# Computer Networks
# COL 334/672

Cellular Networks

Tarun Mangla

*Slides adapted from KR*

Sem 1, 2024-25

# Cellular Networks

- Special kind of network connecting to the Internet
- Primary access medium for a large number of users

| Particulars | Wireless | Wireline | Total (Wireless+ Wireline) |
|---|---|---|---|
| **Broadband Subscribers** (Million) | **806.07** | **33.11** | **839.18** |

- Different generations of cellular technologies (e.g., 2G .., 5G)
- Technical standards: 3rd Generation Partnership Project (3GPP)
  - wwww.3gpp.org

# This Class

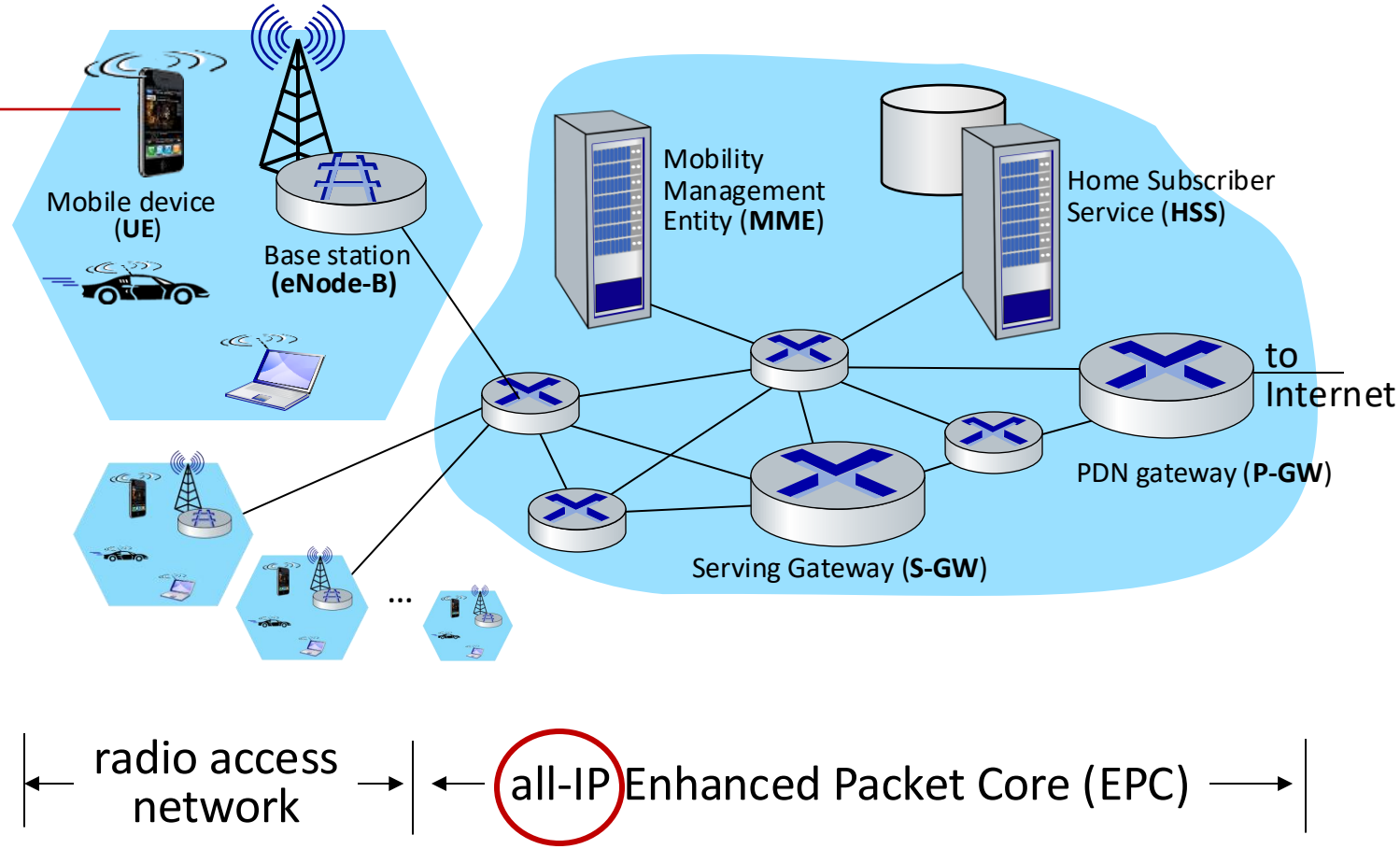
- Overview of how cellular network architecture
  - What (not so much of why)
  - Another course for why ☺
- Focus only on 4G network architecture

