

# **Background:**

## **4G/3G Mobile Networks**

# Outline

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

# Ubiquitous Mobile Network Services



In-building



Outdoor



Walking



Driving



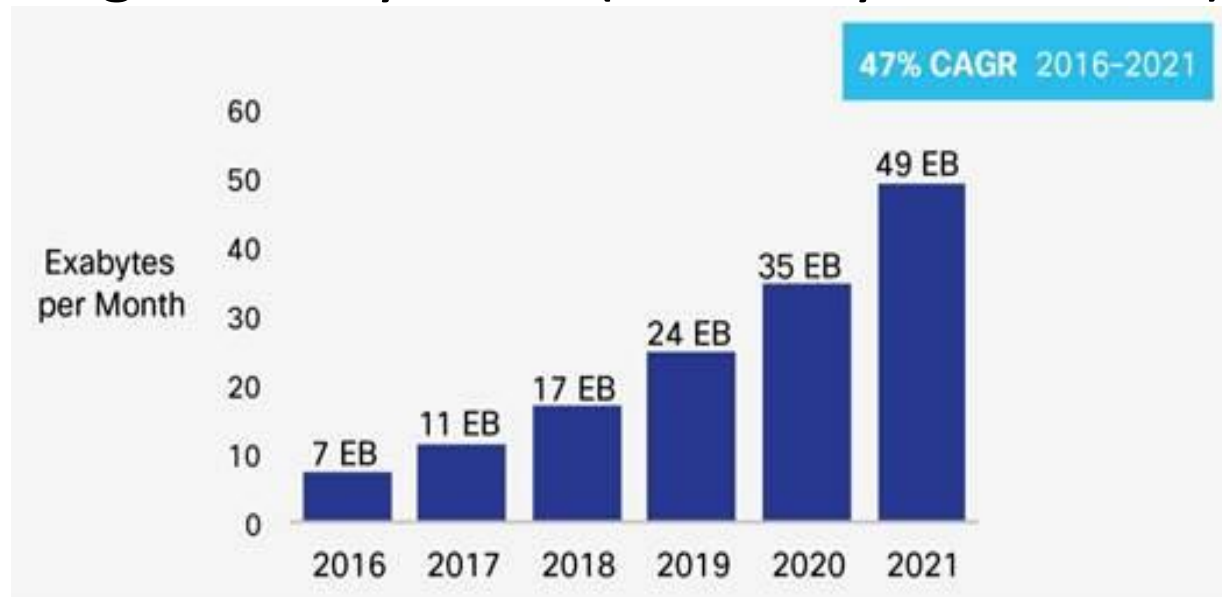
Subway



High-speed train

# Ubiquitous Mobile Network Services

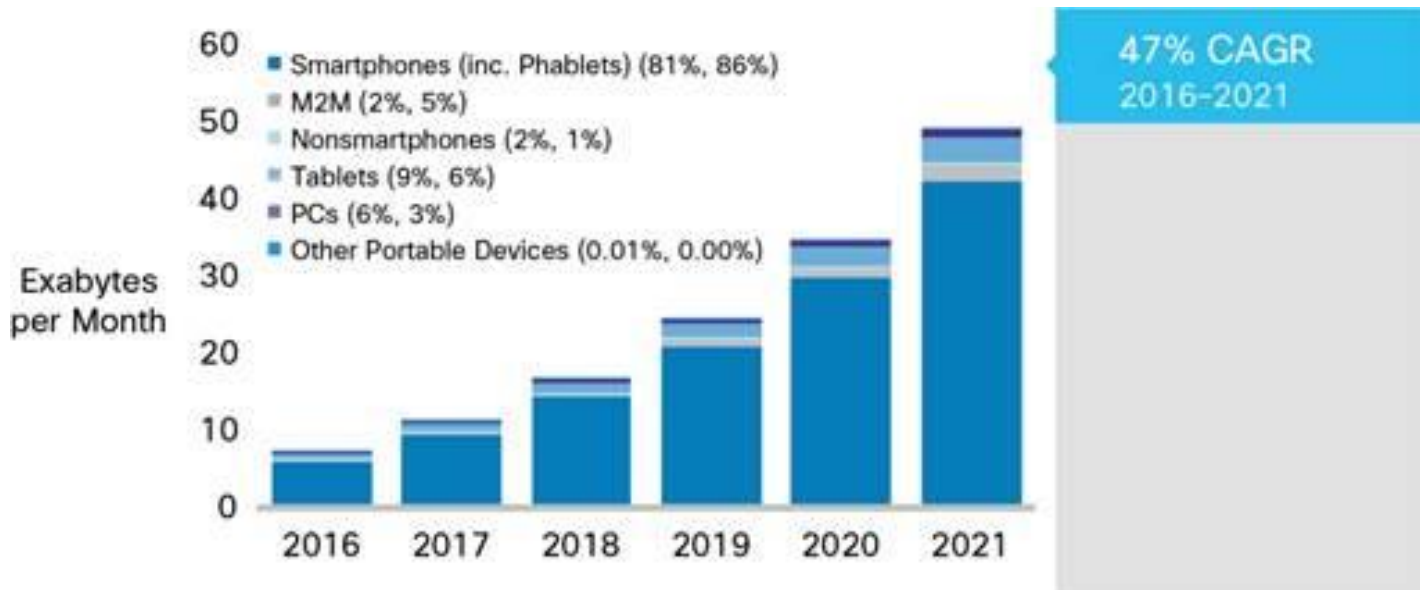
- Global Mobile Data Traffic
  - 7.2 exabytes/month in 2016 (63% growth)
  - 18 fold growth in the past five years
  - 7 fold growth by 2021 (49 exabytes/month)



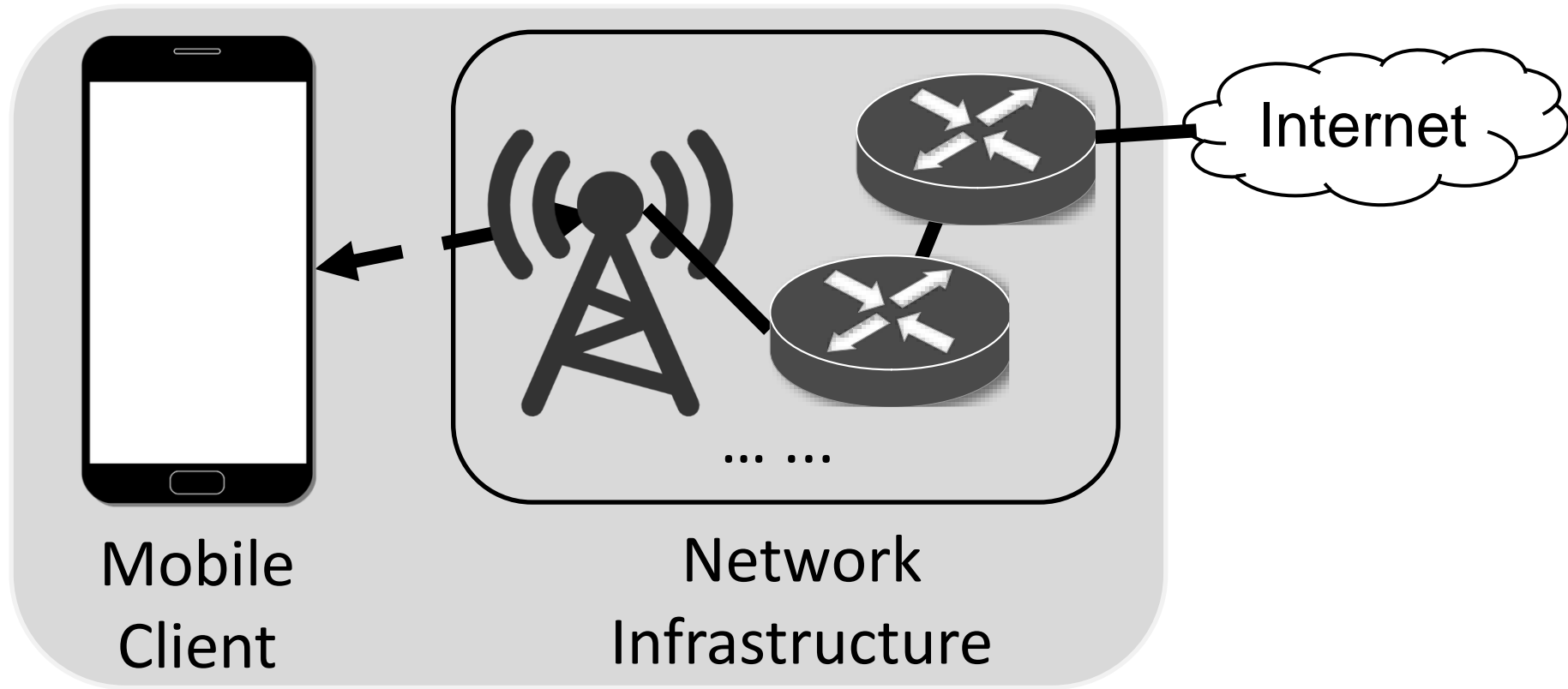
Source: Cisco Visual Networking Index, 2017: Global Mobile Data Traffic Forecast Update, 2016–2021 White Paper

# Ubiquitous Mobile Network Services

- Smartphones: primary internet access points
  - By 2021, 98% traffic and 75% connections from “smart” devices
  - 4G: 75% traffic and 53% connections
  - 5G: 1.5% traffic and 0.2% connections

