Οικονομικό Πανεπιστήμιο Αθηνών
Τμήμα Πληροφορικής

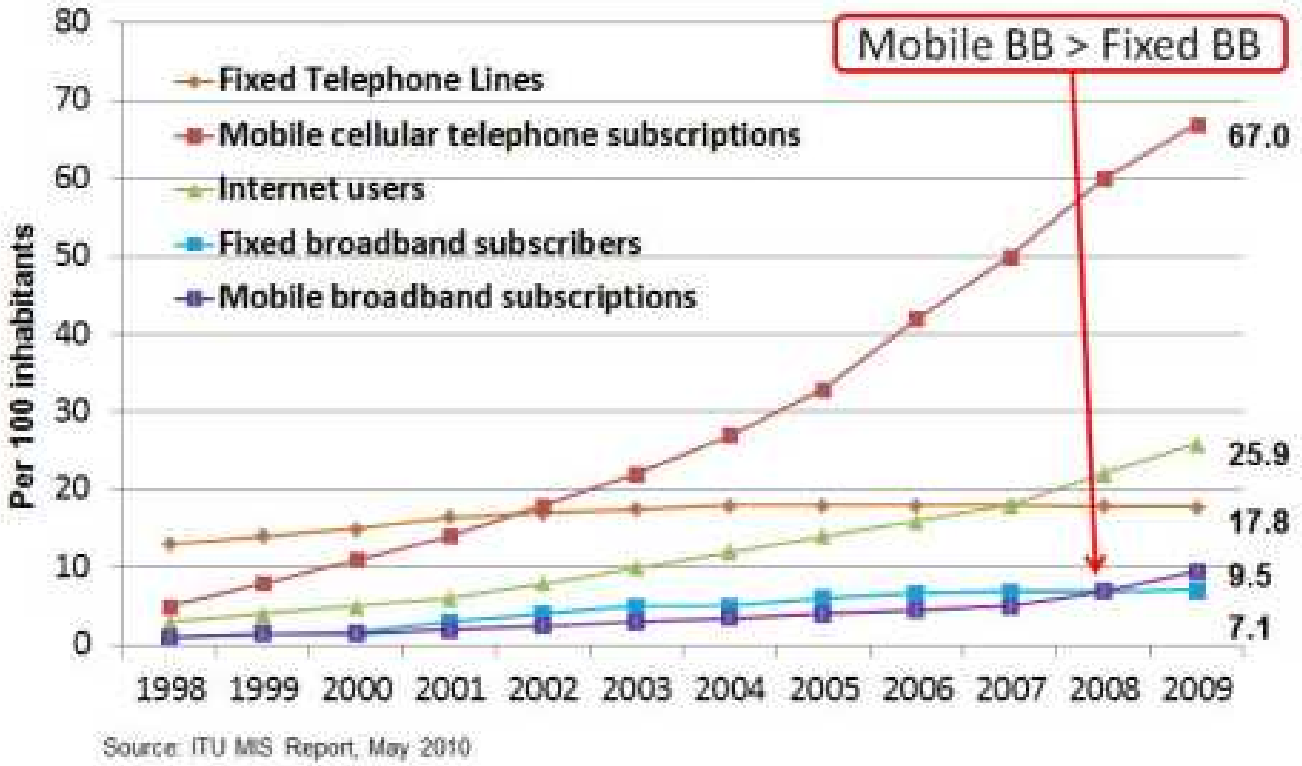
Ευφυή Κινητά Δίκτυα: Επισκόπηση και Τάσεις

Εαρινό Εξάμηνο 2024

Yannis Thomas

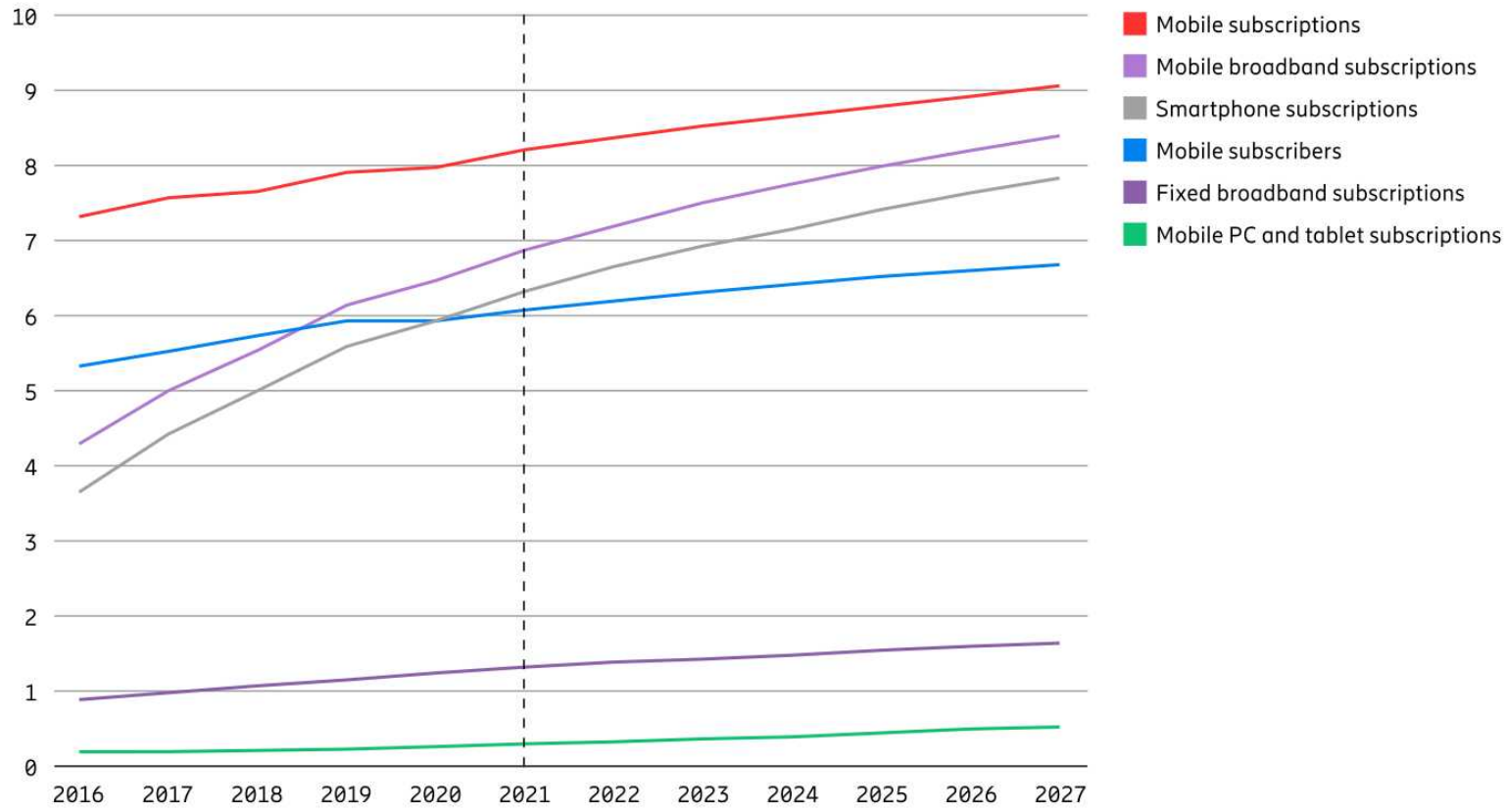
Based on slides made by Βασίλειος Σύρης

Fixed versus mobile broadband



Current period

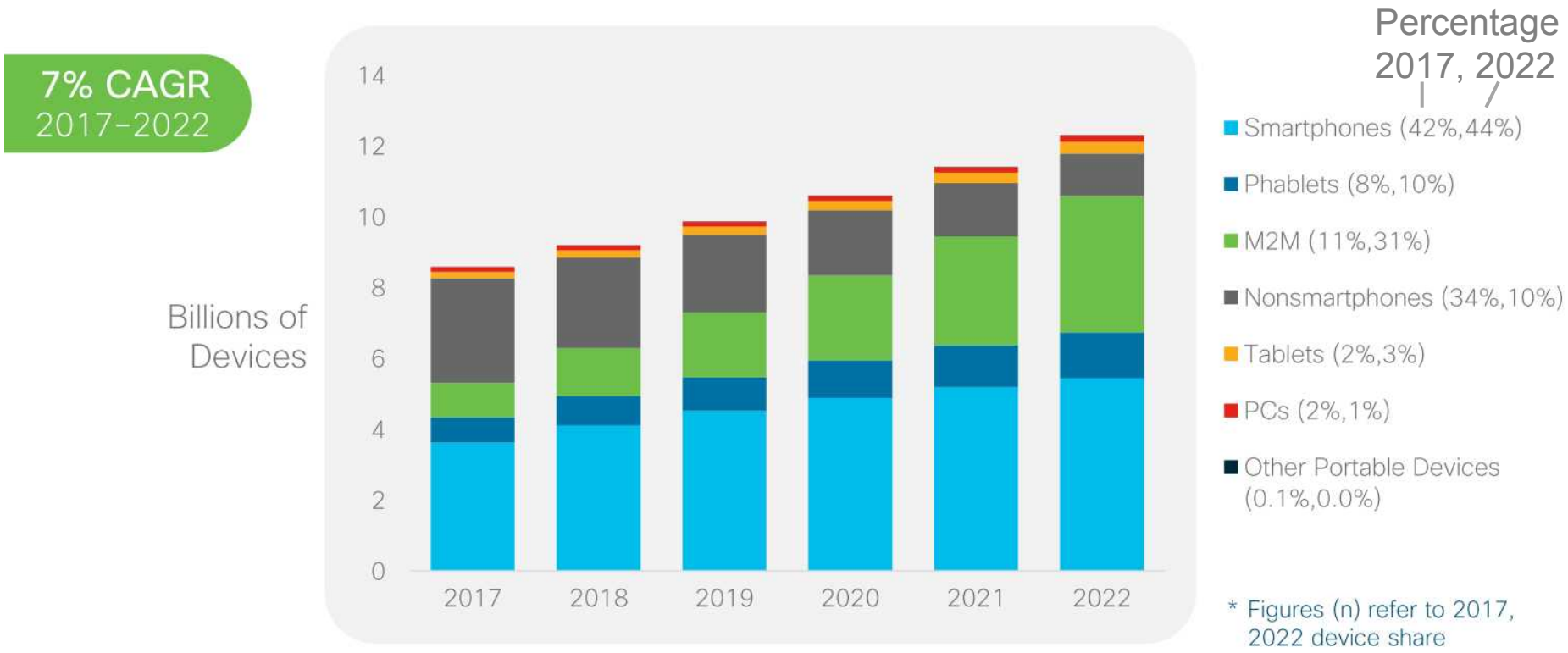
Subscriptions increasing faster than subscribers



eport, June 2022

Check for yourself: https://www.ericsson.com/en/reports-and-papers/mobility-report/mobility-visualizer

