# Softwarization of 5G Core Networks

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SMS
9


Good morning
27

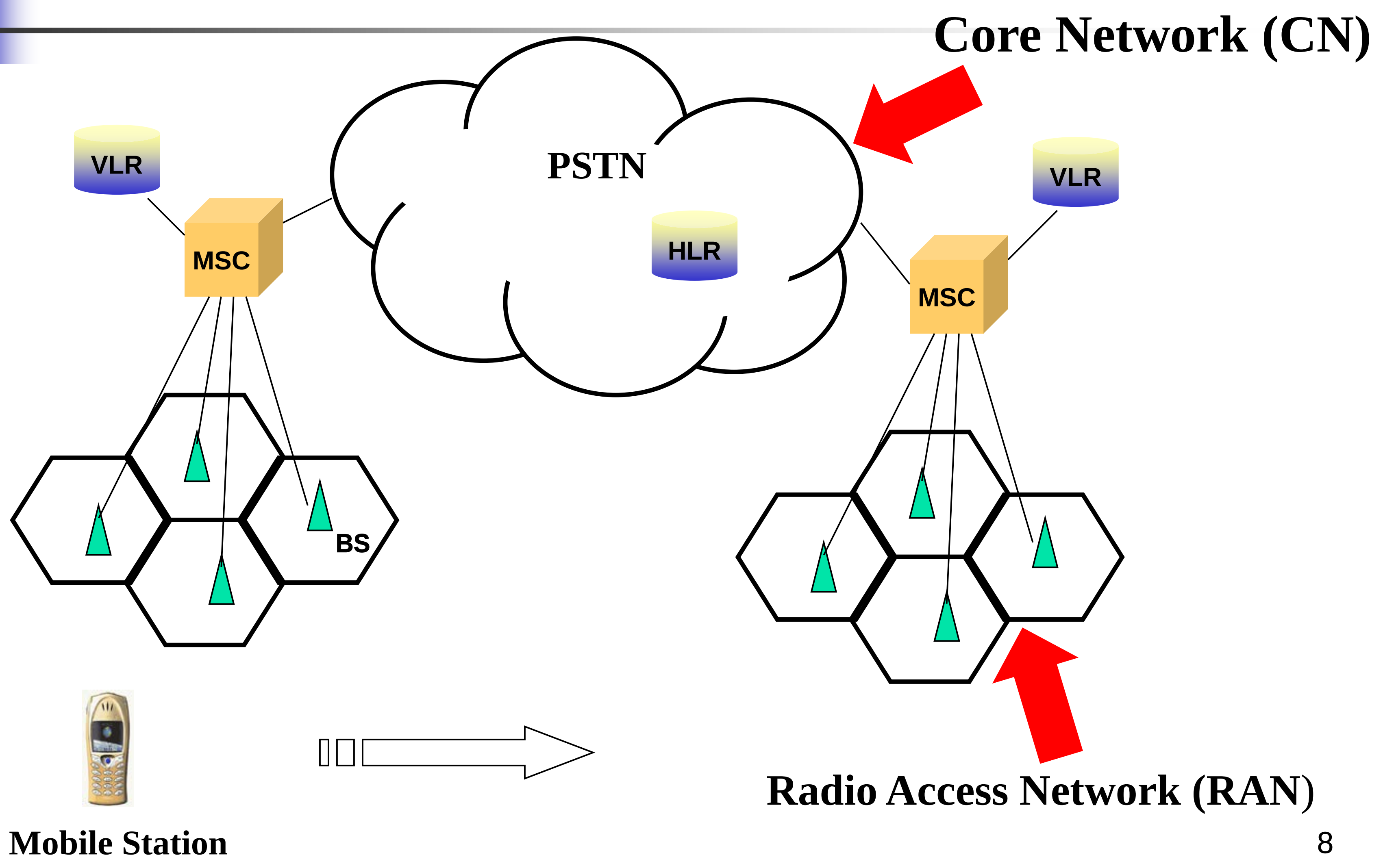

iPhone G
NEXT GENERATION CONCEPT


incoming call
NOKIA
incoming call
中時電子報
chinatimes.com


On/Off
Camera
Loud speaker
12:47
Incoming call...
Volume
Eject
Quality of connection
Charge of battery
Absorption of sunlight
Hold
Natali
Microphone

17:45
69:13
112:44
34:21
中時電子報
chinatimes.com

# Generic 2G Architecture



# Outline

- Evolution of cellular networks from 1G to 4G
  - with focus on core networks
- What is 5G?
  - 5G applications
- Softwarization of 5G core networks

# 1G Wireless Networks

- Became commercially available in the early 1980s
- Analog radio technologies and circuit-switched transmission and networking technologies
- Main service: circuit-switched voice
- Lack the ability to support roaming between different network operators
- Three main 1G radio system standards
  - Advanced Mobile Phone Systems (AMPS) in North America
  - Total Access Communications Services (TACS) in the United Kingdom
  - Nordic Mobile Telephone (NMT) in Nordic countries

# 2G Wireless Networks

- Emerged in the early 1990s
- Digital signal processing and transmission technologies (increased radio capacity and spectrum utilization, enhanced voice quality, reduced power consumption, etc.)
- Standards for core networks
- In addition to circuit-switched voice, enabled the first waves of mobile data and mobile Internet services

# 2G Systems in North America

- RAN
  - IS-136: Time Division Multiple Access (TDMA)
  - IS-95: Code Division Multiple Access (CDMA)
- Core Network
  - IS-41: support roaming between different network operators

# 2G System in Europe

- GSM (Global System for Mobile communications): RAN and core network
- Radio frequencies
  - 900 MHz and 1800 MHz in Europe
  - 800 MHz and 1900 MHz in the United States
- Services
  - circuit-switched voice
  - 9.6 Kbps circuit-switched symmetric channel as a data connection to access the Internet
- Most widely used 2G wireless network standards in the world

# 2G System in Japan

- Personal Digital Cellular (PDC) network
- Services
  - circuit-switched voice
  - data services over 9.6 Kbps radio channels

# 2.5G Wireless Networks

- Provide higher radio system capabilities and per-user data rates than 2G systems, but do not yet achieve all the capabilities promised by 3G systems
- General Packet Radio Services (GPRS)
  - provide a packet-switched core network as an extension to GSM core networks
- Enhanced Data Rates for Global GSM Evolution (EDGE)
  - provide advanced modulation and channel coding techniques to increase the data rates of GSM radio systems
  - support data rates up to 384 Kbps (also regard as a 3G system due to its high speed)

# 3G Wireless Networks

- Significantly increase radio system capacities and per-user data rates over 2G systems
- Support IP-based data, voice and multimedia services
- Enhance quality-of-service (QoS) support
- Improve interoperability

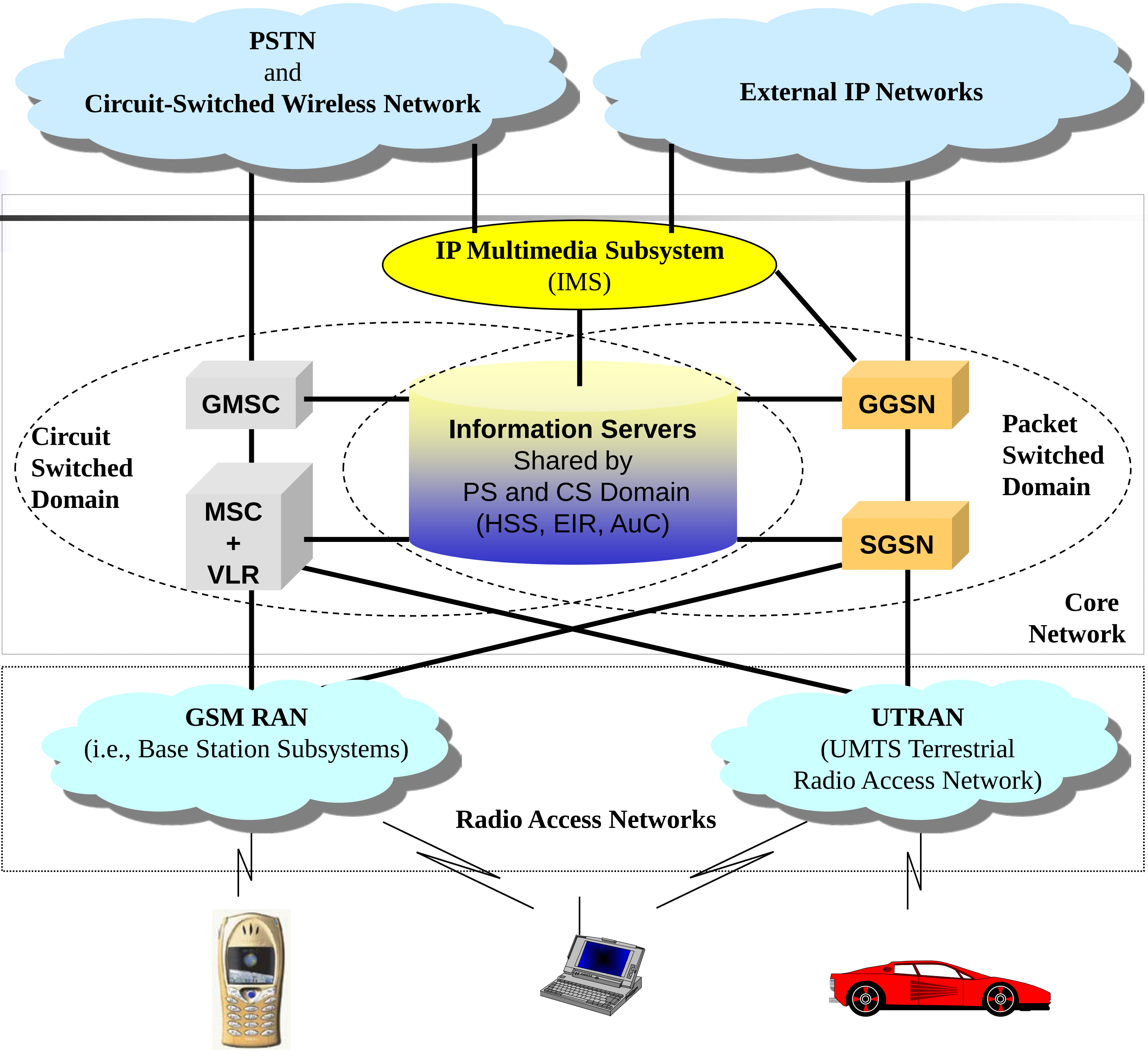
# Third-Generation Partnership Project (3GPP)

- 3G core networks will evolve the GSM core network platform to support circuit-switched mobile services and to evolve the GPRS core network platform to support packet-switched services.
- 3G radio access technologies will be based on the Universal Terrestrial Radio Access Networks (UTRANs) that use Wideband-CDMA (WCDMA) radio technologies.

# Third-Generation Partnership Project 2 (3GPP2)

- 3G core networks will evolve the IS-41 core network to support circuit-switched mobile services and define a new packet core network architecture that leverages capabilities provided by the IS-41 core network to support IP services.
- 3G radio access technologies will be based on cdma2000 radio technologies.