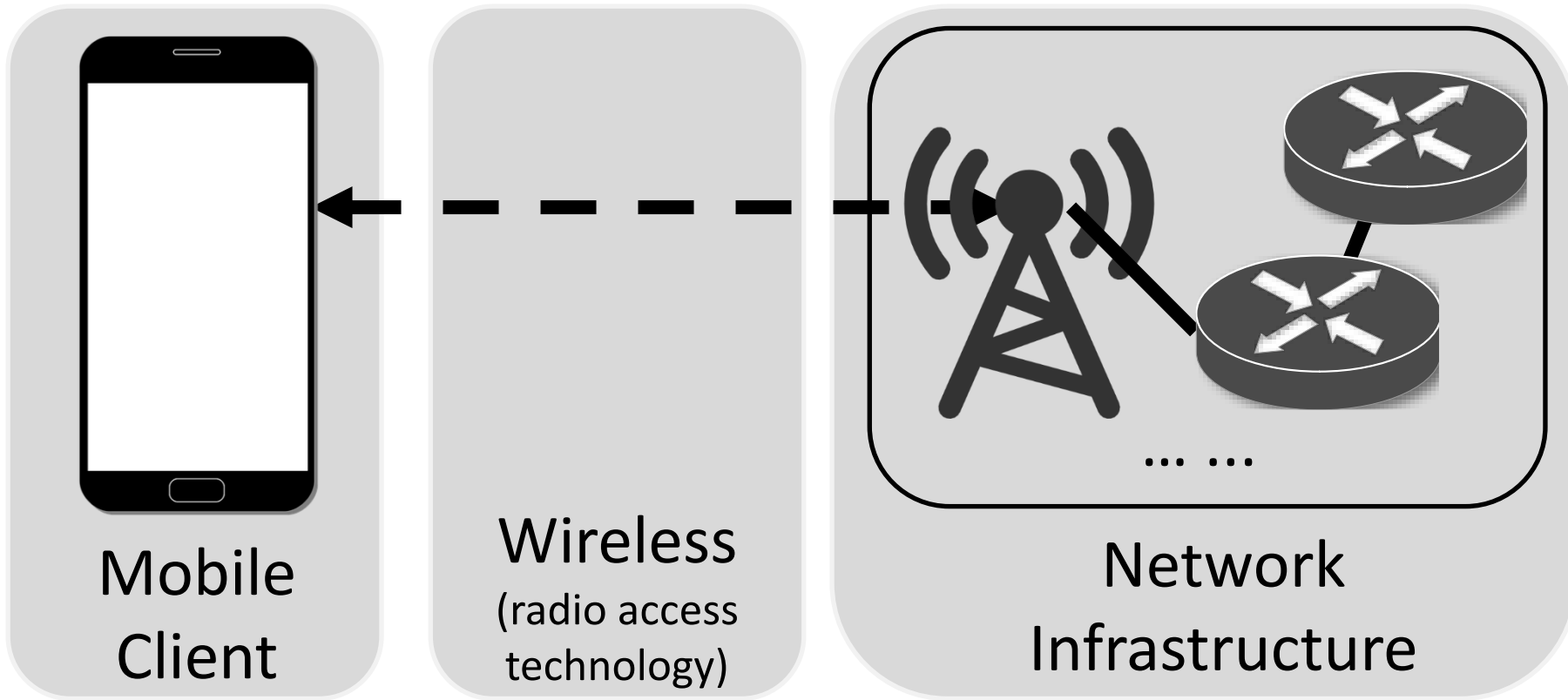


# Empowered by Mobile Networks



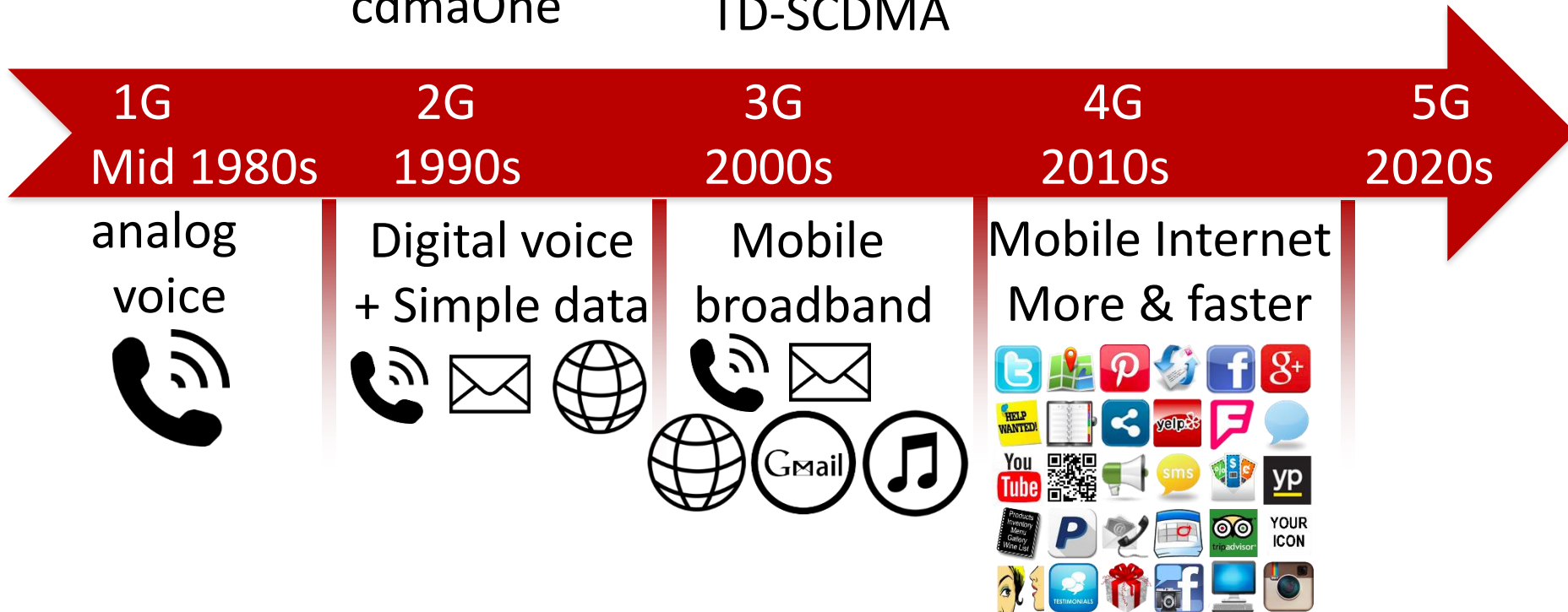
- the **only** large-scale, wide-area wireless network system in par with the Internet

# 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





# Standards Body: 3GPP

- An international standards body
- Evolves and standardizes GSM, UMTS, LTE among others

*The 3rd Generation Partnership Project (3GPP) unites [Six] telecommunications standard development organizations (ARIB, ATIS, CCSA, ETSI, TTA, TTC), known as “Organizational Partners” and provides their members with a stable environment to produce the highly successful Reports and Specifications that define 3GPP technologies*

- We will primarily discuss 3GPP standards

# Cellular Network Standards

Generation	3GPP Circuit Switched	3GPP Packet Switched	3GPP2	Wimax Forum
2G	GSM		cdmaOne	
2.5G		GPRS		
2.75G		EDGE		
3G	UMTS		CDMA2000	
3.5G		HSPA/+	CDMA EV-DO	
4G		LTE	<del>UMB</del>	WiMAX

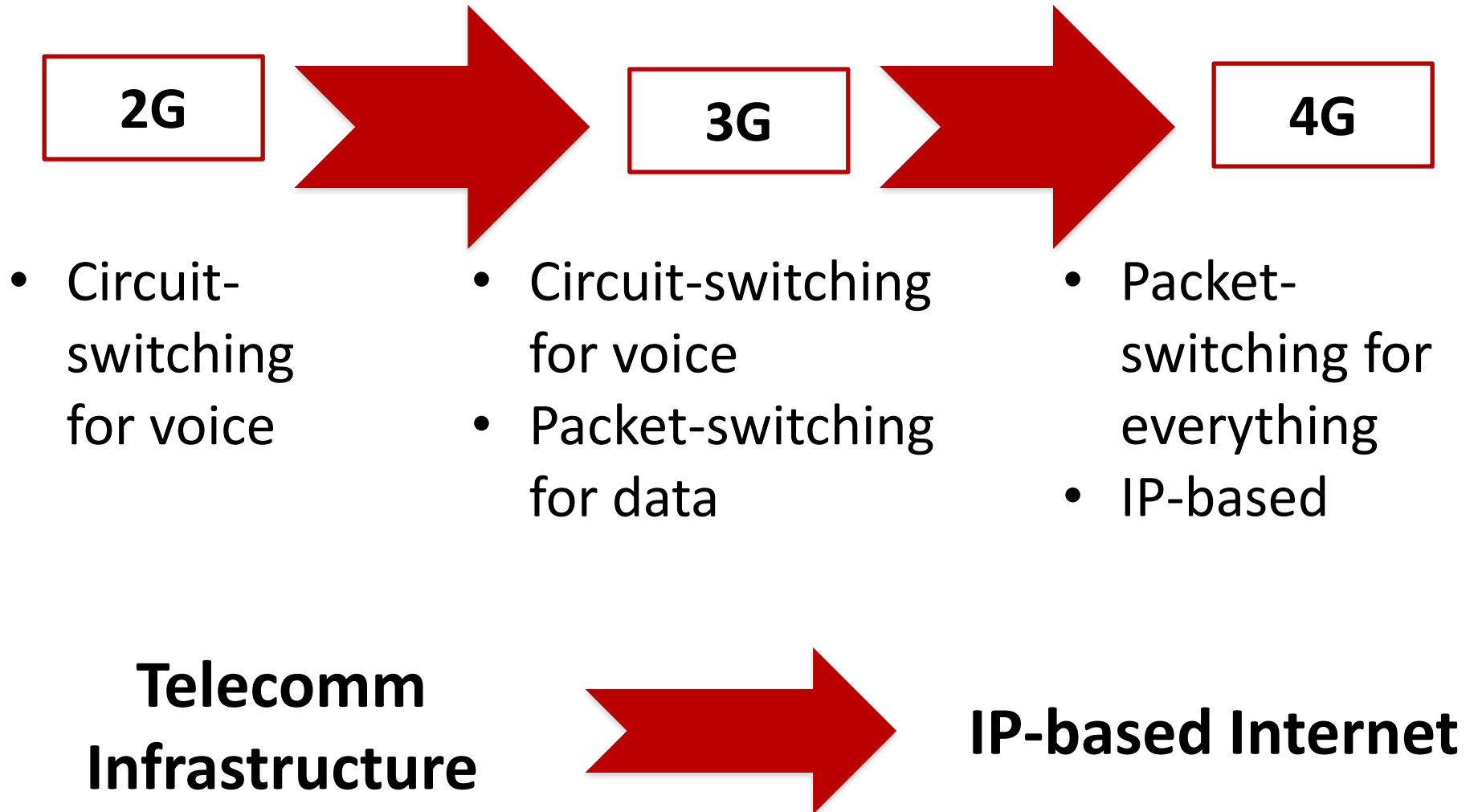
# What is LTE?