# Architecture: Motivation

# Elements of 4G LTE architecture

## Mobile device:

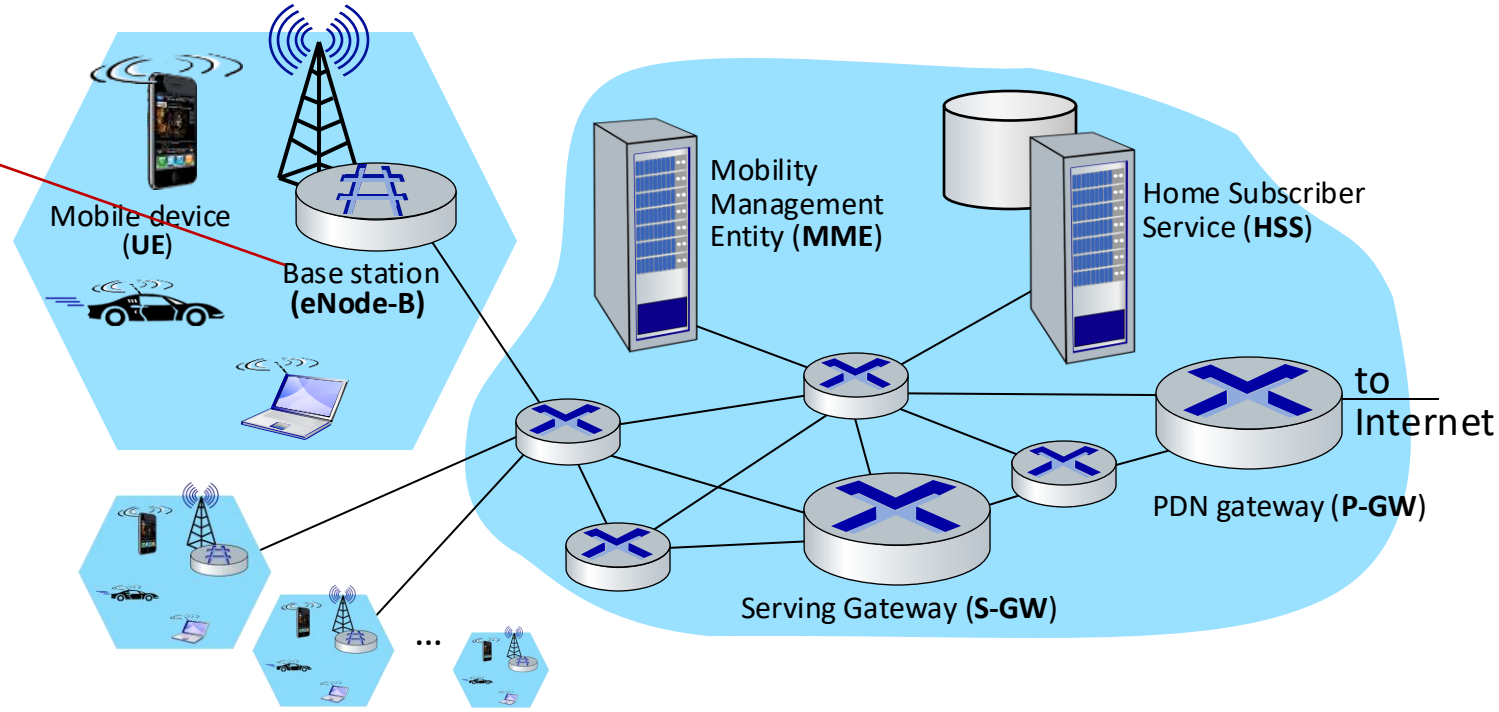
- smartphone, tablet, laptop, IoT, ... with 4G LTE radio
- 64-bit International Mobile Subscriber Identity (IMSI), stored on SIM (Subscriber Identity Module) card
- LTE jargon: User Equipment (UE)



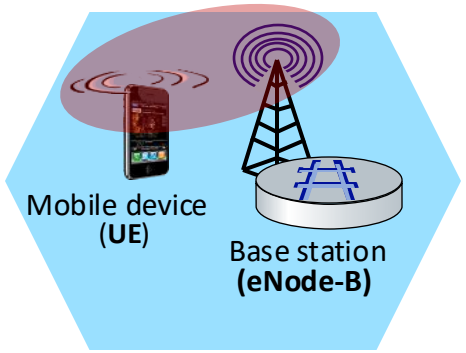
# Elements of 4G LTE architecture

## Base station:

- at “edge” of carrier’s network
- manages wireless radio resources, mobile devices in its coverage area (“cell”)
- coordinates device authentication with other elements
- similar to WiFi AP but:
  - active role in user mobility
  - coordinates with nearly base stations to optimize radio use
- LTE jargon: eNode-B

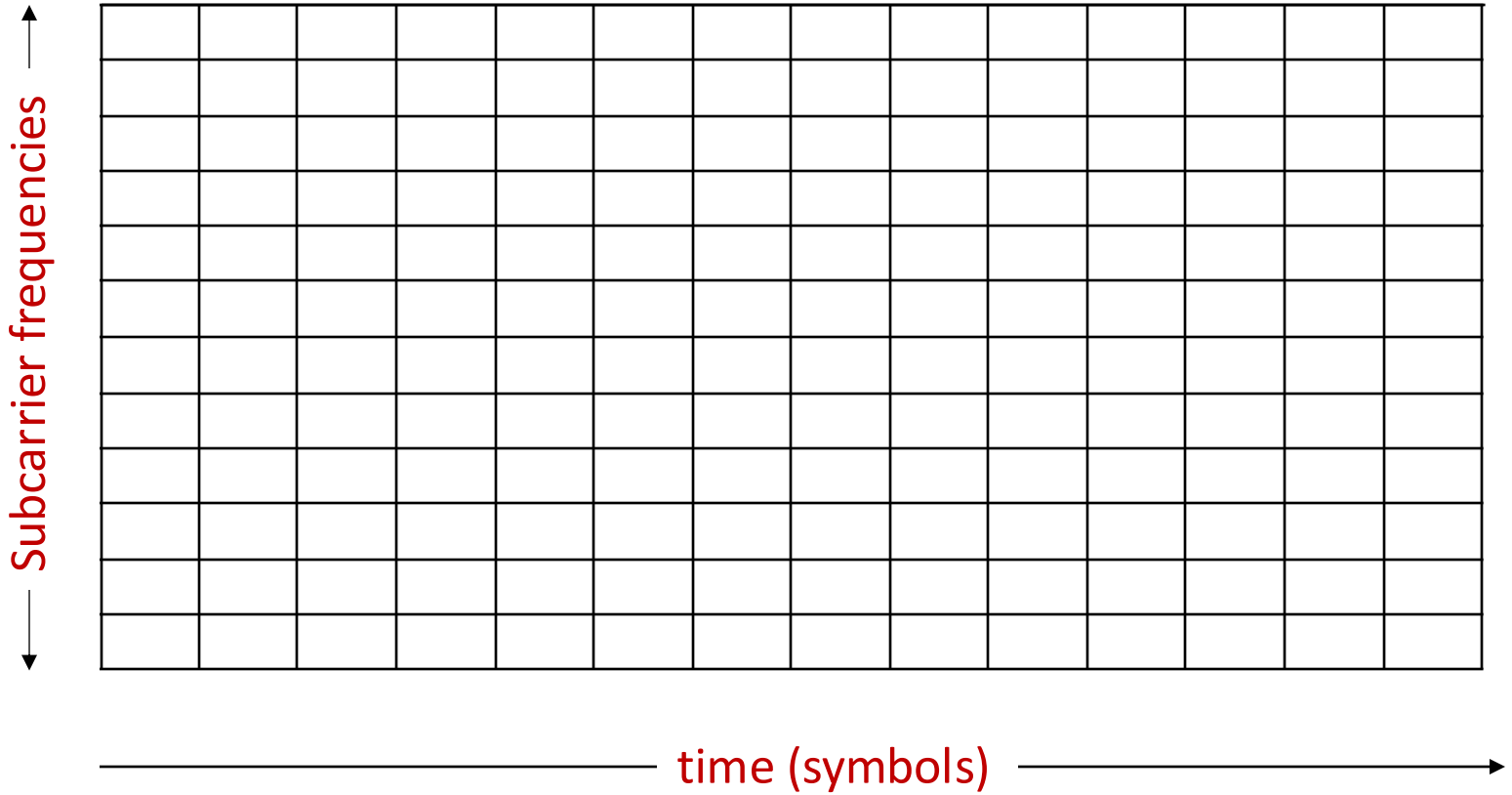


# Radio Access Network: 4G radio




- connects device (UE) to a base station (eNode-B)
  - multiple devices connected to each base station
- many different possible frequencies bands, multiple channels in each band
  - popular bands: 600, 700, 850, 1500, 1700, 1900, 2100, 2600, 3500 MHz
  - separate upstream and downstream channels
- sharing 4G radio channel among users:
  - OFDM: Orthogonal Frequency Division Multiplexing
  - combination of FDM, TDM
- 100's Mbps possible per user/device