# 3GPP conceptual network architecture (Release 5)



# 3.5G

- 3GPP High-Speed Packet Access (HSPA)
- 3GPP2 Evolution - Data Optimized (EV-DO)

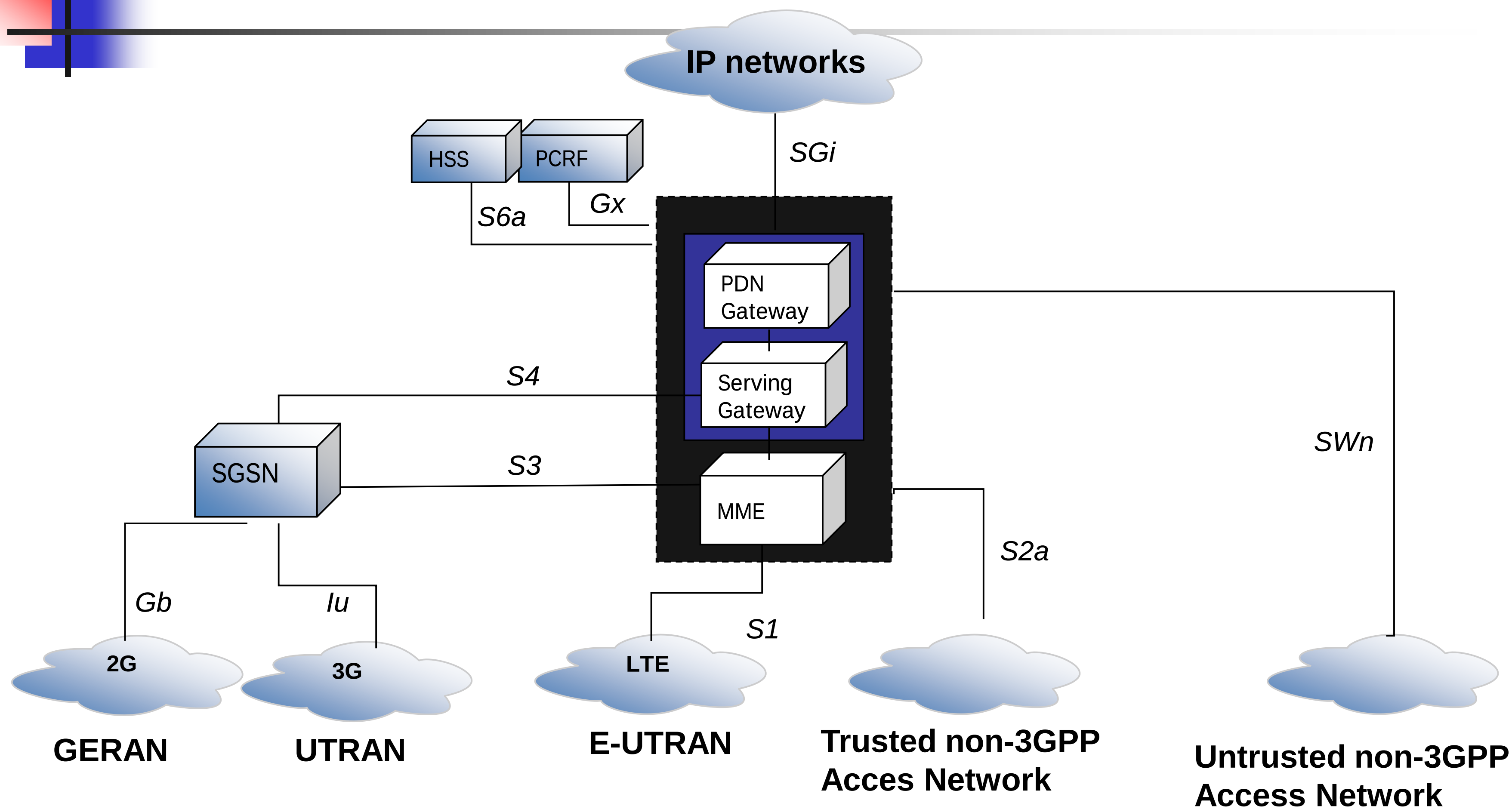
# 4G

- Two 4G candidate systems are commercially deployed:
  - the Mobile WiMAX standard
    - first used in South Korea in 2007
  - the first-release Long Term Evolution (LTE) standard
    - in Oslo, Norway and Stockholm, Sweden since 2009

# 3GPP Architecture (Release 8)

- 3GPP Evolved Packet System (EPS)
  - Radio Side (LTE – Long Term Evolution)
    - Evolved-UTRAN (E-UTRAN)
  - Network Side (SAE – System Architecture Evolution)
    - Evolved Packet Core (EPC)
- 3GPP Release 8 is the first release of the SAE
  - Packet-switched core network only for voice, data, video, and other multimedia traffic
  - Roaming between 3GPP, non-3GPP (trusted and non-trusted), and fixed access networks
  - Designed to optimize network performance

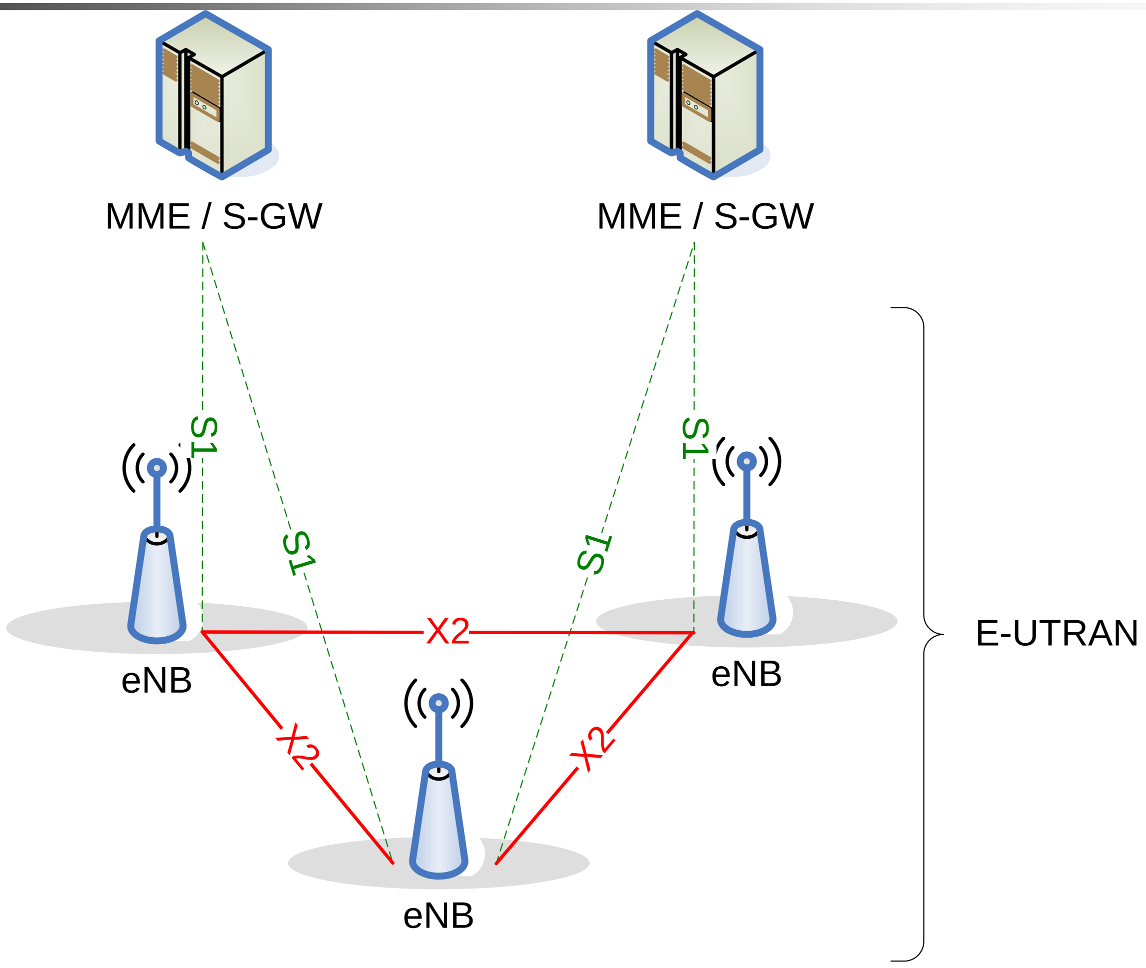
# 3GPP SAE Architecture
## (simplified)



# LTE/SAE Architecture

- All-IP network
- Flat architecture
- Reduce complexity
- Seamless mobility
- Network sharing: a single E-UTRAN can be shared by multiple operators

# E-UTRAN Architecture



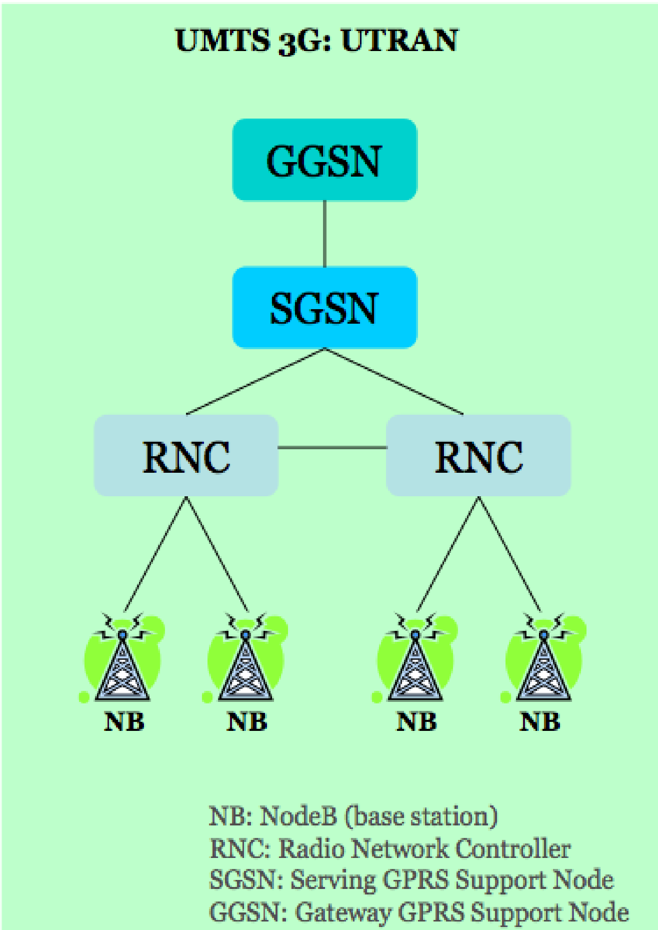
# E-UTRAN

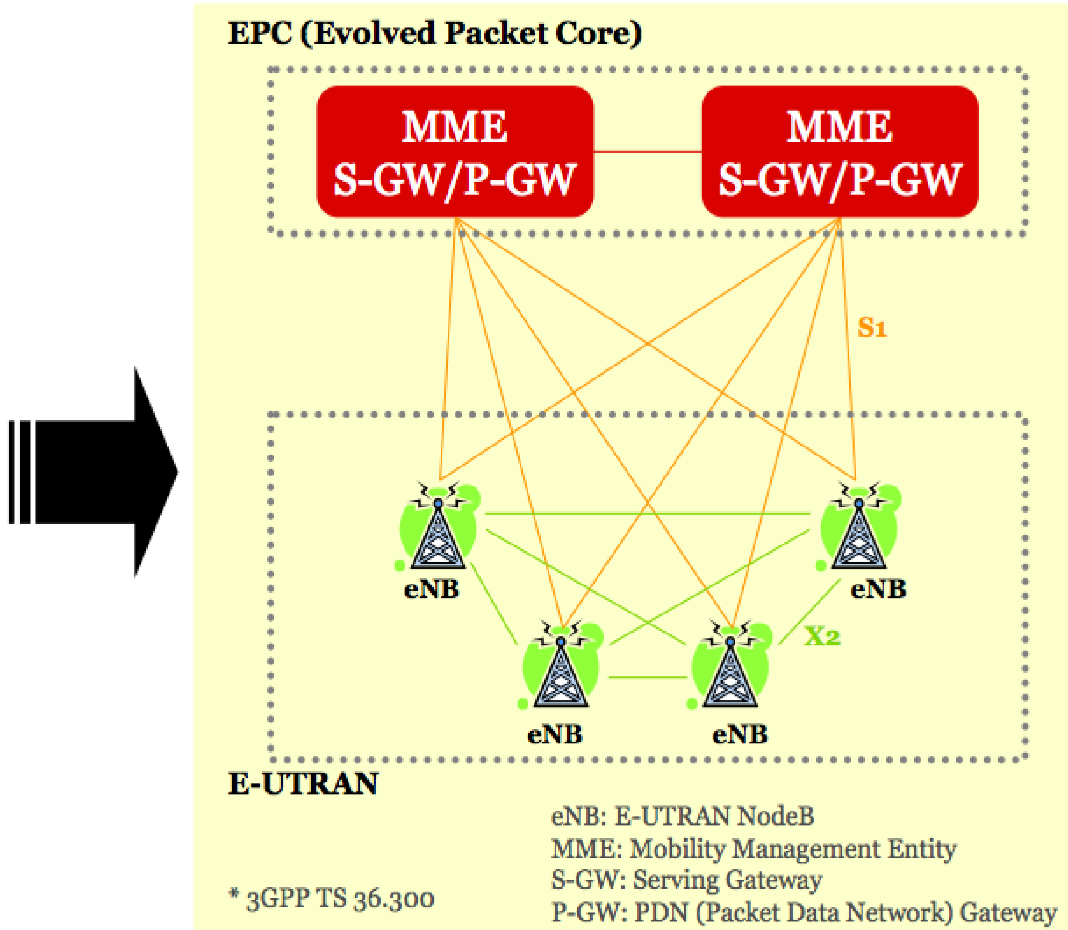
- Only eNodeB in E-UTRAN: support all L1 and L2 features
  - The functions of RNC are distributed between eNodeB, MME, S-GW.
- X2 interface: minimize packet loss due to mobility

