TERAWAY

Terahertz technology for ultra-broadband and ultra-wideband operation of backhaul and fronthaul links in systems with SDN management of network and radio resources

Funded by the Horizon 2020 Framework Programme of the European Union

H2020-ICT-2019-2
ICT-20-2019-2020: 5G Long Term Evolution
GA no: 871668
Starting date: 01.11.2019
Duration: 36 months

Website: https://ict-teraway.eu/

Workshop #8

Photonic integration as a key enabling technology for 6G and beyond

PHOTONICS21 5G PPP

AGENDA

*Session A - **mmW/THz communications' landscape*** (1h 30min, incl. Q&A)

- Keynote "Future outlook to Terahertz communications" Prof. Tadao Nagatsuma (Osaka U, Japan)
- Keynote "Spectrum regulations for Terahertz communications: Trends and needs" Prof. Thomas Kürner (TU Braunschweig, Germany).
- "mmWave & TeraHertz wireless network (transport) applications" Eduardo Yusta-Padilla (Telefónica, Spain)

AGENDA (cont.)

Session B: ***Network architecture for mmWave & TeraHertz communications*** (45min, incl. Q&A)

- THz integration into 3GPP network slicing (Dr. Jose Costa-Requena)
- THz management controller (ONF) (Dr. Nicola Carapellese)

Session C: ***Photonics-enabled wireless transceivers*** (45min, incl. Q&A)

- Novel photonic components for mmWave & THz communications (Prof. Guillermo Carpintero, UC3M)
- From concept to reality: Packaging of Photonics-enabled wireless transceivers (Dr. Zerihun Tegegne, PHIX)
- Experimental results for mmWave and beyond wireless systems based on photonic techniques (Dr. Nikolaos Lyras, ICCS/NTUA)

Session A

mmW/THz communications' landscape

This project is co-funded by

Horizon 2020

National Institute of Information and Communications Technology

Spectrum Regulations for Terahertz Communications: Trends and Needs

Thomas Kürner, Technische Universität Braunschweig, Germany

Keynote @ EuCNC Workshop Photonic integration as a key enabling technology for 6G and beyond, 7 June 2022

Outline

1. Scope of this talk
2. Preparation of WRC 2019
3. ThoR study „Initial results on sharing studies“
4. Outcome of WRC 2019
5. Conseqeunces of WRC 2019
6. Conclusions

Scope of this Talk

- This presentation is intended to provide very brief information on regulatory activities for THz Communications

- Starting point: Standardisation at IEEE 802:
  - A first standard for frequencies in the bands 252 to 325 GHz has been published
  - Work continues in IEEE 802.15 Commitee THz and IEEE 802.15 TG3ma

- Regulation (WRC 2019):
  - At the WRC 2019 the frequency band between 275 GHz and 450 GHz was considered by a specific agenda item AI 1.15 for land-mobile and fixed service
  - The H2020 EU-Japan project ThoR has conducted a sharing study wrt AI 1.15

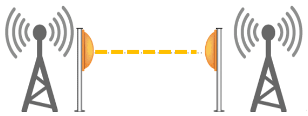
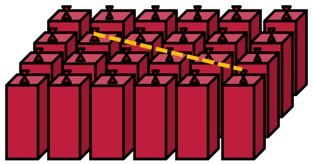
The presentation will discuss the background and consequences of the WRC decision

Standardisation Activities @ IEEE 802

- The first project within IEEE 802 towards 100 Gbps has been approved in March 2014: Task Group IEEE 802.15.3d

- Scope of the project: *„This amendment defines a wireless switched point-to-point physical layer to IEEE Std. 802.15.3 operating at a nominal PHY data rate of 100 Gbps with fallbacks to lower data rates as needed. Operation is considered in bands from 252 GHz to 325 GHz at ranges as short as a few centimeters and up to several 100m. Additionally, modifications to the Medium Access Control (MAC) layer, needed to support this new physical layer, are defined."*

