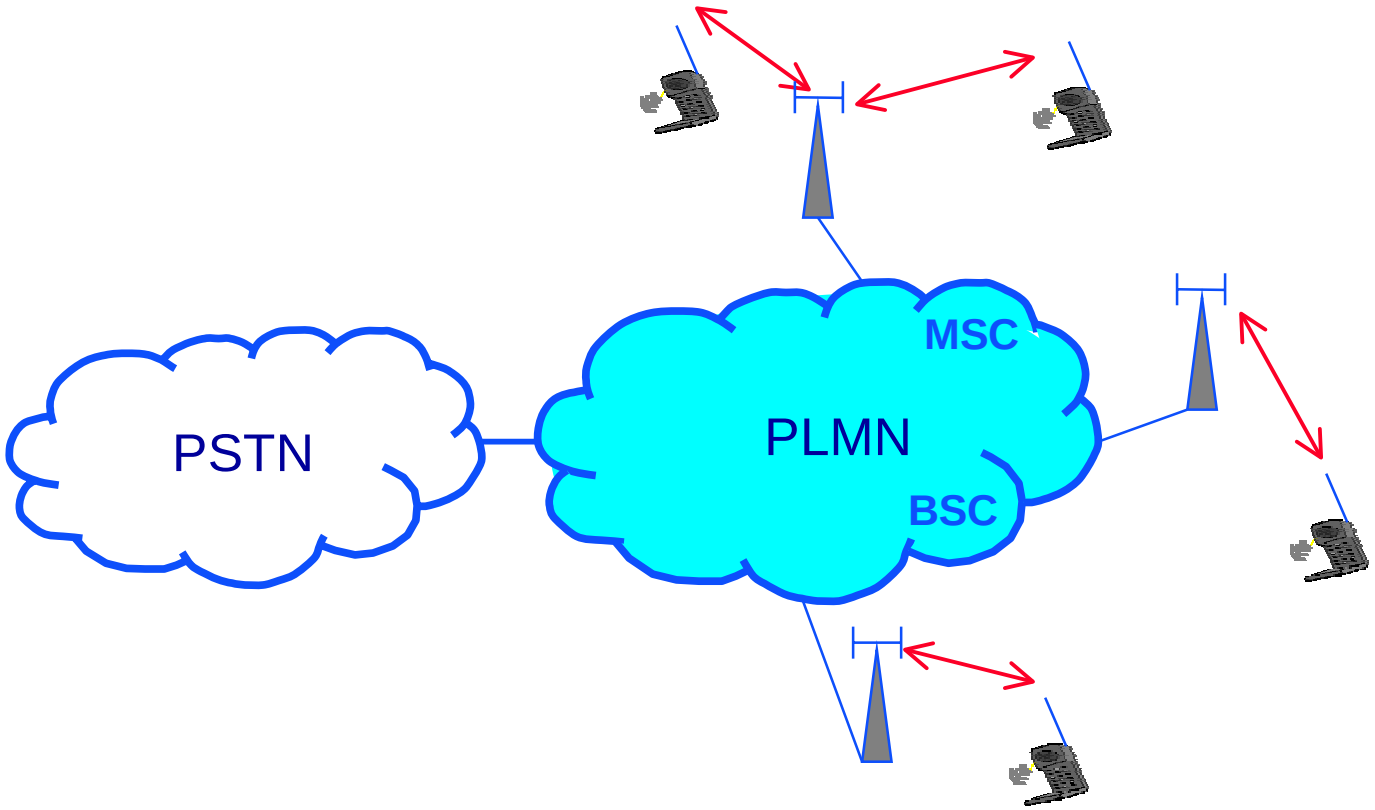
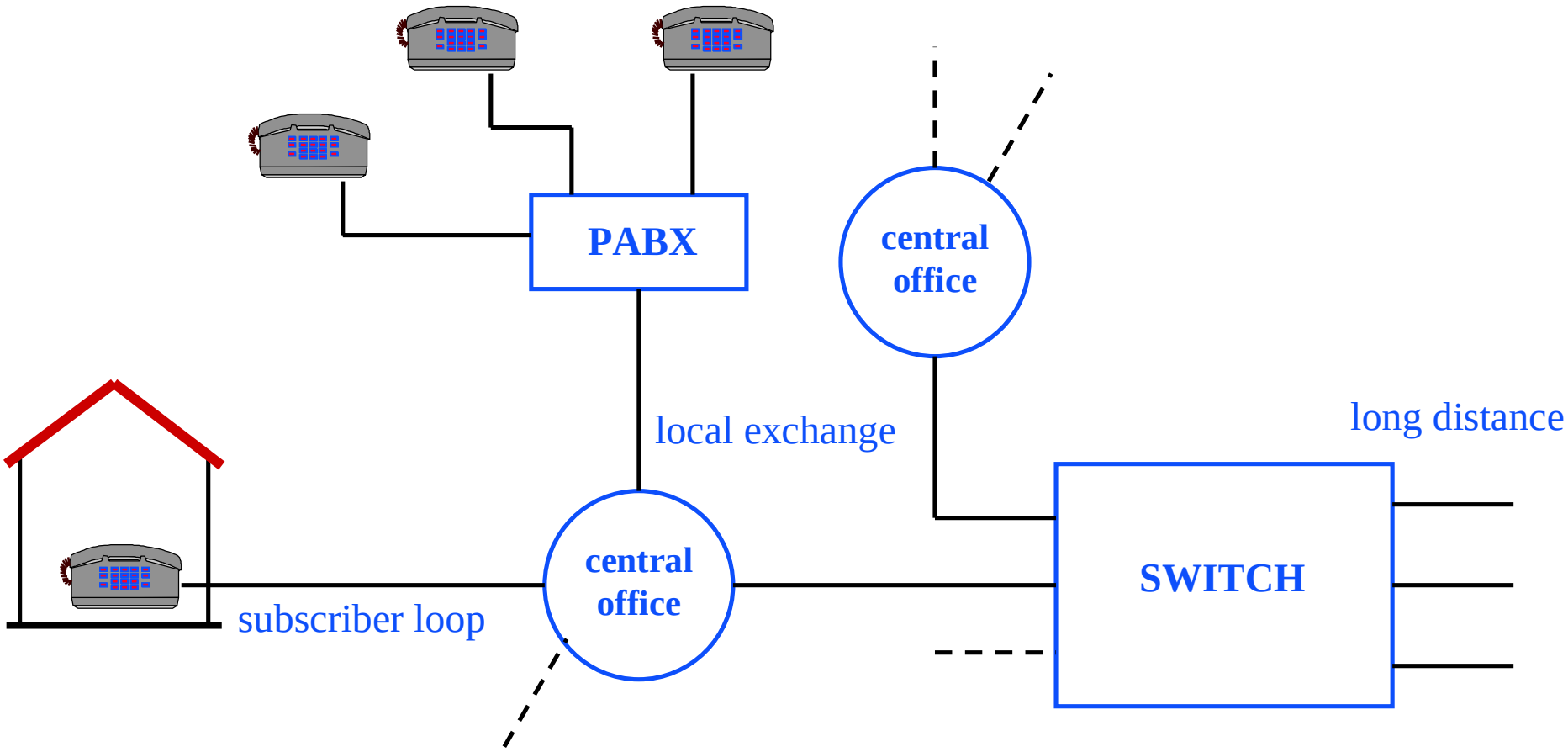
Mobile Radio Communications

Session 7: Wireless networks & WLANs

Backbone network



Public switched telephone network (PSTN)



Signaling formats

- **PCM (8 ks/s, 8b/sample, logPCM, μ-law/A-law)**
- **TDM**

	signal level	bit rate	voice circuits	carrier system
US/Japan	DS-0	64 kb/s	1	
	DS-1	1.544 Mb/s	24	T-1
	DS-1C	3.152 Mb/s	48	T-1C
	DS-2	6.312 Mb/s	96	T-2
	DS-3	44.736Mb/s	672	T-3
	DS-4	274.176 Mb/s	4032	T-4
Europe (CEPT&PTTs)	0	64 kb/s	1	
	1	2.048 Mb/s	30	E-1
	2	8.448 Mb/s	120	E-1C
	3	34.368 Mb/s	480	E-2
	4	139.264 Mb/s	1920	E-3
	5	565.148 Mb/s	7680	E-4

Traffic routing

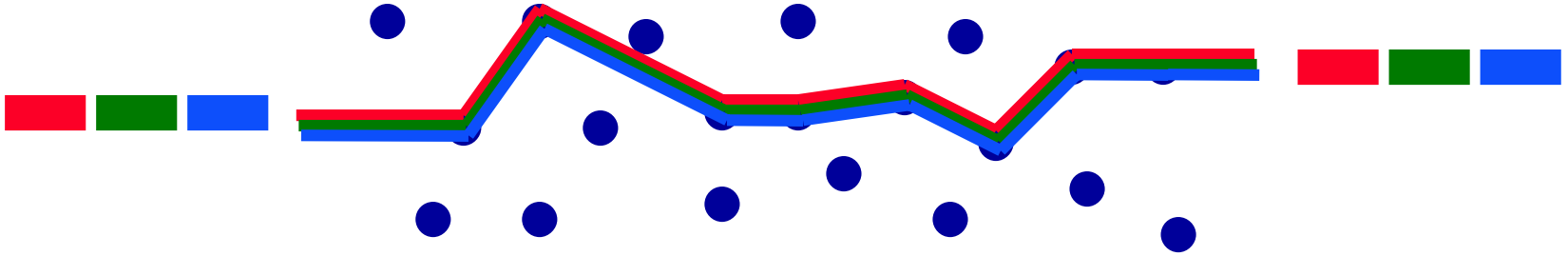
- **Real-time information (voice/video)**
- **Non real-time information (data)**
- **Priority delivery**
- **Best effort delivery**

- **Connection-oriented services**
  - single, (virtual) path
  - call set-up procedure
  - delivery in sequence order

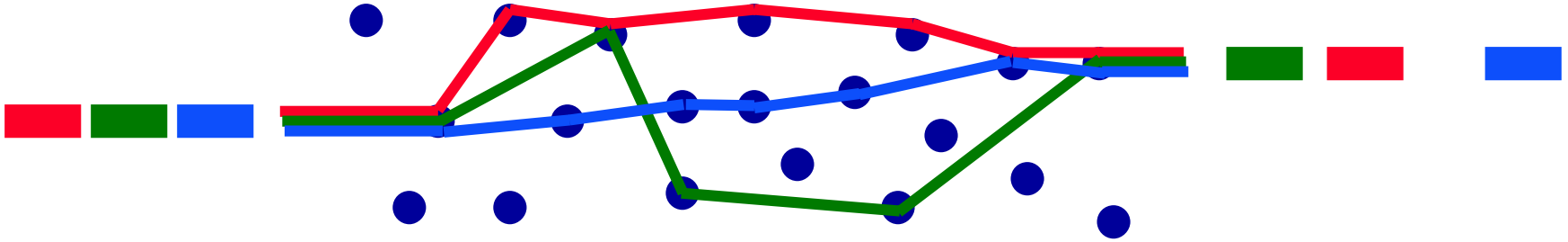
- **Connectionless services**
  - different paths (datagram)
  - always on-line
  - delivery order not guaranteed