# Comparison with 3G/UMTS

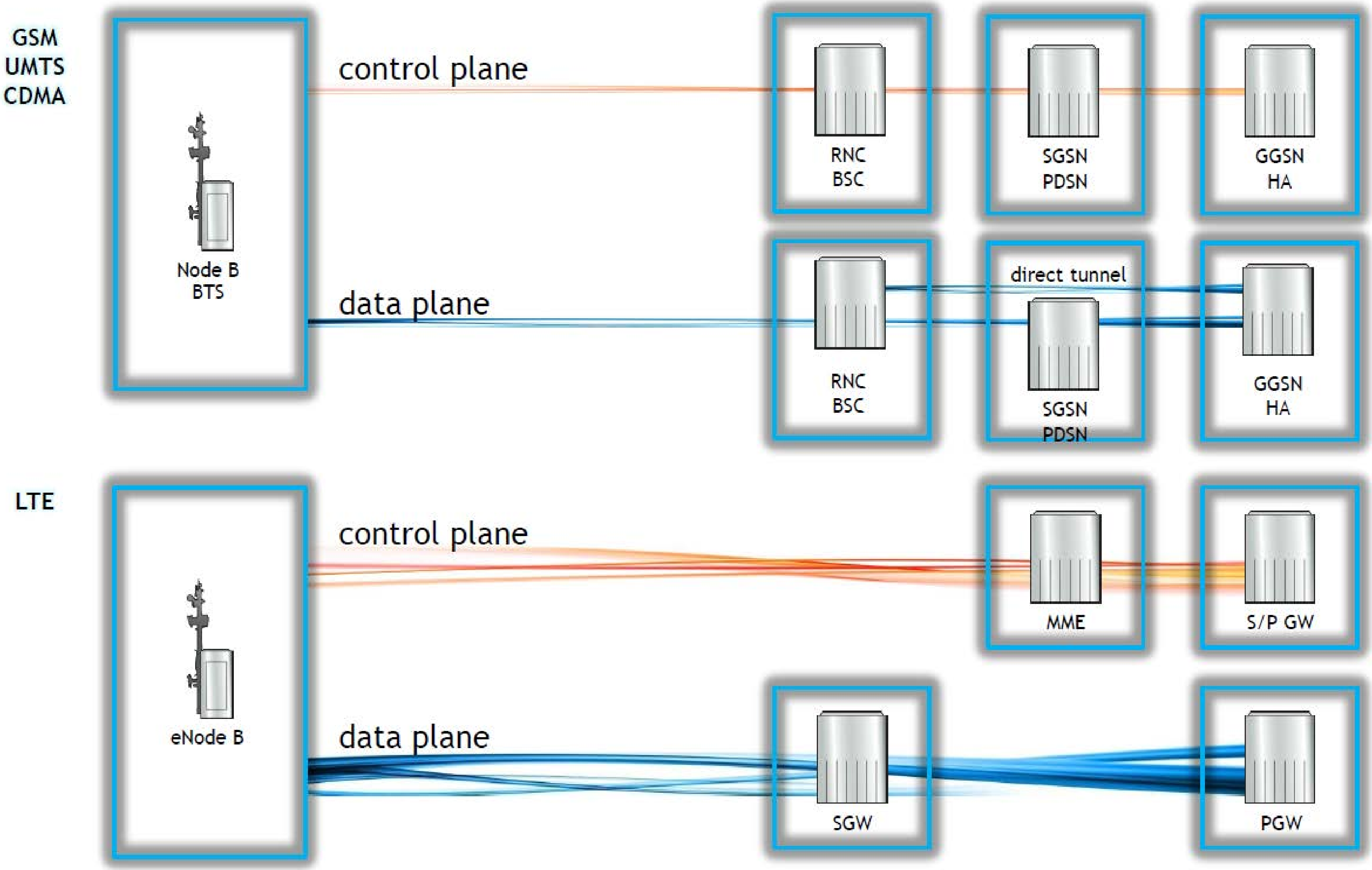
- Simplified architecture/Flat architecture
- Separation of control plane and user plane
- Packet-switched only core network
- Roaming between 3GPP, non-3GPP (trusted and non-trusted), and fixed access networks
- Packets are routed through S-GW for intra E-UTRAN mobility

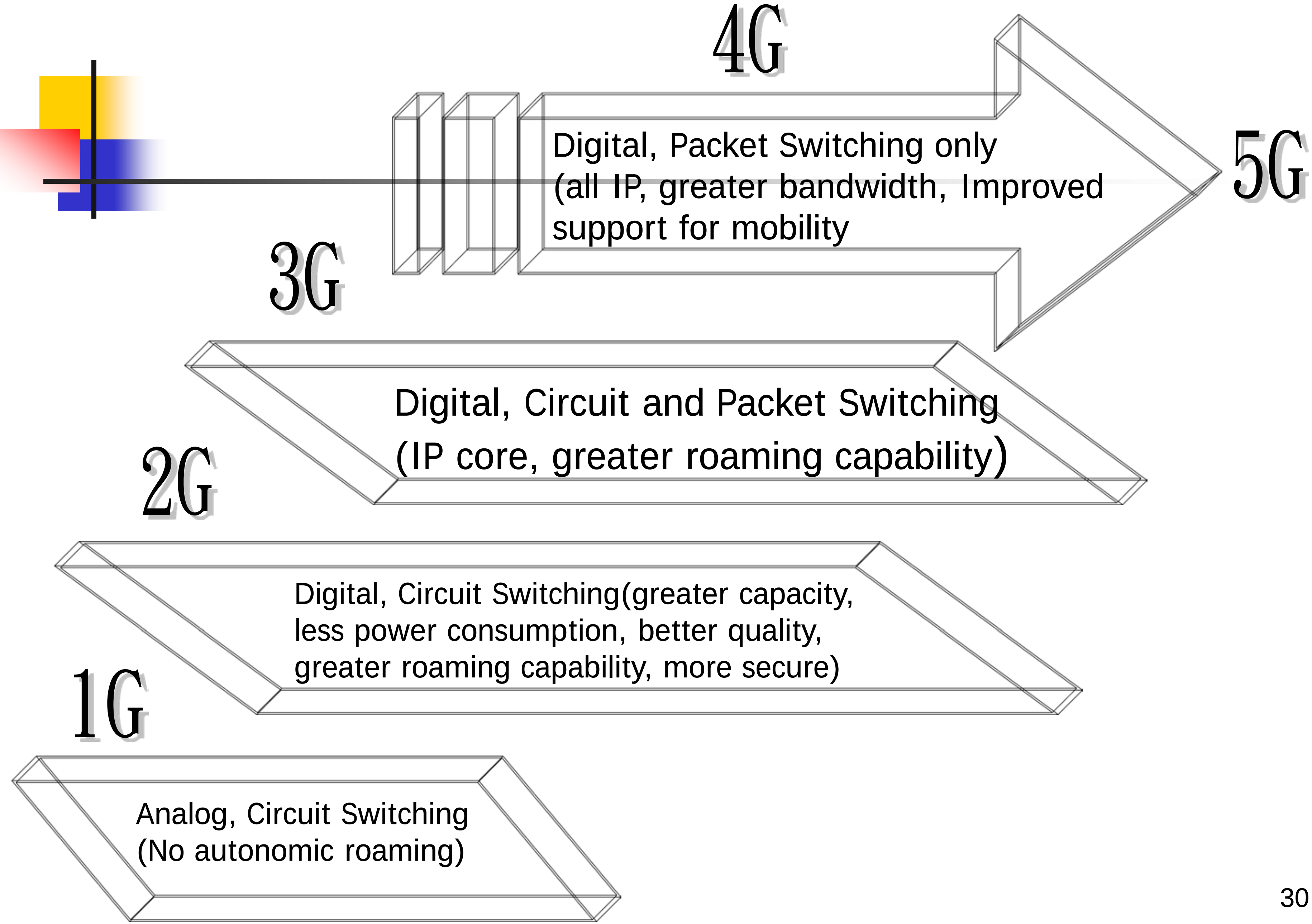
# Architecture Migration



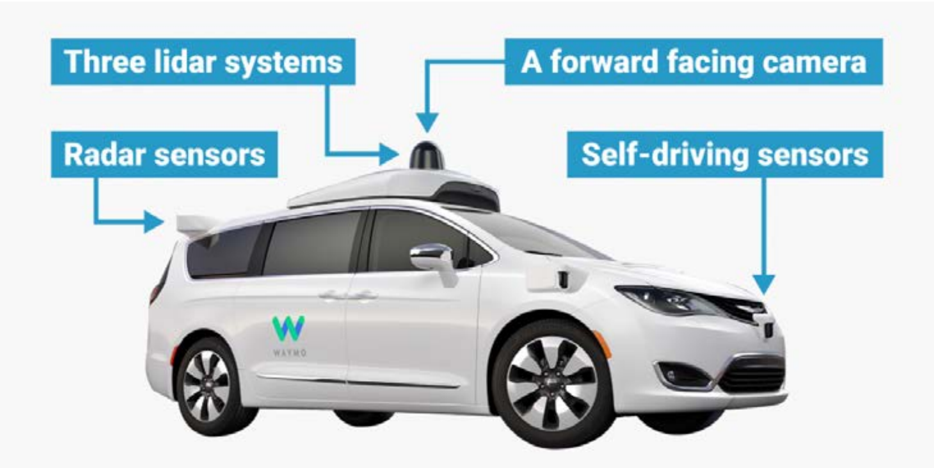
# “Flat IP” = less hierarchy means lower latency



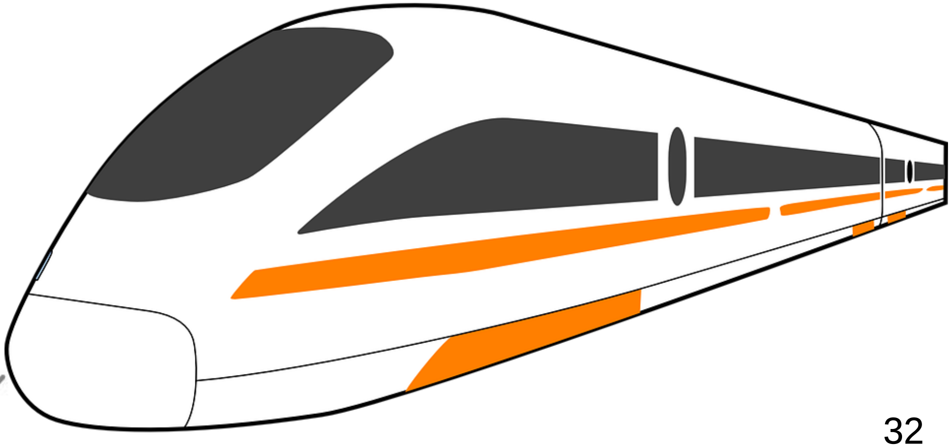

4G
5G
Digital, Packet Switching only
(all IP, greater bandwidth, Improved
support for mobility
3G
Digital, Circuit and Packet Switching
(IP core, greater roaming capability)
2G
Digital, Circuit Switching(greater capacity,
less power consumption, better quality,
greater roaming capability, more secure)
1G
Analog, Circuit Switching
(No autonomic roaming)

