NSF-RCN Workshop #6
Panel 1: State-of-the-Art of mmW Technology –
Recent Significant Developments

Tommy Svensson

Full Professor, PhD, Leader Wireless Systems

Department of Electrical Engineering, Communication Systems Group

Chalmers University of Technology, Sweden

tommy.svensson@chalmers.se

Chalmers University of Technology in Gothenburg (Göteborg)

http://www.goteborg.com/en

- Located in the heart of Scandinavia

- Founded by Gustav II Adolf in 1621

- 2nd largest city in Sweden
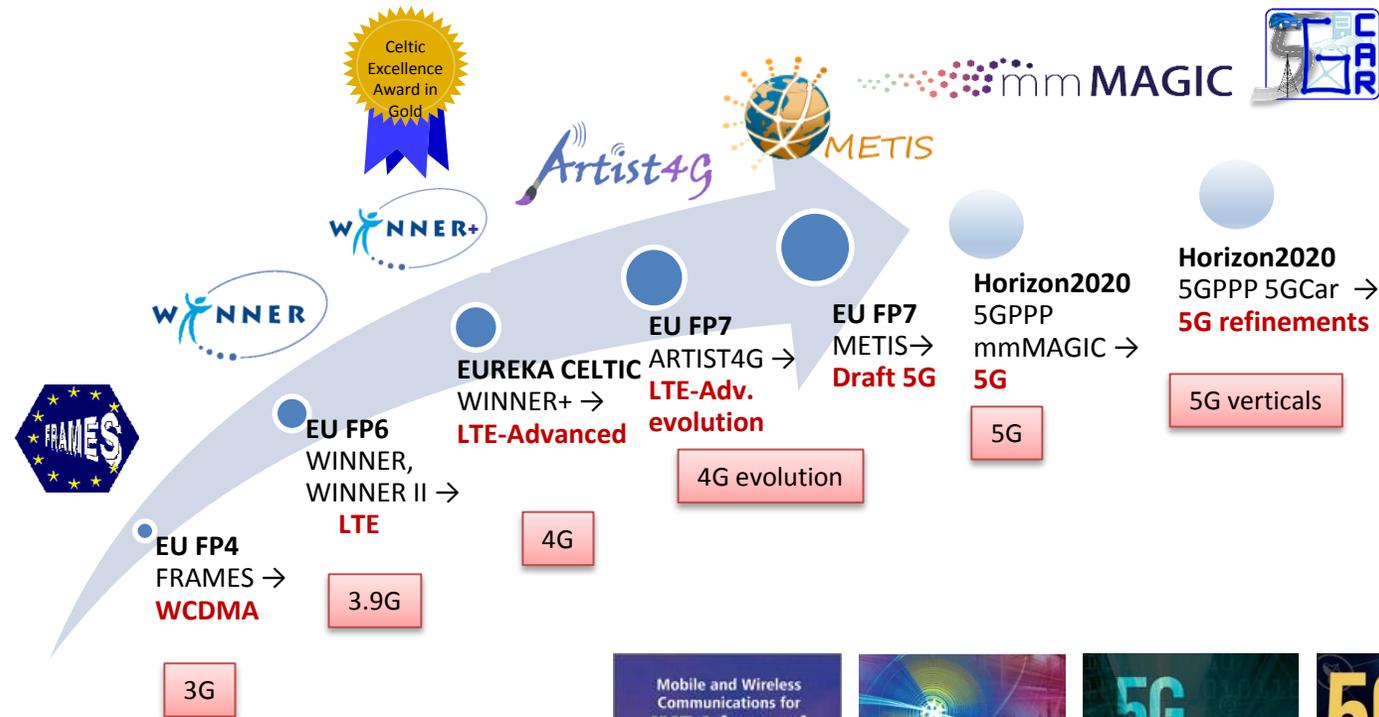 - 890,000 inhabitants

Knowledge and Industry

- Volvo, AstraZeneca, SAAB, SKF, Ericsson

- 2 universities, Chalmers and Gothenburg U. / 61,000 students

Communications Systems group at Chalmers University of Technology
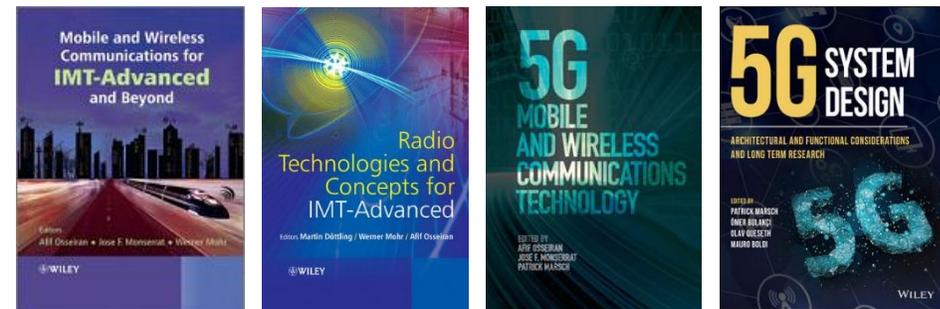Impacts Wireless Standards: 3G, 4G, 5G, and counting...

