

4G & 5G Mobile Networks

Outline

- Evolution of mobile networks
- Network architecture
- Network operations and protocol stack

Ubiquitous Mobile Network Services



In-building



Outdoor



Walking



Driving

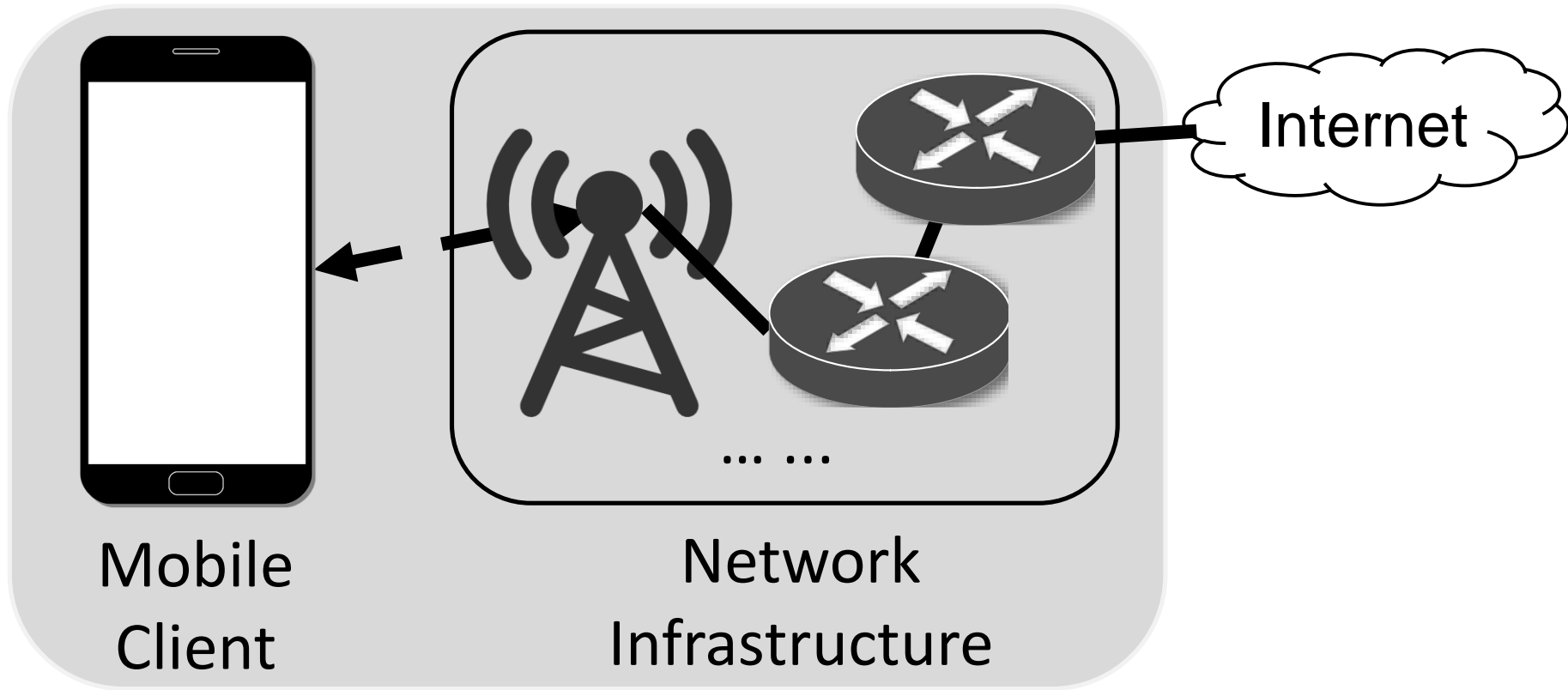


Subway



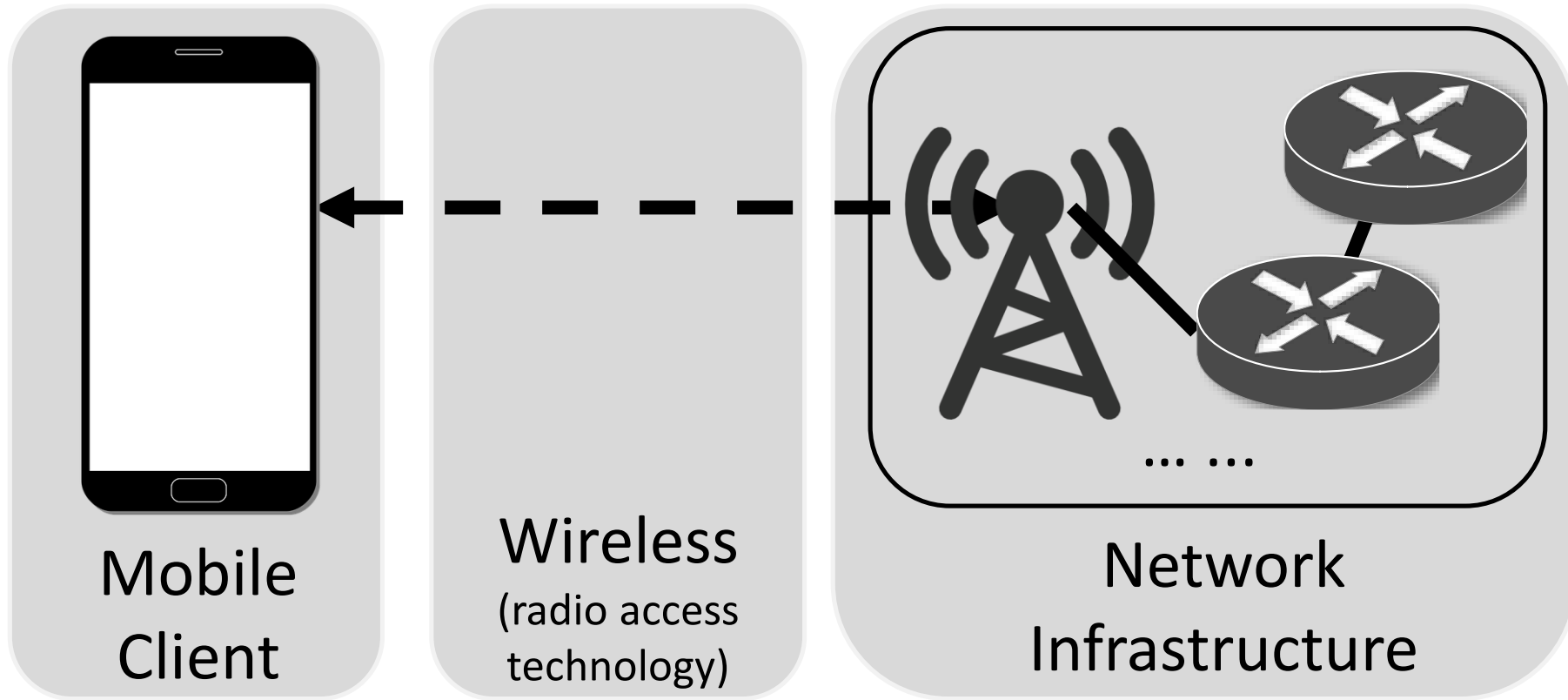
High-speed train

Empowered by Mobile Networks



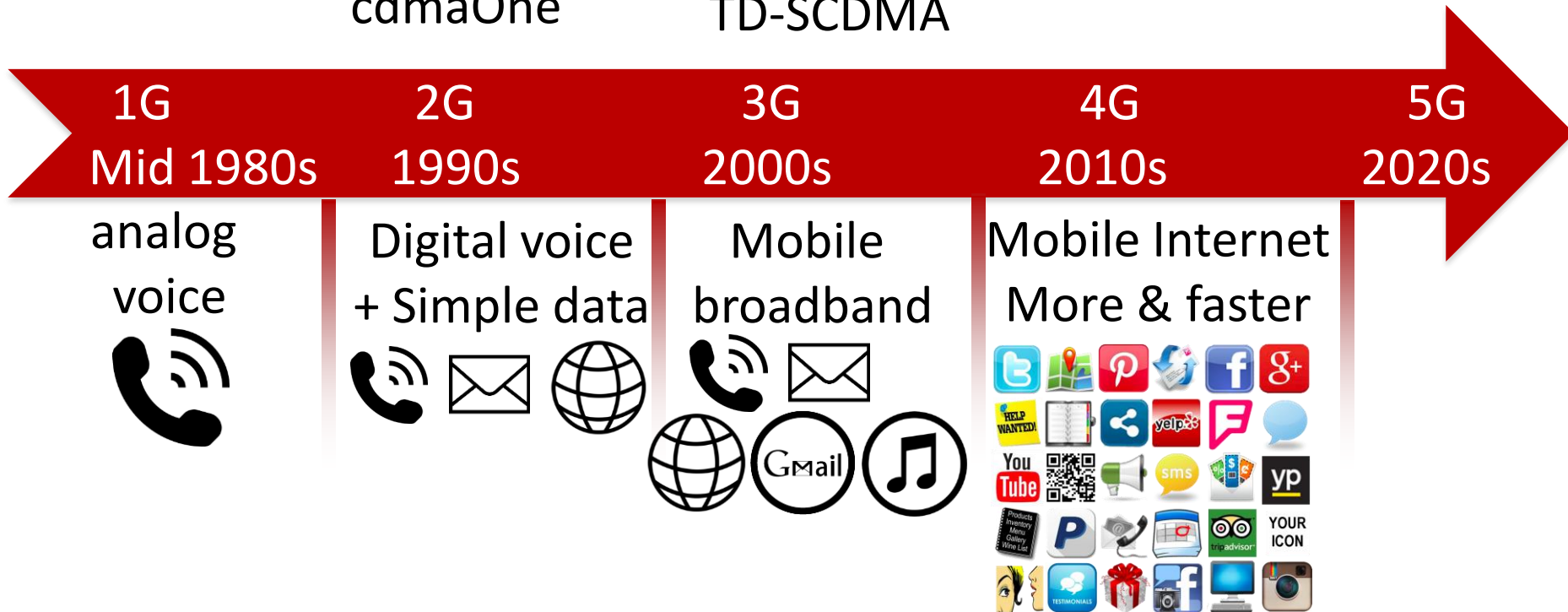
- the **only** large-scale, wide-area wireless network system in par with the Internet