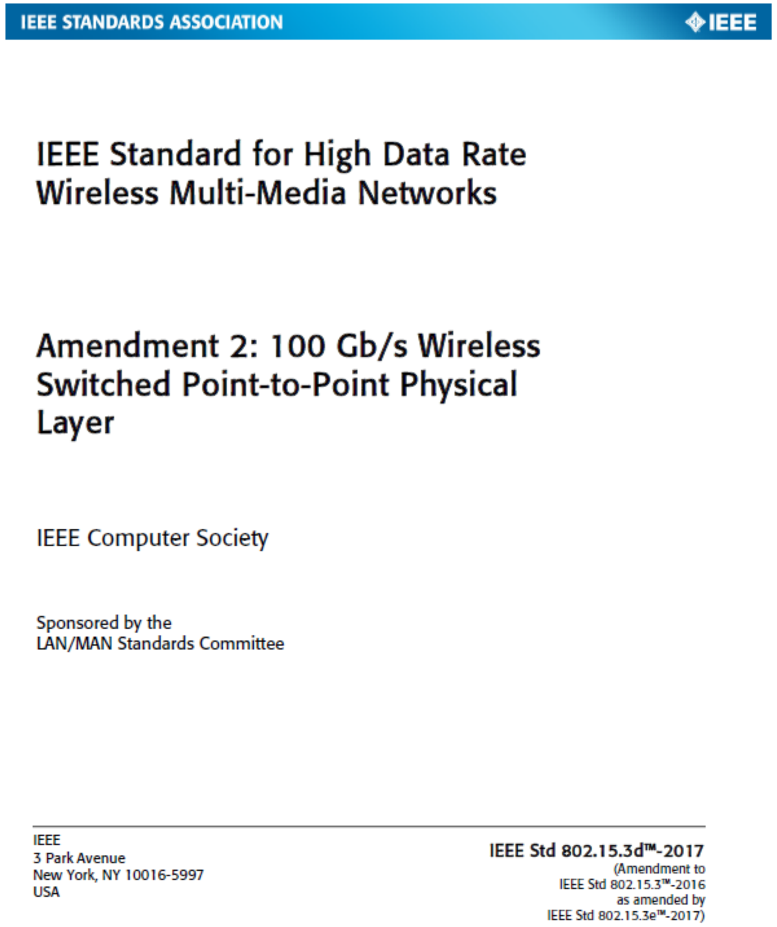
- Targeted applications:

- The standard IEEE 802.15.3d-2017 has been approved on 28th September 2017 and published on 12th October 2017 as the worldwide first wireless communications standard operating at the 300 GHz frequency range

Key facts of IEEE 802.15.3d-2017

- New PHY for Std. IEEE 802.15.3-2016
- MAC is mainly based on IEEE 802.15.3e-2017, which introduced the concept of „Pairnet“
  - Point-to-point nature with highly-directive antennas reduces the problem of interference and „fighting for access“
  - Positions of Tx and Rx antennas are known
- 8 different channel bandwidths (as multiples of 2.16 GHz)
- 2 PHY-modes (THz-SC PHY, THz-OOK-PHY) with 7 modulation schemes:
  - BPSK, QPSK, 8-PSK, 8-APSK, 16-QAM, 64 QAM, OOK
- 3 channel coding schemes:
  - 14/15-rate LDPC (1440,1344), 11/14-rate LDPC (1440,1056), 11/14-rate RS (240,224)-code.


IEEE STANDARDS ASSOCIATION
IEEE

IEEE Standard for High Data Rate Wireless Multi-Media Networks

Amendment 2: 100 Gb/s Wireless Switched Point-to-Point Physical Layer

IEEE Computer Society

Sponsored by the
LAN/MAN Standards Committee

IEEE
3 Park Avenue
New York, NY 10016-5997
USA

IEEE Std 802.15.3d™-2017
(Amendment to
IEEE Std 802.15.3™-2016
as amended by
IEEE Std 802.15.3e™-2017)

Starting point for Radio Regulations: Outcome of WRC 2012

5.565 A number of bands in the frequency range 275-1 000 GHz are identified for use by administrations for passive service applications. The following specific frequency bands are identified for measurements by passive services:

– radio astronomy service: 275-323 GHz, 327-371 GHz, 388-424 GHz, 426-442 GHz, 453- 510 GHz, 623-711 GHz, 795-909 GHz and 926-945 GHz;

– Earth exploration-satellite service (passive) and space research service (passive): 275-286 GHz, 296-306 GHz, 313-356 GHz, 361-365 GHz, 369-392 GHz, 397-399 GHz, 409-411 GHz, 416-434 GHz, 439-467 GHz, 477-502 GHz, 523-527 GHz, 538-581 GHz, 611-630 GHz, 634-654 GHz,657-692 GHz, 713-718 GHz,729-733 GHz, 750-754 GHz, 771-776 GHz, 823-846 GHz, 850-854 GHz, 857-862 GHz, 866-882 GHz, 905-928 GHz, 951-956 GHz, 968- 973 GHz and 985-990 GHz.

The use of the range 275-1 000 GHz by the passive services does not preclude use of this range by active services.

Administrations wishing to make frequencies in the 275-1 000 GHz range available for active service applications are urged to take all practicable steps to protect these passive services from harmful interference until the date when the Table of Frequency Allocations is established in the above-mentioned 275-1 000 GHz frequency range.

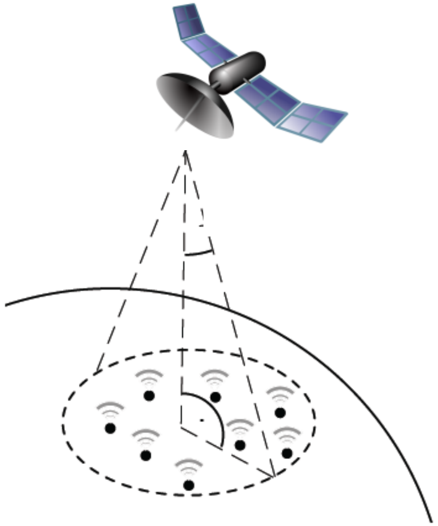
All frequencies in the range 1 000-3 000 GHz may be used by both active and passive services. (WRC-12)

The use of the frequency band 275 to 450 GHz for mobile and fixed services was subject to WRC 2019 AI 1.15

WRC 2015 agreed in resolution 767:

- to have an agenda item for WRC 2019 to consider identification of spectrum for land-mobile and fixed active services in the range of 275 GHz to 450 GHz while maintaining protection of the passive services identified in the existing footnote 5.565.

- Most importantly ITU-R has been invited to
  - study the technical and operational characteristics for the new active services and for existing passive services
  - determine the spectrum needs
  - conduct sharing studies with the passive services
  - identify candidate frequency bands



- Earth-Exploration Satellite Service (EESS) are seen as most critical
- Within the H2020-EU-Japan project ThoR sharing studies for Fixed Service and EESS have been performed (The results are available as Deliverable 5.1 at https://thorproject.eu/results/)