Global mobile device growth

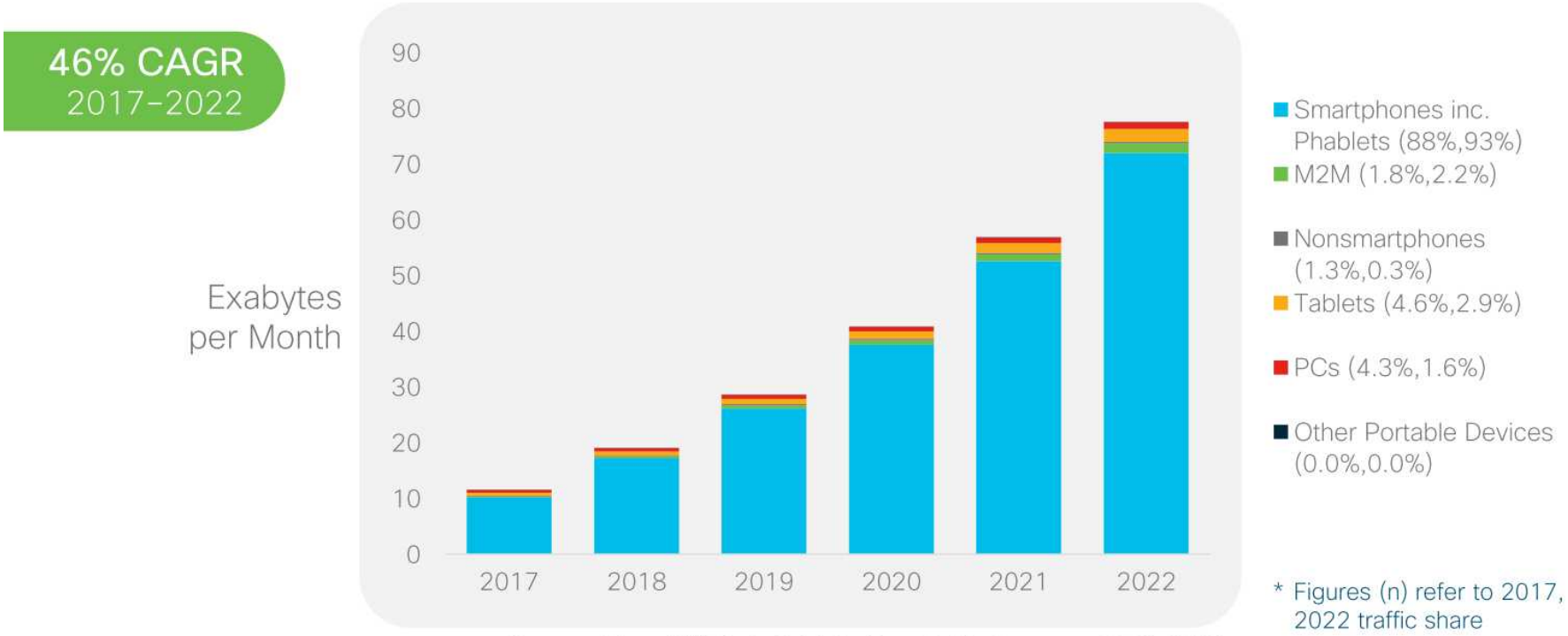


CAGR: Compound Annual Growth Rate

Source: Cisco VNI Global Mobile Data Traffic Forecast Update, 2017-2022

Traffic volume and device type

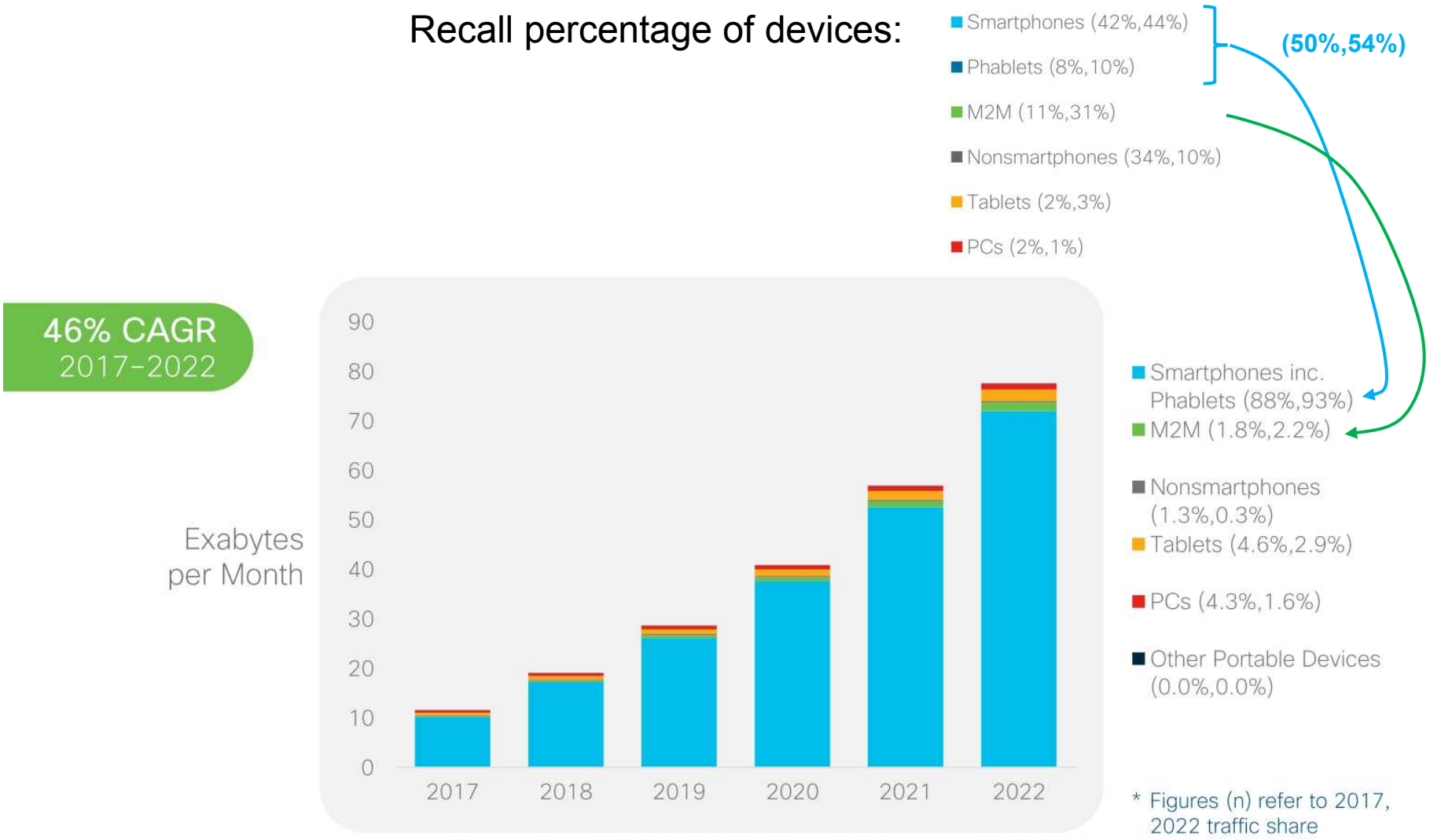
Exabyte = 2^16bit !!



Source: Cisco VNI Global Mobile Data Traffic Forecast Update, 2017-2022

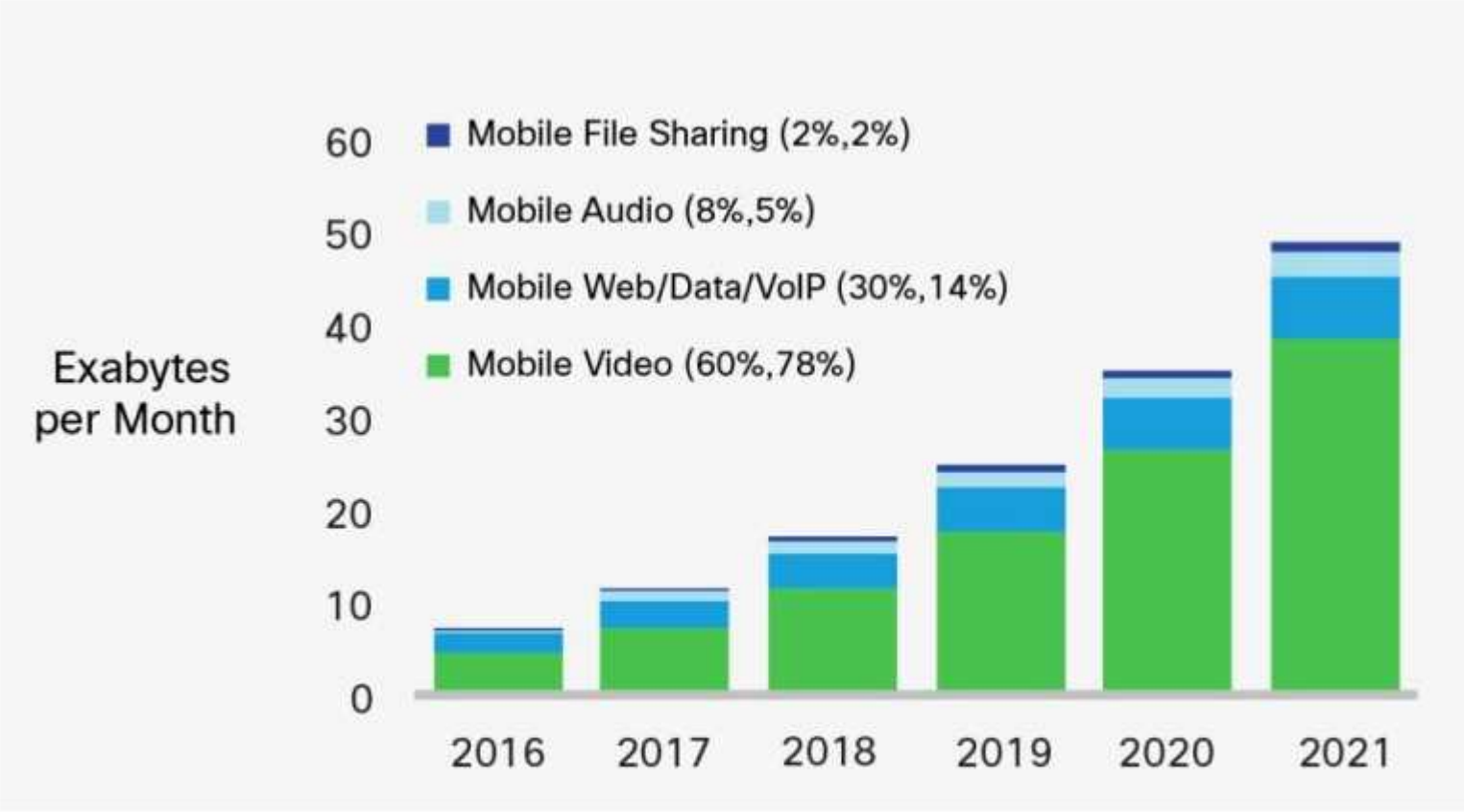
Traffic volume and device type

Recall percentage of devices:



Source: Cisco VNI Global Mobile Data Traffic Forecast Update, 2017-2022

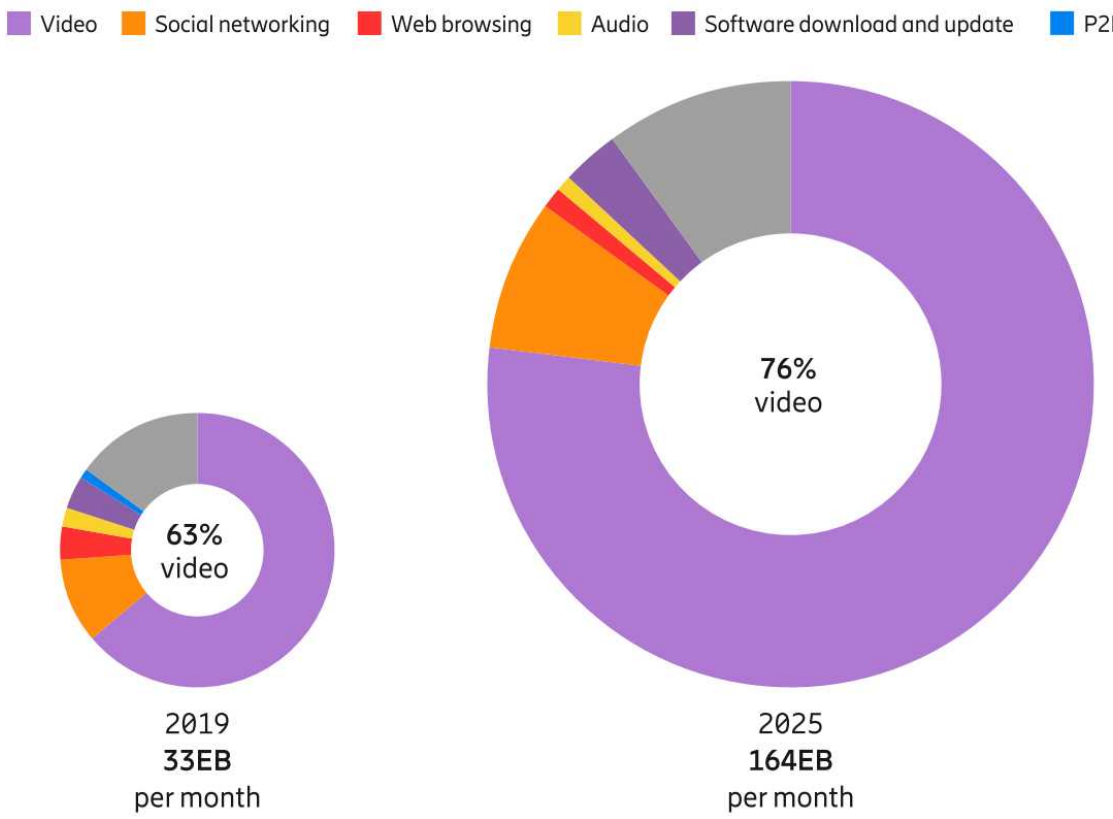
Traffic type



Note: Figures in parentheses refer to 2016 and 2021 traffic share.

Source: Cisco VNI: Global Mobile Data Traffic Forecast Update, 2017

Traffic type



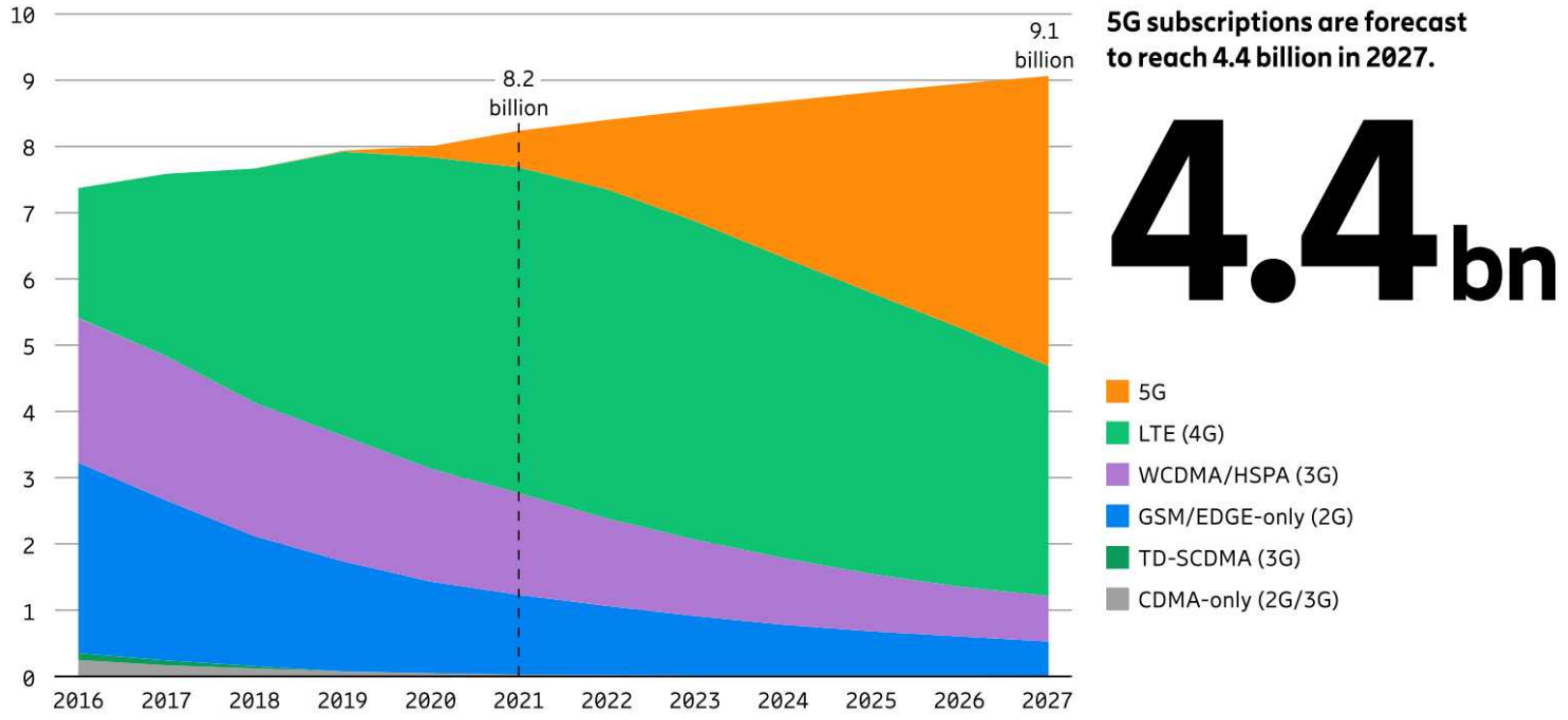
Main drivers for video traffic growth

- Video is part of most online content (news, ads, social media, etc.)
- Video sharing services
- Video streaming services
- Changing user behavior – video being consumed anywhere, any time
- Increased segment penetration, not just early adopters
- Evolving devices with larger screens and higher resolutions
- Increased network performance through evolved 4G deployments
- Emerging immersive media formats and applications (HD/UHD, 360-degree video, AR, VR)

