

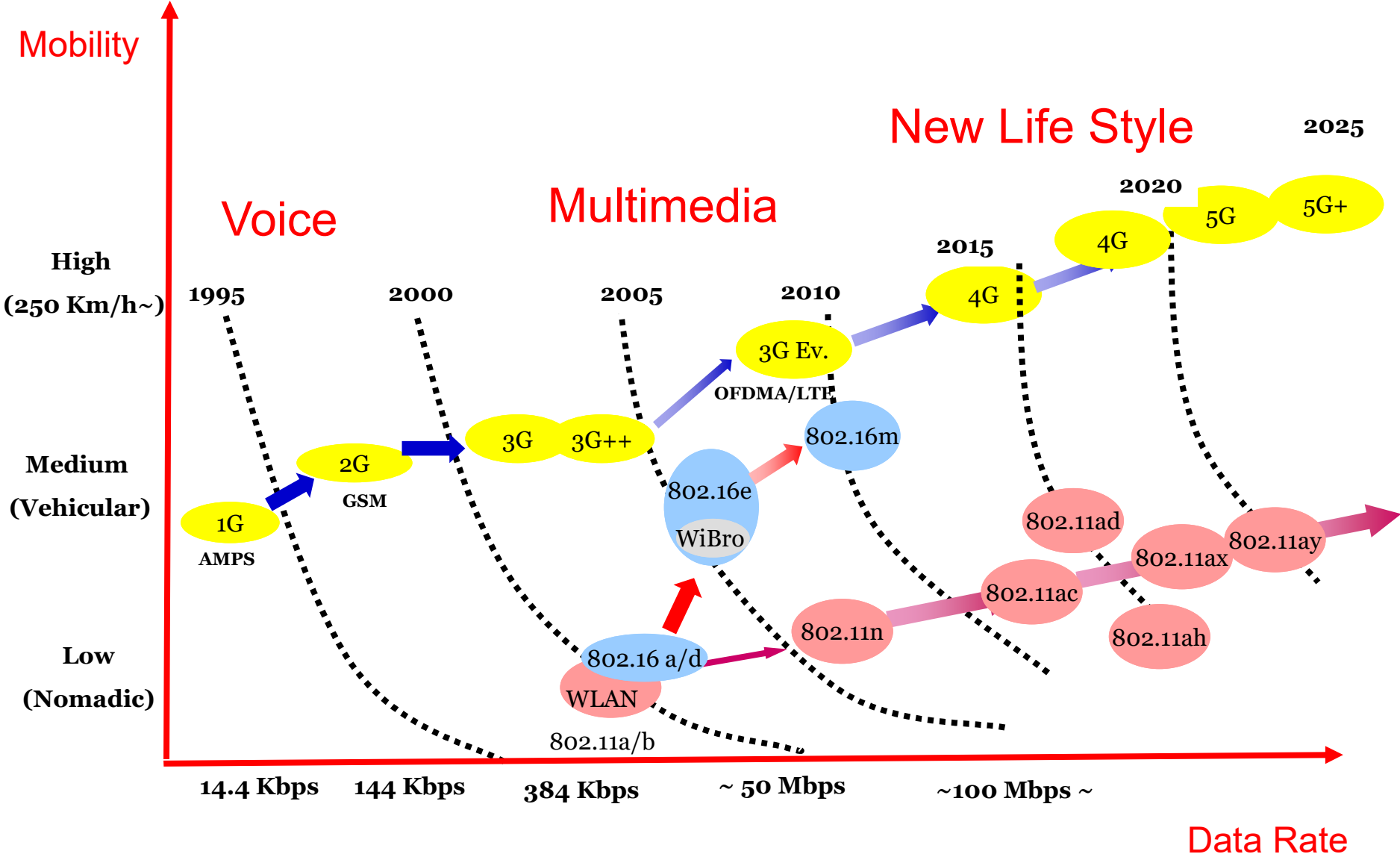
# Cours Cell

LA 4G et la 5G

*Guy Pujolle*

*Guy.Pujolle@lip6.fr*

# Towards 5G

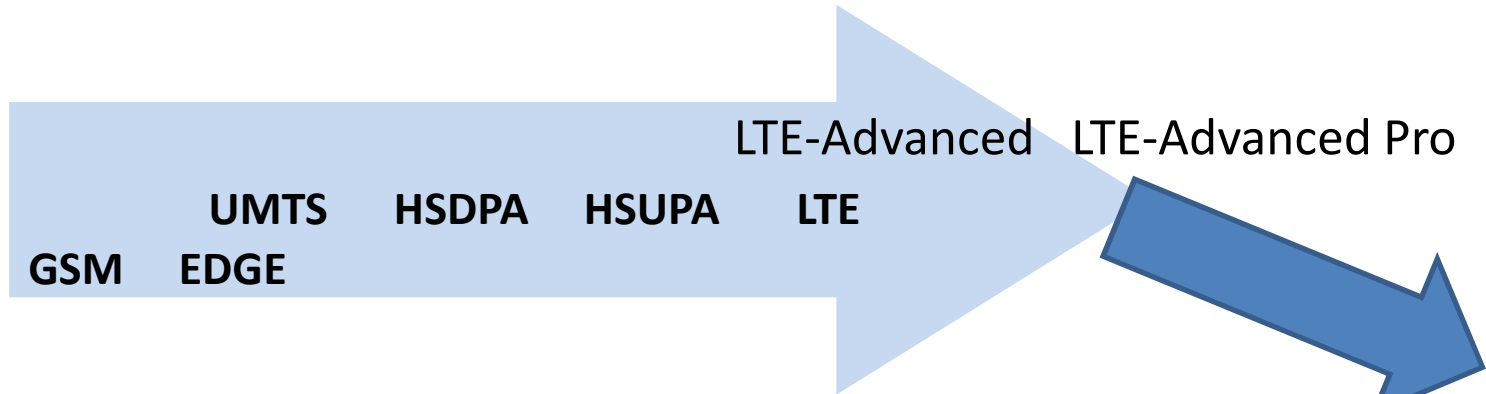


# Réseaux cellulaires mobiles : Générations

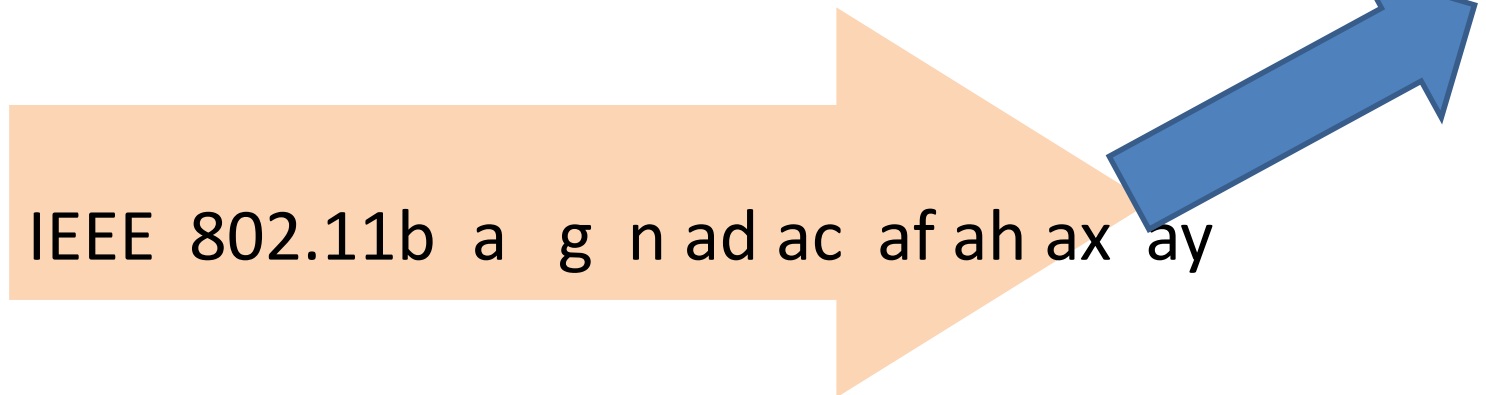
- ❑ 1G NMT (Nordisk Mobil Telefoni), AMPS (Advanced Mobile Phone System) : **analogic**
- ❑ 2G GSM (Global System for Mobile Communications) : **Digital, Circuit switching (CS)**
- ❑ 2,5G GPRS (General Packet Radio Service) : **Digital, Packet switching (PS)**
- ❑ 2,9G Edge (Enhanced Data Rates for GSM Evolution) : **Digital, PS, rapid modulation**
- ❑ 3G UMTS (Universal Mobile Telecommunications System), CDMA2000 : **broadband transmission**
- ❑ 3,5G HSDPA (High Speed Downlink Packet Access)
- ❑ 3,7G HSUPA (High Speed Uplink Packet Access)
- ❑ 3,9G LTE (Long Term Evolution) Under 4G name
- ❑ 4G LTE-A (LTE-Advanced)
- ❑ 4,5G LTE-A extended LTE-U et LTE-M
- ❑ 5G **Billion of connections, Internet of things**
- ❑ 5G+ C-RAN **Cloud Radio Access Network (Full virtualization)**

# Mobile and wireless networks

3GPP



IEEE



# LTE -3G + (3GPP release 8) -2008

- Long Term Evolution 3G+
  - OFDMA instead of CDMA
  - IP-based except telephony
  - On the market 2009/2010
    - 100 countries in 2014
  - Peak rate :
    - 50 Mbps uplink (with 20 MHz)
    - 100 Mbps downlink (with 20 MHz)

# LTE-3G super+ (3GPP release 9) - 2009

- Femtocell
- machine to machine (M2M)
- Public safety warning (Tsunami, etc.)
- Green agenda (optimization of the E-Node-B)

