EITF25 Internet--Techniques and Applications

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Mobile Internet over LTE

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Plan of lecture

- Some history of mobile networks—Past and future
- Idea of network structure
- EPC packet networks
- LTE radio channel
- What comes next?

History of mobile systems

1st generation

- Analog transmission with no security
- Small regions (countries)
  - First NTT (‘79), second NMT (’81)
  - NMT (Nordic), AMPS (NA+Aus), TACS (UK), TZ80x (NTT), DDI (Jap), Radiocom 2000 (Fr), RTMI (It)
  - NMT shut down 2007

History of mobile systems

2nd generation

- Digital voice channel (10kb/s), Circuit switched
- News: SIM card, SMS
- Larger regions (continents)
  - GSM (Eur), IS-136 (N+S Am+Aus), IS-95 (NA+Asia), PDC (Jap)
  - GSM 1991

2.5 generation => Data channels

  - HSCSD, GPRS, EDGE, IS-95B

History of mobile systems

3rd generation

- Packet switched for voice and data
- 144kb/s – 3Mb/s
- Global
    - CDMA2000 (2000)
    - UMTS (2001)
- News:
    - UTRAN

      Universal Terrestrial Radio Access Network

History of mobile systems

4th generation

- Packet switched data traffic

  (Voice over IP)
- 100Mb/s-1Gb/s
- Global: LTE
  - Dec 2009 (Stockholm and Oslo by TeliaSonera)
- News: Smart phones
  - iPhone 2007

History of mobile systems

5th generation

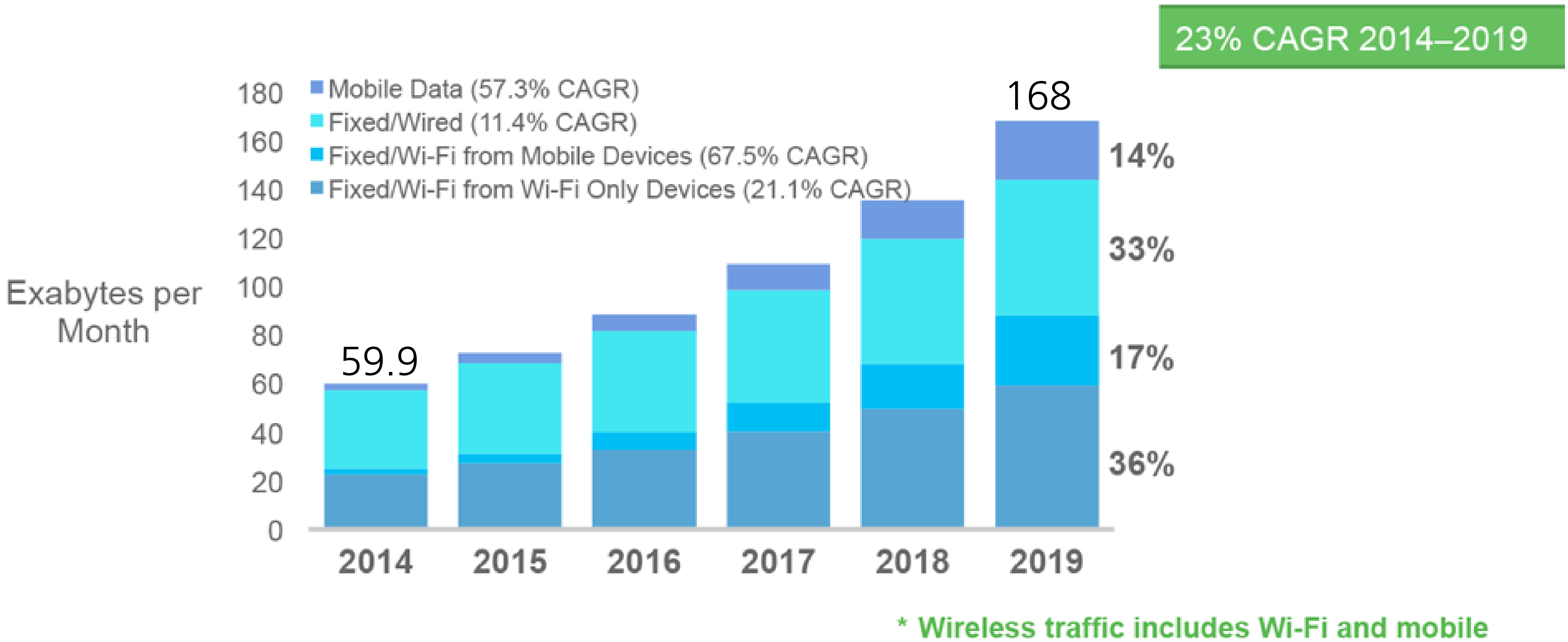
- Packet switched data traffic
- 10-100Gb/s
  - 1Gb/s / user
- ≈2020
- News: Small cells, home cell, IoT (M2M), Massive MIMO, etc

Mobile traffic (CISCO VNI)

- Global mobile data traffic grew 69 percent in 2014
  - 1.5 EB in Dec ’13 to 2.5 EB in Dec ’14
- Global mobile devices and connections in 2014 grew to 7.4 billion (11.5 B in 2019)
  - 26% smart devices generate 80% of traffic
  - 4G devices generate 10 times traffic than non-4G

Total IP traffic

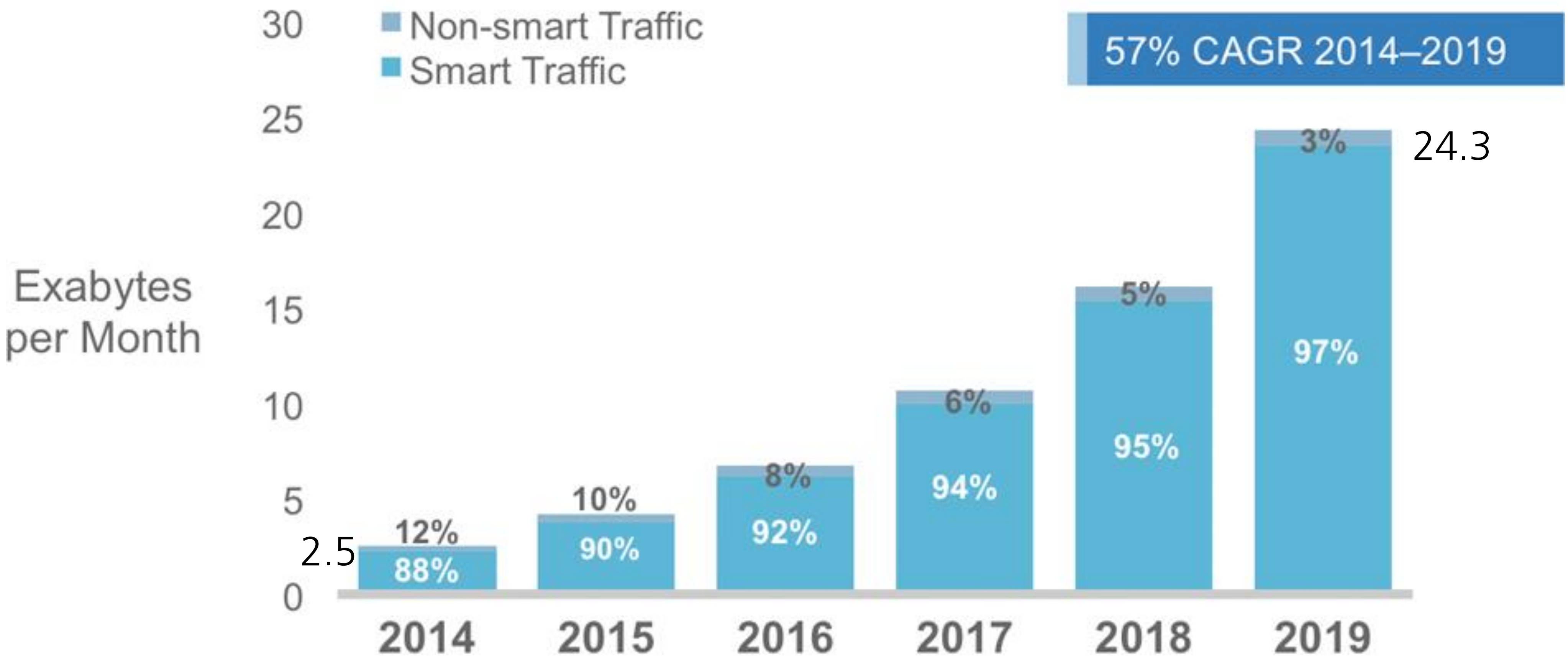
Figure 22. Global IP Traffic, Wired and Wireless