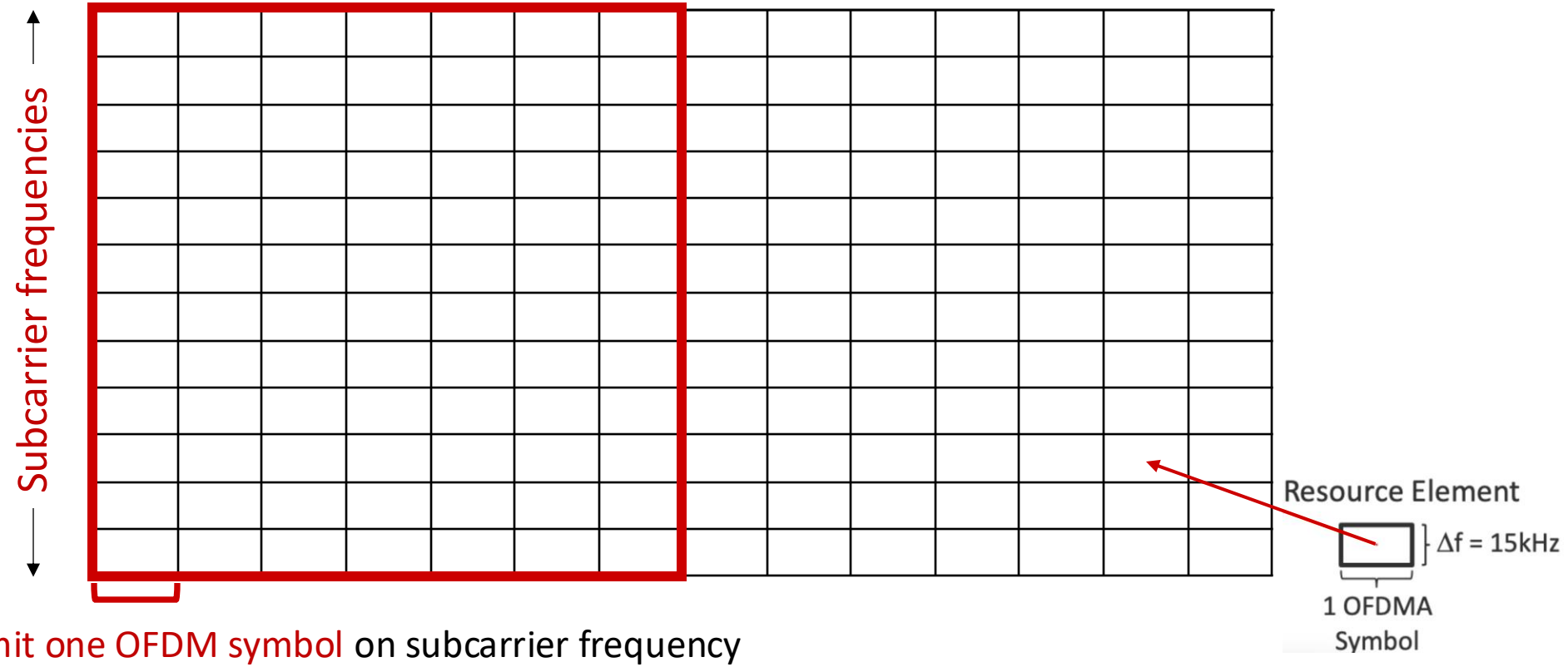
# OFDMA: time division (LTE)