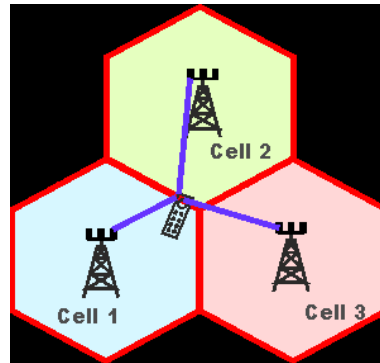


# LTE-A (3GPP release 10) – 2012

- LTE-A = 4G
- Full native IP
  - ToIP
- MU-MIMO (up to 4 antennas)
- Smart antenna (software radio)
- Directive antenna (beamforming)
- Cognitive radio
- Relay and mesh networks
- “Green” properties
- Femtocell

# 4G+ Release 11 - 2013

- LTE- Advanced
- Introduction of service-oriented mobile networks
- Heterogeneous networks (HetNet)
- Coordinated Multi-Point operation (CoMP)



- In-device Co-existence (IDC)
  - Interference between bands due to signal distortion



# 4G++ Release 12 – 2015

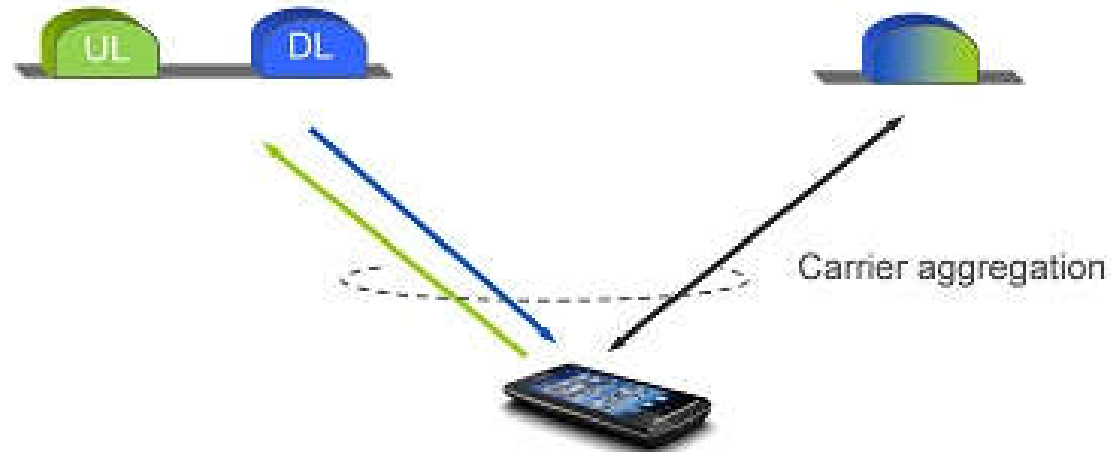
- Improvement of Spectral Efficiency
- LTE Carrier Aggregation
- Multi Access
- Machine-Type Communications (MTC)
- Interworking between Mobile Operators
- Continuity of Data Sessions to Local Networks
- Telepresence

# 4G Pro Release 13 2017

- 4G extension
- Virtualization
- LTE M and beginning of NB-IoT
- LTE-U (Unlicensed)

Primary Carrier – Licensed Spectrum  
Mobility, control signaling, user data, ...

Secondary Carrier – Unlicensed Spectrum  
user data



# 4G Release 14 2019

- Mission critical enhancements (extreme low-latency, high reliability, high availability, and strong security)
- V2x service (between vehicles, vehicle to pedestrian and vehicle to infrastructure)
- eLAA (enhance-Licensed Access)
- LWA (LTE Wi-Fi Aggregation)
- 4 band carrier aggregation
- inter-band carrier aggregation
- multi-hop mesh to extend network coverage

# 5G Release 15 2020

- Term: 2020
- Throughput: 1 to 10 Gbps
- Billions of connected things
  - Medical
  - Home
  - Sensor