Source: Cisco VNI Global IP Traffic Forecast, 2014–2019

Total Mobile traffic

Figure 6. Effect of Smart Mobile Devices and Connections Growth on Traffic

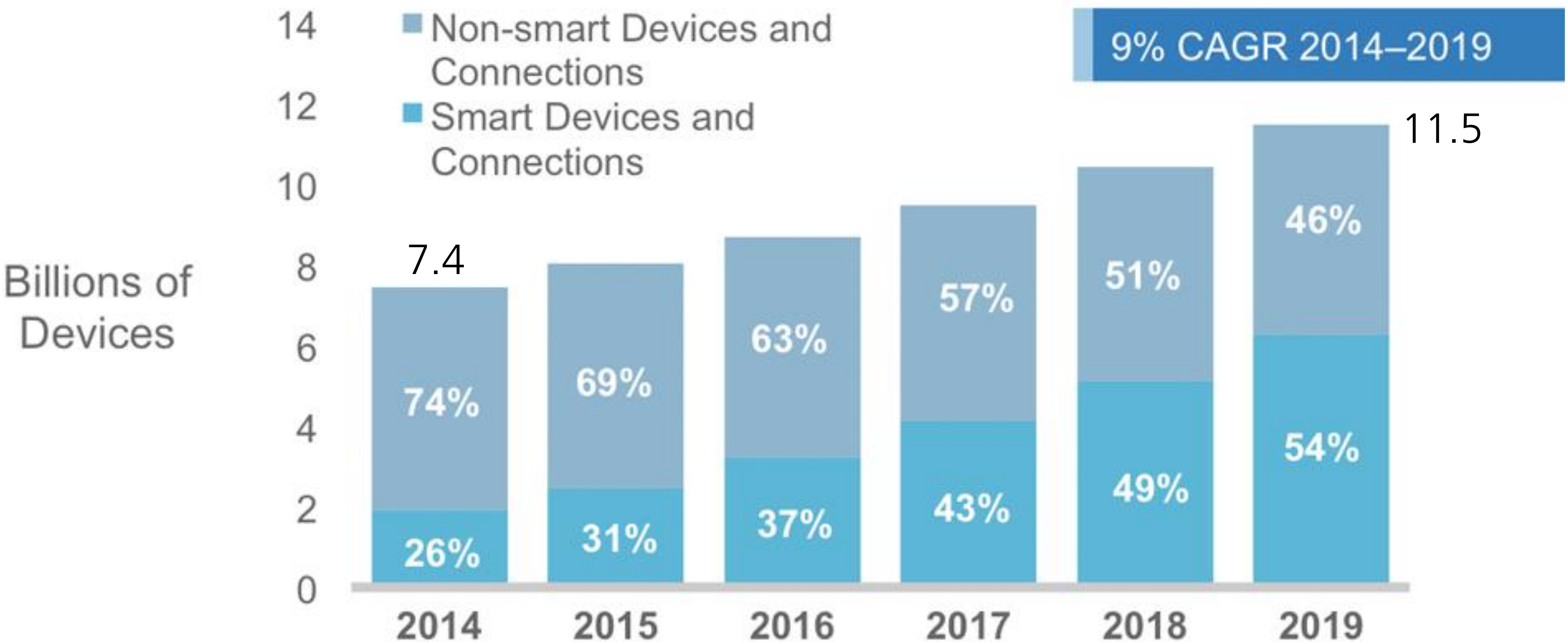


Percentages refer to traffic share.

Source: Cisco VNI Mobile, 2015

Growth of devices

Figure 4. Global Growth of Smart Mobile Devices and Connections

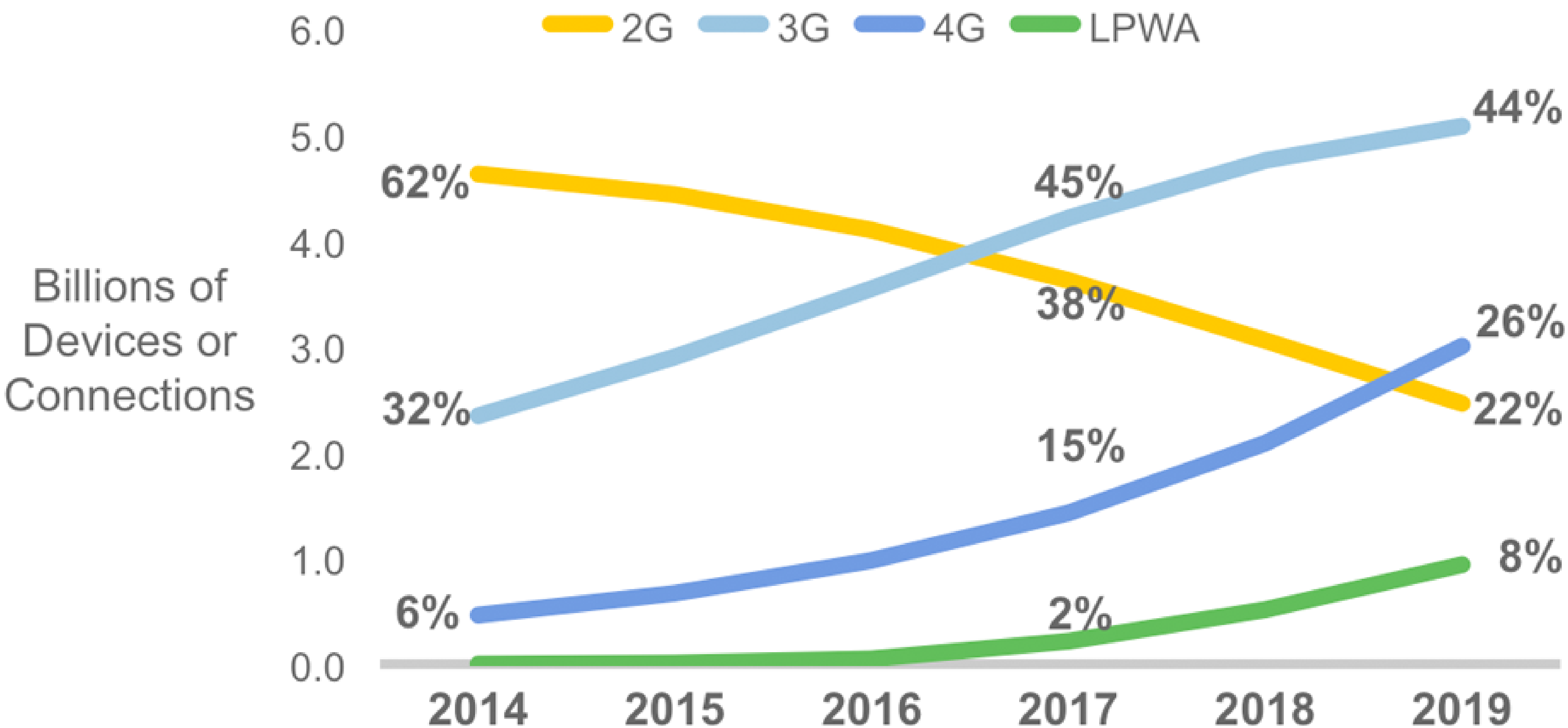


Percentages refer to device and connections share.

Source: Cisco VNI Mobile, 2015

Growth of technology

Figure 7. Global Mobile Devices and Connections by 2G, 3G, and 4G



Percentages refer to device and connections share.

