5G and millimetre wave (mmw) communications

Eye Networks Seminar 2016: Wireless and the Services of the Future
19/04/2016

Isabelle Tardy

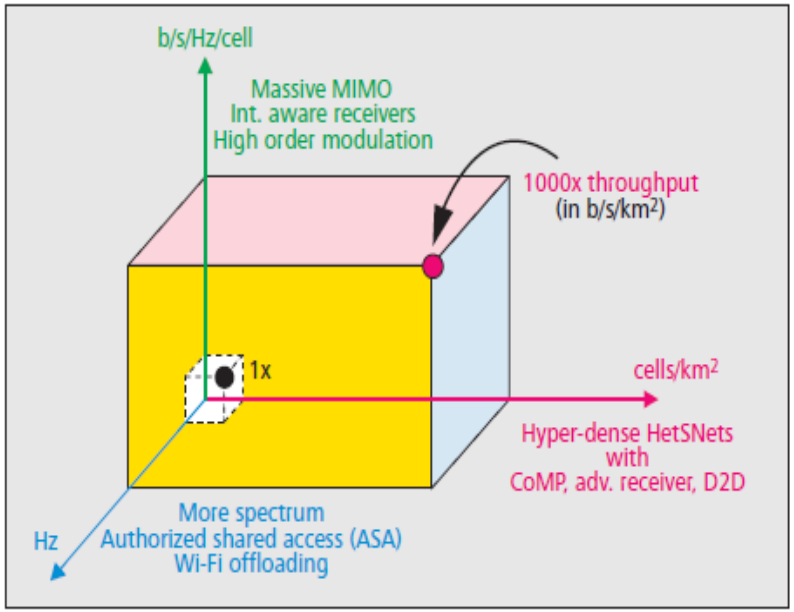
Why mmw? Answering 5G soaring capacity x1000 need

- Three paths to increase the system capacity

1. Allocate additional spectrum through re-farming or introducing new bands,
2. Improve the spectral efficiency of the technologies (e.g., MIMO),
3. Cell densification.

- But, decreasing cell size may induce more interference, affecting in turn the spectrum efficiency.

➡ Non-interfering frequencies within dense deployments, e.g., mmW.



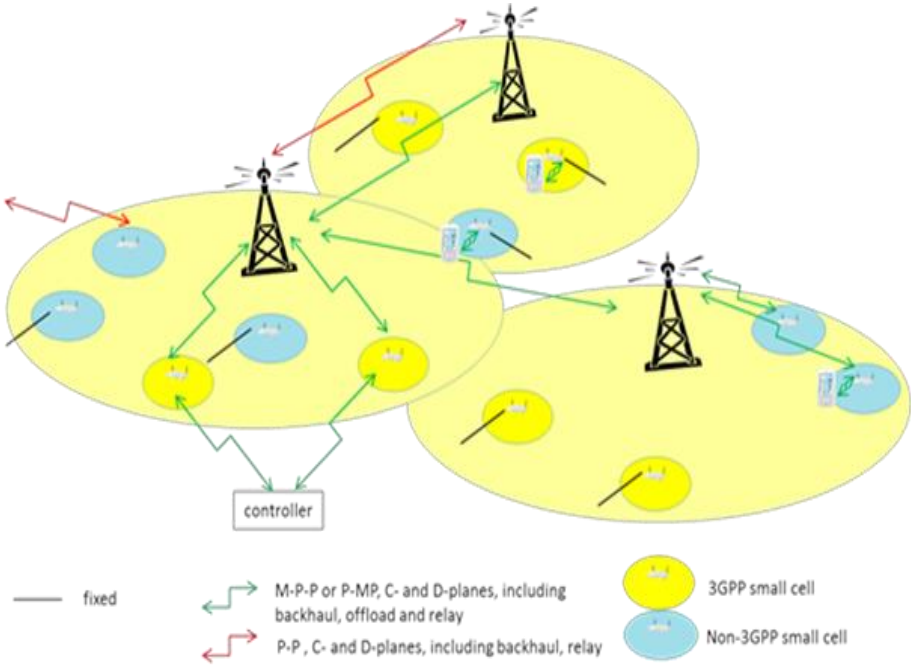
(from I.Wang et al. Qualcomm tech., "A holistic view on hyper-dense heterogeneous and small cell networks", IEEE Comm. Mag, June 2013)

Important 5G challenges wrt. mmw communications

- Integrating mmW communication in 5G networks
  - Access, backhaul, fronthaul
  - Indoor, outdoor
- Beamforming and antenna technology
  - Hybrid analogue/digital beamforming
  - Adaptive beamforming
- MAC and cross-layer design
  - Control channel architecture
  - Initial access, handover
  - Resource allocation