EU FP4
FRAMES →
WCDMA

3G

3.9G

EU FP6
WINNER,
WINNER II →
LTE

4G

EUREKA CELTIC
WINNER+ →
LTE-Advanced

EU FP7
ARTIST4G →
**LTE-Adv.
evolution**

4G evolution

EU FP7
METIS→
Draft 5G

Horizon2020
5GPPP
mmMAGIC →
5G

5G

Horizon2020
5GPPP 5GCar →
5G refinements

5G verticals

Celtic
Excellence
Award in
Gold

https://5g-ppp.eu/5gcar
https://5g-mmmagic.eu
https://www.metis2020.eu
https://ict-artist4g.eu
http://projects.celtic-initiative.org/winner+
http://cordis.europa.eu/infowin/acts/rus/projects/ac090.htm

+52 EU project deliverables (sofar)

Duration: 24 months
Budget: EURO 8.26M
Coordinator: Maziar Nekovee, Samsung
Technical Manager: Peter von Wrycza, Ericsson

mm-wave Based Mobile Radio Access Network for Fifth Generation (5G) Integrated Communications

Horizon 2020 Public Private Partnership Consortium

Coordinator: Samsung Electronics, Europe Ltd.
Technical Management: Ericsson AB

UHD TV/streaming

Immersive and interactive 3D services

Ultra-responsive mobile cloud

Ultra-dense deployment

Multicast support

Self-backhaul/front-haul support

WRC'19 & 3GPP Head-start

Advisory Board

https://5g-mmmagic.eu

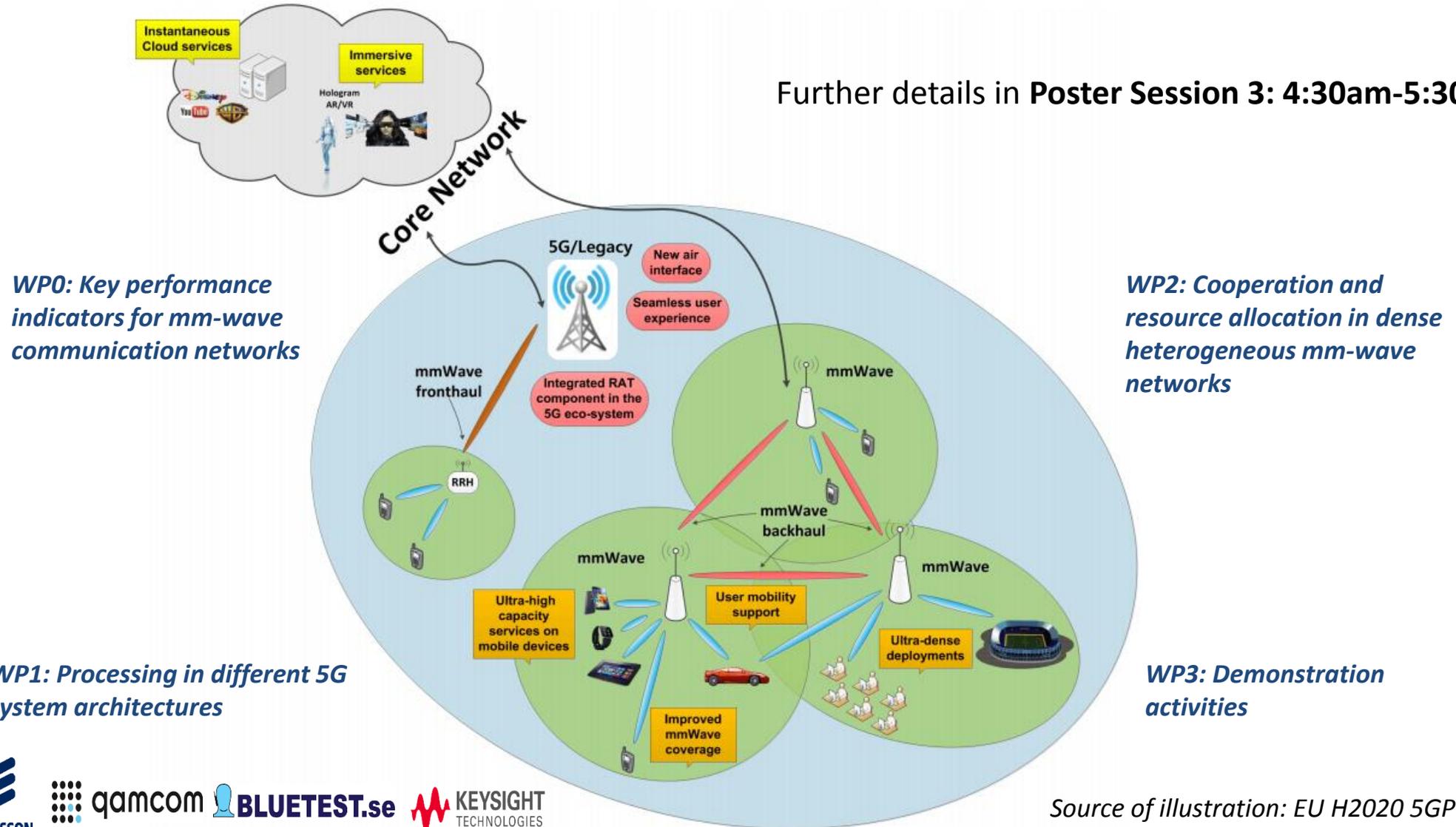# mmMAGIC Key Results

- System concept building on the logical architecture and protocol stack of LTE-A RAN.

- Standalone or non-standalone deployment - dense deployment with multi-node coordination important in standalone.

- Initial access procedure periodically repeated and consisting of three phases: cell discovery phase, random-access phase, and beam refinement and/or tracking.

- Multiple access in spatial domain (SDMA) is a recommended optimized also for scheduling between backhaul and access traffics, for Integrated Access-Backhaul (IAB), but TDMA most likely be the first choice at early deployments.

- Active and idle mode mobility supported to avoid unnecessary initial access procedures.

- Fast HARQ protocols proposed for single-hop and multi-hop scenarios.

- Scalable OFDM waveform and numerology and flexible frame structure for low delays and robustness towards HW impairments were developed.

- Hybrid beamforming was selected for the transceiver architecture, based on a simplified sub-array architecture.

- A complete 6-100 GHz channel model was developed including new important features such as enhanced blockage modelling, incorporation of ground reflection effects, improved cluster modelling, and large-scale parameters, based on a large amount of consolidated measurement and simulation data, publicly available in the QuaDRiGa SW.