[1] Traffic from embedded video in web browsing and social media is included in the application category "Video"

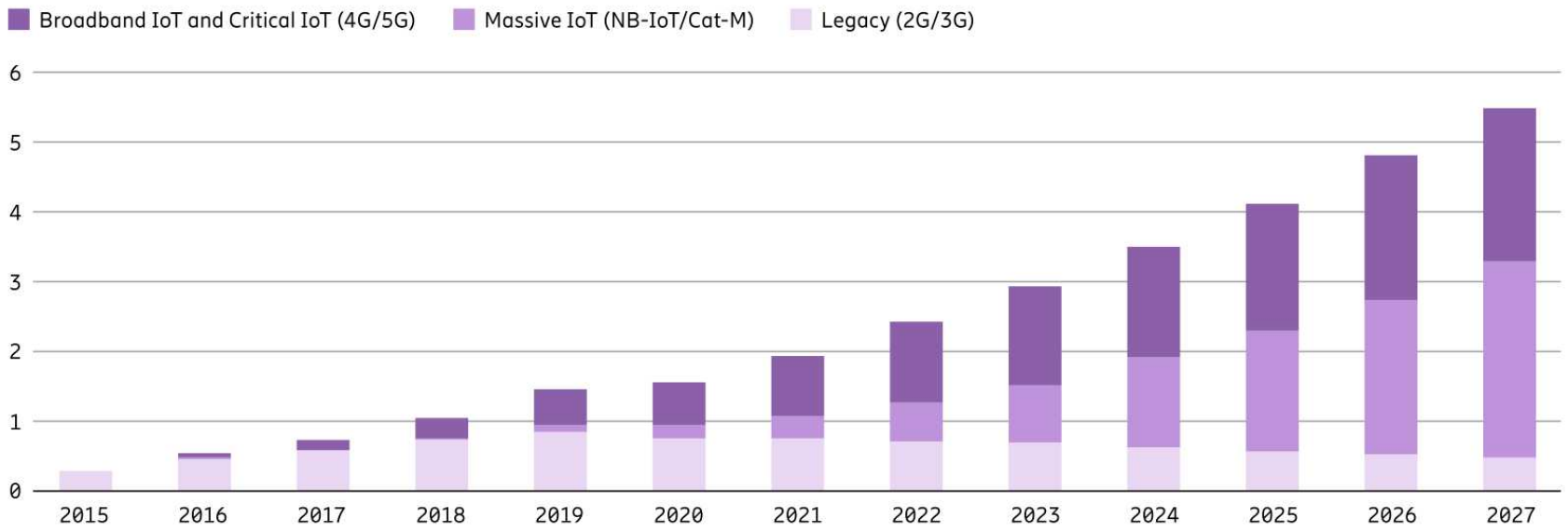
Source: Ericsson Mobility Report 2020

Cellular technologies



Source: Ericsson Mobility Report, June 2022

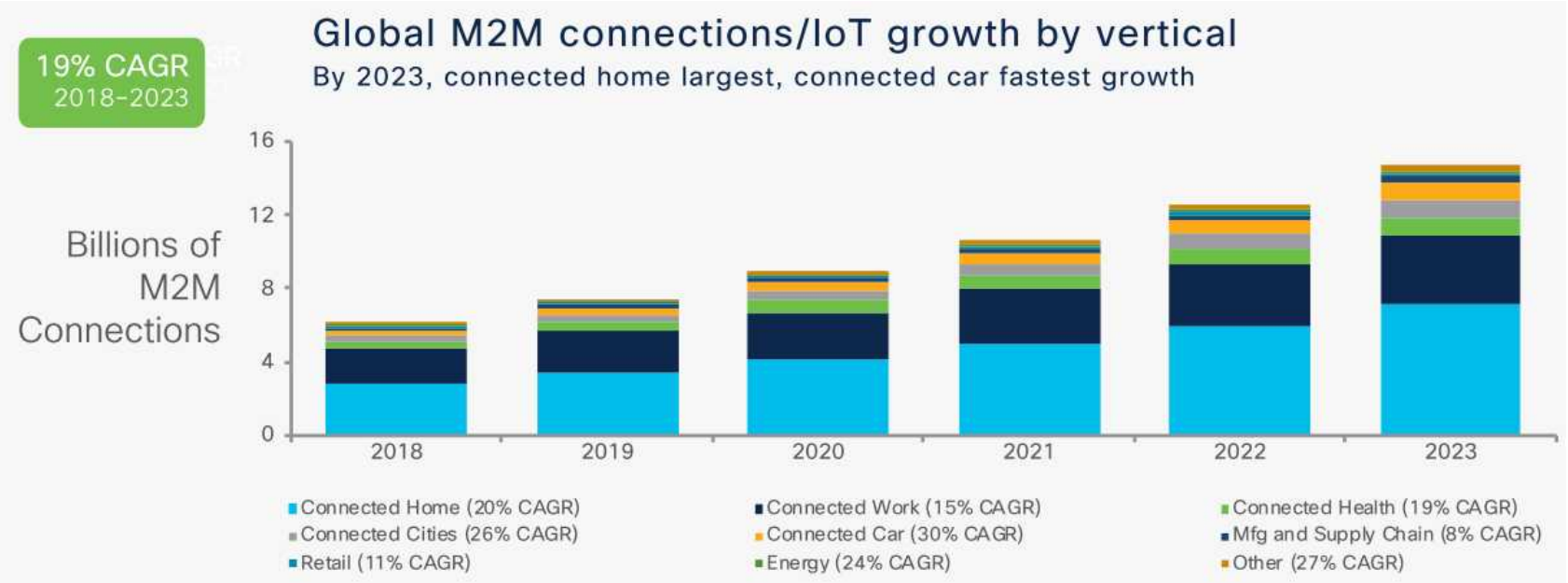
Cellular IoT



Narrowband Internet of things (**NB-IoT**): low-power wide-area network (LPWAN) radio technology

Source: Ericsson Mobility Report, June 2022

M2M/IoT applications

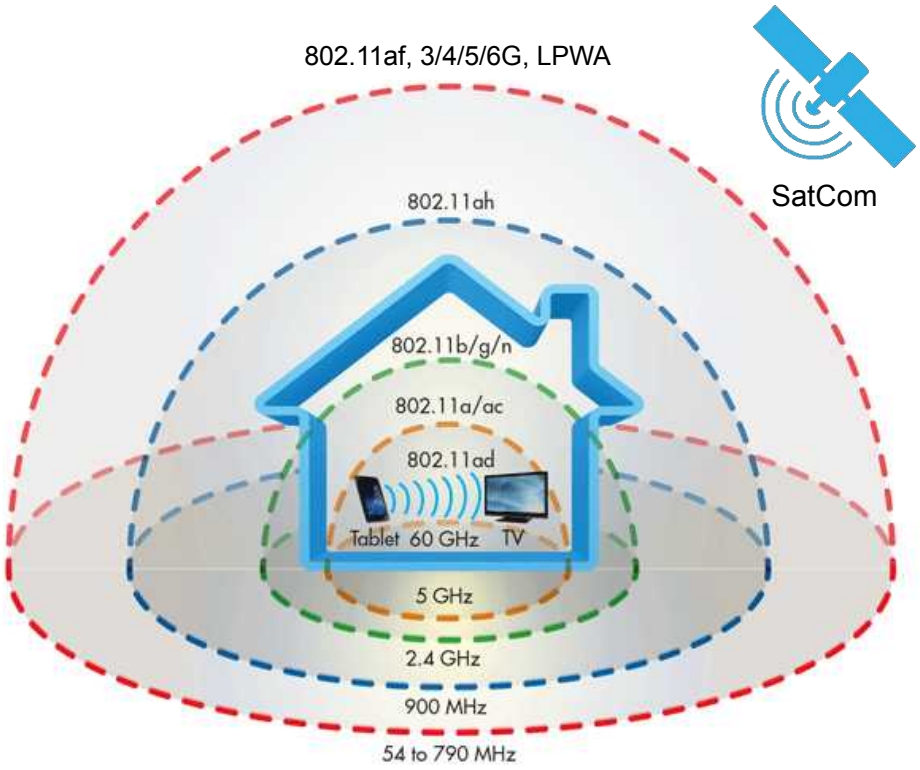


- Connected home applications (home automation, home security and video surveillance, connected white goods, and tracking applications) 48% by 2023
- Connected car applications (fleet management, in-vehicle entertainment systems, emergency calling, Internet, vehicle diagnostics and navigation etc.) fastest-growing category, at a 30% growth

Source: Cisco Annual Internet Report, 2018–2023

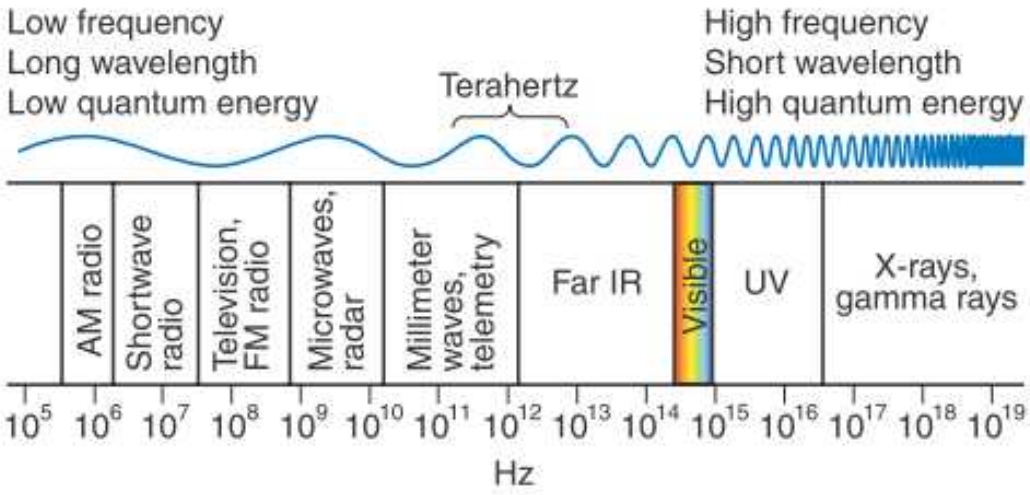
The importance of slow and short

- Fast (high speed) & long distance important
- Slow & short equally important
  - Longer battery lifetime, lower device cost, higher security
- Recent technologies:
  - IEEE 802.11ad/ay (WiGig): 60GHz, single room
  - IEEE 802.11af (white Wi-Fi), 802.11ah (low power Wi-Fi): <900MHz, long distance
  - 4G/LTE-M Rel-12/13: 1.4MHz - 20MHz (Broadband)



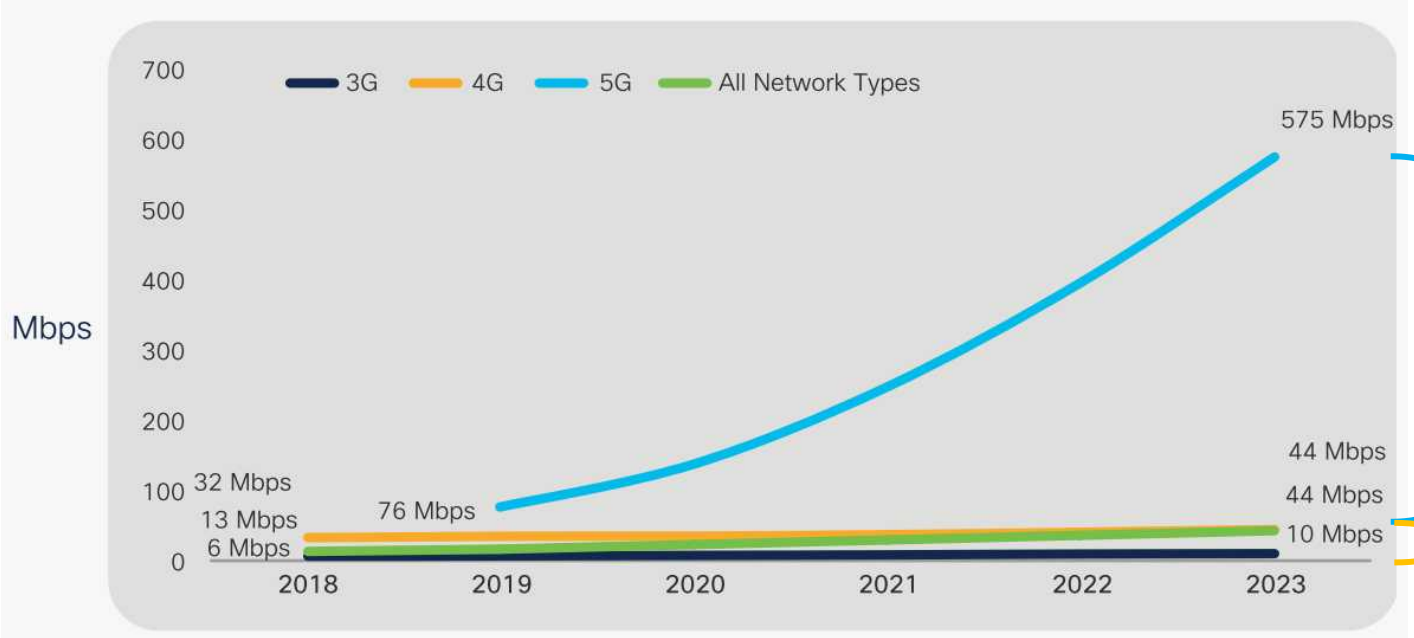
IoT (Internet of Things)

Moving to higher frequencies ...