Integrating mmW communication in 5G networks

- Solutions for *indoors* short-distance, high-capacity networks (HDMI replacement)
- Outdoor *backhauling* to cellular base stations or between them (*x2*-interface)
  - mmW are not expected to be backward-compatible with μW radio access technologies
  - mmW are not expected to be standalone
  - Control information through the macrocells?
- Or *fronthaul* allowing for more flexible radio systems



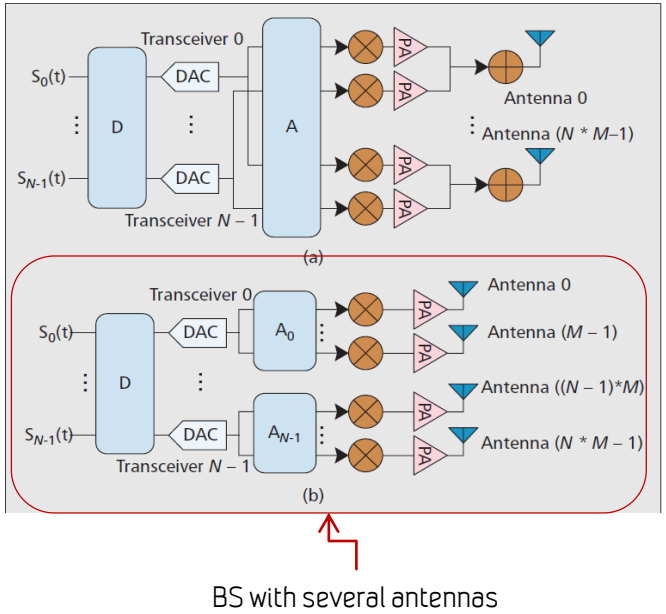
(from I. Tardy and J.E. Håkegård, "Millimeter-wave communication in 5G" chap.5 of the white paper of the IEEE Special Interest Group on Cognitive Radio in 5G, Novel Spectrum Usage Paradigms for 5G. Editors M. Mueck, W. Jiang, G. Sun, H. Cao. E. Dutkiewicz, S. Choi, Nov. 2014.)

Beamforming to compensate for the propagation loss

- Spatial multiplexing for additional gain, capturing energy in selected directions
- Beamforming should strike a balance between performance, complexity and power
  - Analogue beamforming – simple
  - Digital beamforming – better performance, but costly DAC

2-stage, hybrid

- Adaptive beamforming requires precise channel state information (CSI), but considering a spare channel matrix, the Angle of Arrival/Departure (AoA/AoD) are expected sufficient



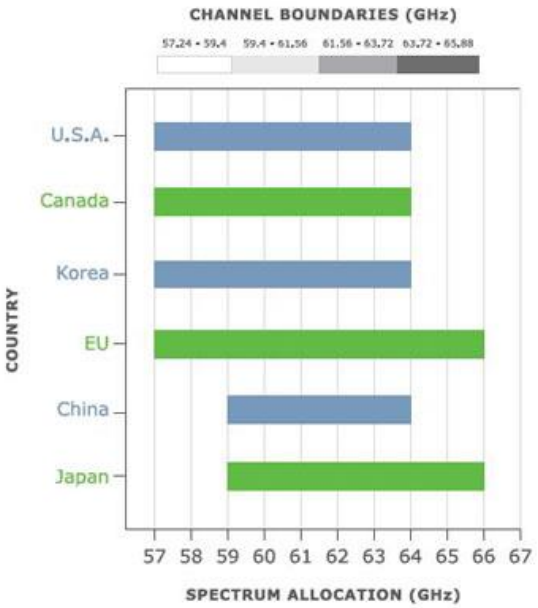
Initial access and handover strategies

- Beam-searching: balance between narrower beams with better directivity gain and wider beams with faster beam-search.
- A priori angular selection to reduce the spatial search overhead.
- Wider beams in the search phase, narrower beams for scheduling traffic.
- Additionally, exploit the channel or beam reciprocity of TDD channels to determine the best beam that the terminal must use.
  - Channel reciprocity holds if the duplexing time is much shorter than the coherence time of the channel. mmW channels have a coherence time an order of magnitude lower than μW, as the Doppler shift scales linearly with frequency. Therefore mmW channels are best suited to scenarios with low mobility.
- More blockage, more handovers.
  - Relays may be necessary
  - Several active beams from UE to several BS?