Ongoing MANTUA project: Converged mmWave Access-Backhaul/Fronthaul Network

Further details in **Poster Session 3: 4:30am-5:30pm.**

WP0: Key performance indicators for mm-wave communication networks

WP2: Cooperation and resource allocation in dense heterogeneous mm-wave networks

WP1: Processing in different 5G system architectures

WP3: Demonstration activities

Source of illustration: EU H2020 5GPPP mmMAGIC

Challenges ahead: Standalone mm-wave Networks -
From hexagonal cells to dense unstructured narrow beam spaces
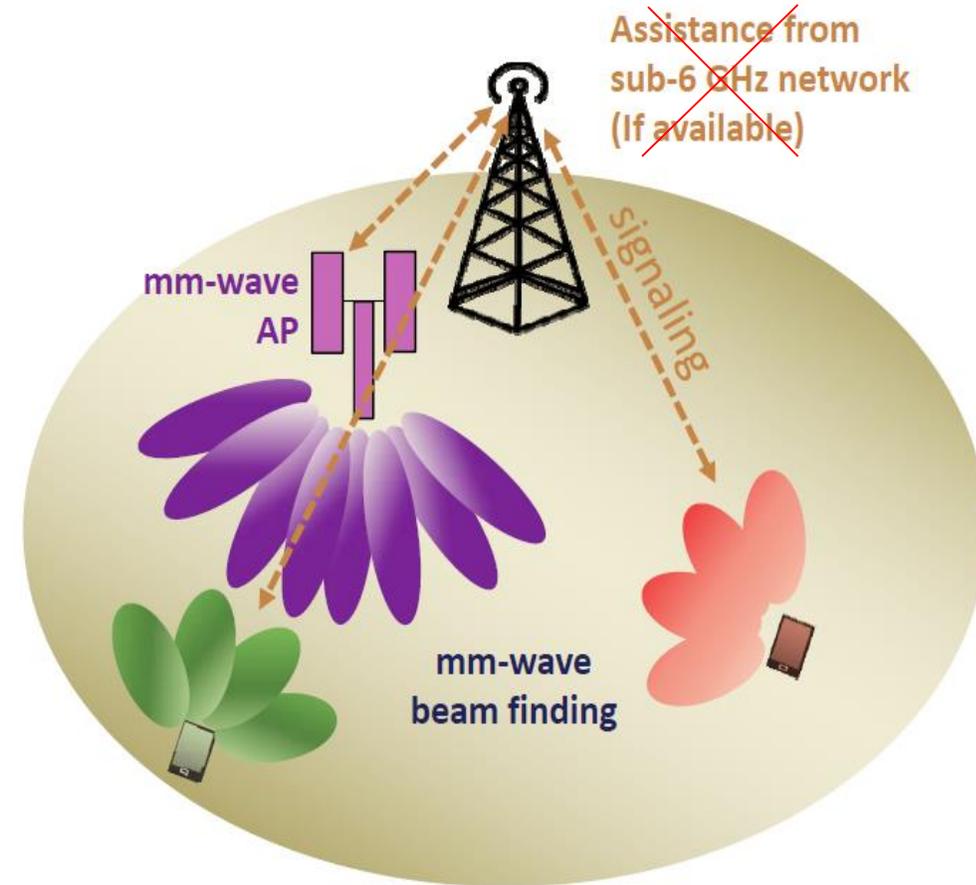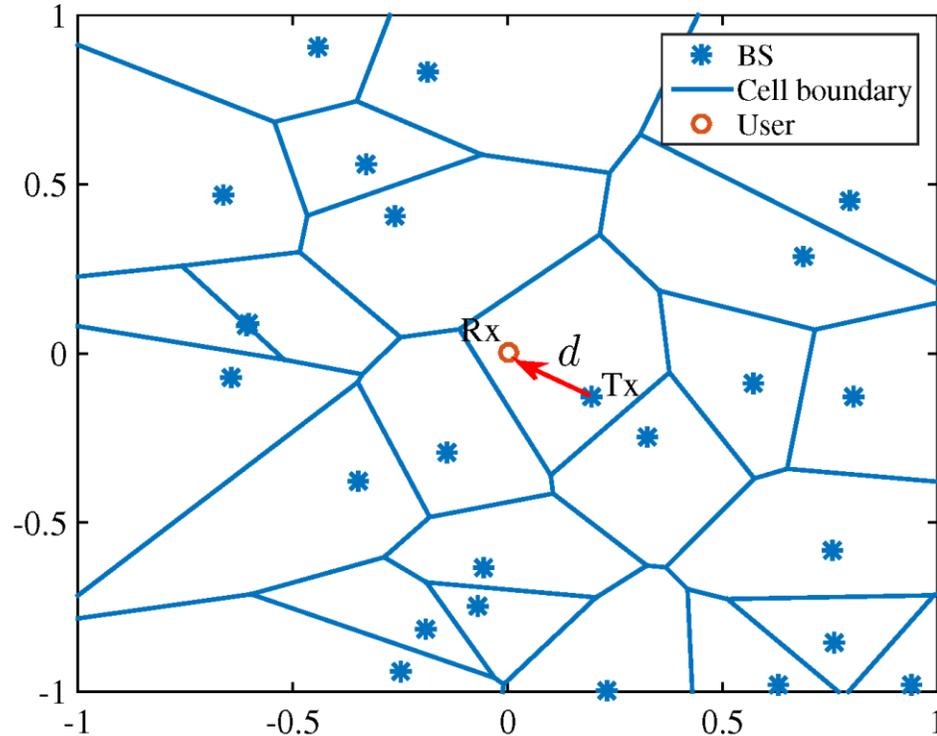
Source: mmMAGIC WP4 presentation, ETSI workshop, Sophia-Antipolis, Jan 28, 2016