Traffic routing

Connection-oriented service

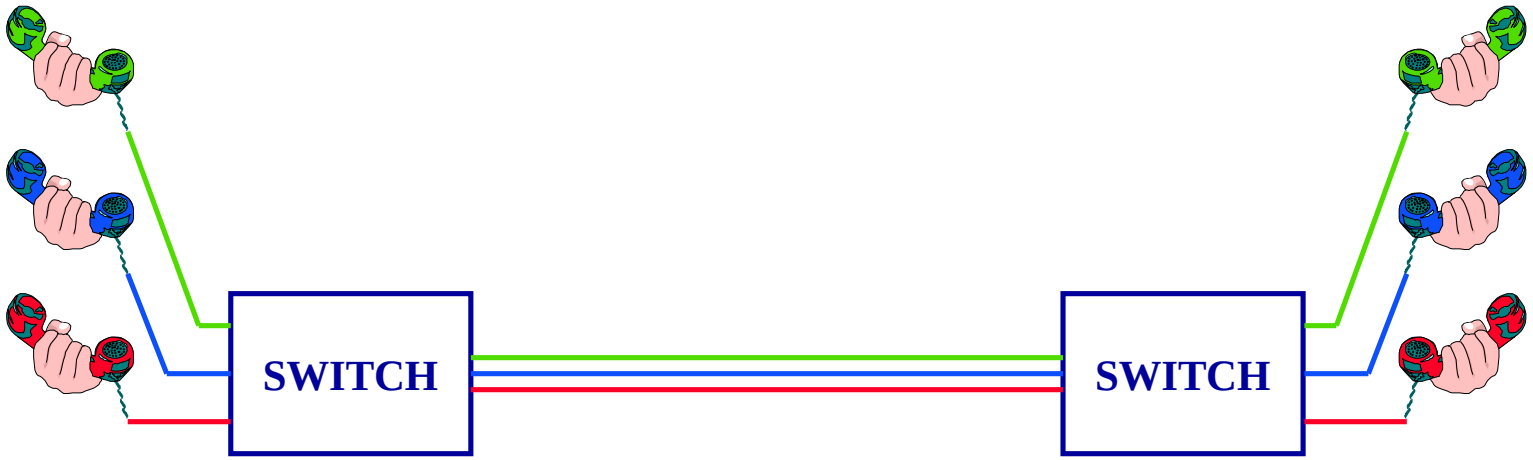


Connectionless service



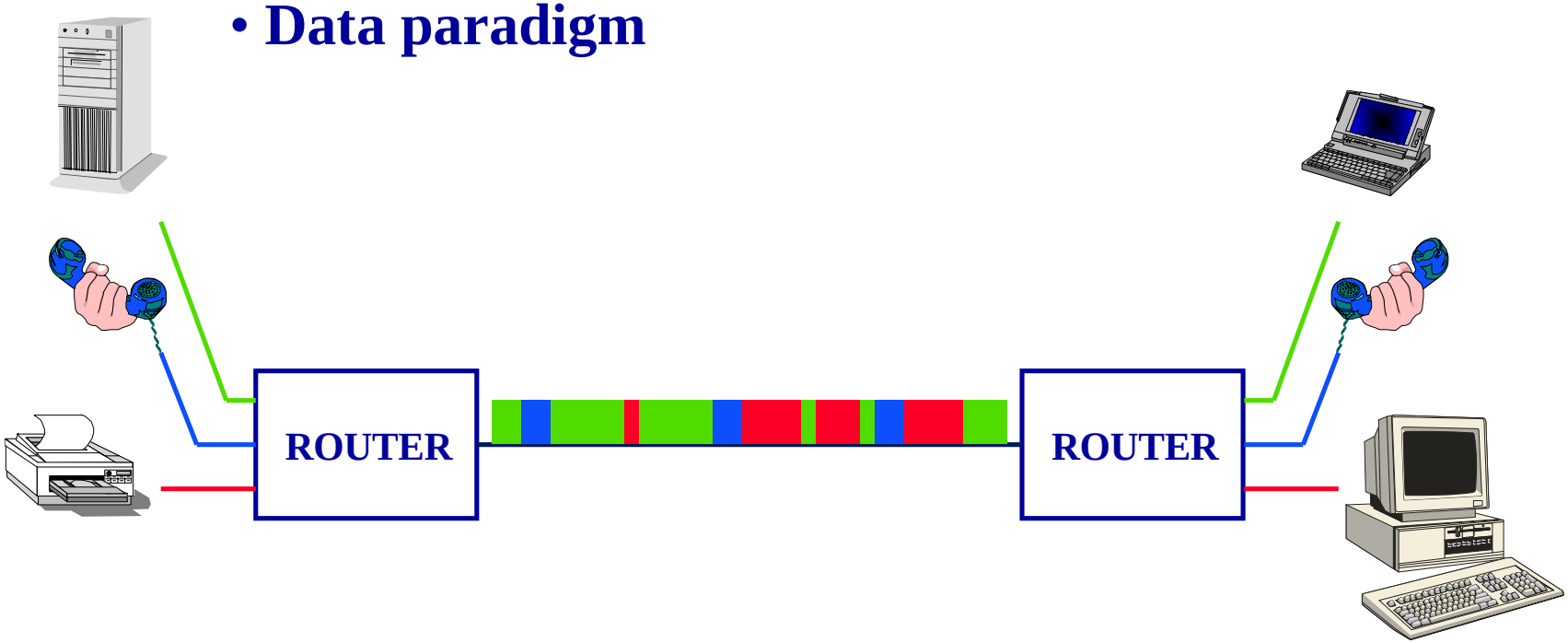
Circuit switching

- Reserved circuits
- Constant bandwidth
- Connection-oriented
- Telephony paradigm



Packet switching

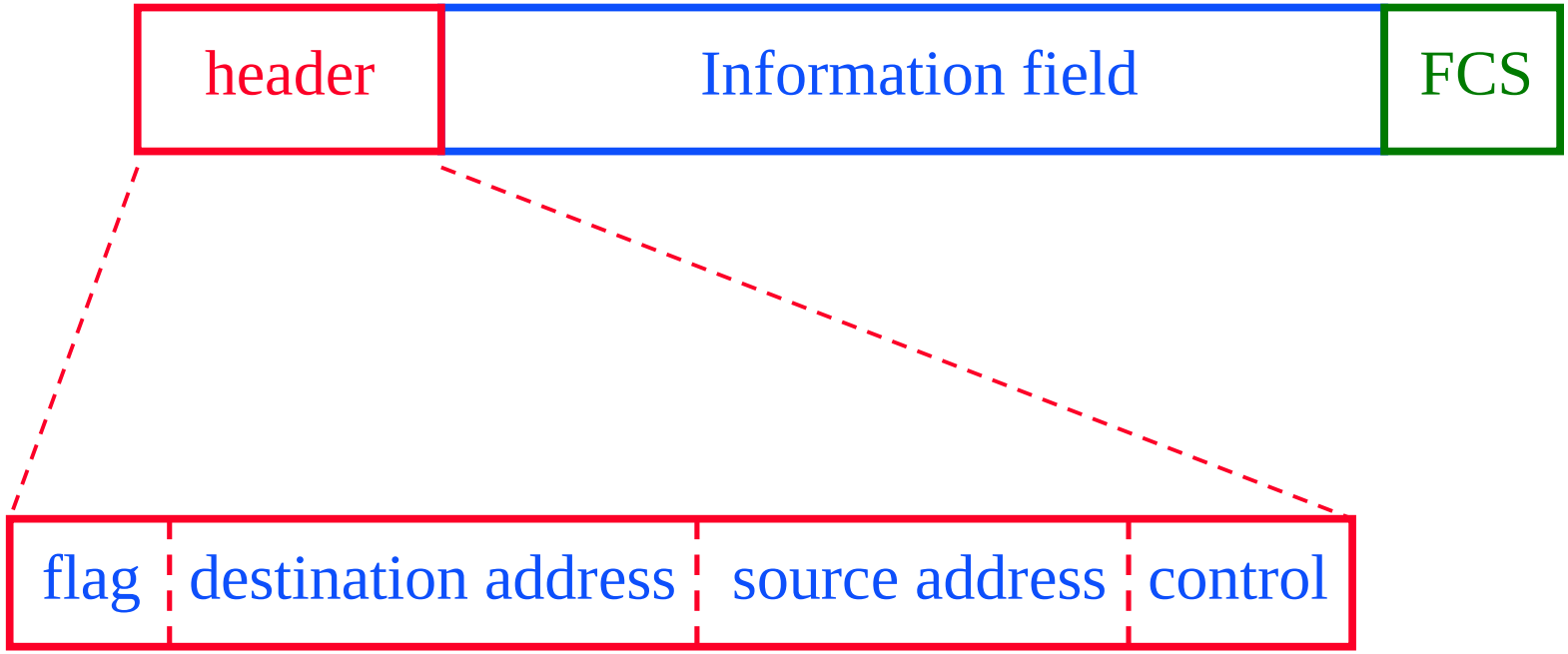
- Packet transmission
- Variable bandwidth
- Connection-oriented (ATM) or connectionless
- Data paradigm



Routing and switching

	circuit	packet
Connection-oriented	PSTN	ATM
Connectionless		Ethernet

Connectionless packet data



Fixed line protocols

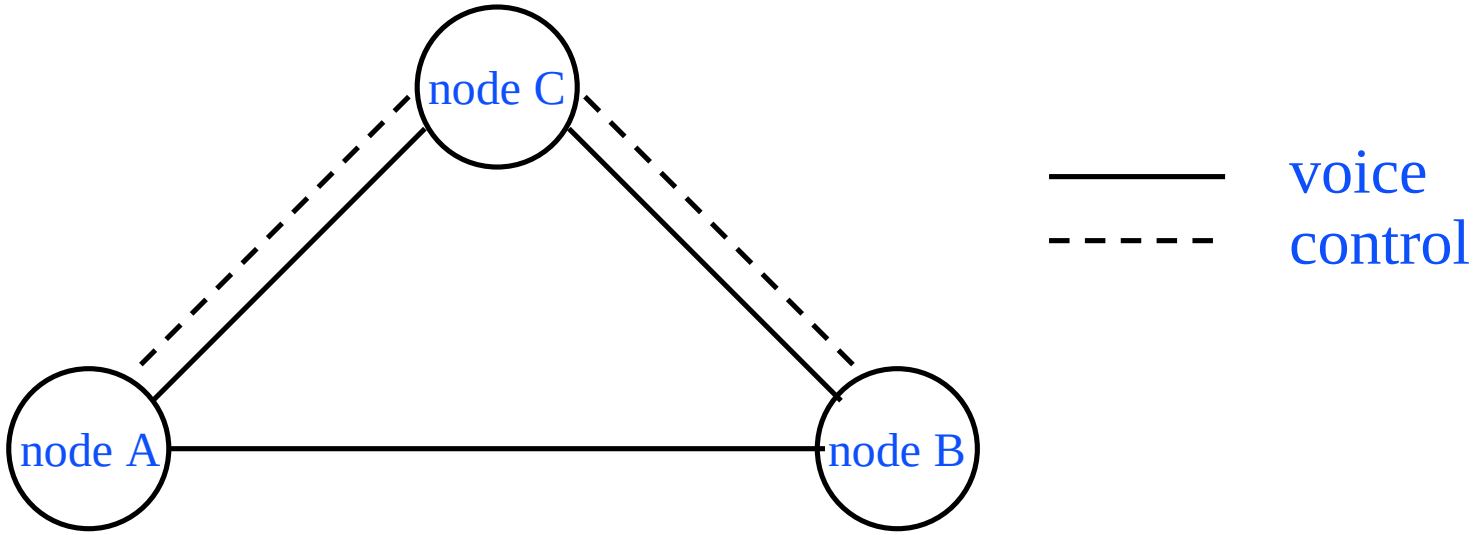
- **PSTN** (or POTS: Plain Old Telephone Service)

