

Computer Networks

COL 334/672

Cellular Networks

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Slides adapted from KR

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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)
 - www.3gpp.org

This Class

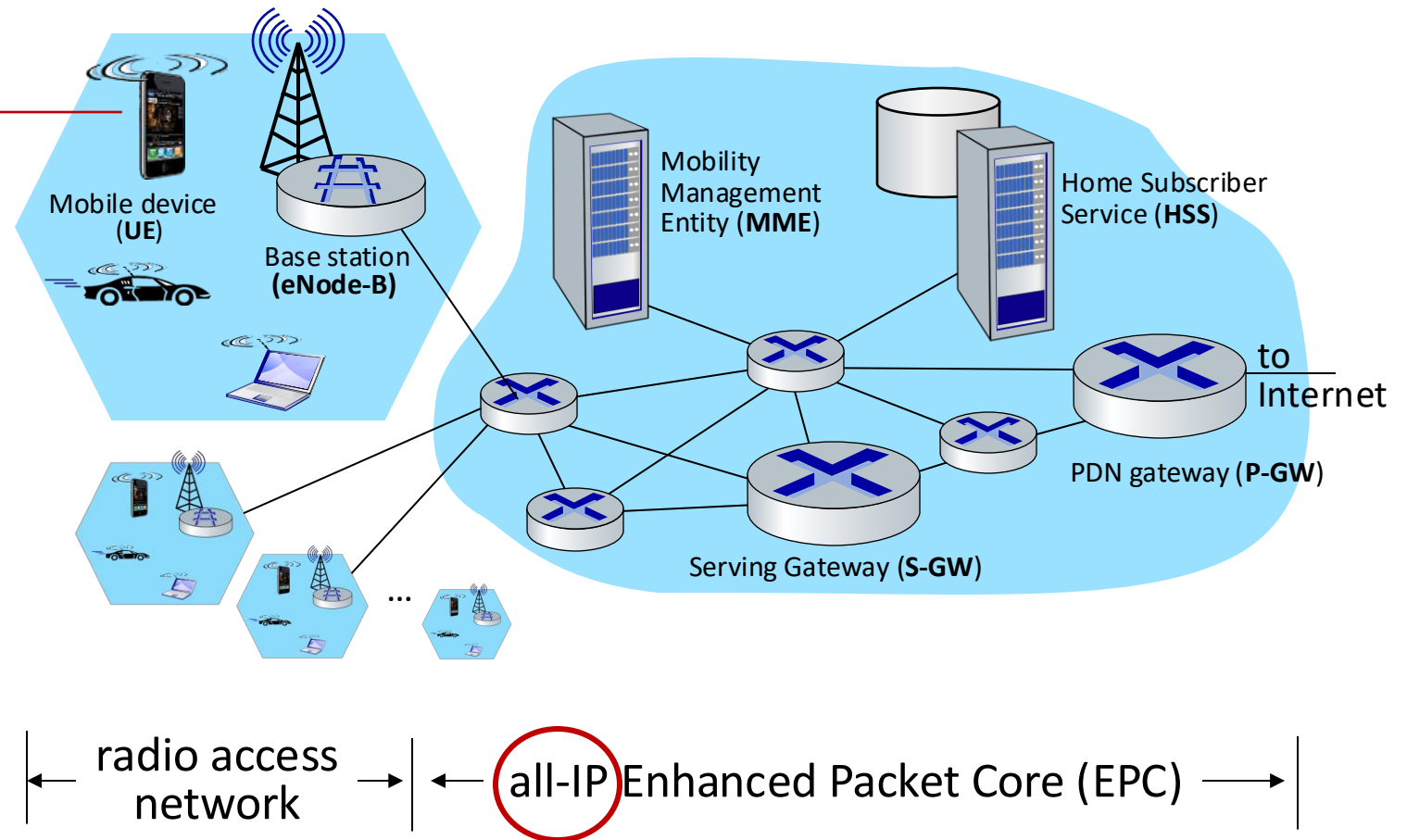
- Overview of how cellular network architecture
 - What (not so much of why)
 - Another course for why 😊
- Focus only on 4G network architecture

Architecture: Motivation

Elements of 4G LTE architecture

Mobile device:

