Οικονομικό Πανεπιστήμιο Αθηνών
Τμήμα Πληροφορικής

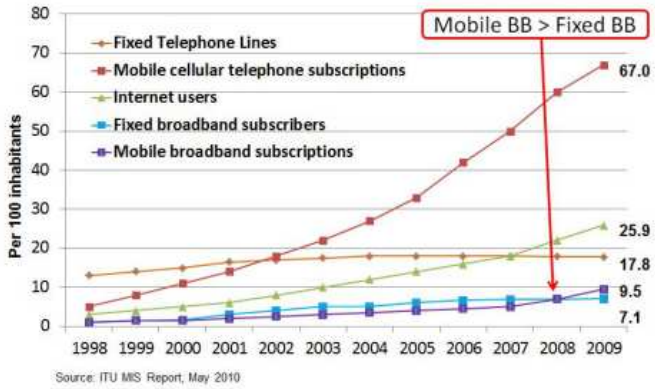
Ευφυή Κινητά Δίκτυα: Επισκόπηση και Τάσεις

Εαρινό Εξάμηνο 2024-25

Βασίλειος Σύρης

1

Fixed versus mobile broadband



- Interplay between communication networks and device (handset) technology

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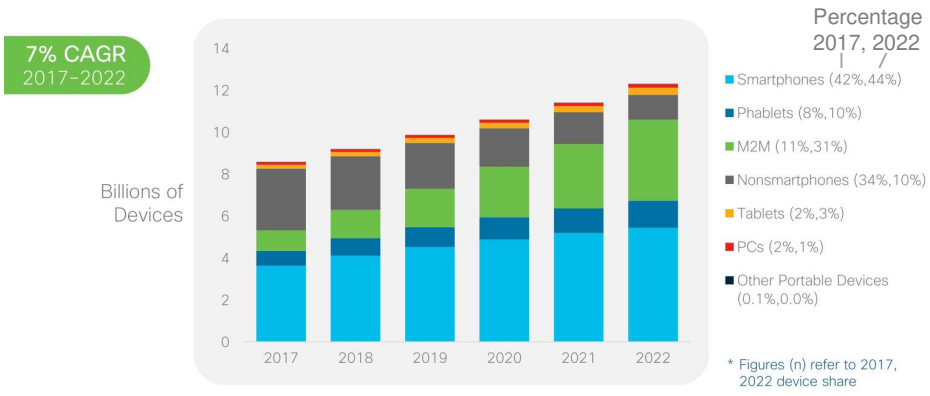
Global mobile device growth



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

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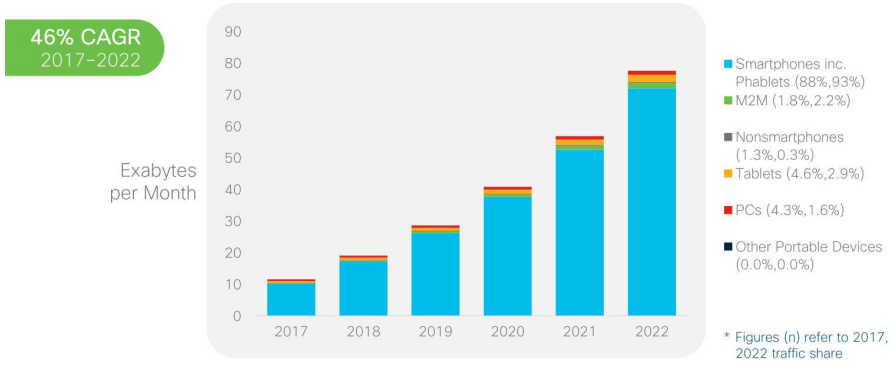
Traffic volume and device type



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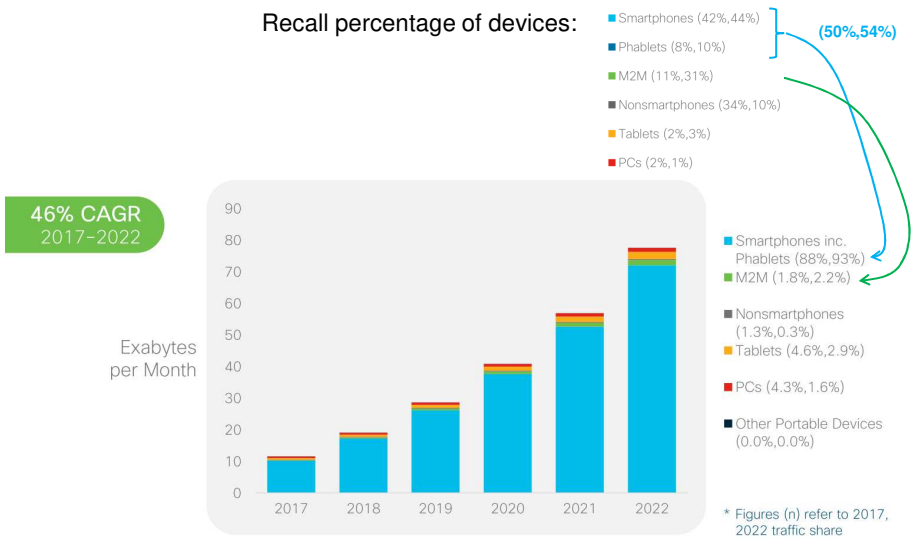