Source: Cisco VNI Mobile, 2015

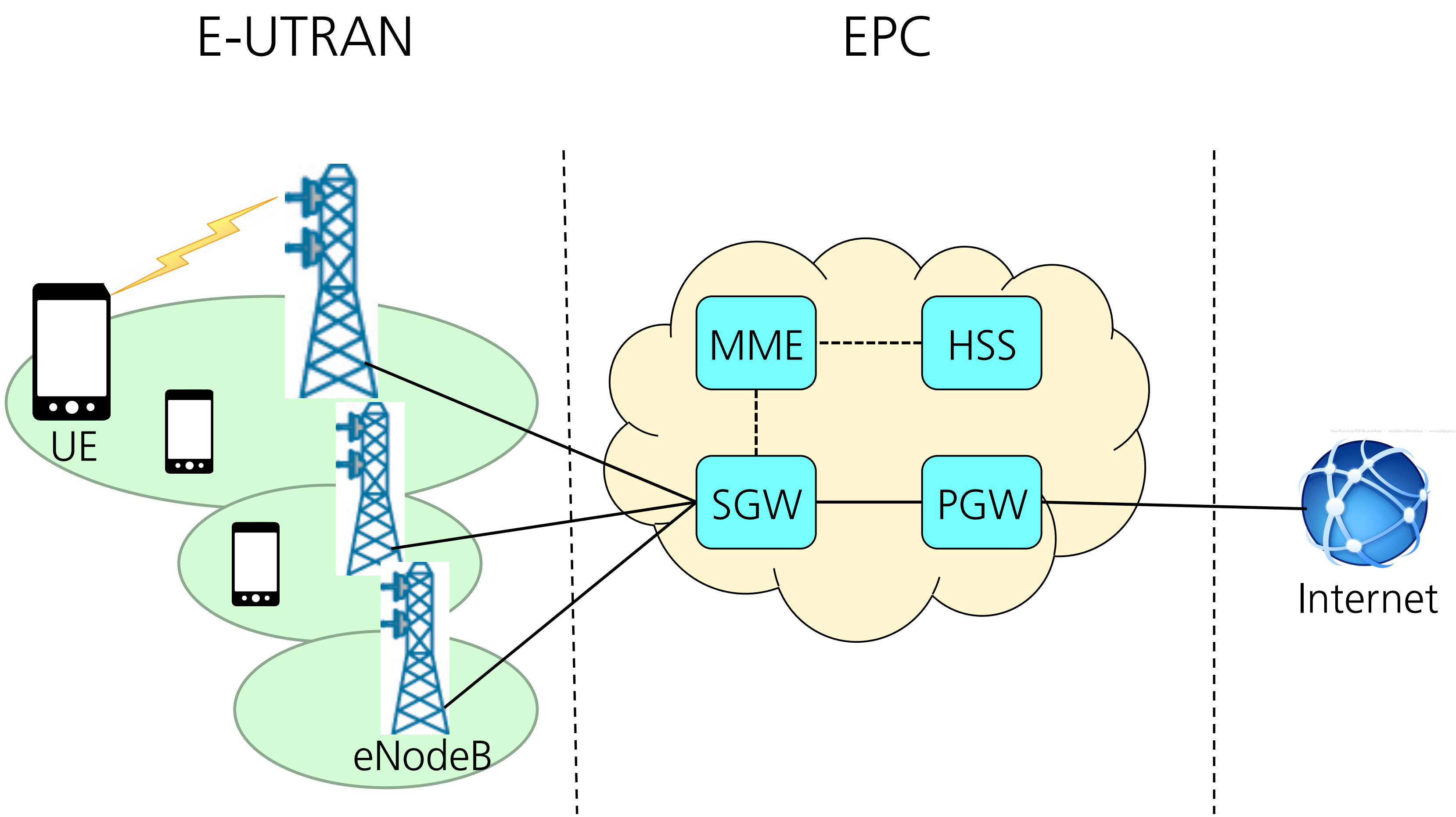
4G – LTE
Long Term Evolution

Standardized by 3GPP

(3rd Generation Partnership Project)

- Radio Access Networks (RAN)
- Service & Systems Aspects (SA)
- Core Network & Terminals (CT)
- GSM EDGE Radio Access Networks (GERAN).

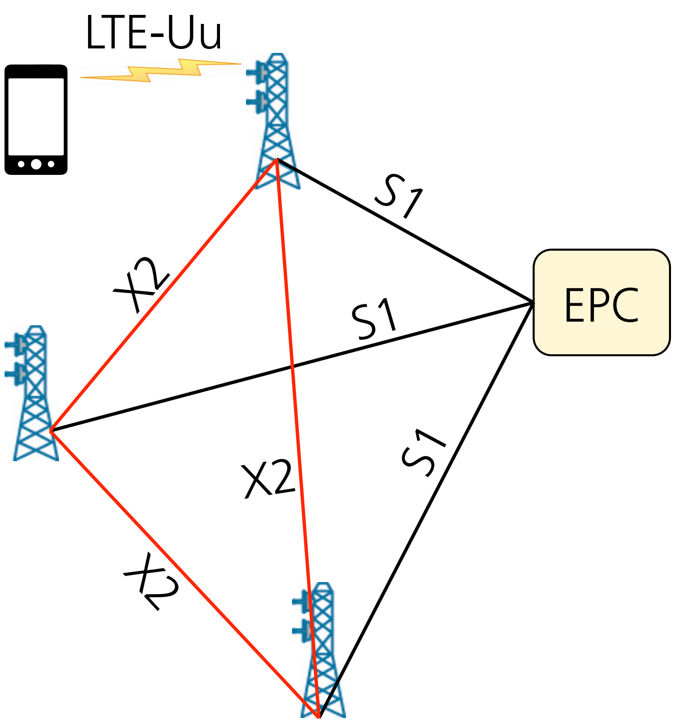
EPS (Evolved Packet System)



EPS challenges

- High speed radio link
  - Bandwidth is extremely expensive. Squeeze out all bits you can
- Access to Internet
  - How to send IP packets
- Security and authentication
  - Especially in the radio link
- User mobility
  - When to change eNB and how to transfer data
- Cost efficient use of infrastructure

EPS interfaces



EPC <-> eNB

- S1 interface
- Split in S1-MME and S1-U
- No centralised node

eNB <-> eNB

- X2 interface
- Coordination and positioning

eNB <-> UE

- LTE-Uu or EUTRAN-Uu

E-UTRAN

Evolved Universal Terrestrial Radio Access Network

RAN responsible for

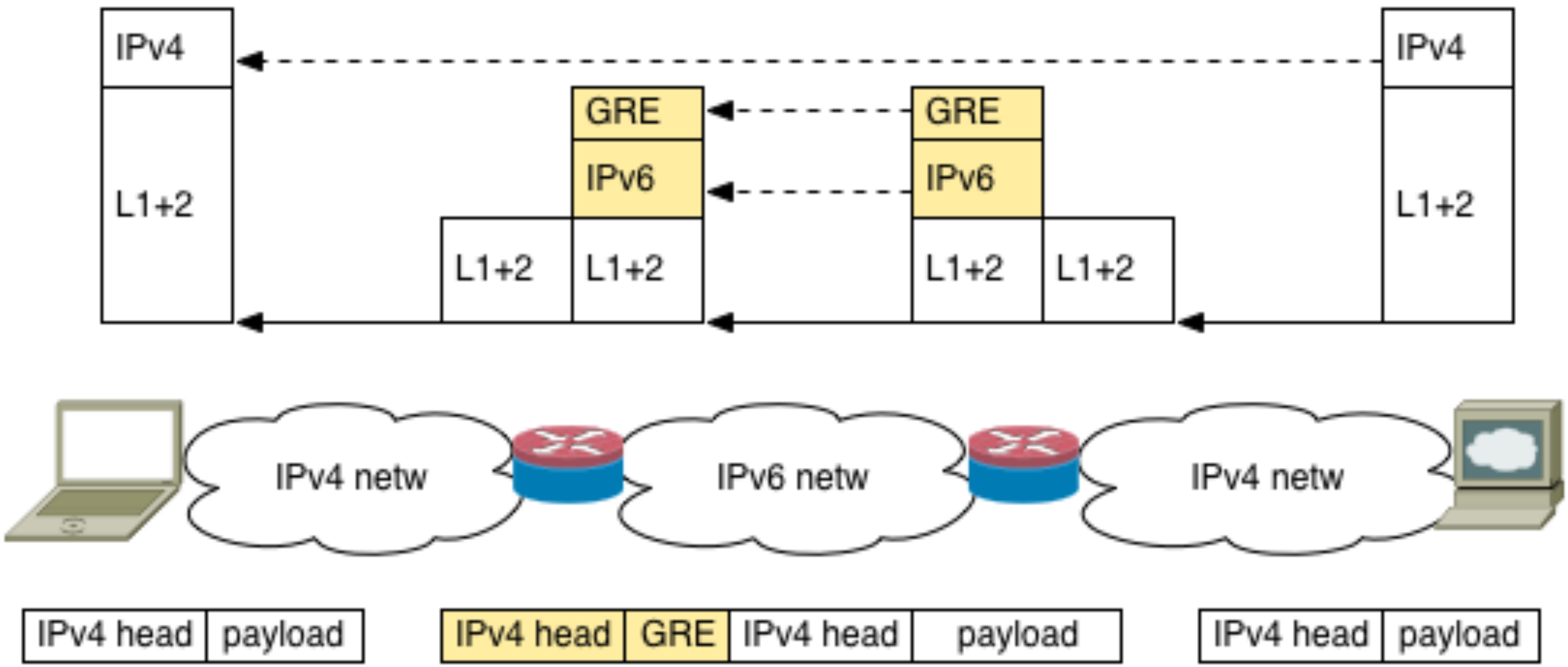
- Resource management
  - Scheduling and dynamic resouce allocation
- Compression
  - IP head compr reduces overhead
- Security
  - Encryption of data
- Positioning
  - UE physical position
- Connection to EPC
  - User and control plane