# What will 5G be?

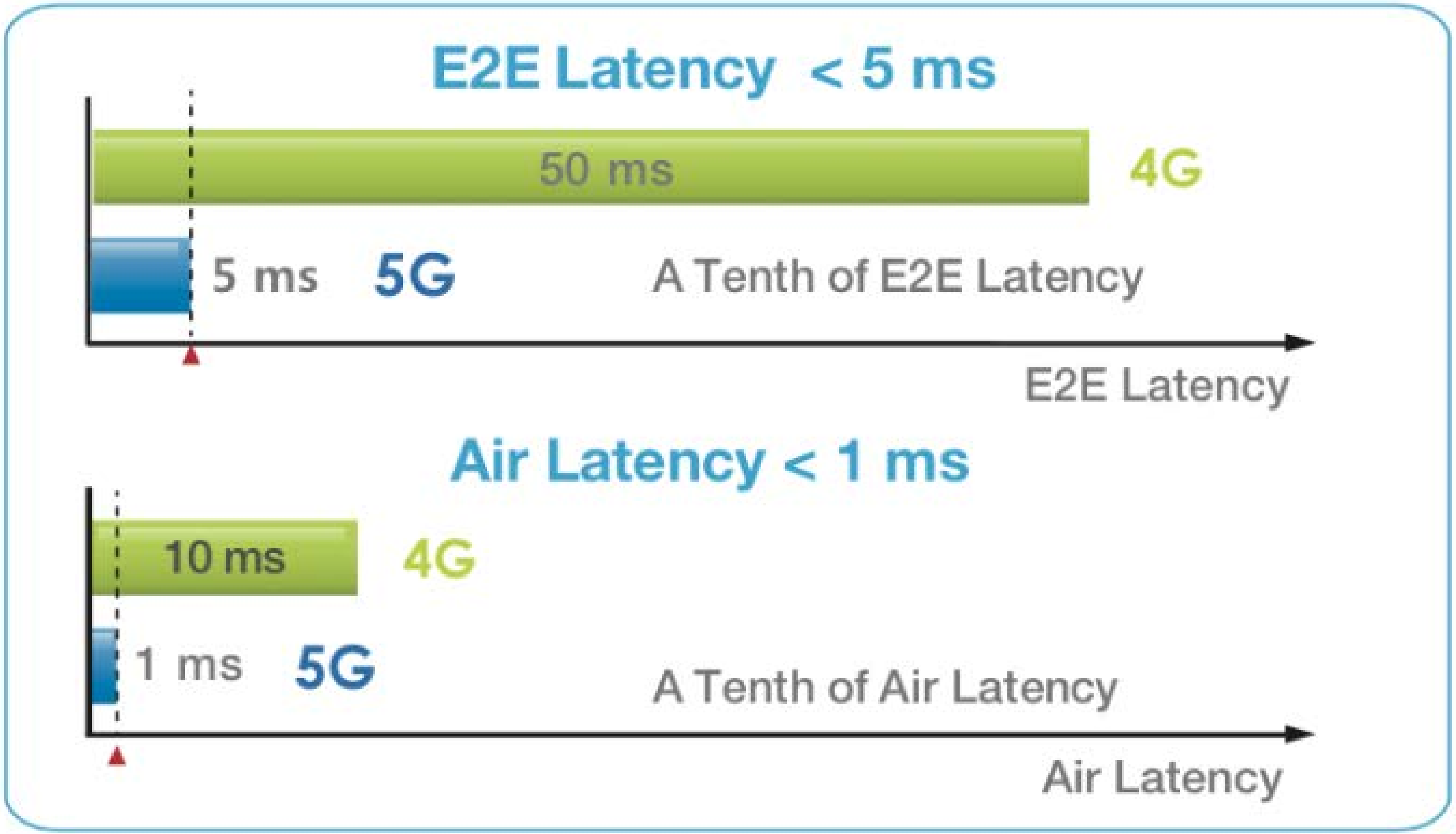
# More and more applications





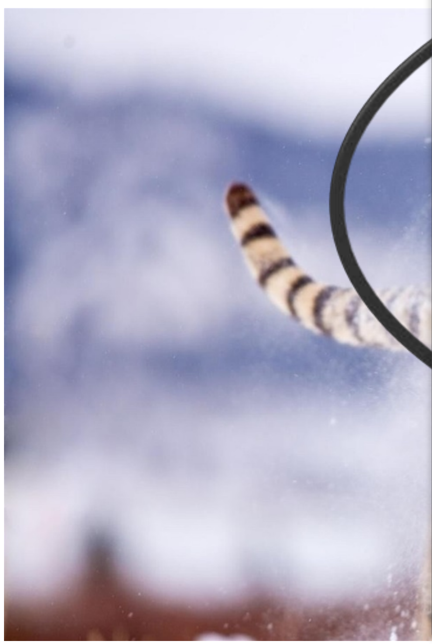


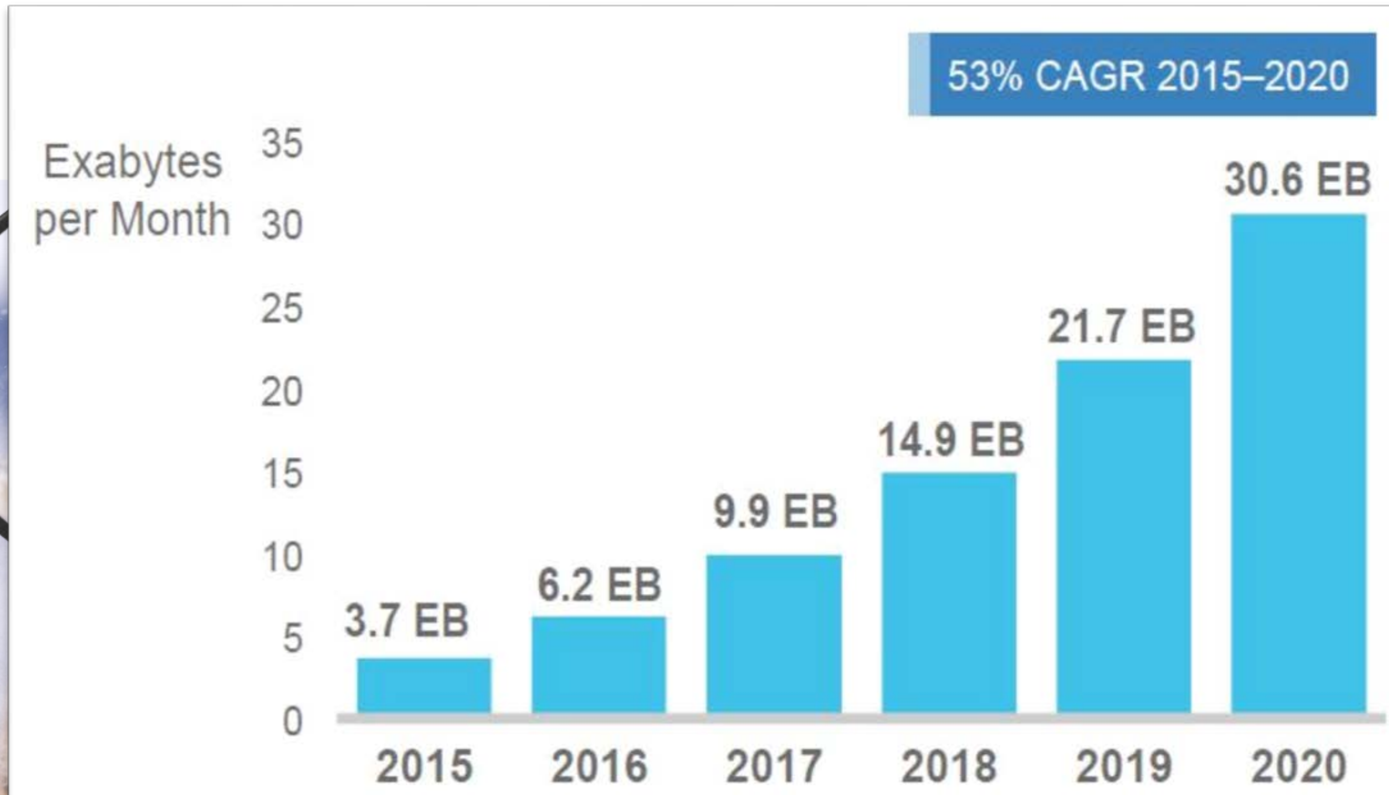
# Lower and lower latency



# More and more data transmitted

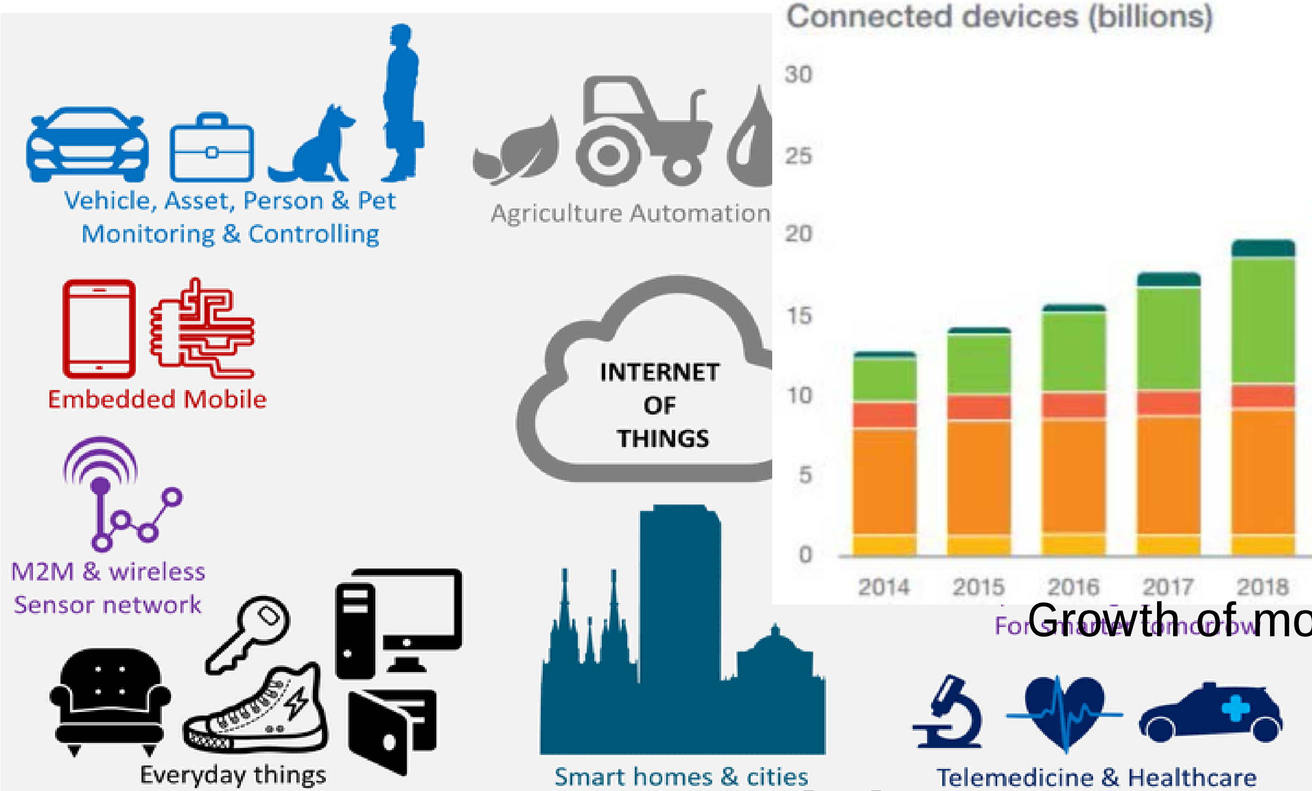
- Explosive social and multimedia services

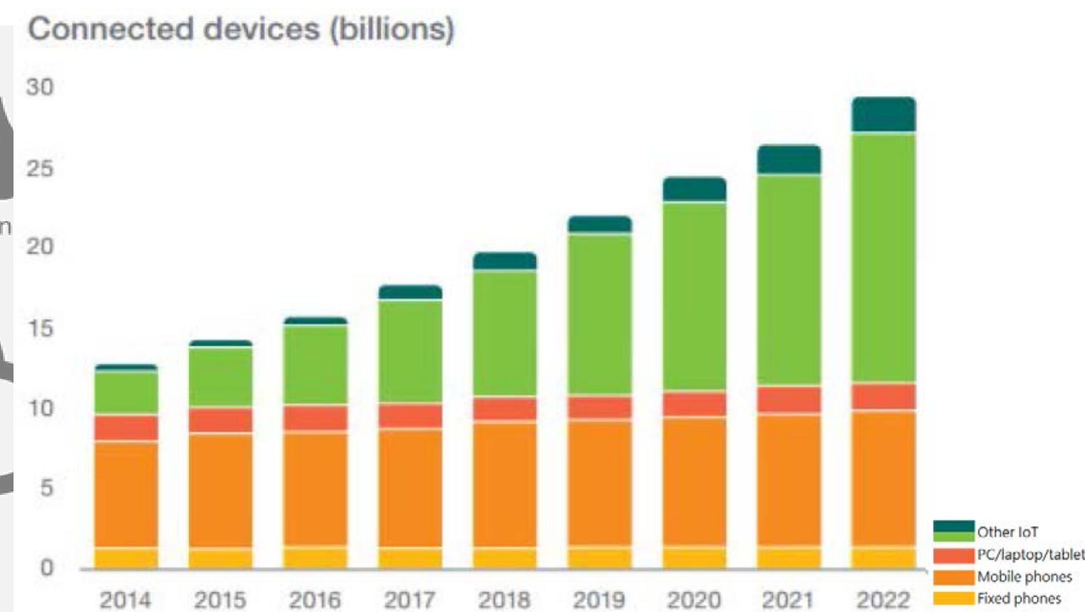





Growth of mobile data traffic [12].

