Rádiós hozzáférés és spektrum-felhasználás az 5G technológiában

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MŰEGYETEM 1782

Outline

- Requirements
- Spectrum aspects
- Physical layer/air interface solutions
- Relevant activities at BME HVT
- Satellite overlay

Relevant requirements mantra

- According to 5G PPP:
  - Providing **1000 times higher wireless area capacity** and more varied service capabilities compared to 2010. (100 Gbit/s?)
  - Saving up to 90% of energy per service provided.
  - Facilitating **very dense deployments** of wireless communication links to connect over 7 trillion wireless devices serving over 7 billion people.

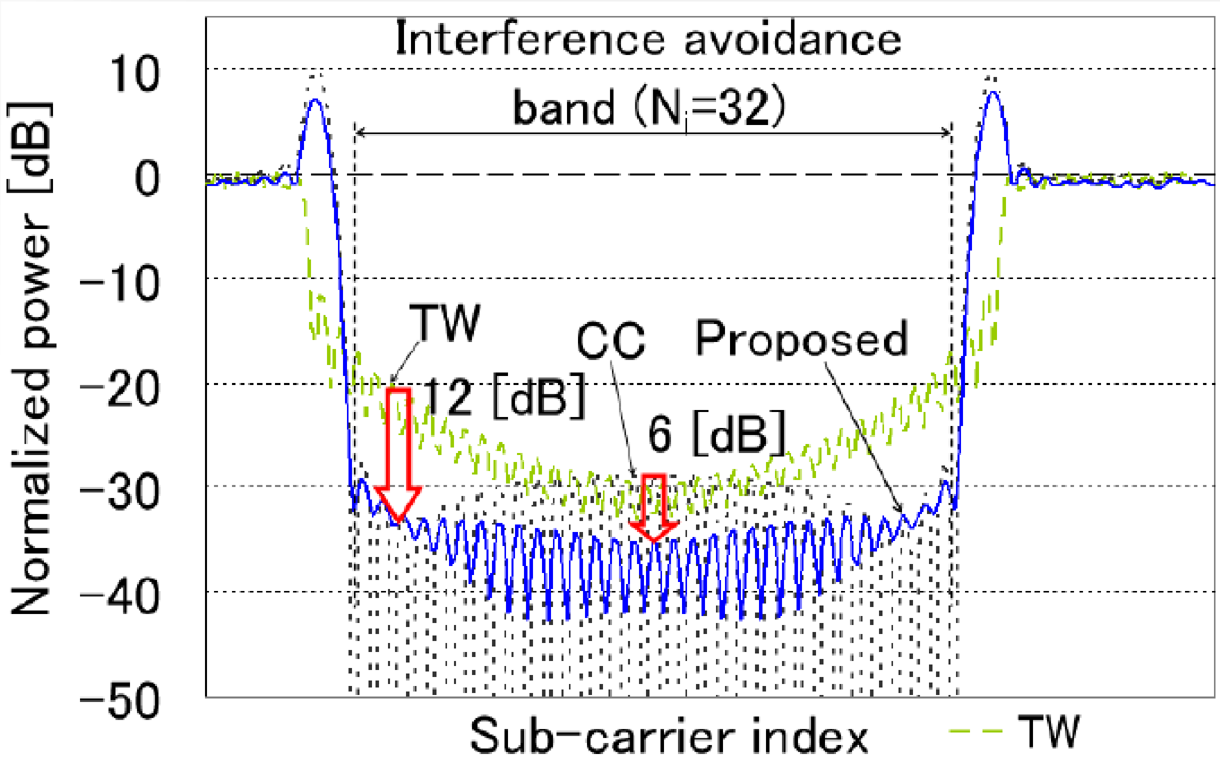
Spectrum requirements

- State-of-art (LTE-A) spectral efficiency (bits/s/Hz) [Sawahashi2010]
- Fragmented spectrum below 6 GHz
  - CA
  - Device limits
- Sharing
- New bands

	Downlink/ Uplink	Antenna configuration	Rel. 8 LTE achievement	LTE-Advanced
Peak data rate	Downlink	—	300 Mb/s	1 Gb/s
	Uplink	—	75 Mb/s	500 Mb/s
Peak spectrum efficiency [b/s/Hz]	Downlink	—	15	30
	Uplink	—	3.75	15
Capacity [b/s/Hz/cell]	Downlink	2 × 2	1.69	2.4
		4 × 2	1.87	2.6
		4 × 4	2.67	3.7
	Uplink	1 × 2	0.74	1.2
		2 × 4	—	2.0
Cell edge user throughput [b/s/Hz/cell/user]	Downlink	2 × 2	0.05	0.07
		4 × 2	0.06	0.09
		4 × 4	0.08	0.12
	Uplink	1 × 2	0.024	0.04
		2 × 4	—	0.07

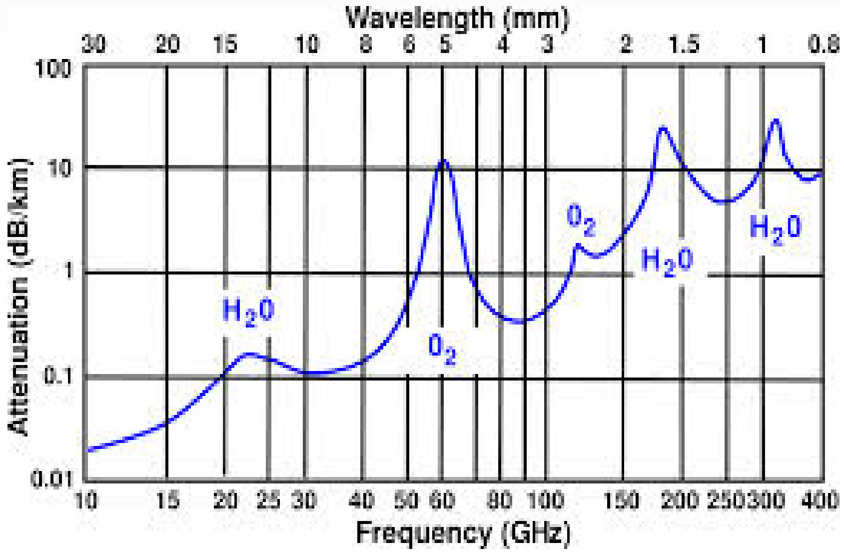
TV white space exploitation

- Spectrum pooling
- “Fill the gaps”