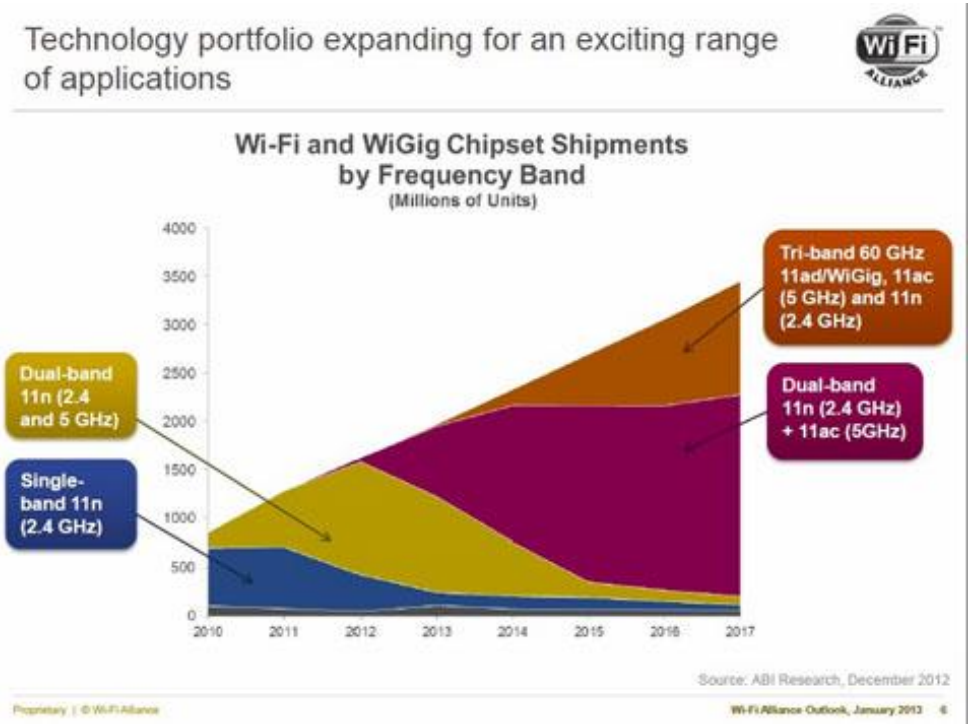
mmW communication standards

- Mostly indoor in the 57-66 GHz range because of common international frequency bands

- IEEE 802.11 ad (WiGig):
  - Adaptive beamforming, Single Carrier and optional OFDM, backward compatibility with 2.4 and 5 GHz IEEE 802.11 n/ac
  - Rates up to 7 Gb/s (x10 highest 802.11n rate) and channel BW=2.16 GHz
  - Adopted in 2015
- IEEE 802.11 ay
  - Improvement of WiGig with rates 20-40 Gb/s
  - Extended range 300-500m
  - New channel models
  - MU-MIMO
  - Expected ready in 2017



IEEE standards and first products



(hotspot at Narita, from Panasonic, feb 2016), http://news.panasonic.com/global/topics/2016/44877.html

(from Wilocity)

(tri-band routers from Netgear)