# 5G

## A unifying connectivity fabric

Always-available, secure cloud access



Enhanced mobile  
broadband

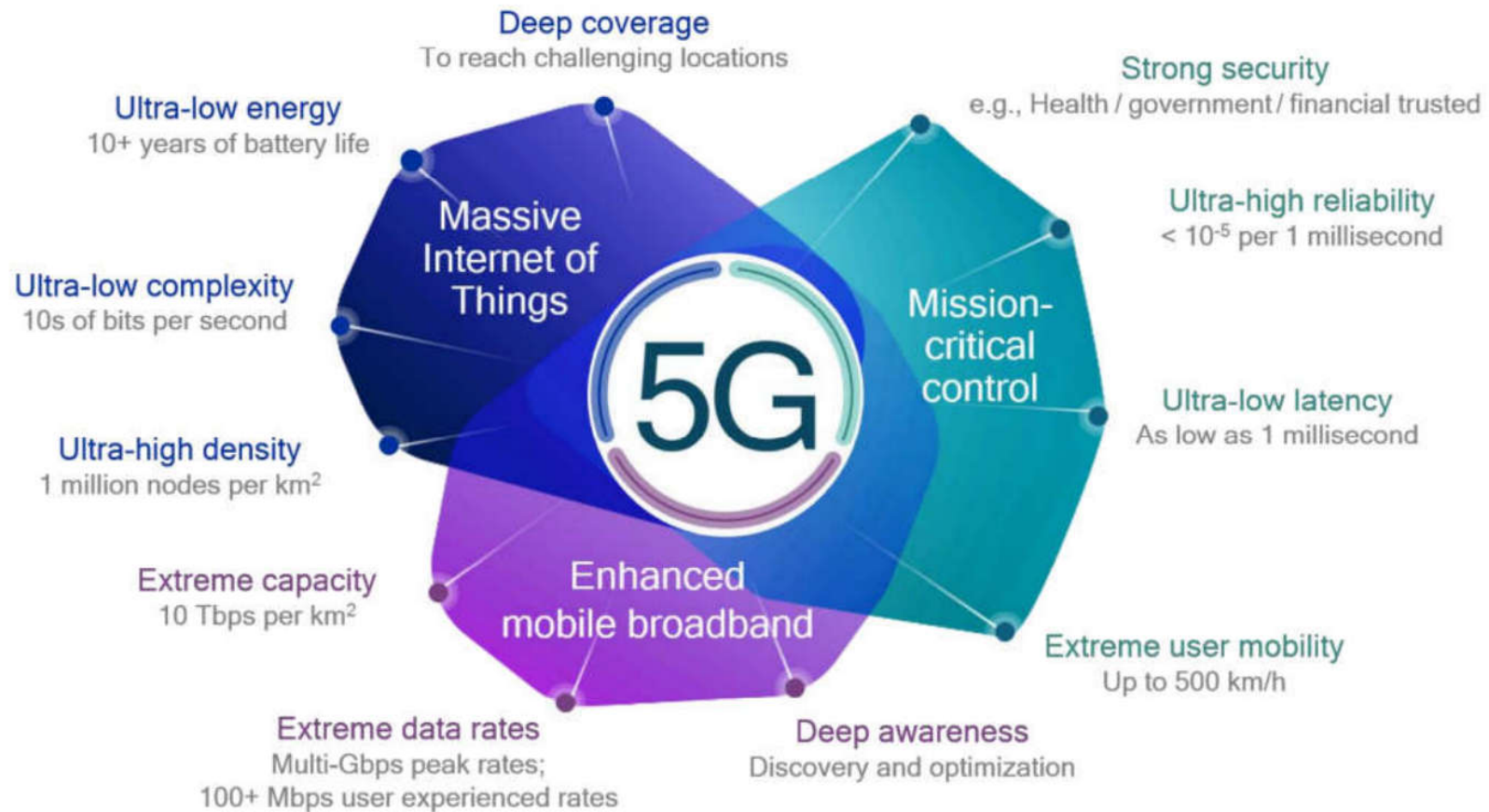


Mission-critical  
services



Massive Internet  
of Things

# 5G



# 5G



Low bands below 1 GHz: longer range for e.g. mobile broadband and massive IoT

Mid bands 1 GHz to 6 GHz: wider bandwidths for e.g. eMBB and mission-critical

High bands above 24 GHz (mmWave): extreme bandwidths

Licensed Spectrum

Exclusive use

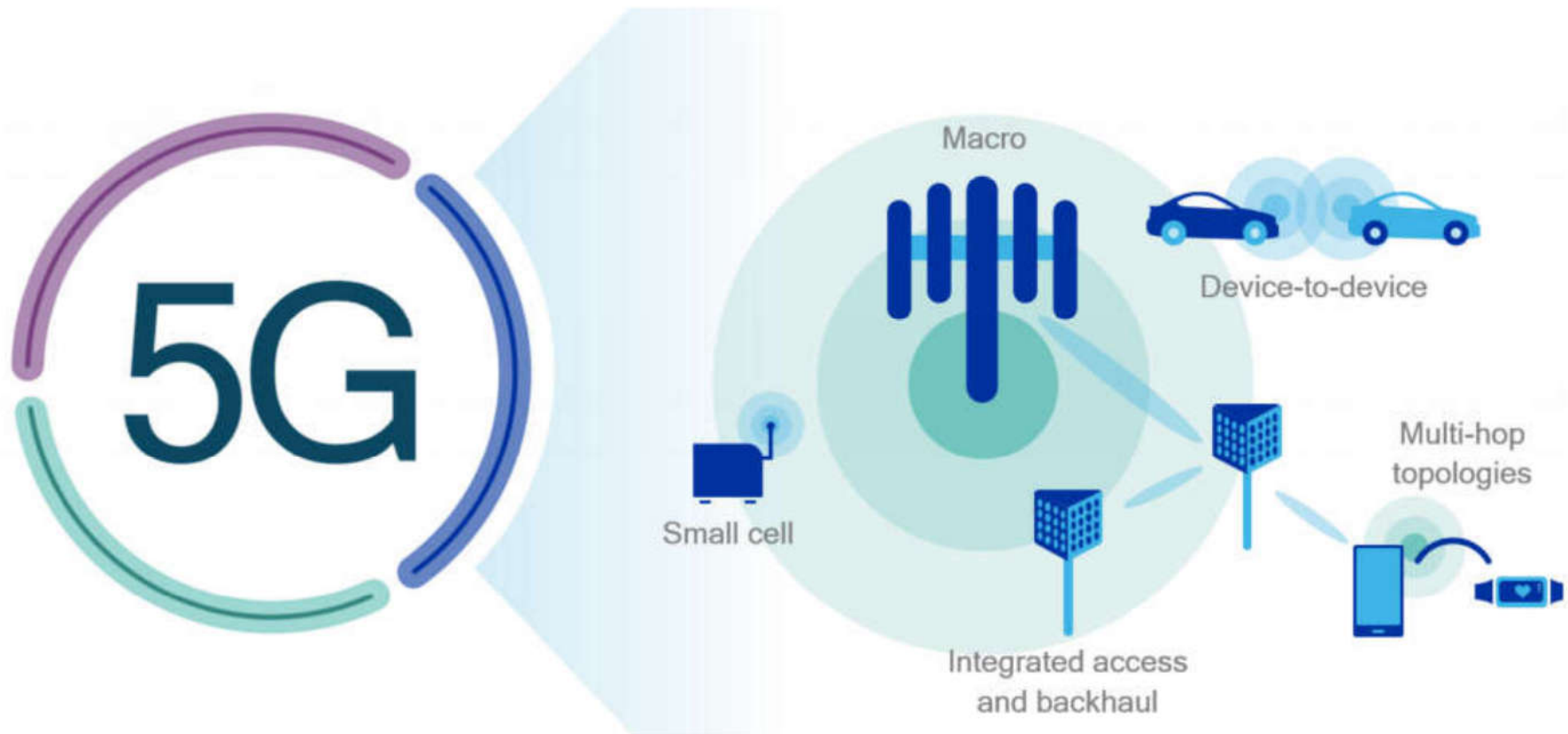
Shared Spectrum

New shared spectrum paradigms

Unlicensed Spectrum

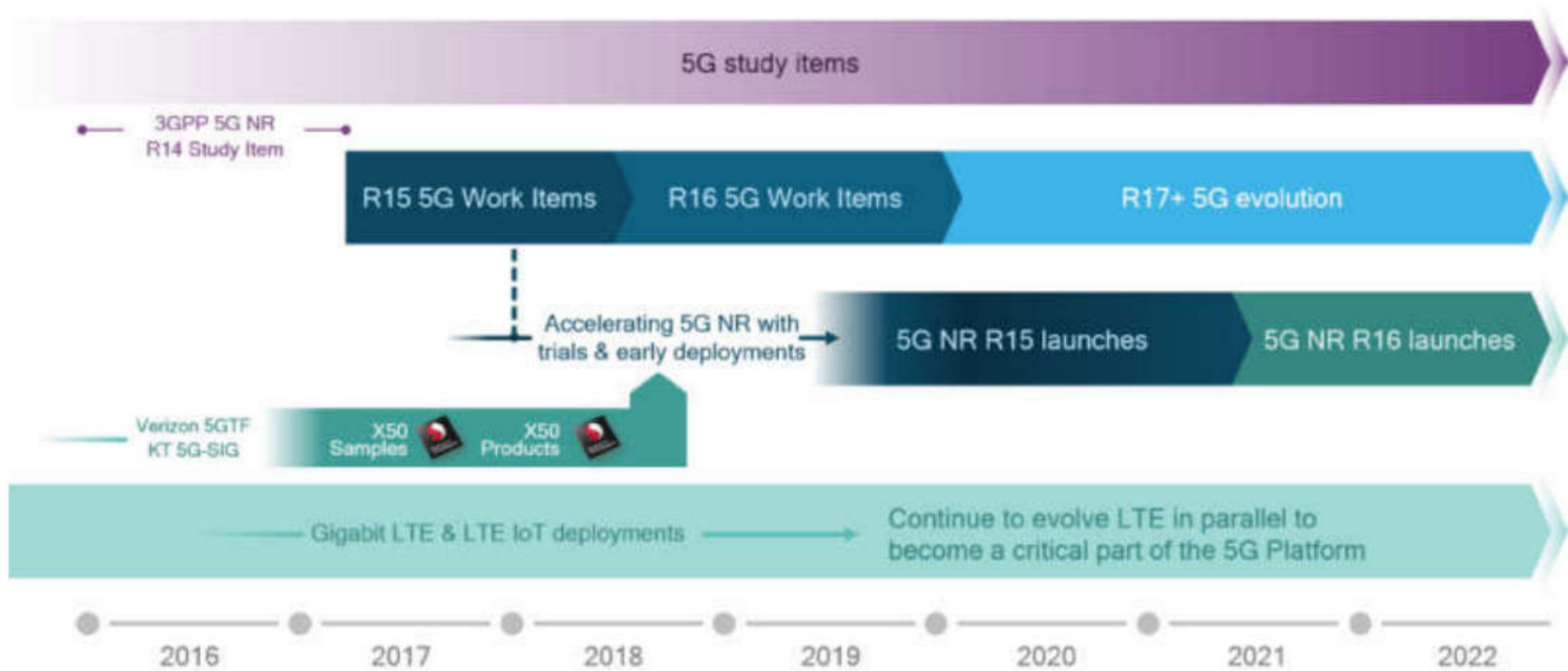
Shared use

# 5G

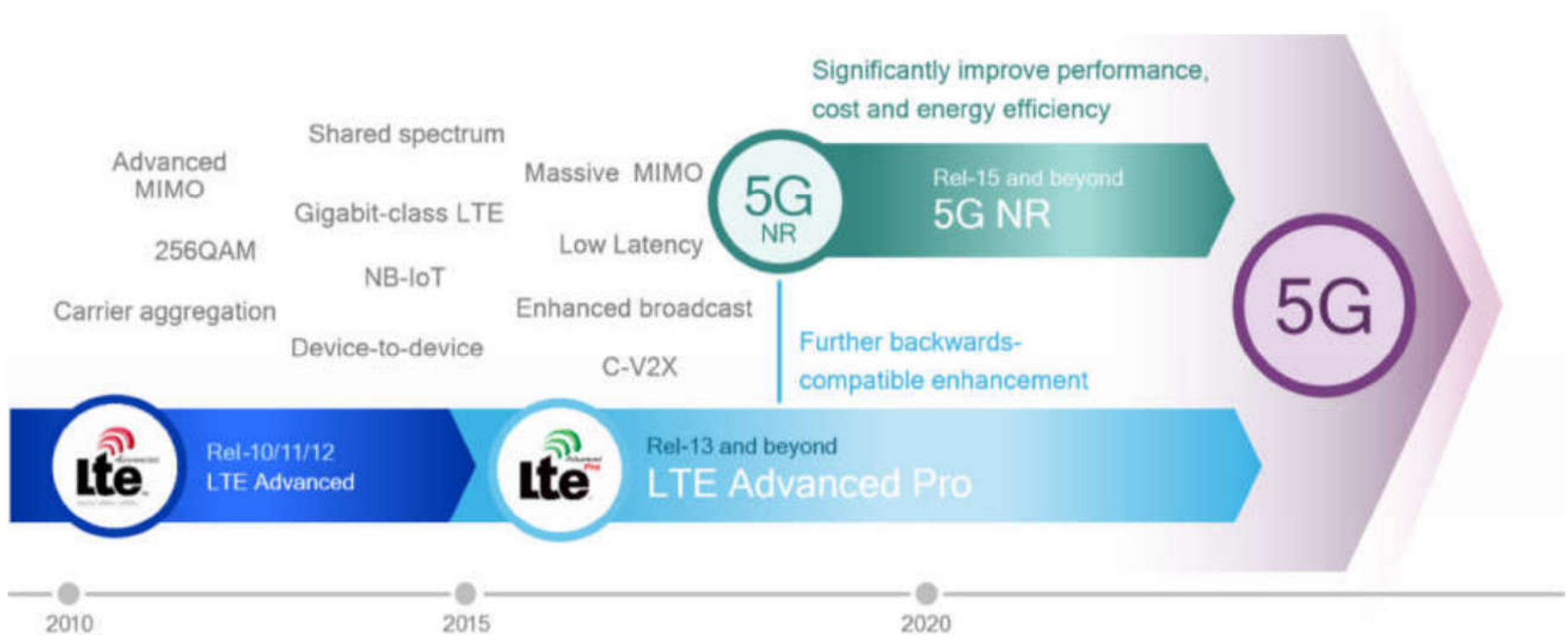




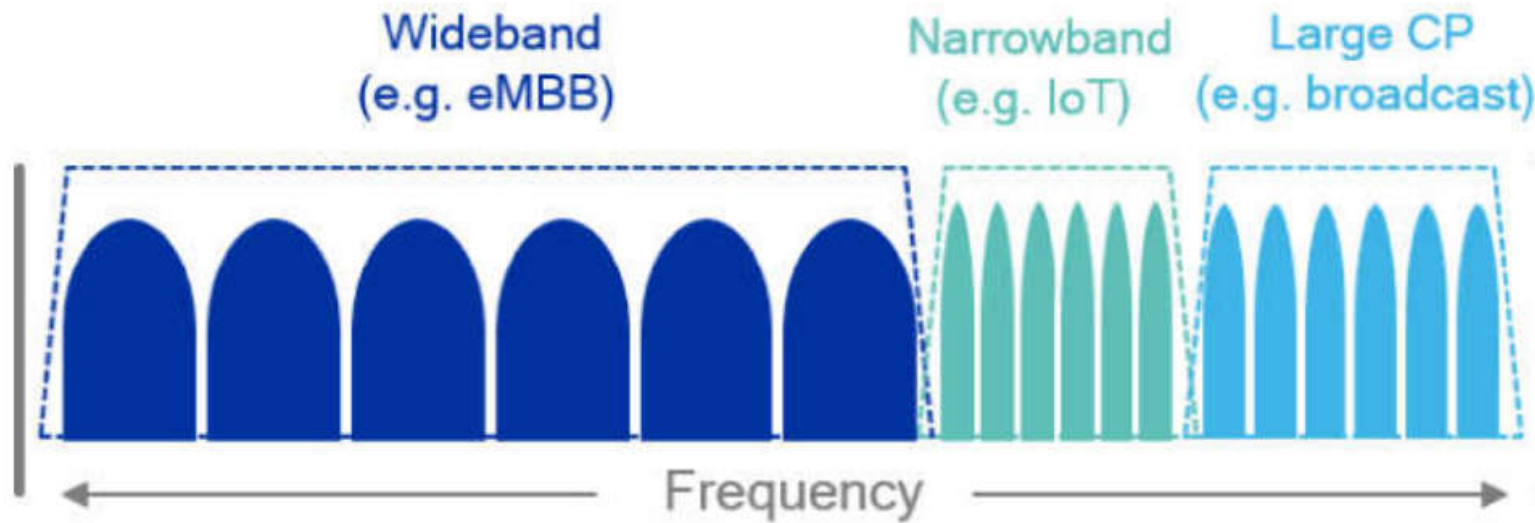
# 5G



# 5G



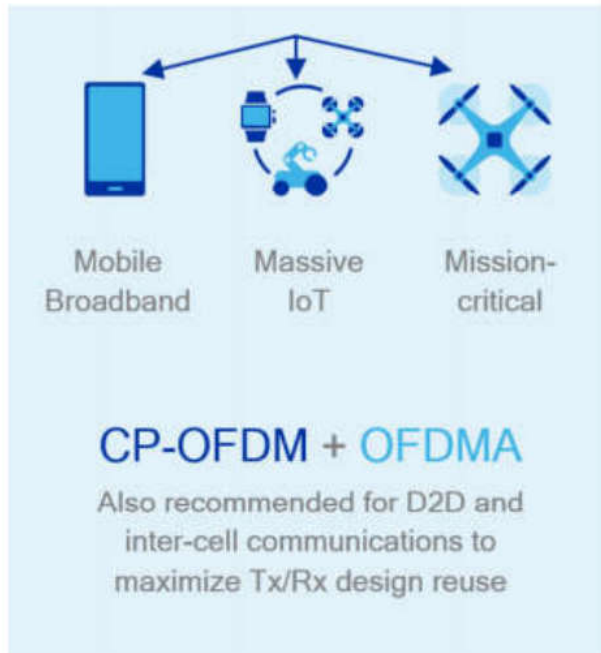
# 5G Multiple services



# 5G Access

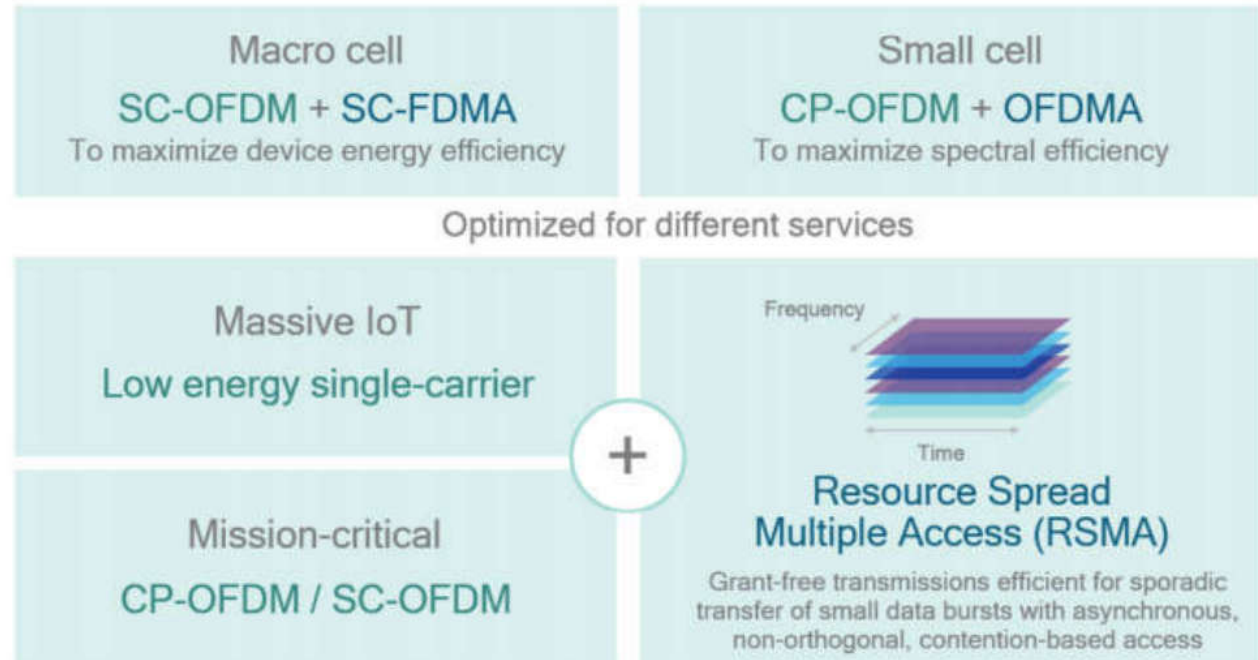
## 5G NR Downlink

Unified downlink design



## 5G NR Uplink

Optimized for different deployments