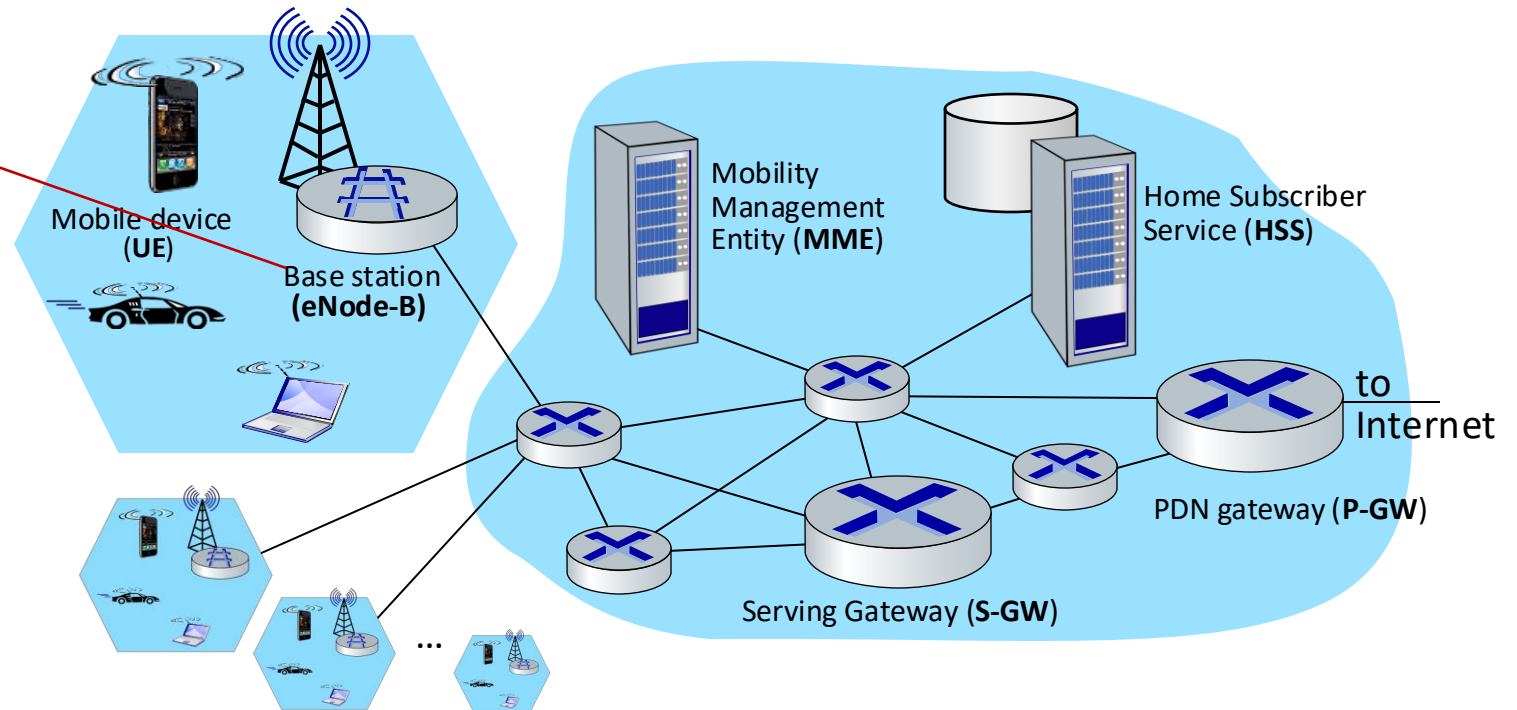
- smartphone, tablet, laptop, IoT, ... with 4G LTE radio
- 64-bit International Mobile Subscriber Identity (IMSI), stored on SIM (Subscriber Identity Module) card
- LTE jargon: User Equipment (UE)



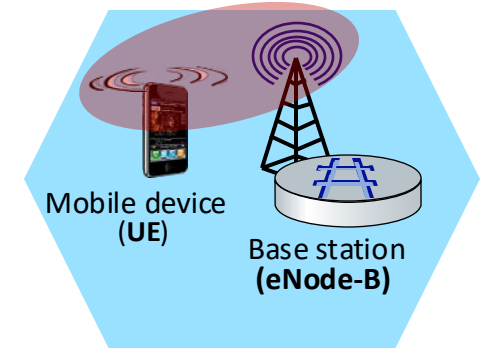
Elements of 4G LTE architecture

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 nearby base stations to optimize radio use
- LTE jargon: eNode-B