Empowered by Mobile Networks



Mobile Network Evolution

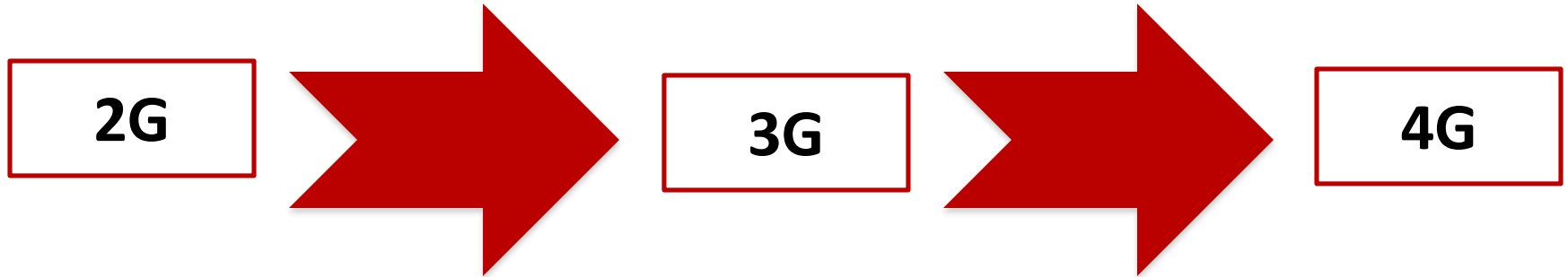
| 1G | 2G | 3G | 4G |
|-------------------|------------------------------|--|--------------|
| AMPS, NMT TACS | GSM/GPRS/ EDGE cdmaOne | WCDMA/HSPA+ CDMA2000/EVDO TD-SCDMA | LTE LTE-A |



COMPARISON OF 1G TO 5G TECHNOLOGIES

| Technology | 1G | 2G/2.5G | 3G | 4G | 5G |
|--------------|------------------|--|---|--|---|
| Deployment | 1970/1984 | 1980/1999 | 1990/2002 | 2000/2010 | 2014/2015 |
| Bandwidth | 2kbps | 14-64kbps | 2mbps | 200mbps | >1gbps |
| Technology | Analog cellular | Digital cellular | Broadbandwidth /cdma/ip technology | Unified ip &seamless combo of LAN/WAN/WLAN/PAN | 4G+WWWW |
| Service | Mobile telephony | Digital voice,short messaging | Integrated high quality audio, video & data | Dynamic information access, variable devices | Dynamic information access, variable devices with AI capabilities |
| Multiplexing | FDMA | TDMA/CDMA | CDMA | CDMA | CDMA |
| Switching | Circuit | Circuit/circuit for access network&air interface | Packet except for air interface | All packet | All packet |
| Core network | PSTN | PSTN | Packet network | Internet | Internet |
| Handoff | Horizontal | Horizontal | Horizontal | Horizontal&V ertical | Horizontal&V ertical |

Network Architecture Evolution

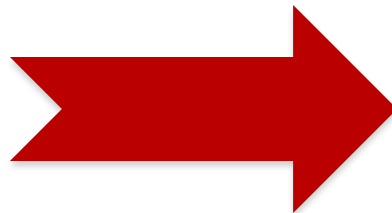


- Circuit-switching for voice

- Circuit-switching for voice
- Packet-switching for data

- Packet-switching for everything
- IP-based

Telecomm Infrastructure

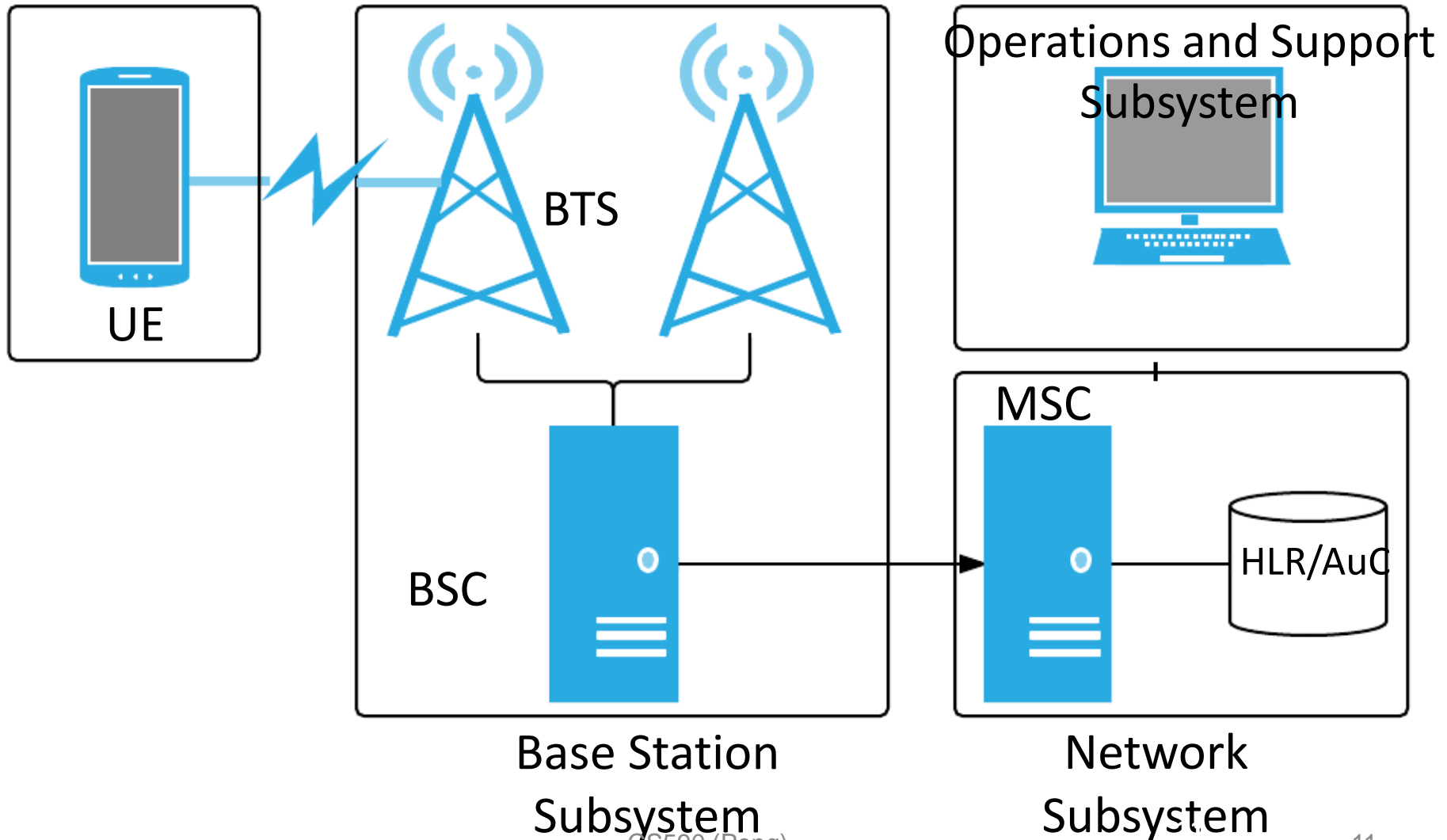


IP-based Internet

Inter-Generation Technologies

- CS networks need to be able to connect with PS networks and other distinct cellular networks
 - The internet is a good example of PS network
- GPRS (General packet radio service)
 - 2.5G packet switched technology
- EDGE (Enhanced Data Rates for GSM Evolution)
 - 2.75G packet switched technology
- HSPA (High Speed Packet Access)
 - 3.5/3.75 packet switched data technology
 - There were a few quick iterations on this technology, thus “variants”