ThoR Sharing Study:
System types in the EESS

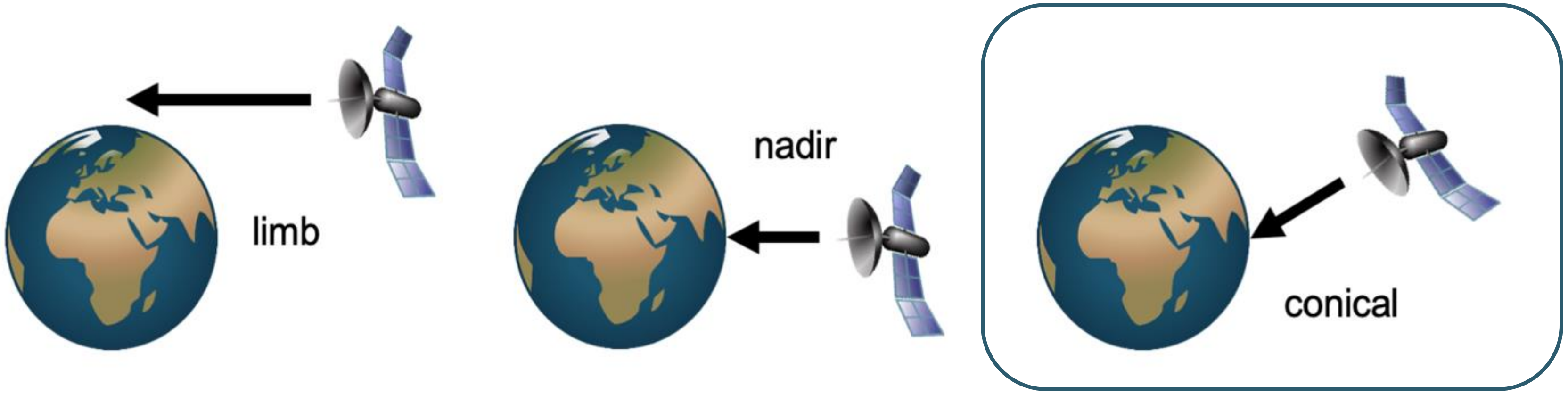


Table 3: Excerpt of the technical parameters of conical type EESS systems in the relevant bands.

EESS band no.	2	3	4	5	6	8	9
Band (GHz)	296-306	313-356	361-365	369-392	397-399	416-434	439-467
System	ICI	ICI	ICI	GOMAS	ICI	GOMAS	ICI
Altitude (km)	817	817	817	35684	817	35684	817
Nadir angle	45°	45°	45°	8.5°	45°	8.5°	45°
Elevation at the ground	25.7°	25.7°	25.7°	12.7°	25.7°	12.7°	25.7°
Max. antenna gain (dBi)	55	55	55	79	55	79	55
IFOV (km^2)	200	200	200	890	200	890	200

ThoR Sharing Study:
Technical Parameters for the Fixed Service

Table 1: Excerpt of the technical parameters of the fixed services from ITU-R F.2416 [3]

Frequency band	275-325 GHz	380-445 GHz
Antenna gain range	24 … 50 dBi	24 … 50 dBi
EIRP range	44 … 70 dBm	37 … 60 dBm
EIRP density range	30 … 67 dBm/GHz	19 … 57 dBm/GHz
Antenna pattern	Recommendation ITU-R F.699 (Single entry) Recommendation ITU-R F.1245 (Aggregate)	Recommendation ITU-R F.699 (Single entry) Recommendation ITU-R F.1245 (Aggregate)
Antenna type	Parabolic Reflector	Parabolic Reflector
Antenna height	6-25 m	10-25 m
Antenna elevation	±20° (typical)	±20° (typical)
Link length	100 … 300 m	100 … 300 m

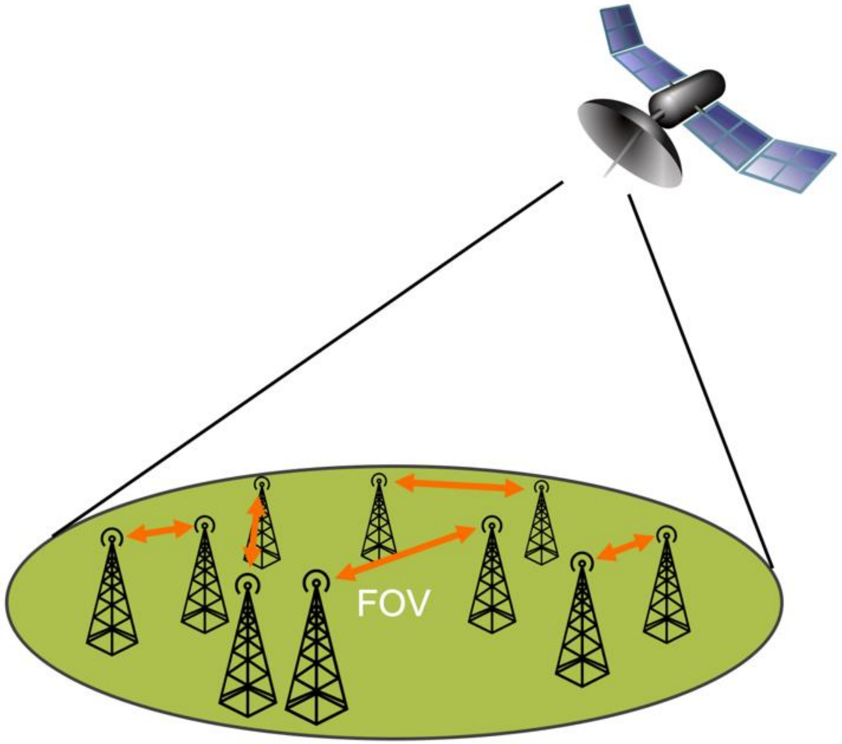
ThoR Sharing Study:
Interference Criteria for EESS