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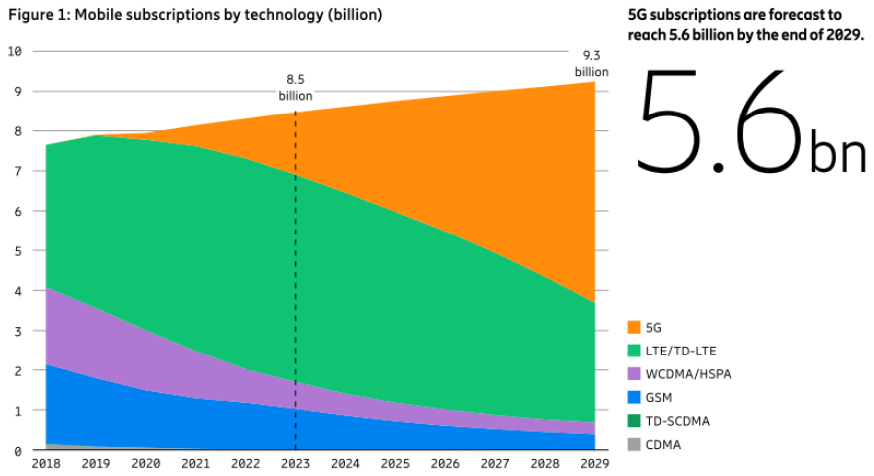
Cellular technologies



5G subscriptions are forecast to reach 5.6 billion by the end of 2029.

5.6bn

Source: Ericsson Mobility Report, June 2024

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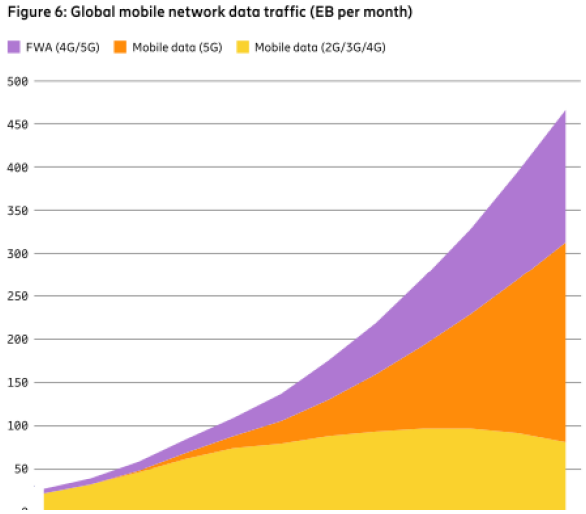
Mobile network data traffic



Source: Ericsson Mobility Report, June 2024

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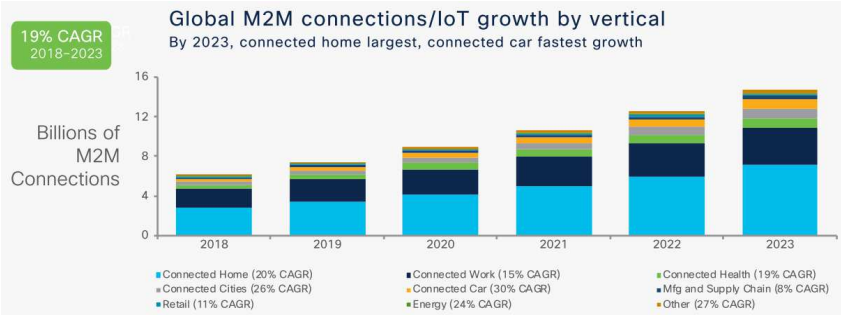
M2M/IoT applications



- 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

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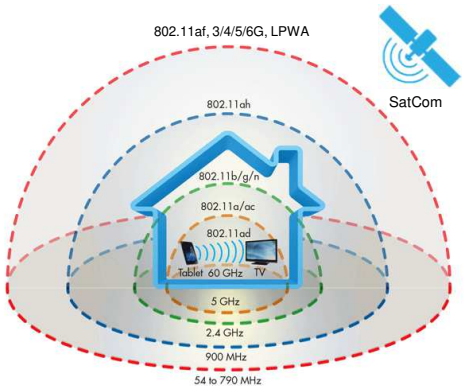
The importance of slow and short

- 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, 0.2MHz (Broadband: 20MHz)



IoT (Internet of Things)

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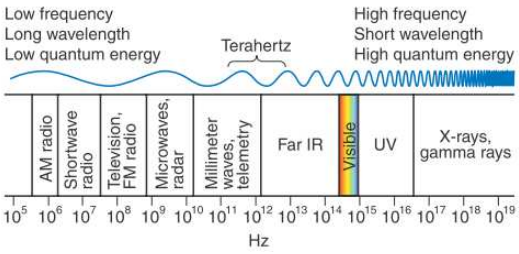
Moving to higher frequencies ...