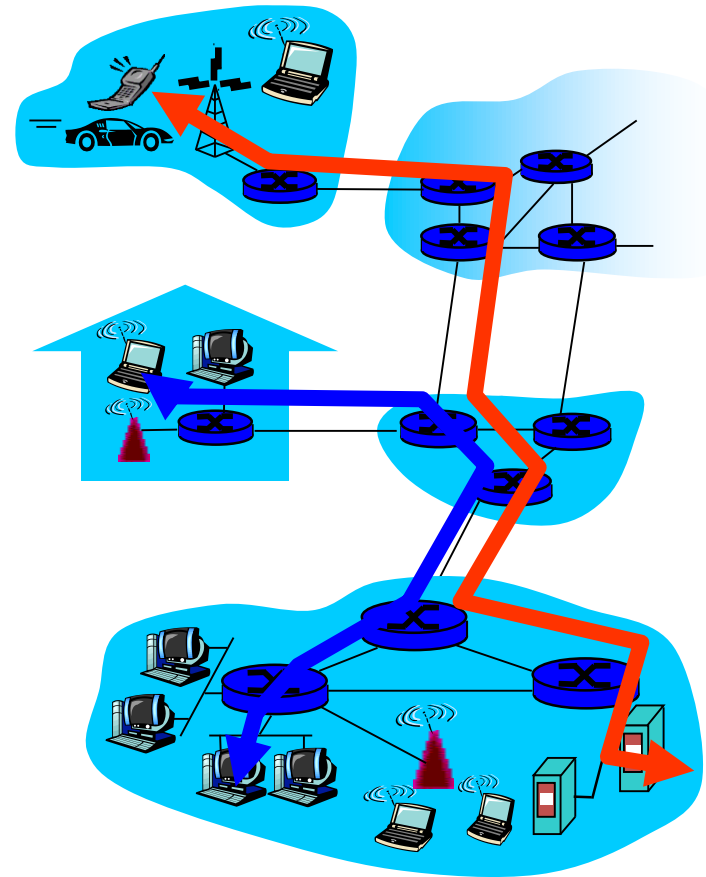
2G Network Architecture (GSM)



2G Based on Circuit Switching (CS)

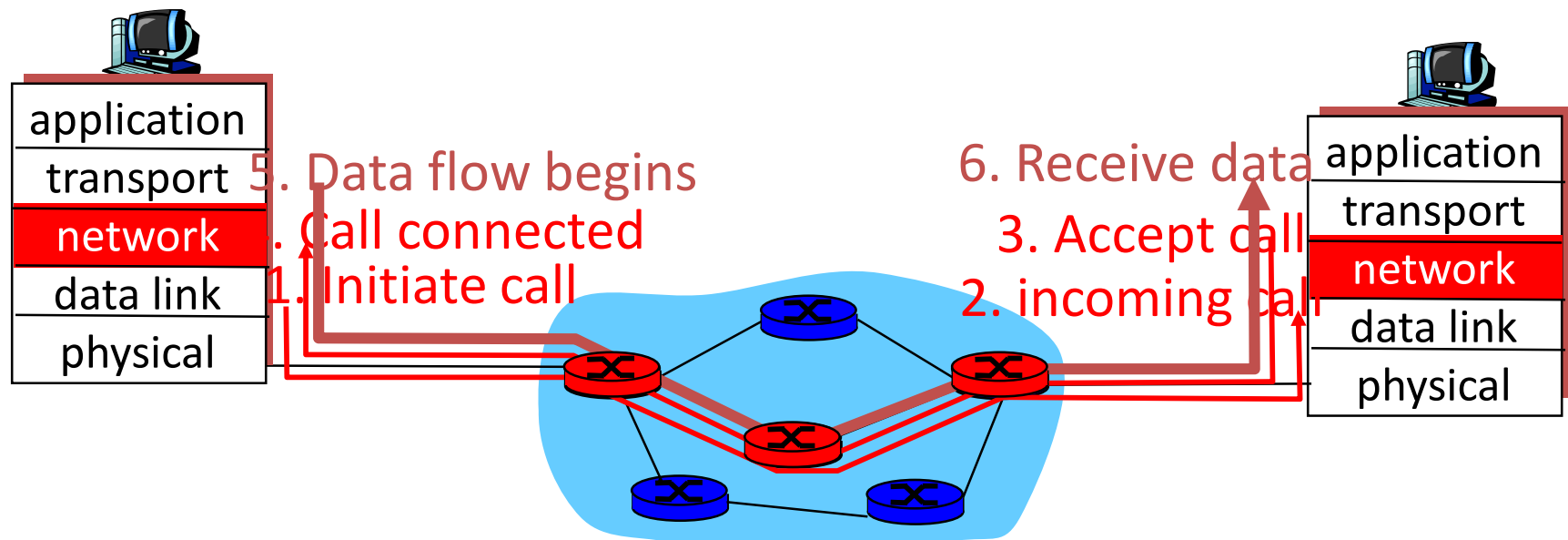
End-end resources reserved for “call”

- link bandwidth, switch capacity
- dedicated resources: no sharing
- circuit-like (guaranteed) performance
- call setup required

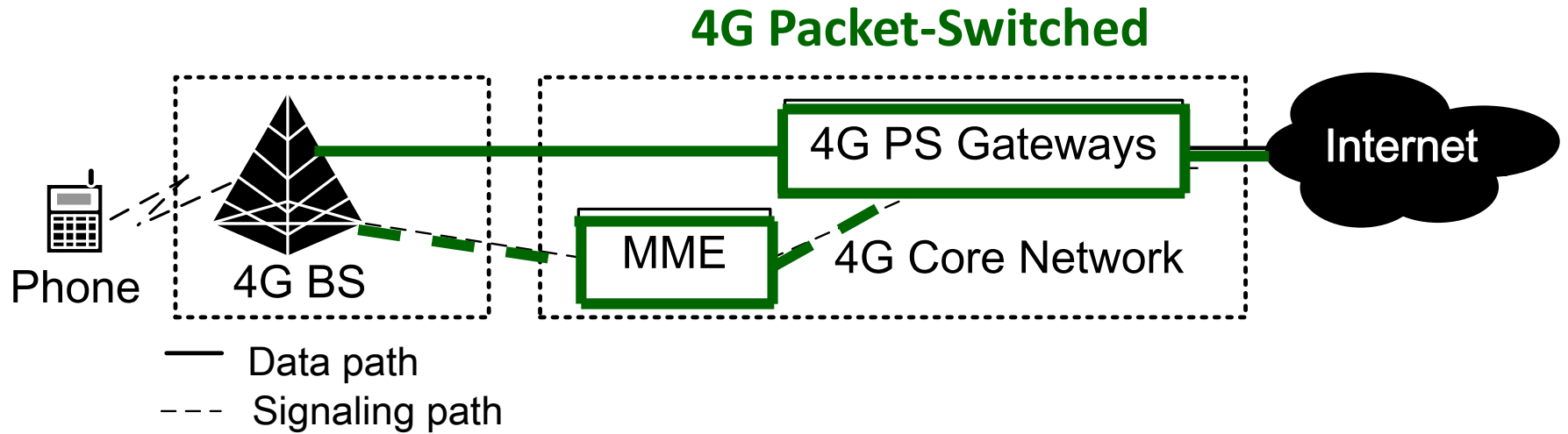


CS Signaling

- used to setup, maintain teardown VC
- used in 2G, as well as in 3G
- not used in today's Internet

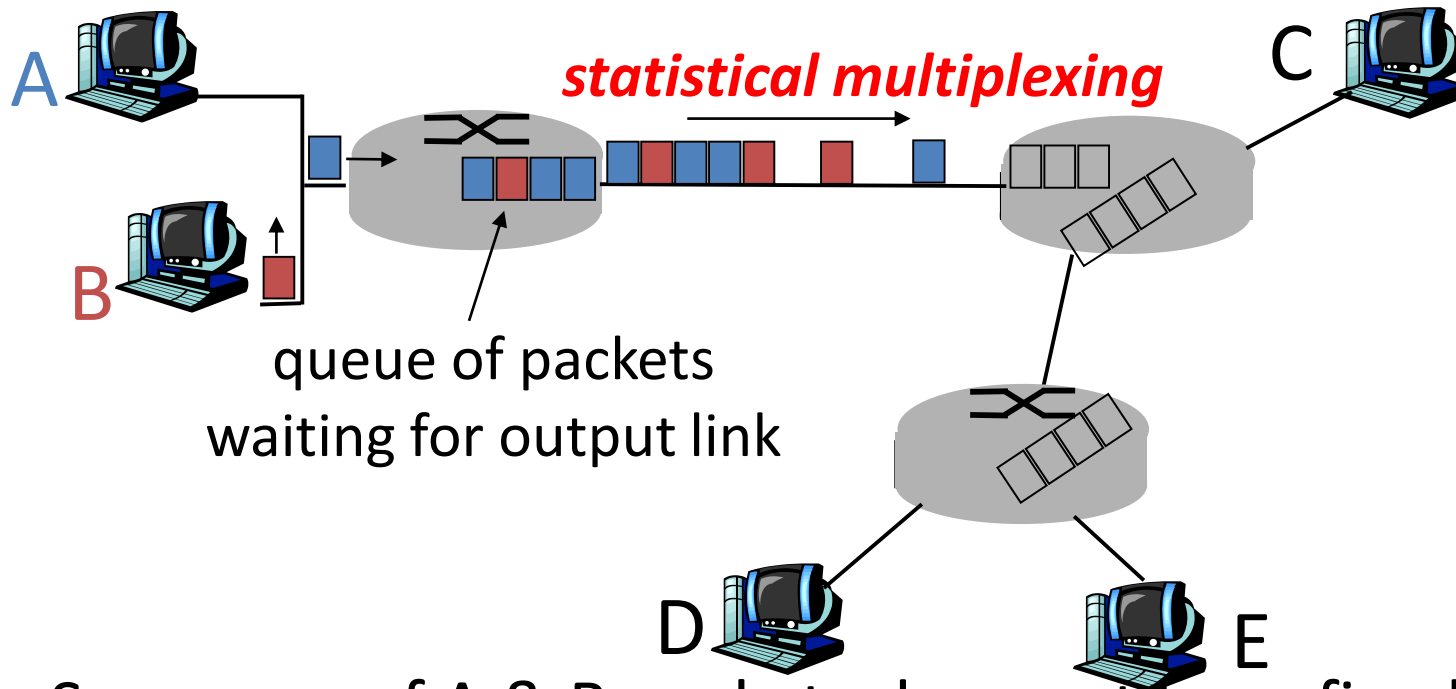


4G Network Architecture (LTE)