Table 5: Excerpt from table "Interference criteria for satellite passive remote sensing up to 1 000 GHz" in ITU-R RS.2017 with the footnotes [7].

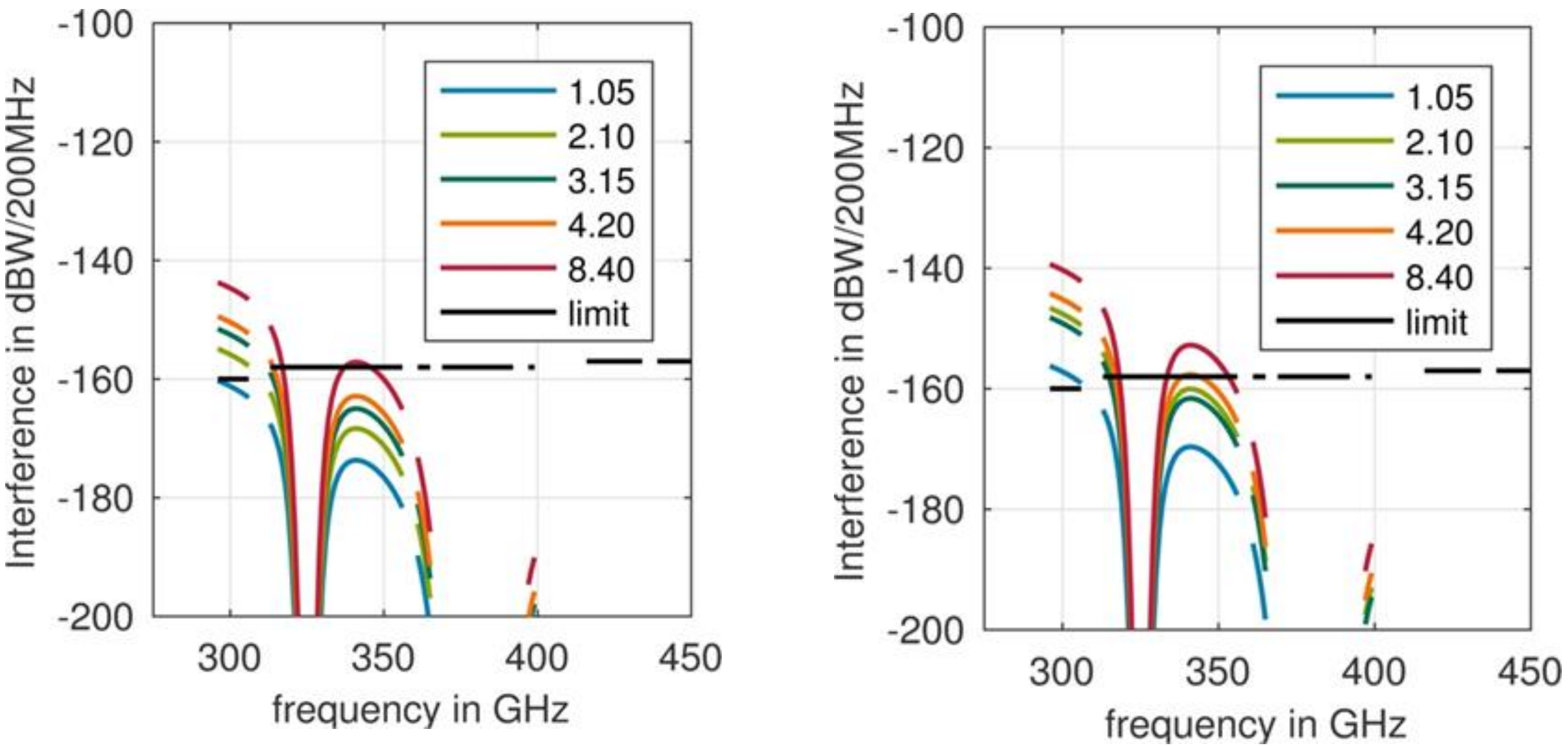
Frequency band(s) (GHz)	Reference bandwidth (MHz)	Maximum interference level (dBW)	Percentage of area or time permissible interference level may be exceeded[(1)] (%)	Scan mode (N, C, L)[(2)]
275-285.4	3	−194	1	L
296-306	200/3[(3)]	−160/−194[(3)]	0.01/1[(3)]	N, L
313.5-355.6	200/3[(3)]	−158/−194[(3)]	0.01/1[(3)]	N, C, L
361.2-365	200/3[(3)]	−158/−194[(3)]	0.01/1[(3)]	N, L
369.2-391.2	200/3[(3)]	−158/−194[(3)]	0.01/1[(3)]	N, L
397.2-399.2	200/3[(3)]	−158/−194[(3)]	0.01/1[(3)]	N, L
409-411	3	−194	1	L
416-433.46	200/3[(3)]	−157/−194[(3)]	0.01/1[(3)]	N, L
439.1-466.3	200/3[(3)]	−157/−194[(3)]	0.01/1[(3)]	N, C, L