- LTE stands for “Long Term Evolution”
- Fourth-generation (4G) cellular technology from 3GPP
- Deployed worldwide
- 4G LTE: First global standard
  - Increased speed
  - IP-based network (All circuits are gone/fried!)
  - New air interface: OFDMA (Orthogonal Frequency-Division Multiple Access), MIMO (multiple antennas)
    - Also includes duplexing, timing, carrier spacing, coding...
  - New service paradigm (e.g., VoLTE)

# What is LTE?

- LTE is always evolving and 3GPP often has new “releases”
  - First release: Rel-8
  - Current: Rel-11, Rel-12
  - Toward LTE-Advanced (4.5G)

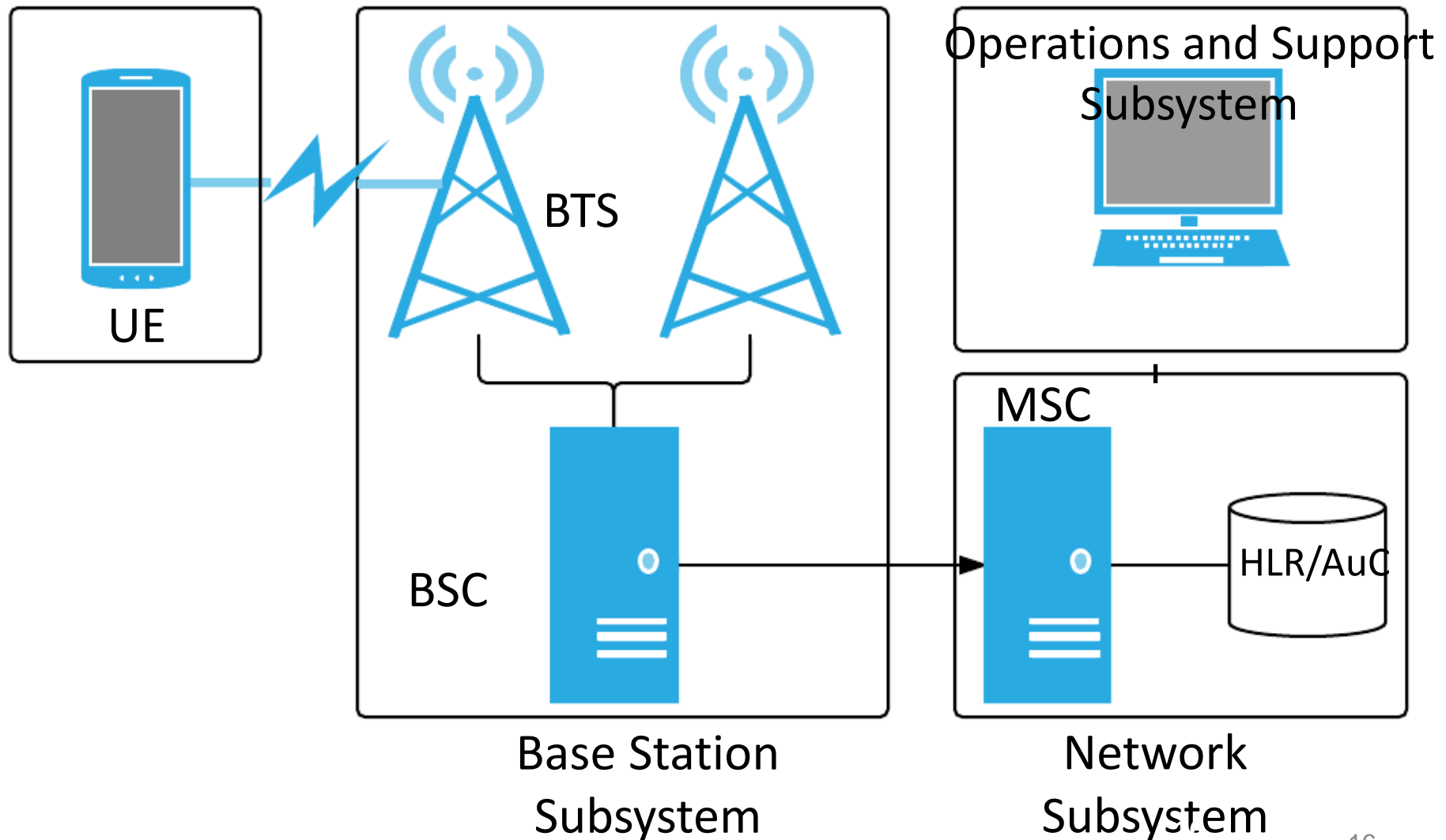
# Network Architecture Evolution



# 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”

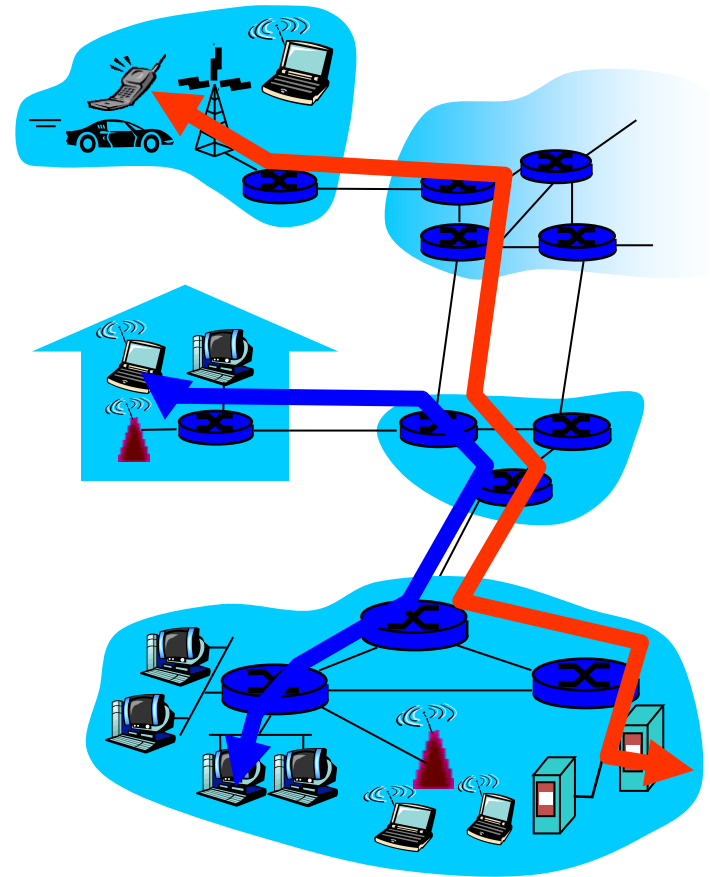
# 2G Network Architecture (GSM)



# 2G Based on Circuit Switching (CS)

End-end resources  
reserved for “call”

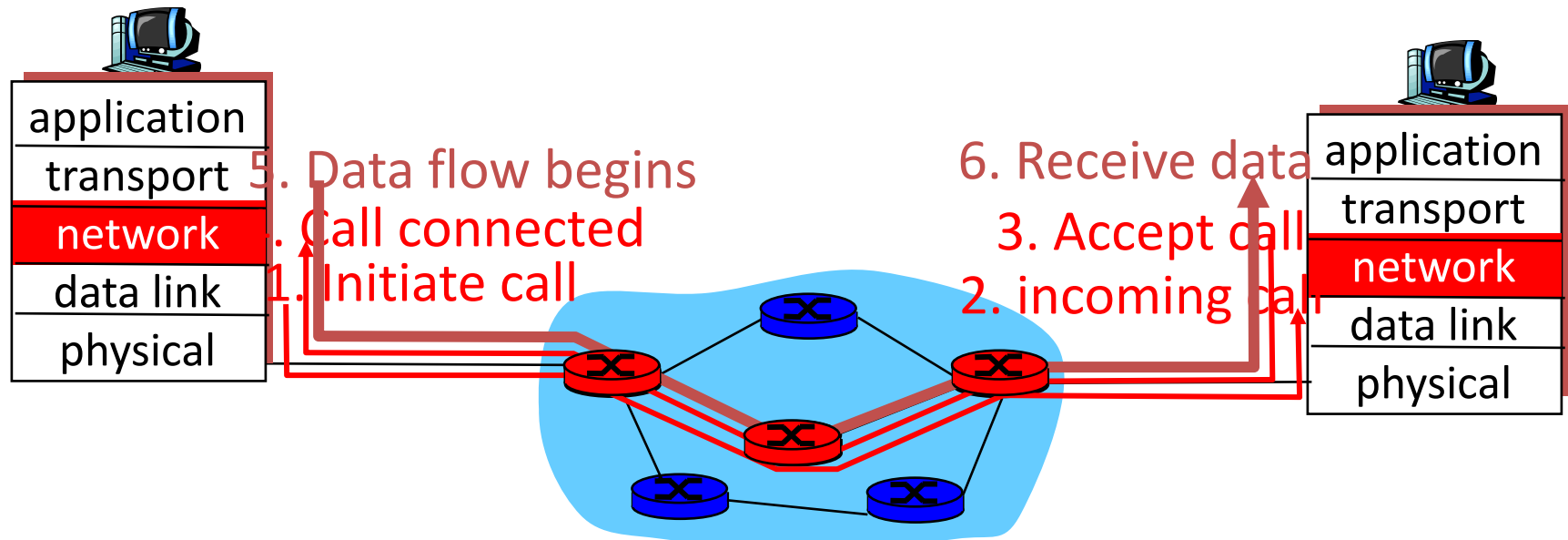
- link bandwidth, switch capacity
- dedicated resources: no sharing
- circuit-like (guaranteed) performance
- call setup required