MME: Mobility Management Entity
BS: Base Station (4G: eNodeB)

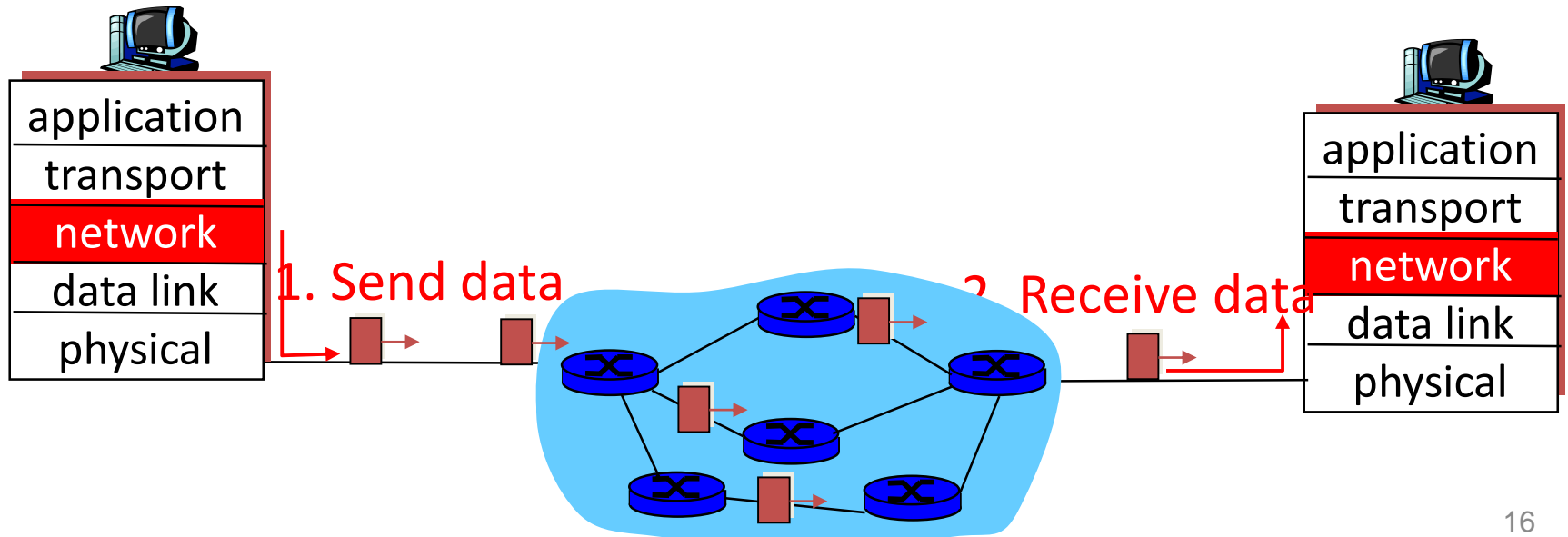
Packet Switching (PS)



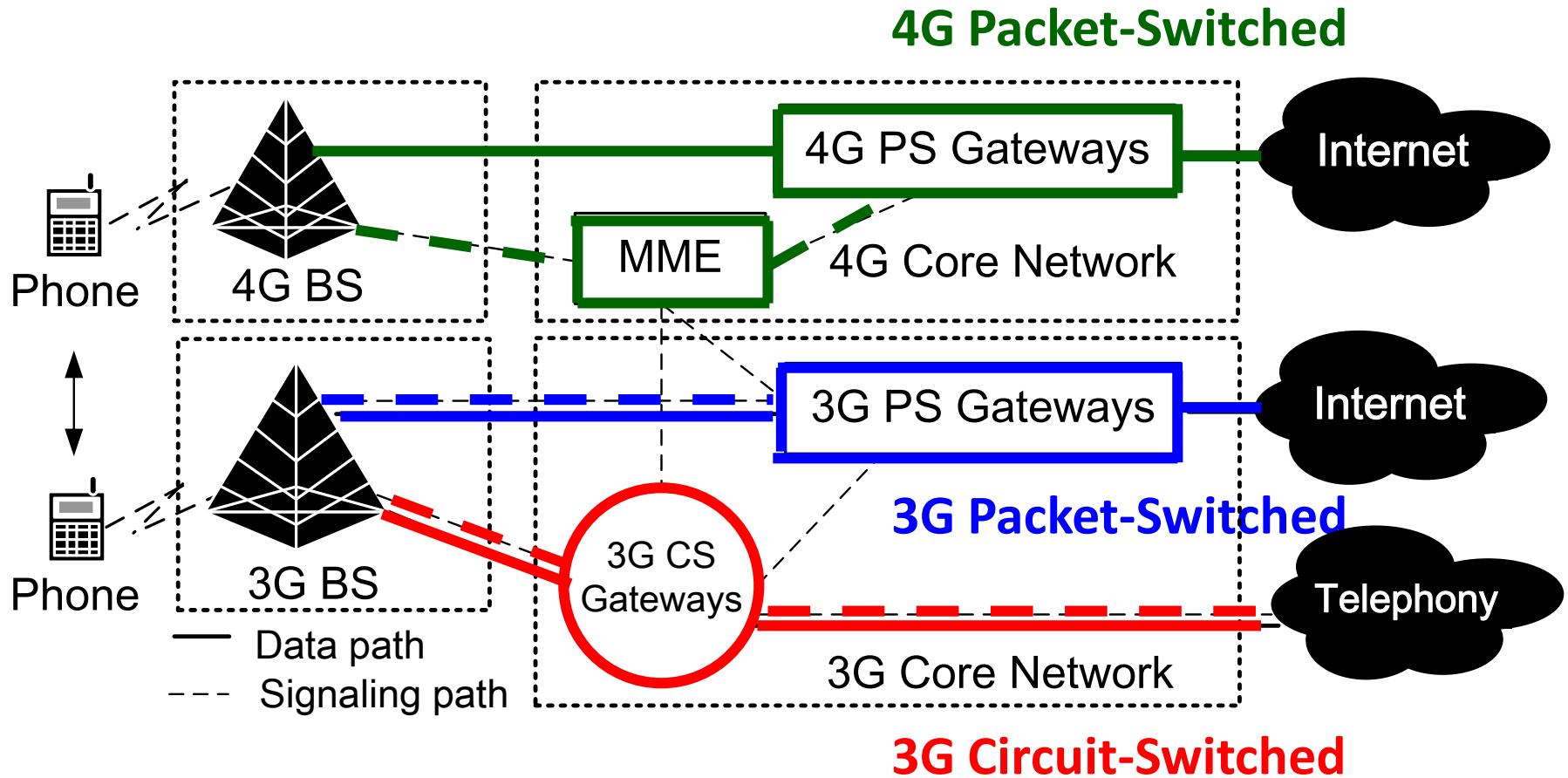
- Sequence of A & B packets does not have fixed pattern, bandwidth shared on demand → statistical multiplexing
- Store-and-forward at intermediate routers
- Used by the Internet

PS Signaling

- no call setup at network layer
- routers: no state about end-to-end connections
 - no network-level concept of “connection”
- packets forwarded using destination host address
 - packets btw same source-dest pair may take different paths



3G/4G Network Architecture



Operations

Two main planes in operation in parallel:

- **Data plane (also called User plane)**: content delivery
- **Control plane**: signaling functions

There is an additional plane that works with the above two planes:

- **Management plane**: configurations, monitoring

Illustration of Data and Control Planes

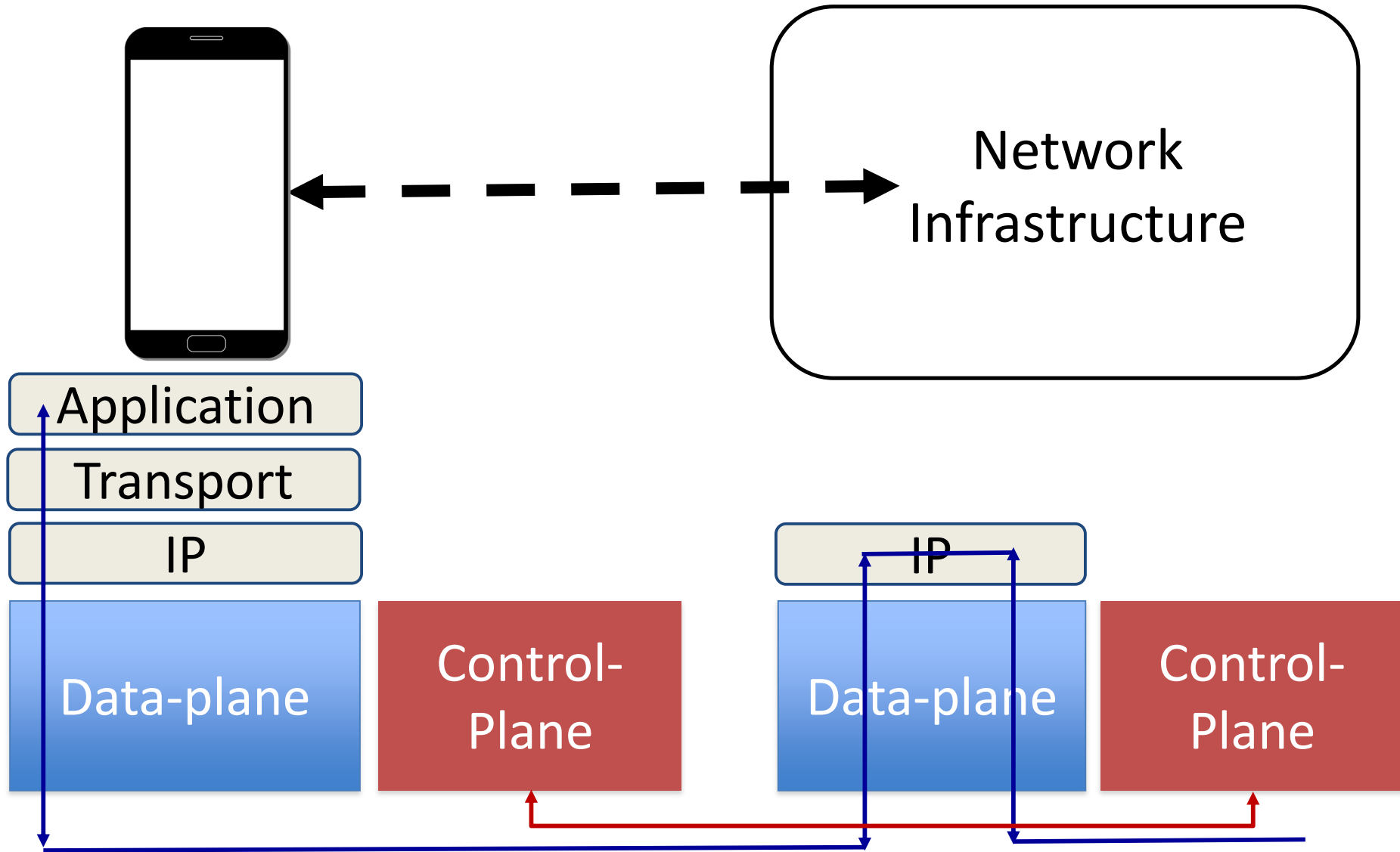
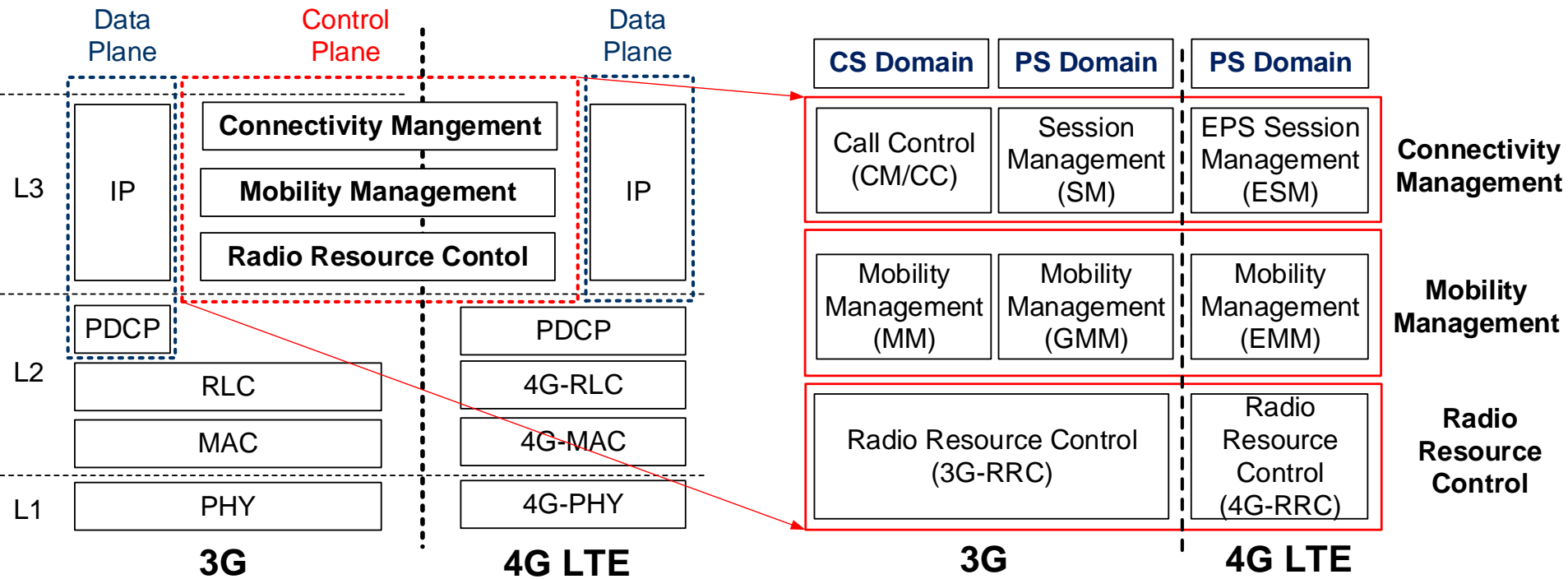