- **ISDN** (Integrated Services Digital Network)
  - B-channels (64 kb/s)
  - D-channels (16 kb/s for BRI, 64 kb/s for PRI)
  - Basic Rate Interface: 2B+D
  - Primary Rate Interface: 23B+D (US/Japan) or 30B+D (Europe)

- **ATM** (Asynchronous Transfer Mode)
  - ATM cells: 53 bytes (5-byte header, 48-byte payload)
  - connection-oriented (virtual circuit), routing labels

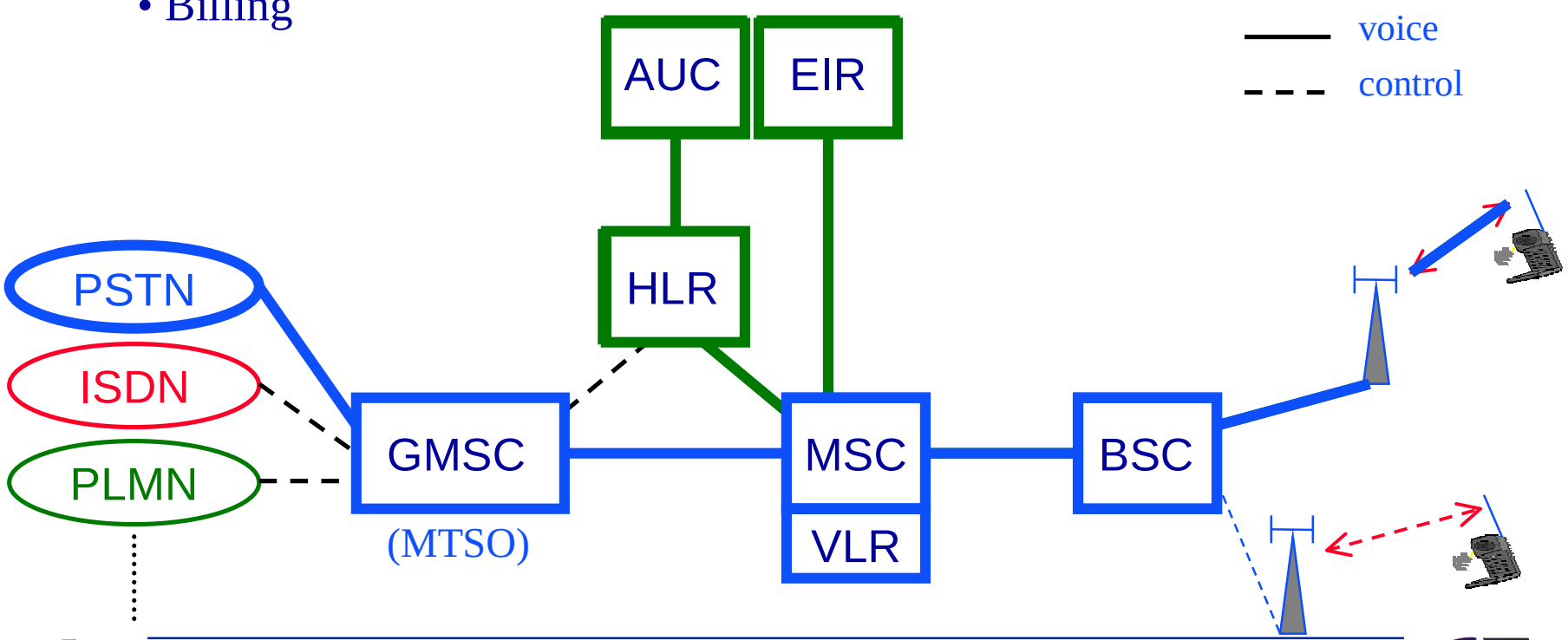
Common channel signaling

- **Separate signaling traffic (control) from user traffic**
- **out-of-band signaling**
- **Signaling System No.7 (SS7)**



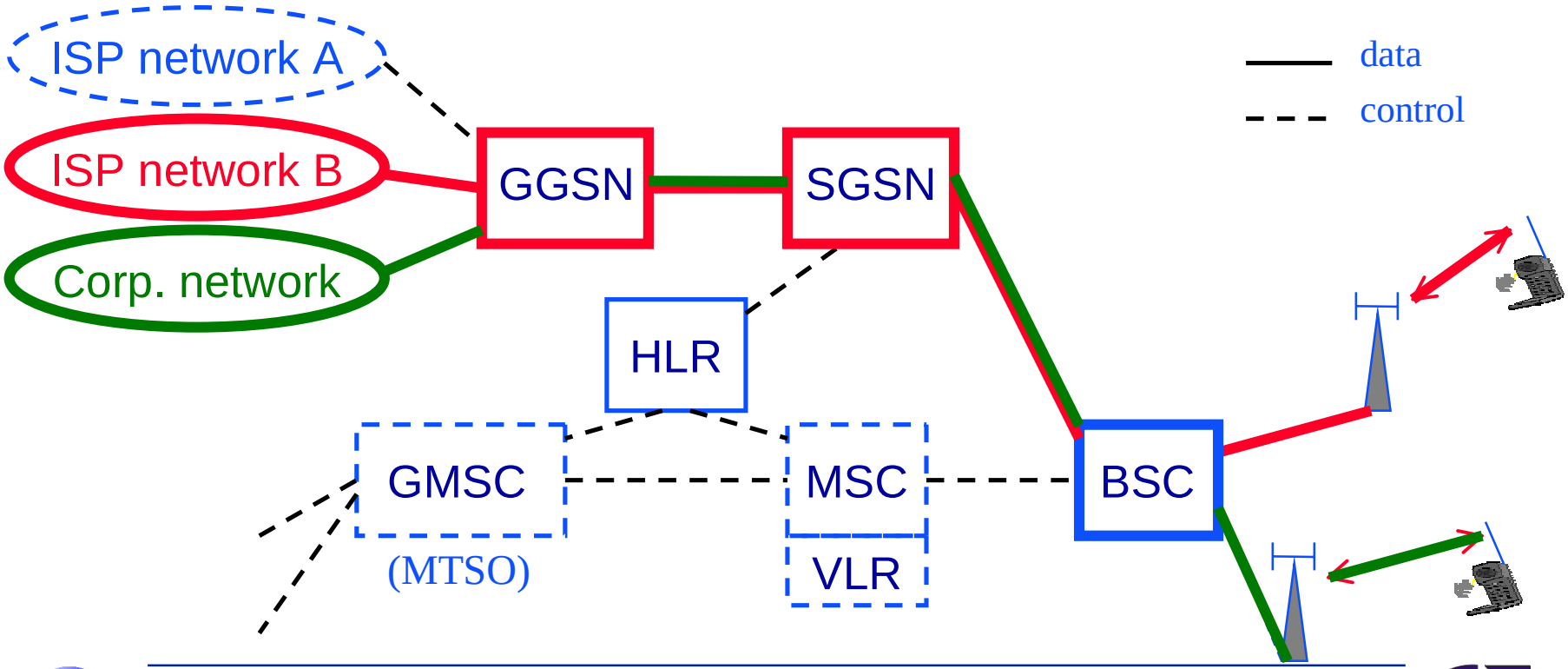
Mobile switching system

- Mobility
- Routing
- Resource allocation
- Billing



Mobile switching system

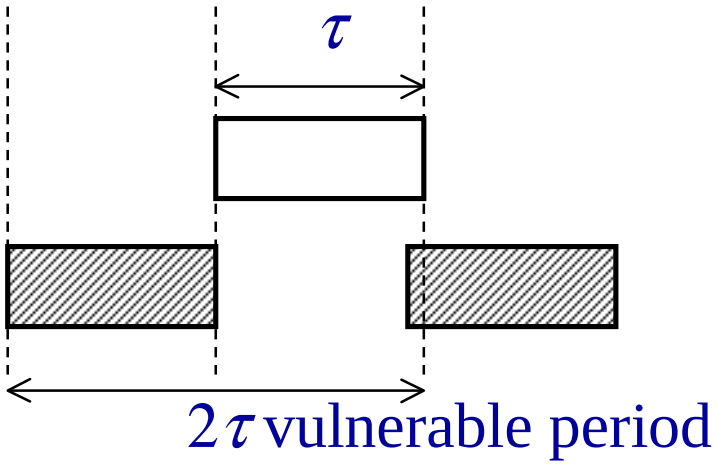
- GPRS: General Packet Radio System
- SGSN: Serving GPRS Support Node
- GGSN: Gateway GPRS Support Node



Packet radio

- **Single channel (medium)**
- **Multiple users access same medium**
  - medium access control (MAC)
  - uncoordinated
    - random access
    - contention based
    - collisions
  - coordinated
    - scheduled access
    - contention free (reserved)
  - hybrid (combination of contention and contention-free)
  - push-to-talk

Throughput



- Constant packet length τ seconds
- Fixed data rate
- Random packet generation λ packets/s
- Poisson arrival distribution

$$R = \lambda \cdot \tau$$

$$T_{ch} = \lambda \cdot \tau \cdot \Pr(no\ collision)$$

$$\Pr(n\ arrivals\ \ within\ \ \tau) = \frac{R^n e^{-R}}{n!}$$

$$\Pr(0\ arrivals\ \ within\ \ \tau) = e^{-R}$$

ALOHA

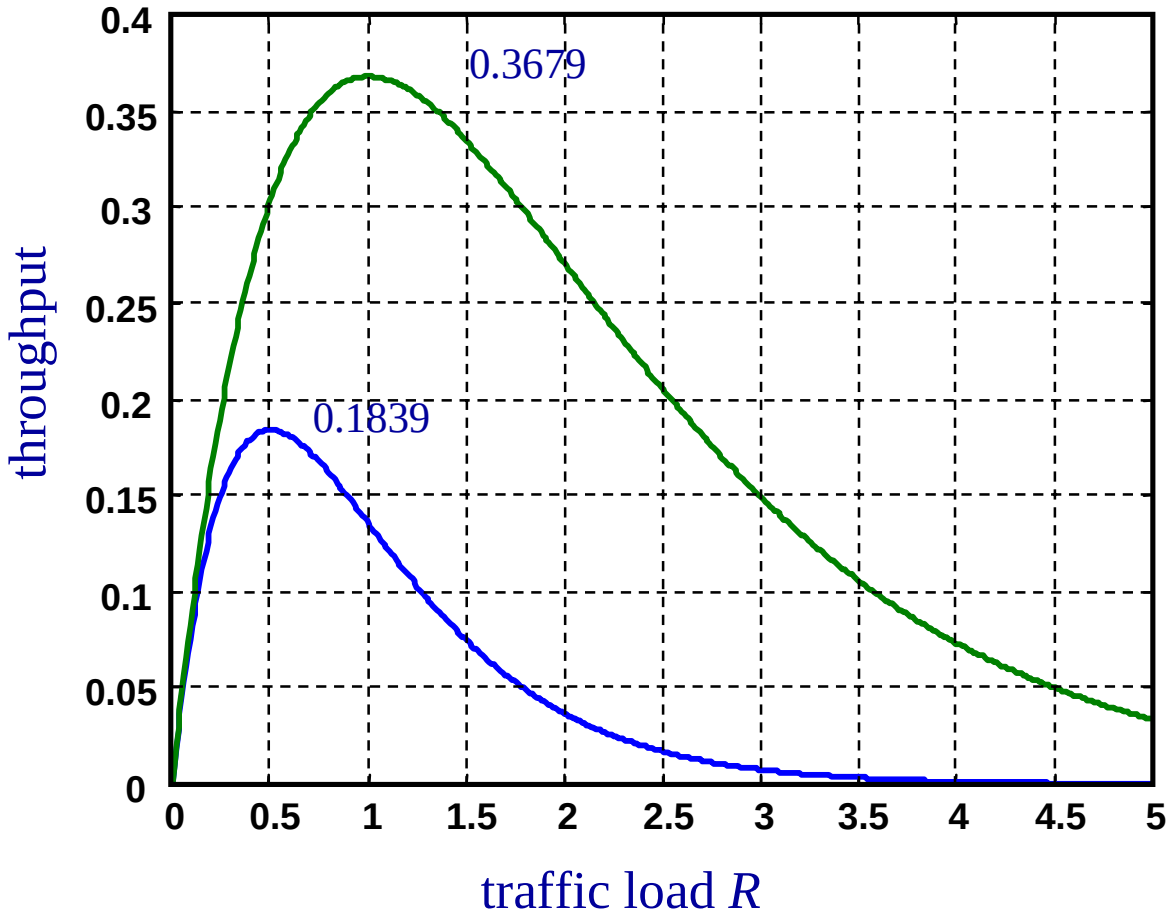
Pure ALOHA:

