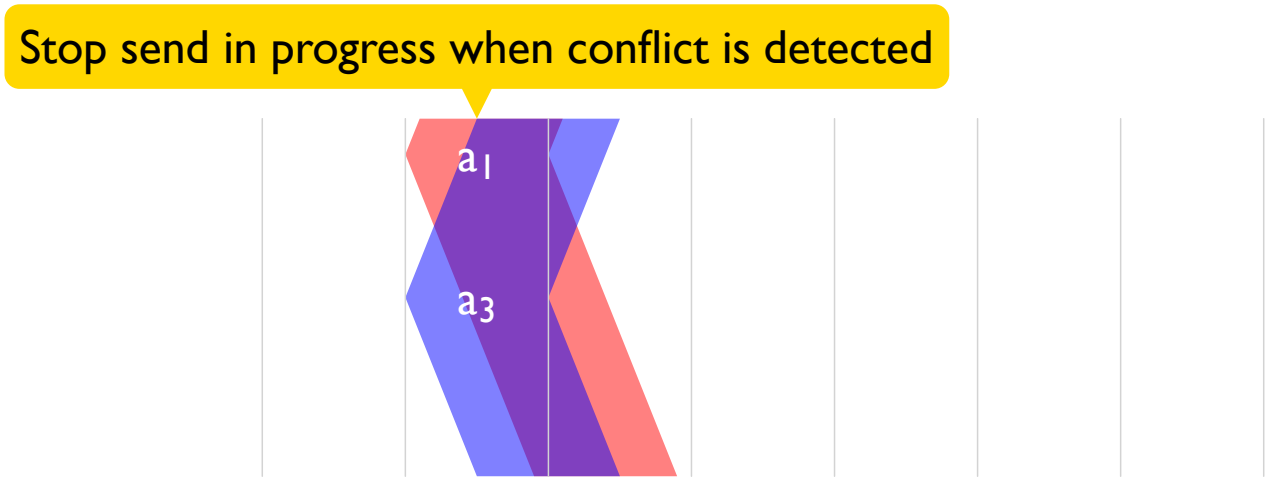

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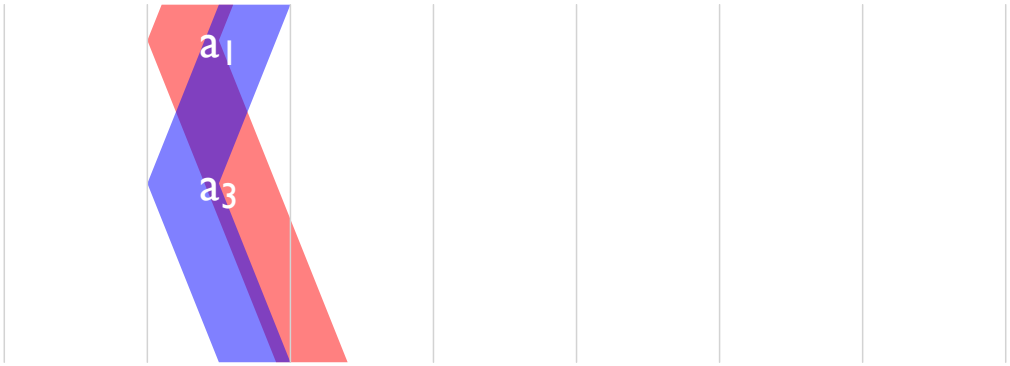