- 5G in Greece: 700 MHz, 2 GHz, 3.4-3.8 GHz, 26 GHz
  - 3G/4G bands: 800 MHz, 1.8 GHz, 2.1 GHz, 2.6 GHz
- mm-wave: 26-300 GHz (802.11ad/ay,WiGig: 60 GHz)

Higher frequency benefits

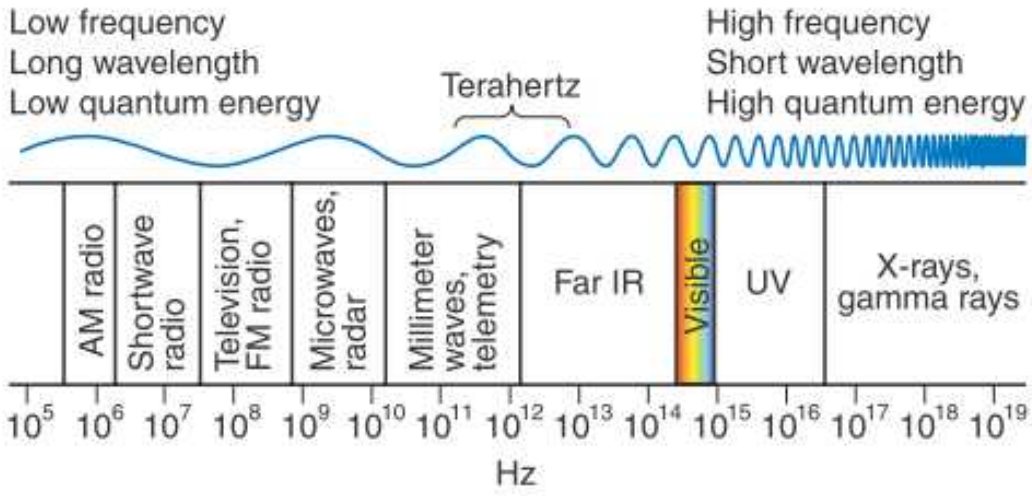


5G speeds > **13 X** 4G speeds, due to use of higher frequencies

4G speeds > **4.4 X** 3G speeds

Source: Cisco Annual Internet Report, 2018–2023

Moving to higher frequencies ...
without leaving lower frequencies



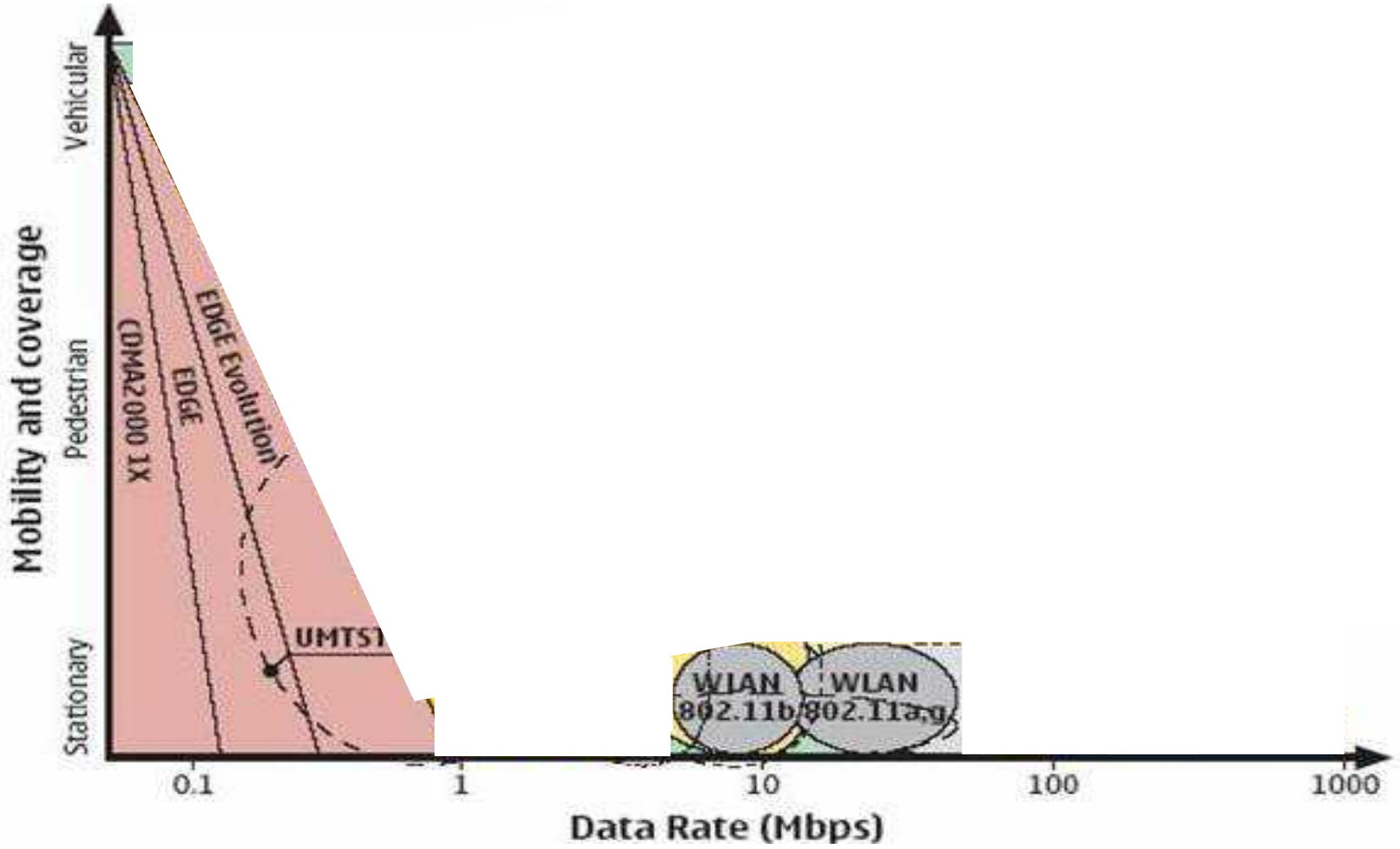
A mobile network will be able to use all bands opportunistically

*This justifies need for wireless & mobile networks to be **intelligent***

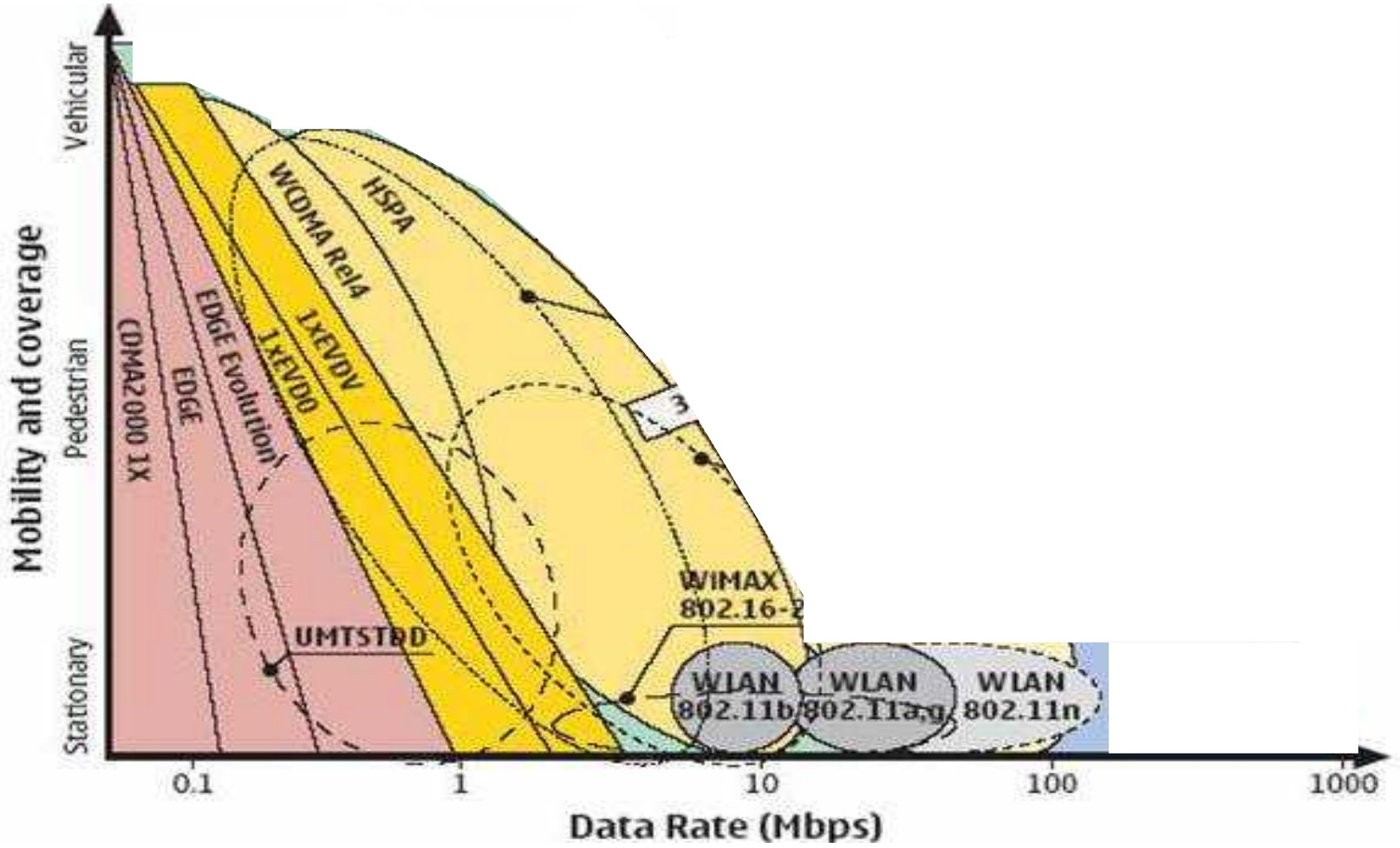
- 5G in Greece: 700 MHz, 2 GHz, 3.4-3.8 GHz, 26 GHz
  - 3G/4G bands: 800 MHz, 1.8 GHz, 2.1 GHz, 2.6 GHz
- mm-wave: 26-300 GHz (802.11ad/ay,WiGig: 60 GHz)
- Terahertz: 300 GHz-3 THz
- Visible light: 430-750 THz, infrared: 300-430 THz, ultraviolet: 750-1650 THz