Protocol stack

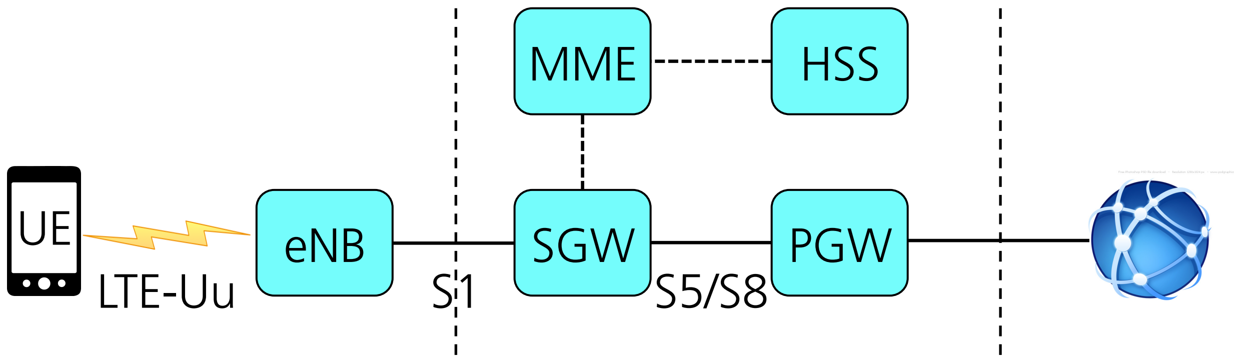
- S1 often tunneled over the fix network architecture
- A tunnel is a way to send packets over other types of network. E.g.
  - IPv4 over IPv6 and vice versa
  - IP over Ipsec
- GTP: GPRS Tunneling Protocol

Example of tunneling

IPv4 over IPv6 using GRE (Generic routing encapsulation)



IP packets in LTE (User plane)



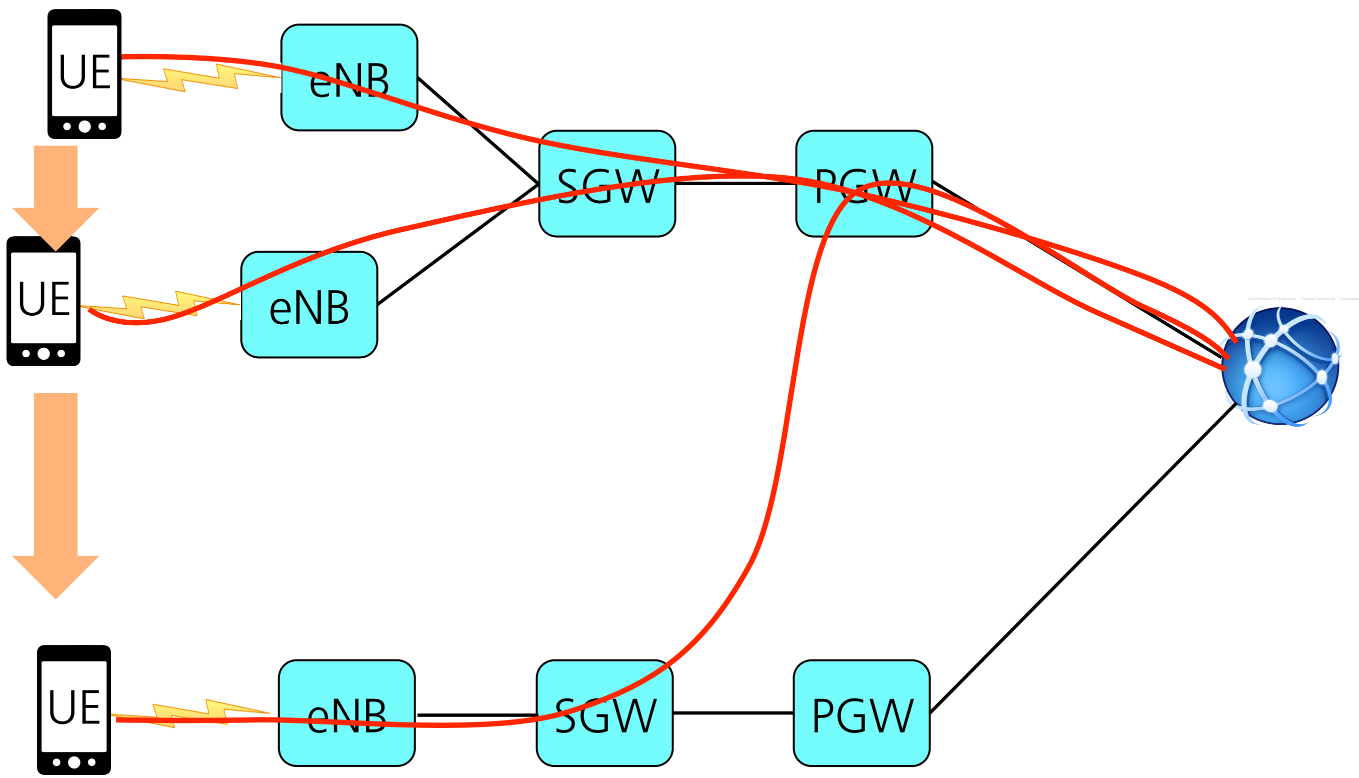
PGW

- IP edge for user
- IP address allocation to UE
- QoS filtering
- Mobility anchor
  - Does not change during session. Preserves the IP addr

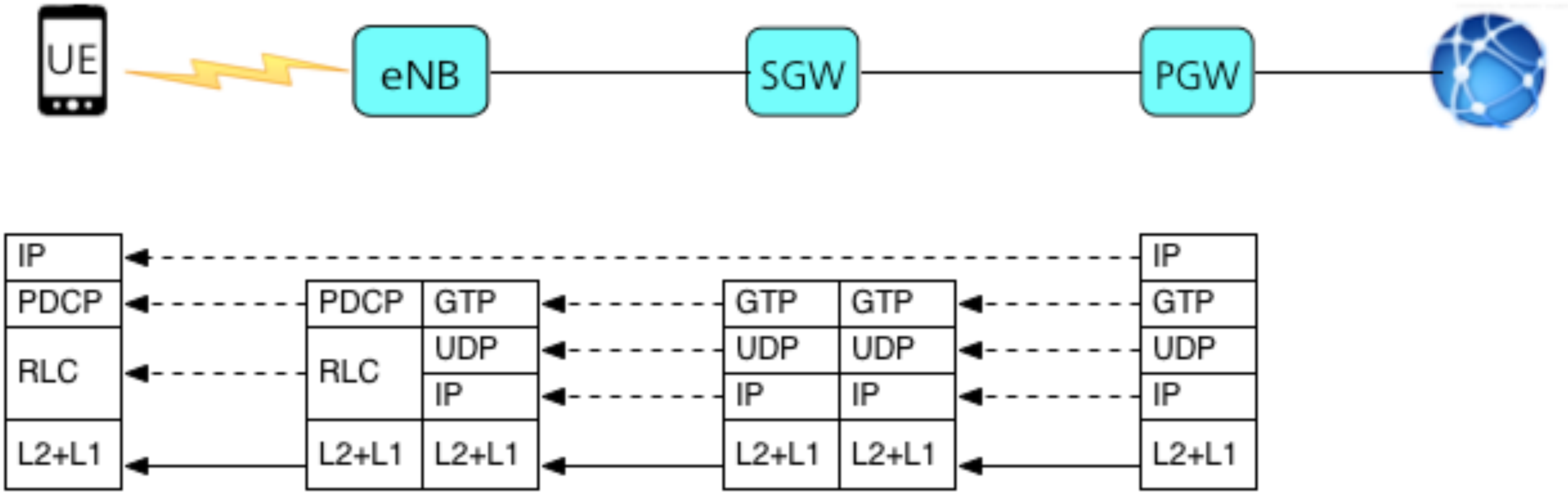
SGW

- Collecting charging info
- Local anchor towards eNB
  - Can change due to mobility

IP packets in LTE (User mobility)



Protocol stacks (User plane)