CP Cyclic Prefix  
SC Single Carrier

# 5G inventions

## Massive IoT

---

- Low complexity narrowband
- Low power modes for deep sleep
- Efficient signaling
- Grant-free uplink transmissions
- Optimized link budget
- Managed multi-hop mesh



## Mission-Critical Control

---

- Low-latency with bounded delay
- Efficient multiplexing with nominal traffic
- Grant-free uplink transmissions
- Simultaneous redundant links
- Reliable device-to-device links
- Optimized PHY/pilot/HARQ

## Enhanced Mobile Broadband

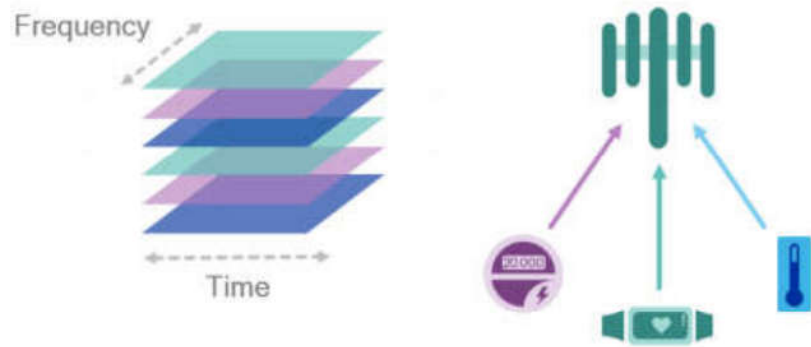
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- Wider bandwidths
- Mobilizing mmWave
- Shared spectrum
- Device-centric mobility
- Dynamic, low-latency TDD/FDD
- Massive MIMO
- Advanced channel coding
- Native HetNet and multicast support

# 5G extension

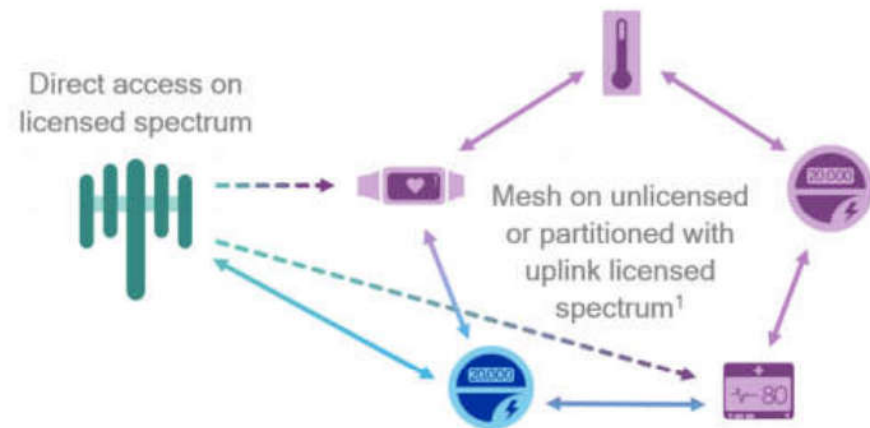
## Grant-free uplink

Resource Spread Multiple Access (RSMA)