- 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)

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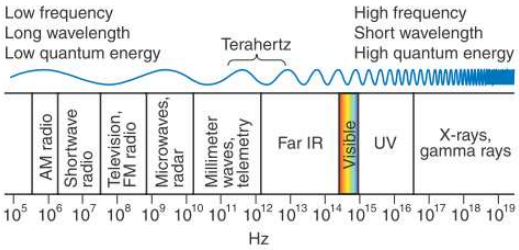
Moving to higher frequencies ...



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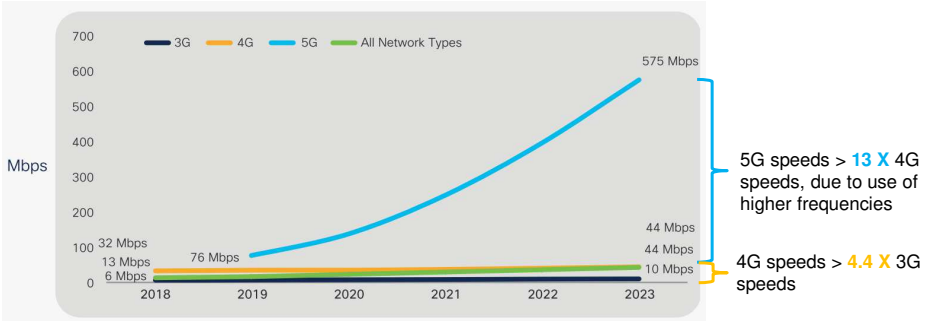
Higher frequency benefits



Source: Cisco Annual Internet Report, 2018–2023

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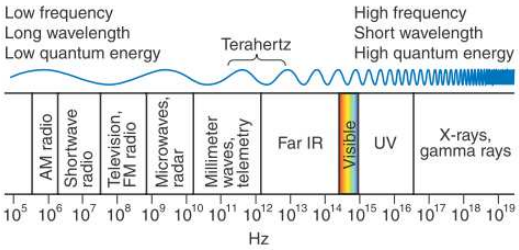
Moving to higher frequencies ...
without leaving lower frequencies



A mobile network will be able to use all bands opportunistically

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

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  - 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

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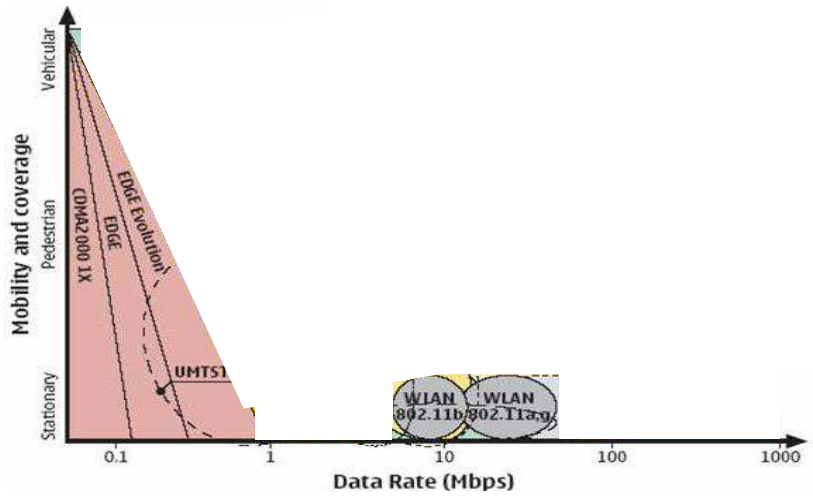
Evolution