- Random access at any time
- Vulnerable period 2τ
- Collision probability $\Pr(0\ arrivals\ \ within\ \ 2\tau) = e^{-2R}$
- Throughput $T_{ch} = R \cdot e^{-2R}$

Slotted ALOHA:

- Random access at slot boundary only
- Vulnerable period τ
- Collision probability $\Pr(0\ arrivals\ \ within\ \ \tau) = e^{-R}$
- Throughput $T_{ch} = R \cdot e^{-R}$

Througput ALOHA



CSMA protocols

Carrier sense:

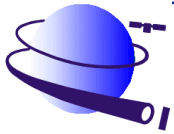
- Listen to channel
- Retry after random delay

CSMA/CD:

- Collision Detect
- Listen-while-talk
- Not for radio

CSMA/CA:

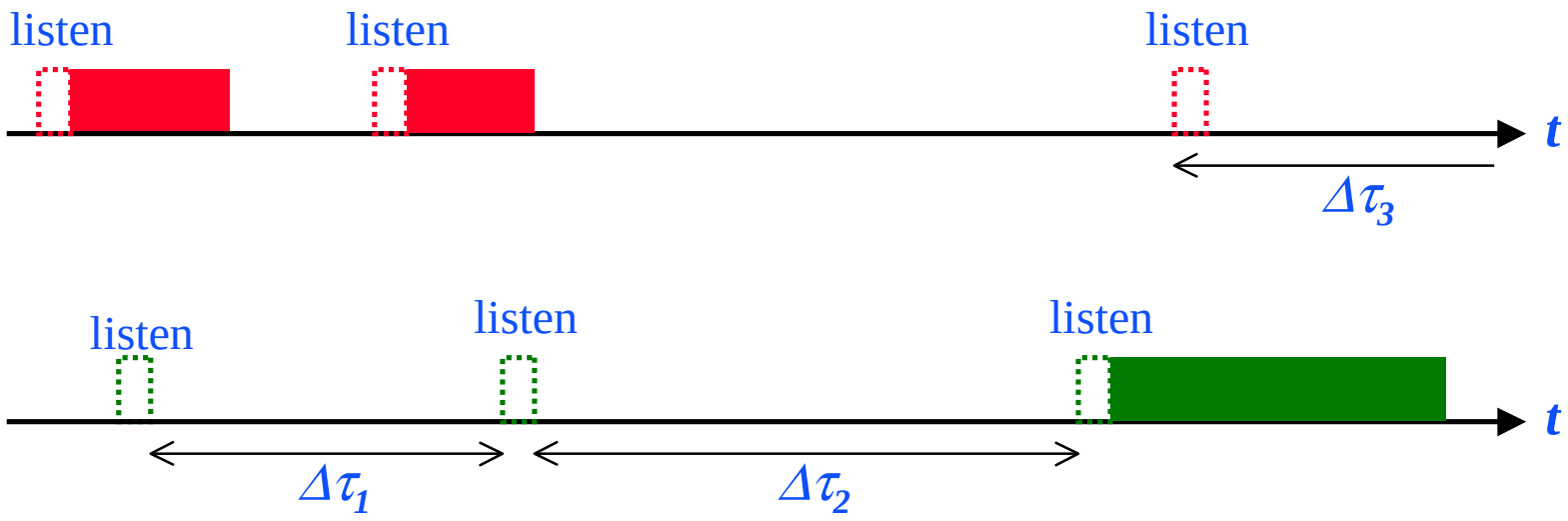
- Collision Avoidance
- Listen-before-talk



CSMA/CA

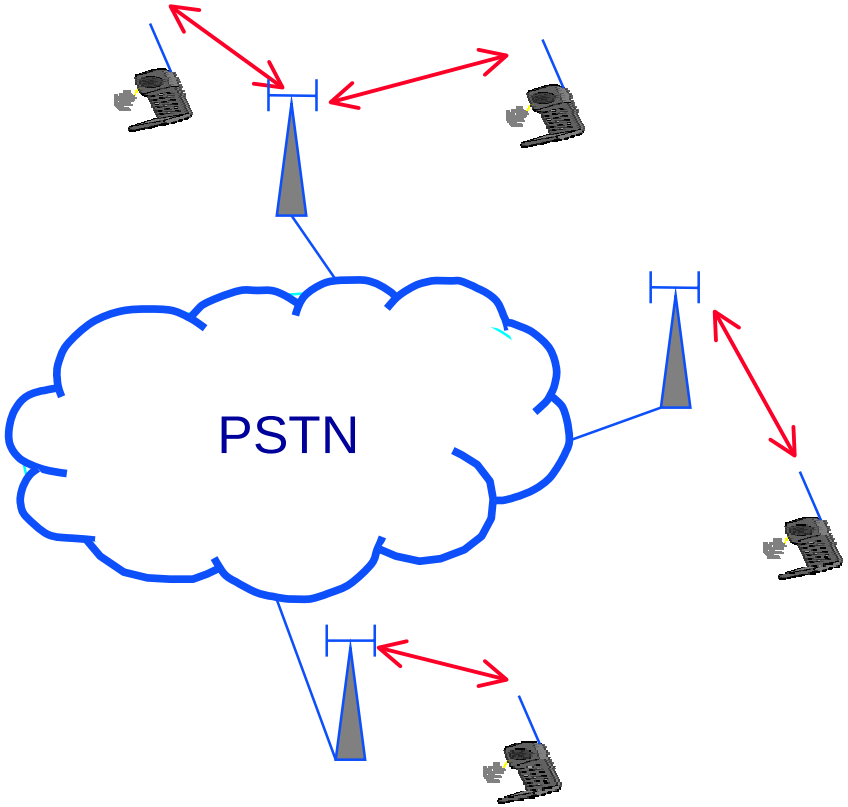
Carrier sense, collision aviodance:

- Listen to channel
- If busy, retry after random delay



Wireless extensions

- **PSTN: DECT**
- **LAN: WLANs**
  - Ethernet: 802.11 WLAN
  - ATM: HIPERLAN/2

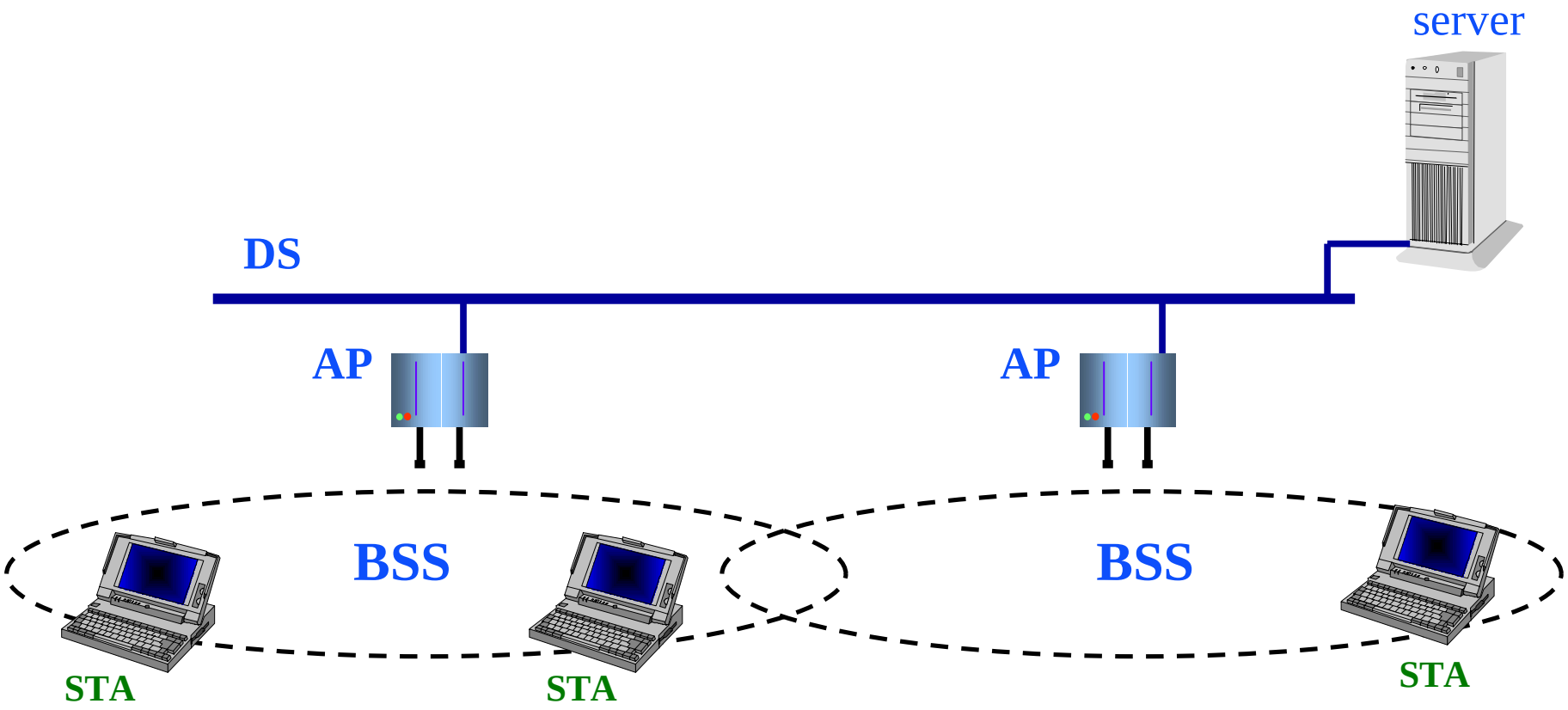


WLAN IEEE 802.11

- **PHY and MAC description**
- **PHY:**
  - Infrared
  - Frequency-Hop Spread-Spectrum (FHSS)
  - Direct-Sequence Spread-Spectrum (DSSS)
- **Three flavours**
  - **802.11** 2.4 GHz, 1-2 Mb/s
  - **802.11b** 2.4 GHz, 11 Mb/s
  - **802.11a** 5 GHz, 20^{+} Mb/s
- **Developed under IEEE 802**