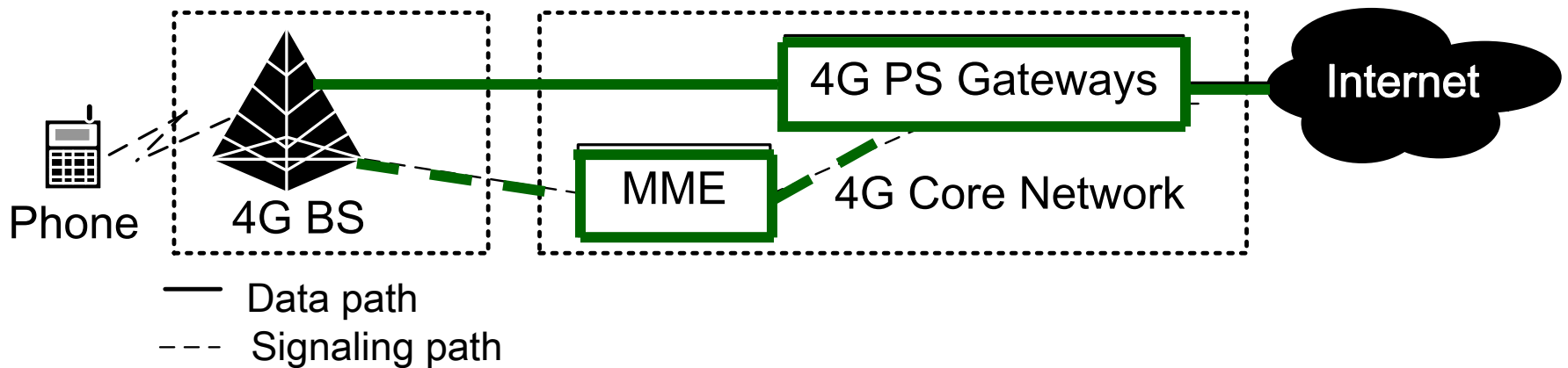
# CS Signaling

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



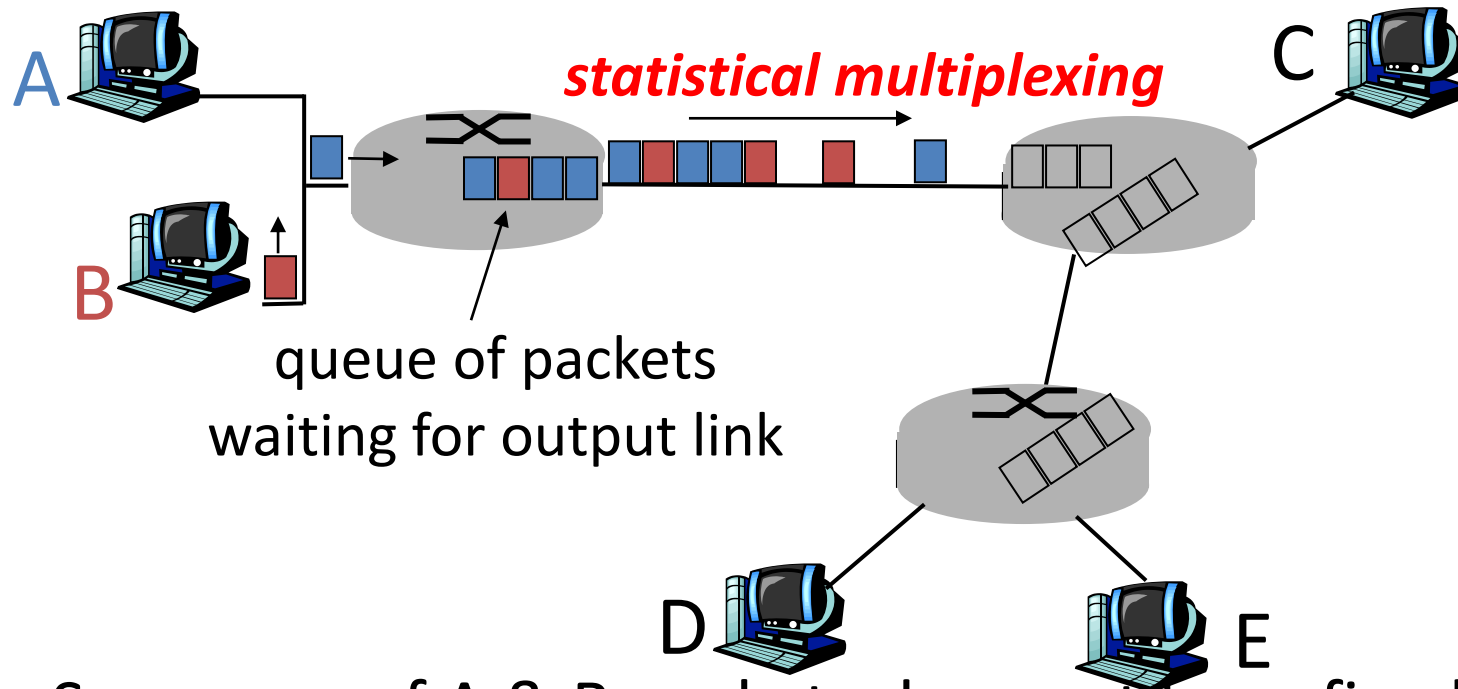
# 4G Network Architecture (LTE)

## 4G Packet-Switched



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

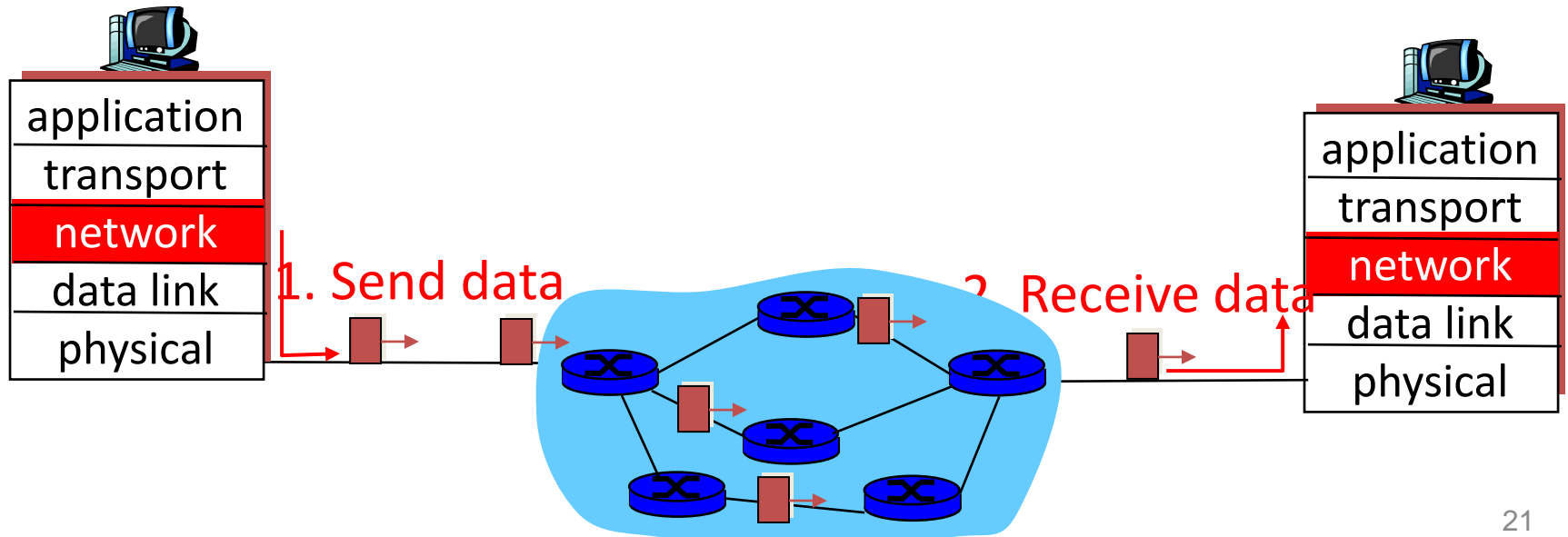
# Packet Switching (PS)



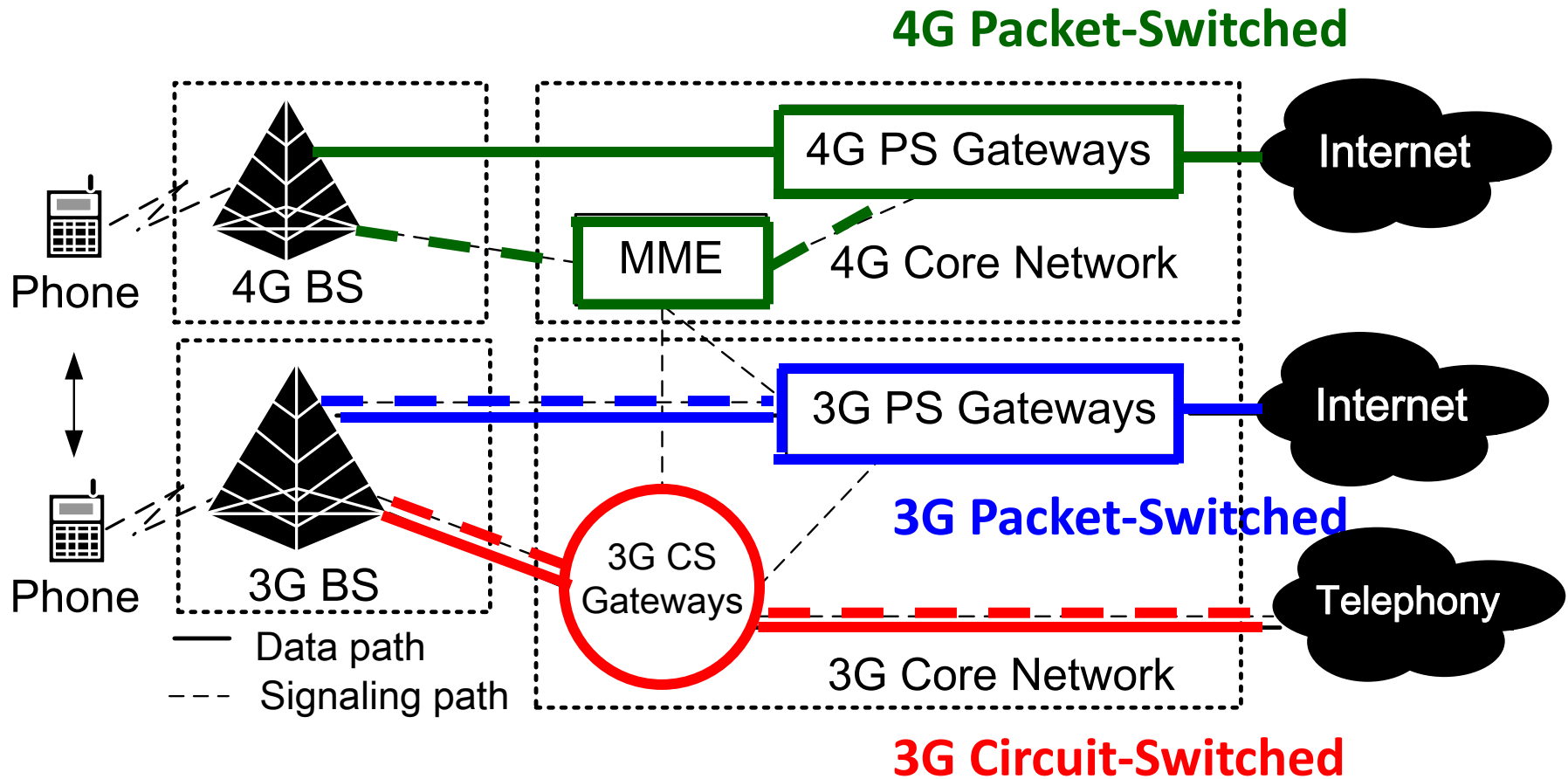
- Sequence of A & B packets does not have fixed pattern, bandwidth shared on demand → statistical multiplexing
- Store-and-forward at intermediate routers
- Used by the Internet