## Coverage extension

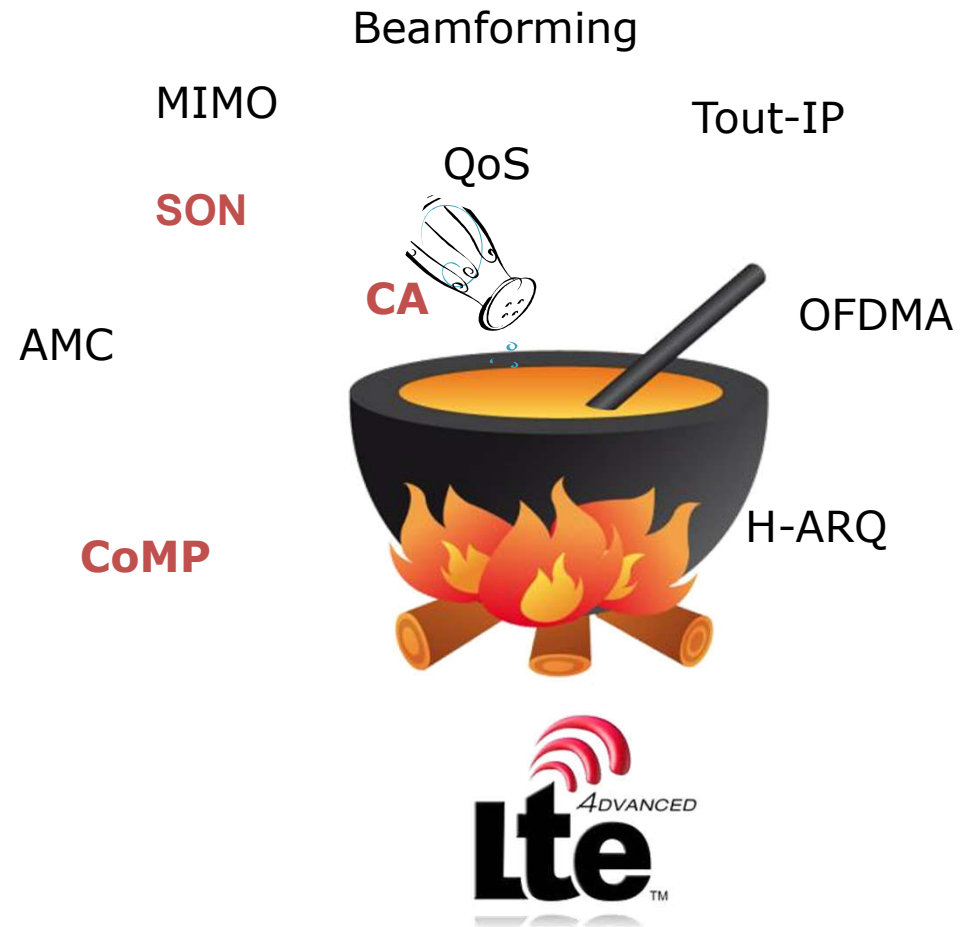
Multi-hop mesh with WAN management



Quelques évolution dans la 4G

# 4G : nouveautés

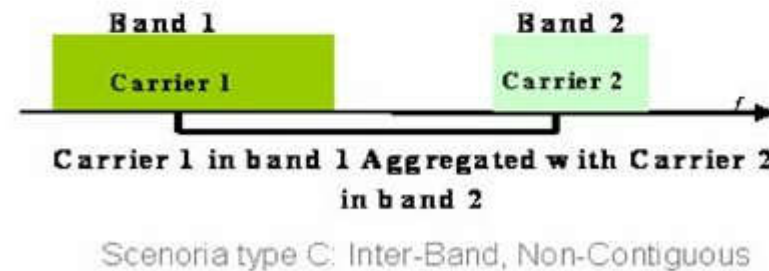
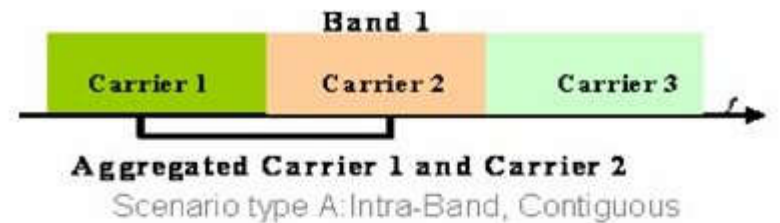
- ▶ CA (Carrier aggregation)
- ▶ CoMP (Coordinated Multipoint Transmission)
- ▶ Support de relais (ad hoc, mesh)
- ▶ SON (Self Organization Networks)
- ▶ Antennes intelligentes
- ▶ Radio cognitive



--- **Nouveauté**  
--- Commun à LTE et WiMAX



# CA (Carrier Aggregation) : Scénarios



Typical Carrier Aggregation Scenarios

Via: [3g4g.blogspot.com](http://3g4g.blogspot.com)

# CoMP

Réseau existant



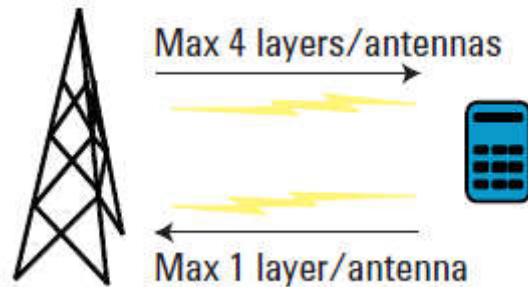
Communiquer avec  
une cellule dédiée  
(cell-centric)

Réseau de nouvelle génération

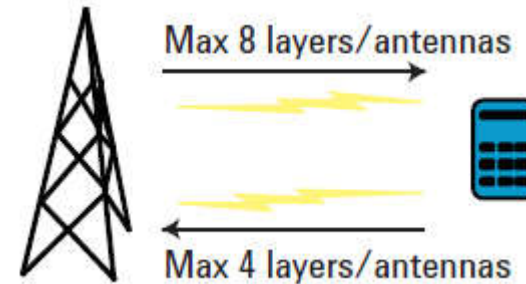


Communiquer avec  
plusieurs cellules  
voisines (user-centric)

# Antennes plus avancées



*Release 8 LTE maximum number of antenna ports and spatial layers*

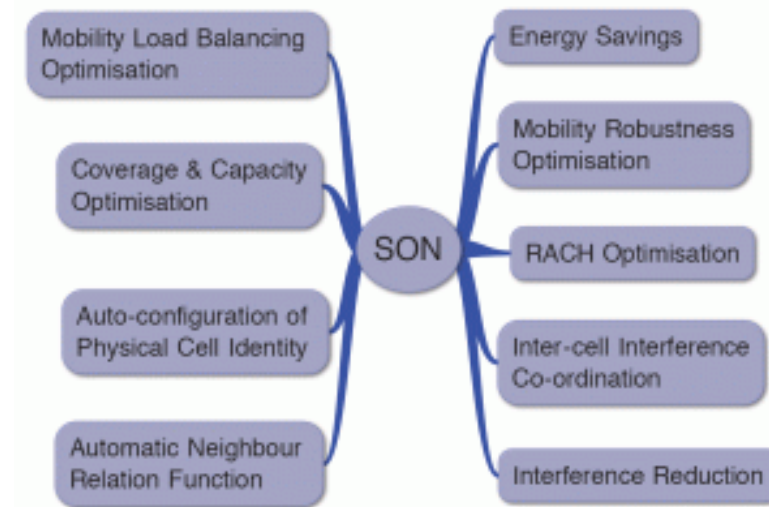


*LTE-Advanced maximum number of antenna ports and spatial layers*

- MIMO avancé avec Multi MIMO
- Smart antennas ou AAS (adaptive antenna systems) : les faisceaux sont dirigés vers les utilisateurs : ceci nécessite la connaissance de leur positions via des systèmes de géolocalisation
  - Puissance dynamique
  - Direction dynamique
  - Fréquence dynamique

# SON (Self Optimizing Network)

- Self configuration : fonctionnement P&P
  - Découverte de voisins, allocation de cell\_ID, chargement automatique de software
- Self optimization : ajustement automatique de paramètres de transmission
  - Amélioration de la couverture et de la capacité
- Self healing : reprise automatique suite aux problèmes
  - Détection et correction des 'ping-pong'

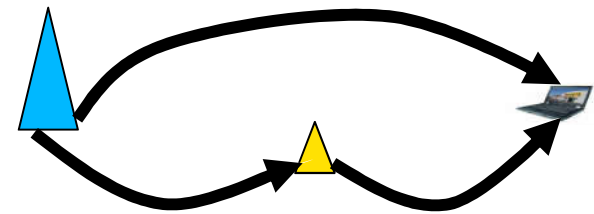
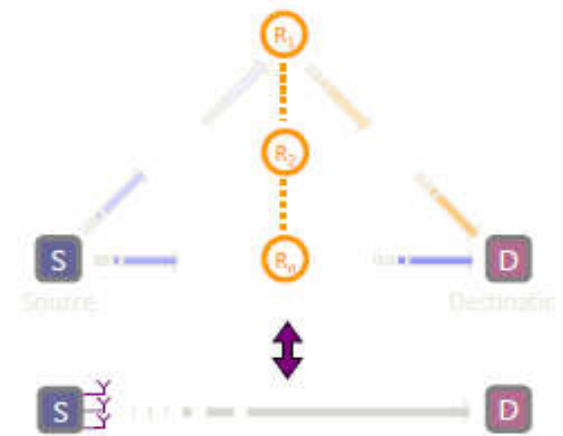


# Fonctionnalités de la radio cognitive

- L'écoute du spectre
  - Evaluer si la ressource est utilisée (de façon analogique ou numérique)
- L'allocation de ressources exploitables
  - Choix de la fréquence et de la puissance
- La mobilité du spectre
  - Handover spectral
- Le partage de spectre
  - Eviter les collisions entre les clients cognitifs