GTP: GPRS Tunneling Protocol

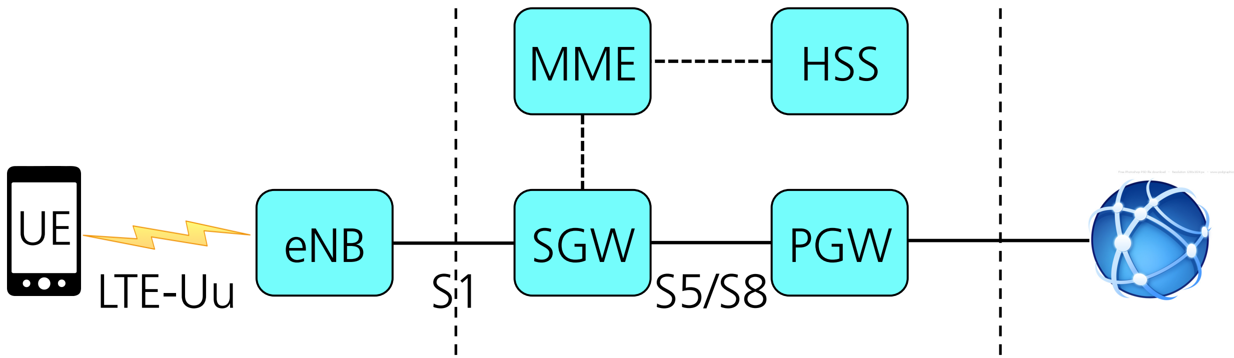
PDCP: Packet Data Convergence Protocol

(IP<->Radio, Header compression, security)

RLC: Radio Link Control

(Segmentation, reordering)

Control plane in EPC



MME

(Mobility Management Entity)

- Communicates with eNB and SGW
- Handles tunnels

HSS

(Home Subscriber Server)

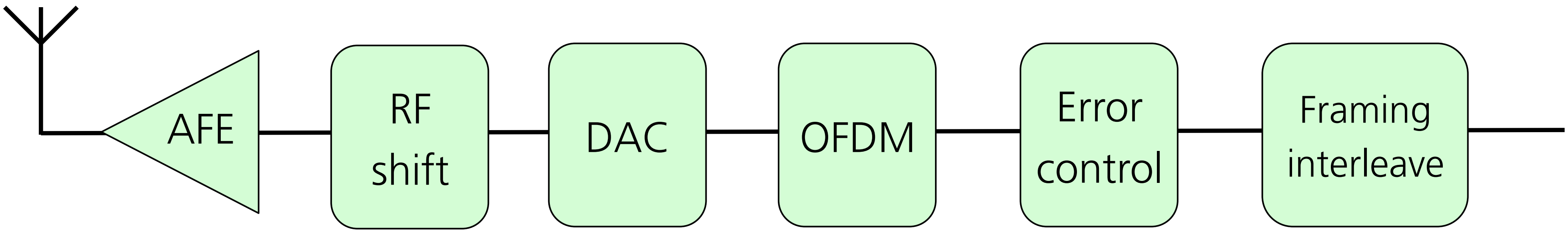
- Subscriber data base
- SIM card key exchange
- AAA
  - Authentication, Authorization and Accounting

The radio channel

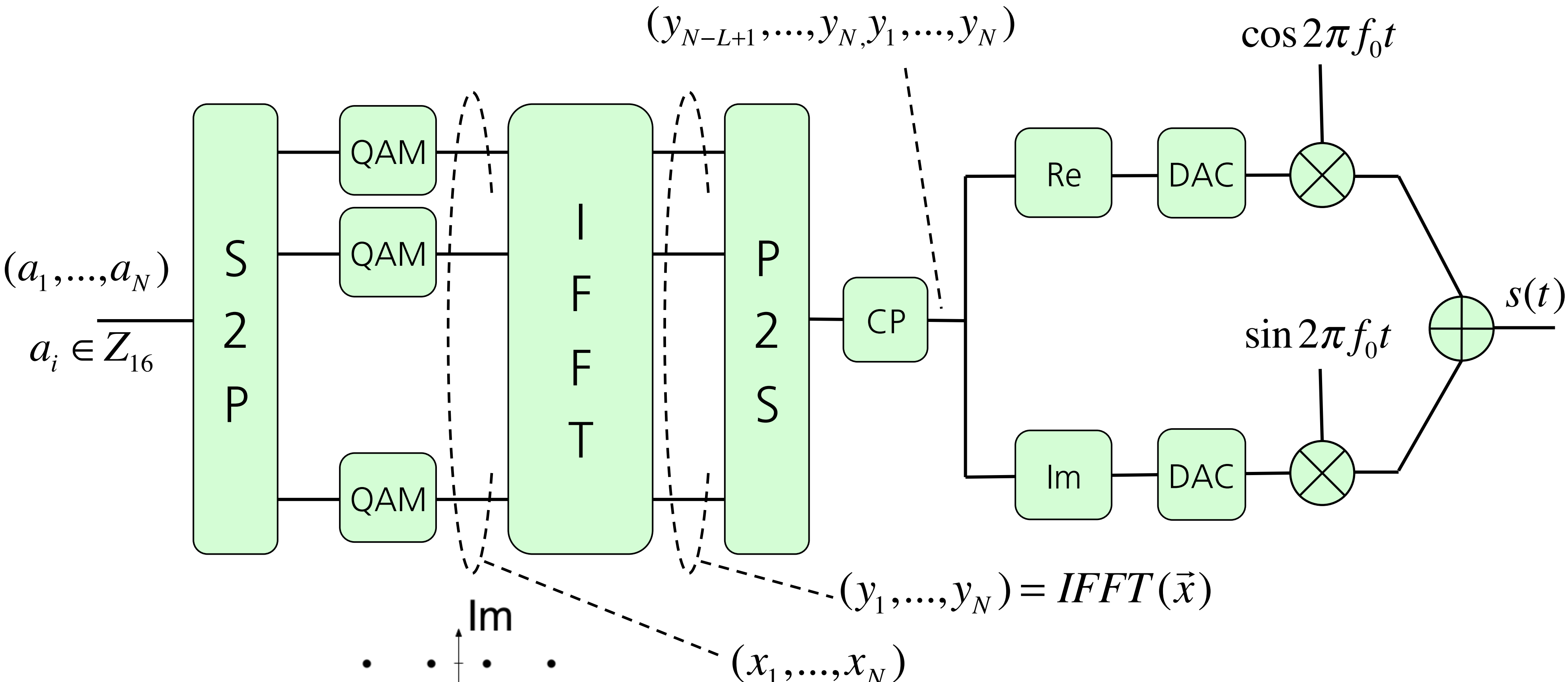
- Licensed frequency bands (slots of 20 MHz)
  - In 0.5-4 GHz
- Cost in order of Billions $
- Alternative: FDD and TDD
  - Most common FDD
- Efficient transmission
  - UE low power => long(er) battery life

    => very low power at receiver

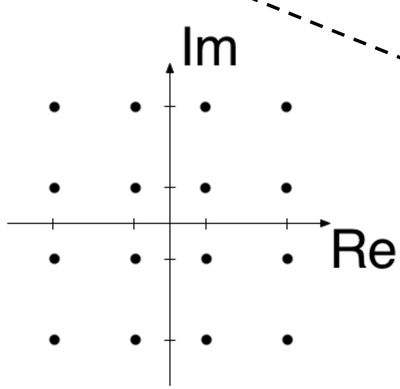
eNodeB structure (physical layer)



OFDM
Orthogonal Frequency Division Multiplexing



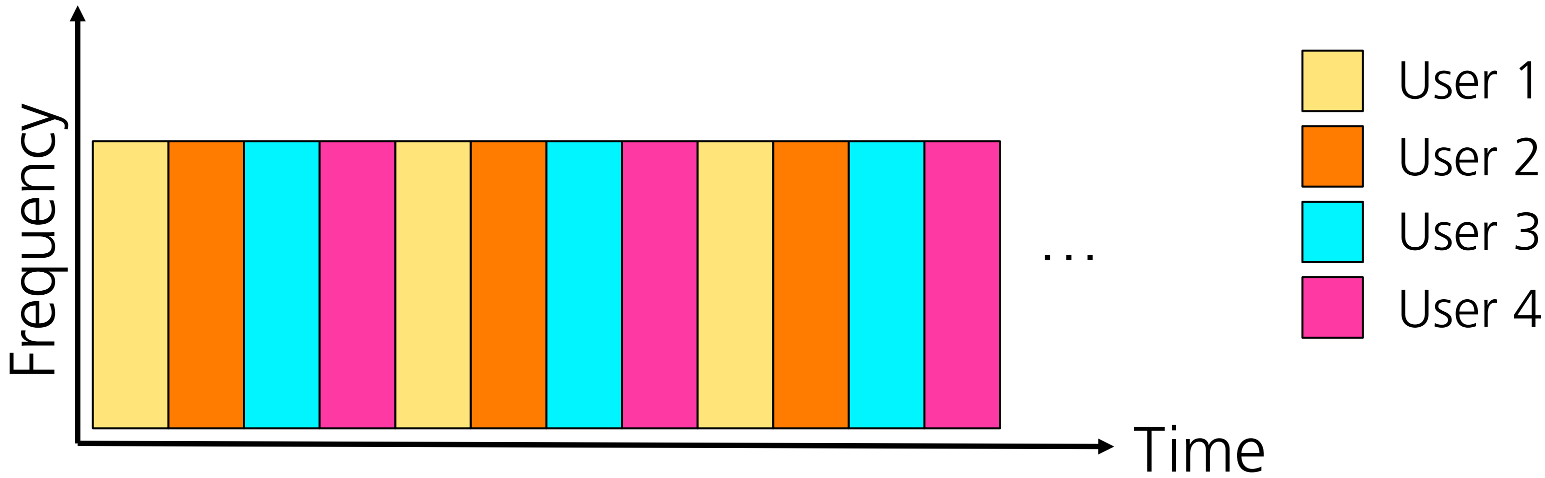
16-QAM mapping:



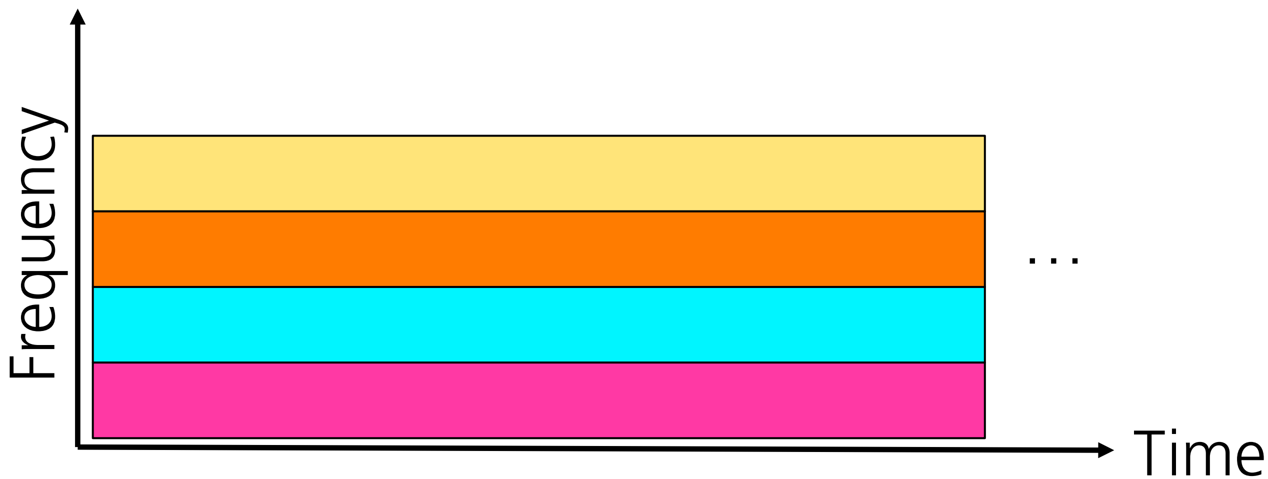
Can be used with M=4, 16, 64 (or 256)

Time-frequecy multiple access

TDMA:

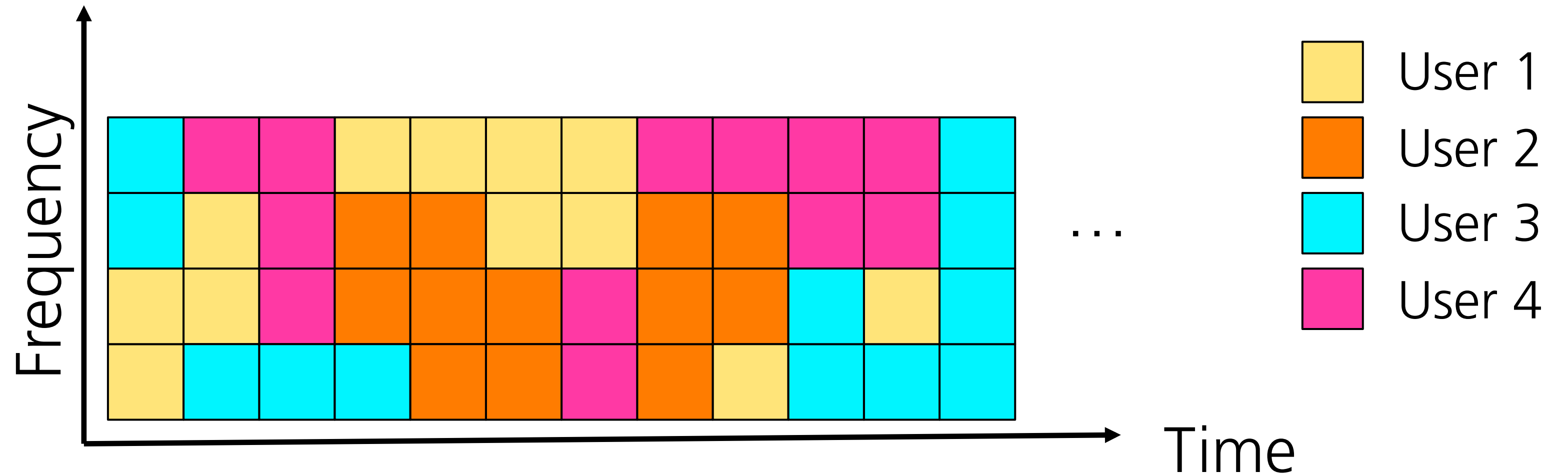


FDMA:



Time-frequecy multiple access

OFDMA:



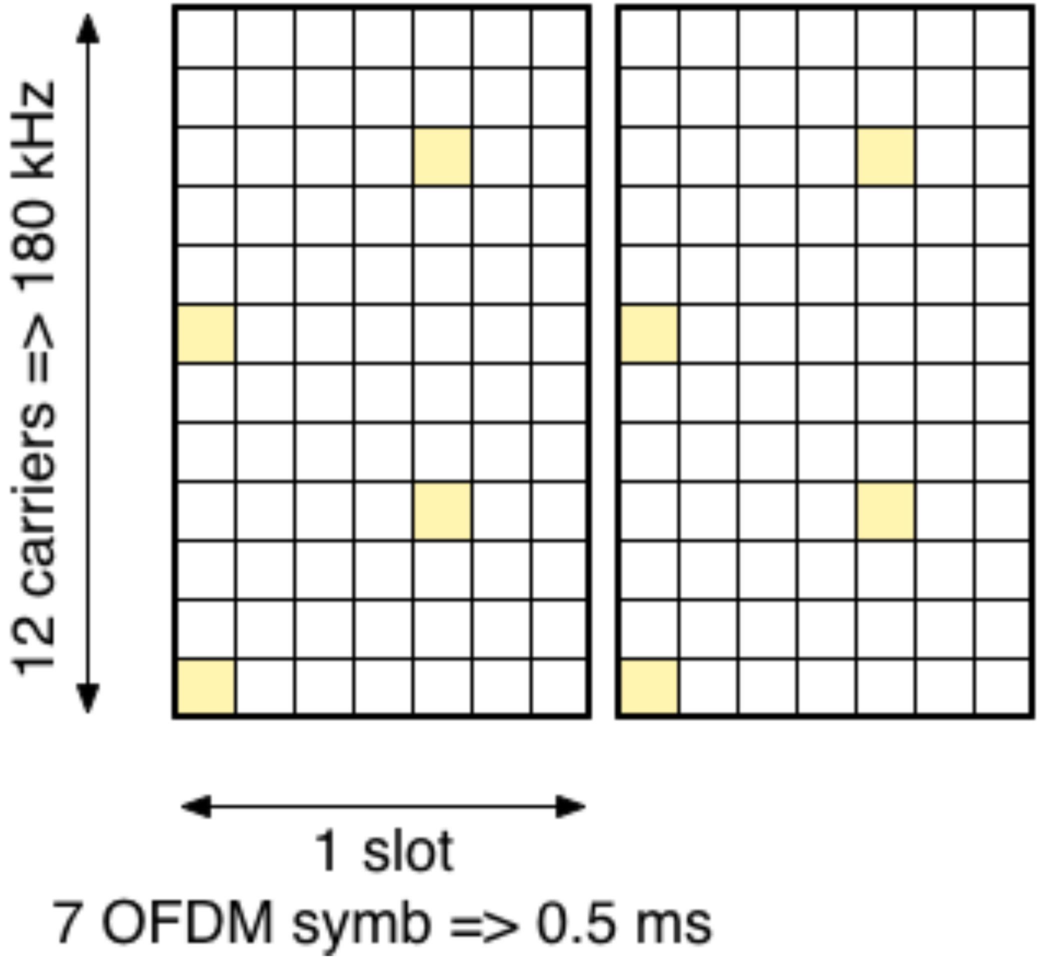
In LTE

- Resource element (RE) is one carrier over one OFDM symbol

  This is the least time-frequency resource

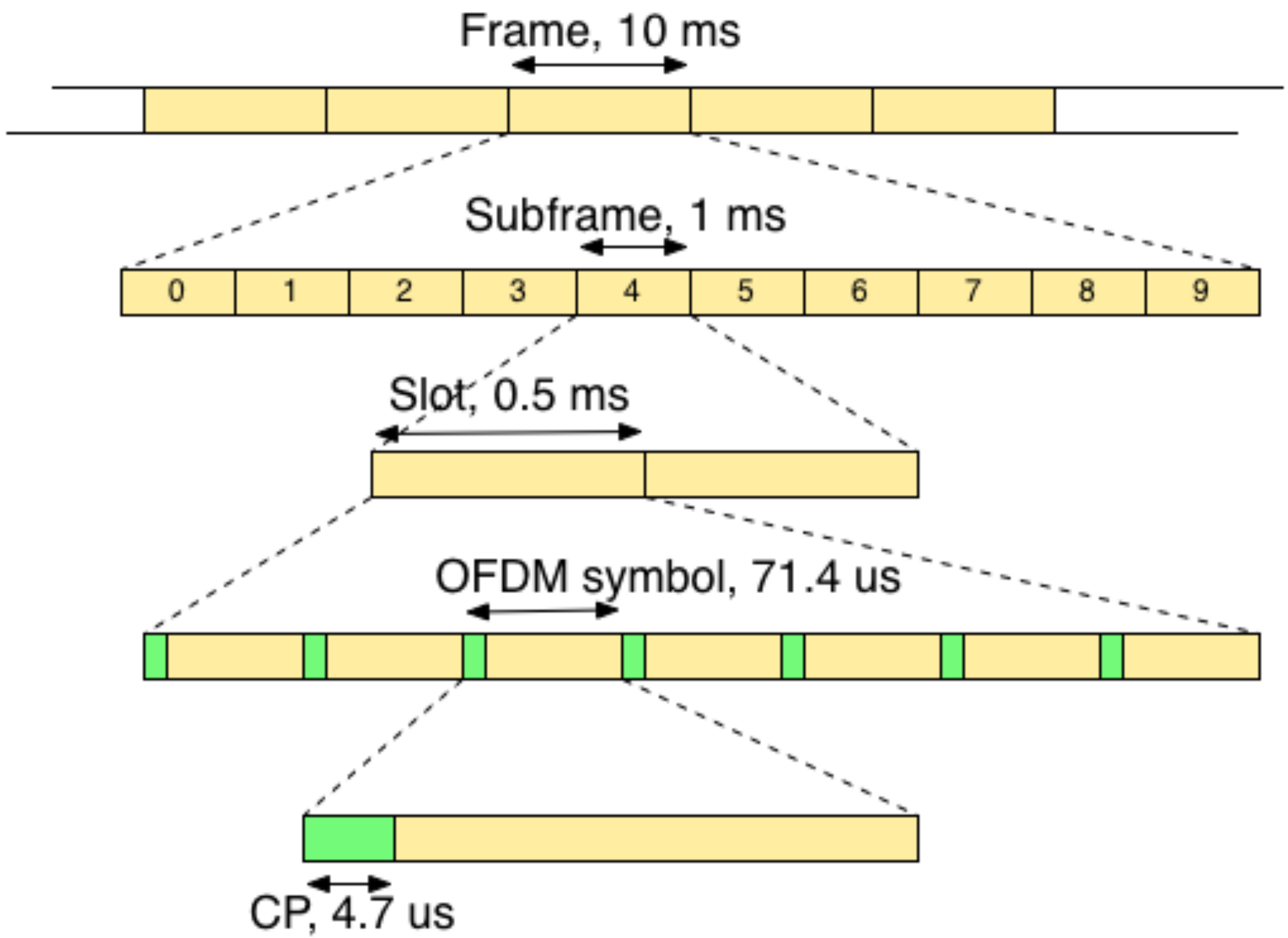
  - 15 kHz X 71.4 us

Resource block (RB)



A pair of RB is the least assigned resource

Frame structure in time



Resource allocation in frequency

BW [MHz]	1.4	3	5	10	15	20
N	128	256	512	1024	1536	2048
#alloc RB (in Freq)	6	12	25	50	75	100
#used carrier	72	144	300	600	900	1200
Oversampling	1.78	1.78	1.71	1.71	1.71	1.71
Max Rate [Mb/s]	6	12	25	50	75	100

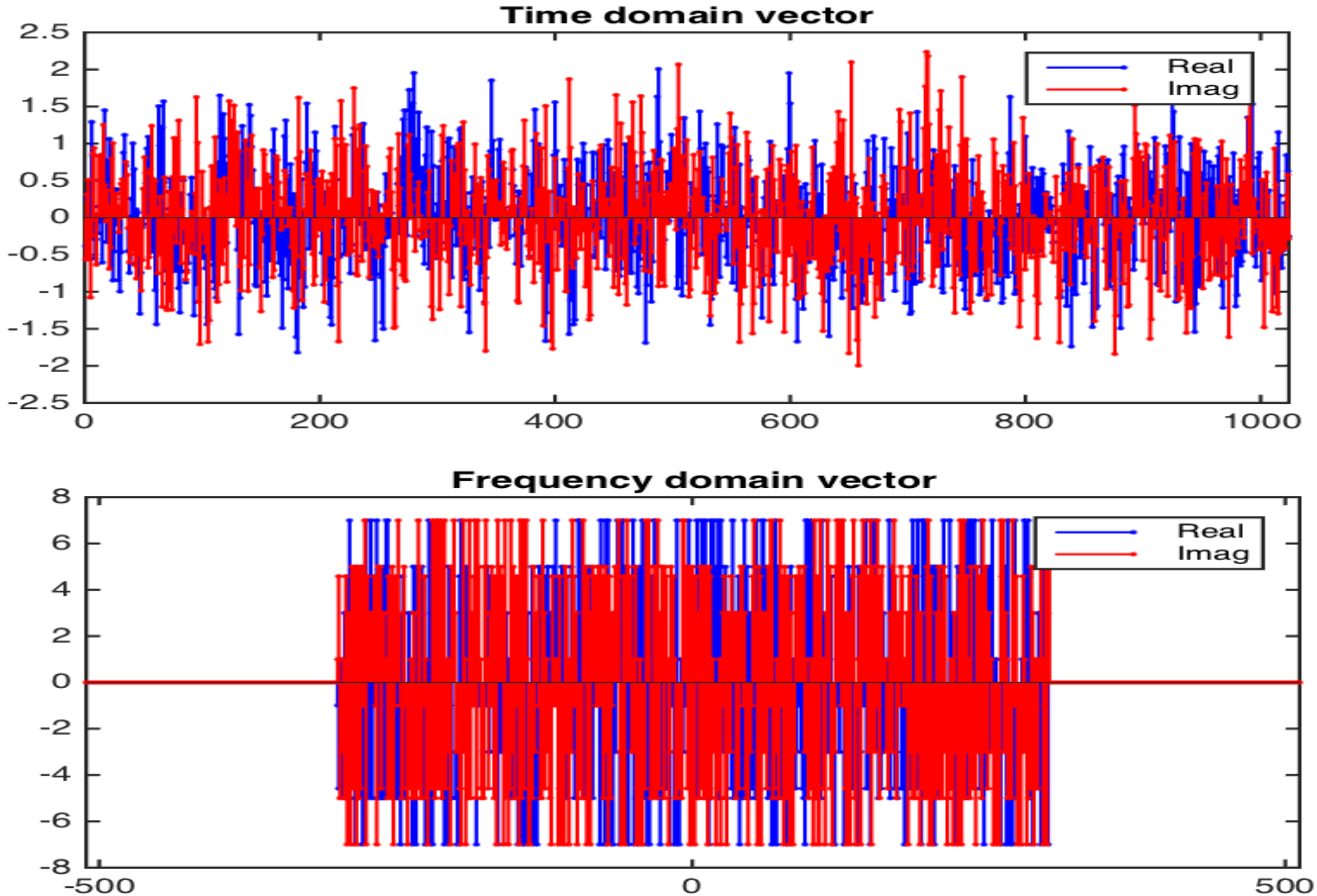
Max Rate is for 64-QAM, i.e. 6 bit/carrier

Then $R = \# carrier \cdot 6 \cdot 7 \cdot 2 \cdot 10 \cdot 100$ [b/s]