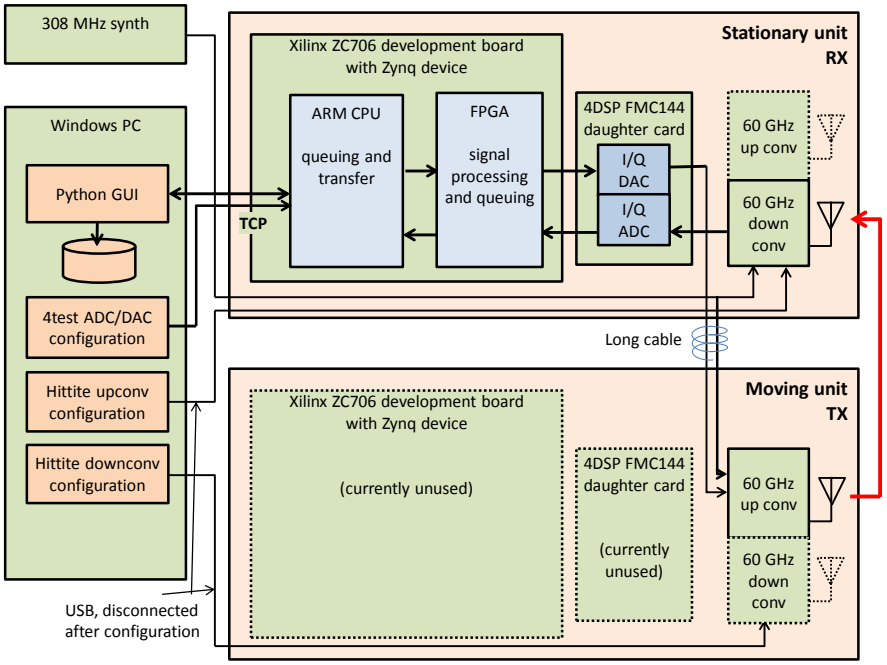
Other initiatives

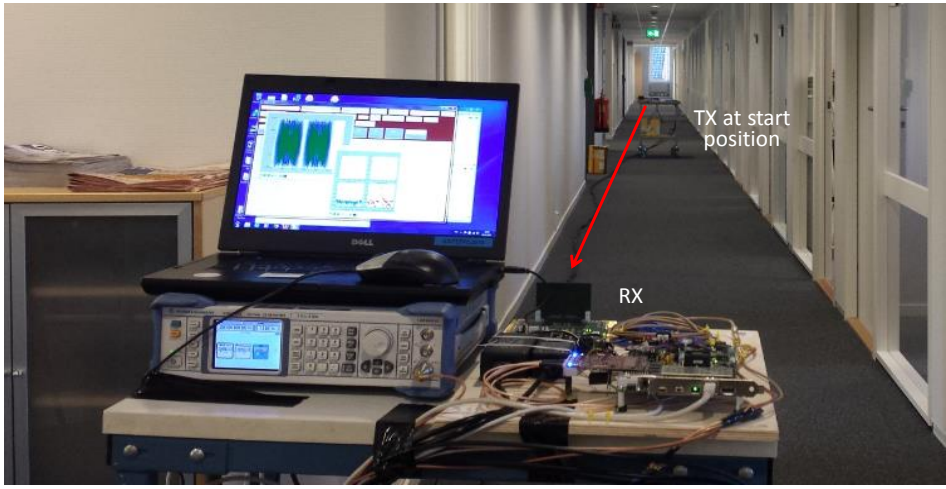
- ETSI ISG mWT
  - ""*ISG mWT was conceived as an industry wide platform to prepare for large scale usage of millimetre wave spectrum in current and future transmission networks*"
  - Started 01/2015 with five new specifications
    - An analysis of the maturity and field proven experience of mmw transmission
    - Potential applications and use cases of mmw transmission
    - An overview of V-band and E-band worldwide regulations
    - An analysis of V-band street level interference
    - Analysis of the mmw semiconductor Industry technology status and evolution.
- NIST 5Gmmw channel model alliance
  - Initiative to support the development of more accurate, consistent, and predictive channel models than those developed by international standards-making bodies.
  - Focusing on unaddressed usage scenarios, parameters, frequencies, and architecture.
  - Aggregating new and improved channel measurement and modeling methodologies and best practices.

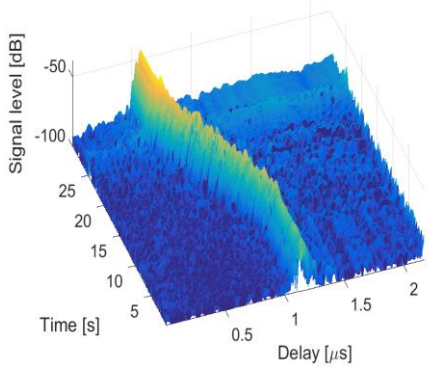
Mmw channel sounder

- 2 programmable SoCs connected to 60 GHz front-ends. Model-based design.
- Channel sounder based on a linear frequency modulated chirp of length 1024 waveform. The bandwidth of the measurements is 368.4 MHz.
- It assists in dynamically evaluating new mm-wave systems.
- To evolve to 1x2 SIMO and 2x2 MIMO.
- Channel characteristics may be shown in real time, such as path loss, impulse response, 3D time-delay plot, delay spread using a defined threshold wrt. the noise floor and Doppler spread.
- The platform may add to the channel measurements being done elsewhere (e.g., IEEE 802.11ay and academia), by verifying dynamic channel characterisations and models in well-defined scenarios and by adding new environments and scenarios such as industrial environments.

60 GHz channel sounder







5G-SIG (www.5gsig.no)

- ***Goals***
  - ***Coordinate*** and help to increase the utilization of results produced by Norwegian scientists in the area of 5G.
  - Create the ***liaison*** to the European Technology Platform NetWorld2020.
  - Identify ***research opportunities*** in 5G technologies, applications and services, focusing on the Norwegian context.
  - Form a research and development ***community*** with a focus on challenges in 5G issues.
  - Assist emerging ideas to find ***support for research*** in 5G from the appropriate funding agencies at national and European level.