# 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

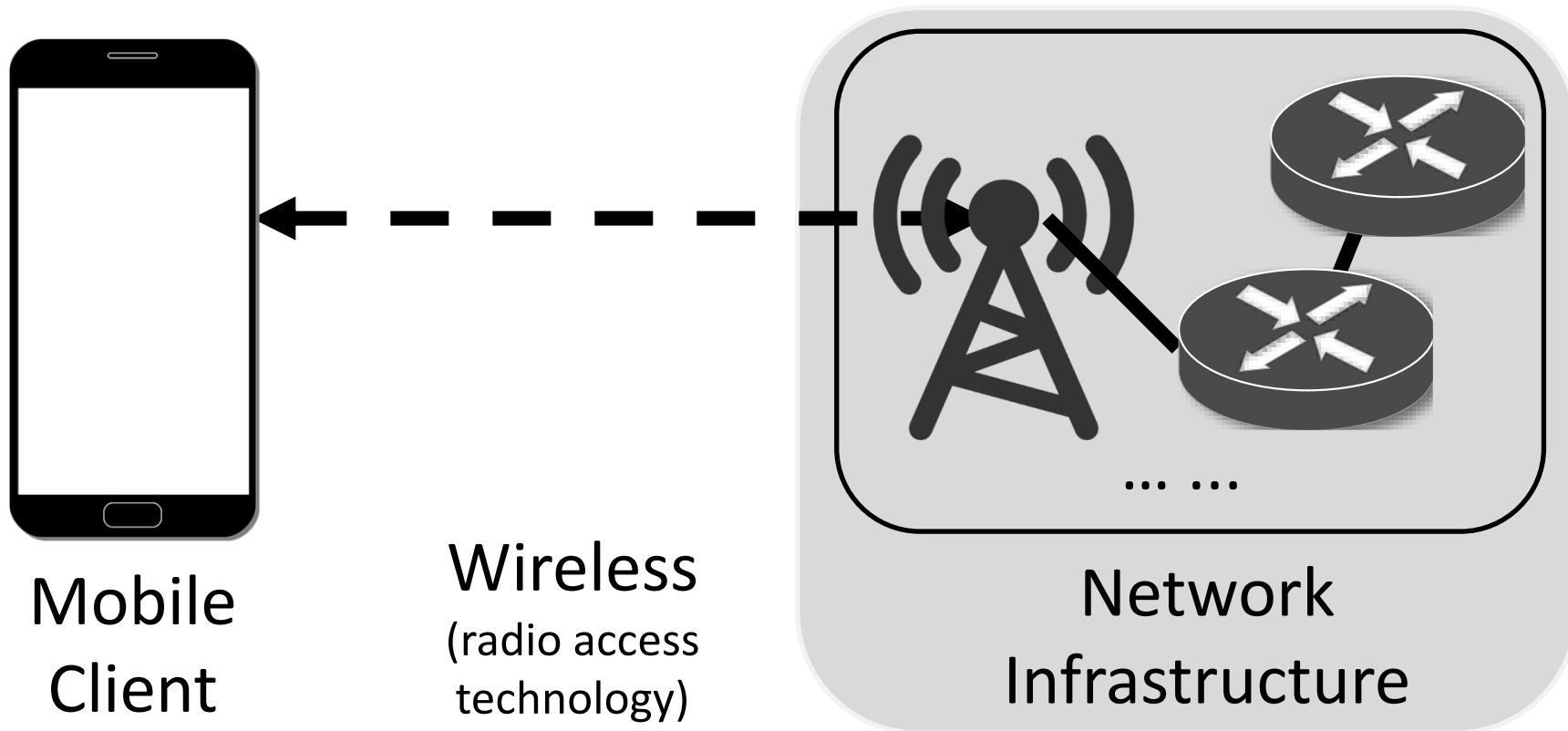


# 3G/4G Network Architecture



## So far, Our Focus

- We mainly focus on current 3G/4G systems, particularly 4G LTE network



# Outline

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

# Operations

Two main planes in operation in parallel:

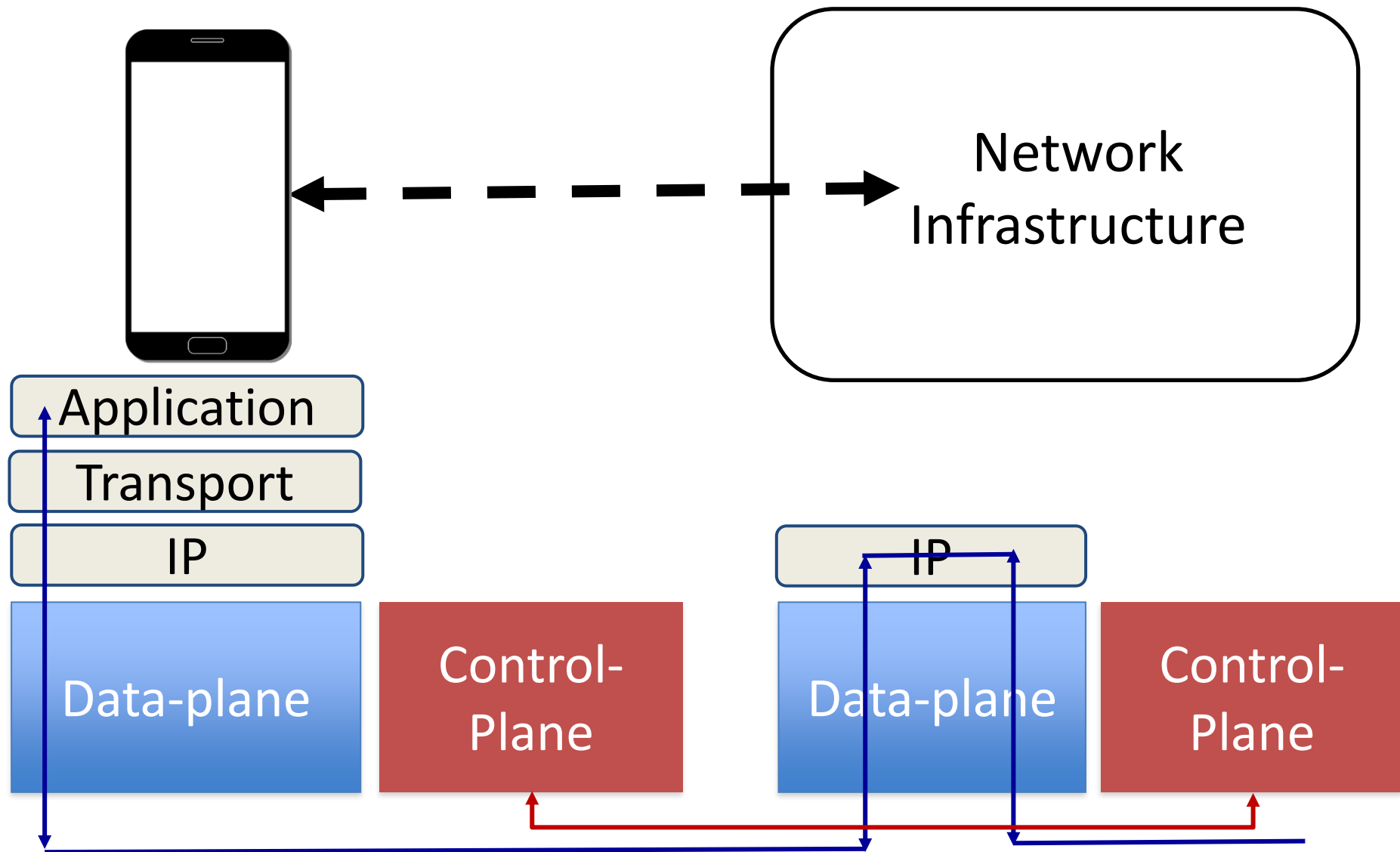
- **Data plane (also called User plane)**: content delivery
- **Control plane**: signaling functions