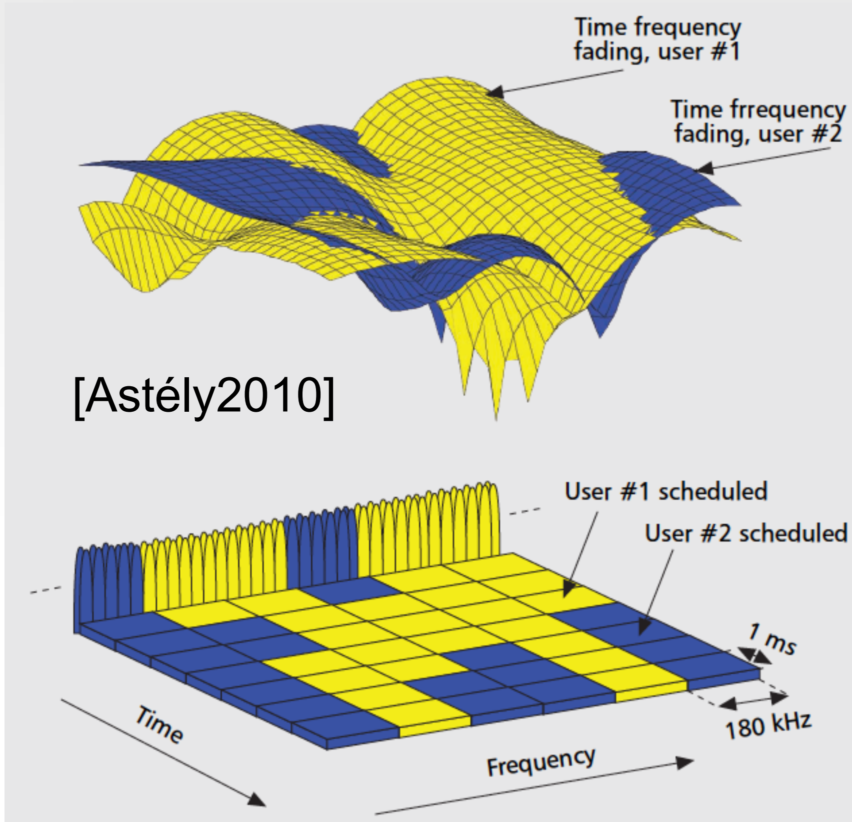
Millimetre-wave Access

- Spectrum shortage below 6 GHz
- Target bands between 20 and 90 GHz
- Known example: 60 GHz indoor
  - High path loss
  - Dense deployments
- **Shared** usage between
  - access, backhaul
- **Mesh** relay



Air interface – Modulation

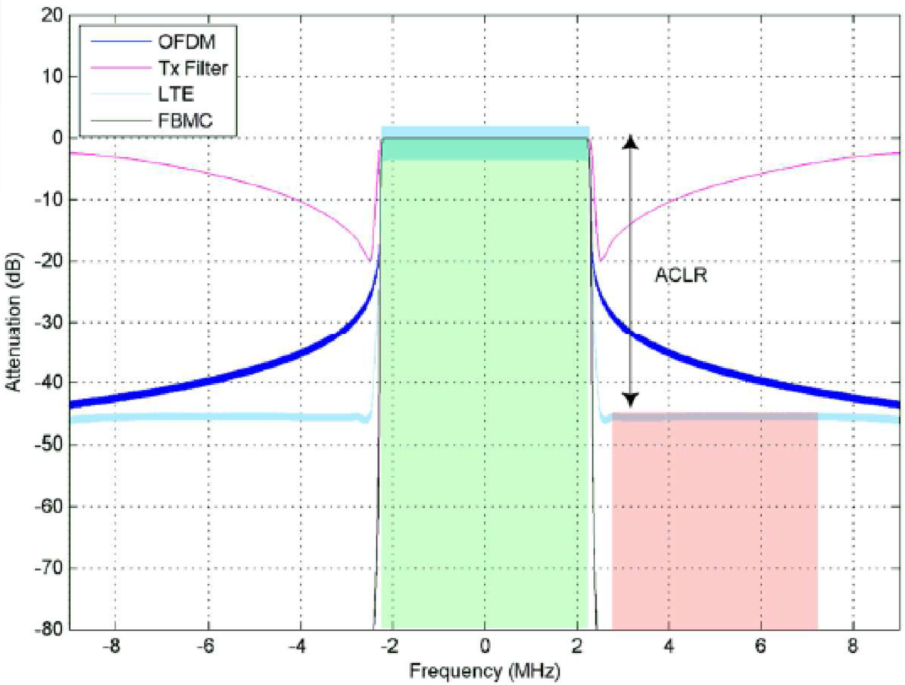
- LTE, LTE-A: Orthogonal Frequency Division Multiplex (OFDM)
- Multicarrier
- Access to time and frequency domain adaptation



[Astély2010]

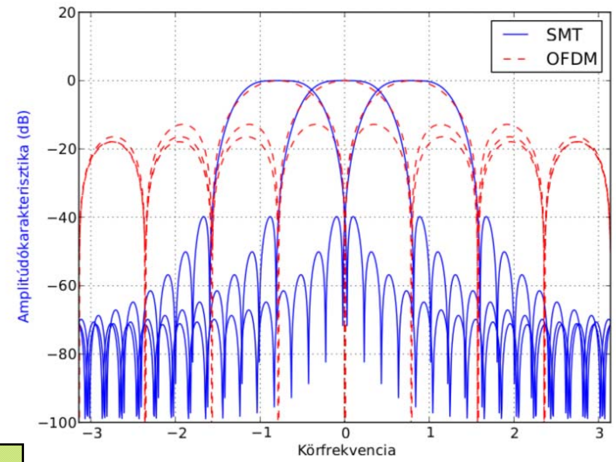
Air interface – Modulation

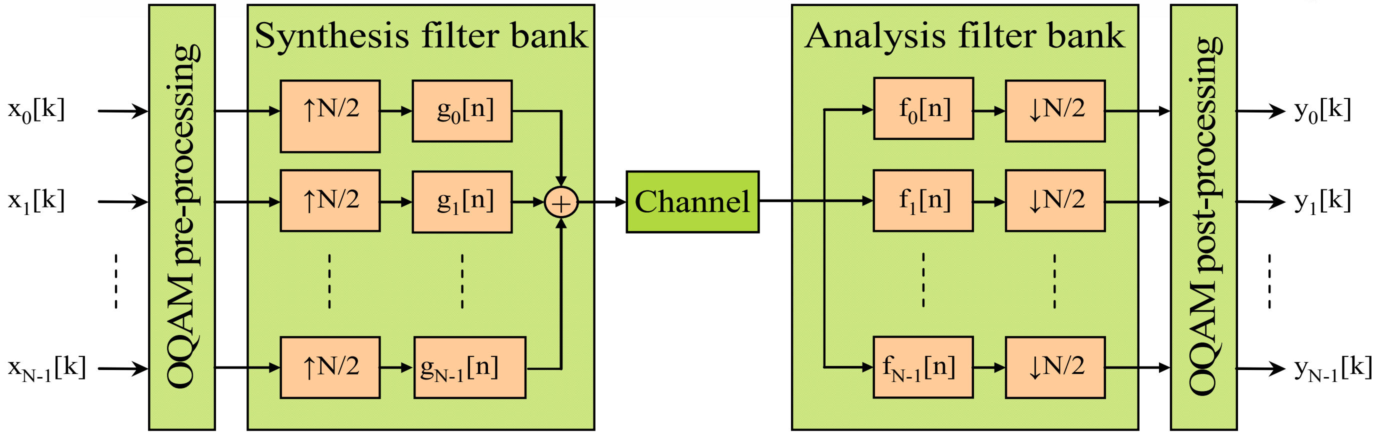
- Generalized multicarrier modulation
  - Such as Filter Bank Multicarrier (FBMC)
  - Better spectral containment (low ACLR)
- Other ideas
  - Single carrier?
  - Non-orthogonal?
  - …