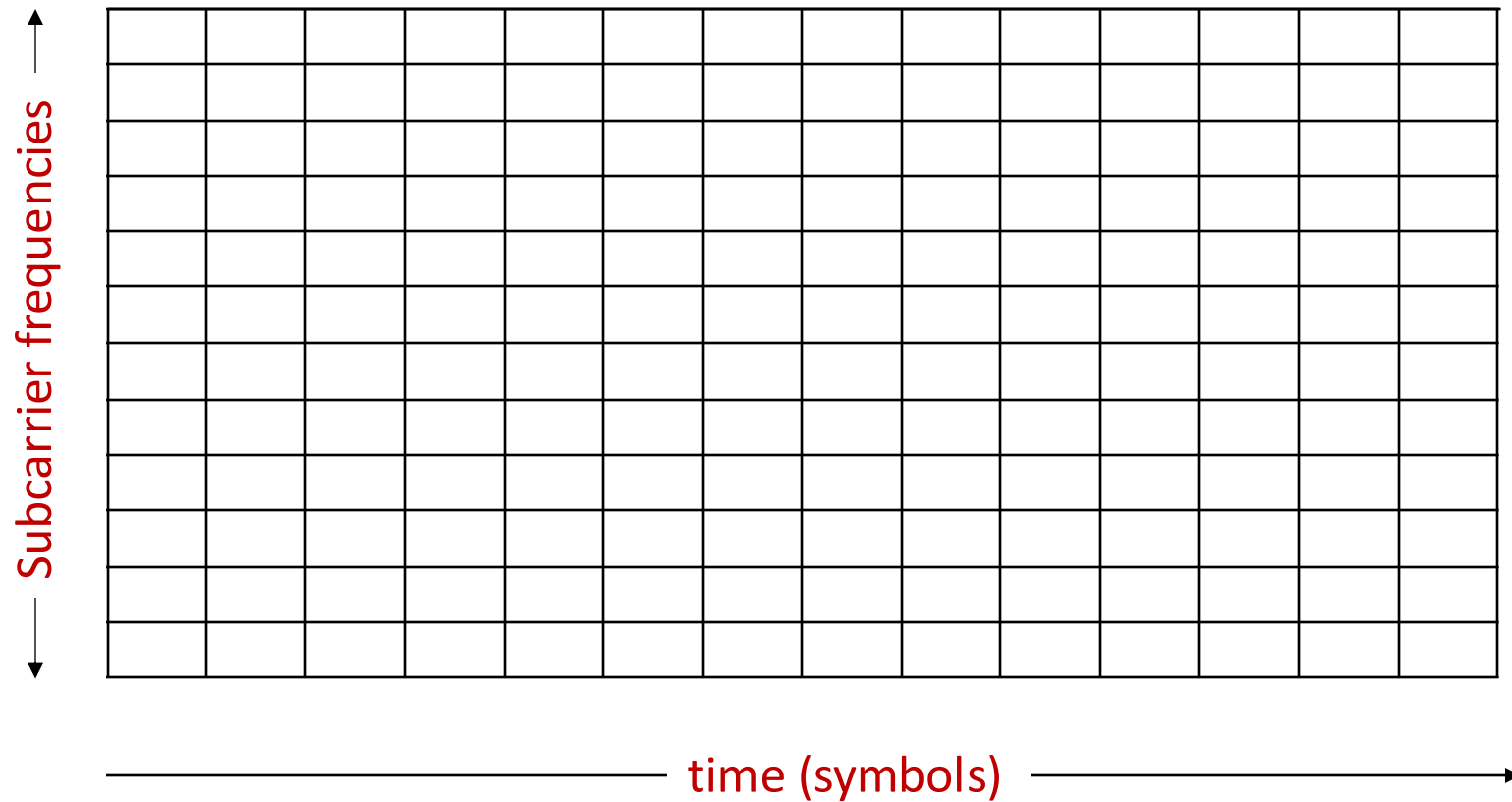


Radio Access Network: 4G radio



- 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

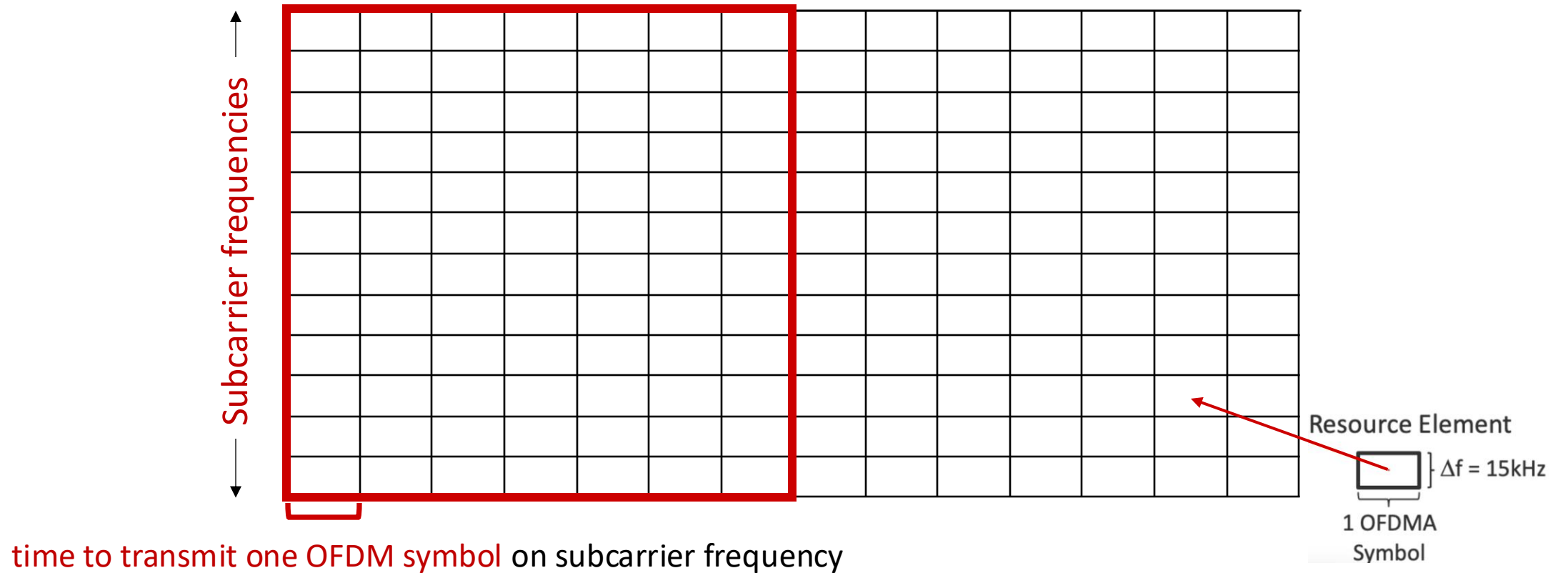
OFDMA: time division (LTE)



OFDMA: time division (LTE)