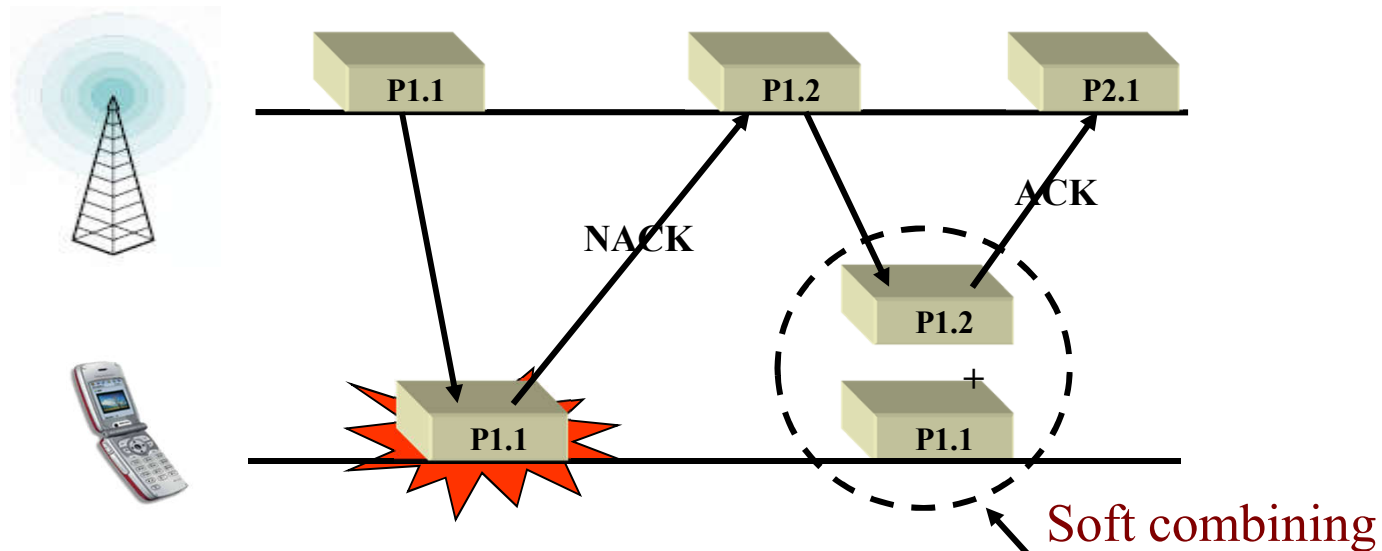
# Diversité de coopération

- Principe de la coopération
  - Pour les réseaux autonomes multi-sauts
    - Ad hoc
    - Mesh
  - Définition d'un «MIMO virtuel»
    - Nœuds coopérants = relais
    - Relais : antennes virtuelles du nœud source
      - Diversité - Diminution du taux d'erreur
  - Technologie Green
    - Baisse de la puissance des émetteurs radio



# Retransmissions HARQ

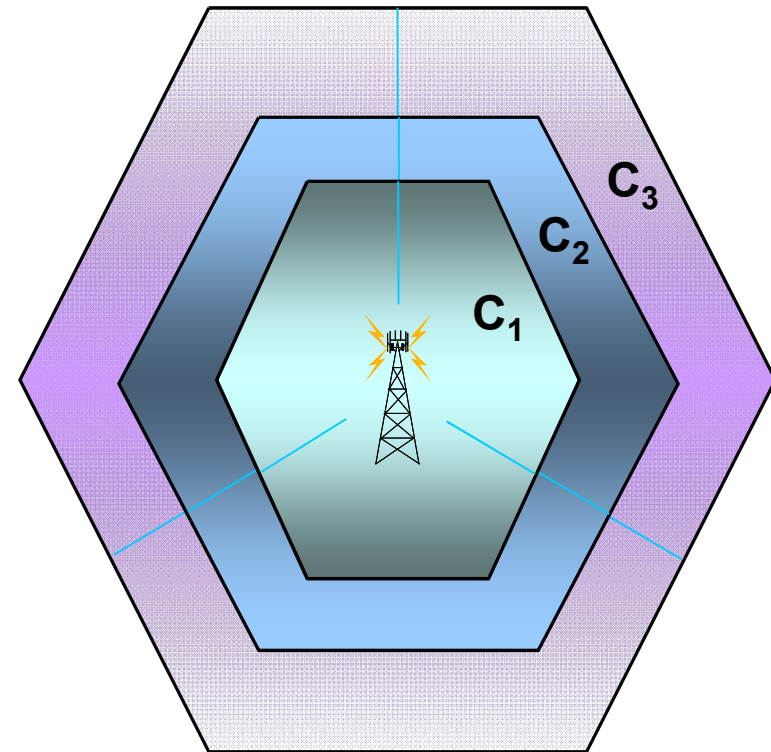
- HARQ : Hybrid Automatic Repeat reQuest
  - Stockage d'une transmission erronée & combinaison avec la (les) retransmission(s) → Gain en SNR



$P_{i,j}$  : Transmission j du paquet i

# AMC

- | Adaptive Modulation and Coding
- | Le profil de burst change selon l'état du canal (SINR)
- | Compromis débit – robustesse



$C_1 = 64$  QAM  
 $C_2 = 16$  QAM  
 $C_3 =$  QPSK



# Antennes

- Permet d'améliorer les transmissions radio
  - Ne joue pas le rôle d'amplificateur
- La «performance» d'une antenne est exprimée en dBi
  - dBi: Décibel isotropique
- Les différents types d'antennes
  - Omni (360°)
    - Exemple : Clé USB Wi-Fi ou 3G
    - Gain entre 2 et 10 dBi
  - Sectorielle (180°)
    - Exemple : Antenne télé
    - Gain entre 10 et 19 dBi
  - Directionnelle (30°)
    - Exemple : Parabole
    - Gain supérieur à 20 dBi

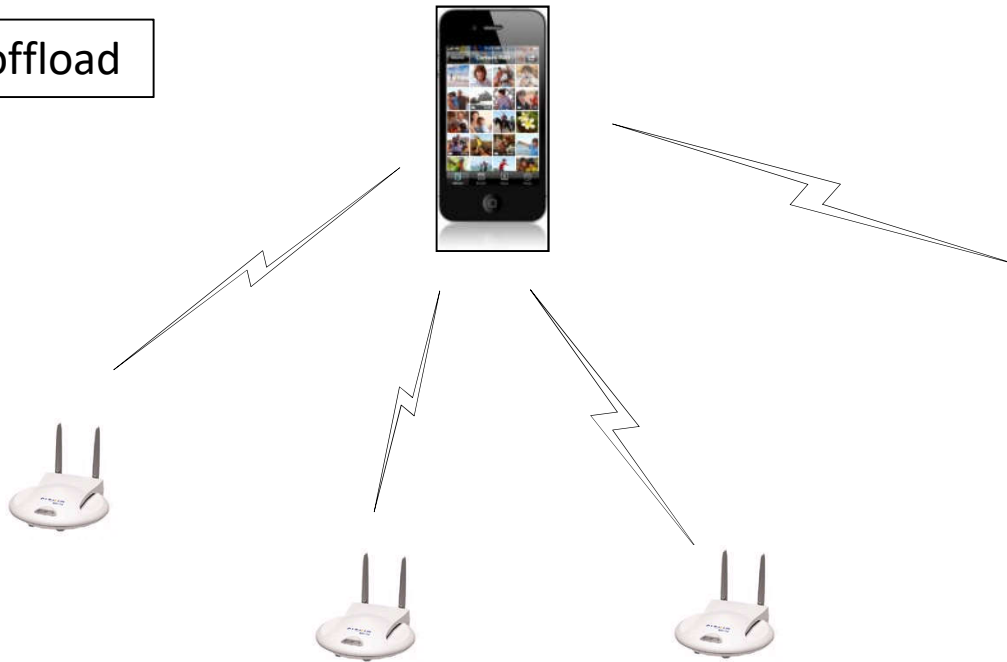
# VoLTE

- Voice over LTE
  - Voix IP native avec une priorité plus élevée par rapport à la data
  - Meilleure expérience usager
    - Utilisation de la voix haute définition, réduction du bruit
    - Téléphonie vidéo et multi-parties
    - Gestion de carnet d'adresse avancée (présence, localisation, capacités)
    - Meilleure QoS (MOS), latence
  - Solution standard donc indépendance des OS et des constructeurs
- Standard défini par le groupe GSMA
  - Organisation composée d'opérateurs GSM, 3G et LTE
  - Émet des rapports (IR: internal Reports) indiquant
    - Les informations à partager dans les accords de roaming
    - Les informations de facturation
  - IR 92 décrit la transmission en mode paquet de
    - Voix de base et SMS
    - Services supplémentaires (3-way call, call waiting, voice mail indication)