Architecture

- Extended Service Set (ESS)
- Backbone: Ethernet, token ring, token bus

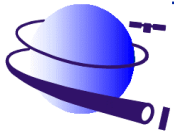


Physical layer

- **Radio band 2400 - 2483.5 MHz, Industrial-Scientific-Medical (ISM) unlicensed band**
  - **FH spread spectrum**
    - 79 hop frequencies, 1 MHz spacing
    - 2-level GFSK (1 Mb/s) and 4-level GFSK (2 Mb/s)
    - 3 hop sets, each set with 26 sequences of 79 hops
  - **DS spread spectrum**
    - DBPSK (1 Mb/s) and DQPSK (2Mb/s)
    - 11-chip Barker spreading code
    - 11 MHz wide channels (MC)
    - 2 channels per BSS
- **Wavelenghts 850-950nm**
  - **Infrared**
    - Pulse Position Modulation

Medium access control layer

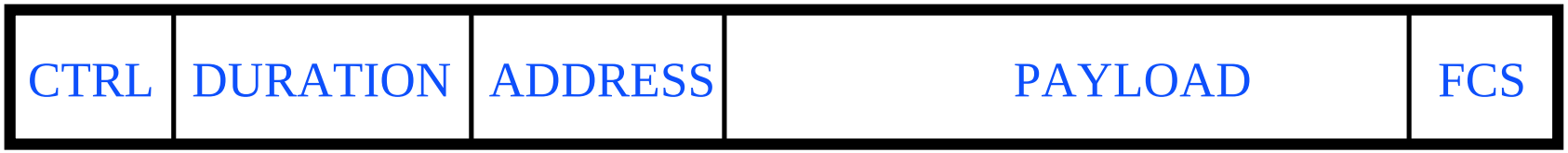
- Channel access
- Addressing
- Frame formatting
- Error checking
- Fragmentation/re-assembly



Channel access

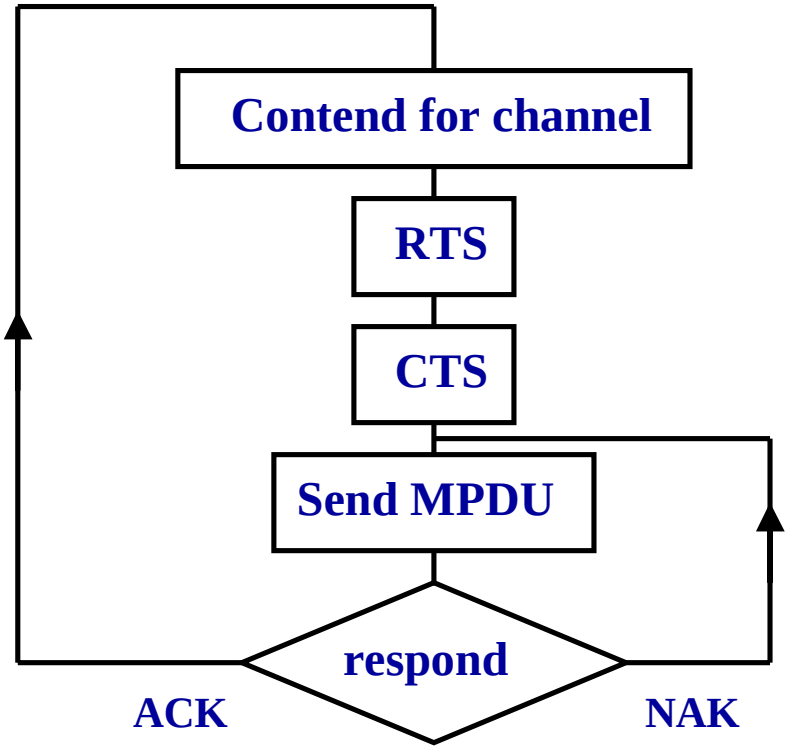
- **Packet radio**
  - multi-carrier ESS
  - single channel per BSS
- **Distributed control (DCF)**
  - best effort services
  - CSMA/CA
- **Centralized control (PCF)**
  - Priority delivery
  - Point coordinator (AP)
  - Polling scheme

MAC frame



- **CTRL**
  - type, direction, mode, etc.
- **Duration**
  - time duration of transaction (NAV update, virtual carrier sense)
- **Address**
  - source & destination
- **Payload**
  - MAC protocol data unit (MPDU)
- **FCS**
  - CRC

DCF data transaction

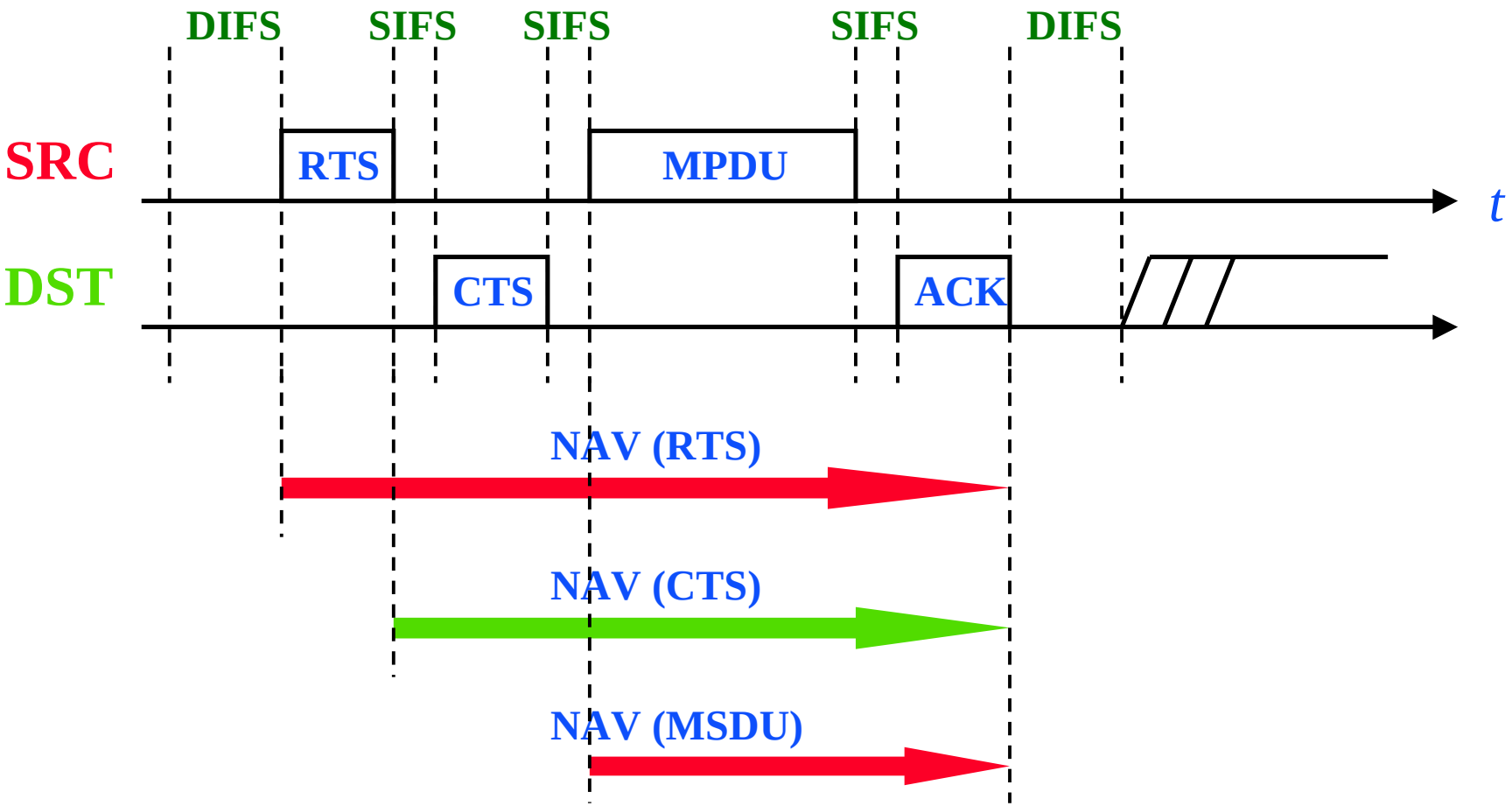


stop-and-wait ARQ

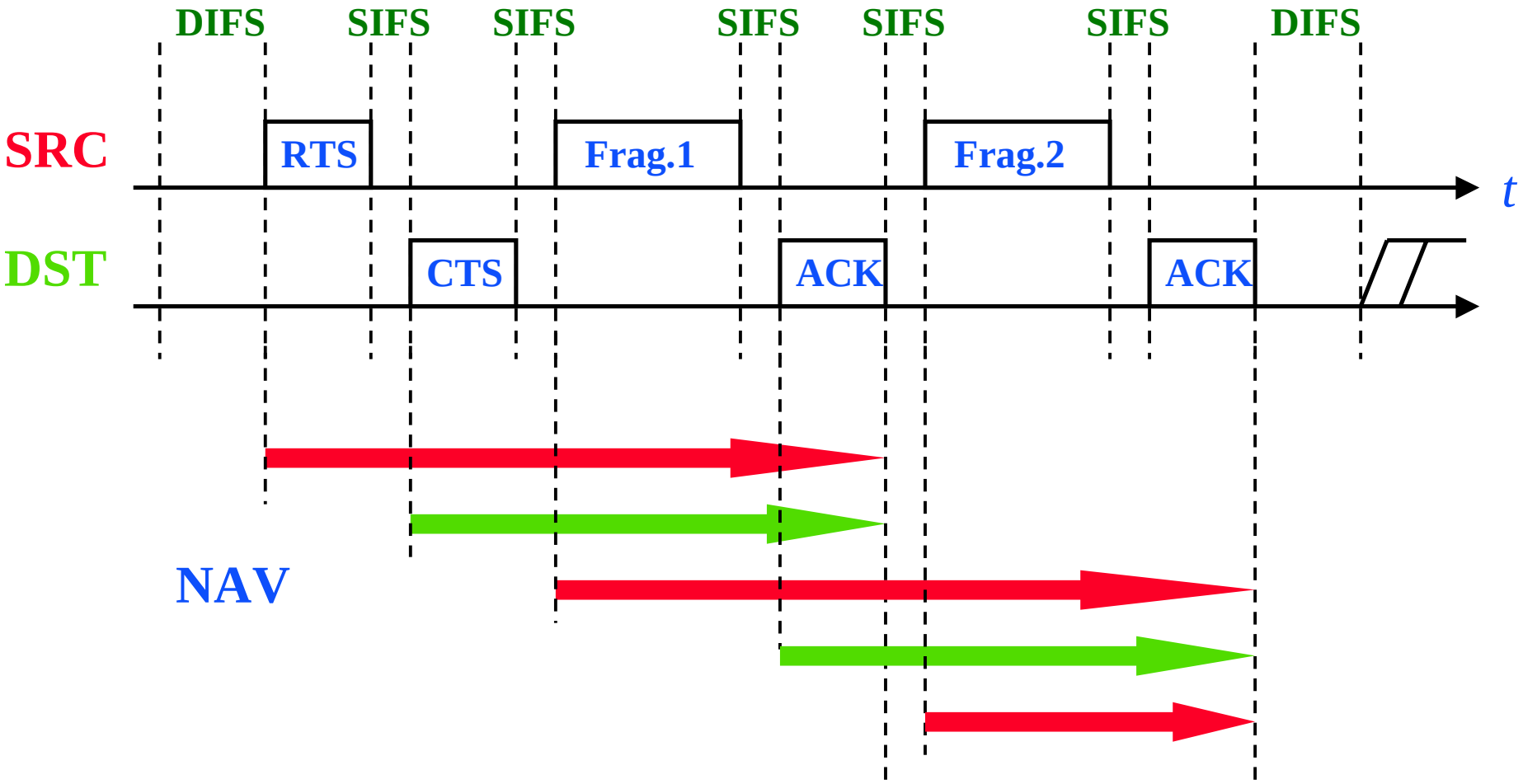
Hidden node problem

- STA_C hears STA_B, but not does not hear STA_A
- RTS/CTS reserves channel in area around A and B