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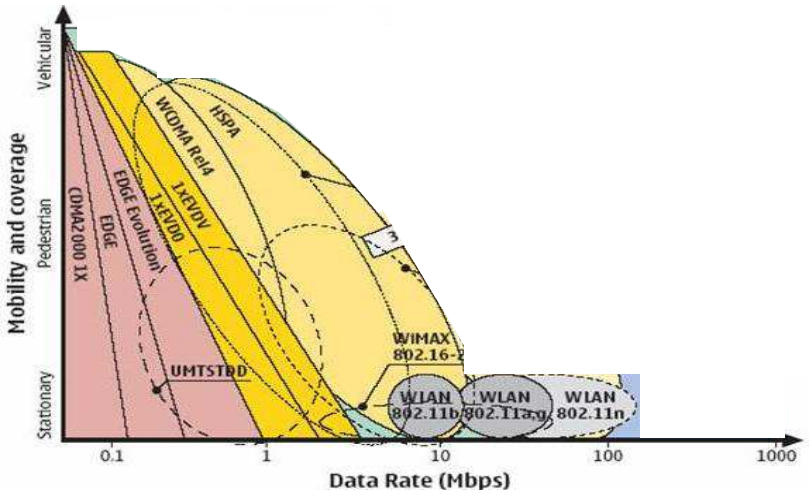
Evolution



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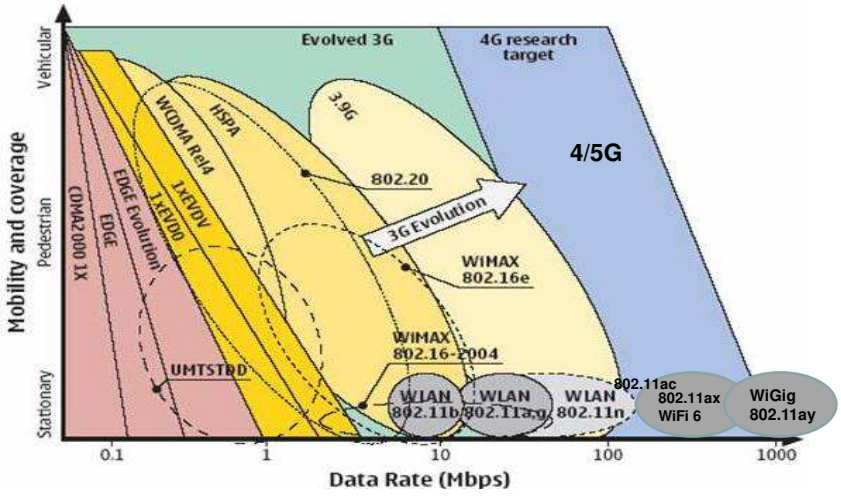
Evolution



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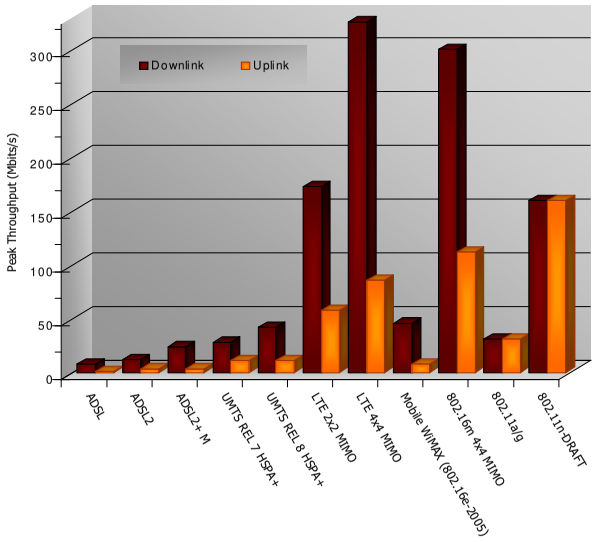
Uplink versus downlink



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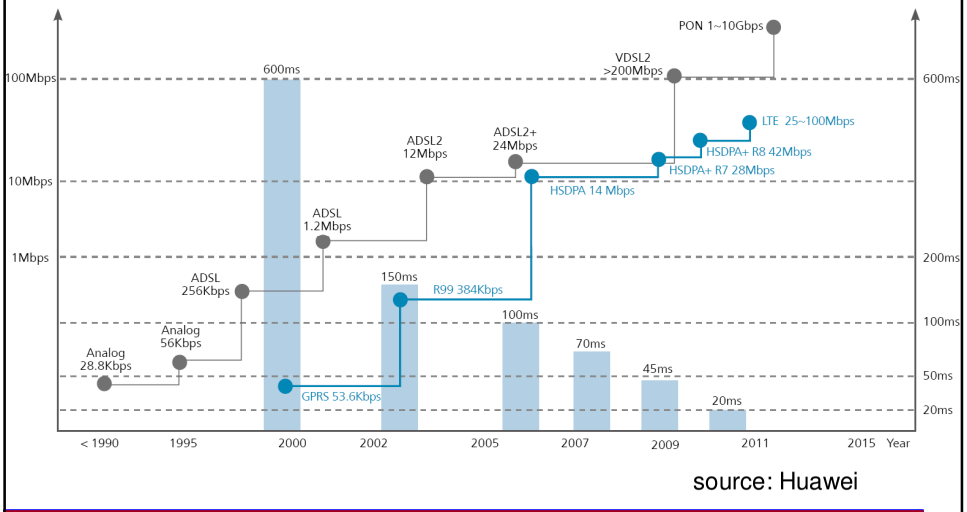
Wired versus wireless