ThoR Sharing Study:
Interference Scenario and Monte Carlo Simulation

- An Area is defined with the size of the FOV for the passive system type.
- A number of links is randomly deployed according to the link density for this iteration run.
- The position of the satellite is calculated according to its nadir angle and the altitude with an assumed azimuth of 0° relative to the middle of the FOV (Field of View).
- The slant path length and the elevation on earth from the middle of the FOV to the satellite are calculated.
- Path loss is calcuted according to ITU-R P.525 and ITU-R P.676



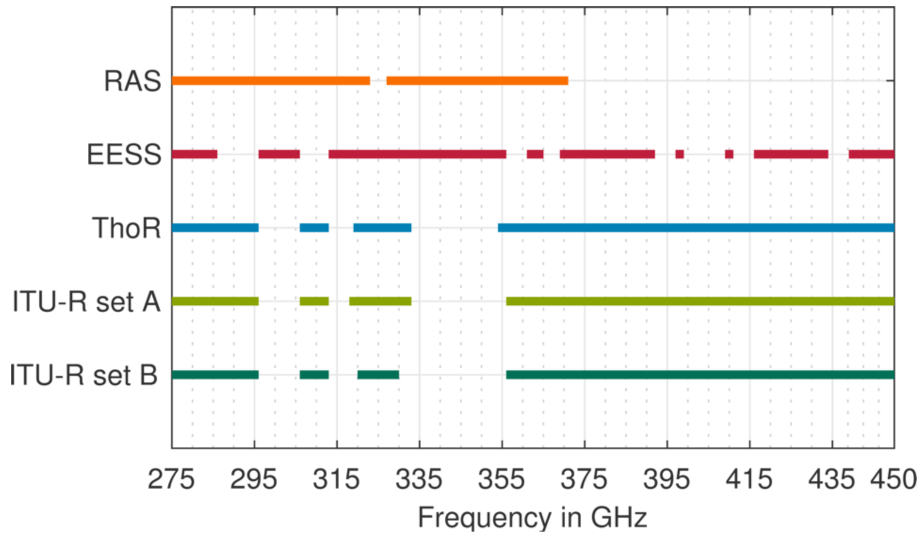
ThoR Sharing Study:
Interference Study Results for the ICI type Conical System



Maximum simulated interference power densities to an ICI type system for elevation angles between -20° and +20° (left) and -65° to 65° (right) for systems for several link densities (colour) in links-per-square kilometre (colour) and the maximum interference level to the EESS.