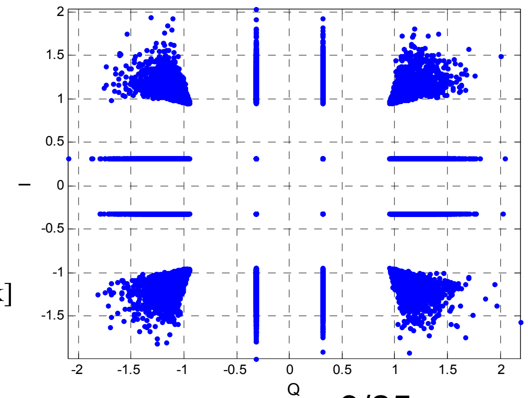


Air interface – filter bank techniques

- Allow significant inter-symbol interference in the time domain
- High PAPR, equalization, …

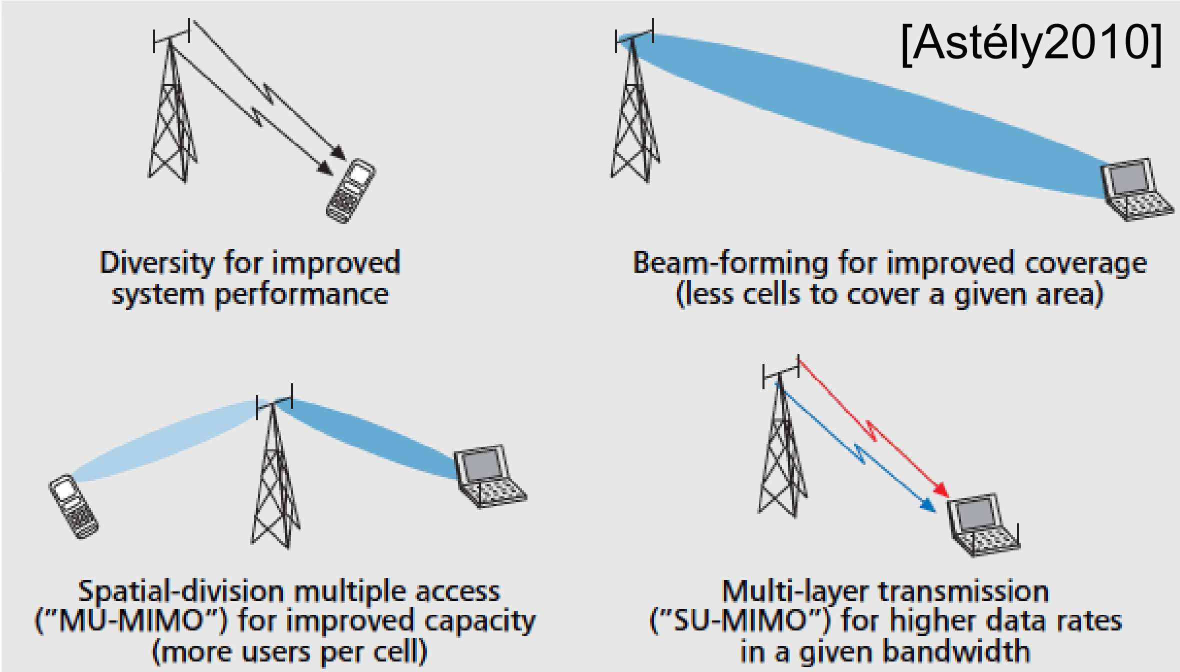






Air interface – MIMO

- Multiple Input, Multiple Output (MIMO)
  - LTE-A: **nine** different MIMO modes
  - Up to 8x8 antennas

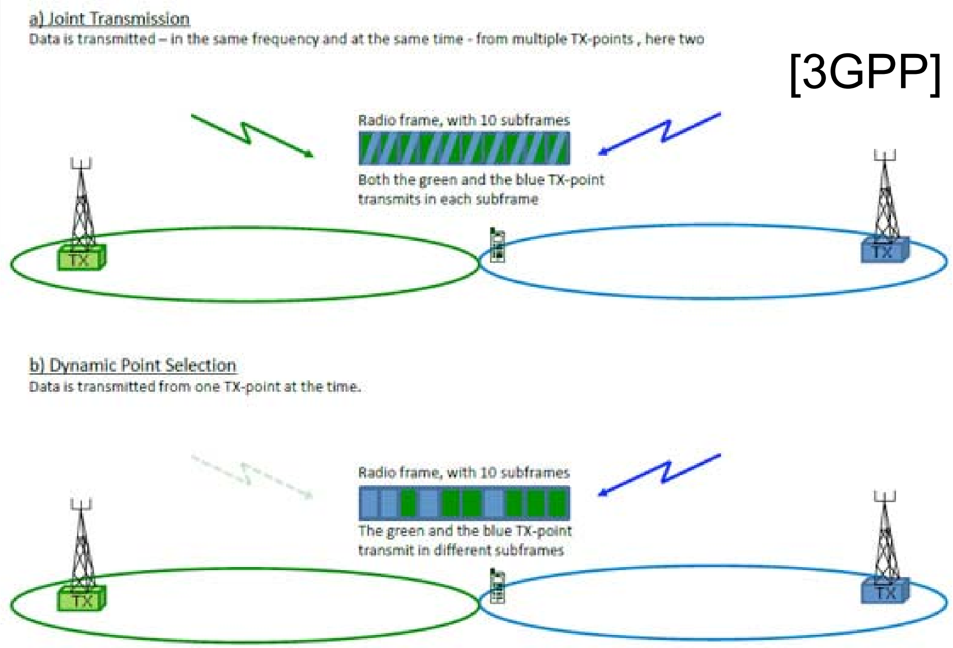


Air interface – MIMO

- Improve LTE-A along conventional lines
  - Multiuser MIMO
  - Limited channel state knowledge
- Introduce massive amounts of MIMO
  - 3D beamforming
  - Pencil beams
  - Hundreds of antenna ports in mm-wave bands

Air interface – coordinated transmission

- Leverage the capacity potential in interference coordination
  - Joint transmission
  - Dynamic cell selection
  - Coordinated beamforming



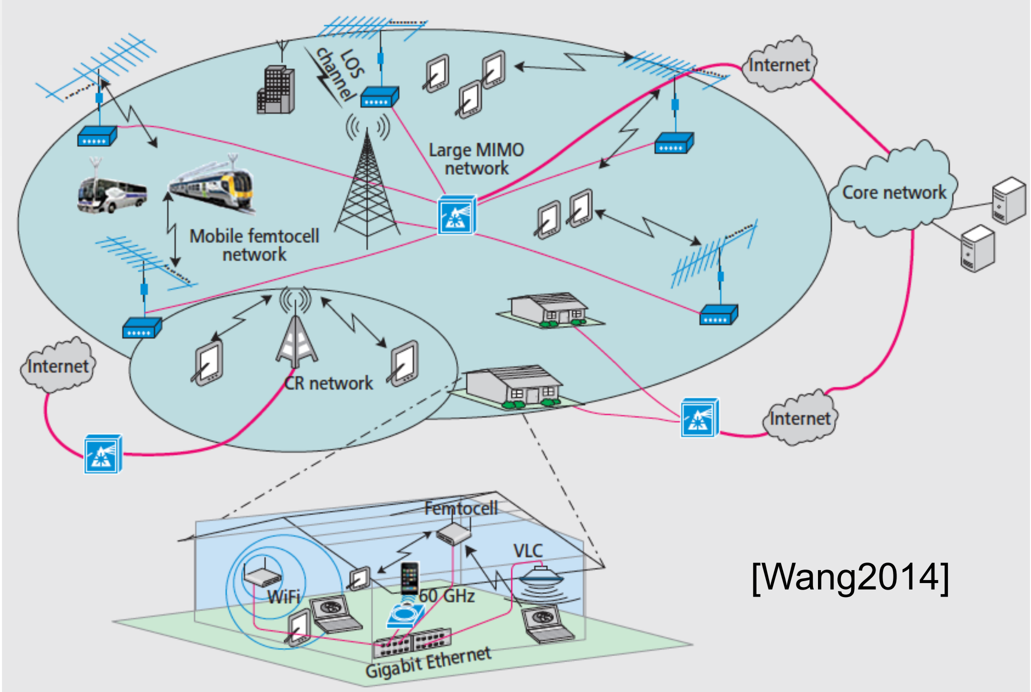
[3GPP]