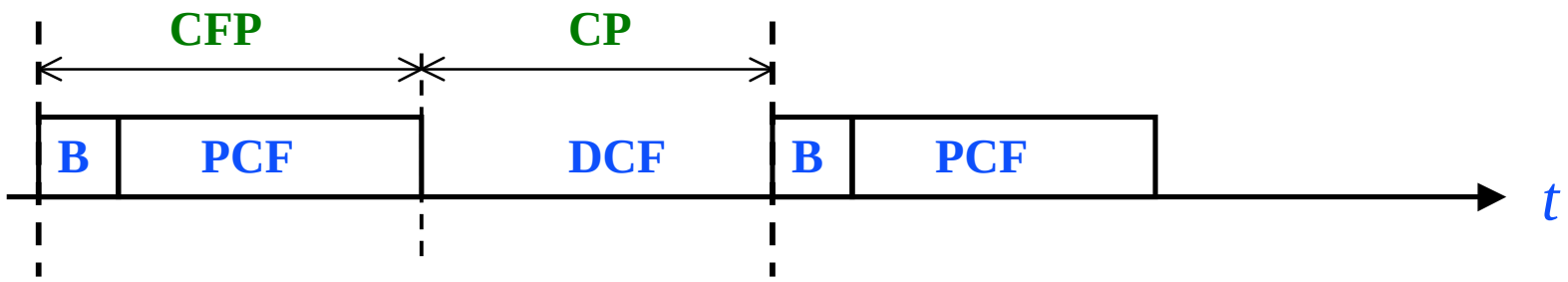
DCF data transaction



Fragmentation



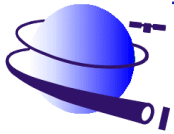
PCF data transaction



- Beacons sent by AP
- Contention-free-period:
  - Polling
  - PIFS
  - priority data

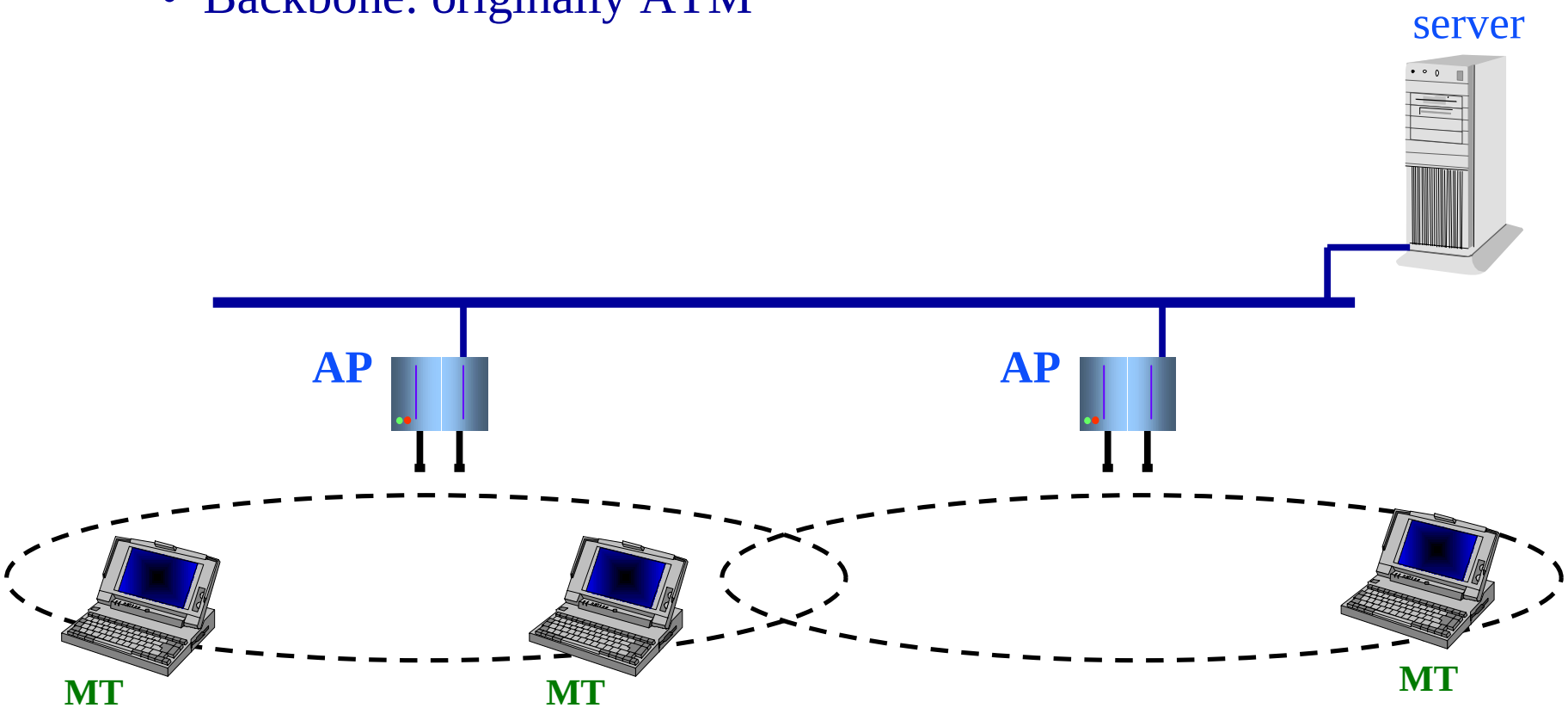
HIPERLAN

- **HIgh PErformance Radio Local Area Network**
- **System description (including mobility)**
- **Hot-spot fill for cellular**
- **Two flavours**
  - **type 1** similar to 802.11
  - **type 2** cellular based
- **Developed under ETSI BRAN**



Architecture

- Cellular network topology
- Backbone: originally ATM



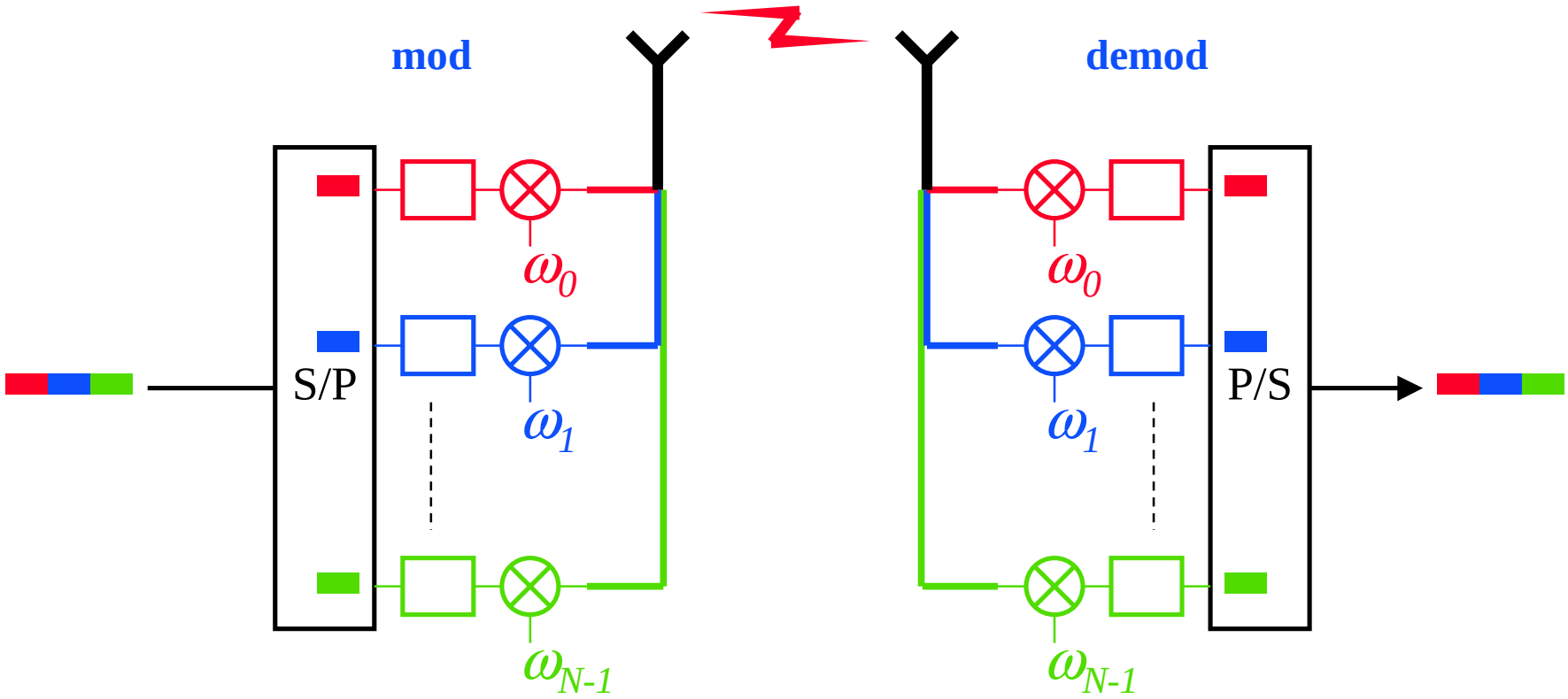
Physical layer

- **5150 - 5300 MHz and 5470 - 5725 MHz, license-exempt band**
- **TDMA/TDD**
  - MAC frames
  - uplink/downlink slots
- **Multi Carrier**
  - 20 MHz spacing
- **Orthogonal Frequency Division Multiplexing (OFDM)**
  - 52 subcarriers
  - 312.5 kHz spacing
  - 800ns cyclic prefix

OFDM

1. Serial-to-parallel conversion
2. Send in parallel each bit on narrowband subcarrier
3. Keep subcarriers orthogonal
4. Demodulate each subcarrier separately and retrieve bits
5. Parallel-to-serial conversion