# OFDMA: time division (LTE)

Physical Resource Block (PRB ): blocks of 7x12=84 resource elements

- unit of transmission scheduling



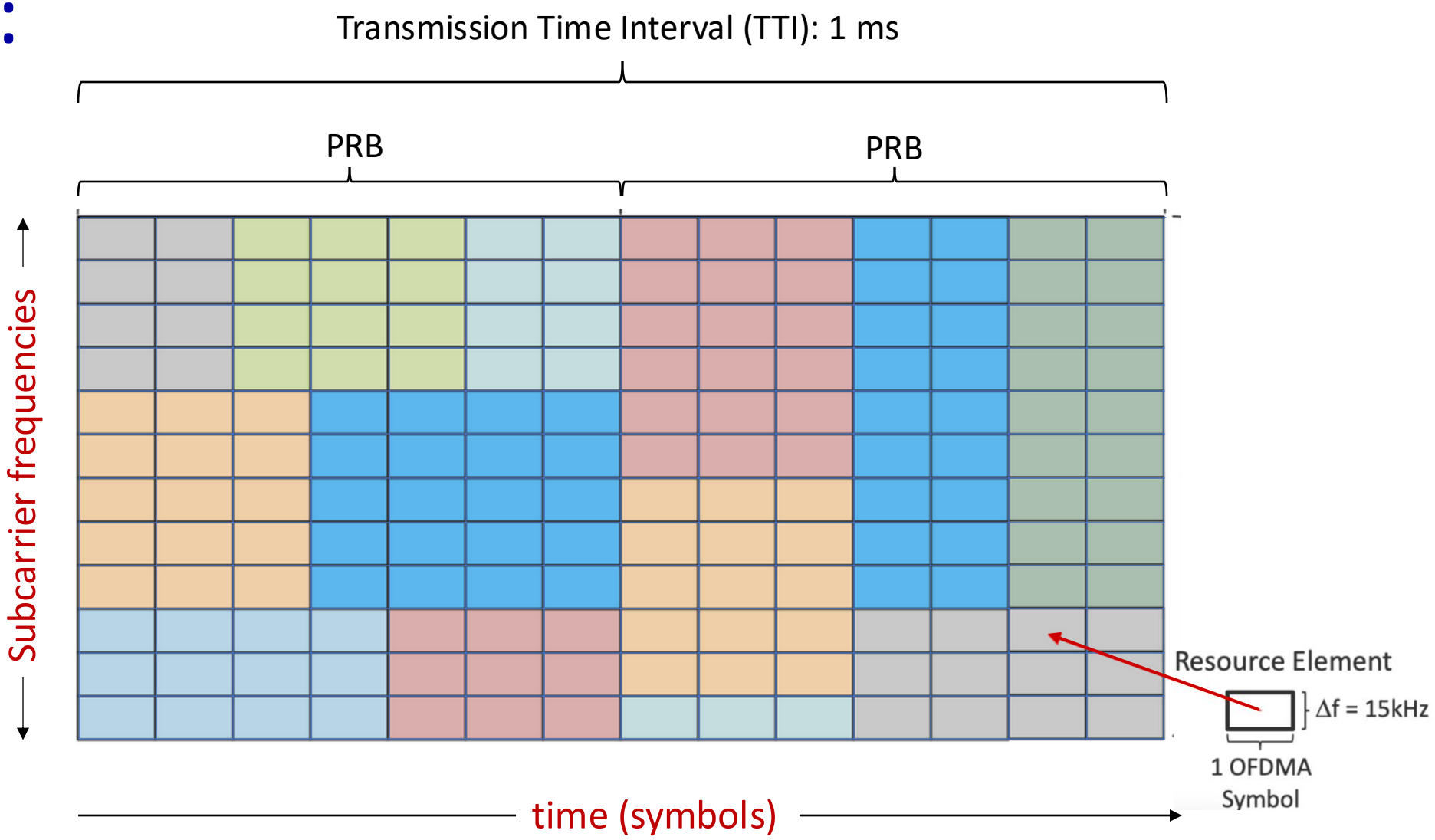

time to transmit one OFDM symbol on subcarrier frequency

# OFDMA:

## Transmission scheduling example:

- Send to 7 UEs in 7 blocks of REs in one PRB

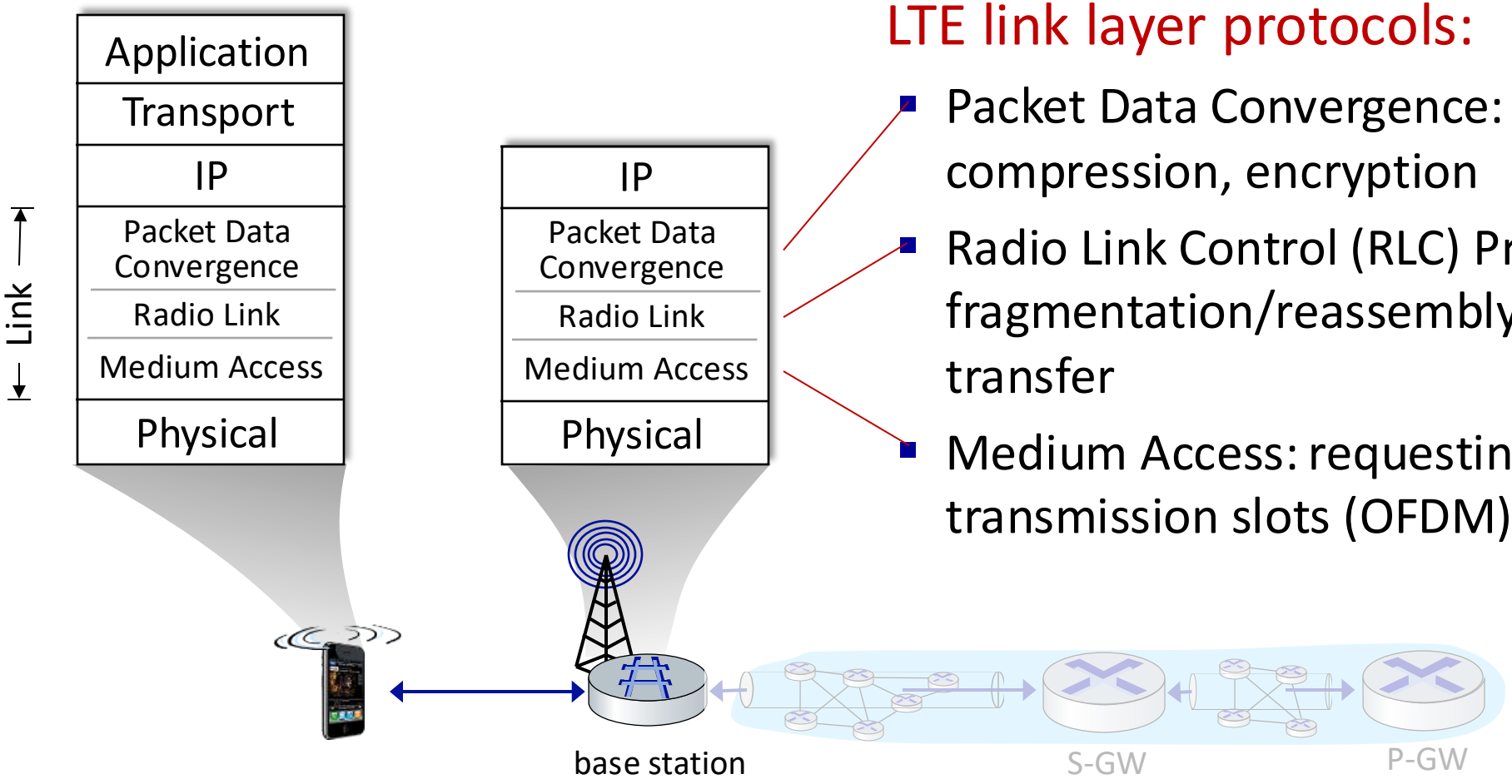
$UE_1$
$UE_2$
$UE_3$
$UE_4$
$UE_5$
$UE_6$
$UE_7$



# Spectrum Allocation

| Frequency Range (MHz) | Primary Allocation | Secondary Allocation | Notes |
|---|---|---|---|
| 0 - 68 | Fixed, Mobile | Radiolocation | Various services based on WRC regulations (NFAP 2022 Document for ...) |
| 68 - 87.5 | Broadcasting | Mobile | In some regions, agreements are required (NFAP 2022 Document for ...) |
| 88 - 108 | Broadcasting (FM Radio) | - | FM radio broadcasting is primary here (NFAP 2022 Document for ...) |
| 138 - 144 | Mobile, Maritime Mobile | Radiolocation, Fixed | Available for certain maritime and land mobile services (NFAP 2022 Document for ...) |
| 174 - 230 | Broadcasting | Mobile, Aeronautical Mobile | Allocated for digital TV broadcasting in specific bands (NFAP 2022 Document for ...) |
| 450 - 470 | Mobile | Earth Exploration Satellite | Limited to mobile and related services (NFAP 2022 Document for ...) |
| 694 - 790 | IMT (Mobile Broadband) | - | Reserved for mobile broadband and telecom use (NFAP 2022 Document for ...) |
| 880 - 960 | Mobile | Fixed | Widely used for GSM cellular networks (NFAP 2022 Document for ...) |