Physical Resource Block (PRB): blocks of $7 \times 12 = 84$ resource elements








- unit of transmission scheduling

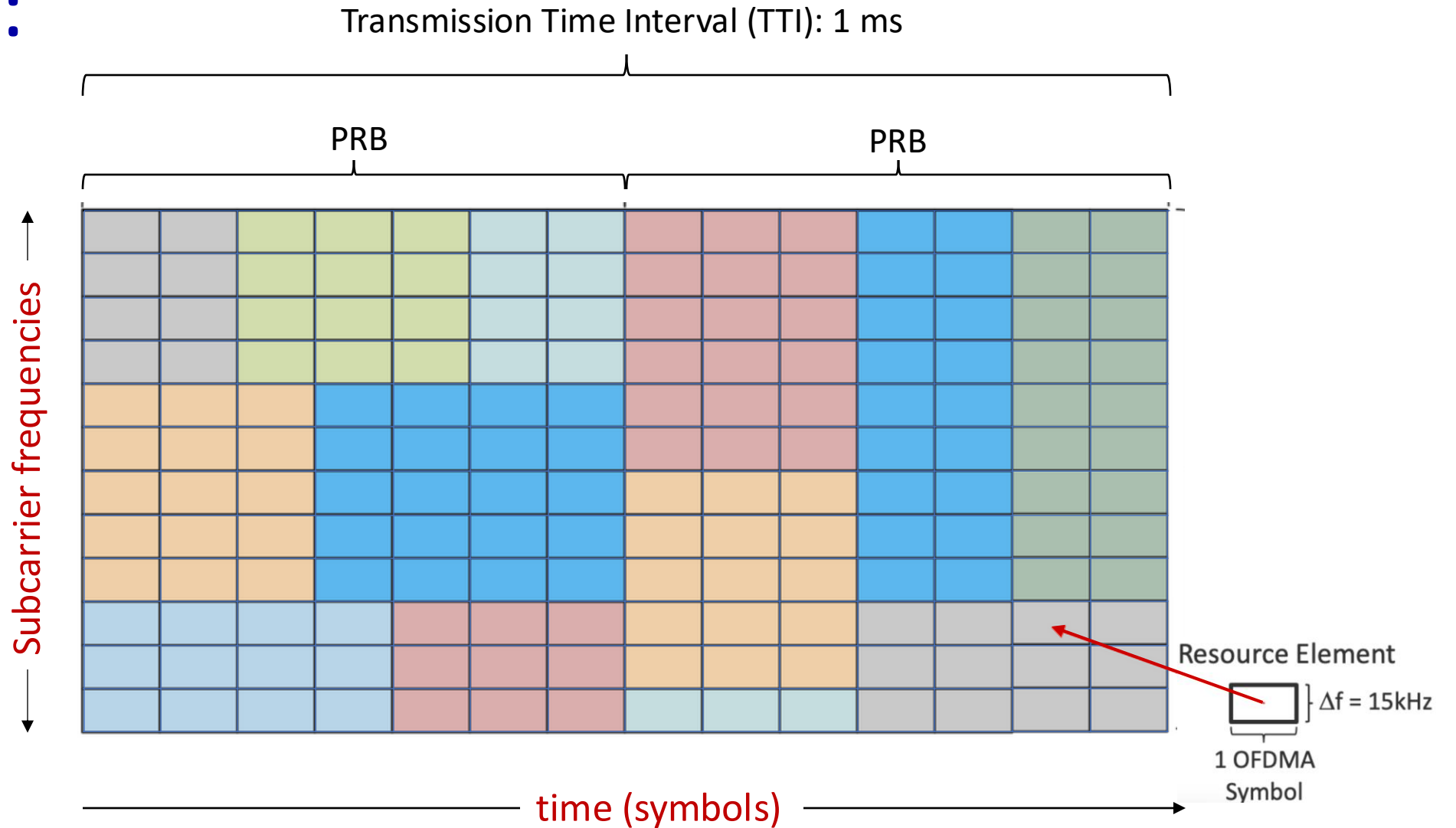


OFDMA:

Transmission scheduling example:

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

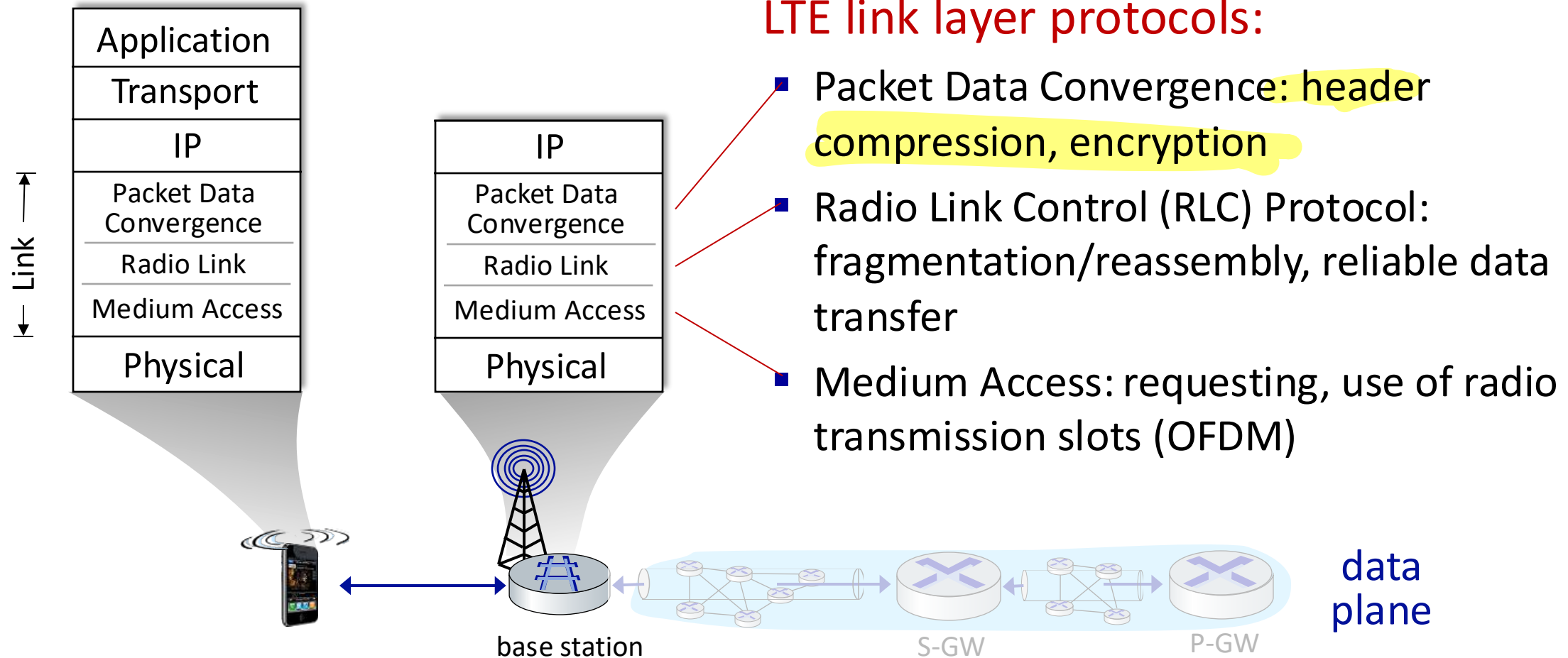
UE ₁	
UE ₂	
UE ₃	
UE ₄	
UE ₅	
UE ₆	
UE ₇	



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 ...)