Parallel transmission



Orthogonality

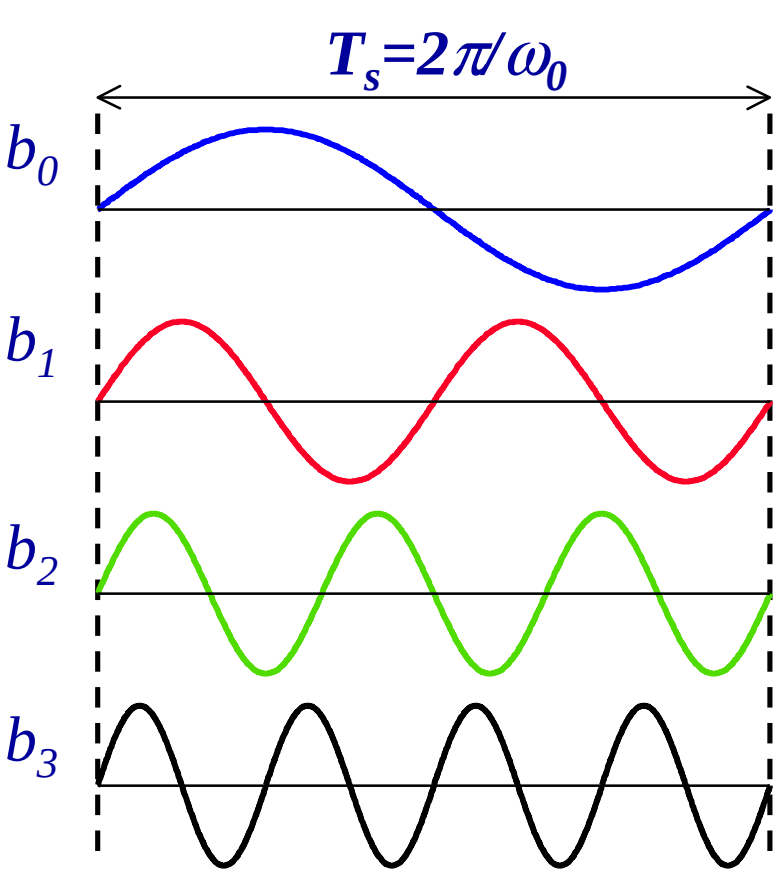
$$\int_0^T \phi_i(t) \cdot \phi_j(t) dt = \begin{cases} 1 & \text{if } i=j \\ 0 & \text{if } i \neq j \end{cases}$$

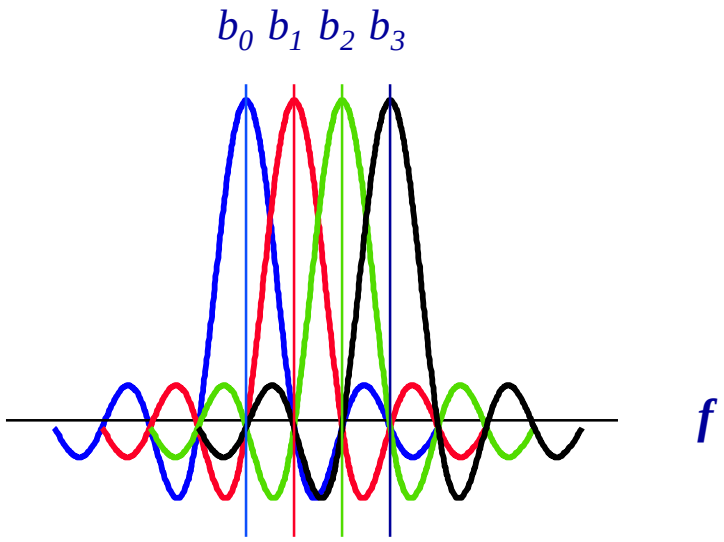
Choose $\phi(t)$ to be $\cos(k \cdot \omega_0 \cdot t)$ and $\sin(k \cdot \omega_0 \cdot t)$

$$\frac{1}{T_s} \int_0^{T_s} \cos\left(2\pi \cdot k \frac{t}{T_s}\right) \cdot \cos\left(2\pi \cdot n \frac{t}{T_s}\right) dt = \begin{cases} 1 & \text{if } n=k \\ 0 & \text{if } n \neq k \end{cases}$$

Mapping is **Fourier transform**

OFDM



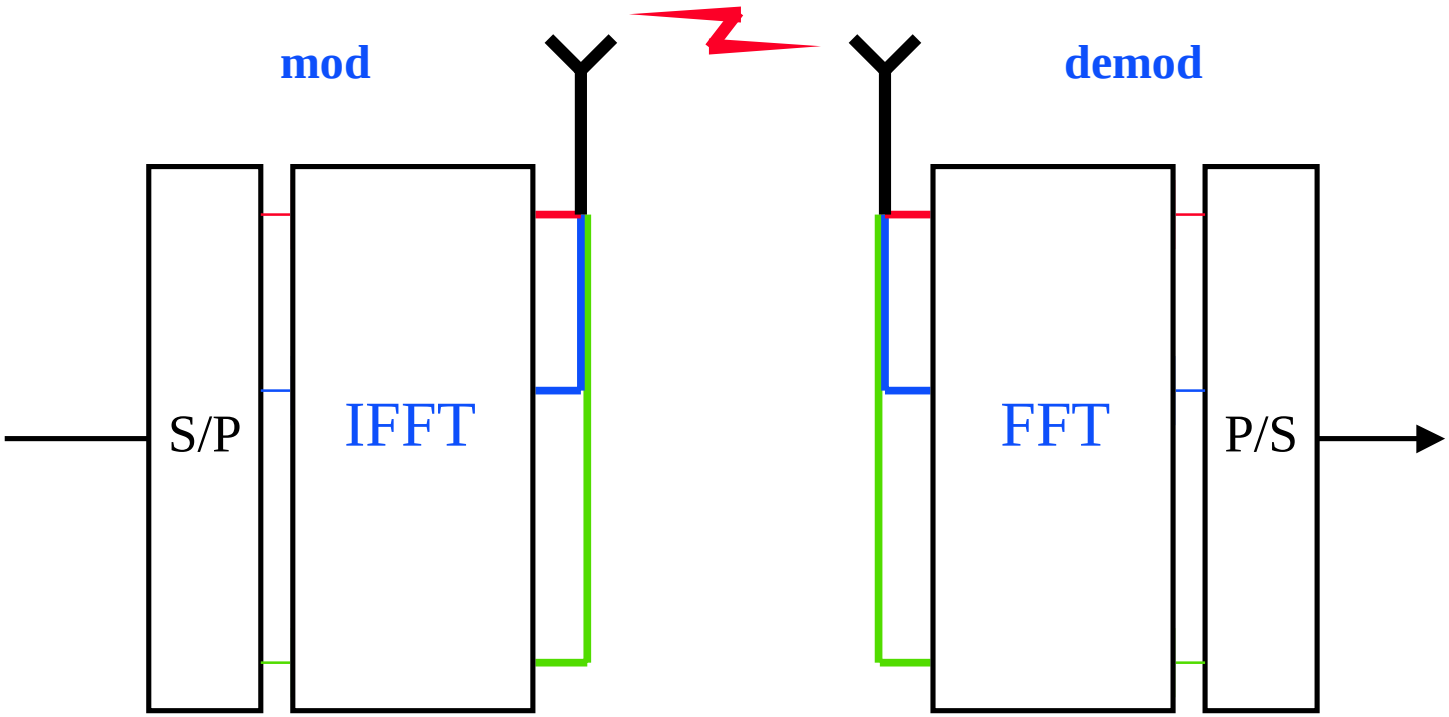


subcarriers

$b_i \rightarrow I_i \cos(k\omega_0 t) + Q_i \sin(k\omega_0 t)$

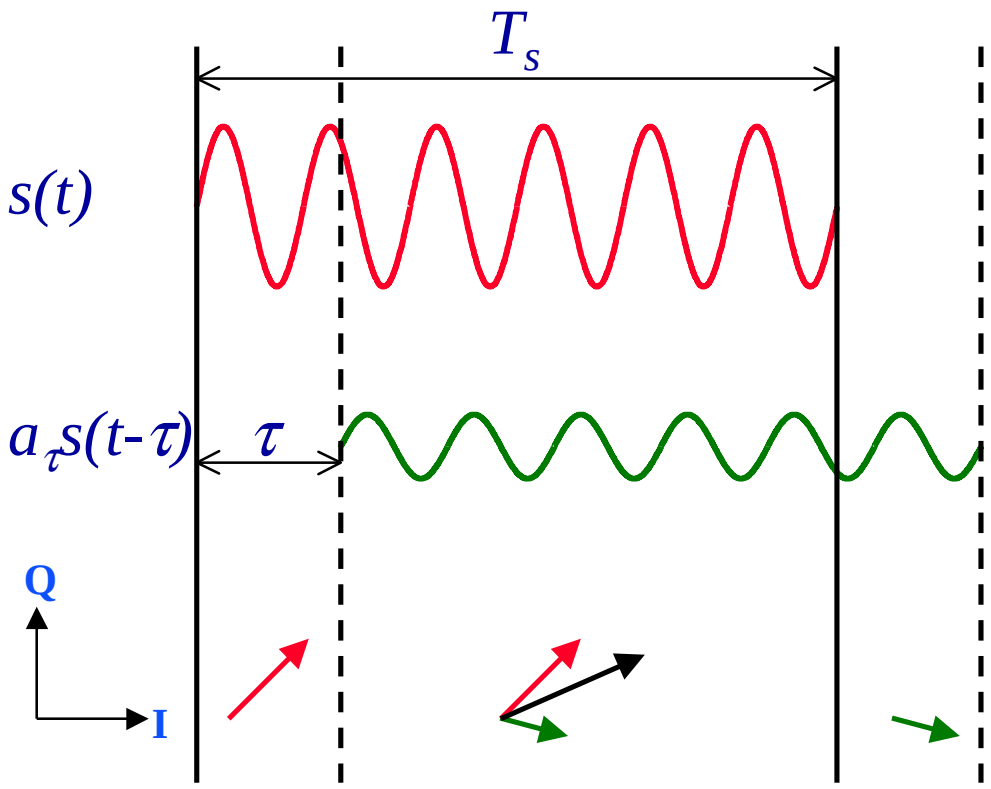
any from BPSK to 64QAM

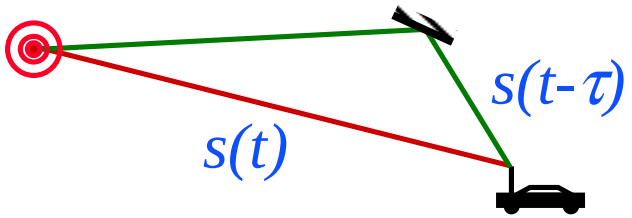
Fast Fourier transforms



Multipath resistant

- Long symbol time (narrowband subband)