# LTE data plane protocol stack: first hop



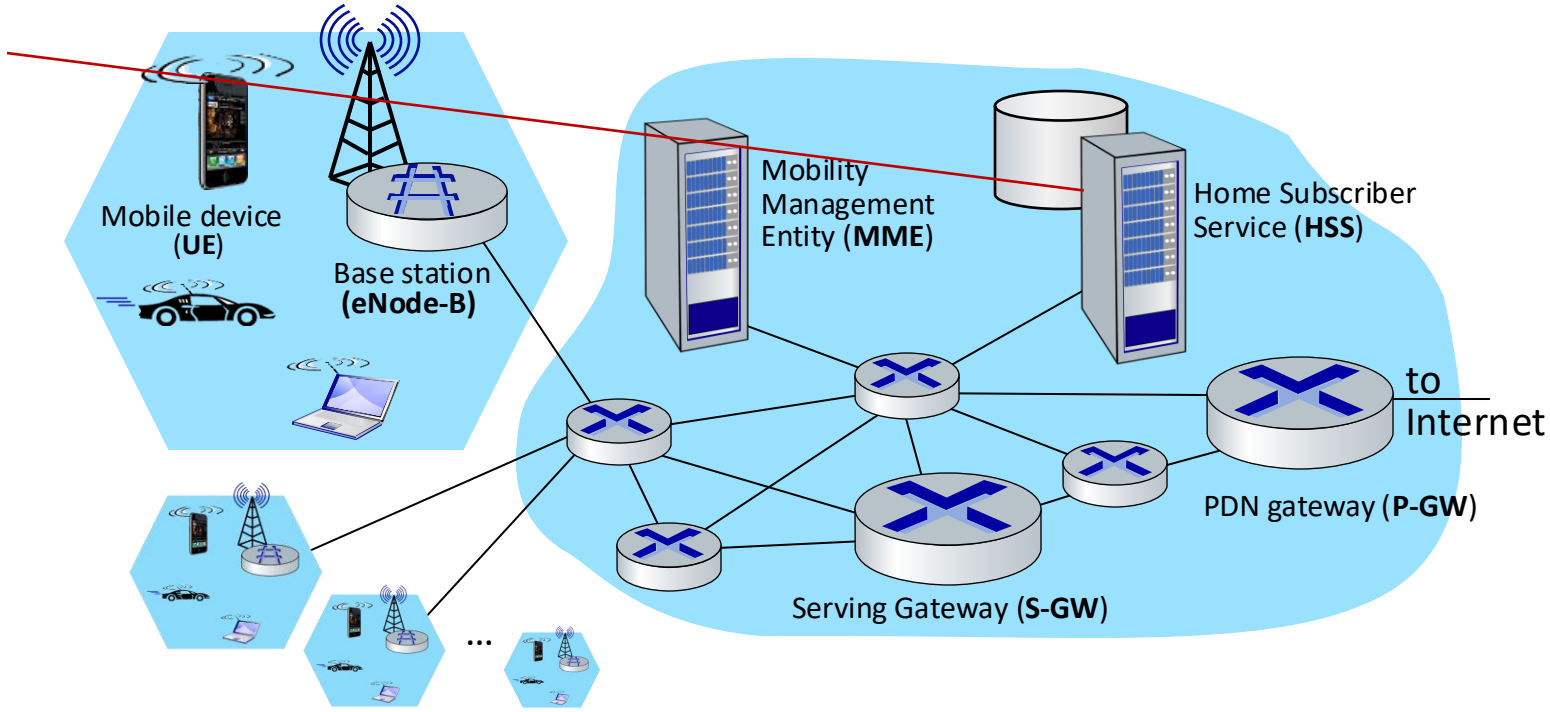

## LTE link layer protocols:

- Packet Data Convergence: header compression, encryption
- Radio Link Control (RLC) Protocol: fragmentation/reassembly, reliable data transfer
- Medium Access: requesting, use of radio transmission slots (OFDM)

# Elements of 4G LTE architecture

## Home Subscriber Service

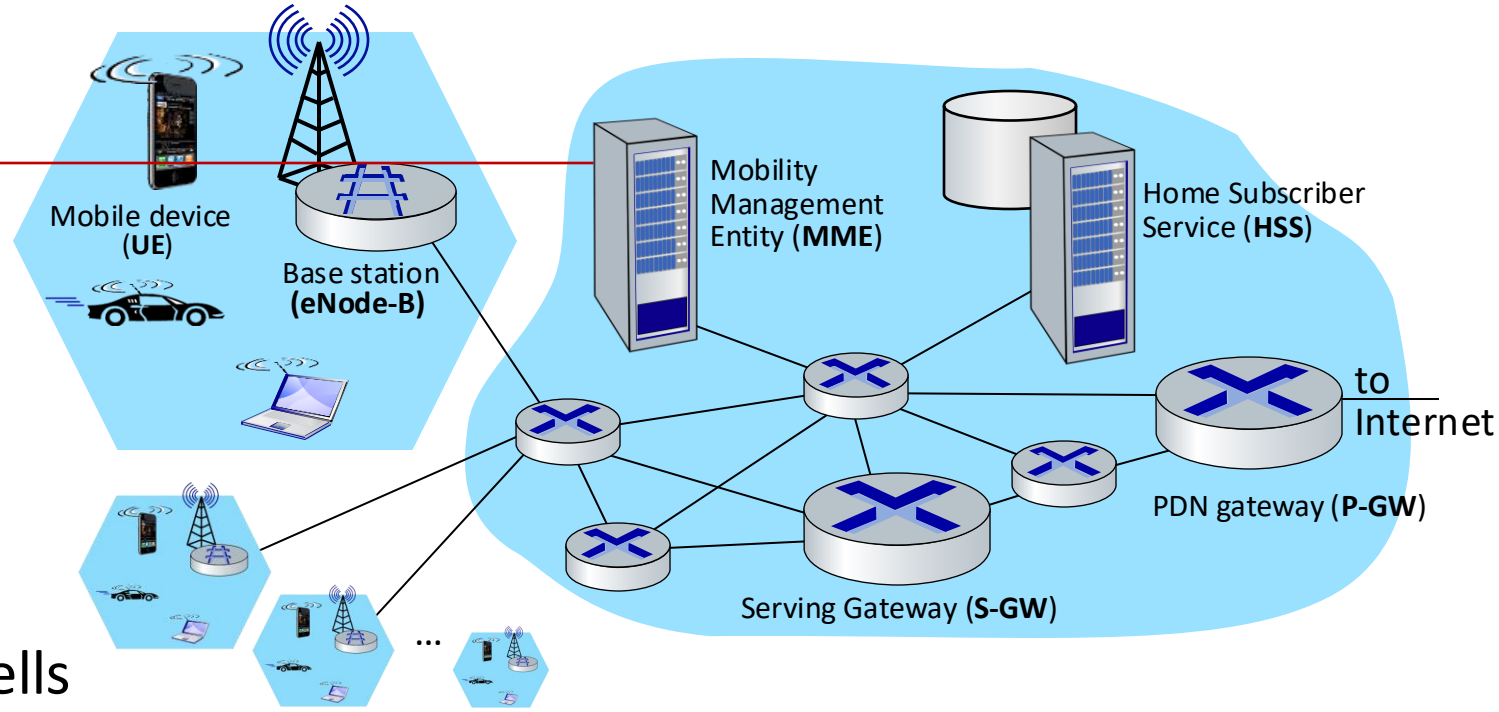
- stores info about mobile devices for which the HSS's network is their "home network"
- works with MME in device authentication