6G

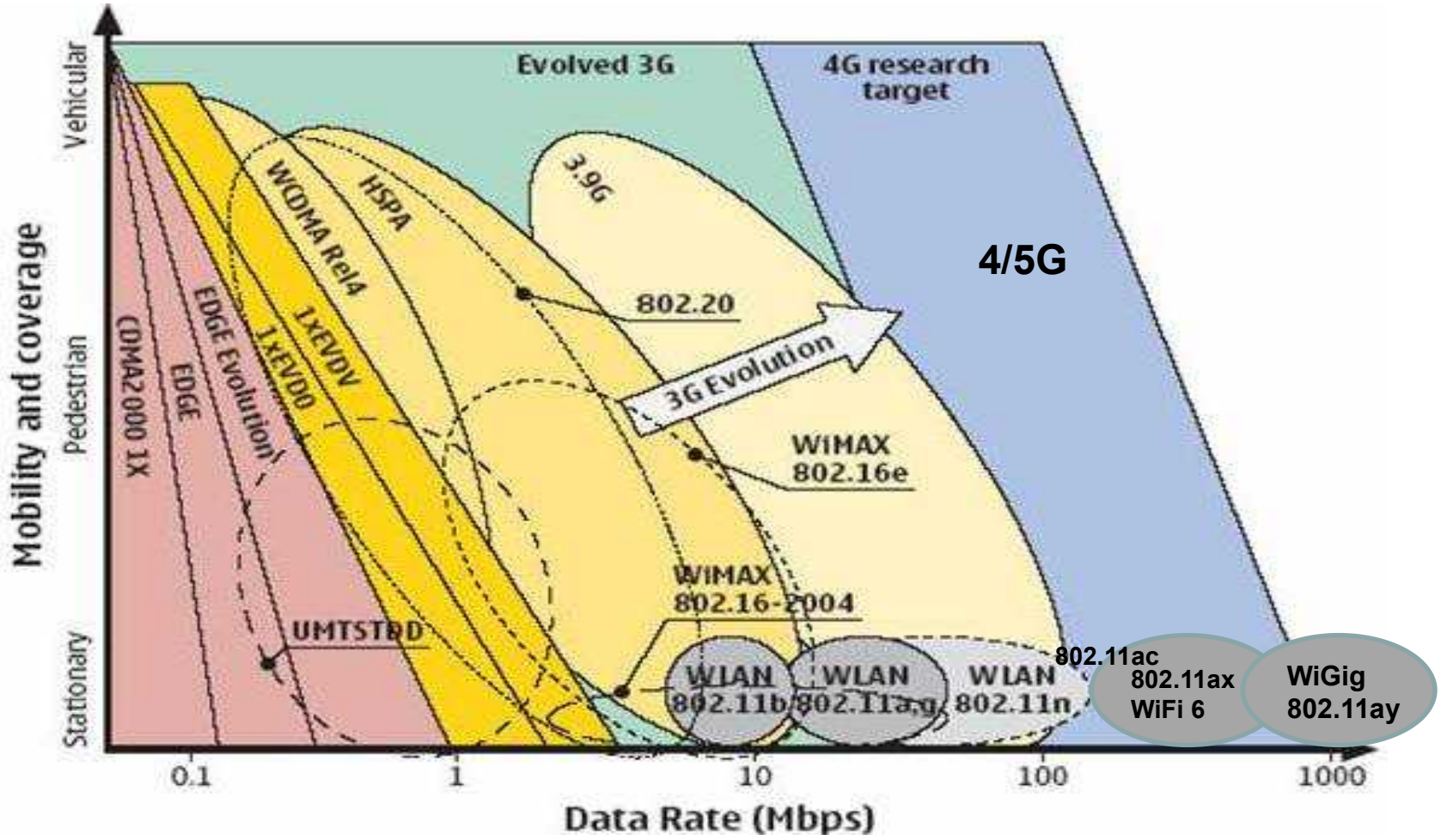
Evolution


Mobility and coverage
Vehicular
Pedestrian
Stationary
CDMA2000 1X
EDGE
EDGE Evolution
UMTS
WLAN
802.11b
WLAN
802.11a,g
0.1
1
10
100
1000
Data Rate (Mbps)

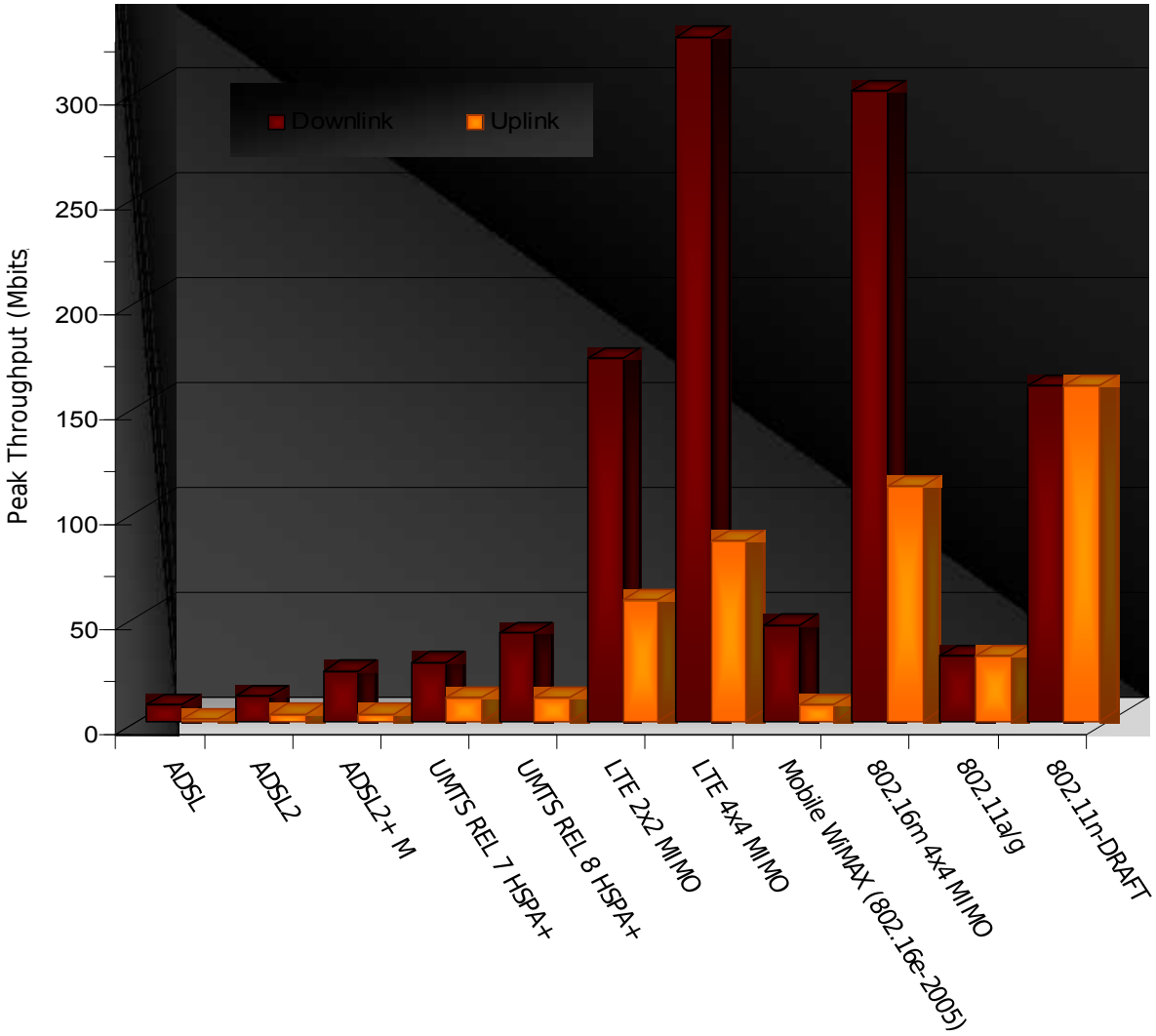
Evolution


Mobility and coverage
Vehicular
Pedestrian
Stationary
CDMA2000 1X
EDGE
EDGE Evolution
1XEVDO
1XEVDV
WCDMA RelA
HSPA
UMTSTDD
WIMAX
802.16-2
WLAN
802.11b
WLAN
802.11a,g
WLAN
802.11n
0.1
1
10
100
1000
Data Rate (Mbps)

Evolution


Evolved 3G
4G research target
4/5G
Vehicular
Pedestrian
Stationary
Mobility and coverage
CDMA2000 1X
EDGE
EDGE Evolution
1XEVDO
1XEVDV
WCDMA RelA
HSPA
3.9G
802.20
3G Evolution
WiMAX 802.16e
WiMAX 802.16-2004
UMTSTDD
WLAN 802.11b
WLAN 802.11a,g
WLAN 802.11n
802.11ac
802.11ax WiFi 6
WiGig 802.11ay
0.1
1
10
100
1000
Data Rate (Mbps)

Uplink versus downlink



Mobile network evolution

- 1st Generation
  - Analogue mobile phone (e.g., AMPS, NMT)
  - Low quality speech, low speed data 2.4 kbps
- 2nd Generation
  - Digital mobile (e.g., GSM)
  - Digital voice, low speed data (9.6 kbps)
- Generation 2.5 [2.5G]
  - Packet switching data, Internet access
    - e.g., GPRS
  - higher data-rates
    - 10…171.2 kbps, in theory, ~40 kbps in practice

Mobile network evolution (cont)

- 3rd Generation [3G, 3G+]

(digital) multimedia (e.g., UMTS)

  - Higher data-rate (144 kb/s … 2 Mb/s, in theory)
  - HSDPA, HSUPA, HSPA, LTE
  - Interoperation with 2G and national roaming

- 4th Generation [4G]
  - Seamless High-speed wireless Internet access (e.g., LTE-Advanced, IEEE 802.11n, mobile WiMAX, 802.16e)
    - IP based communication (11 … 54 Mb/s)
  - Short range, high capacity Wireless Internet Access (1 Gb/s)
  - “virtual reality” connection to the Internet
- 5th Generation [5G]
  - Heterogeneous small cells
  - mmWave
  - Network slicing, Network Function Virtualization (NFV)

Wireless Evolution

- Unlicensed spectrum
- WLANs 802.11 (Wi-Fi):
  - 802.11b, 802.11g/a, 802.11n/Wi-Fi 4 (~150-300Mbps),
  - 802.11ac/Wi-Fi 5 (~300-900Mbps, max 5.4Gbps)
  - 802.11ax/Wi-Fi 6 (max 9.6Gbps) - 2020
  - 802.11ad (WiGig, 60 GHz, up to 8Gbps)
  - 802.11ay (WiGig2, 60 GHz, up to 176 Gbps)
  - 802.11ah (700 MHz), 802.11af (TV white spaces), long range communication
- Metropolitan/community wireless networks, opportunistic device-to-device communication

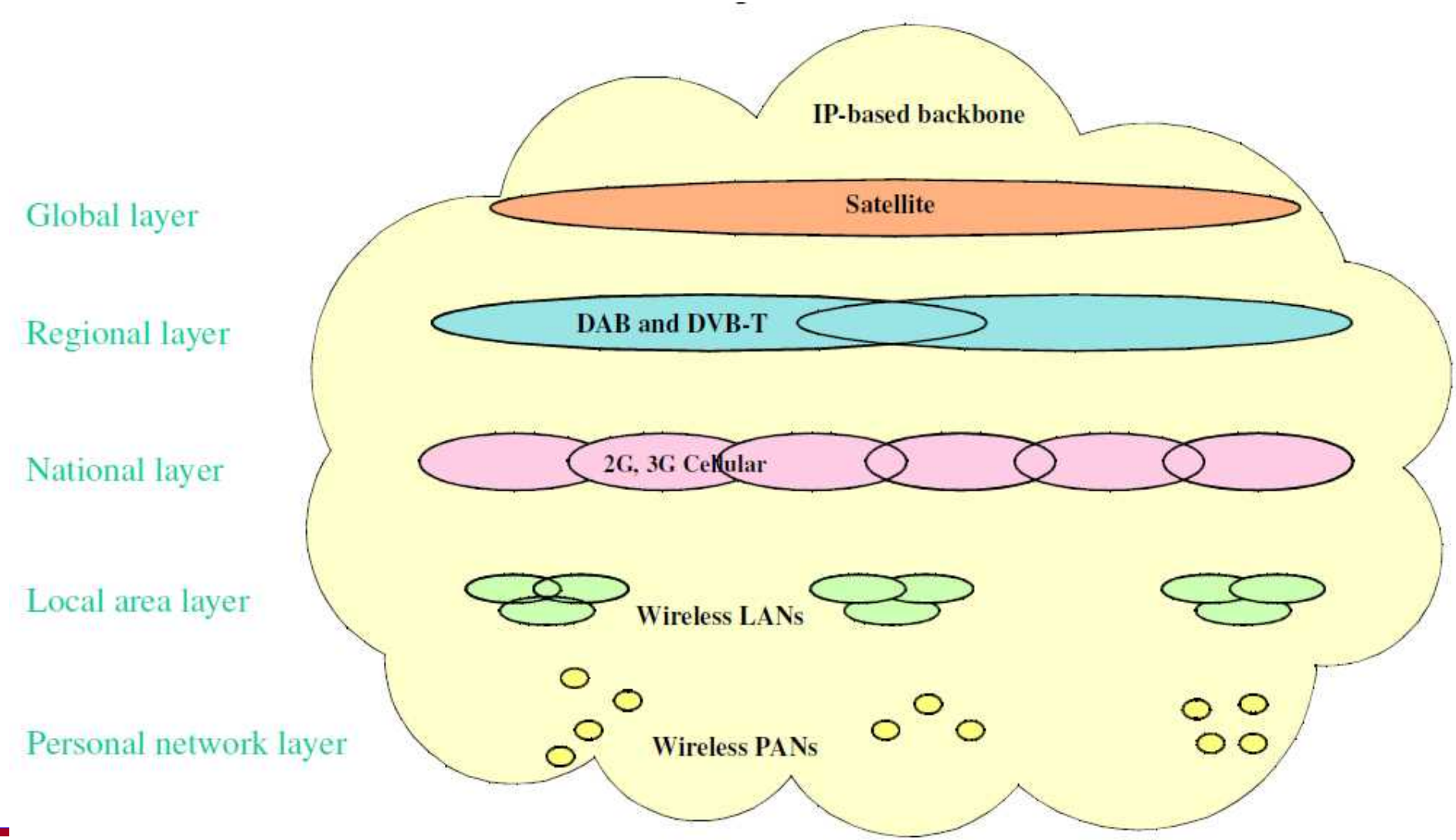
Wired vs. wireless

- wired: very low attenuation, no interference, low bit error probability, high deployment cost (digging)
- wireless: high attenuation (variable), interference (variable), high bit error probability (variable), low deployment cost