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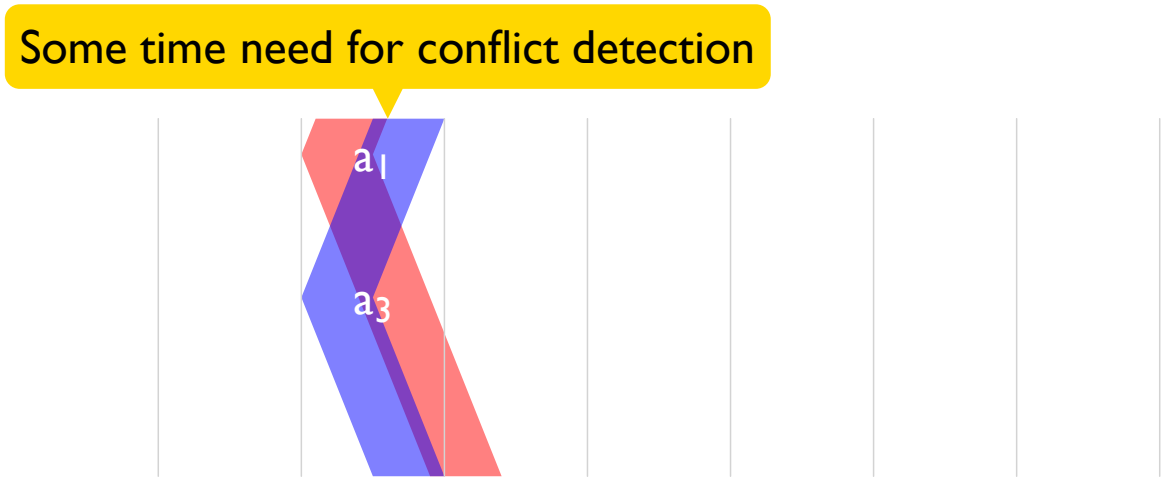
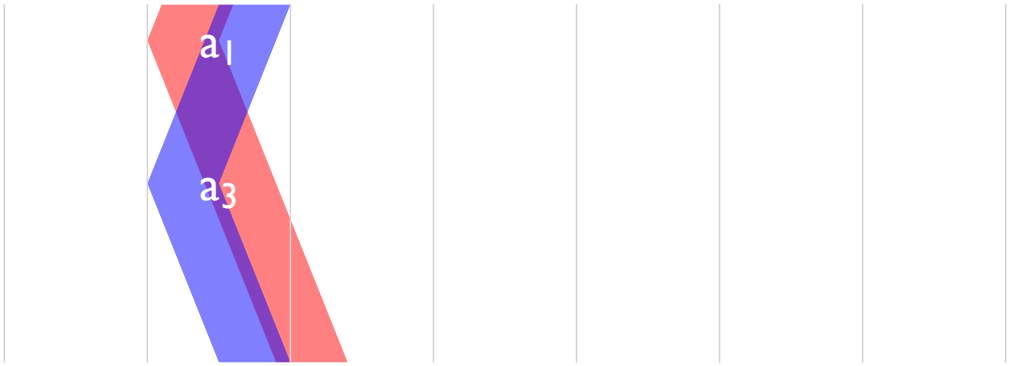


Handling Conflicts in CSMA

Random delay before retry



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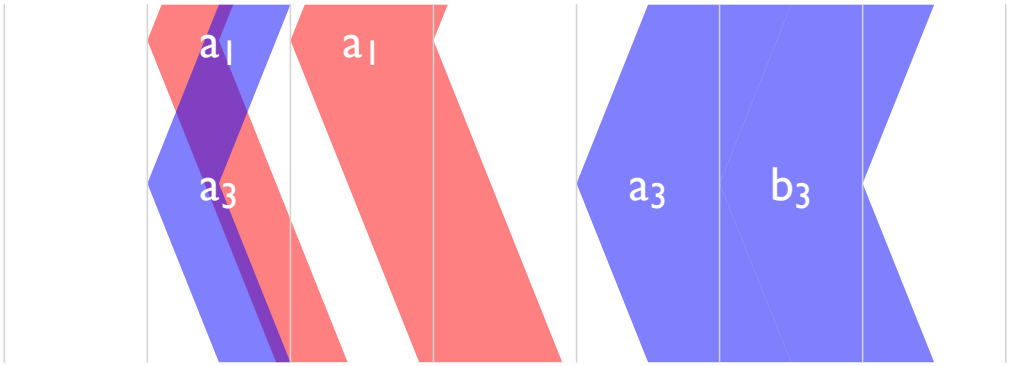