# Elements of 4G LTE architecture

## Mobility Management Entity

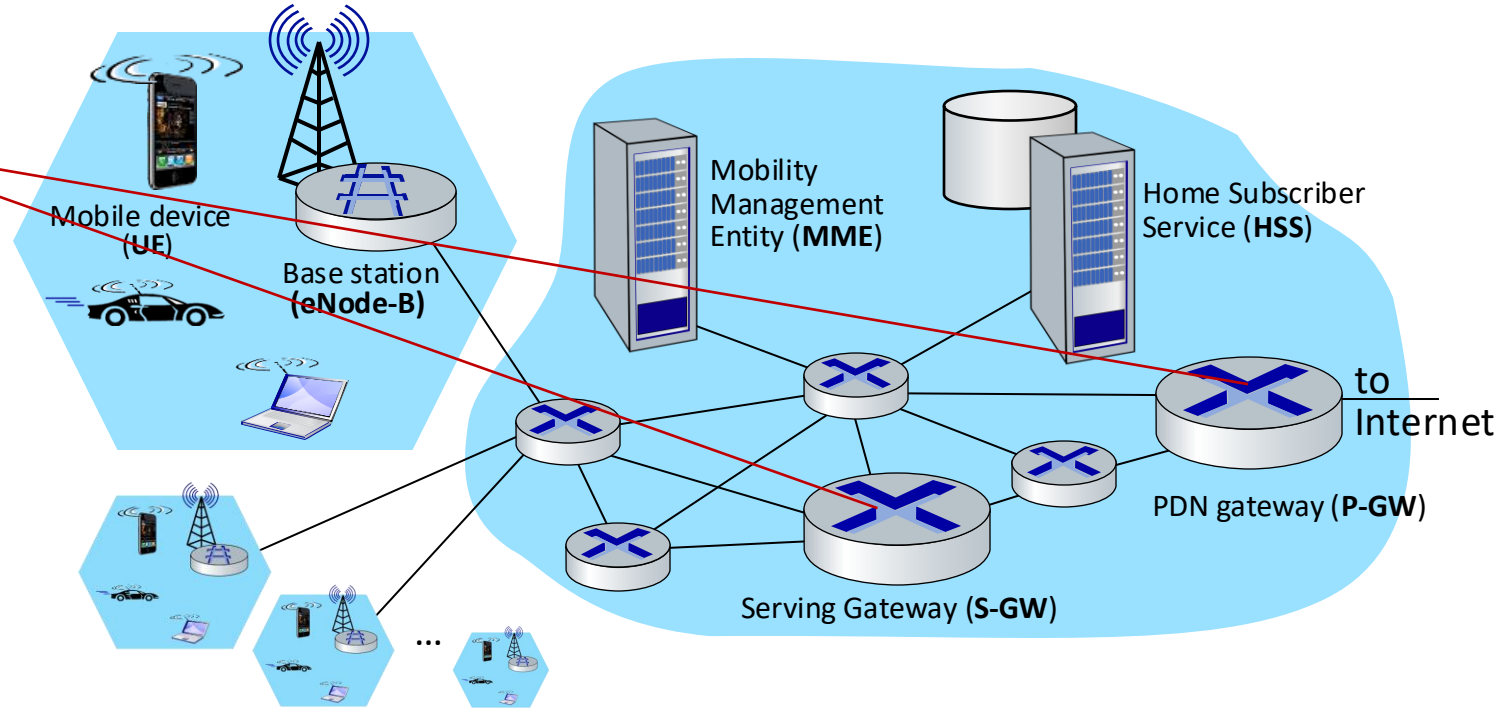
- device authentication (device-to-network, network-to-device) coordinated with mobile home network HSS
- mobile device management:
  - device handover between cells
  - tracking/paging device location
- path (tunneling) setup from mobile device to P-GW