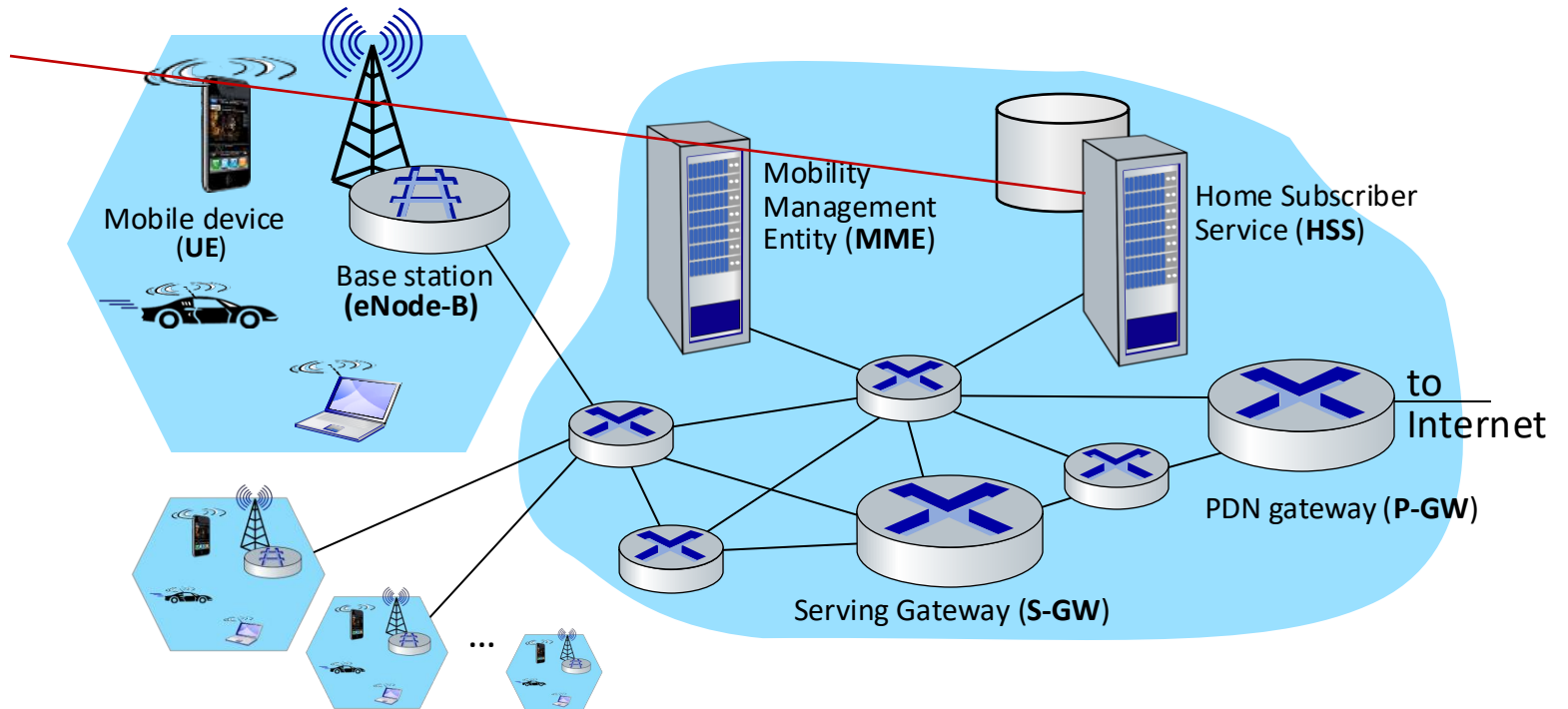
LTE data plane protocol stack: first hop



Elements of 4G LTE architecture

Home Subscriber Service

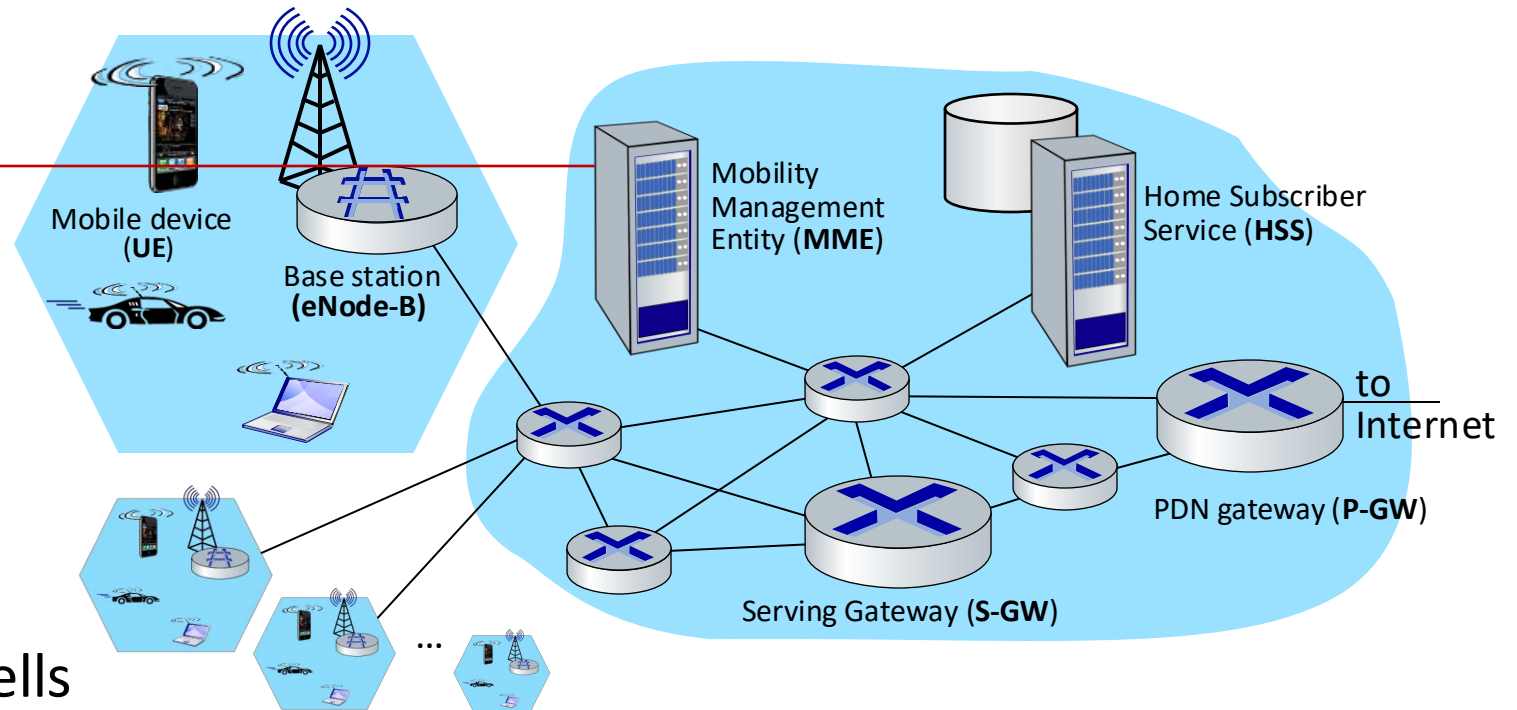
- stores info about mobile devices for which the HSS's network is their “home network”
- works with MME in device authentication