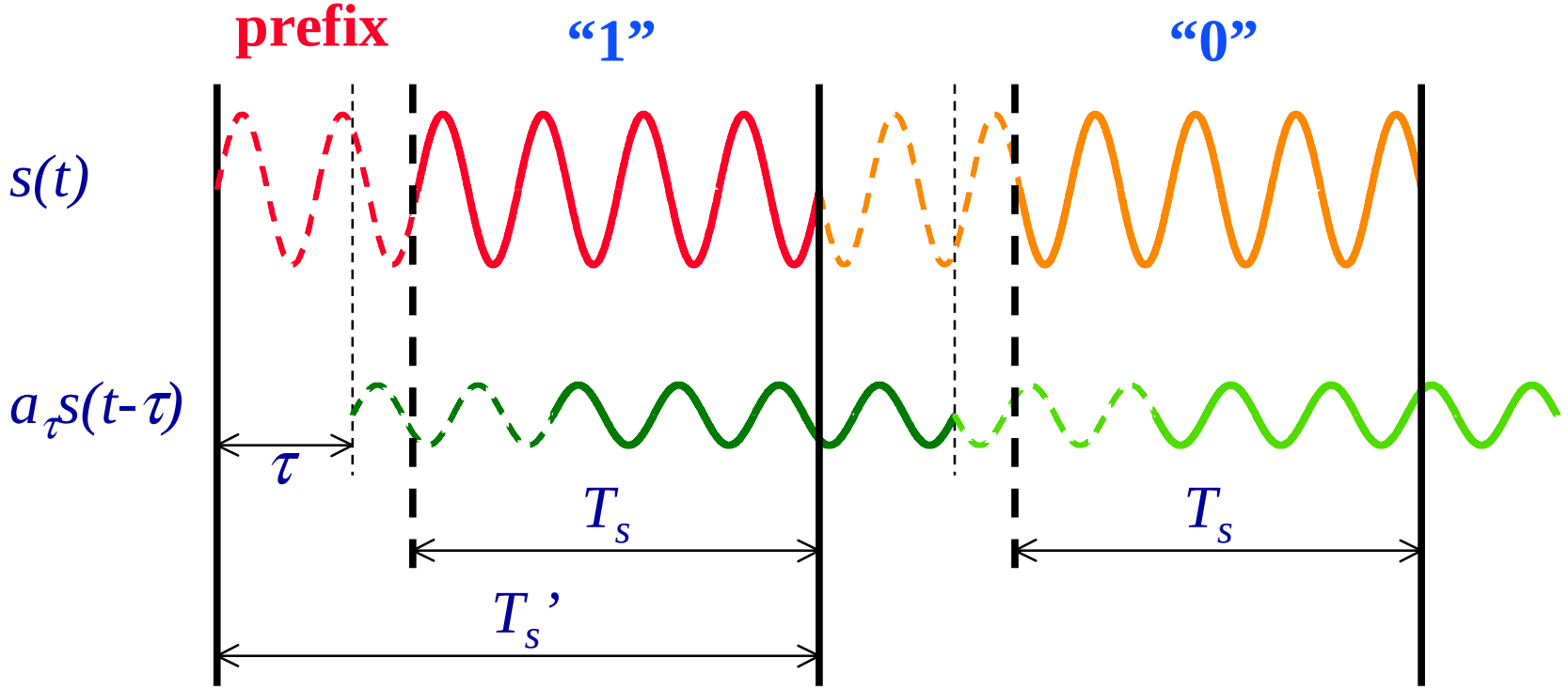




No symbol distortion

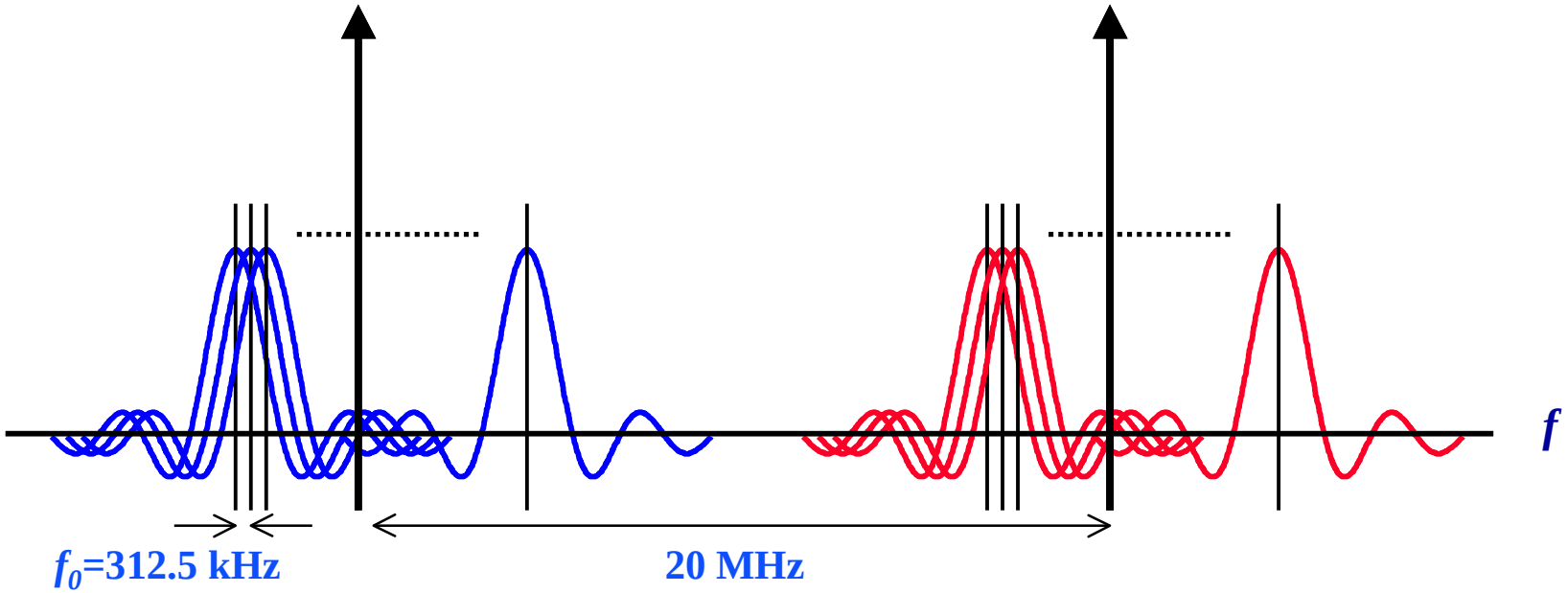
Cyclic prefix

- 800ns prefix $\Rightarrow$ 250ns T_{rms}
- orthogonal within T_s



HIPERLAN/2 OFDM

- 64-point FFT
- 312.5kHz subcarrier spacing
- 20 MHz carrier spacing
- 48 data subcarriers
- 4 pilot subcarrier
- 12 guard subcarriers



HIPERLAN/2 rates

- Subcarrier modulation BPSK/QPSK/16QAM/64QAM
- Coding, convolutional 1/2, 3/4, 9/16 rates, constraint length 7

Example: Subcarrier spacing = 312.5kHz

T_s = 3.2μs

prefix 800ns: T_s' = 4μs

Effective rate/subcarrier = 250ks/s

48 subcarriers ⇒ 12 Ms/s gross rate

QPSK, 3/4-rate convolutional code ⇒

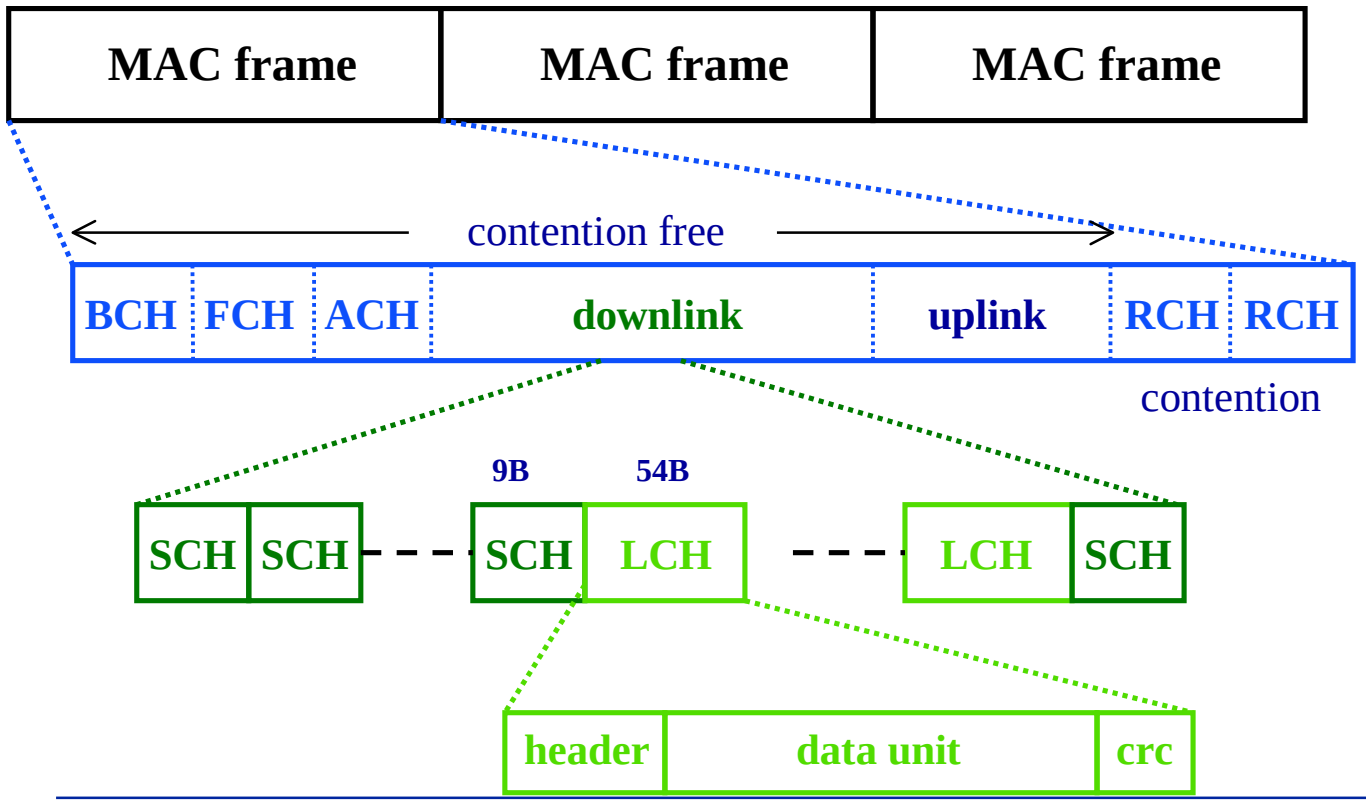
data rate = 12Msym/s × 2b/sym × 3/4 = **18Mb/s**

HIPERLAN/2 rates

mode	modulation	code rate	data rate (Mb/s)
1	BPSK	1/2	6
2	BPSK	3/4	9
3	QPSK	1/2	12
4	QPSK	3/4	18
5	16QAM	9/16	27
6	16QAM	3/4	36
7	64QAM	3/4	54

MAC frame structure

- Fixed-length MAC frames
- AP controls traffic flows (including in direct mode)



DLC layer

- **Control**
  - BCH: broadcast information (radio resource control)
  - FCH: frame information: allocation of downlink/uplink/RCH
  - ACH: access feedback control for MT requests
  - RCH: random access, contention based
  - SCH: short transport channel for control in payload
- **Traffic**
  - SCH: long transport channel for uplink/downlink user data
- **Downlink**
  - data from AP to MTs
  - BCH/FCH/ACH
- **Uplink**
  - data from MTs to AP
  - RCH

Channel allocation

- **Downlink**
  - Scheduling by AP
  - allocation of downlink SCH/LCH by AP
- **Uplink**
  - MT initiated (contention based):
    1. RCH → ACH/FCH
    2. Allocation of uplink SCH/LCH by AP
  - AP initiated (contention free):
    1. Polling of MT by AP
    2. Return request SCH by MT
    3. Allocation of uplink SCH/LCH by AP
- **Allocation**
  - indicated in FCH

Radio network functions

- **Dynamic frequency selection (DFS)**
  - uncoordinated selection of OFDM carrier
  - interference measurements in AP and MT
- **Link adaptation**
  - changing coding scheme
  - changing modulation scheme
- **Power control**
- **Quality of service**
  - synchronous/isochronous services
  - polling by AP

FOR NEXT TIME

- **Read:**

  Chapter 10: §10.1-10.4 (not 10.1.4), 10.12

- **Solve problems:**

  Chapter 9: none