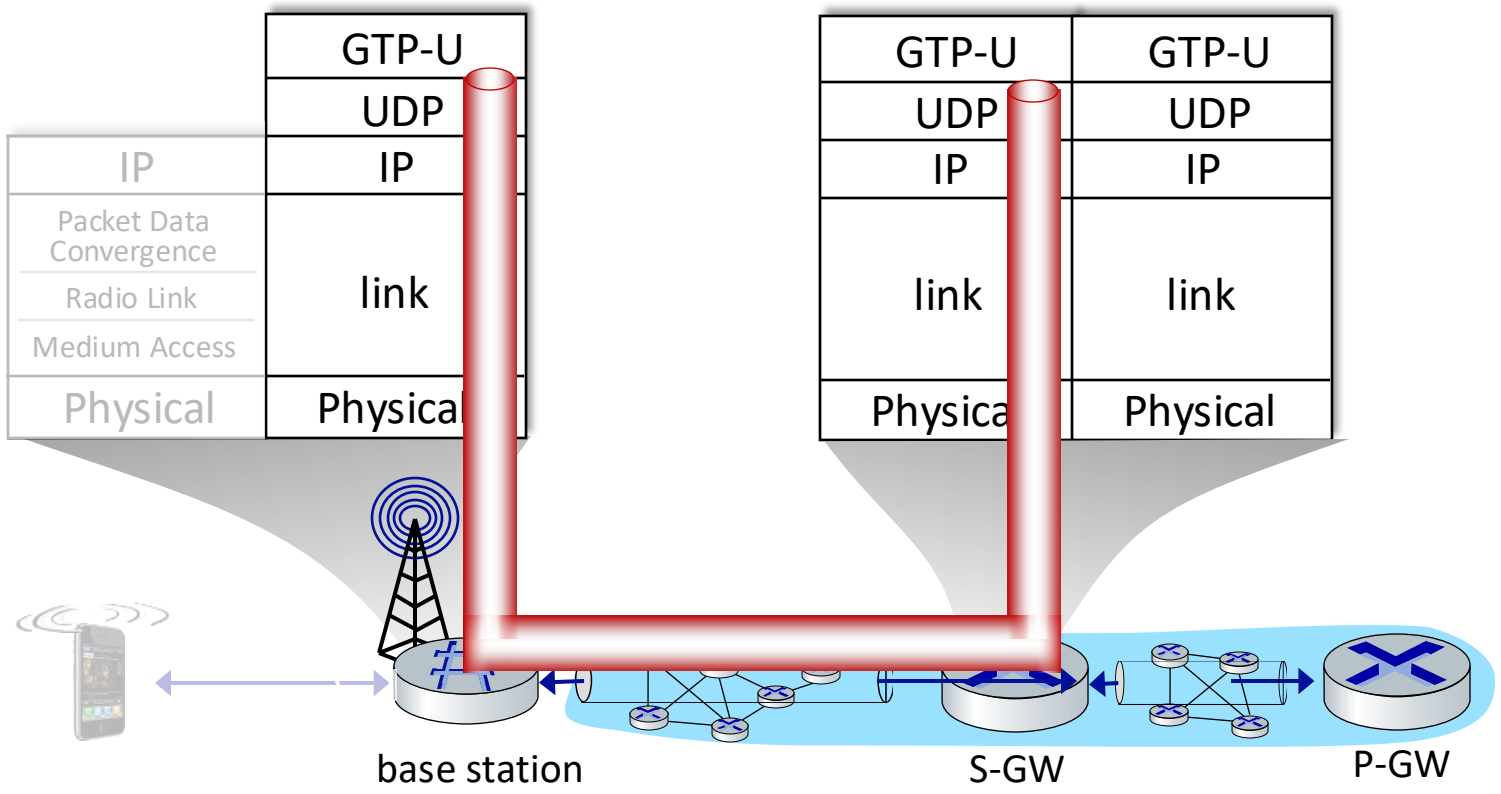
# Elements of 4G LTE architecture

Serving Gateway (S-GW),
PDN Gateway (P-GW)

- lie on data path from mobile to/from Internet
- P-GW
  - gateway to mobile cellular network
  - Looks like any other internet gateway router
  - provides NAT services
- other routers:
  - extensive use of tunneling



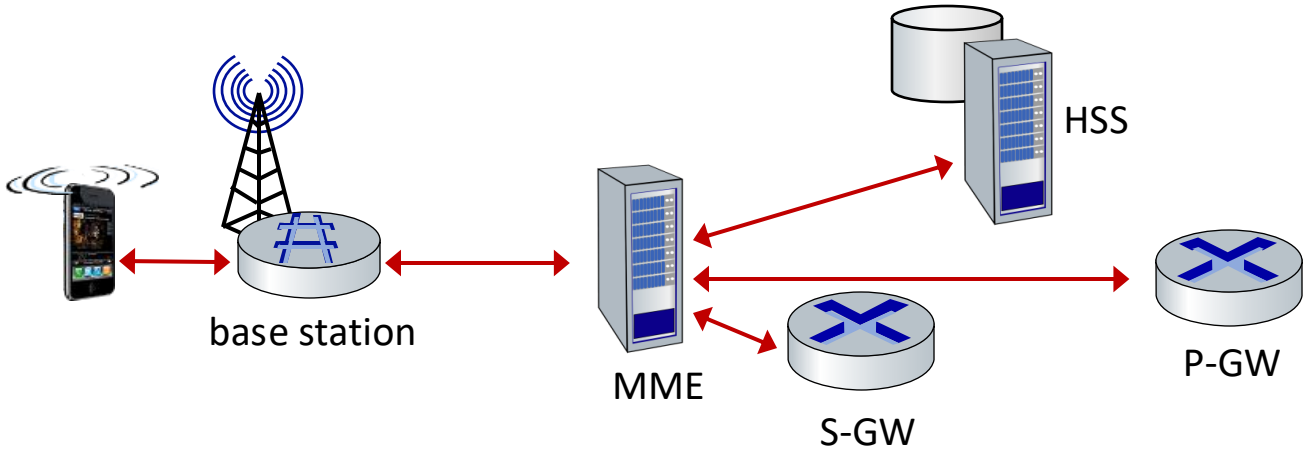
# LTE data plane protocol stack: packet core




tunneling:

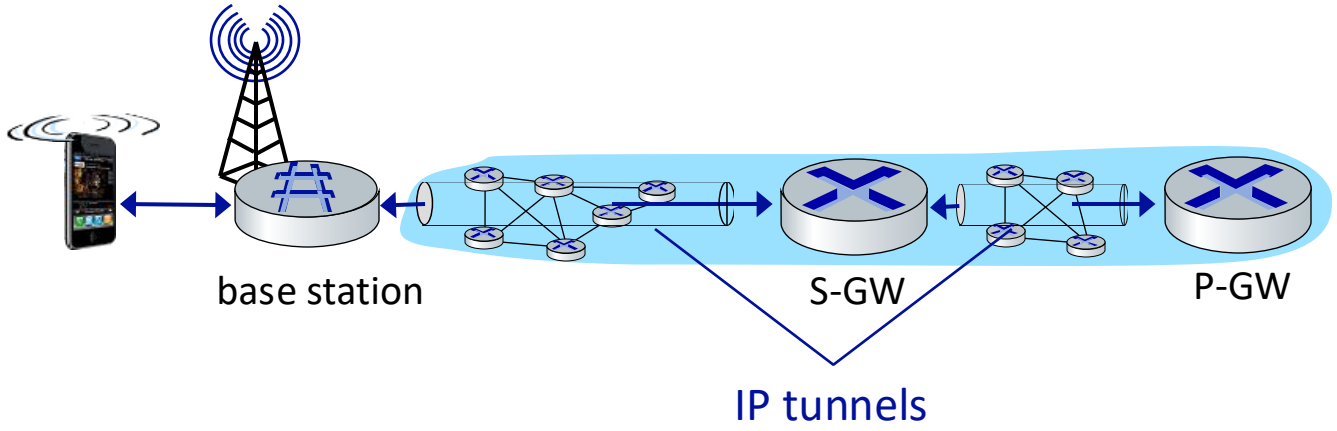
- mobile datagram encapsulated using GPRS Tunneling Protocol (GTP), sent inside UDP datagram to S-GW
- S-GW re-tunnels datagrams to P-GW
- supporting mobility: only tunneling endpoints change when mobile user moves