# 4G and Wi-Fi convergence

- Lack of radio resource

Wi-Fi offload



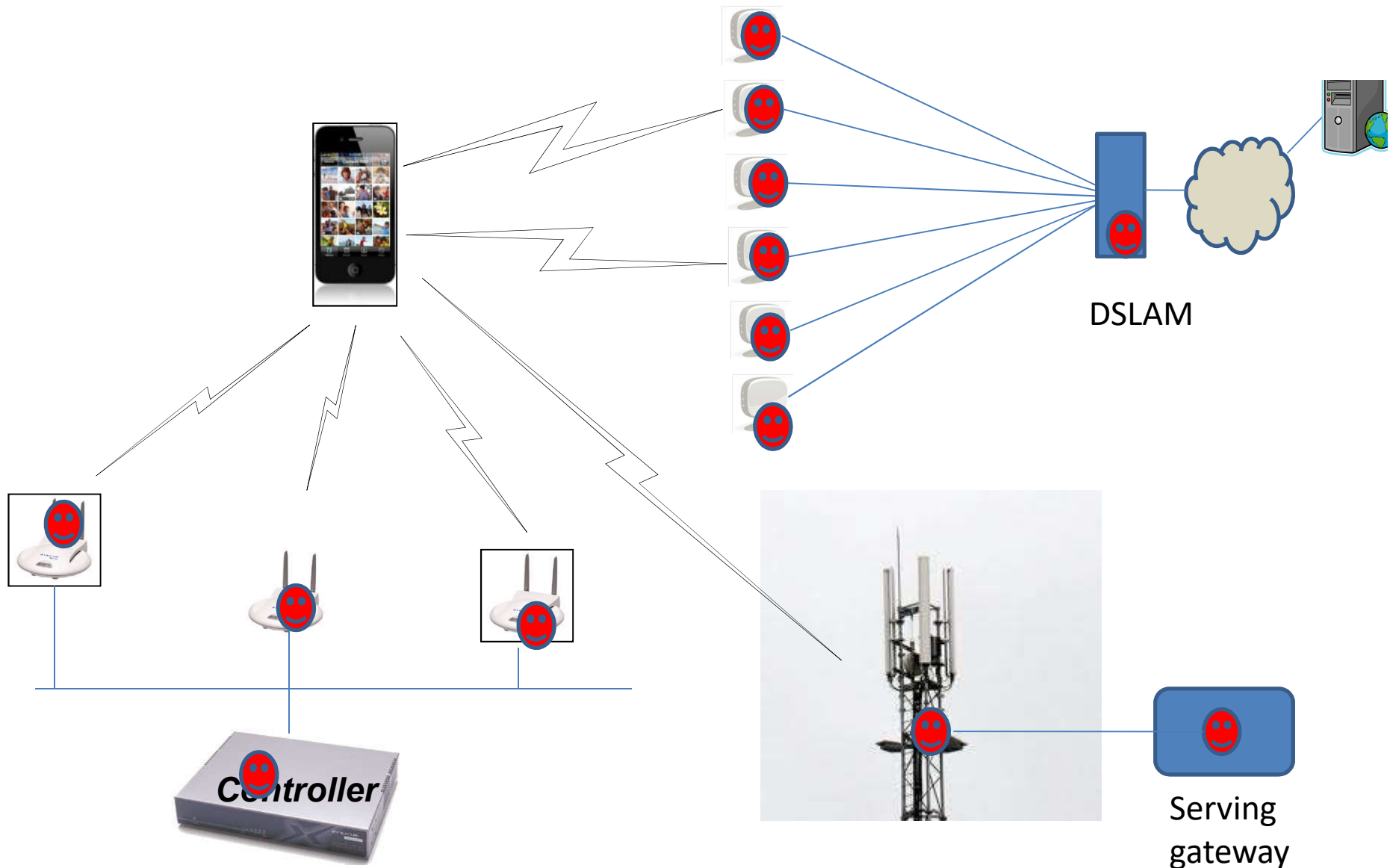
NGH: Next generation hotspot or Hotspot 2.0

NGH enables operators to continuously monitor and manage

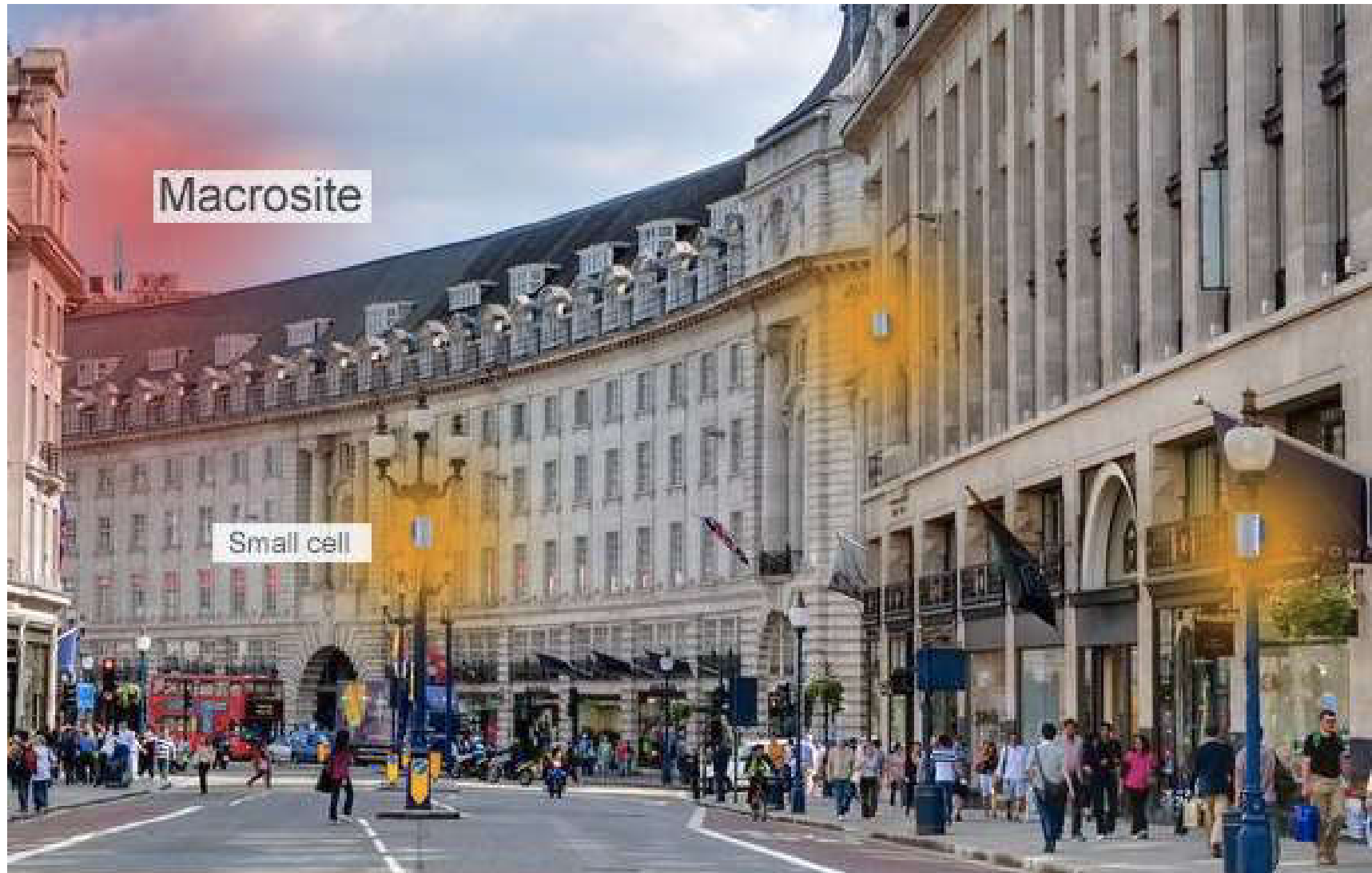
“cellular-like” service over Wi-Fi

IEEE 802.11u and EAP- (SIM, AKA, TLS,...)