Elements of 4G LTE architecture

Mobility Management Entity

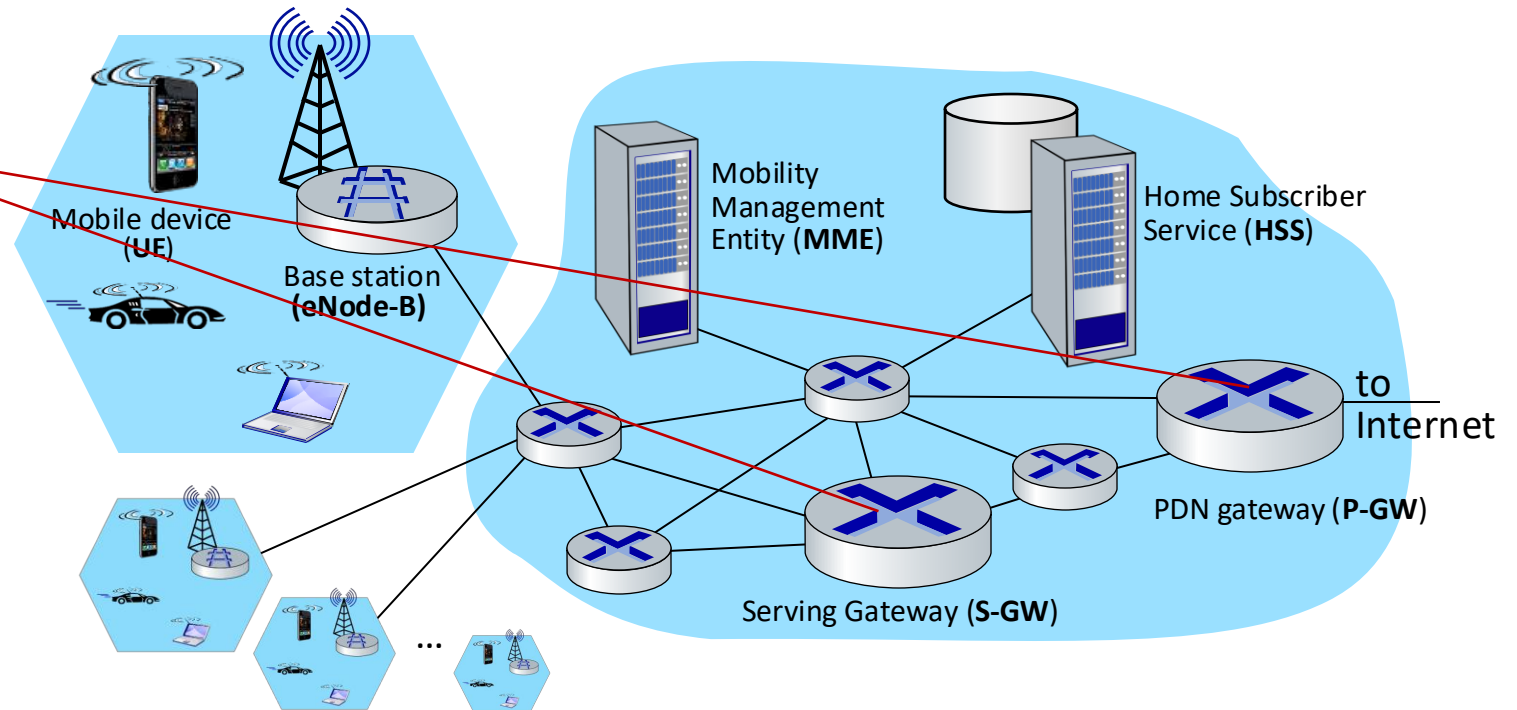
- device authentication (device-to-network, network-to-device) coordinated with mobile home network HSS
- mobile device management:
 - device handover between cells
 - tracking/paging device location
- path (tunneling) setup from mobile device to P-GW