# LTE: data plane control plane separation




control plane

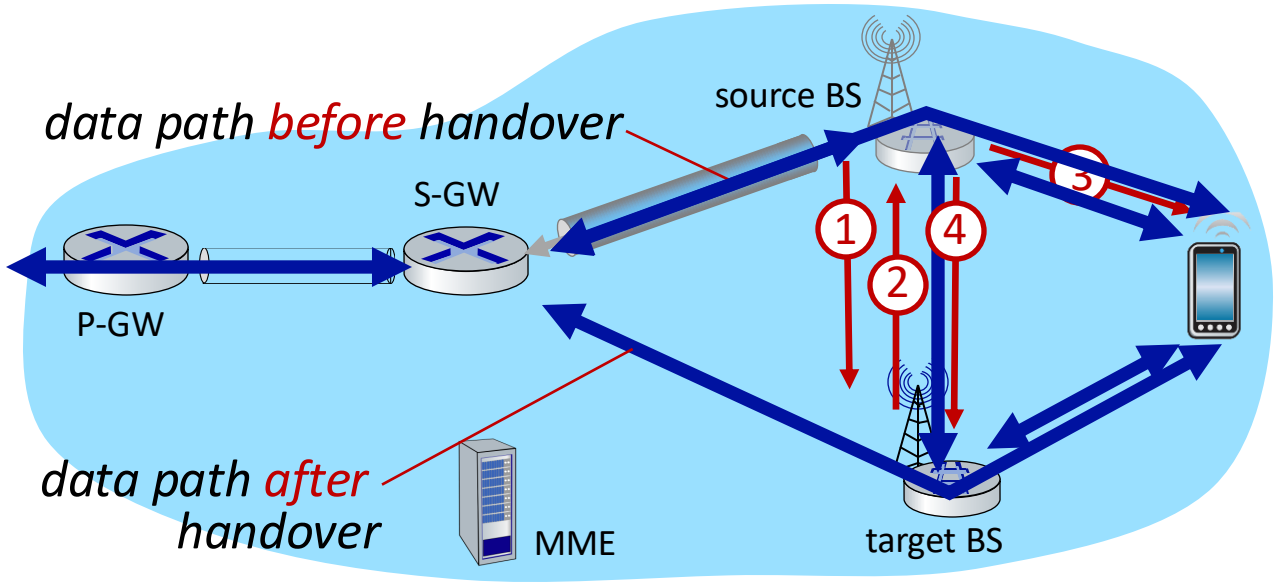
- new protocols for mobility management , security, authentication (later)




data plane

- new protocols at link, physical layers
- extensive use of tunneling to facilitate mobility

# Handover between BSs in same cellular network



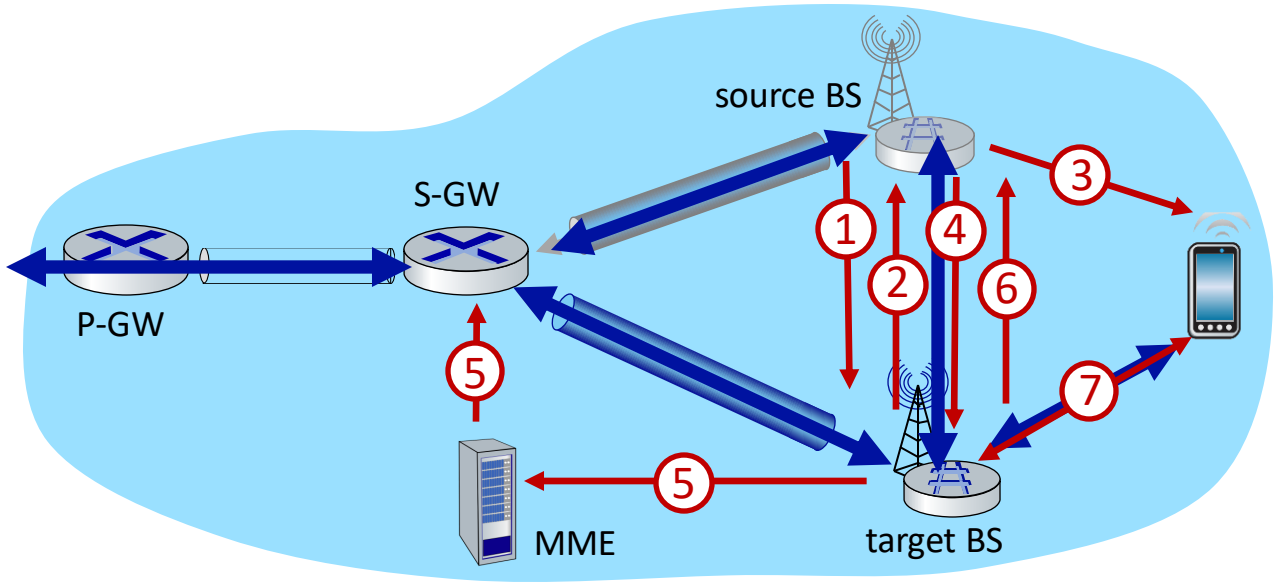

1. current (source) BS selects target BS, sends *Handover Request message* to target BS

2. target BS pre-allocates radio time slots, responds with HR ACK with info for mobile

3. source BS informs mobile of new BS
   - mobile can now send via new BS - handover *looks* complete to mobile

4. source BS stops sending datagrams to mobile, instead forwards to new BS (who forwards to mobile over radio channel)

# Handover between BSs in same cellular network




5 target BS informs MME that it is new BS for mobile
- MME instructs S-GW to change tunnel endpoint to be (new) target BS

6 target BS ACKs back to source BS: handover complete, source BS can release resources

7 mobile's datagrams now flow through new tunnel from target BS to S-GW

# Wireless, mobility: impact on higher layer protocols

- logically, impact *should* be minimal …
  - best effort service model remains unchanged
  - TCP and UDP can (and do) run over wireless, mobile
- … but performance-wise:
  - packet loss/delay due to bit-errors (discarded packets, delays for link-layer retransmissions), and handover loss
  - TCP interprets loss as congestion, will decrease congestion window un-necessarily
  - delay impairments for real-time traffic
  - bandwidth a scare resource for wireless links

# Attendance