Calls for *integrated* computing and communications to meet stringent delay and energy efficiency requirements.
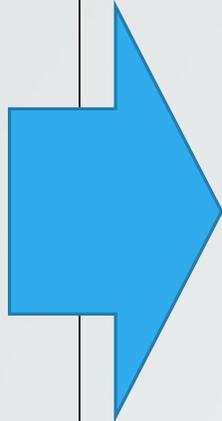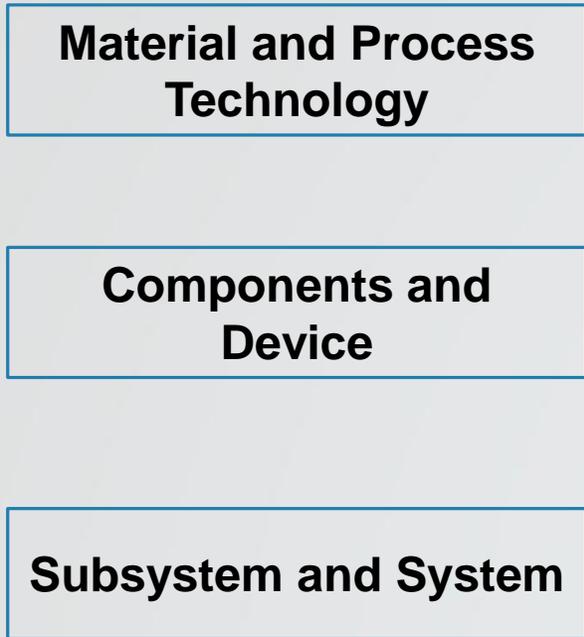
Important Research Directions related to Mobile mmWave Networks

- Access-Backhaul-Fronthaul/Core network convergence
  - Structured -> Unstructured networks
  - Cells –> Beams => tight design with antenna systems
  - Ultra-dense cooperative mesh networks
  - Integrated Access-Backhaul (IAB)
  - Generalized resouce allocation and integrated mobility
  - Communications <-> computing tradeoffs
- Vertical convergence => 3D networks
  - Vertical cells/beams, Satellite networks, Drones
- Ad-hoc network elements => Hybrid networks
  - Moving base stations => "Integrated Moving Networks"
  - Self-deployed network elements
- Context information for pro-active resource allocation
  - Out-of-system measurements, Big data aided
- Hybrid machine-learning/deterministic algorithms for complex reliable networks
- THz communications and/or/joint Free space optical communications
- Hybrid wireless/photonics networks
- Joint communications <-> sensing
- Deeply integrated security
- Agile networks – "Network slicing enablers"
  - Dynamic centralization/decentralization architecture
  - Adapt to instantaneous performance metric: throughput, latency, reliability, **energy efficiency**, **security**, coverage...
  - Utilize locality

Pioneering THz Frequency: THz Flagship

Mission: To catalyse the **revolution** of THz science and technology (S&T) and **transform** business of all the industries in the THz value chain in the next 10 years.

THz Value Chain

Material and Process Technology

Components and Device

Subsystem and System

Application Areas

Future Connectivity

Radar and Sensing for Mobility

Manufacturing and Robotics

Security

Health

Space Exploration and Climate Change

Food and Agriculture

TERA FLAG

Open Science Track

https://teraflag.eu/

Fifth Generation Communication Automotive Research and innovation

5G-PPP: Phase 2

5GCAR

Project Manager:
Dr. Mikael Fallgren, Ericsson

Facts

5G PPP Phase 2 Project
June 2017 – July 2019
30 Full time researchers
8 M€ budget

5GCAR contact

Webpage
https://5g-ppp.eu/5gcar/
https://5gcar.eu/

Email
5GCAR-Contact@5g-ppp.eu

Panel Questions

- **What should we expect by the end of 2019 on products and services?**
  - Enhanced Mobile Broadband. (eMBB) services

- **When can we expect mmWave mobile devices, specially smart phones, to enter the US market? Have they been introduced elsewhere?**
  - I have no input here.

- **What do you see as the role of universities? What are fundamental research challenges where universities can contribute?**
  - We need to further understand how to build agile mmWave networks that can support various use cases and be efficiently deployed, including high mobility and/or airborne platforms, as well as at higher frequencies

- **There have been several major trials at ATT, Verizon and others, and recent deployments at 28 GHz and 39 GHz. What have we learned from these recent efforts?**
  - We know how to build mm-wave links that works, including single-user beam-tracking.

- **What are some observations related to blockage and coverage in mmWave? Will 5G mmWave networks be reliable and provide good coverage?**
  - I think the non-standalone mode will important for long time, until we know how to efficiently deploy dense cooperative mmWave networks with efficient backhauling networks.

- **Have your thoughts on research directions changed since the trials? Are there new problems that were not anticipated?**
  - No drastic changes from my side.

- **What is the industry perspective on research testbeds on mmW networks (e.g. PAWR)? Would the provide any new insights, or is 5G mmW merely a lot of engineering challenge?**
  - From my understanding, we need further testbed activities related to dense mmWave networks and in particular high mobility scenarios. We also need further channel modeling for high mobility at 0.x THz frequencies.

- **What would you recommend as a research topic to a new PhD student who just started doing research on mmWave technology?**
  - Looking into integrated access-backhauling, high mobility (also airborne), and upper mmWave/0.x THz bands.