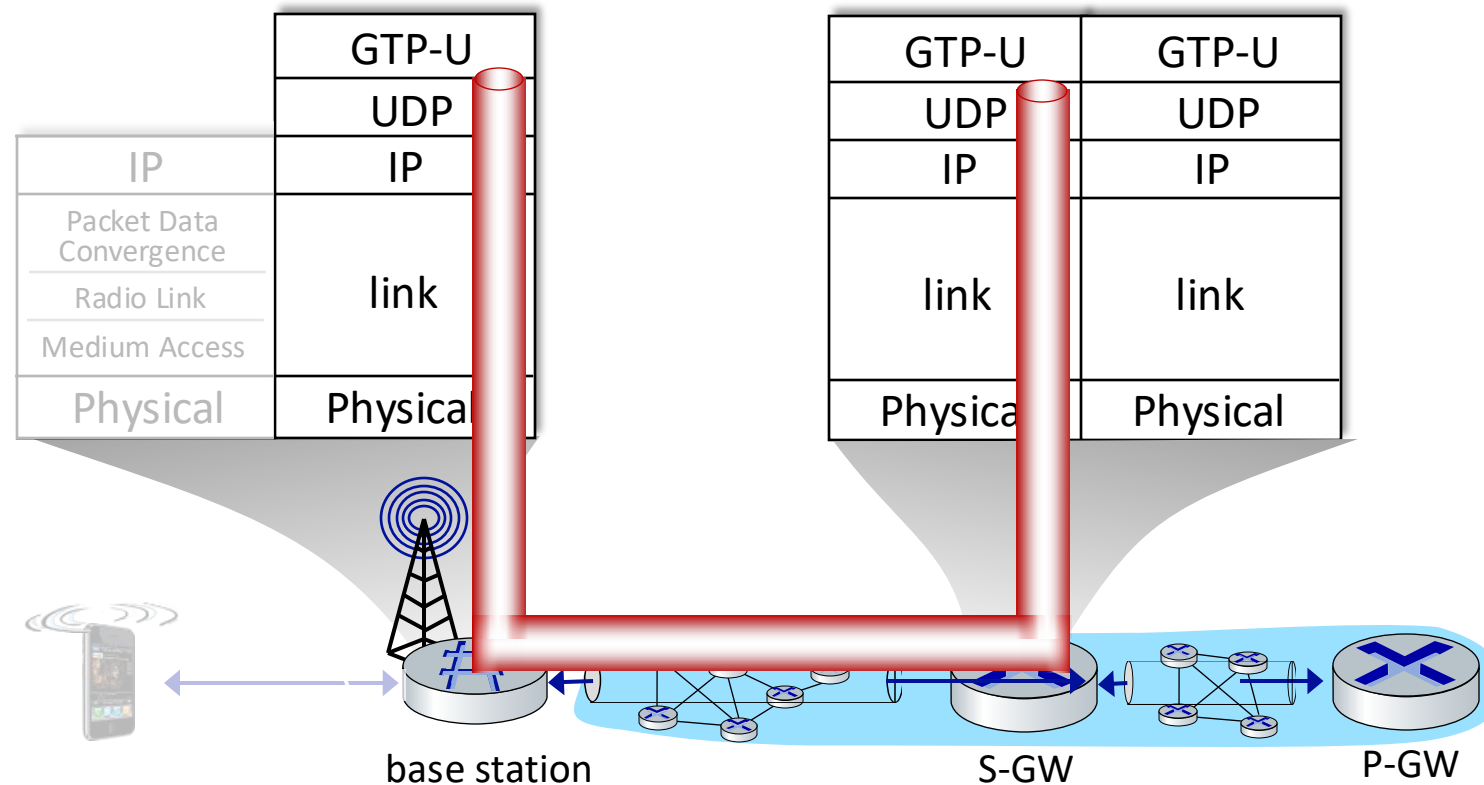
Elements of 4G LTE architecture

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



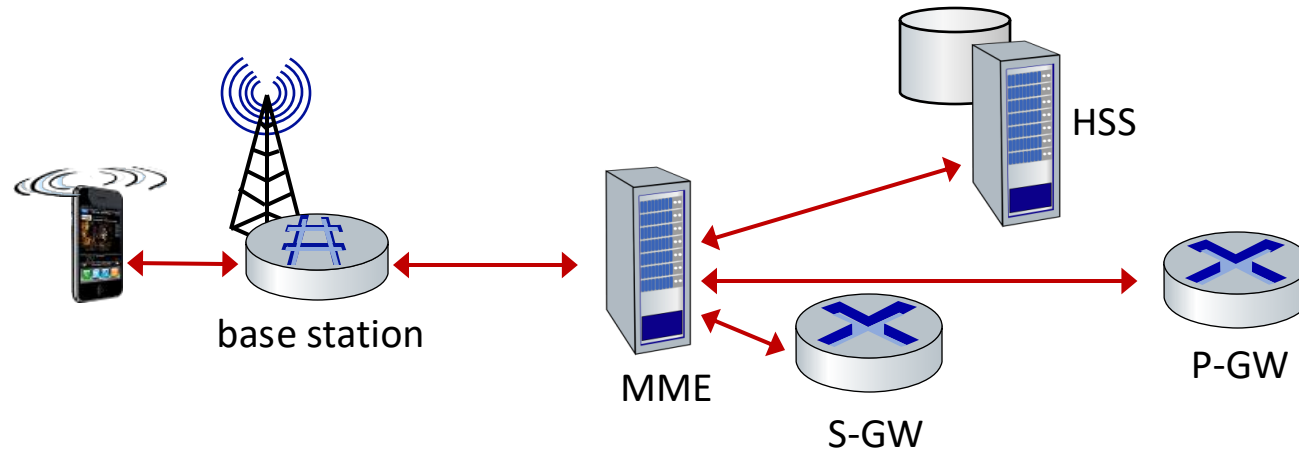
LTE data plane protocol stack: packet core



tunneling:

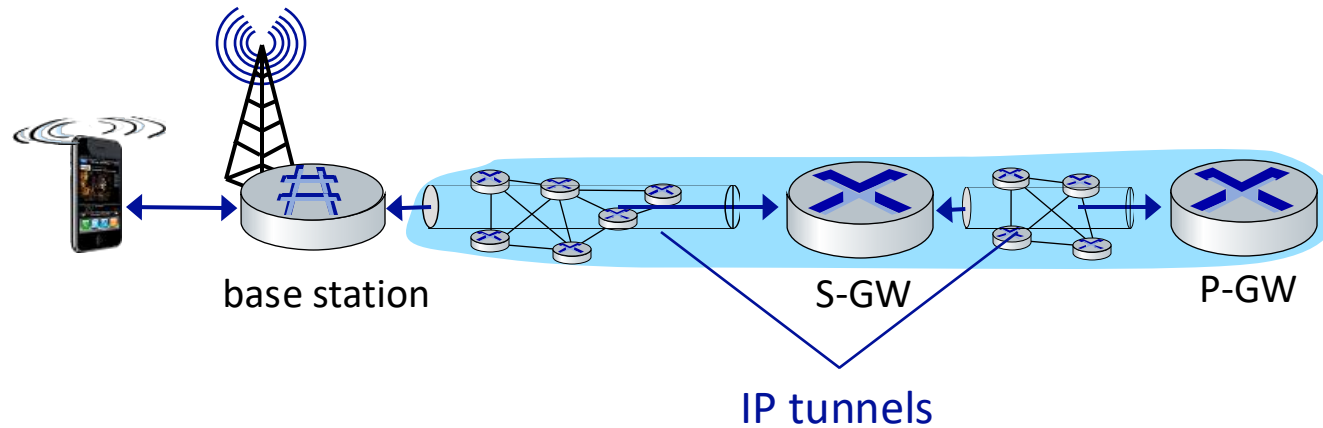
- mobile datagram encapsulated using GPRS Tunneling Protocol (GTP), sent inside UDP datagram to S-GW
- S-GW re-tunnels datagrams to P-GW
- supporting mobility: only tunneling endpoints change when mobile user moves