ThoR Sharing Study:
Brief Comparison with ITU-R Results

- Comparison of the simulation results with the EESS and RAS bands and with the summarized results discussed within ITU-R



	candidate band 1	candidate band 2	candidate band 3	candidate band 4
ThoR	275-296 GHz	306-313 GHz	319-333 GHz	354-450 GHz
ITU-R set A	275-296 GHz	306-313 GHz	318-333 GHz	356-450 GHz
ITU-R set B	275-296 GHz	306-313 GHz	320-330 GHz	356-450 GHz

Overview of the resulting candidate bands

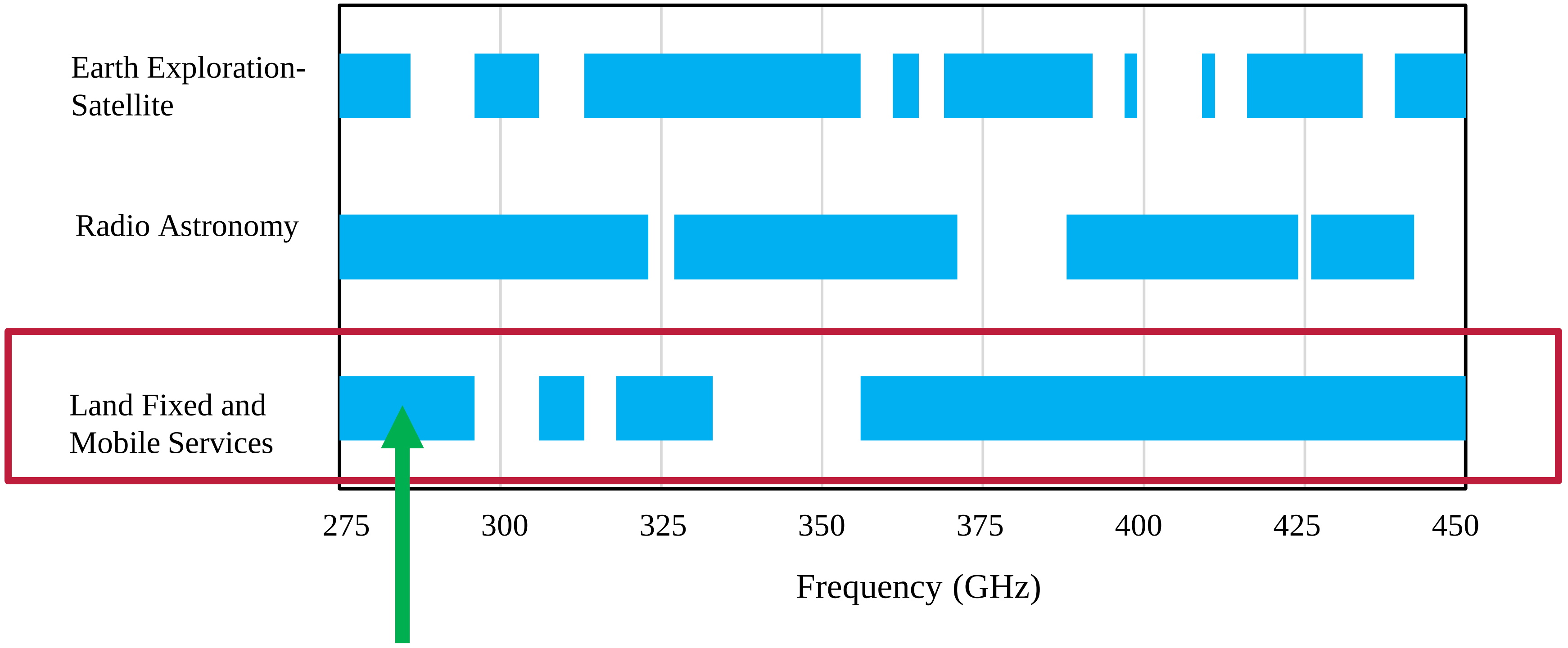
Outcome of WRC 2019

The outcome is described in the Final Acts of WRC 2019*, where the specific outcome of AI 1.15 is the introduction of a new footnote 5.564A, which contains four key items