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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

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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)

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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

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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

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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

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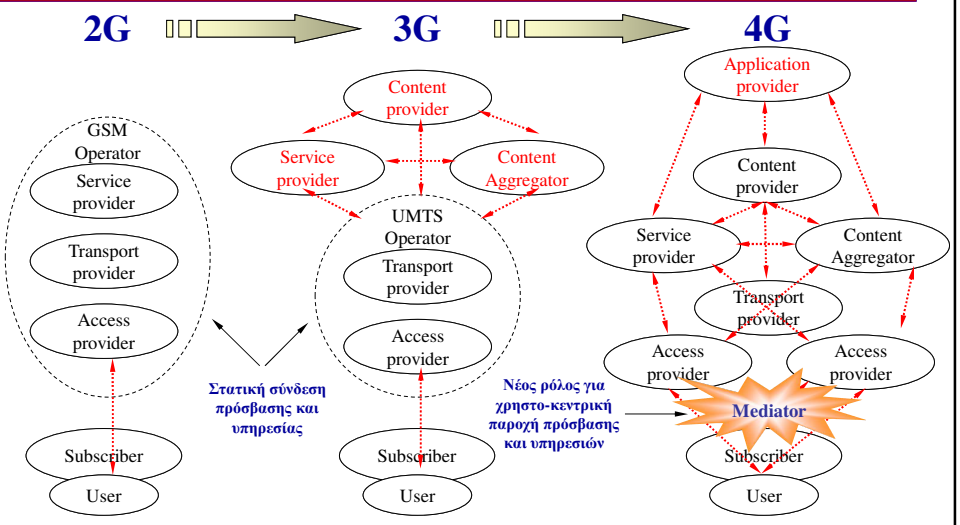
Service provision model trends



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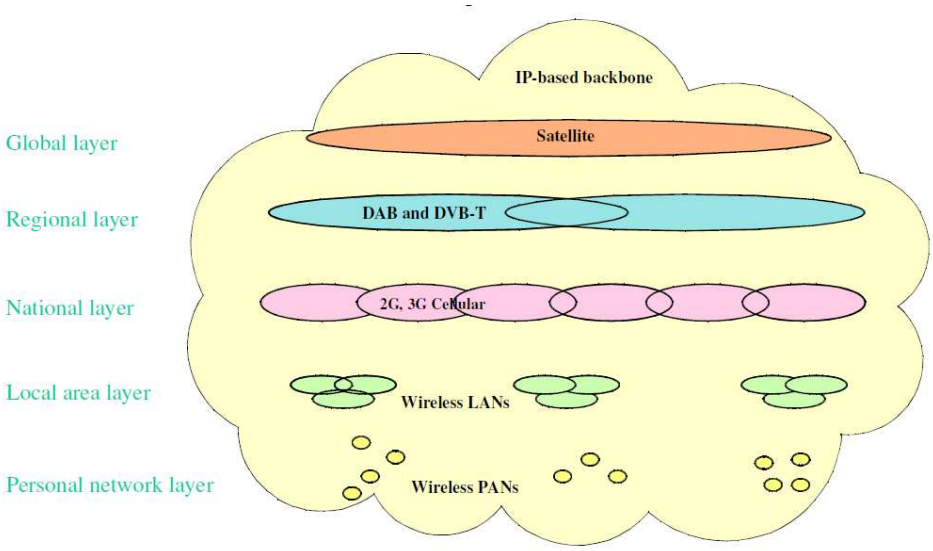
Interconnection at multiple layers



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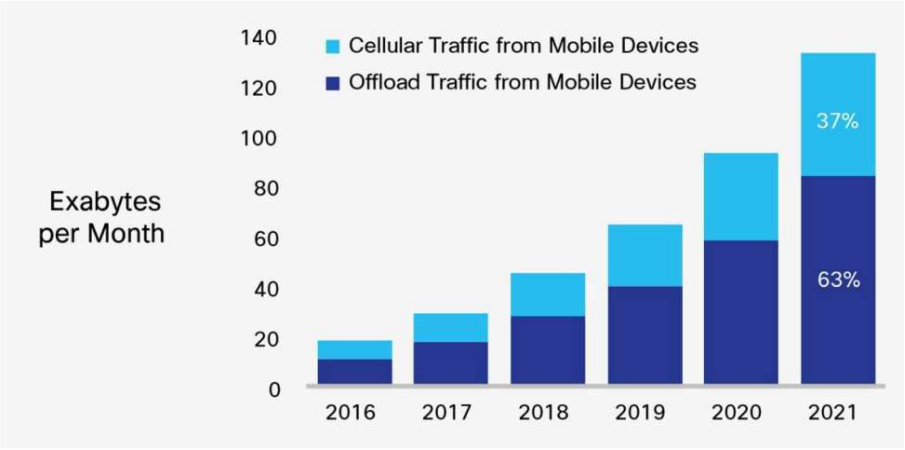
Mobile traffic offloading