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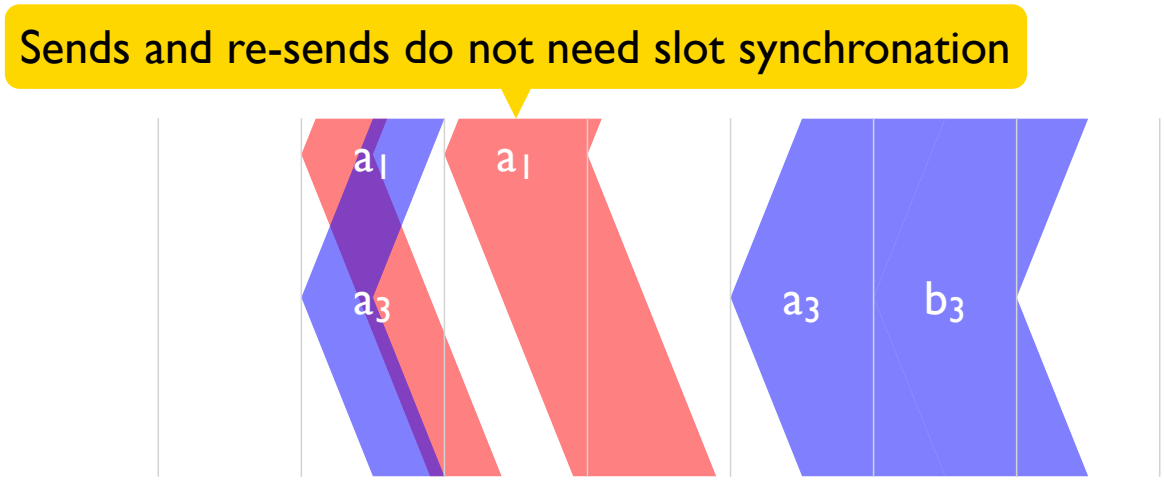
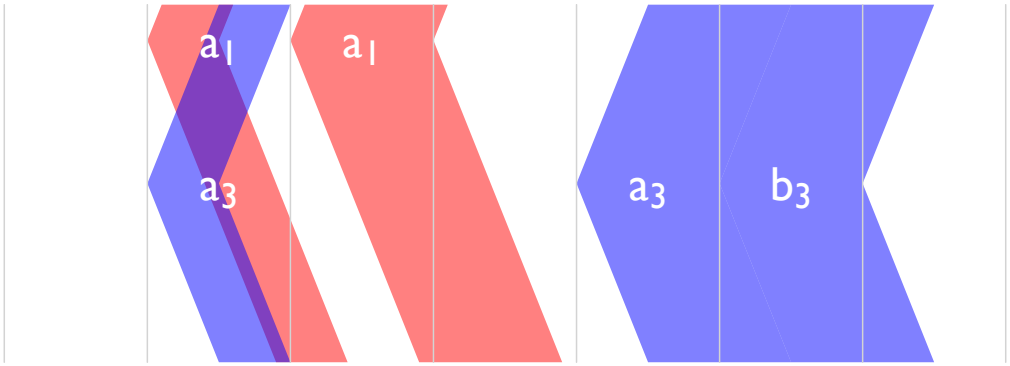
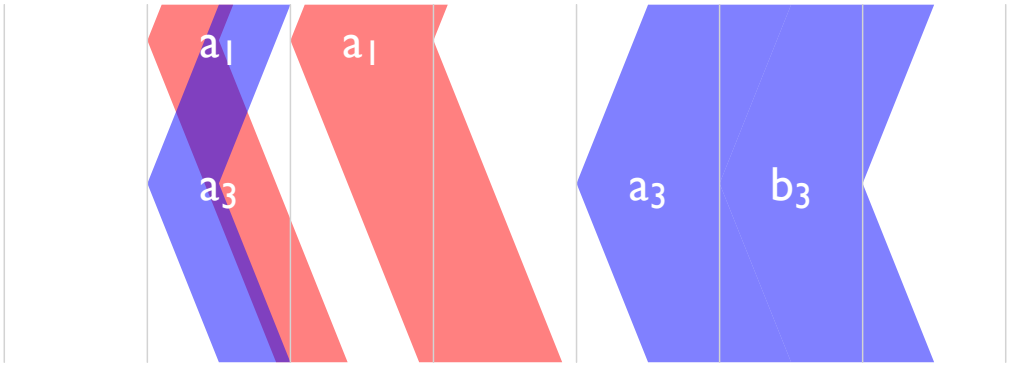