Machine-type communications (MTC) or Machine-to-Machine (M2M)

- 10 to 100x as many machine-type devices as conventional mobiles by 2020
  - Smart metering
  - Sensor and actuator networks
  - Industrial applications
- Current mobile PHYs are not suitable
  - Low rate, many terminals, low latency
- Current MTC PHYs use ‘80s technology (802.15.4 et al)

Visible light communications (VLC)

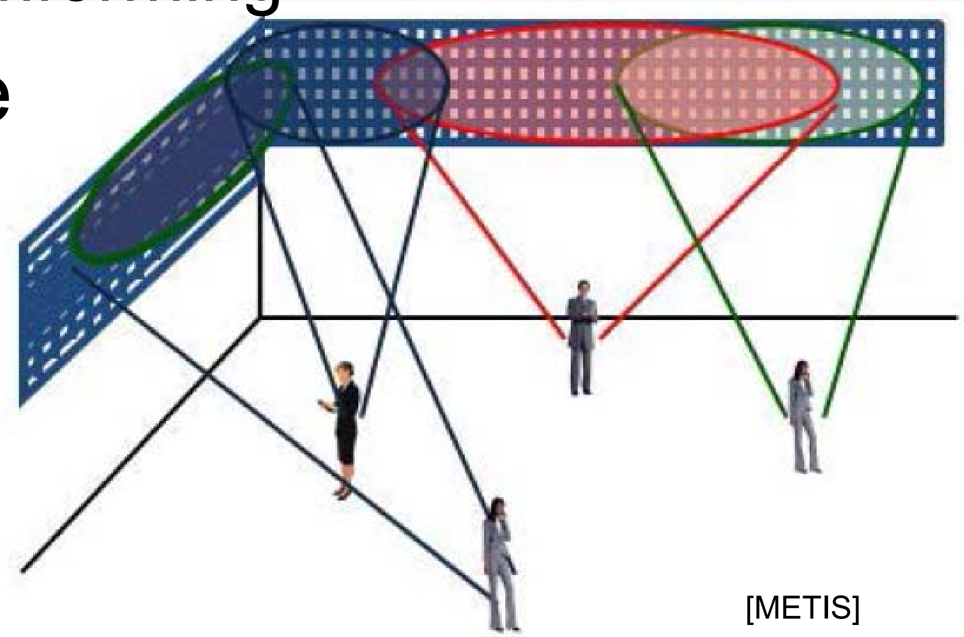
- Intensity modulating white LEDs
- 3+ Gbps link-level
- No fast fading
- No interference
- “attocells” of a few meters’ extent



[Wang2014]

Channel modeling

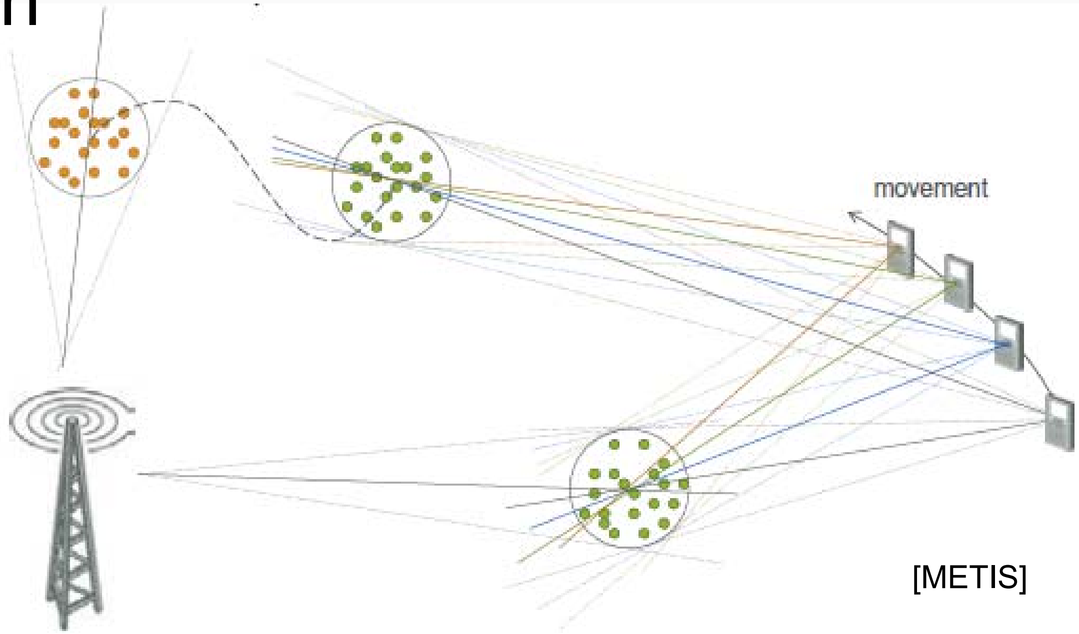
- Very large antenna arrays
  - Massive multi-antenna (MIMO)
  - Highly directive beamforming
- Crossing large-scale fading regions
- Plane-wave ass.?



[METIS]

Channel modeling

- Spatially consistent, wideband channel models?
  - Temporal evolution while terminals moving
  - Multi-transmission
  - High-speed
  - Vehice-to-X