# Not just smartphones anymore



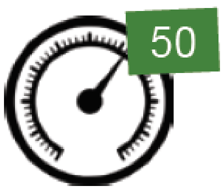

Growth of mobile devices [12].

IoT use cases [13].

# NGMN White paper

**Broadband access everywhere**

50+ MBPS EVERYWHERE

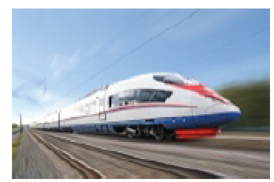



**Broadband access in dense areas**

PERVASIVE VIDEO

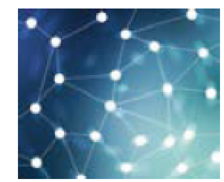
**Higher user mobility**

HIGH SPEED TRAIN



**Massive Internet of Things**

SENSOR NETWORKS

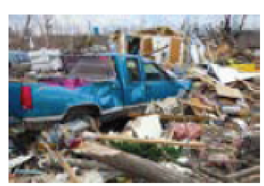


**Extreme real-time communications**

TACTILE INTERNET

**Lifeline communications**

NATURAL DISASTER



**Ultra-reliable communications**

E-HEALTH SERVICES

**Broadcast-like services**

BROADCAST SERVICES

# 1G to 4G

- Mainly used by human beings
  - 1G and 2G were about voice
  - 3G was about data
  - 4G is about video

# 5G

- 5G, will be about intelligent networks that can handle billions of connected devices while remaining stable and operational.

Source: http://money.cnn.com/2012/03/08/technology/5G-wireless/index.htm?iid=GM

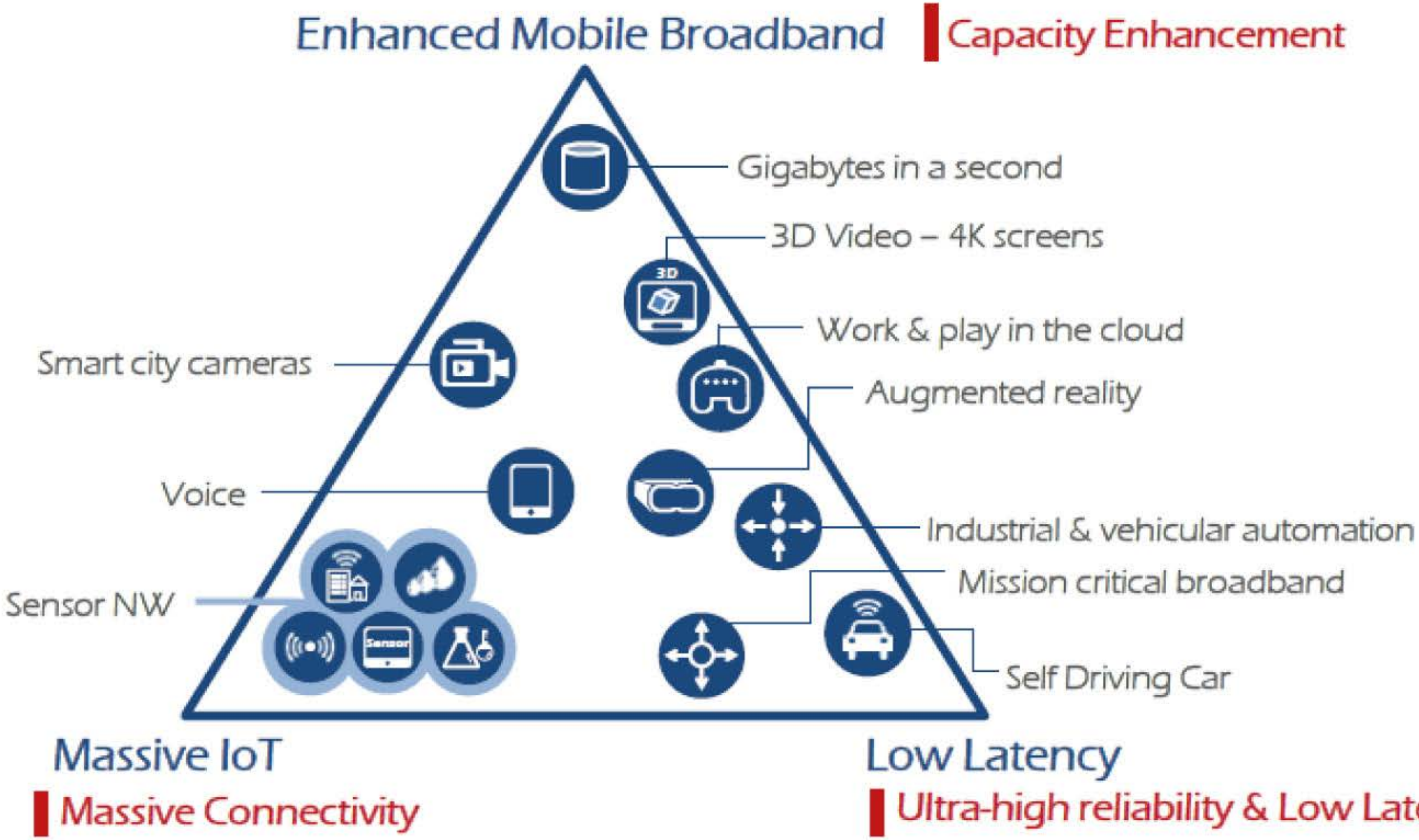
# 5G Vision


source：IBM, Microsoft, Sony, NTT DoCoMo

# NGMN 5G vision

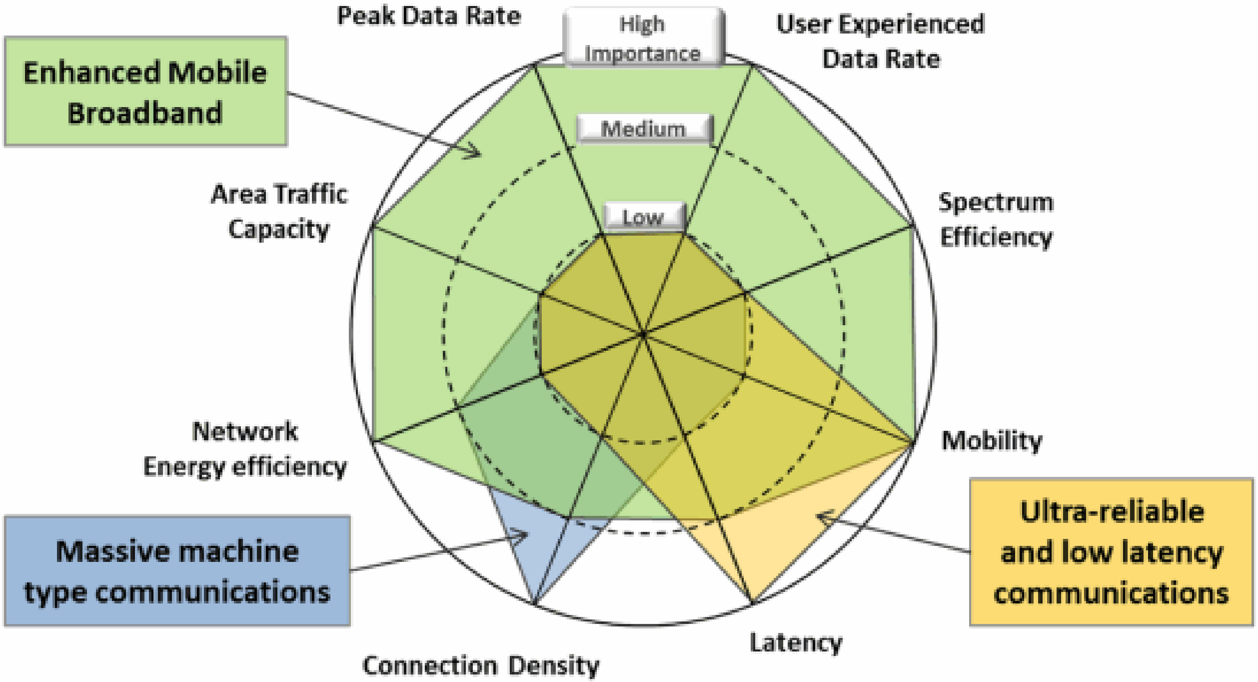
- Faster data rate: 1~10 Gbps
  - Download HD videos in seconds, AR, VR
- Lower end-to end latency: 1~10ms
  - Autonomous driving, Tactile Internet, Interactive applications
- Higher user mobility: >500km/h
  - High Speed Train
- Broadband access in dense areas
  - HD video/photo sharing in stadium
- Ultra-reliable communications
  - E-health, Remote surgery, Drones
- Massive machine type communications
  - Smart grid, Smart transportation, Industrial 4.0 (Internet of Things)

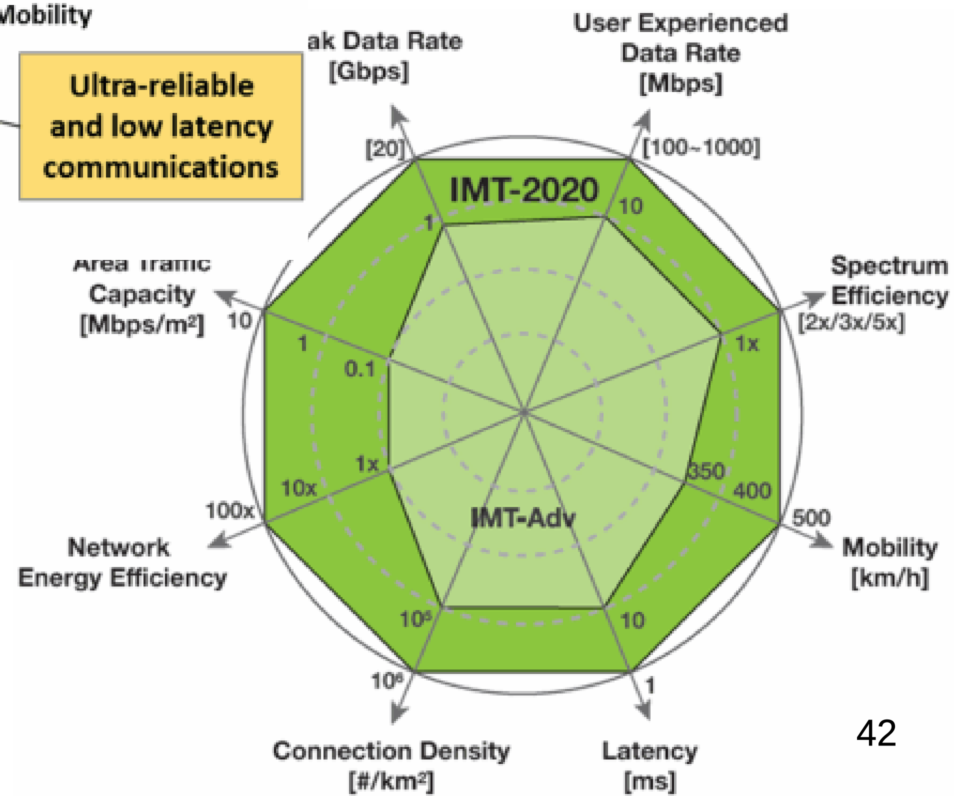
# Three key use cases of 5G




(Source: ETRI graphic, from ITU-R IMT 2020 requirements)