Handling Conflicts in CSMA

Exponential back-off:
If another conflict, double average retry delay



Handling Conflicts in CSMA

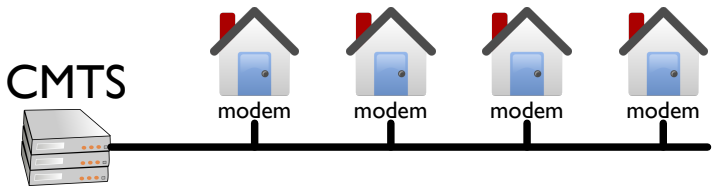


d_{prop} = max delay for signal

d_{trans} = max duration for frame

$$\text{efficiency} = \frac{1}{1 + 5\frac{d_{prop}}{d_{trans}}}$$

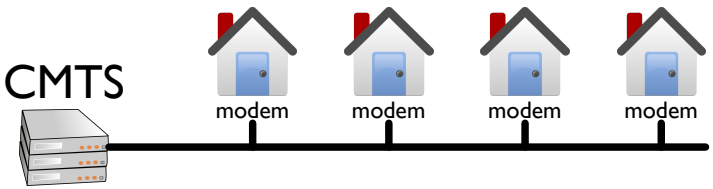
DOCSIS Cable Internet Protocol



Shared line is split into channels by frequency (FDM):

- Some channels are download: all modems receive
- Remaining channels are upload: CMTS receives

DOCSIS Cable Internet Protocol

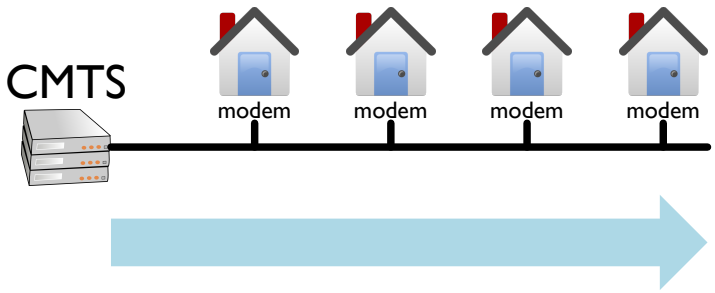


Shared line is split into channels by frequency (FDM):

- Some channels are download: all modems receive
- Remaining channels are upload: CMTS receives

Fewer, which explains asymmetric speed

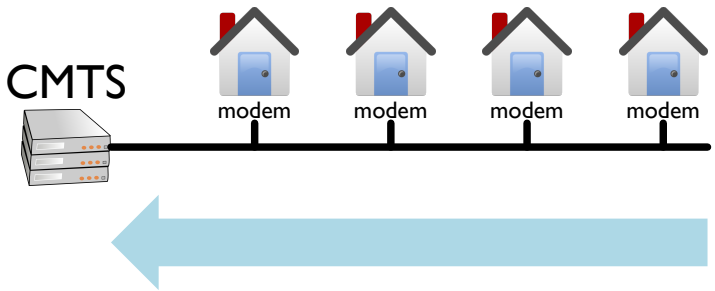
DOCSIS Cable Internet Protocol



Download:

- Only one sender, so no coordination needed
- Modems listen on all channels, but they ignore frames intended for others

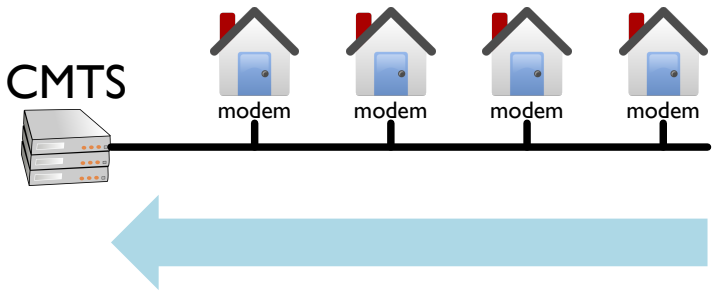
DOCSIS Cable Internet Protocol



Upload uses a hybrid of TDM and polling-ish turn taking:

- Designated short slots used for requests
- CMTS broadcasts slot assignments to grant modem requests
- Modem uses assigned slots for data upload

DOCSIS Cable Internet Protocol



Ok to rely on leader, because CMTS has to work, anyway

Upload uses a hybrid of TDM and polling-ish turn taking:

- Designated short slots used for requests
- CMTS broadcasts slot assignments to grant modem requests
- Modem uses assigned slots for data upload