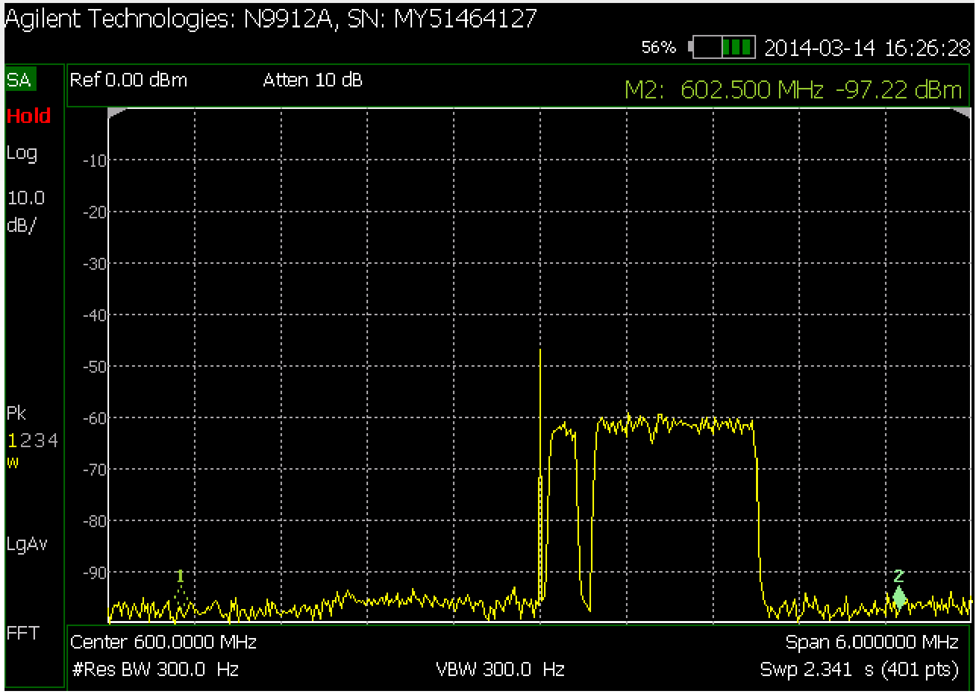
[METIS]

Relevant activities at BME HVT

- Generalized multicarrier, cognitive radio, FBMC
- Millimetre-wave propagation and channel modeling
  - Computational electromagnetics (CEM)
  - Channel measurements
- Exploitation of (TV) white spaces by cognitive radio
- VLC

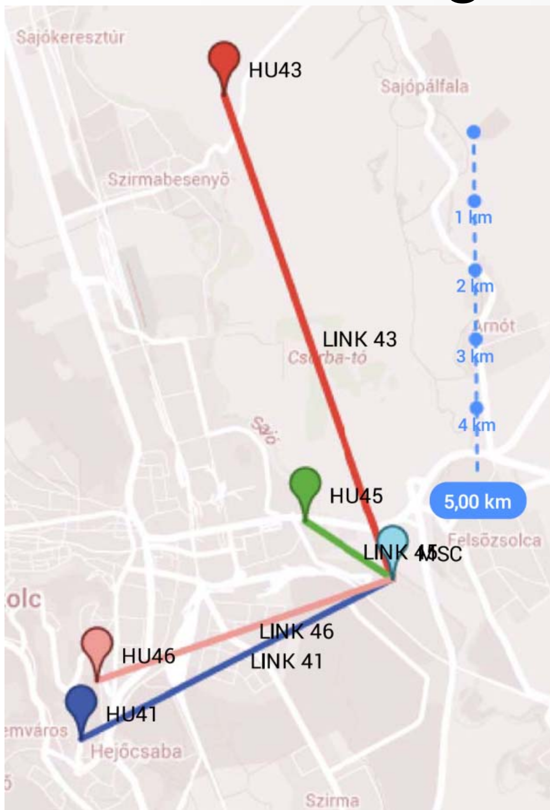
Generalized multicarrier

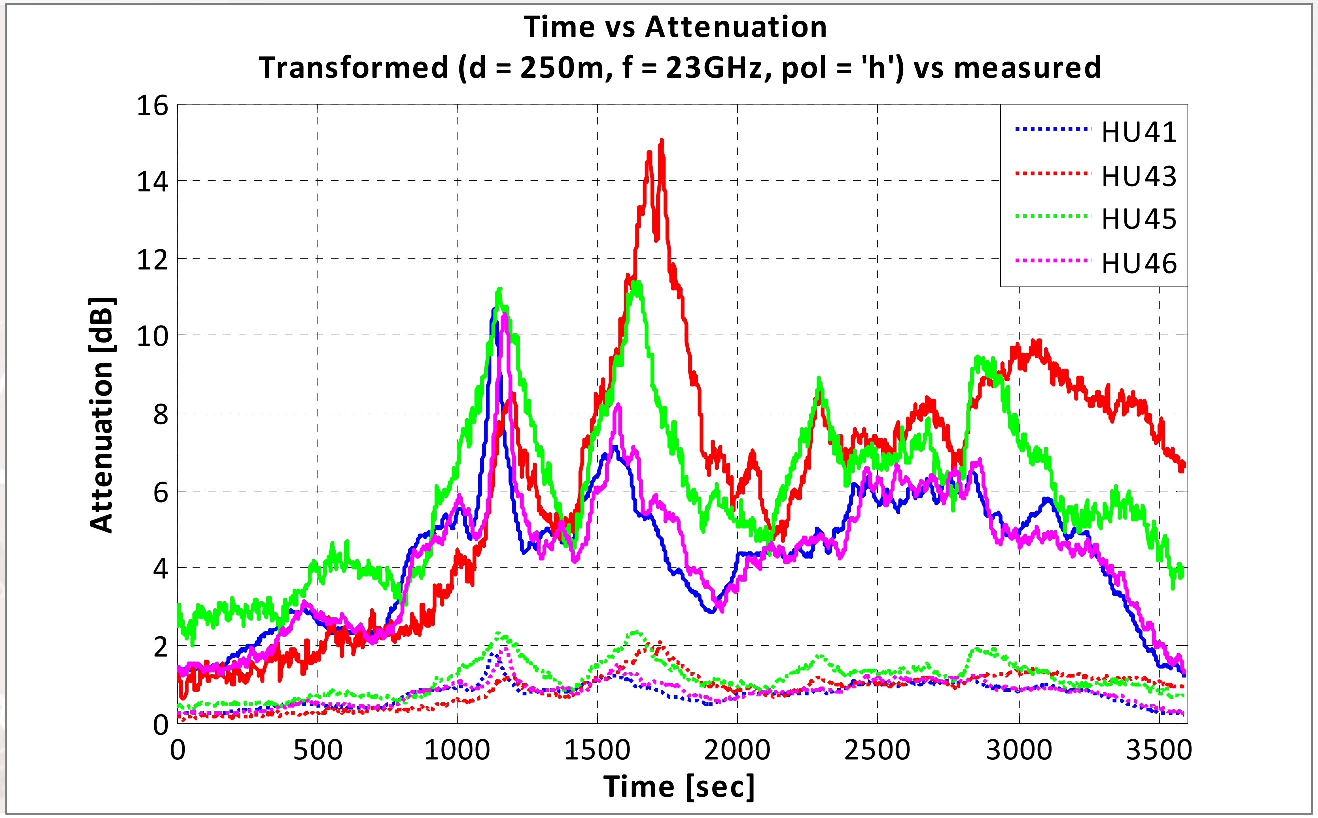
- FBMC-related research since 2010
  - PAPR reduction
  - Effects of nonlinear dist.
- Successful design at the DARPA Spectrum Challenge



Millimetre-wave Access – Precipitation

- Significant attenuation due to rain
- Short range? Mesh?