# Key capabilities of 5G

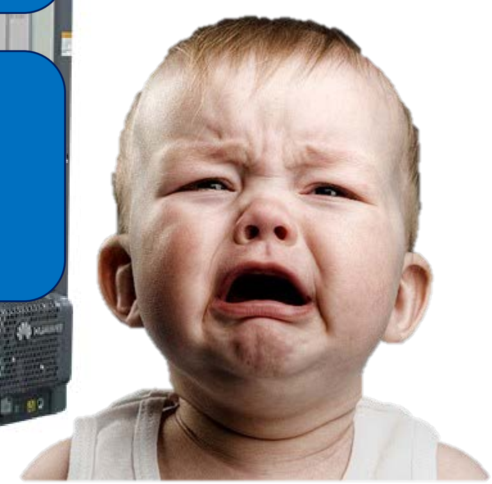



Source ITU-R M.2083-0

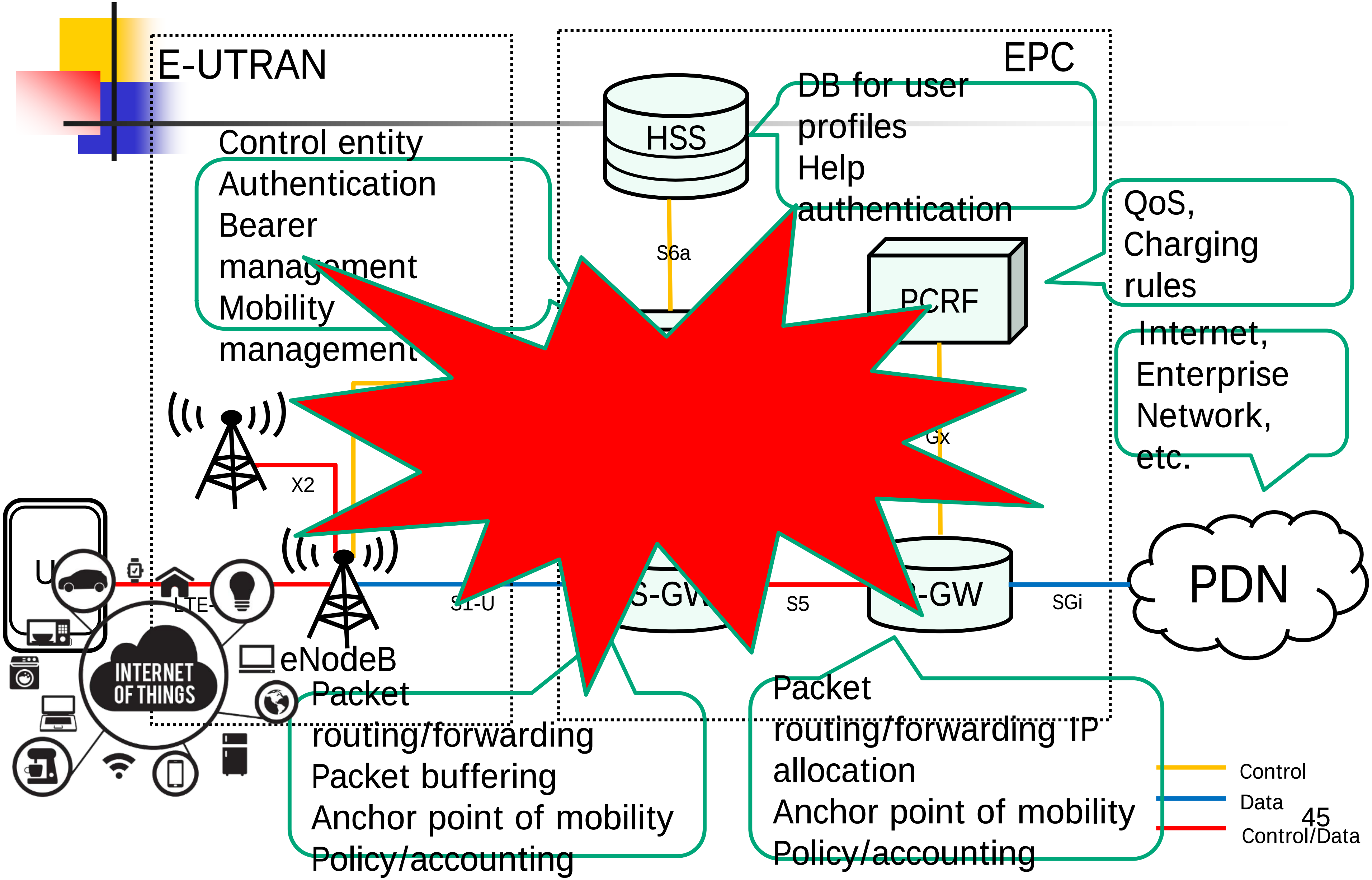
# What’s wrong with the current 4G core network?