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

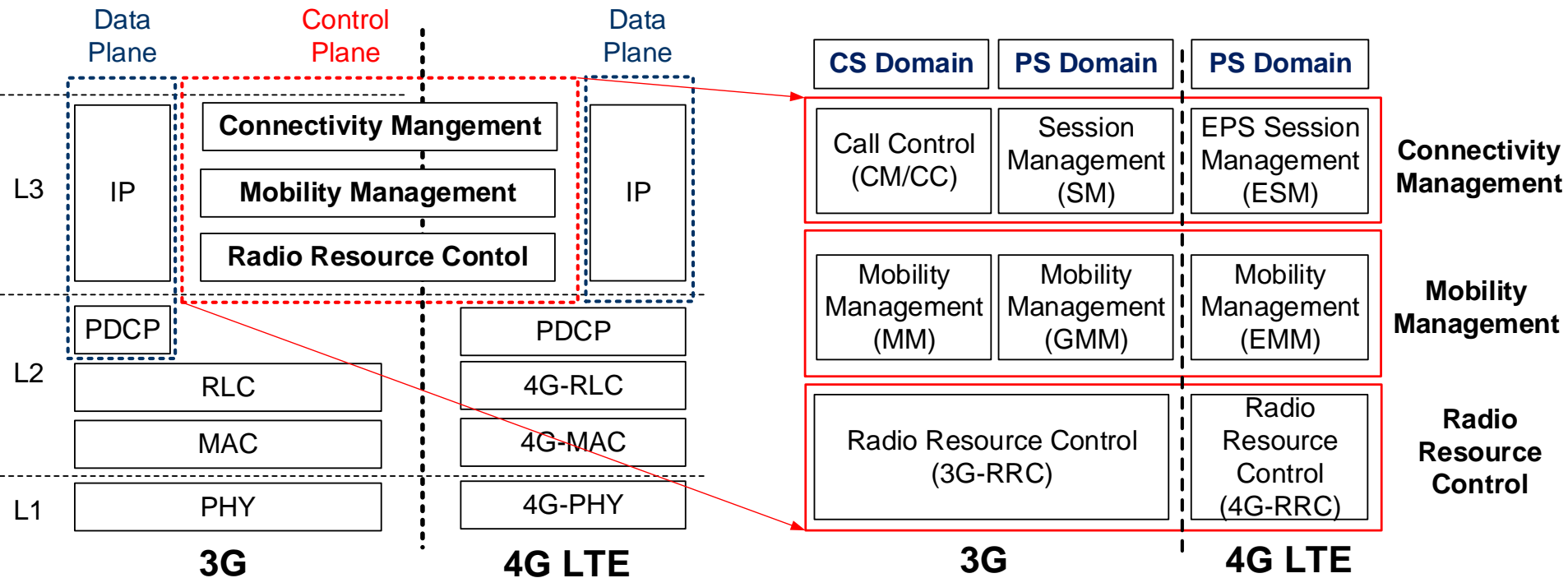
- **Management plane**: configurations, monitoring



# Illustration of Data and Control Planes



# Illustration of Data and Control Planes



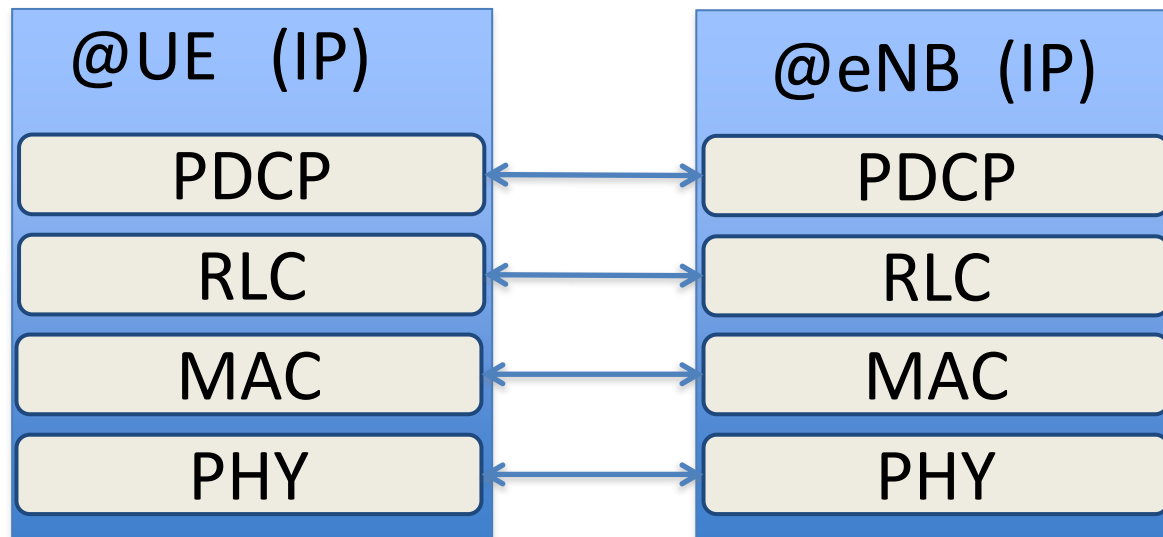
EPS: Evolved Packet System

PDCP: Packet Data Convergence Protocol

RLC: Radio Link Control

MAC: Medium Access Control

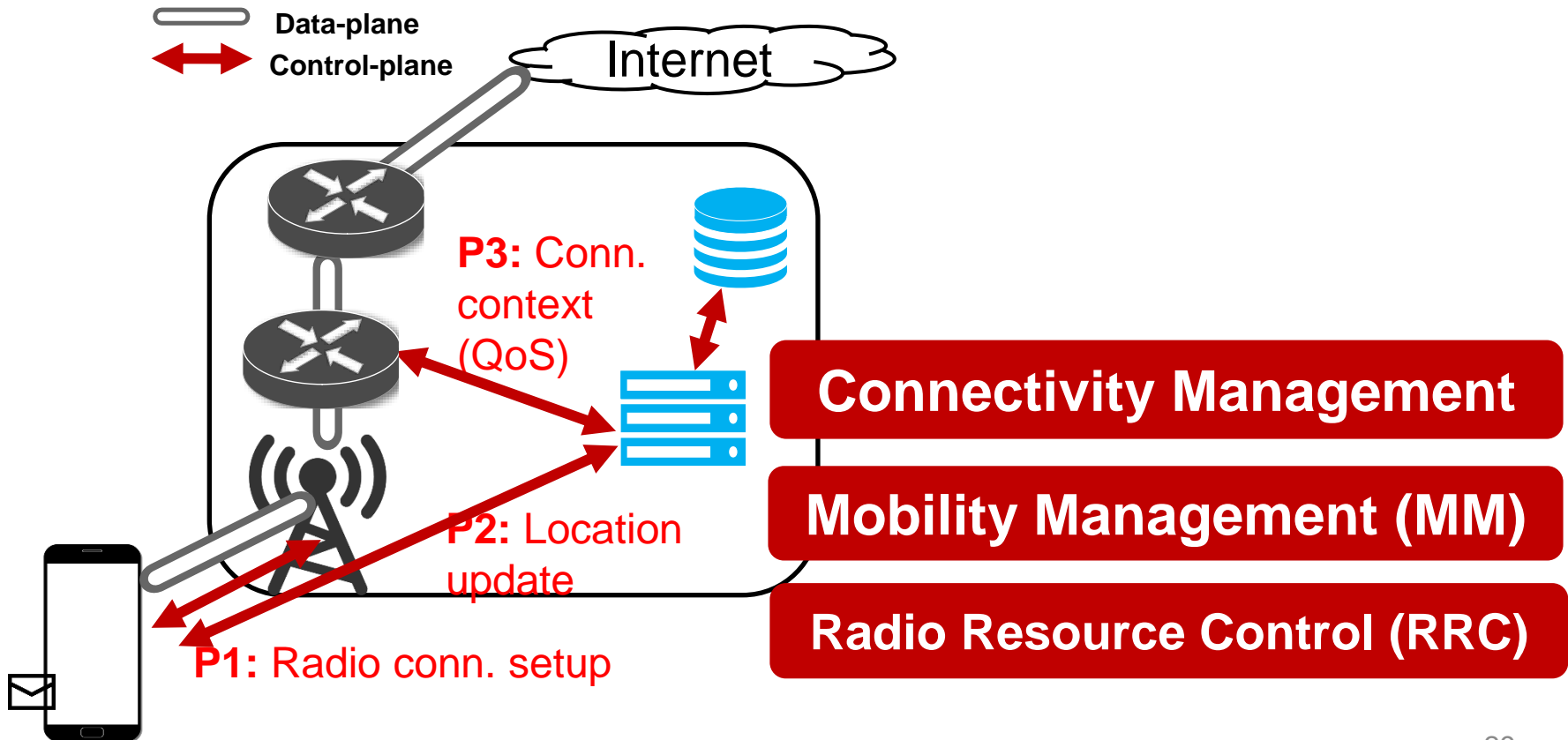
# Data-Plane Protocols: IP + lower layers