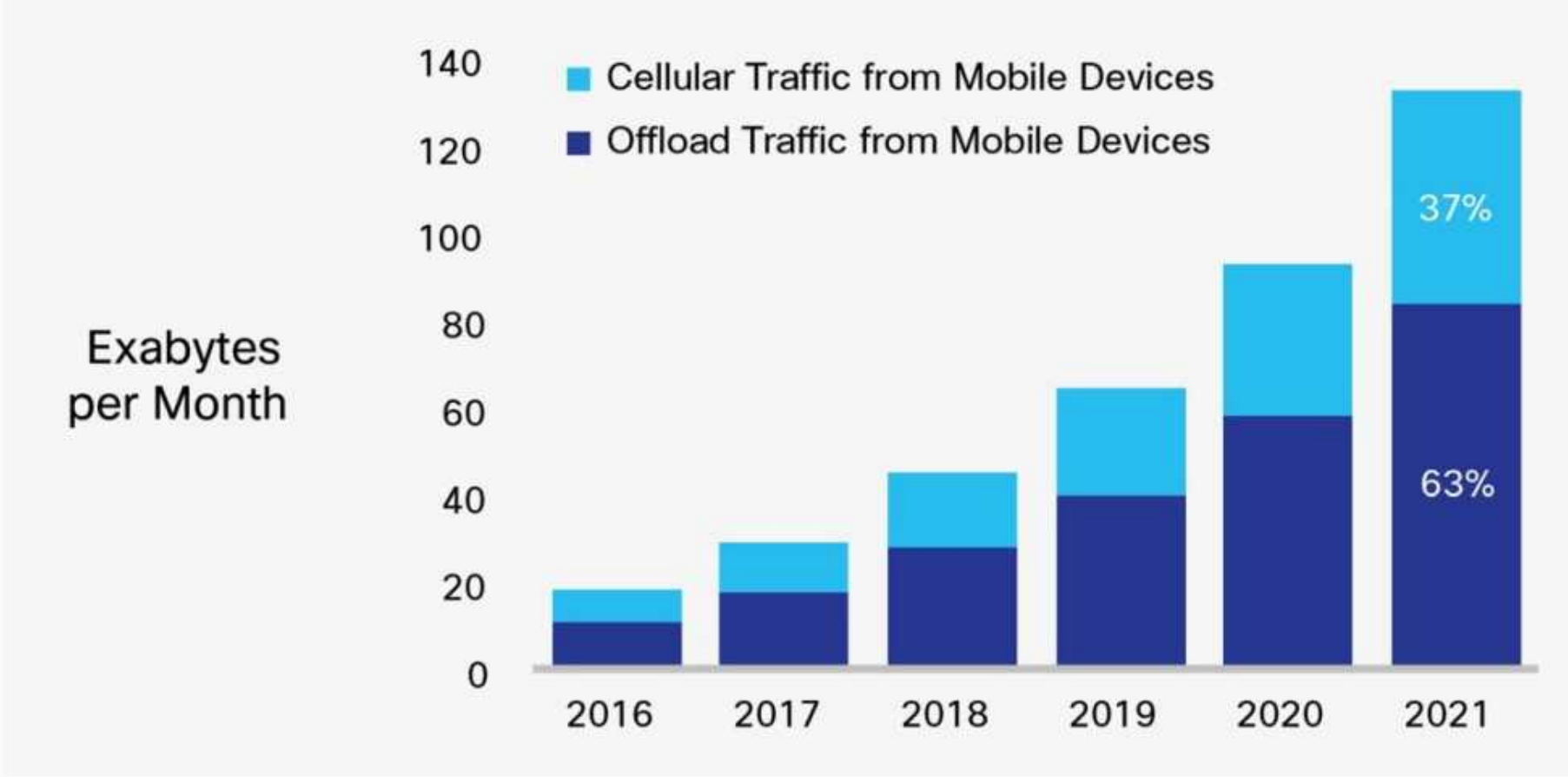
Packet-based future

	2G (2000)	Early 3G (2002/3)	Late 3G (2004/5)	4G (2006+)
Air Interface				
Voice	Circuit	Circuit	Circuit	Packet
Data	Circuit	Packet	Packet	Packet
Access Network				
Voice	Circuit	Circuit	Packet	Packet
Data	Circuit	Circuit	Packet	Packet
Core Network				
Voice	Circuit	Packet	Packet	Packet
Data	Overlay Packet	Packet	Packet	Packet

Interconnection at multiple layers



Mobile traffic offloading



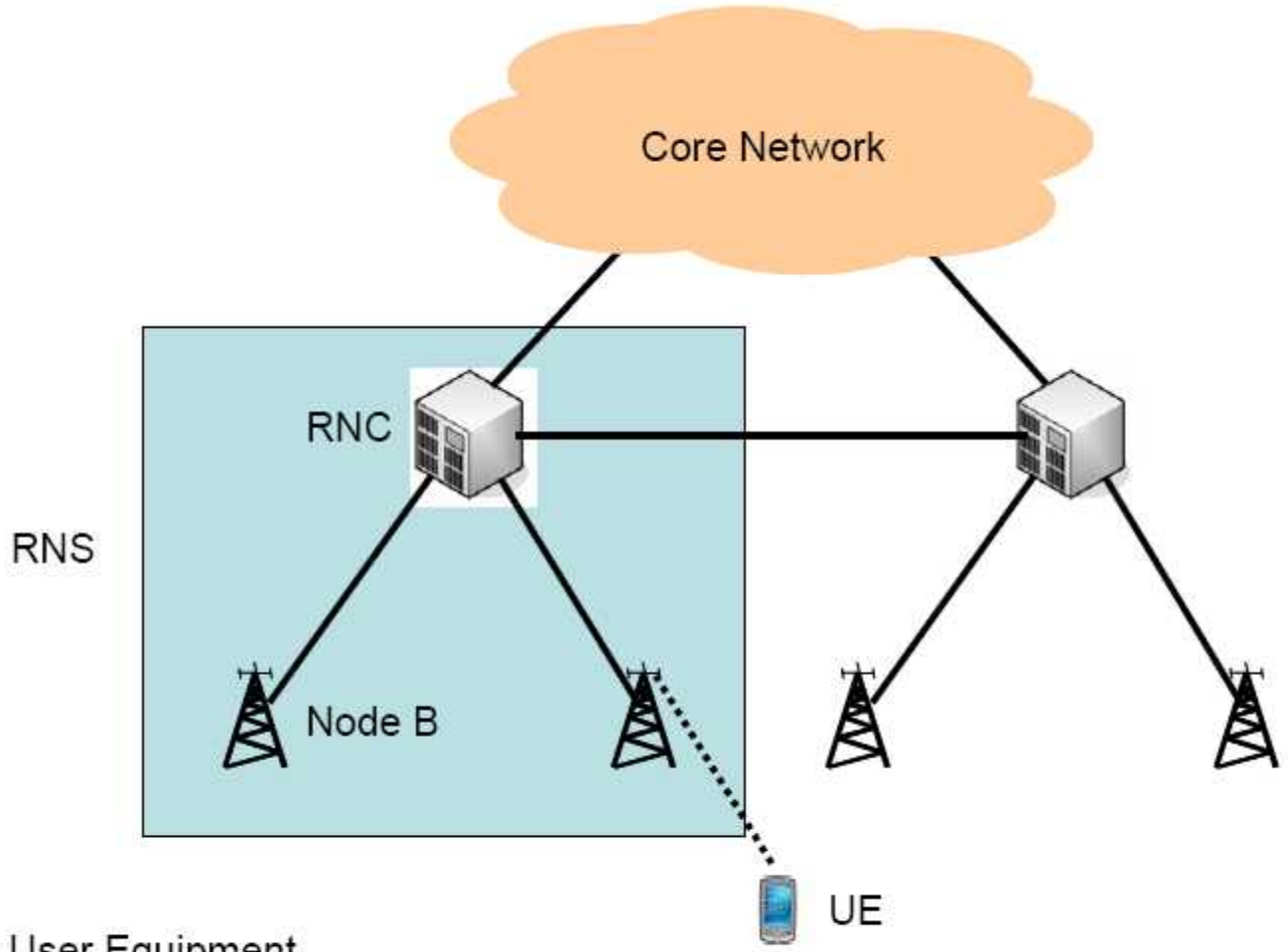
Note: Offload pertains to traffic from dual-mode devices (excluding laptops) over Wi-Fi or small-cell networks.

Source: Cisco VNI: Global Mobile Data Traffic Forecast Update, 2017

Wireless architectures

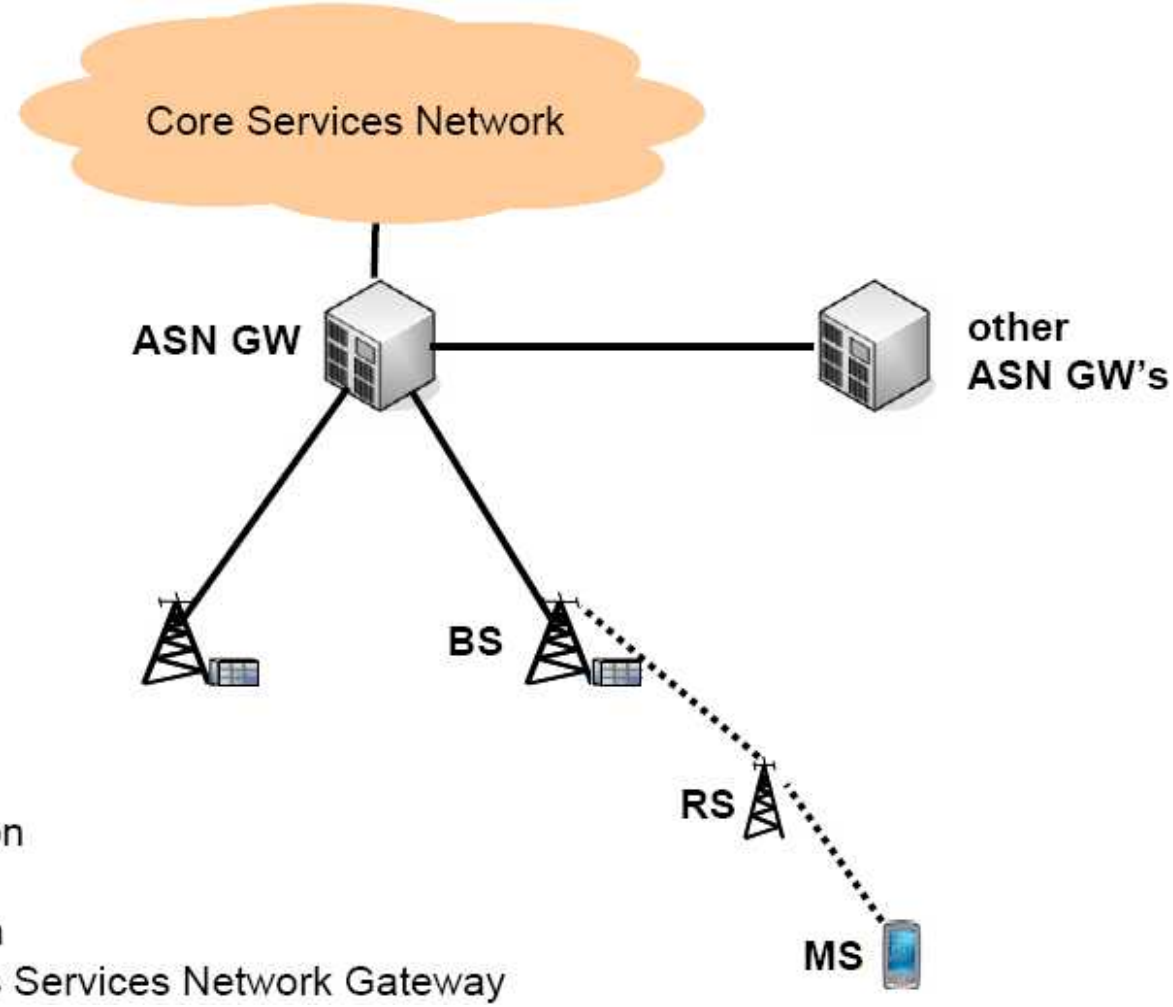
- Cellular
  - hierarchical RAN (Radio Access Network)
  - moving towards flat, peer-to-peer, mesh
- WLAN
  - local connectivity (until now)
  - dense deployments
- Wireless multihop
  - Ad Hoc: infrastructure-less
  - Wireless Mesh Networks: GateWays connecting to fixed network
- Sensor networks

3G/UMTS Hierarchical Radio Access Network (RAN)