# All Propriety Hardware

Huawei eCNS600 eLTE Core Network Access System

# Current 4G Architecture



# High cost, low revenue

## limits innovation

## Not flexible

# How to solve?

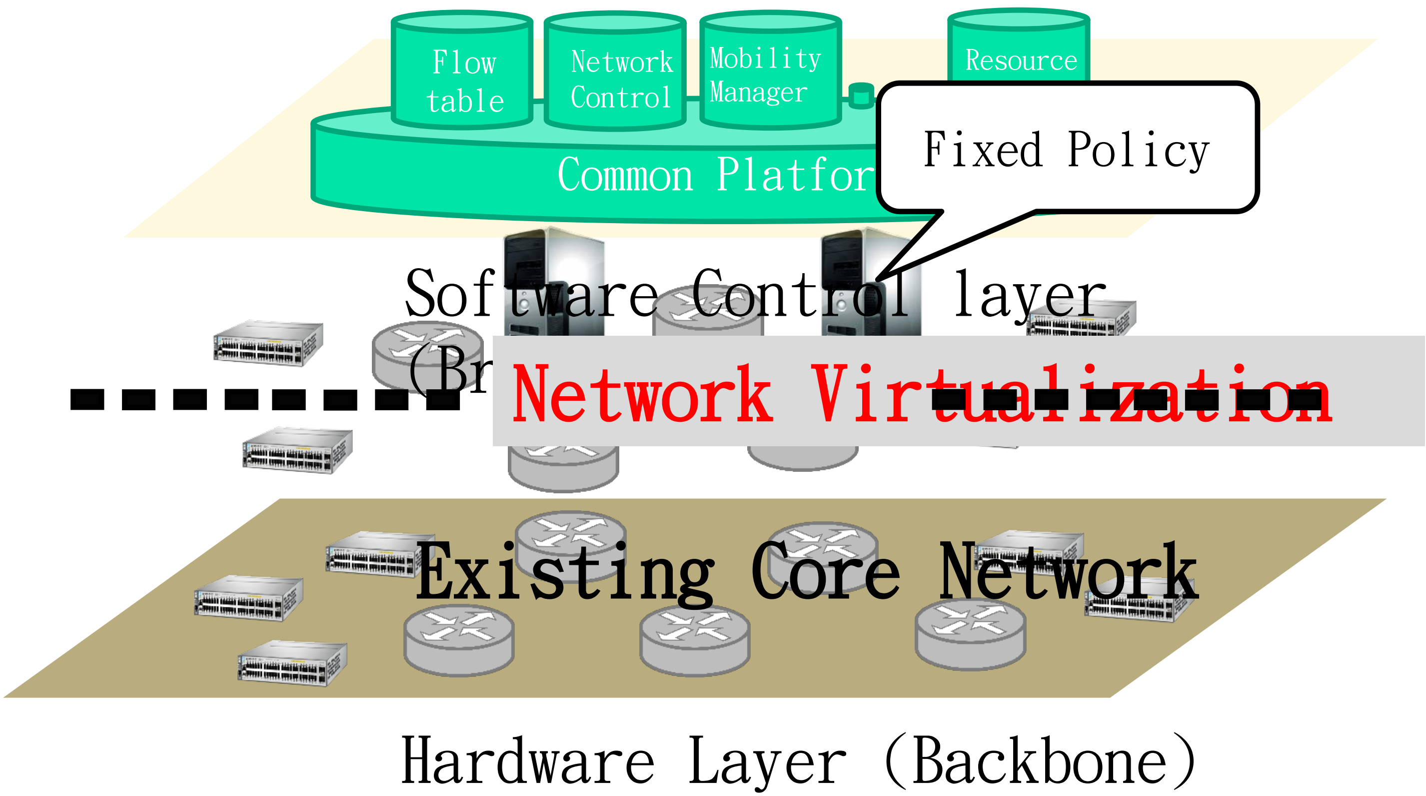
# Softwarization

# (SDN/NFV)

# 5G architecture based on SDN/NFV

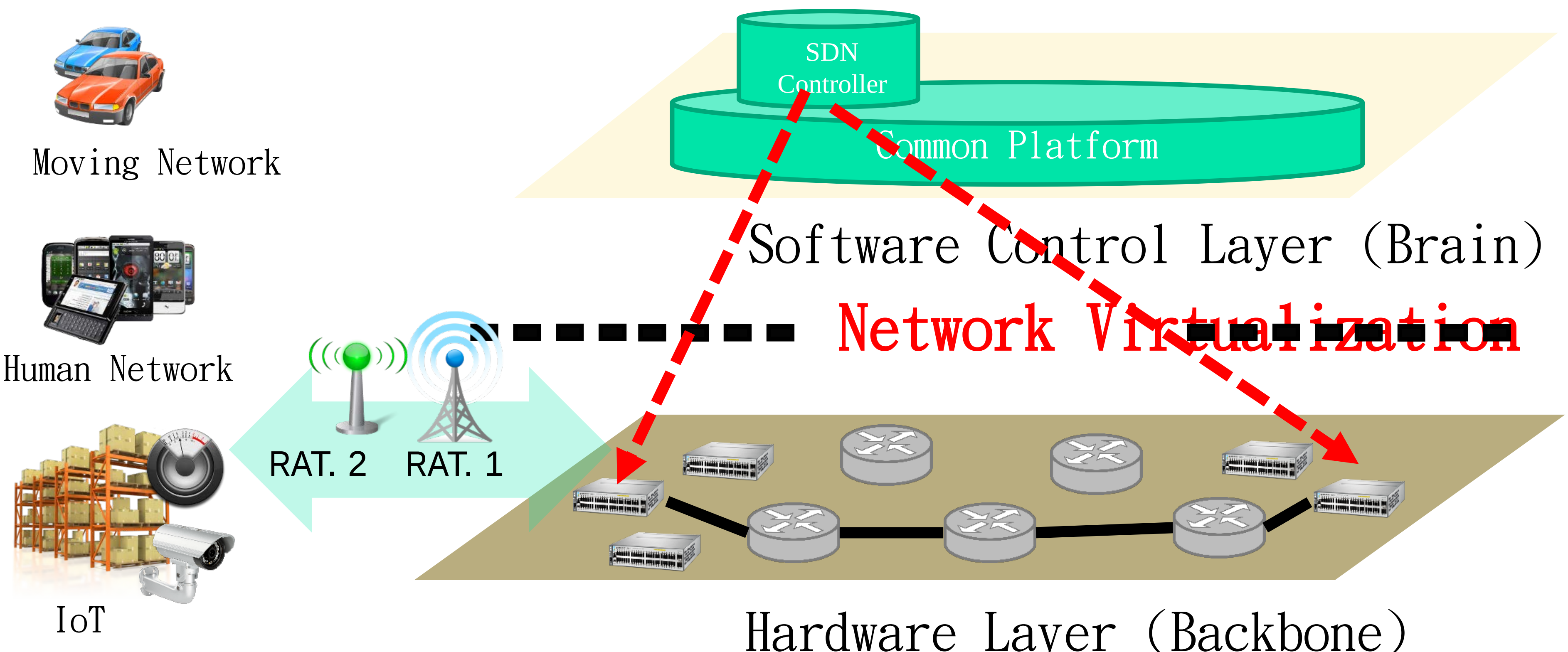
# NFV

**Network Function Virtualization**

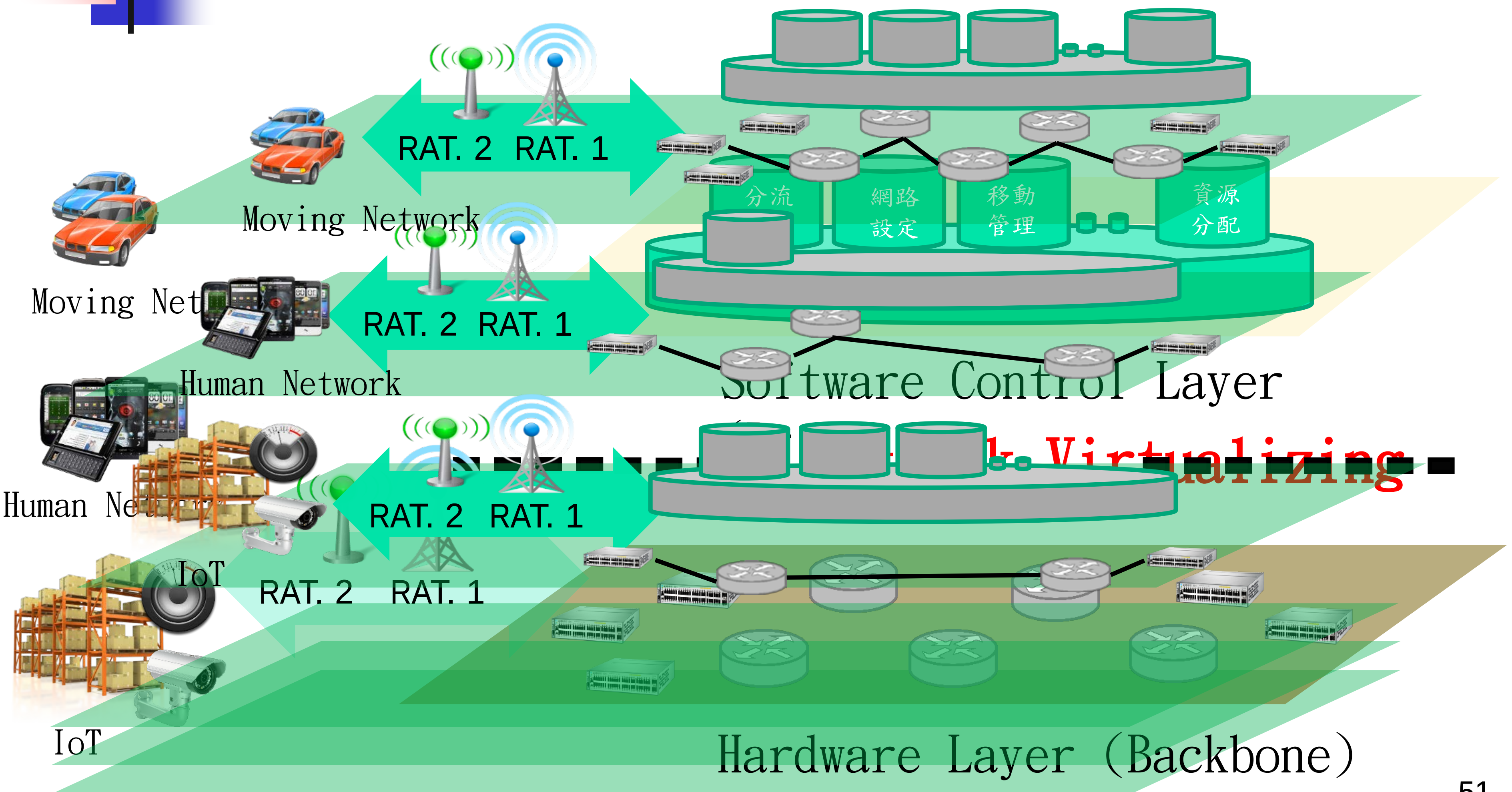


# SDN

**Software-defined network**



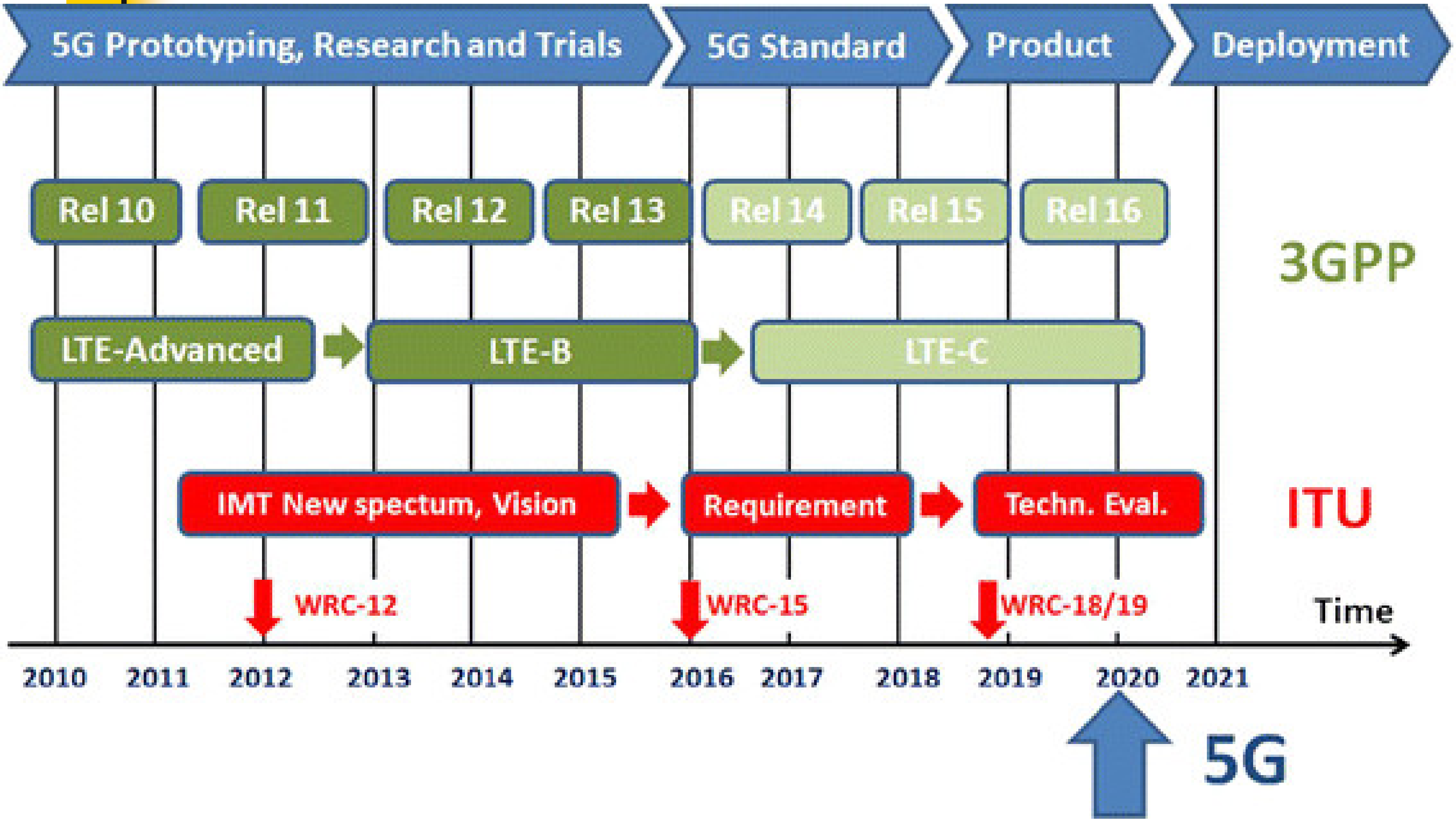
# Network Slicing



# Benefits of Softwarization

- Reduced cost
  - Reduced equipment costs and reduced power consumption
  - Eliminate unneeded feature
  - Scale in/out according to network demand
- Rapid innovation
  - Innovation at software speed
  - Can do experiments
  - Standards will follow software deployments
  - Open up network innovation to great minds around the world
- flexibility
  - Deploy services according to geography
  - Deploy services according to user characteristics
  - Dynamically route packets to its particular network slice

# 5G roadmap and timeline



# Research topics of softwarization

- How to integrate OpenFlow-based data plane with legacy 4G core network data plane?
- How to retain the required performance for network entities while it is virtualized?
- How to design and implement the automatic self-management MANO system?
- ……
- **How to implement customized VNFs efficiently for a flexible *OPEN* 5G core?**

# Reconfigurable Core

# (RECO)

# Use cases

- For remote-control surgery
- For high-speed users

# For remote-control surgery

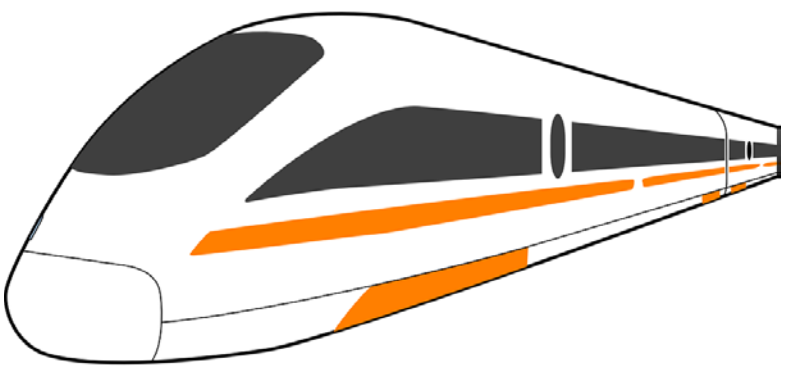
- Low latency → GTP module
- High security → NAS and S6a module