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

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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

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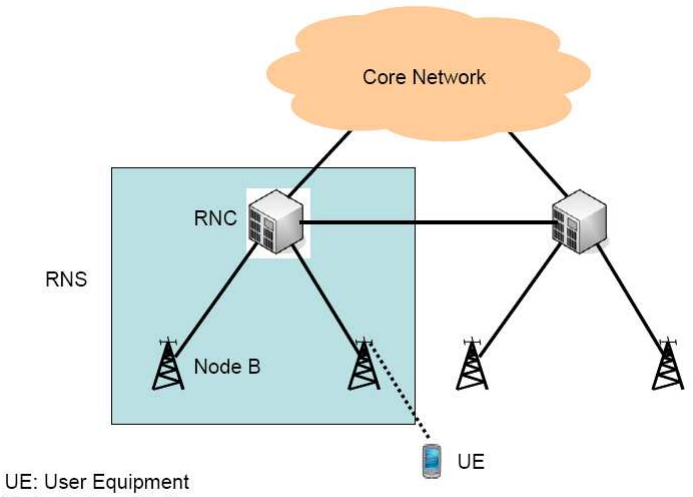
3G/UMTS Hierarchical Radio Access Network (RAN)



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

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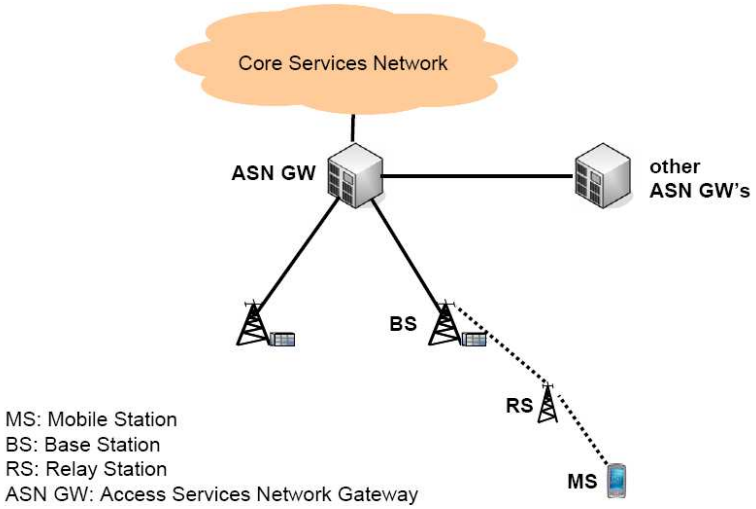
WiMAX (IEEE 802.16) RAN with relaying



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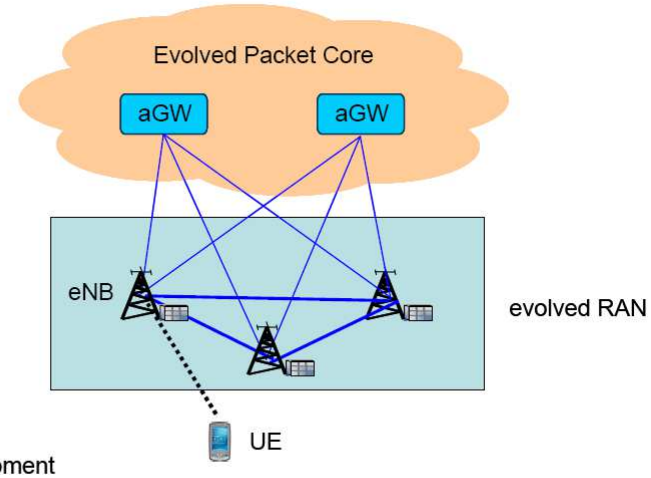
3G Long Term Evolution (LTE) RAN



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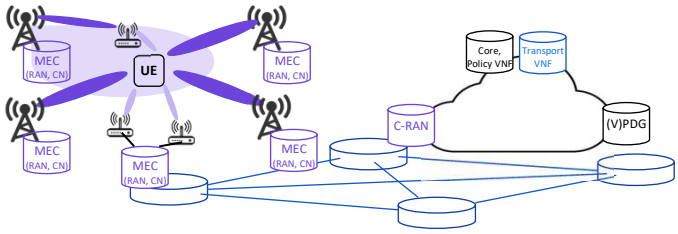
5G flexibility



- '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
- C-RAN – removal of functionality from cell sites to consolidation point in the network
- MEC – pushing Core Network functions and content ingress to cell sites