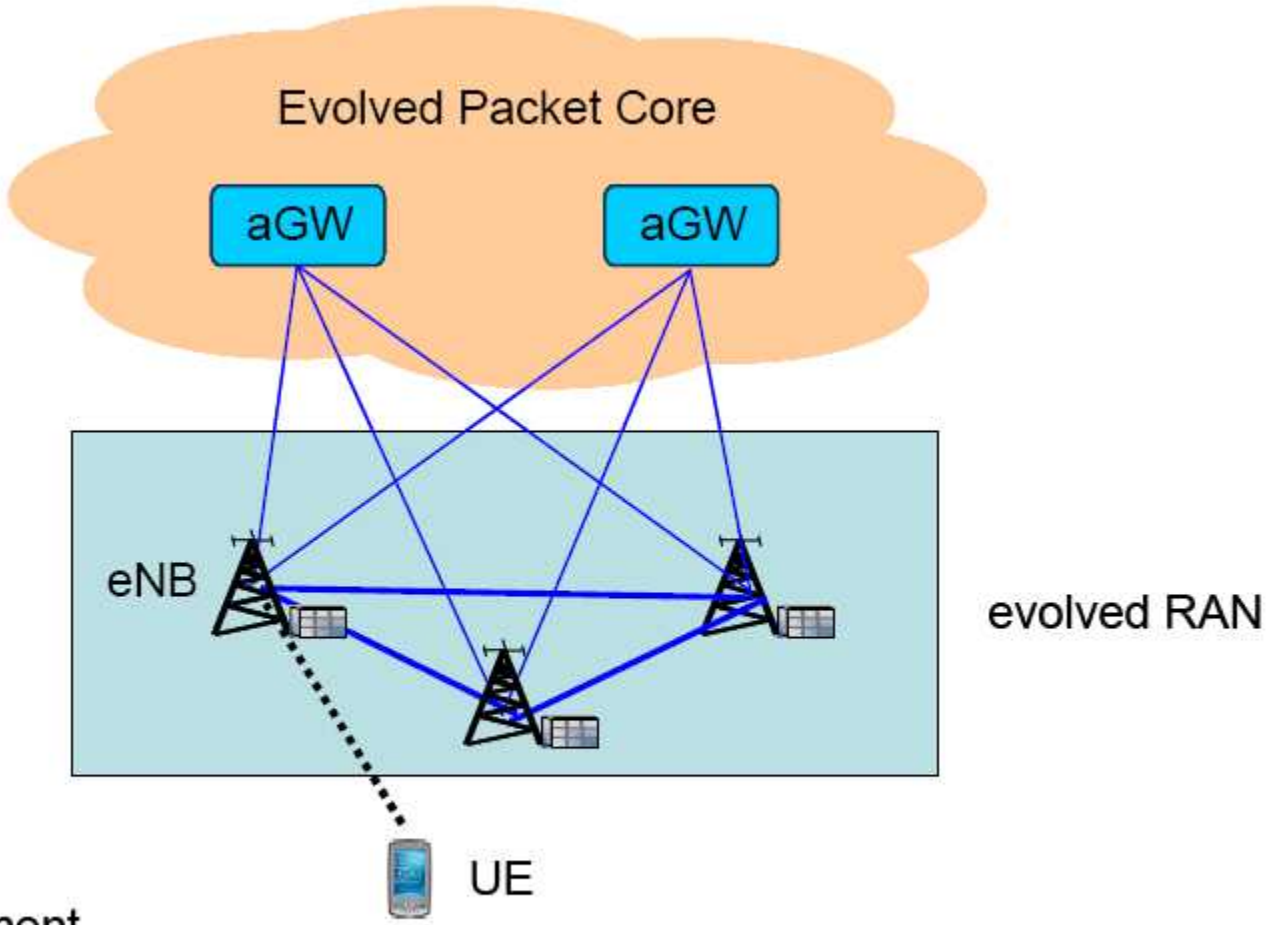
UE: User Equipment
Node B: Base Station
RNC: Radio Network Controller
RNS: Radio Network Subsystem

WiMAX (IEEE 802.16) RAN with relaying



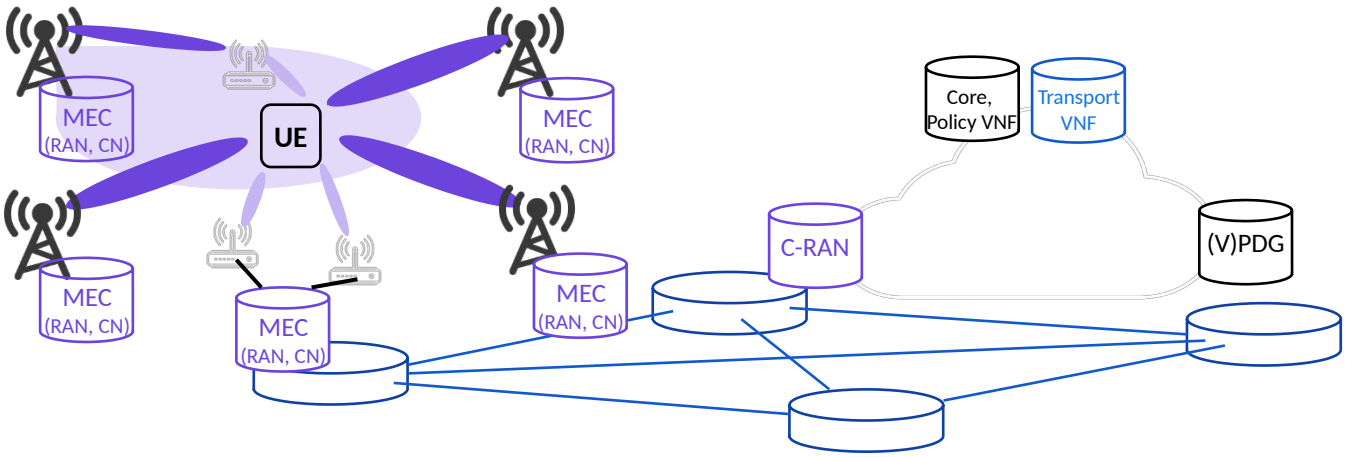
MS: Mobile Station
BS: Base Station
RS: Relay Station
ASN GW: Access Services Network Gateway

3G Long Term Evolution (LTE) RAN



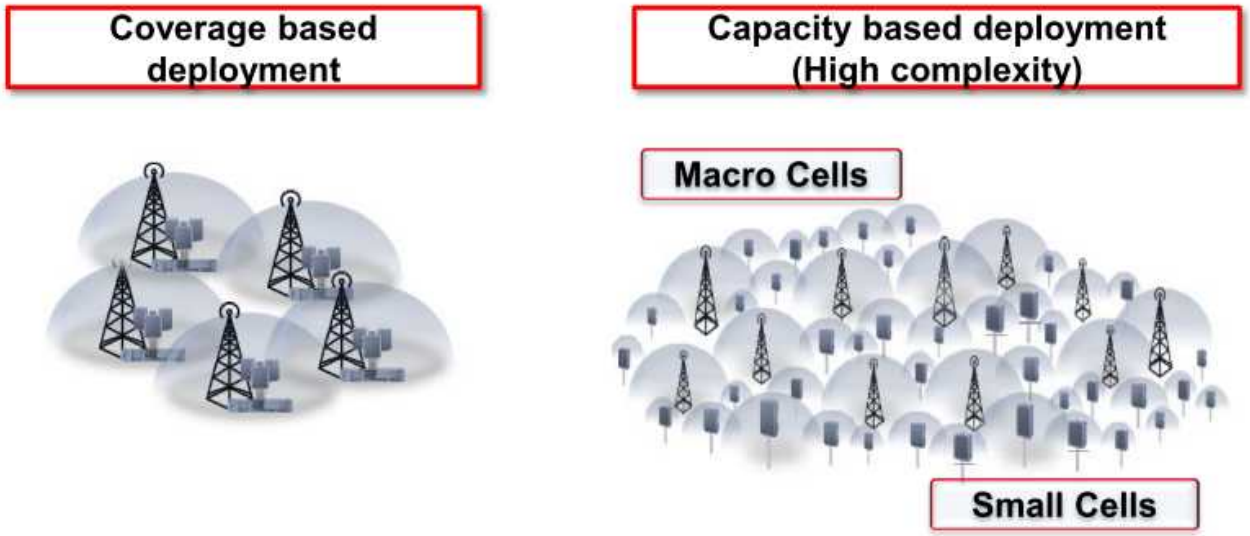
UE: User Equipment
aGW: Access Gateway
eNB: enhanced Node B

5G flexibility – SDN & NFV



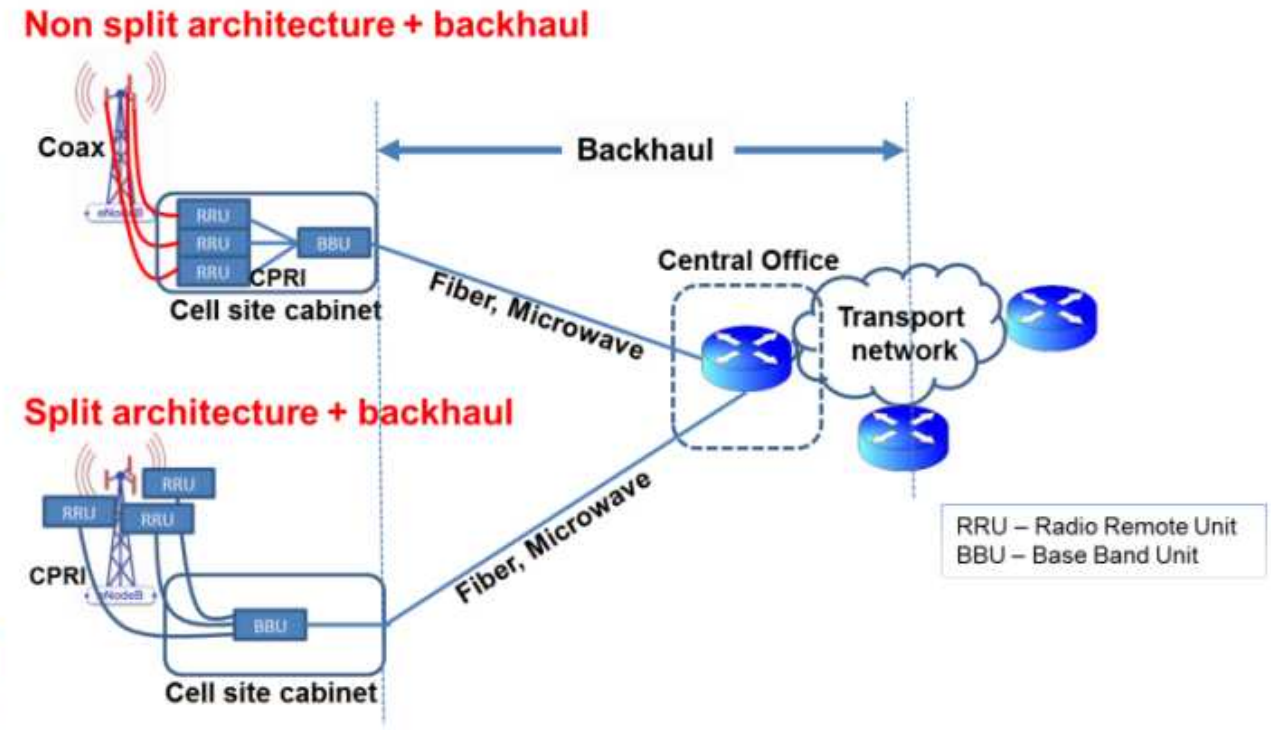
- ‘Softwarisation’ of the network
- NFV and SDN – enabling flexibility in where functions are deployed and scaled
- CP/UP split – decoupling of user plane traffic from control plane functions
- Centrlaized-RAN – centralized cloud-based architecture
- Multi-access Edge Computing (MEC) – pushing Core Network functions and content ingress to cell sites

From coverage to capacity deployments



- Installation/Maintenance/Interference optimization is important
- Centralization necessary => Cloud RANs
- Intelligent necessary

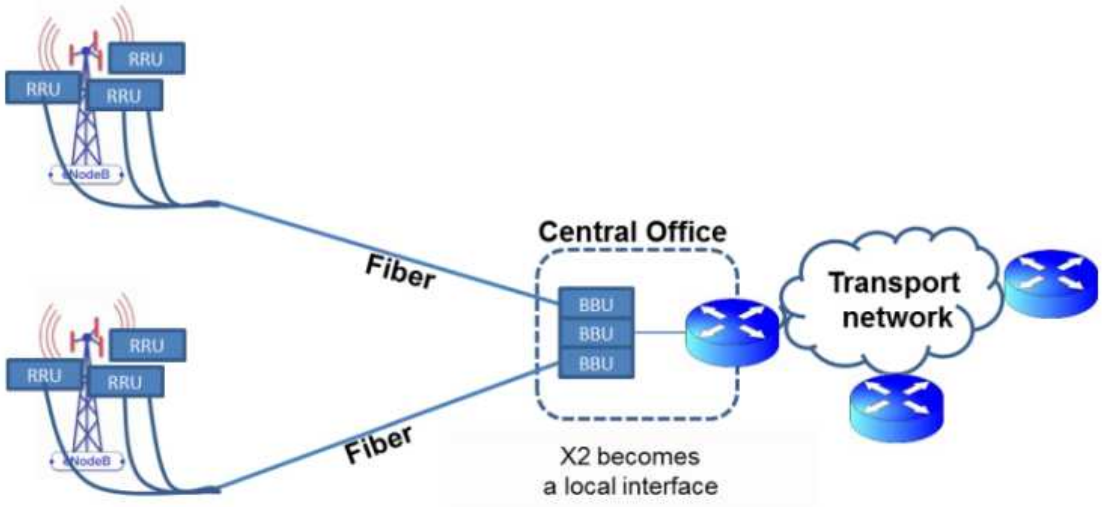
RRU-BBU separation



- RRU (Remote Radio Unit): sends/receives signals (EM waves) through antenna
- BBU (BaseBand Unit): conversion between analog and digital signals
- CPRI (Common Public Radio Interface): specification that defines the interfacing transport, connectivity and control communications between BBUs and RRUs