LTE: data plane control plane separation



control plane

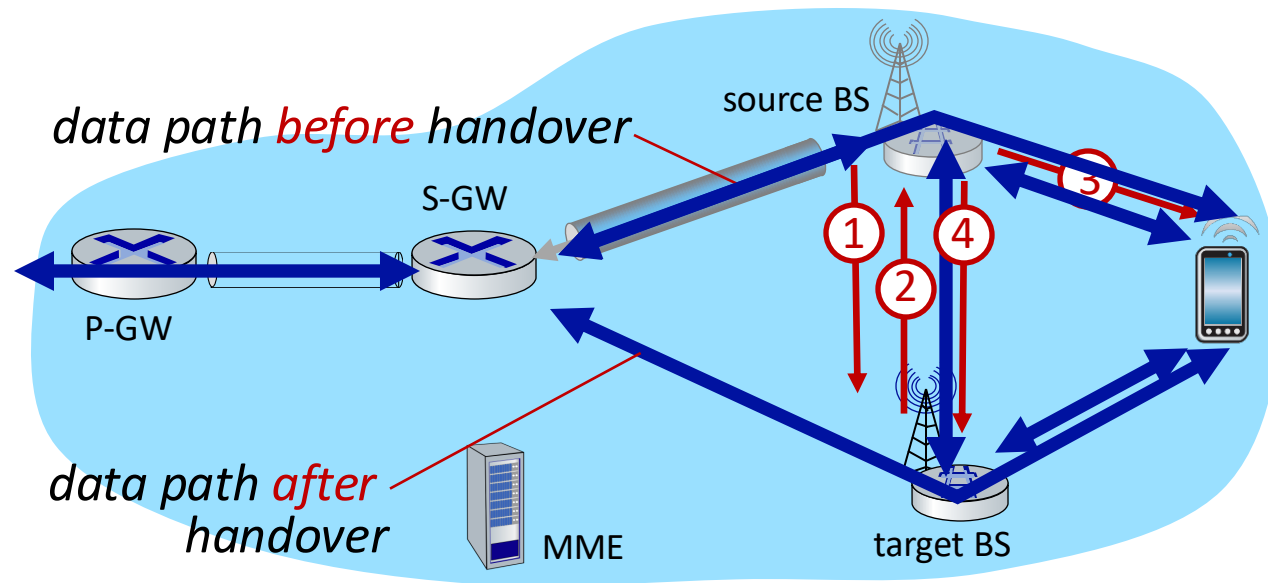
- new protocols for mobility management , security, authentication (later)



data plane

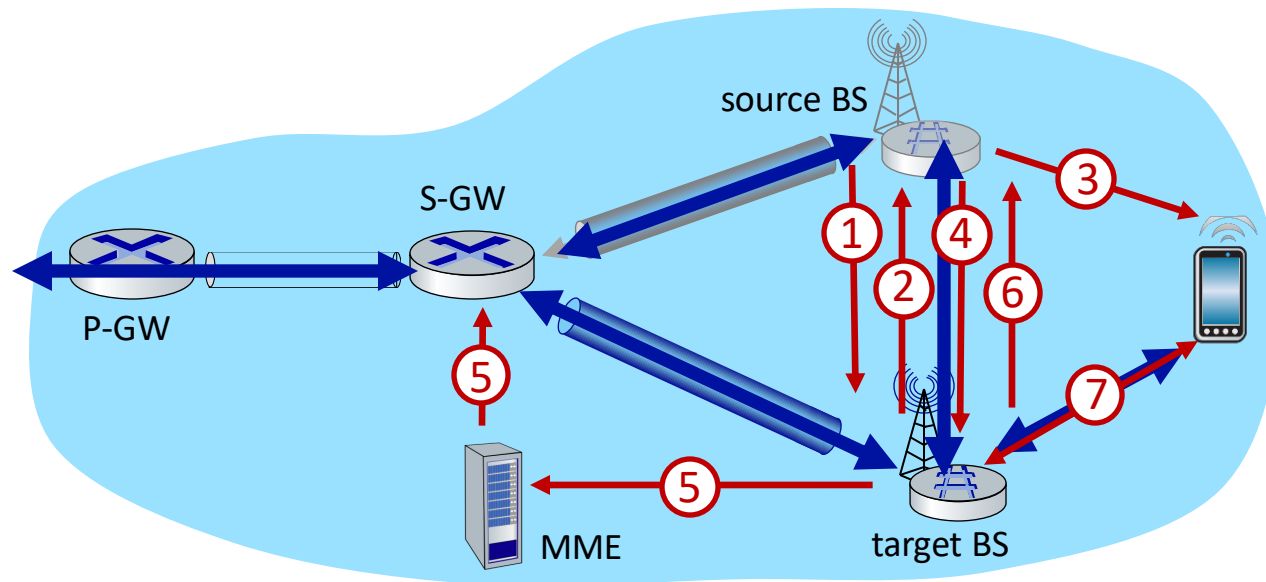
- new protocols at link, physical layers
- extensive use of tunneling to facilitate mobility

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 unnecessarily
 - delay impairments for real-time traffic
 - bandwidth a scarce resource for wireless links

Attendance