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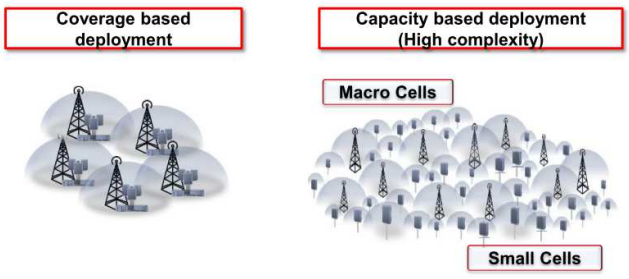
From coverage to capacity deployments



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

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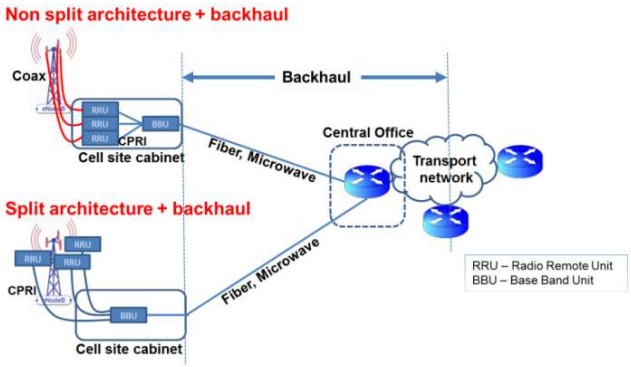
RRU-BBU separation



- RRU (Radio Remote Unit): sends/receives signals (EM waves) through antenna
- BBU (BaseBand Unit): conversion between analog and digital signals

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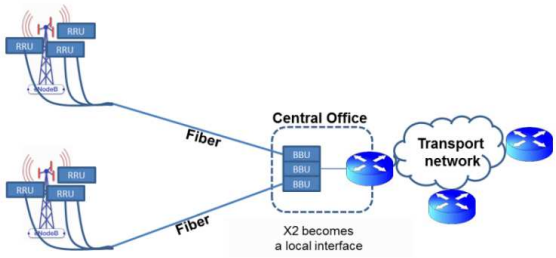
BBU centralization and pooling: Cloud RAN

BBU centralization:



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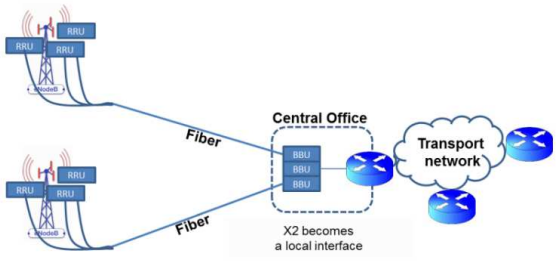
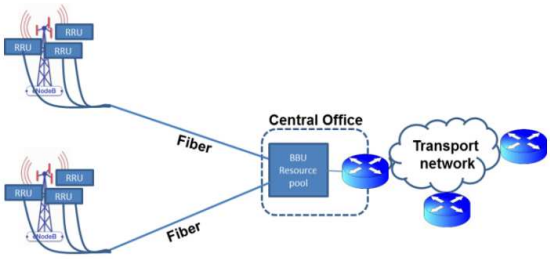
BBU centralization and pooling: Cloud RAN

BBU centralization:



BBU pooling (Cloud RAN):



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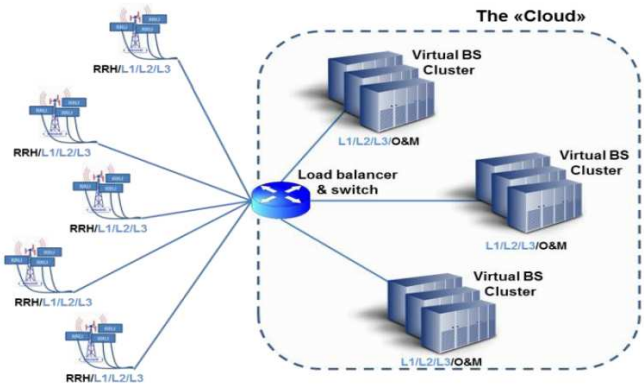
Cloud RAN with virtualization



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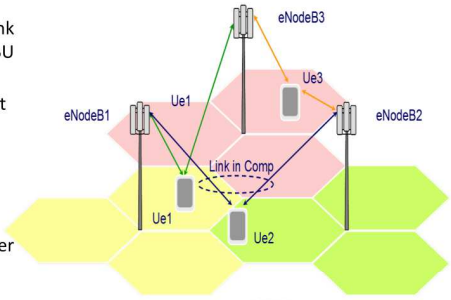
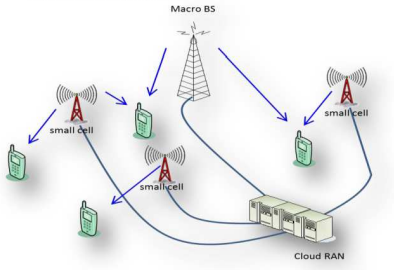
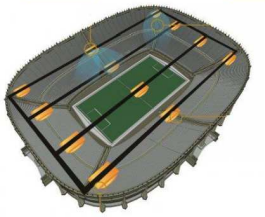
Cloud RAN with virtualization: Why?