- **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

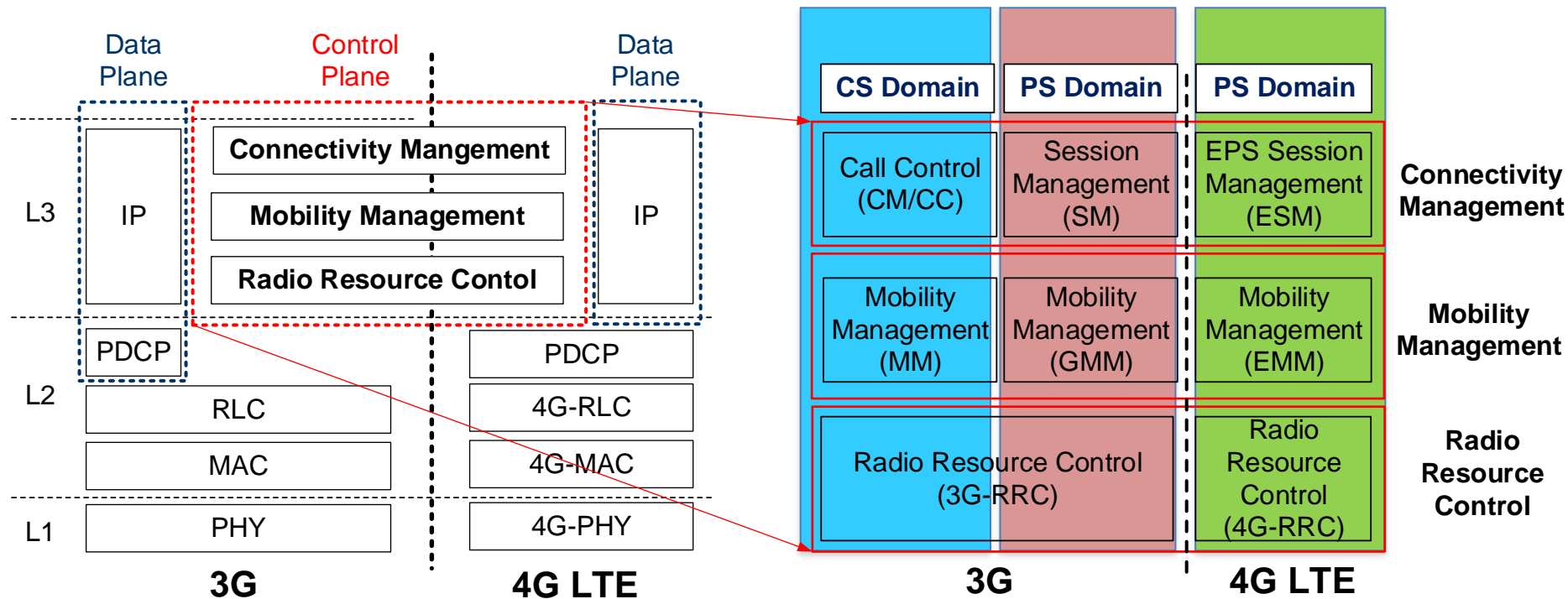
# Control-Plane Protocols

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

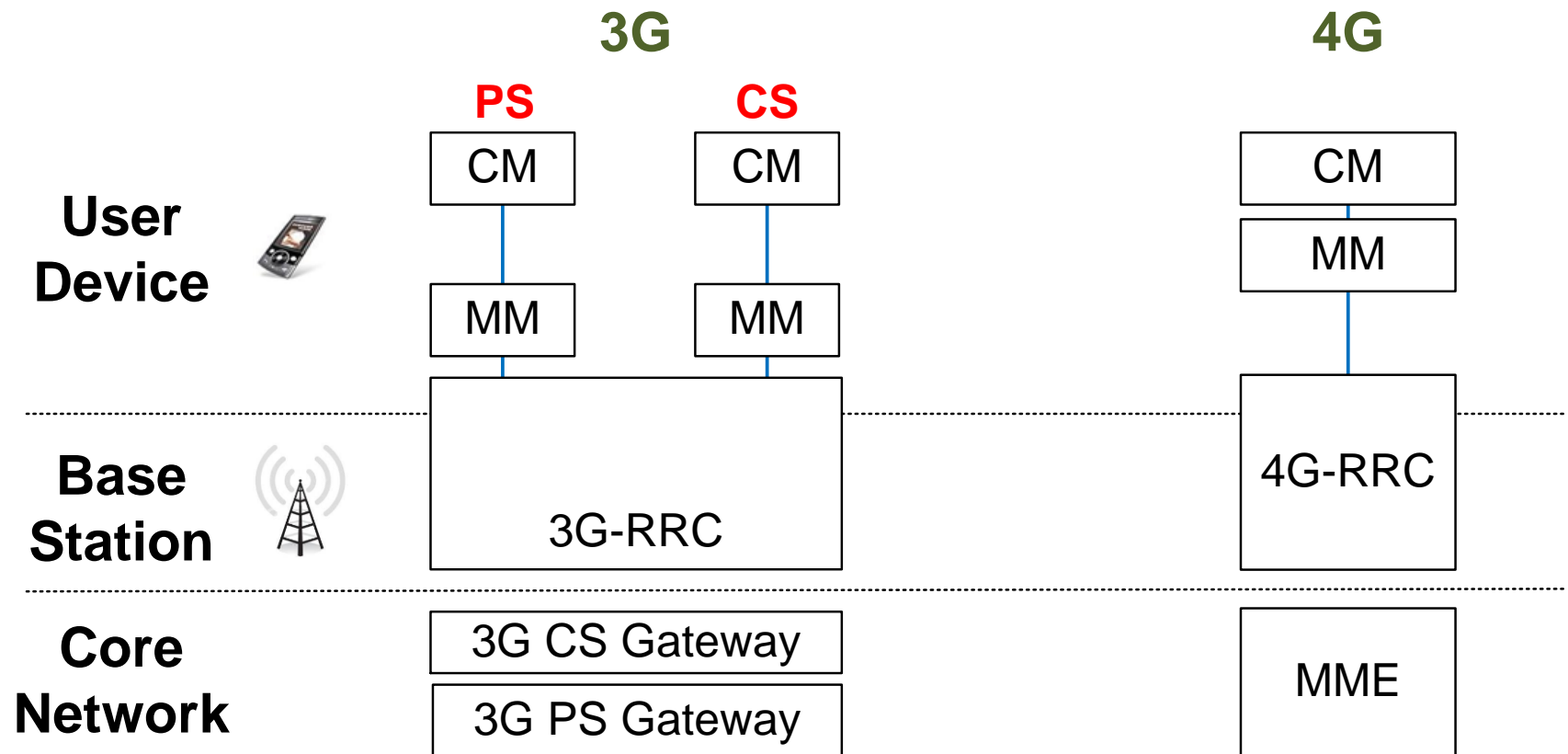


# Control-Plane Protocols in 4G/3G

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

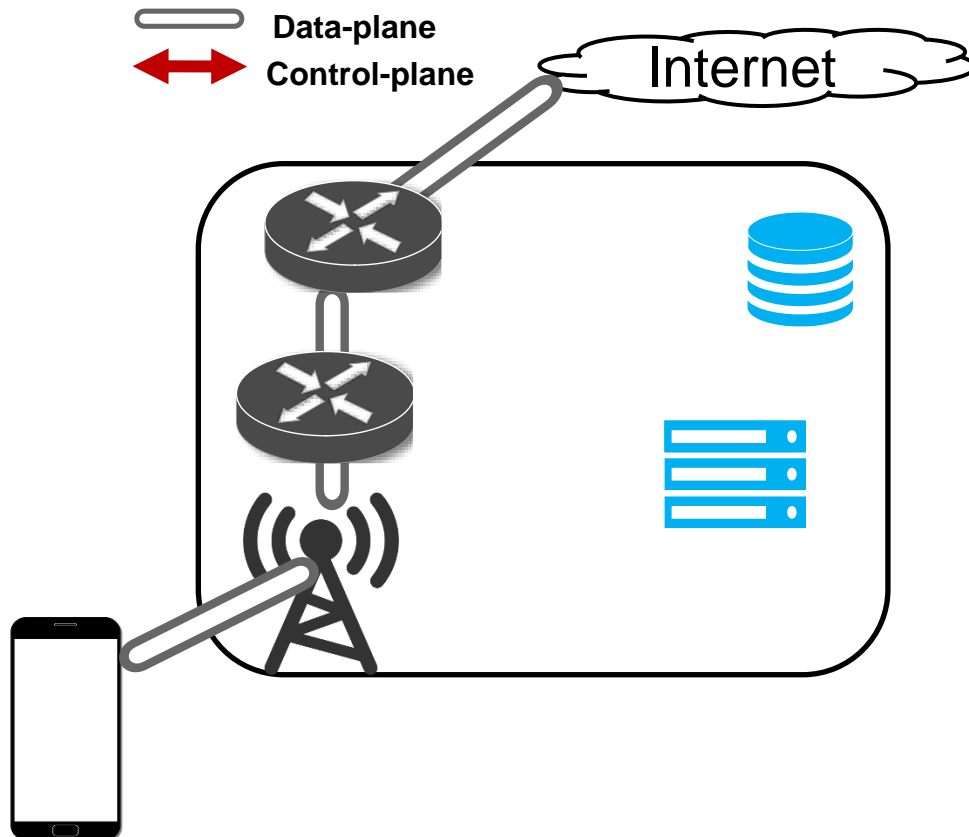


# Distributed Operations: Device, base station, core networks

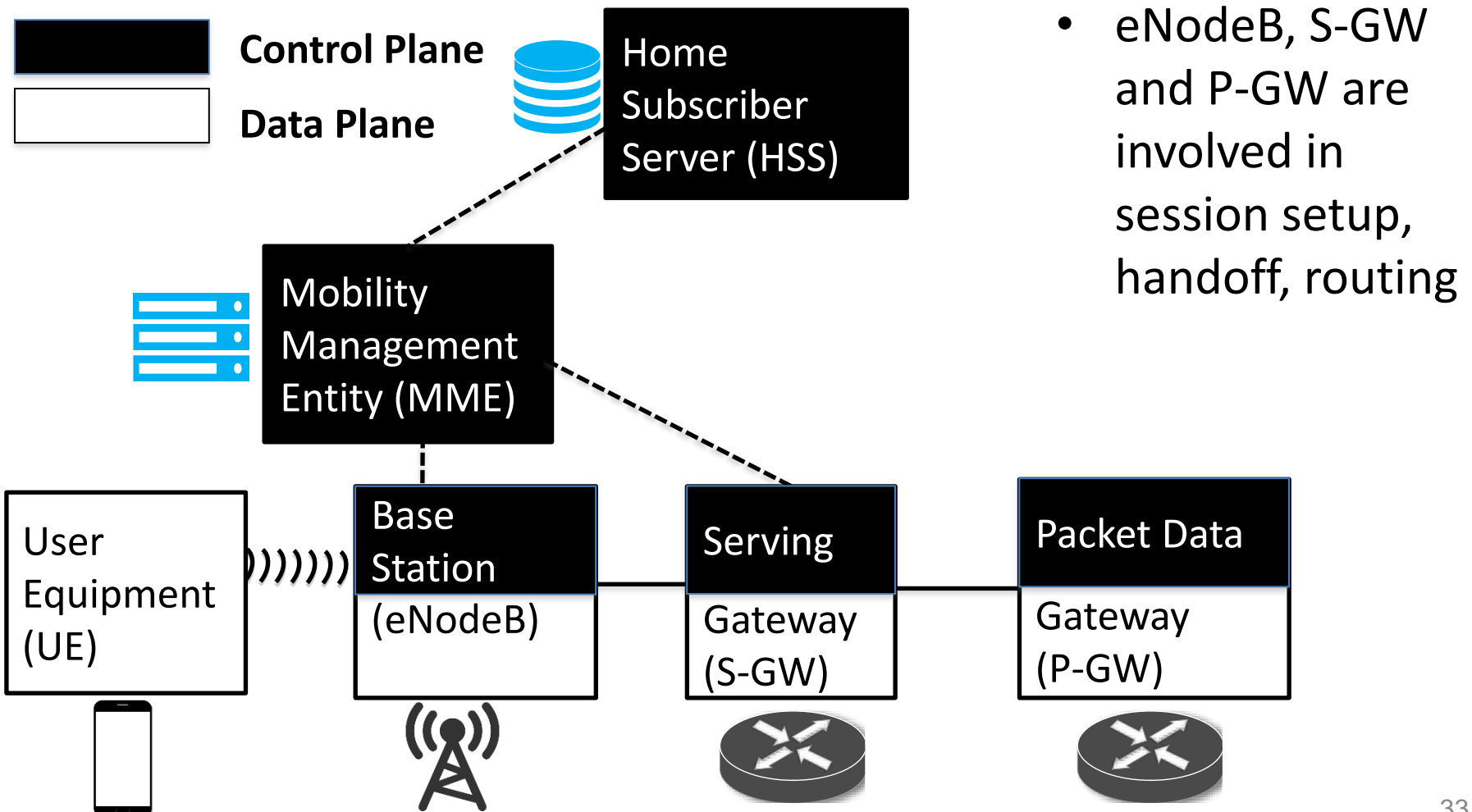


# Put Them Together

- Setting up data service in 4G

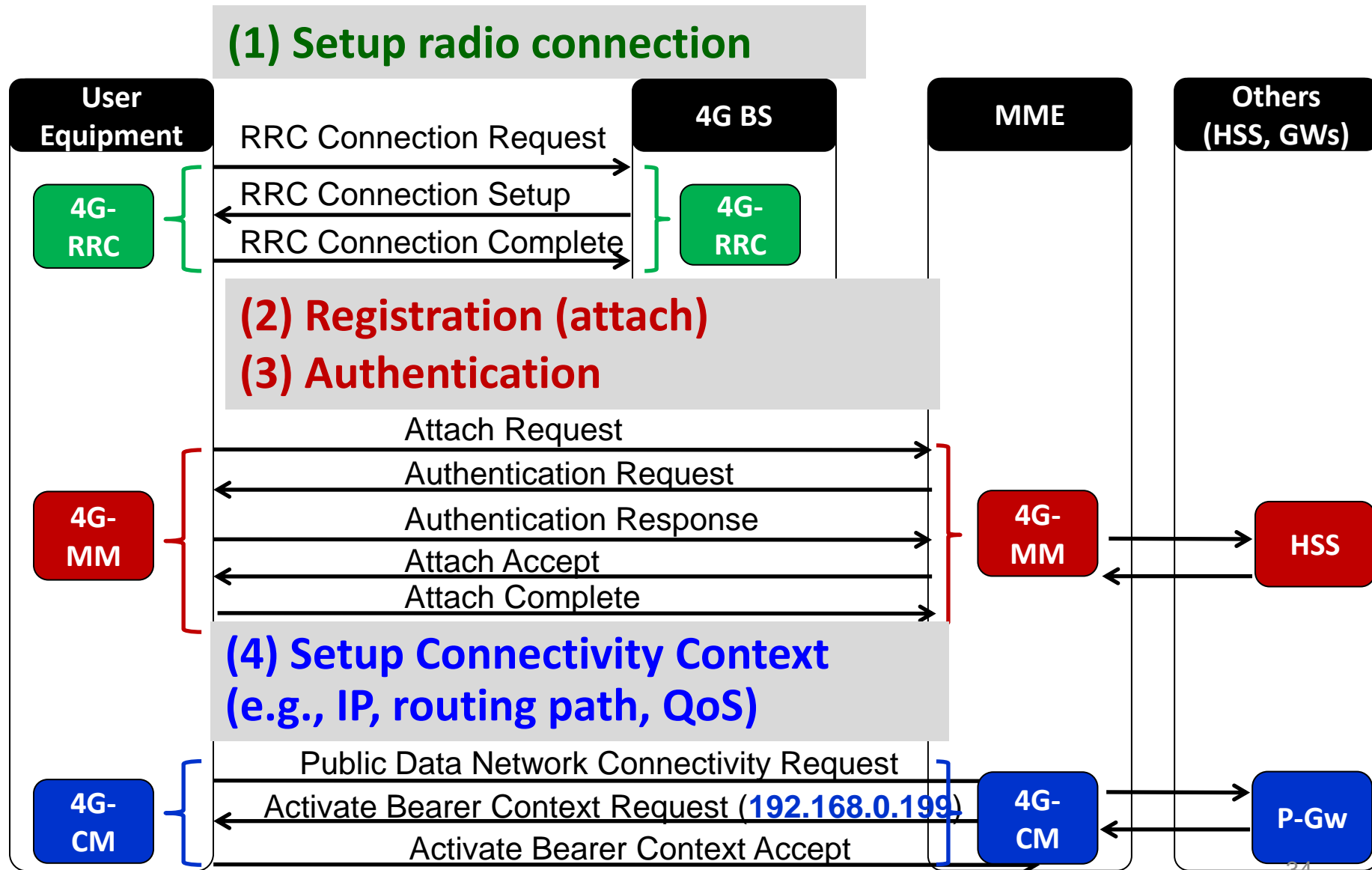


# Data and Control Planes in LTE



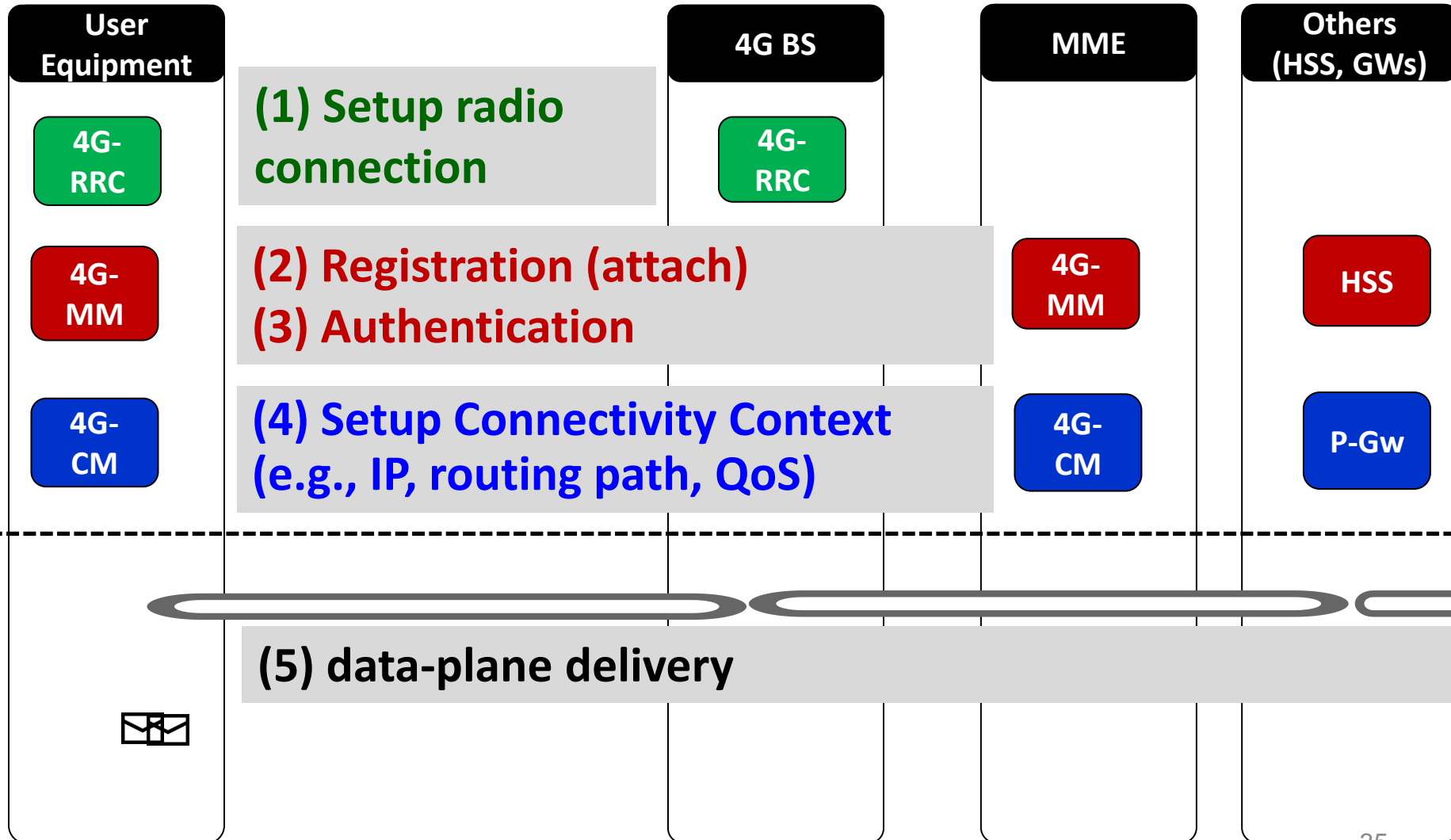


# Setting Up Data Service in 4G



# Setting Up Data Service in 4G

## Control-Plane Functions



# Summary and Discussion

- Primer on mobile network: architecture, protocols, operations
  - And its evolution
  - And its complexity
- Difference from wired Internet and WiFi
  - What?
  - Why?

## After-class Reading (Optional)

- Learn more about control plane protocols and their interactions: SIGCOMM'14
- Learn more about radio connection setup: check RRC papers
- LTE tutorial and reference:  
<https://www.tutorialspoint.com/lte/>

# Action Items

- Work on your course project early
  - Topic and team
- Check the reference and reading list
  - Updates shortly
- Next Chapter: 5G apps