Illustration of Data and Control Planes



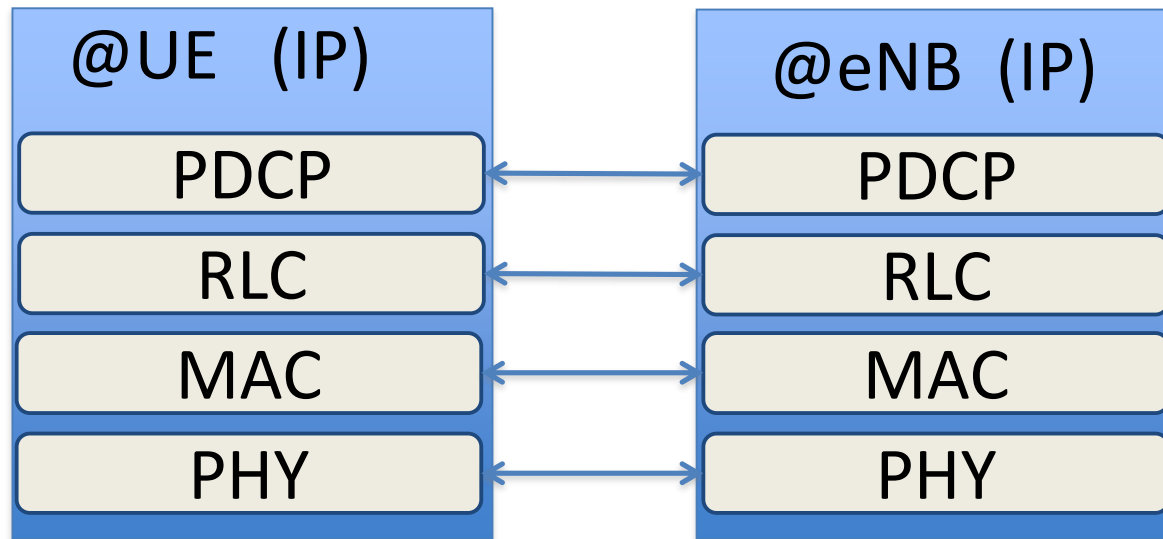
EPS: Evolved Packet System

PDCP: Packet Data Convergence Protocol

RLC: Radio Link Control

MAC: Medium Access Control

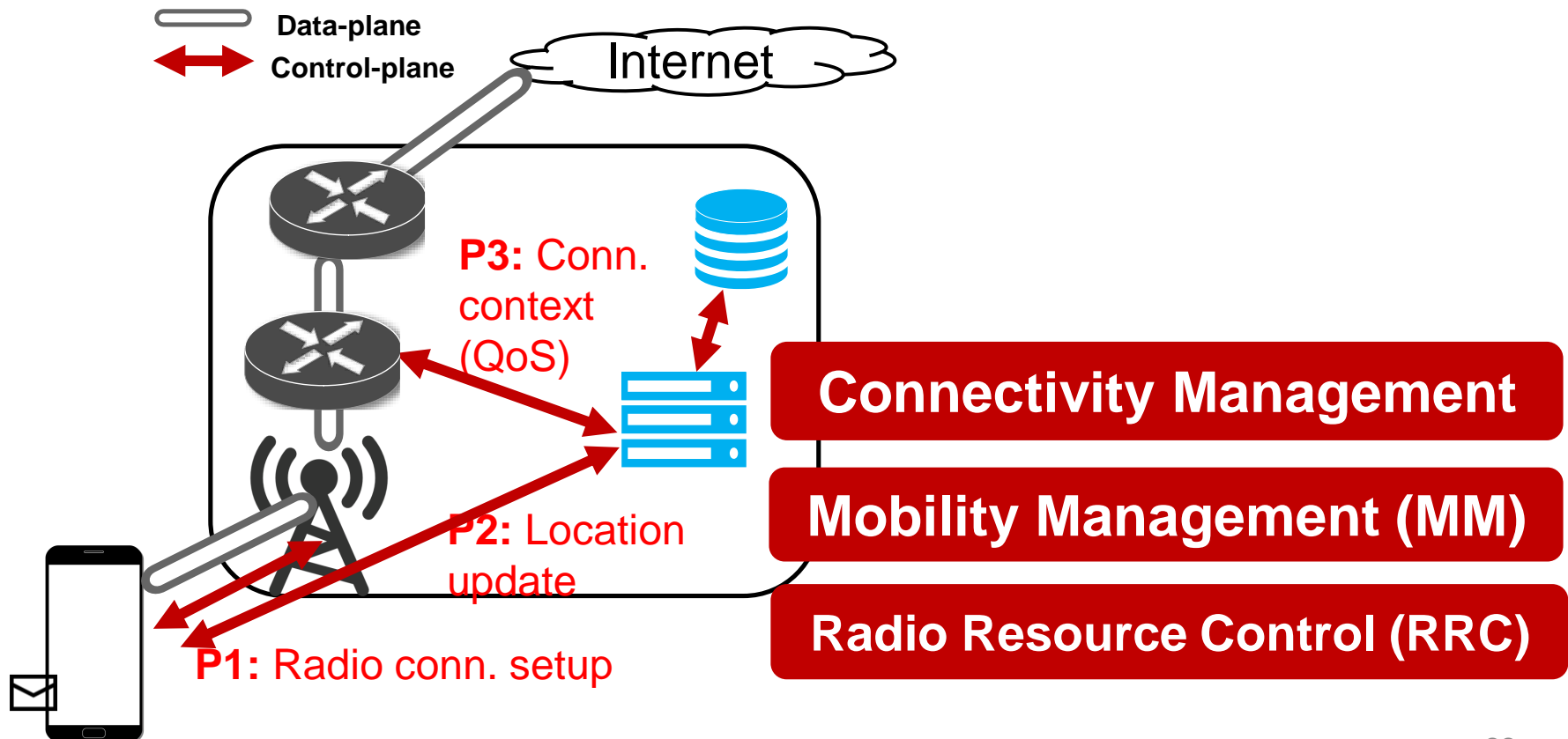
Data-Plane Protocols: IP + lower layers



- **Packet Data Convergence Protocol (PDCP)** – header compression, radio encryption
- **Radio Link Control (RLC)** – Readies packets to be transferred over the air interface
- **Medium Access Control (MAC)** – Multiplexing, QoS

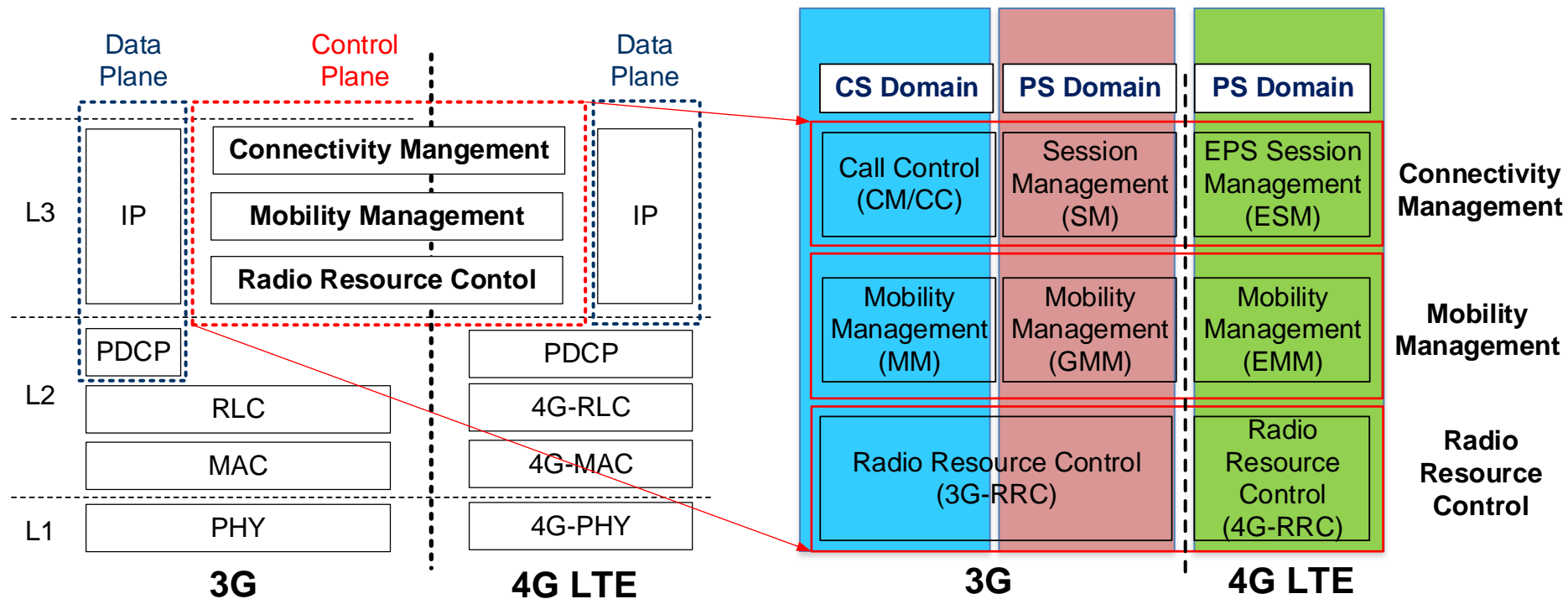
Control-Plane Protocols

- Control utilities: mobile network specific
 - Different from Internet counterparts

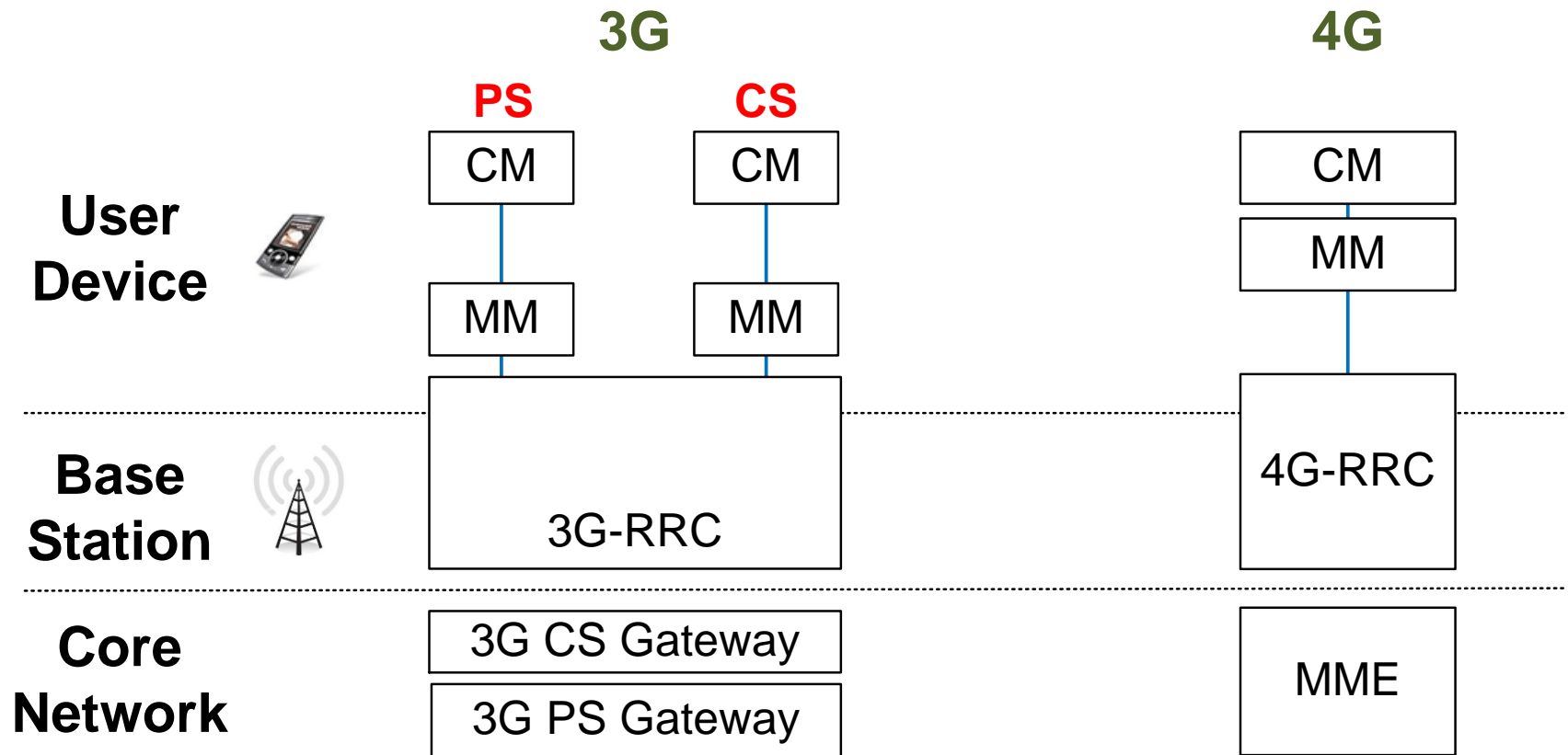


Control-Plane Protocols in 4G/3G

- Variants for same/similar control functions
 - Hybrid 4G/3G systems
 - Domains separated for voice (CS) and data (PS)