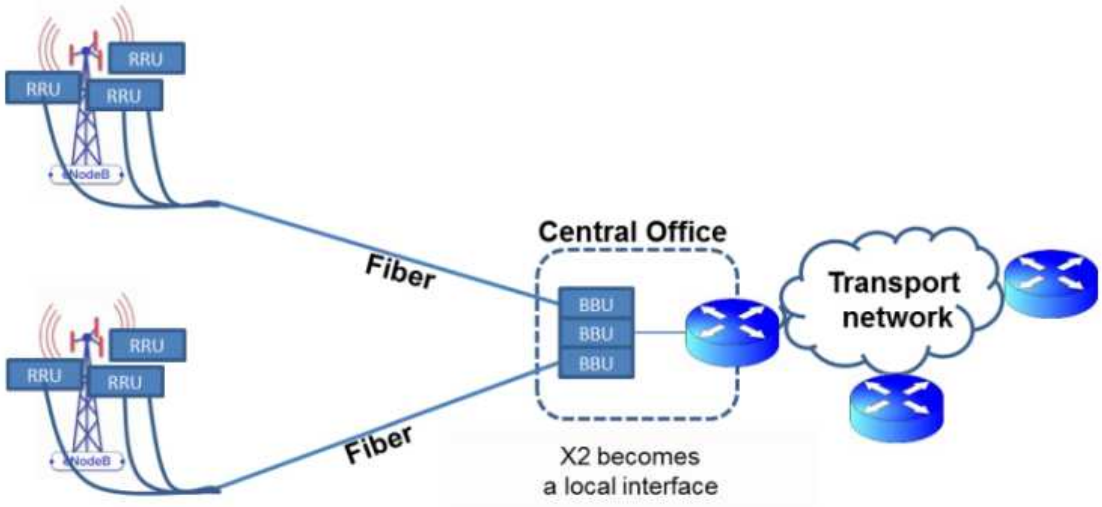
BBU centralization and pooling: Cloud RAN

BBU centralization:

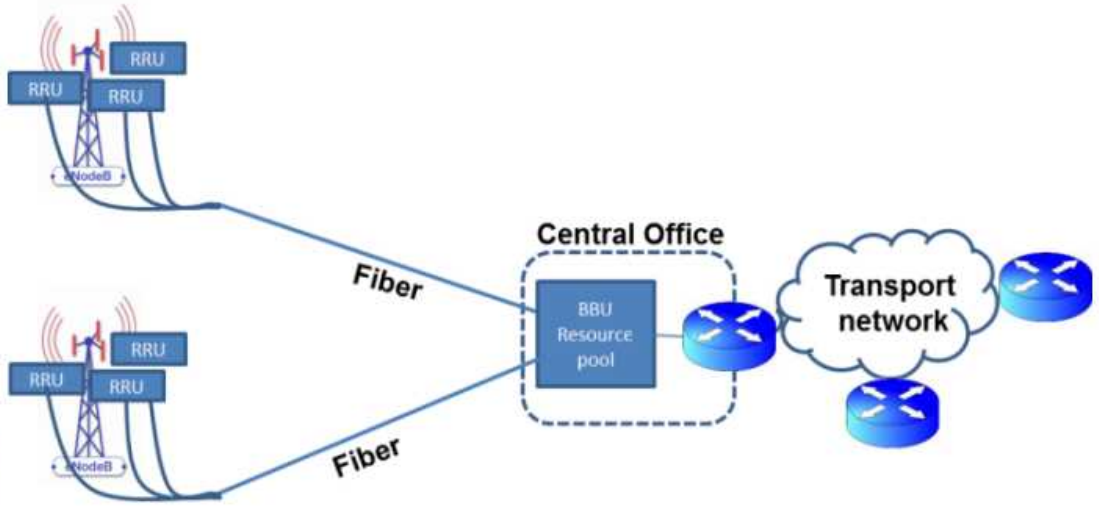


BBU centralization and pooling: Cloud RAN

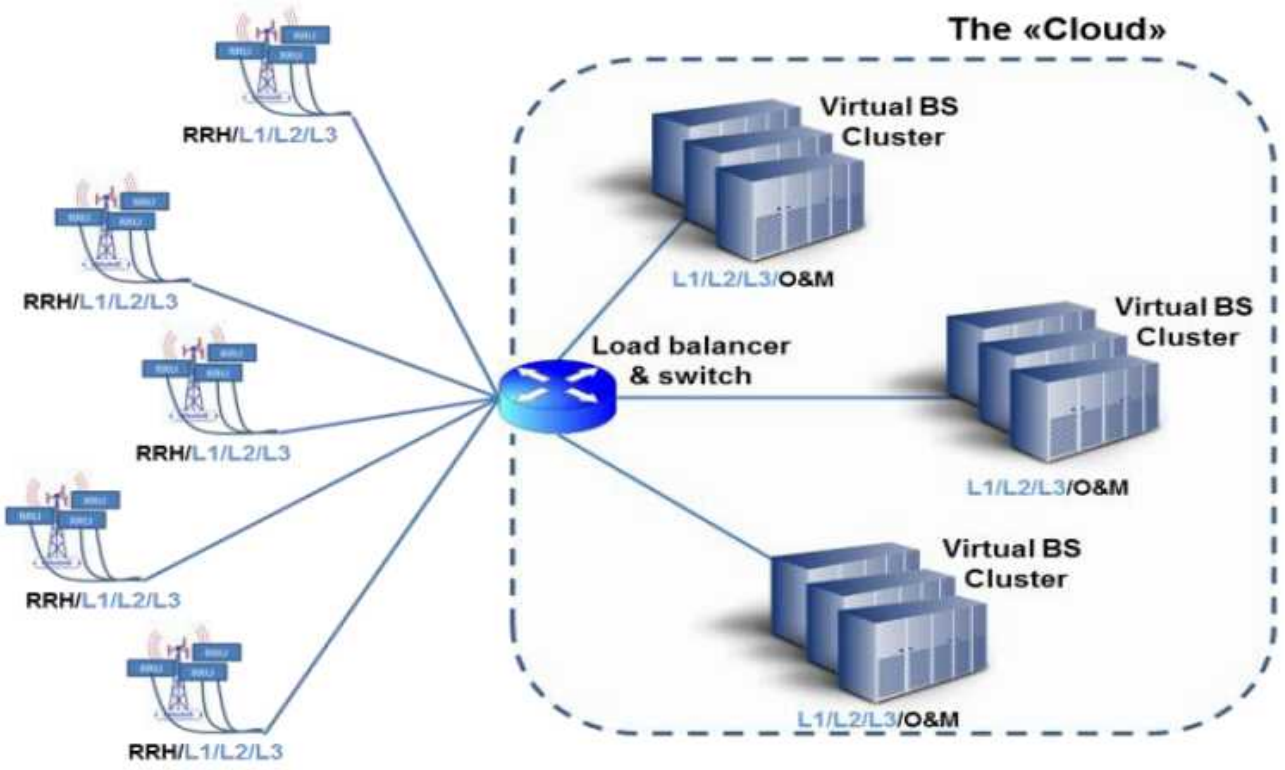
BBU centralization:



BBU pooling (Cloud RAN):



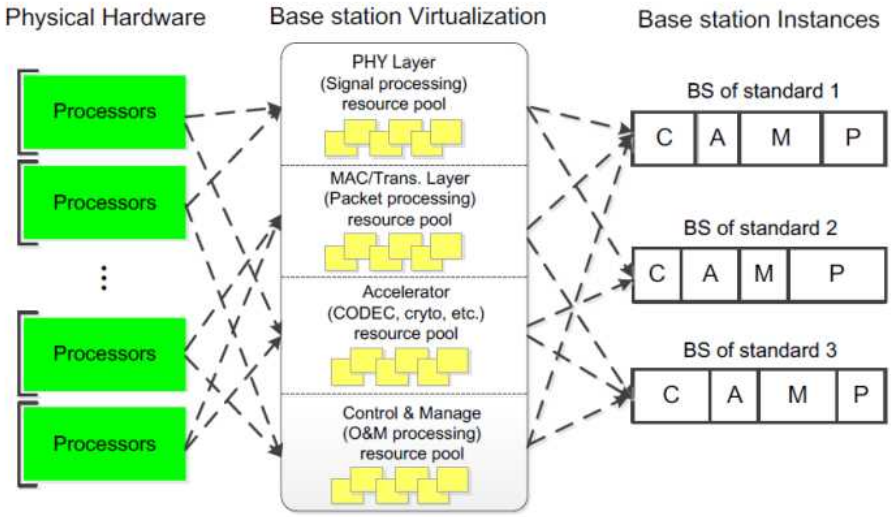
Cloud RAN with virtualization



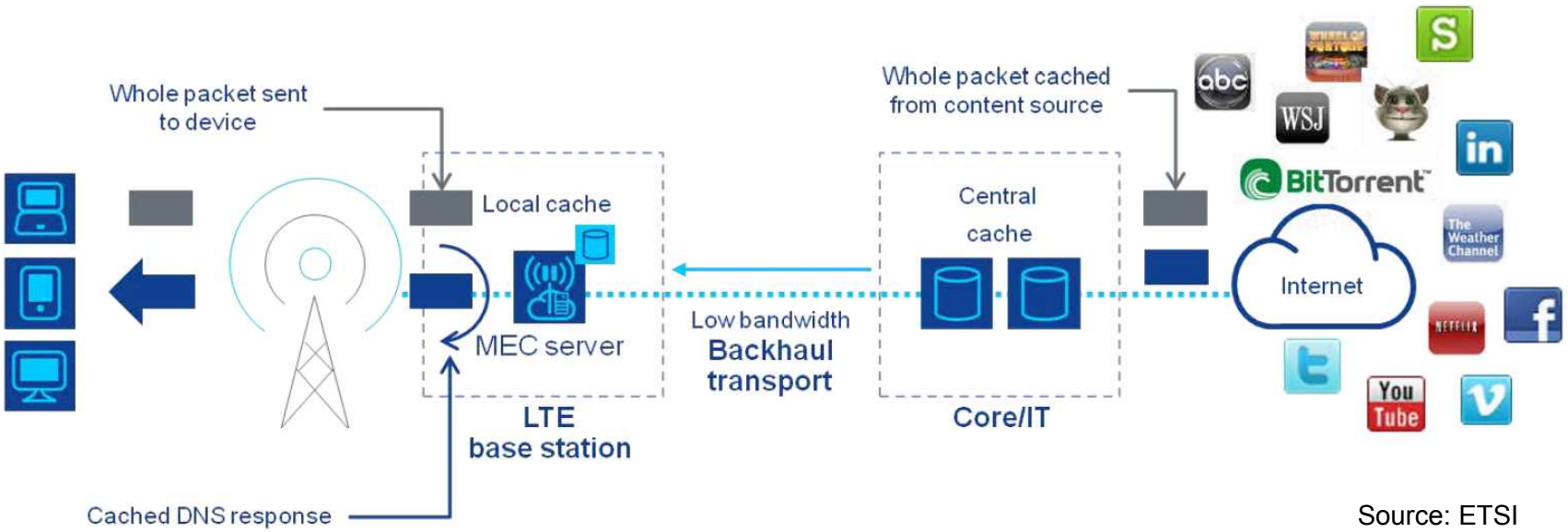
Remote Radio Head (RRH) synonym for RRU

Virtualization gains

- HW and SW totally decoupled
- Operator can dynamically allocate processing resources within a centralized baseband pool to different virtualized base stations and different air interface standards
- simpler inter-vendor interoperability
- cost reduction to manage, maintain, expand and upgrade base station



Multiaccess Edge Computing: Caching



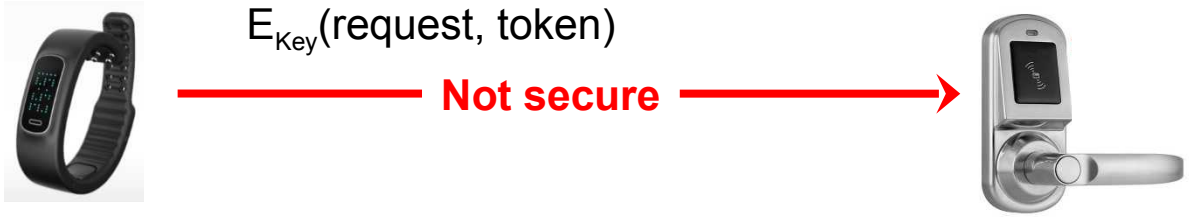
Source: ETSI

Pushing to the edges

- Multi-access edge computing (MEC) enables cloud computing capabilities and an IT service environment at the edge of the cellular network and, more in general at the edge of any network.

From **small cells** to **no cells**: **device-to-device** communication

- Constrained IoT devices (Things): limited/no connectivity, insecure channel

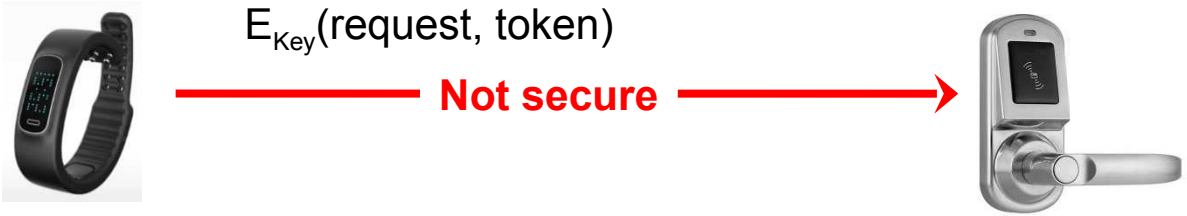


Disconnected from the Internet device

Disconnected from the Internet device

From **small cells** to **no cells**: **device-to-device** communication

- Constrained IoT devices (Things): limited/no connectivity, insecure channel
- Secure and trusted communication between disconnected IoT devices
  - Trusted = perform actions according to owner defined policies



Disconnected from the Internet device

Disconnected from the Internet device

Θα ξεκινήσουμε στις 12:10

Επιστρέφουμε 2:00