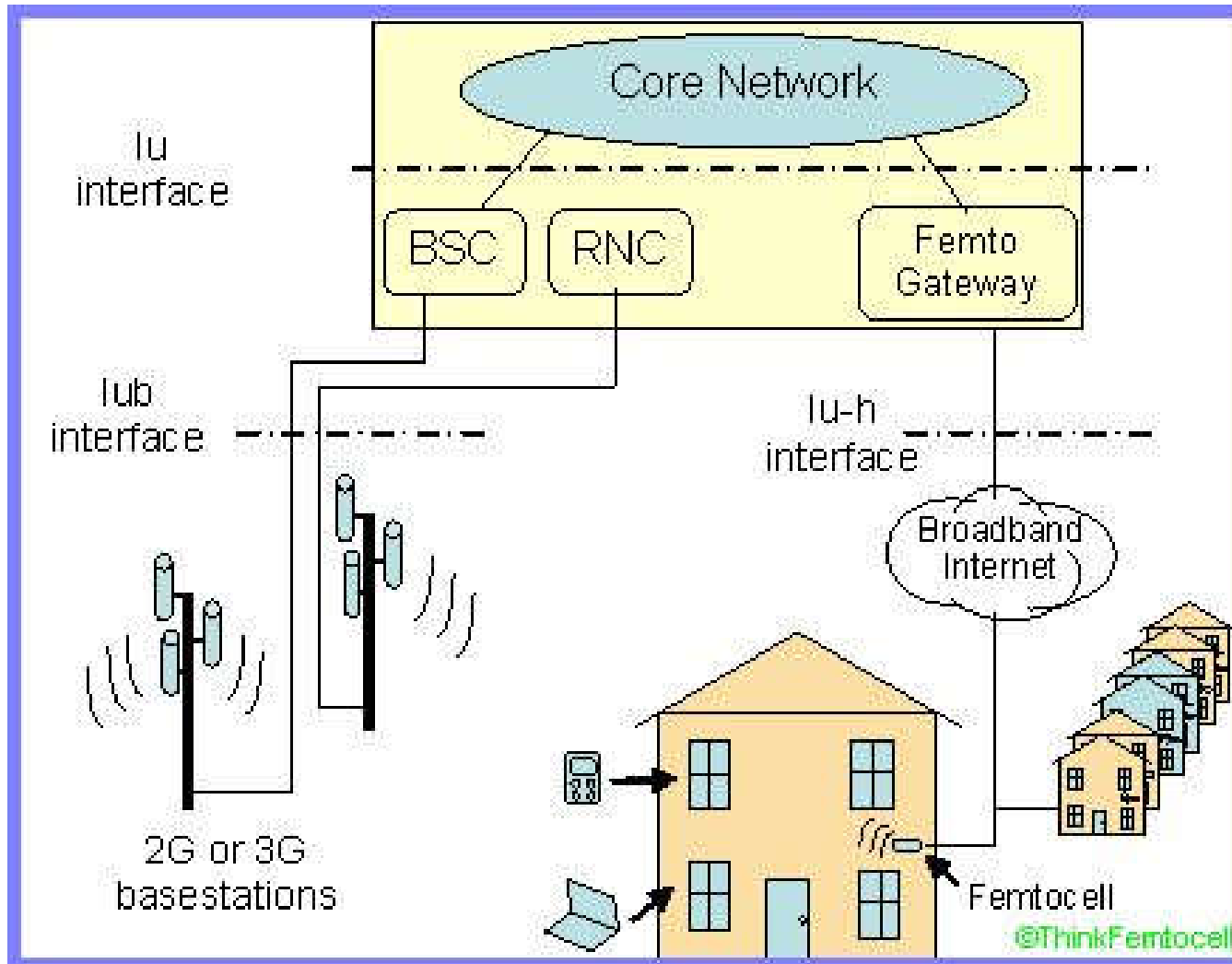
# The global management and control



# Small cells



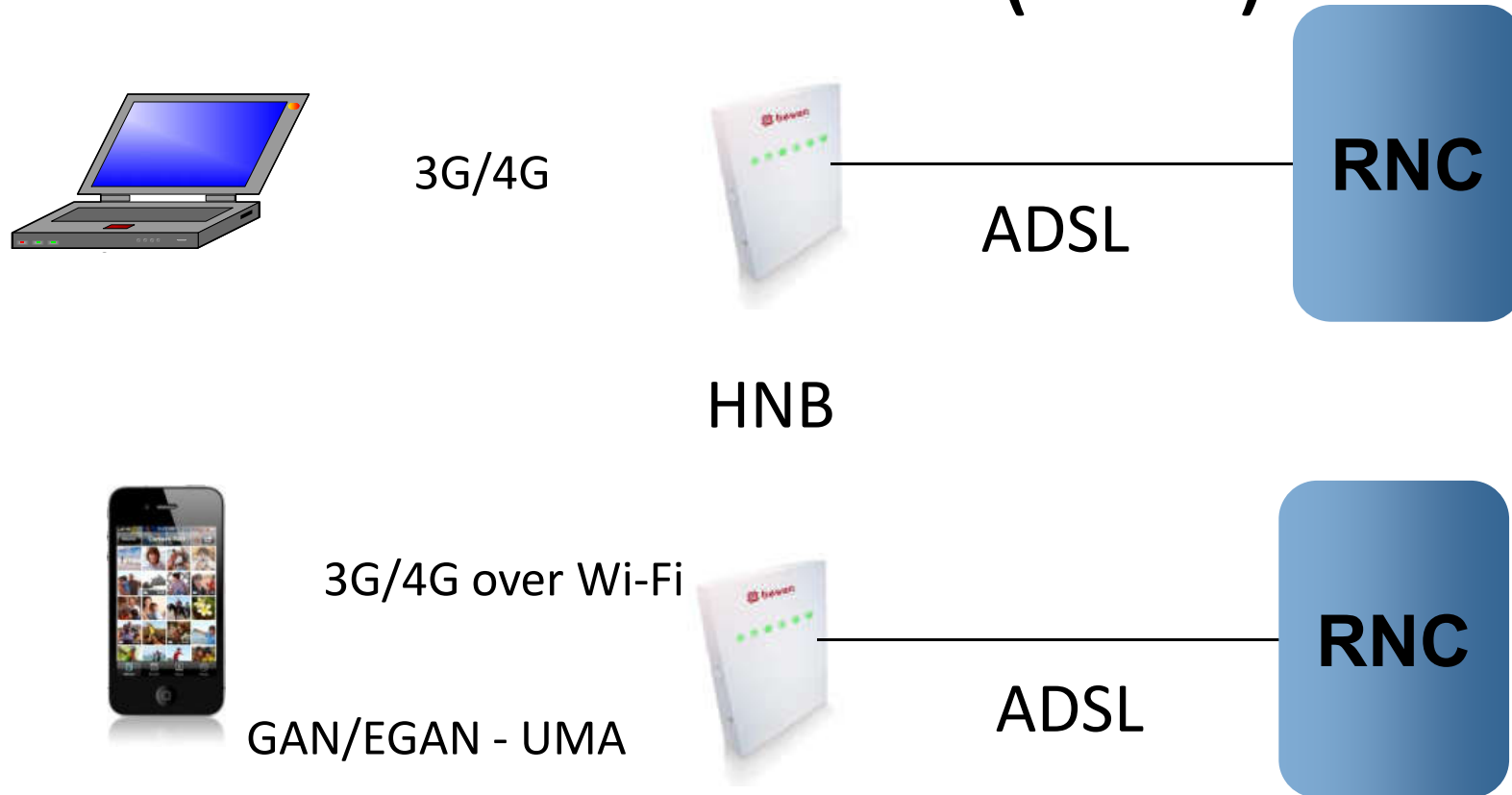
# Femtocell



# Home Node-B (HNB)



# Home Node B (HNB)

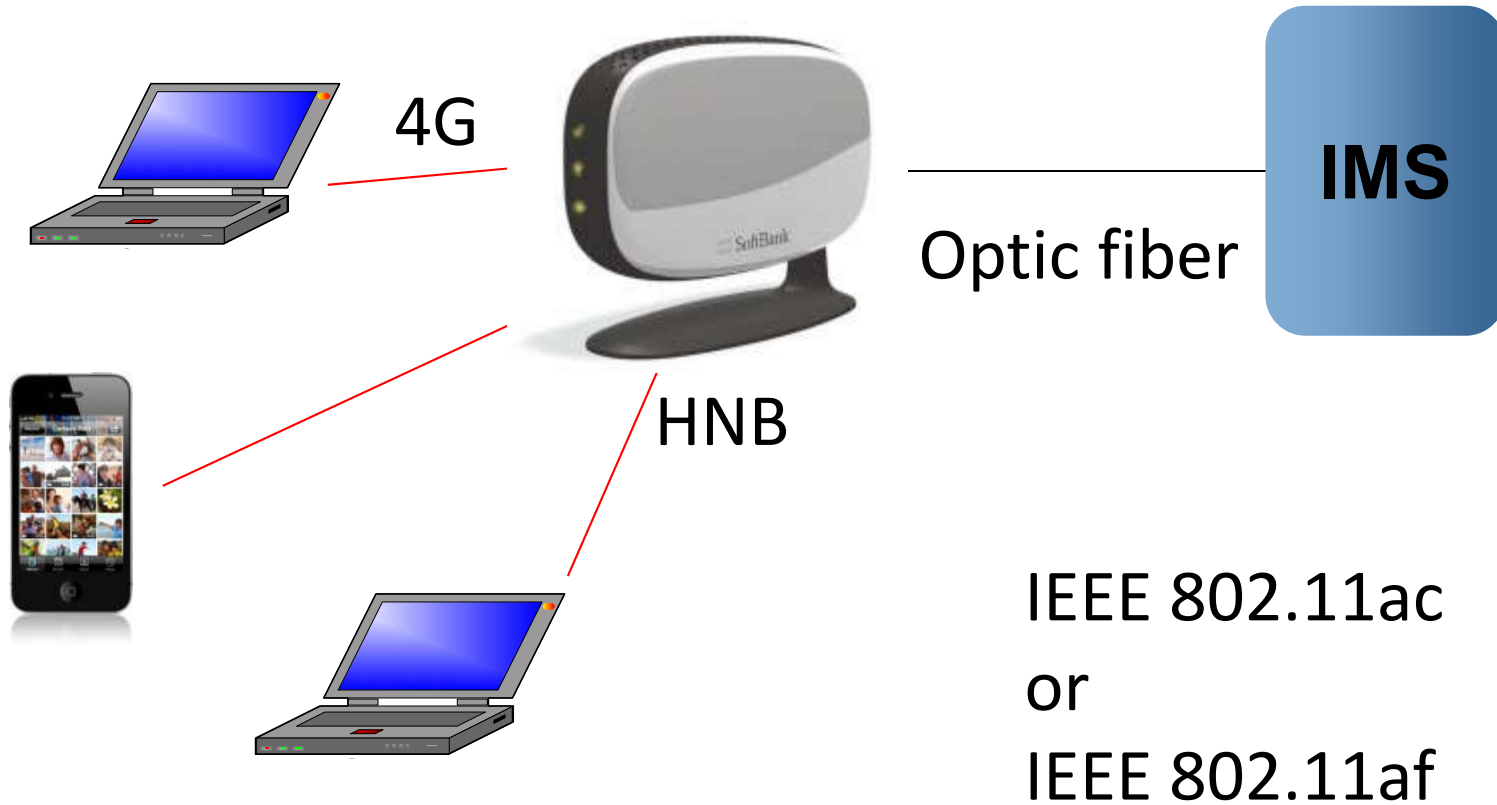


Unlicensed Mobile Access or UMA

Commercial name for 3GPP: Generic Access Network or GAN standard.



# Femtocell 4G



How to manage interferences between users  
How to mutualize antenna

# Réseaux Ad Hoc

- ❑ D2D, Décentralisé
- ❑ Réticence des opérateurs mobiles au début
  - ❑ Changement de tendance avec les forfaits illimités



# Réseaux Mesh

- ❑ Relais issus de différentes technologies (802.11s, 802.16j, LTE),
- ❑ Relais statiques, topologie fixe, avec infrastructure
- ❑ Relais mobiles (V2V)
- ❑ Deux scénarios
  - ❑ L'un des relais joue le rôle de passerelle vers internet
  - ❑ Système clos
- ❑ Réseau multi-sauts : résistance aux défaillances