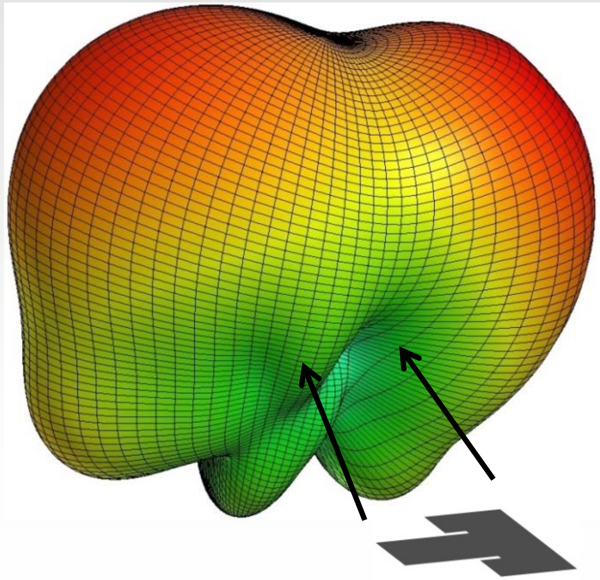


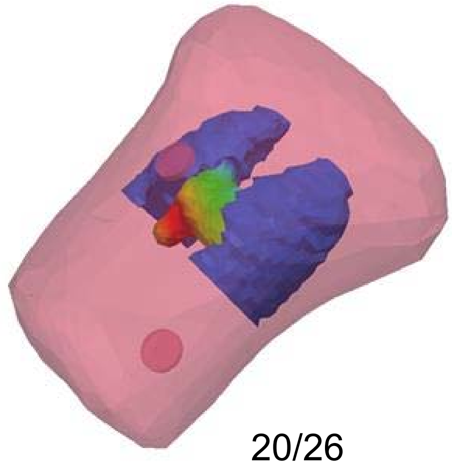


Multi-Solver Computational EM for mm-wave Studies

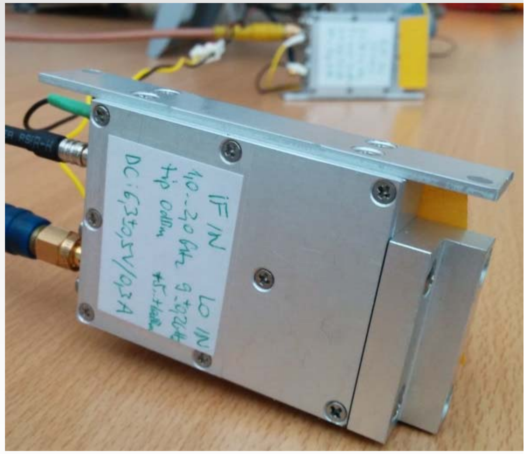
Techniques:

- Full-wave simulation of critical components of propagation scenarios
  - Finite element method (FEM)
  - Integral equation methods (MOM & BEM)
  - Finite difference time domain method (FDTD)
- Asymptotic HF expansion methods for large objects
  - Physical Optics (PO); Geometrical Optics (GO) - ray tracing
  - Unified Theory of Diffraction (UTD)
- Measurement data integration into CEM models
  - Measurement data as source in CEM models
  - Identification of model parameters by measurement
  - Verification of the simulations by measurements
- Development of channel models based on EM simulation
  - Illustrative example: calculation of vegetation/rain attenuation
- Design optimization and inverse problems in mm-wave engineering
  - Surrogate modeling of devices and environments
  - High performance local and global optimization techniques
- GPU acceleration of computations



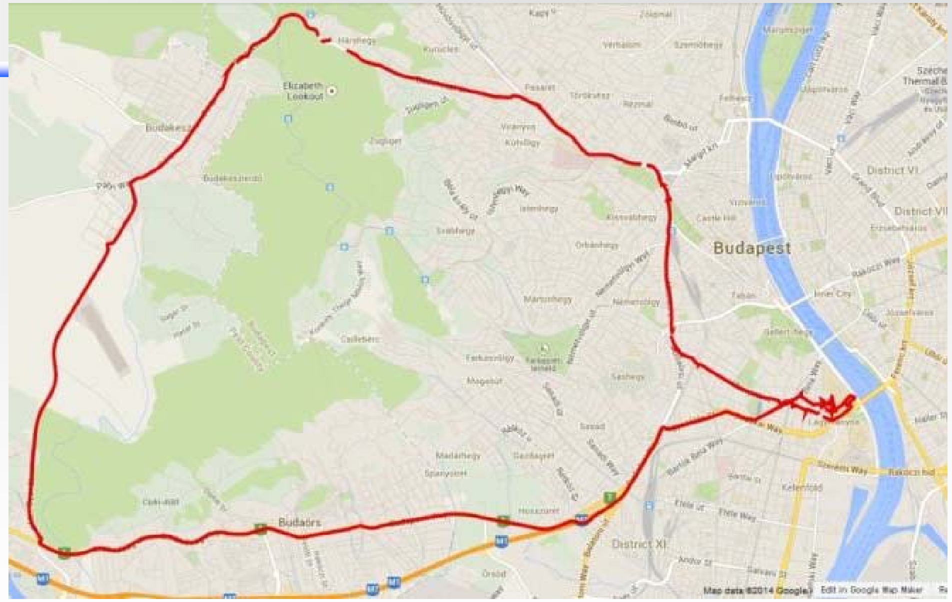


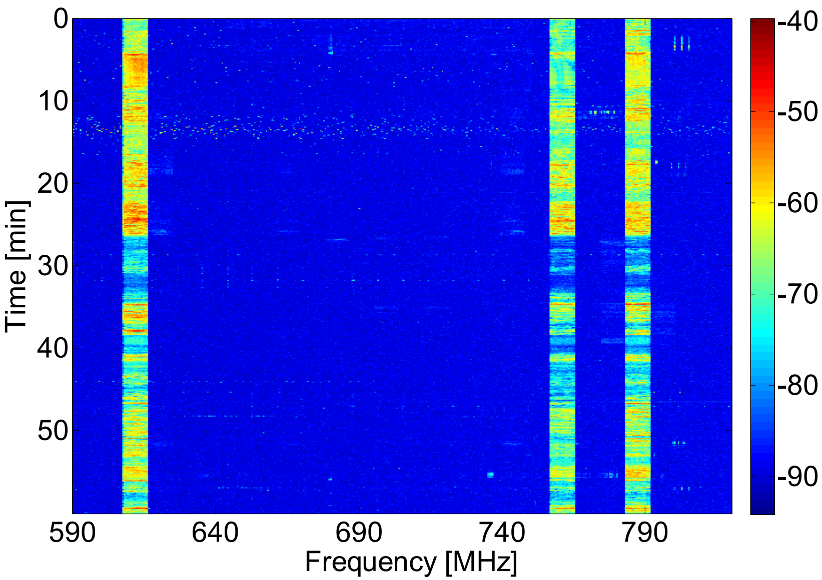
mm-Wave Outdoor Channel Characterization



- Outdoor channel characterization system
  - Under development for a single, wideband link
  - Entirely digital IF processing capability
  - Channel bandwidth in excess of 500 MHz
- RF chains
  - Proprietary up-/downconverters
  - for the ~38 GHz band
  - for the ~26 GHz band
- Goals:
  - Validate results from Computational EM models/calculations
  - Build a small, short-range 38 GHz outdoor mesh network
    - Using low(er) cost IF subsystems
    - Provide simultaneous link characterization