Impact of control signals is not included

Example

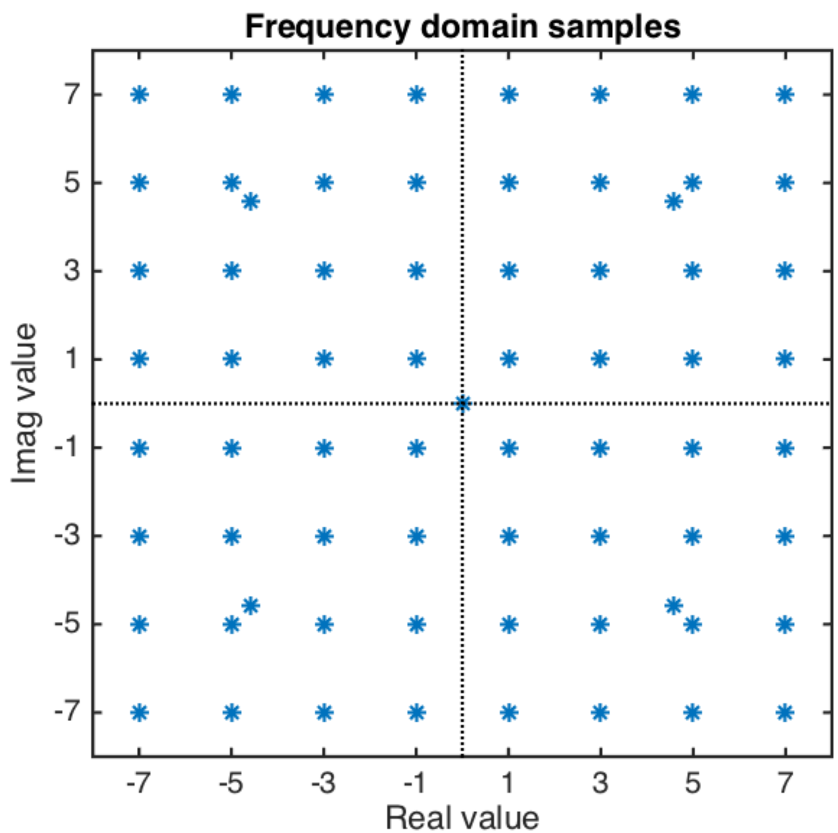
One OFDM symbol for BW=10 MHz and 64-QAM



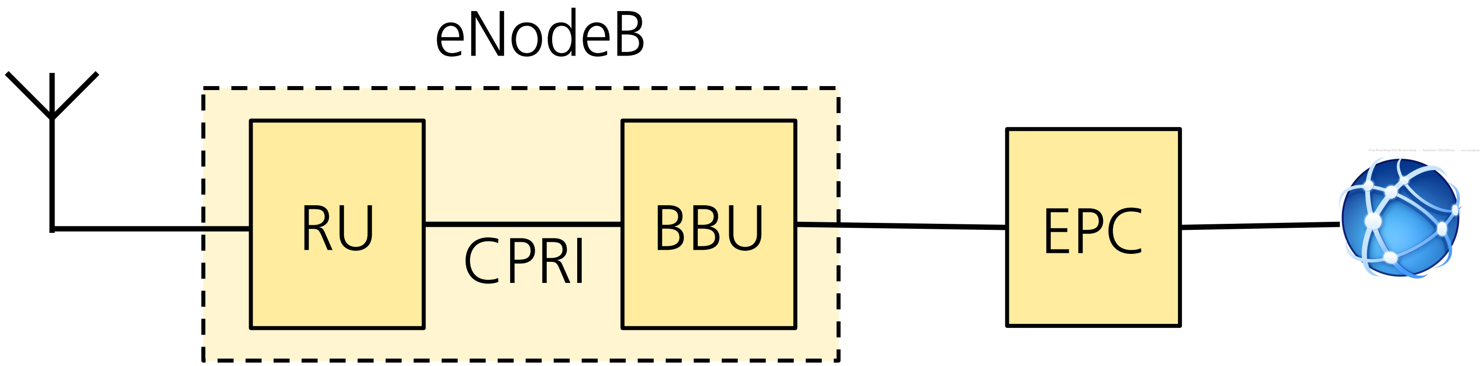
Example

One OFDM symbol for BW=10 MHz and 64-QAM

Plot of (all) frequency domain samples as I-Q



What comes next 1
BBU hoteling



Baseband unit (BBU)

- Binary data to baseband samples
  - QAM mapping, IFFT, etc

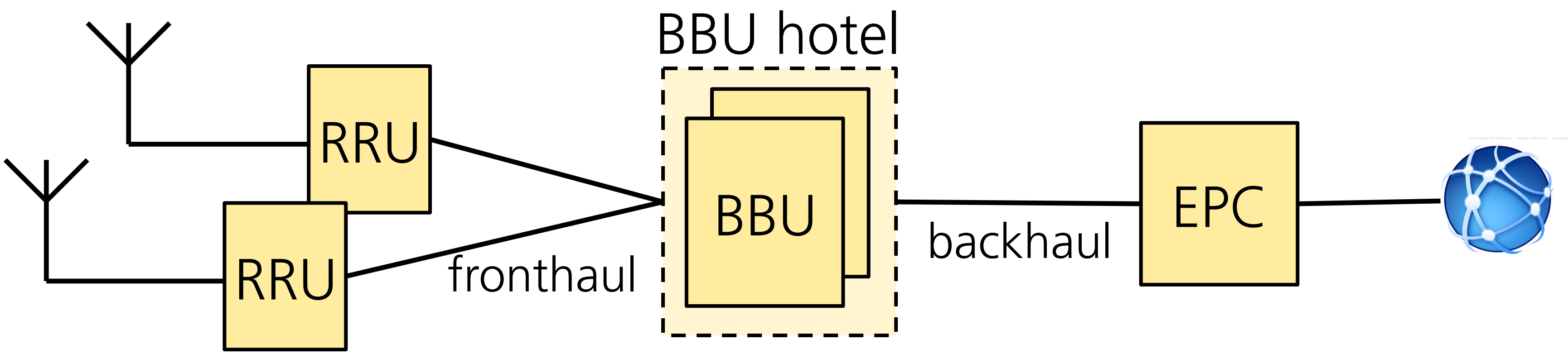
Radio unit (RU)

- Digital/analog conversion
- Mixing to RF

What comes next 1
BBU hoteling

To utilize recourses better split BBU and RRU in network

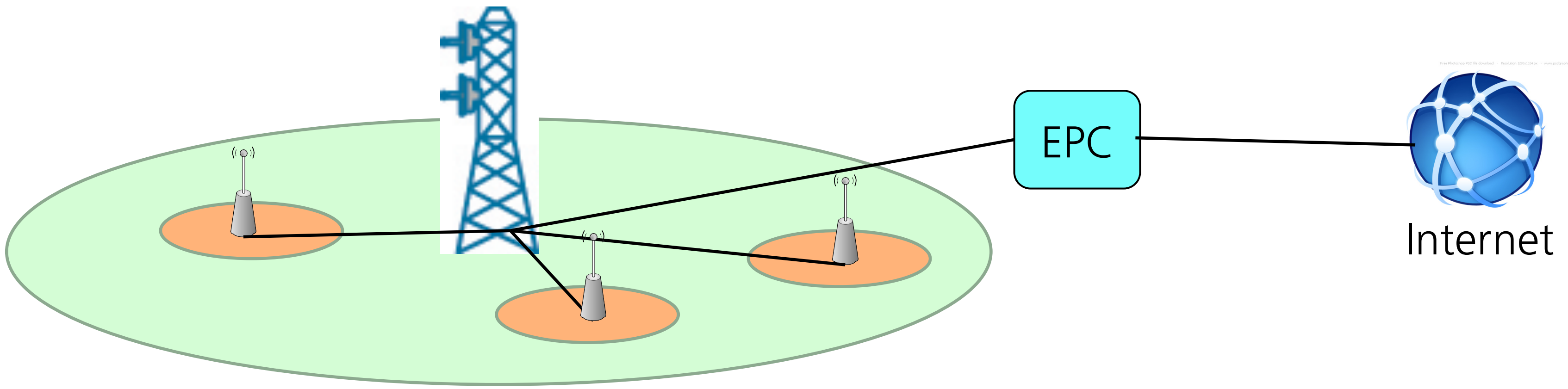
- Use CPRI to transmit BB samples between BBU and RRU



RRU = Remote Radio Unit

Problem: Data rate expansion in transmission of radio samples of approximately a factor 10

What comes next 2
Small cells



- Small cells work in
  - Short distance (low power)
  - High data rate (few users)
- In public places, offices, shopping malls, etc
- Even plans for small cells in homes
  - Instead or together with WiFi?

Problems

- How to backhaul/fronhaul
- Can they be part of coordination?
  - Pico cell: with coordination
  - Femto cell: no coordination

What comes next 4
5G

- Rughly a factor of 10 everywhere
  - 10 times faster
  - 10 battery life (for low power devices)
  - 1000 times traffic volume
  - 10 times harder (at least)
- Small cells everywhere
- M2M; Everything is connected
  - Car2Car, IoT, Skynet, …
- Expected 2020