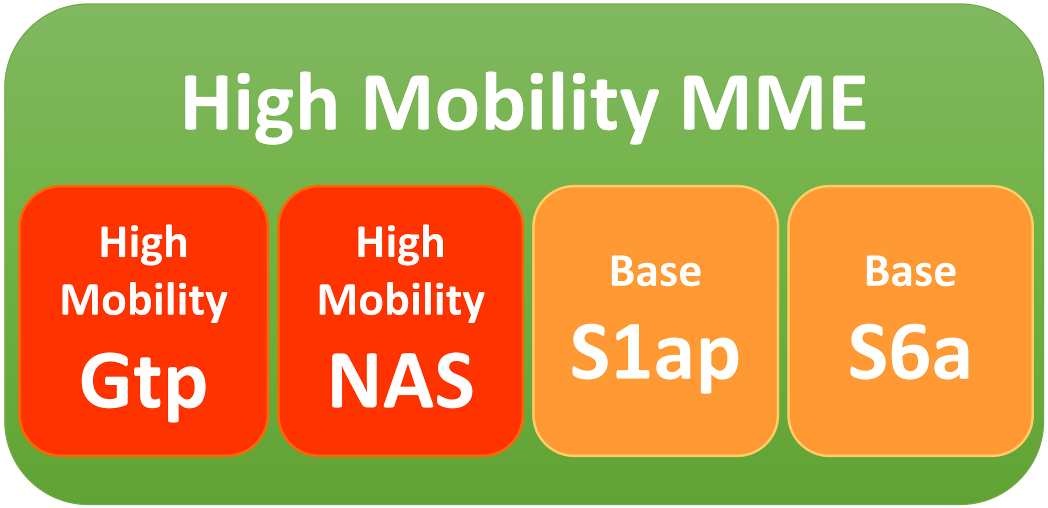
Healthcare MME

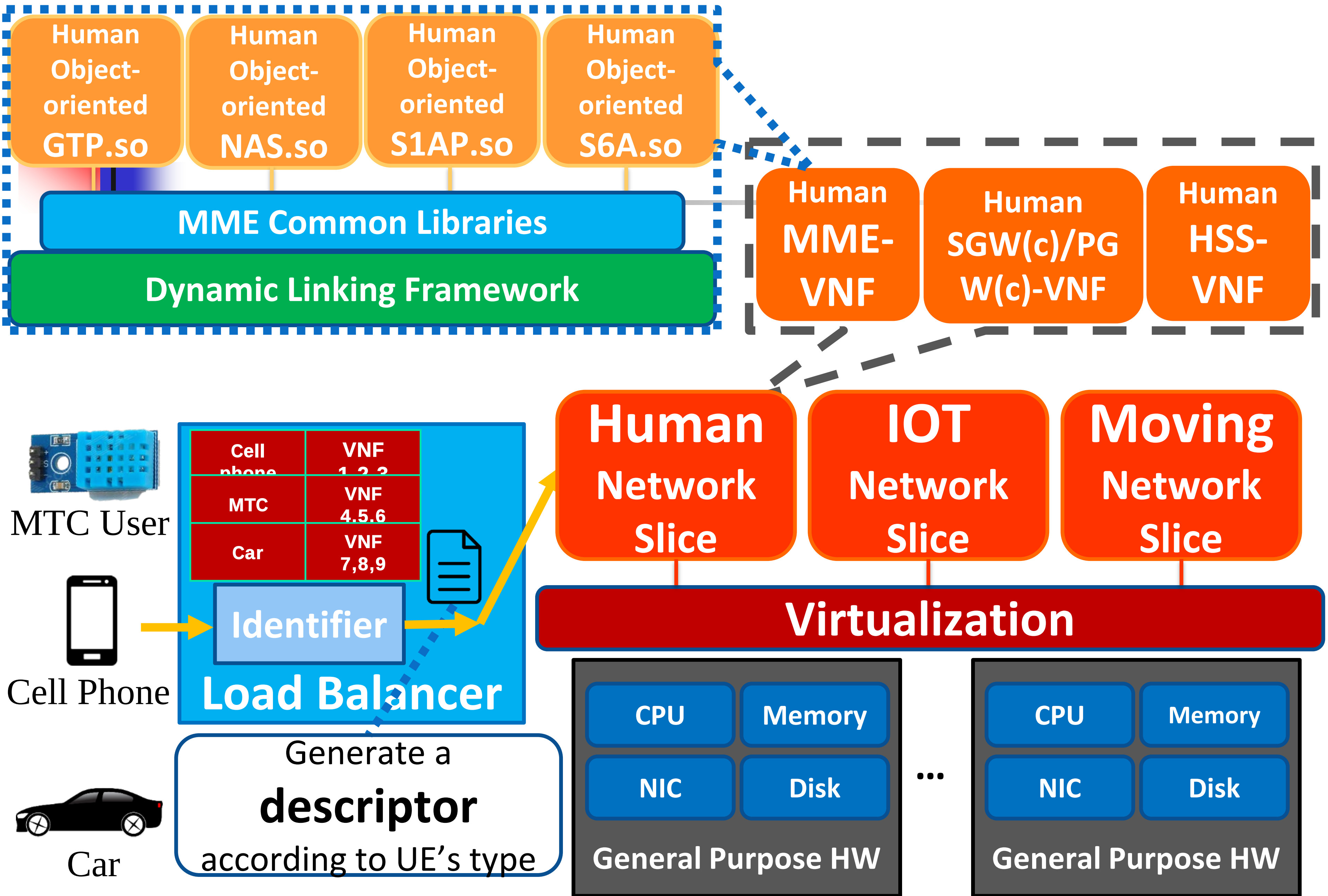
Healthcare Gtp | Healthcare NAS | Base S1ap | Healthcare S6a

# For high-speed users

- High mobility → GTP module
- Frequent handover and location update → NAS module

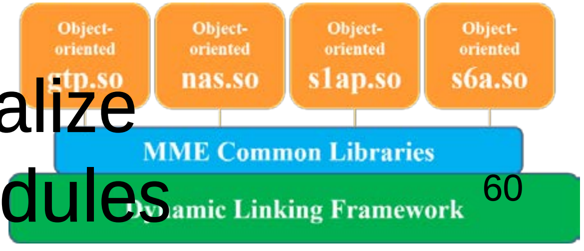




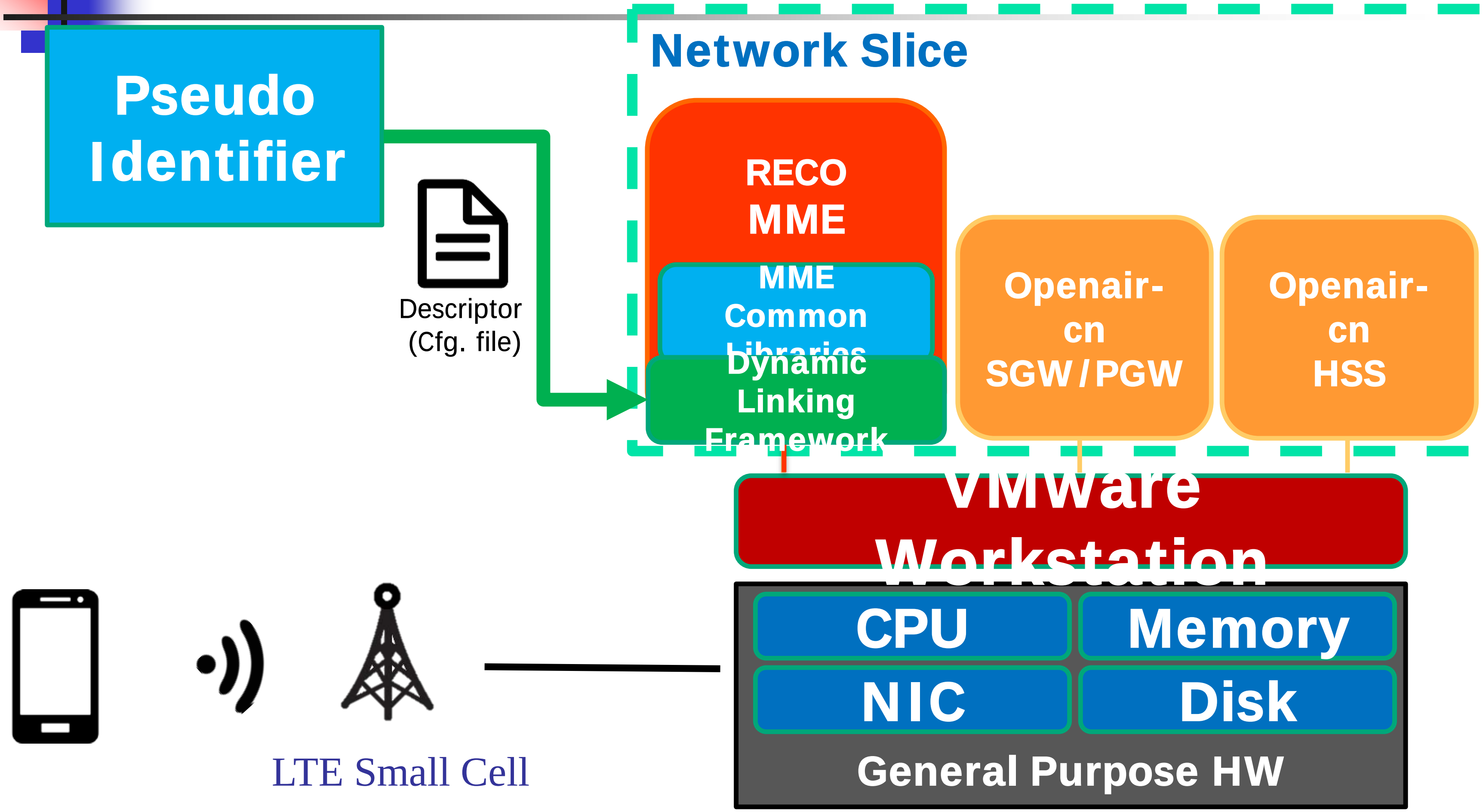

Human Object-oriented GTP.so
Human Object-oriented NAS.so
Human Object-oriented S1AP.so
Human Object-oriented S6A.so
MME Common Libraries
Dynamic Linking Framework
Human MME-VNF
Human SGW(c)/PGW(c)-VNF
Human HSS-VNF
Human Network Slice
IOT Network Slice
Moving Network Slice
Virtualization
MTC User
Cell Phone
Car
Cell
VNF
MTC
VNF 4,5,6
Car
VNF 7,8,9
Identifier
Load Balancer
Generate a
descriptor
according to UE's type
CPU
Memory
NIC
Disk
General Purpose HW
...
CPU
Memory
NIC
Disk
General Purpose HW

# Reconfigurable Core (RECO)

- Common modules
  - common MME libraries which different types of users share. E.g., UDP, SCTP, hash table
- Object-oriented customized modules
  - customized modules which differ between different types of users
- Dynamic Linking Framework
  - parse descriptor load and initialize corresponding customized modules



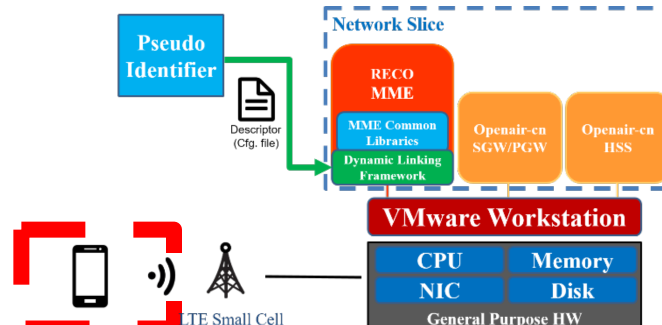
# Verify the correctness of RECO MME



# Equipment (1/2)

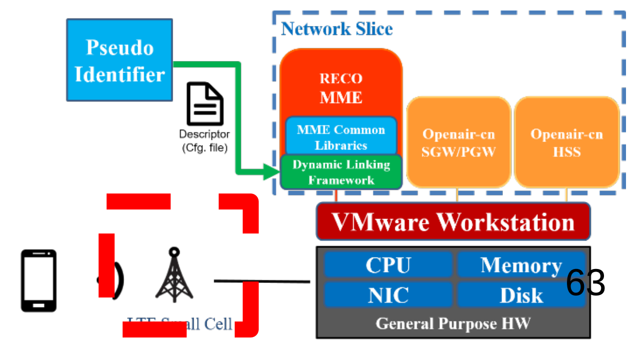
- UE1: Sony Xperia T3 D5103
- UE2: ASUS UX410 & Huawei LTE Dongle
- Programmable SIM card programmed by PySIM



# Equipment (2/2)

- LTE Small Cell: Wistron NeWeb OSQ4G-01E2

# Demo Video

# Comparison

| | Open source | Completeness | Status | Reduce Disk & memory | Flexibility | OOP design |
|---|---|---|---|---|---|---|
| Open5GCore | No, very expensive | V | Active | V | V | |
| OpenEPC | No, very expensive | V | Active | V | V | |
| nwEPC | V | | Frozen | | | |
| Openair-cn | V | | Active | | | |
| **RECO** | **V** | | **Active** | **V** | **V** | **V** |

# Concluding remarks of RECO

- Absolutely free
- Easy to install (hopefully)
- Object-Oriented Programming (OOP) design
  - easier to understand, reuse, modify, and extend
  - Easily to add your own modules
    - Real core network to implement your ideas, not just simulation and/or math analysis
  - Professors can design labs for students

# Building Blocks For 5G CN

| | | | | |
|---|---|---|---|---|
| Control plane(NFV+Cloud) | Network Data Analytics | PaNDA | | |
| | Management & Orchestration | Open Source MANO | OPEN BATON | ECOMP |
| | Virtual Network Functions | OPEN AIR INTERFACE 5G | nwEPC | RECO |
| | VIM Management System | openstack | | |
| Data plane(SDN) | Network Control | OPEN DAYLIGHT | ONOS | OPENCONTRAIL |
| | IO Abstraction | OvS Open vSwitch | DPDK DATA PLANE DEVELOPMENT KIT | OpenDataPlane .org |
| | | fd.io | | |
| HW/OS | Operating Systems | Linux | | |
| | Hardware | OPEN Compute Project | | |

RECONet

- This is just a first step.
- Please use it, give us feedbacks, and even join us to develop the first comprehensive, free, and open-source 5G core network.

# For more information

- Website: http://www.reconet.org/
- Video: https://youtu.be/6iuCq350LYM
- Source code: https://github.com/RECONet/RECO
- Paper: “Poster - RECO: A Reconfigurable Core Network for Future 5G Communication Systems,” to appear in ACM MobiCom, Snowbird, Utah, USA, Oct. 2017

Thank You