(TV) white space exploitation





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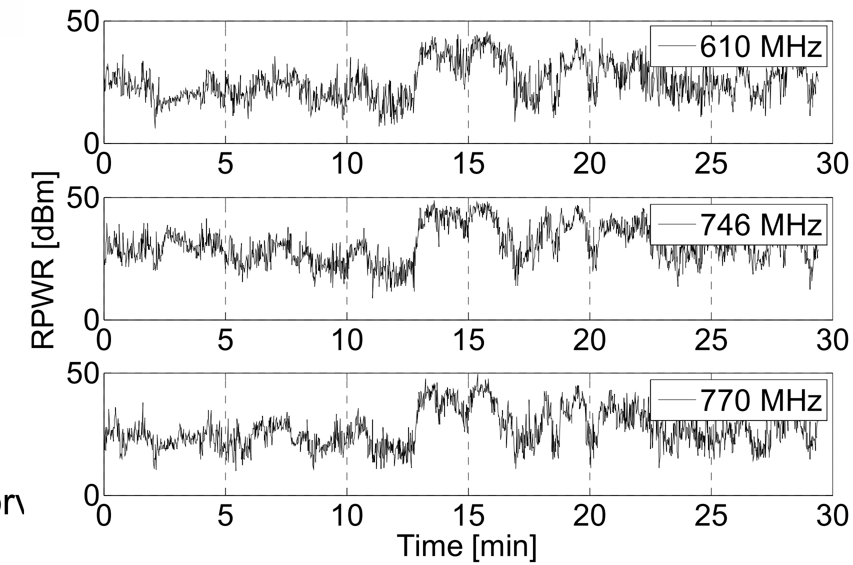
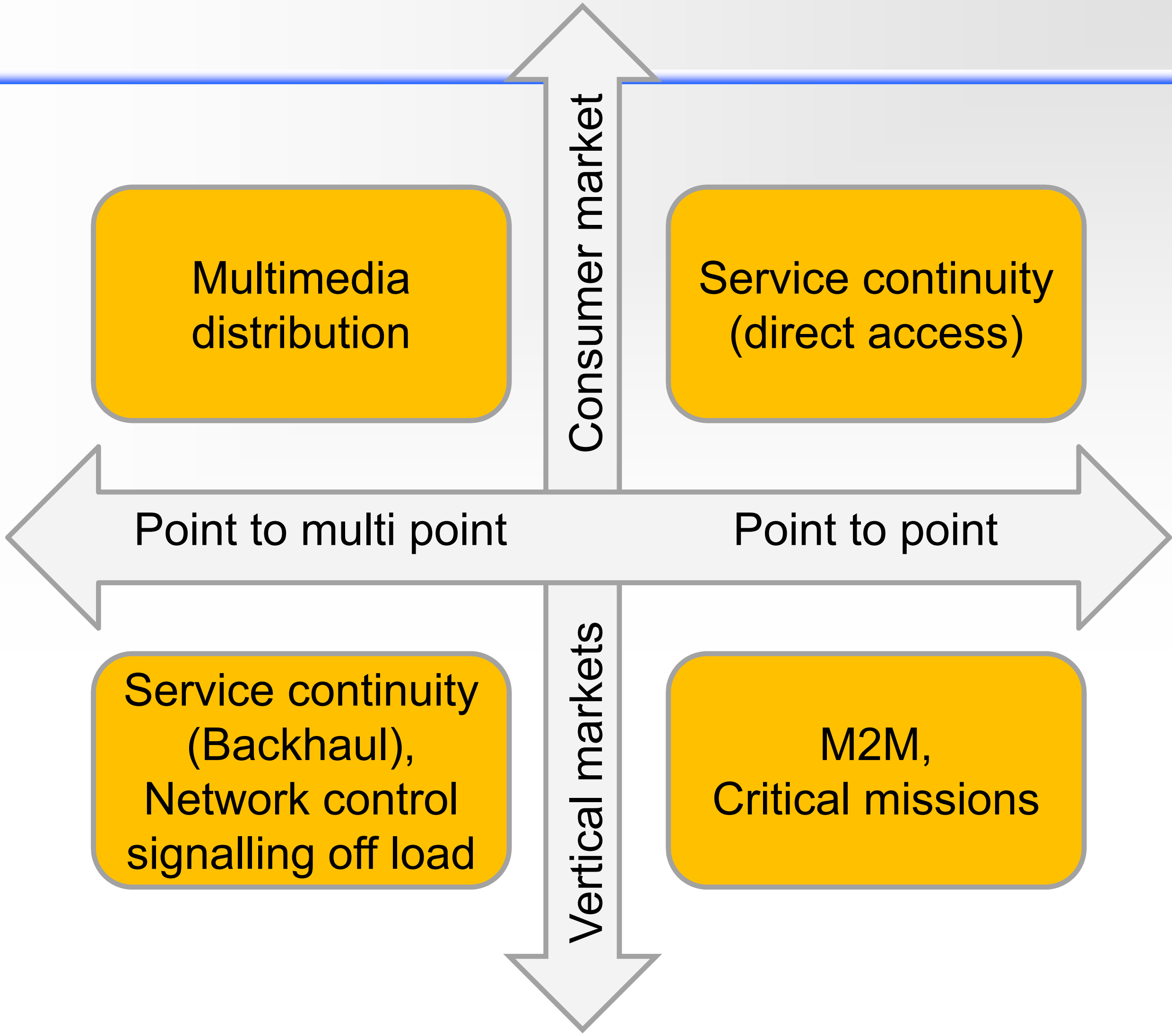


The role of satellite comms

- As seen by the 5G PPP satellite communications working group (SatCom WG)
- (True) integration with terrestrial infrastructure/services where service provision by satellites is essential

SatCom use cases in 5GPPP

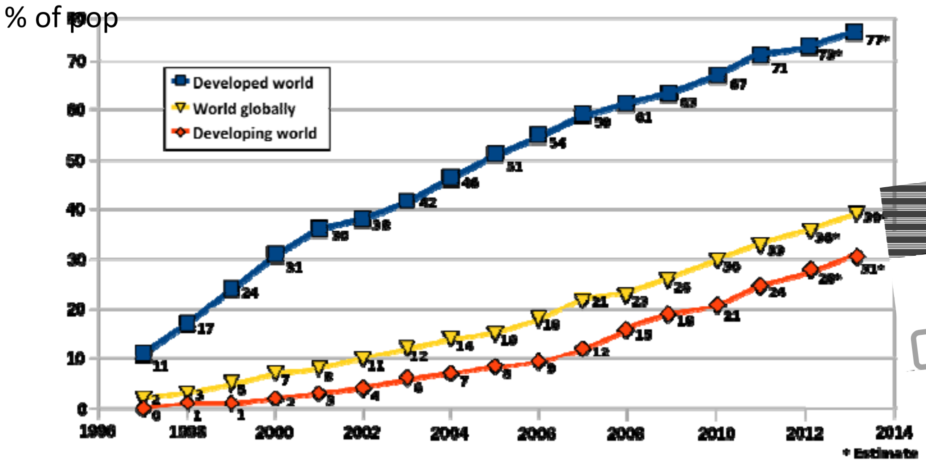


SatCom relevant use cases for 5G

Service continuity use cases

- Satellite essential for True global 5G service

  - Everywhere: Maritime (vessels, oil platforms), Aeronautic (aircrafts, UAVs), Land (unserved and underserved areas)
  - Everyone: 4+ out of 7+ billions population have no internet