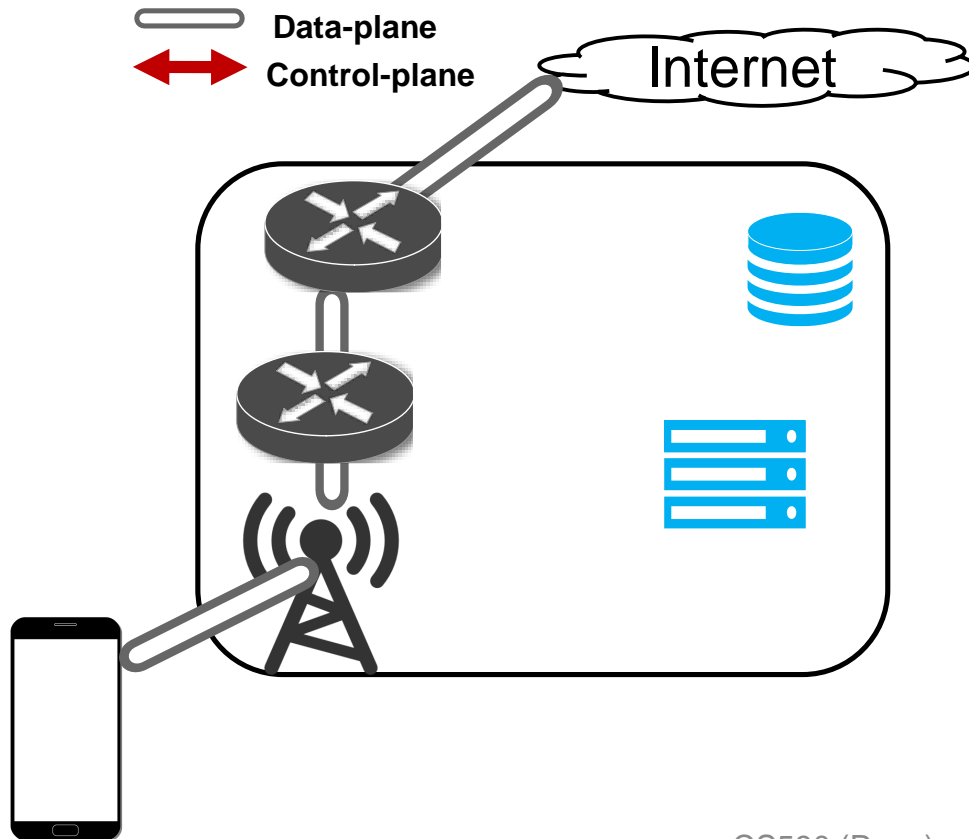


Distributed Operations: Device, base station, core networks

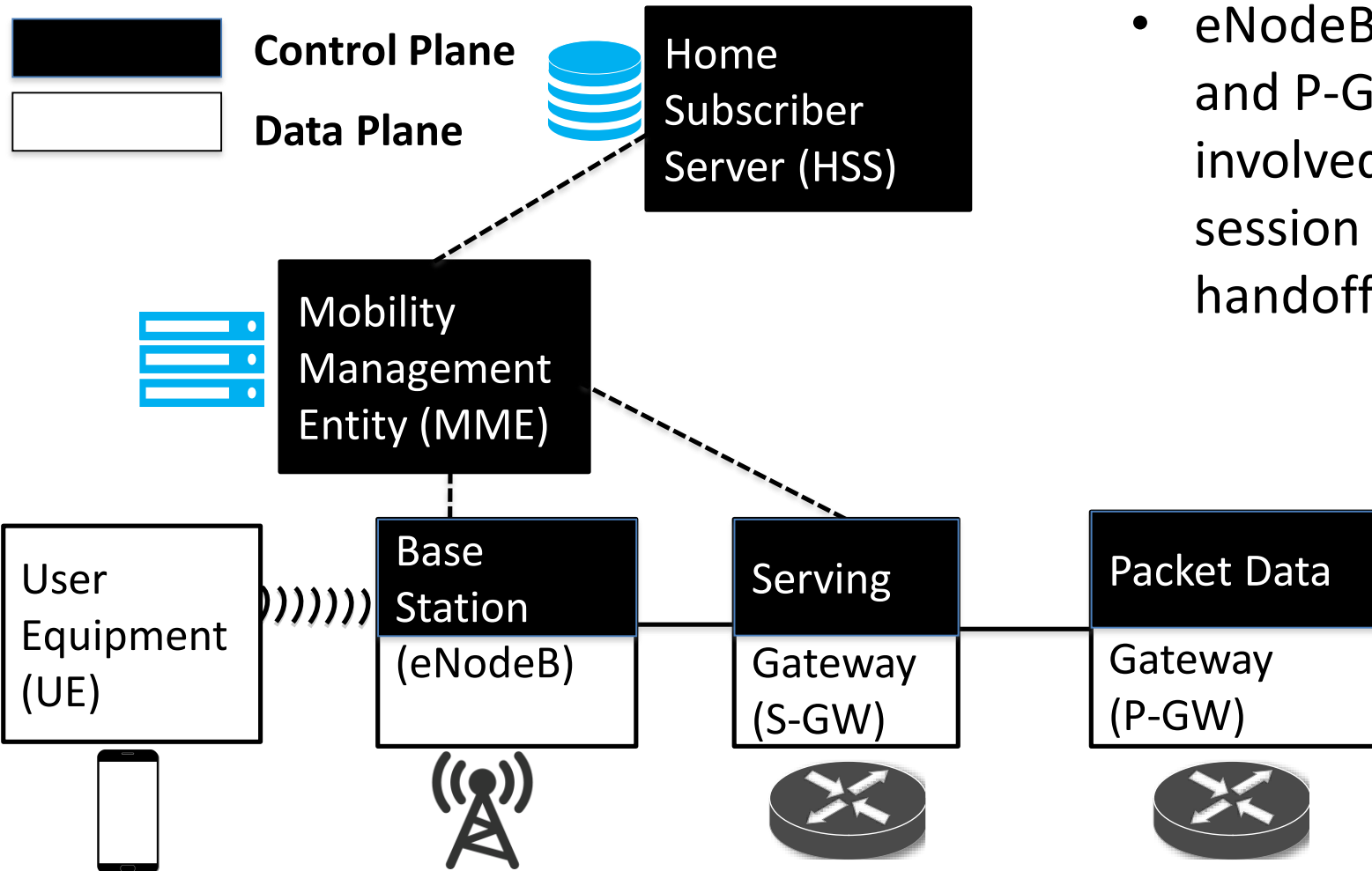


Put Them Together

- Setting up data service in 4G



Data and Control Planes in LTE



- eNodeB, S-GW and P-GW are involved in session setup, handoff, routing

5G Technology: 3 Key Features



5G Technology



300+ Mbit/s
100X of current HD video requirements

Cloud Storage as Fast as Local Storage

Over 1 Gbit/s
Uplink Data Rate for Cloud Access Everywhere

1 ms Latency

Ultra High **Reliability**

Virtual Reality,
An Immersive Experience

Diversity Challenges and Gaps to Reach 5G

| 5G | Latency | Throughput | Connections | Mobility | Network Architecture |
|-----|--|--|---|---|--|
| | 1 ms E2E Latency  | 10G bps Per Connection  | 1,000K Connections Per km ²  | 500 km/h High-speed Railway  | Slicing Ability Required  |
| GAP | 30~50x | 100x | 100x | 1.5x | NFV/SDN |
| 4G | 30~50ms | 100Mbps | 10K | 350Km/h | Inflexible |

Key Concerns for Reaching 5G

Spectrum



Aggregate All
Available Bands

New Architecture



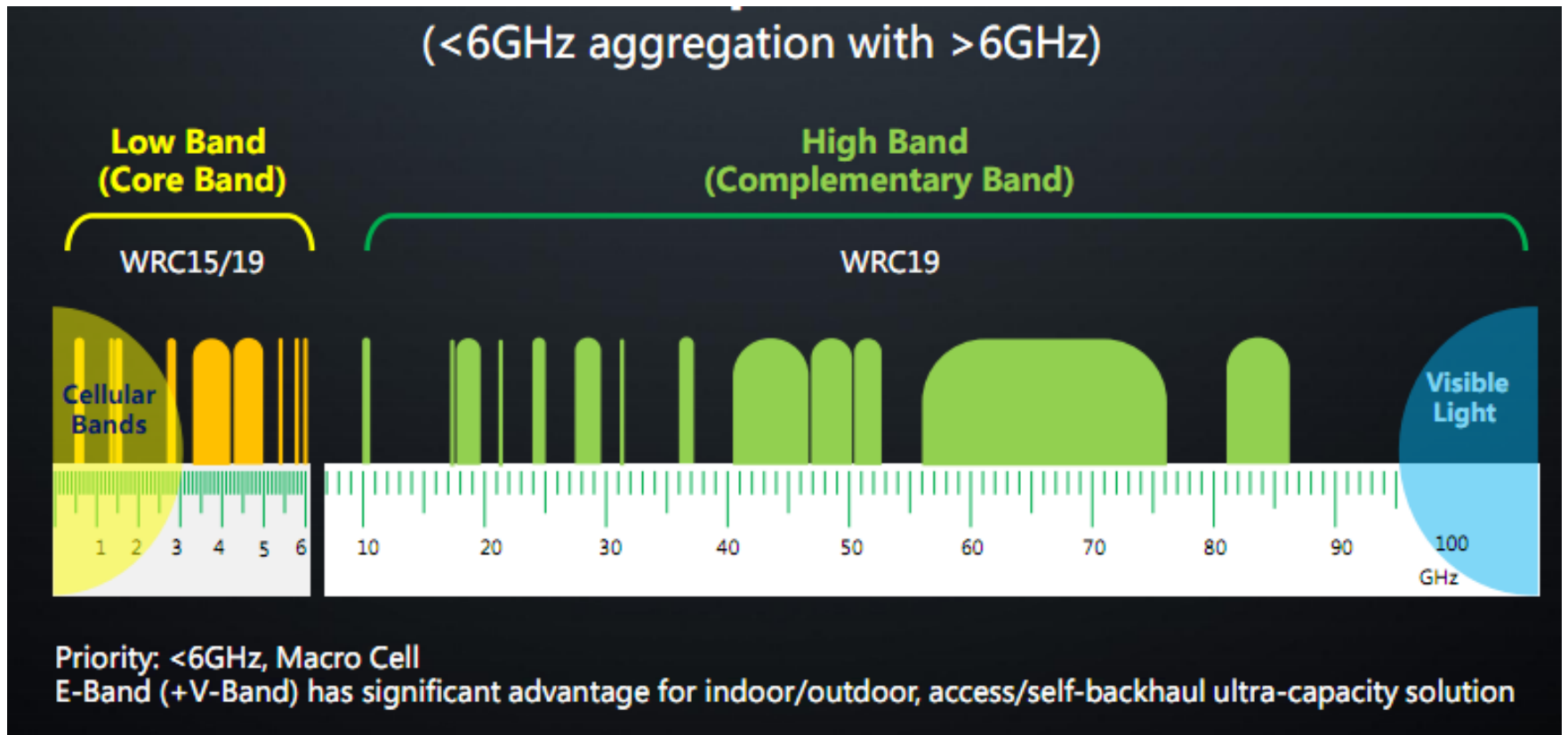
One Physical Network
Multiple Industries