- **Inter-site CoMP**: both downlink and uplink algorithms (up to Rel. 12) require BBU centralization (intra eNodeB solutions).
- Macro only solutions show limited gains at cell edge. **Higher values for uplink CoMP** and in intra-site only (adressed by first implementations)
- **Higher gains in HetNet scenarios** (for example Stadium) due to the higher interference levels:







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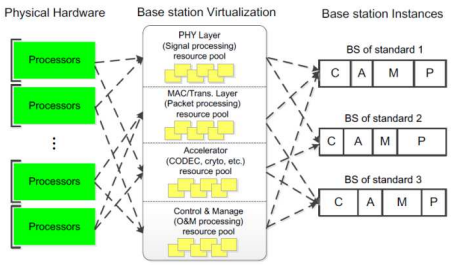
Virtualization gains

- 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



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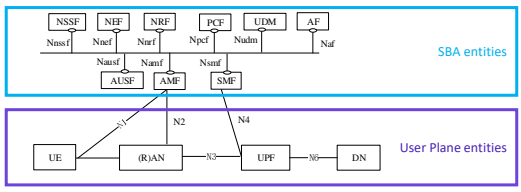
5G CN: Service-Based Architecture (SBA)



Authentication Server Function (AUSF)
Access and Mobility Management Function (AMF)
Session Management Function (SMF)
Network Slice Selection Function (NSSF)
Network Exposure Function (NEF)
NF Repository Function (NRF)
Policy Control Function (PCF)
Unified Data Management (UDM)
Application Function (AF)

Unified Data Repository (UDR)
Unstructured Data Storage Function (UDSF)
5G-Equipment Identity Register (5G-EIR)
Security Edge Protection Proxy (SEPP)
Network Data Analytics Function (NWDAF)

User Plane Function (UPF)
Data Network (DN), e.g. operator services, Internet access or 3rd party services
User Equipment (UE)
(Radio) Access Network ((R)AN)

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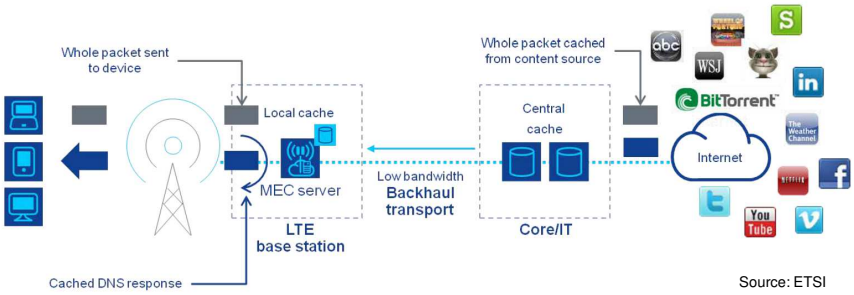
Multiaccess Edge Computing: Caching



Source: ETSI

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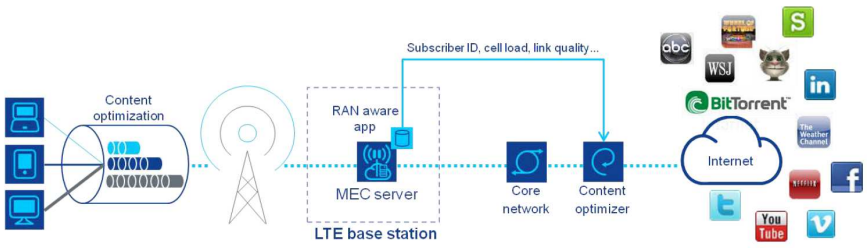
MEC: Content optimization



Source: ETSI

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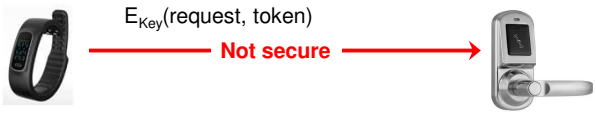
From **small cells** to **no cells**: **device-to-device** communication

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



Disconnected from the Internet device

Disconnected from the Internet device

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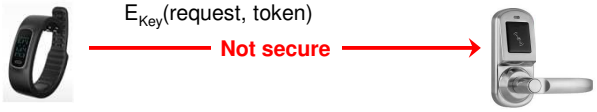
From **small cells** to **no cells**: device-to-device communication

- 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

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