Source: ITU, Wikipedia


THE WALL STREET JOURNAL. | TECH

Google Invests in Satellites to Spread Internet Access

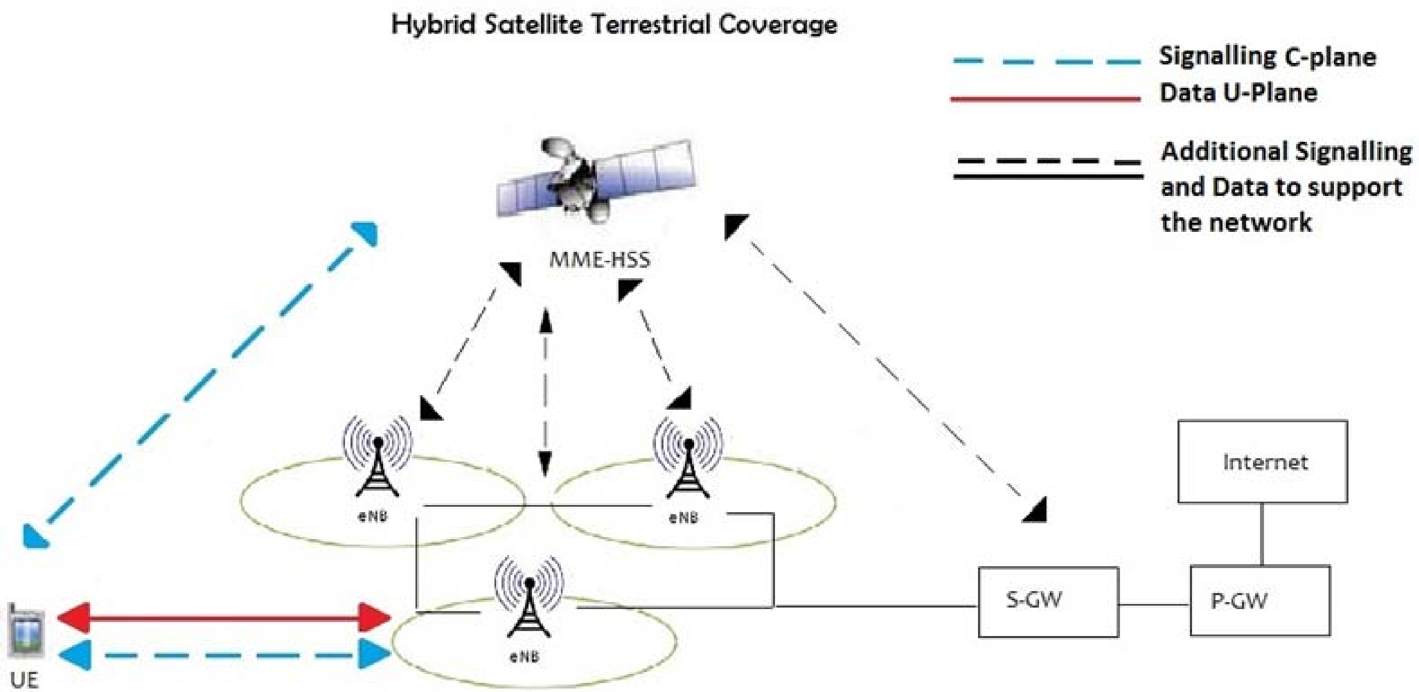
Company Projects Spending More Than $1 Billion to Connect Unwired Reaches of the Globe

June 1, 2014 7:48 p.m. ET

SatCom is no longer unknown to big players

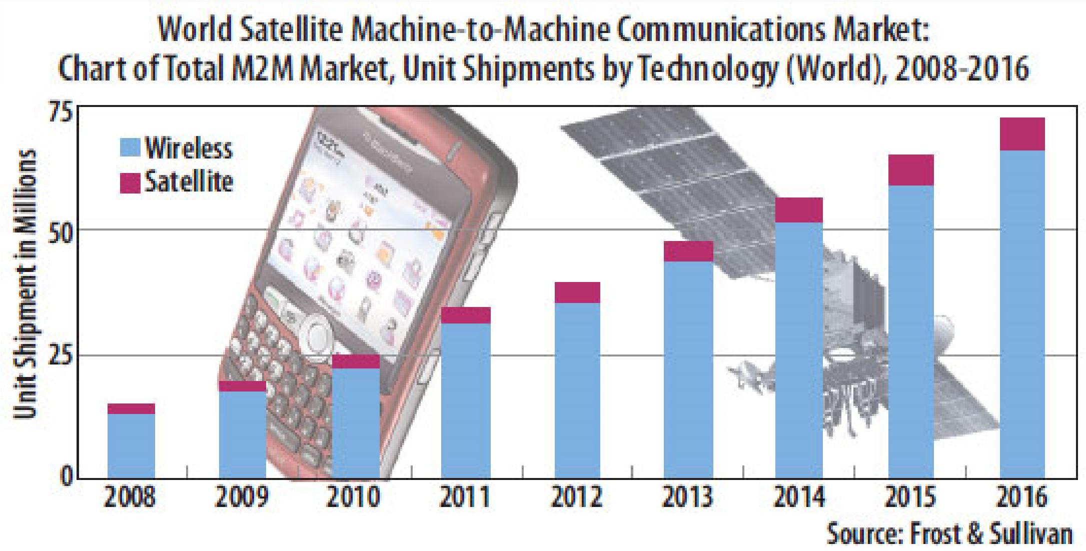
SatCom relevant use cases for 5G

- **Network control signalling offload use case**
  - Split the control plane C and the data plane U
  - Provide C plane via overlay satellite cells



SatCom relevant use cases for 5G

- **Satellite machine-to-machine (M2M)**
  - Real-time asset tracking: e.g. containers, transport
  - Data collection from sensors deployed in areas beyond cellular reach



Satellite is a small portion of the total wireless M2M market, but it is a lucrative portion in terms of average sales price for equipment and monthly sales ARPU. Satellite is also used for the most difficult installations and most crucial communications, as well as being used in hybrid networks as a fail safe for data transmission when a cheaper network is used for primary service delivery.

SatCom contribution to Performance KPIs

- Providing 1000 times higher wireless area capacity and more varied service capabilities compared to 2010.
  - Introducing **satellite broadcast/multicast resources** to offload part of the traffic to optimise the infrastructure dimensioning.
  - High speed broadband satellite for **backhauling to extend the reliable delivery of 5G services** to public transportations (aircrafts, vessels, trains, busses)
- Reducing the average service creation time cycle from 90 hours to 90 minutes (as compared to the equivalent time cycle in 2010).
  - Seamless integration of satellite access networks in 5G will result in a **unified service delivery and aligned service creation time**.
- Very dense deployments to connect over 7 trillion wireless devices serving over 7 billion people.
  - **Part** of the M2M devices/traffic **will be off loaded to satellite systems** to **ensure global service continuity** (asset tracking…).
- Secure, reliable and dependable Internet with zero perceived downtime for services provision.
  - Satellite overlay network to enable a **high network resiliency** and to **support rapid service deployment/recovery**

Conclusions

- New bands, integrated spectrum usage
  - Cognitive radio?, millimetre-wave, mesh
- Evolved and tailor-made air interfaces
  - Massive MIMO, filterbank multicarrier?
  - MTC PHY/MAC
  - Challenges in channel modeling
- Optical communications
  - VLC, FSO