New Air Interface

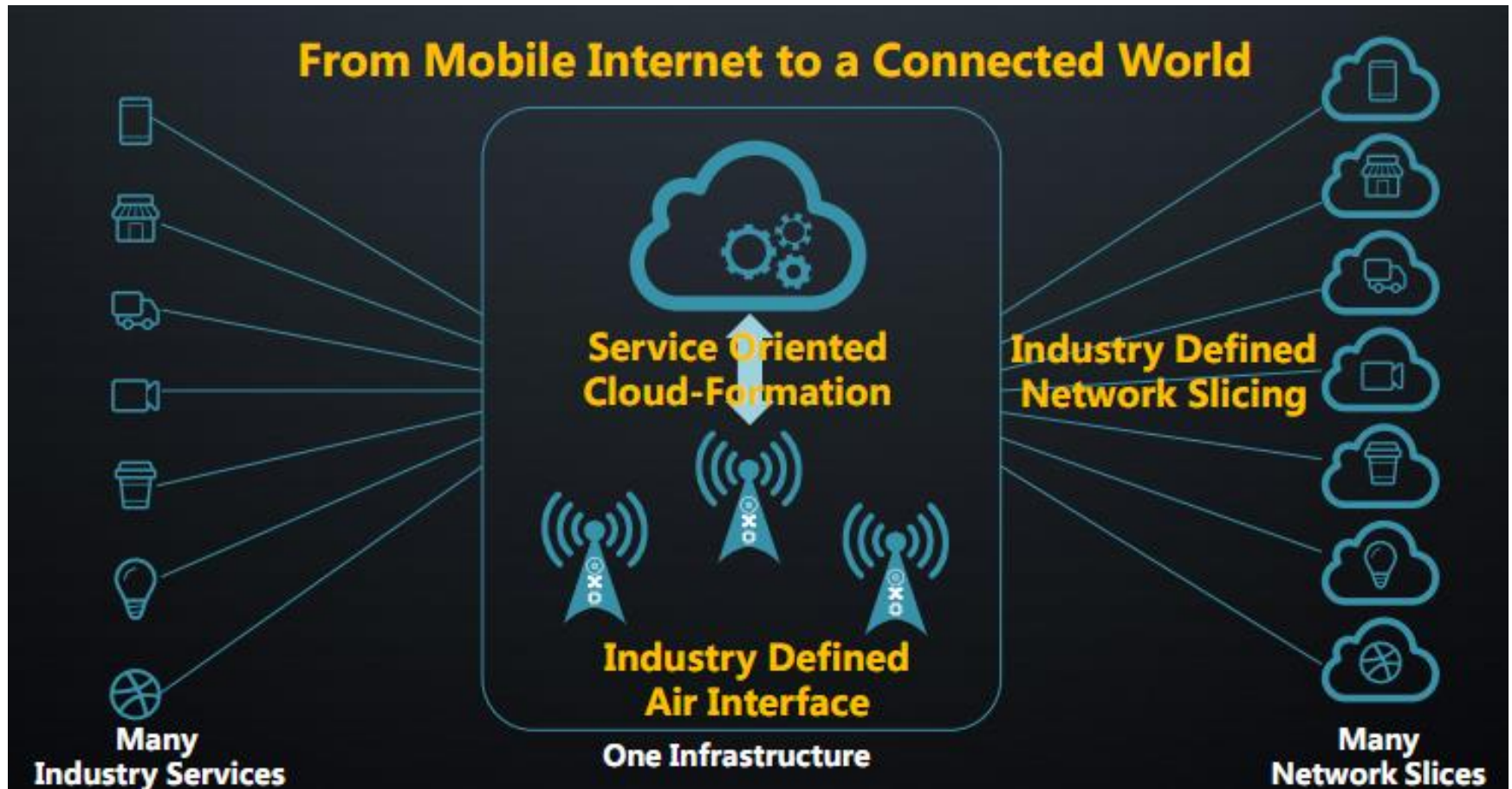


Flexibility &
Spectrum Efficiency

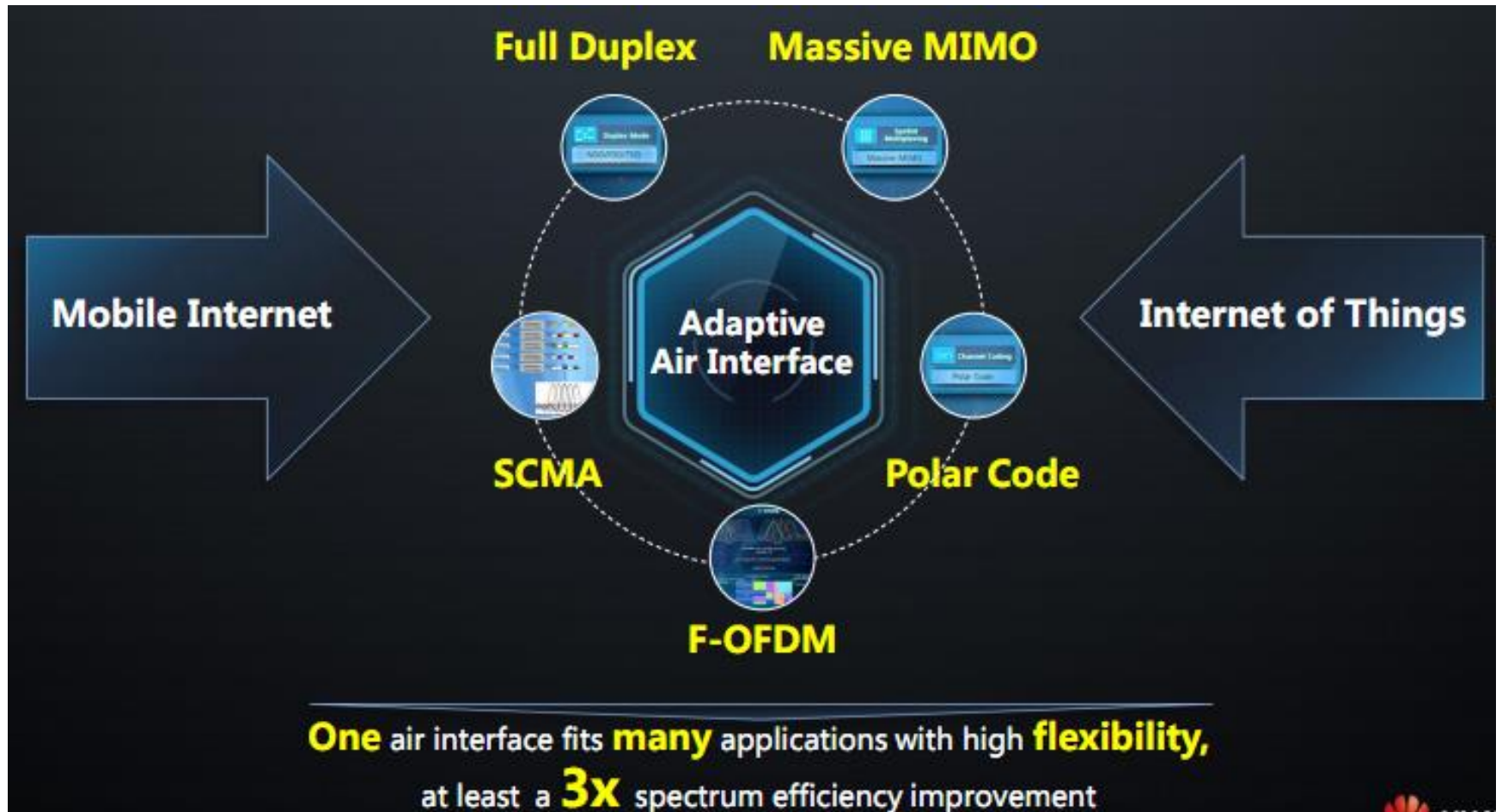
5G is a Full Spectrum Access



A New Architecture to Carry MBB & Verticals



New Air Interface



- How about 6G and 7G?

References:

- Presentation: Background 3G/4G Mobile Networks
- Presentatin: 4G Technology by Nithin Raj
- Seminar on 5G Technology by www.studymafia.org
- Huawei 5G Overview