- In total, 137 GHz in the band 275 to 450 GHz have been identified for use for land mobile and fixed service, where sharing with EESS is possible and no specific conditions are necessary to protect EESS
- The remaining 38 GHz of spectrum may only be used by fixed and land mobile service applications when specific conditions to ensure the protection of Earth exploration-satellite service (passive) applications are met.
- For the whole frequency band 275-450 GHz, specific conditions to protect radio astronomy service may apply. Such conditions are for example a minimum distance and/or avoidance angles.
- The use of the identified bands for land mobile service and fixed service does not preclude the use of the bands by other application or radio service, e. g. radar or imaging

* World Radiocommunication Conference 2019 (WRC-19) Final Acts; [online]: https://www.itu.int/dms_pub/itu-r/opb/act/R-ACT-WRC.14-2019-PDF-E.pdf

Total available Spectrum for THz Communications



Most favourable band for THz backhaul/fronthaul links

Conditions for the Use of Spectrum for THz Communications

Frequency in GHz	Status in Radio Regulations
252-275	Allocation for land mobile and fixed service on a co-primary basis
275-296 306-313 318-333 356-450	Identification for use for the implementation of land mobile and fixed service according to FN 5.564A; no specific conditions are necessary to protect Earth exploration-satellite service (passive) applications
296-306 313-318 318-356	may only be used by fixed and land mobile service applications when specific conditions to ensure the protection of Earth exploration-satellite service (passive) applications are determined in accordance with Resolution 731 (Rev.WRC-19).

T. Kürner, A. Hirata, On the Impact of the Results of WRC 2019 on THz Communications, Proc. International Workshop on Mobile THz Systems, 2-3 July 2020

A sound Regulatory Framework

The outcome of WRC 2019 provides a sound regulatory framework for the implementation of future THz communication systems in the frequency band 252 to 450 GHz.

Within this band, four contiguous bands with bandwidths of

- 44 GHz (between 252 and 296 GHz),
- 7 GHz (between 306 and 313 GHz),
- 15 GHz (between 318 and 333 GHz) and
- 94 GHz (between 356 and 450 GHz)

are available for almost unrestricted use by THz Communications.

Consequences wrt IEEE 802.15.3d

- The current IEEE Std. 802.15.3d-2017 covers the frequency bands 252 to 321 GHz.

- Thereof, two potential (future) activities have been identified in the context of this standard:

  - The continuing use of the frequency bands 296-306 GHz and 313-318 GHz by this standard will be possible, if additional sharing studies in accordance with Resolution 731 (Rev.WRC-19) show that no harmful interference to EESS occurs. This may trigger a potential regulatory activity towards future WRCs.

  - In order to make use of the large chunk of spectrum between 356 GHz and 450 GHz, this will be considered in the ongoing revision project IEEE P802.15 TG3ma

Longterm Activites towards WRC 2027

- The use of the identified bands for land mobile service and fixed service does not preclude the use of the bands by other application or radio service.
  - Such services are for example radar or imaging applications.
  - With its resolution, COM6/19 (WRC-19) has defined a preliminary agenda for the WRC 2027, on the identification of spectrum for radio location applications in frequency bands in the range 275-700 GHz for millimetre and sub-millimetre wave imaging systems.
- The potential agenda item at WRC 2027 on the identification of spectrum for radio location applications in the range 275-700 GHz will require sharing studies with THz communications as the incumbent application.
  - This may trigger another potential regulatory activity towards WRC 2027.

Conclusions

- The regulatory situation for THz Communciation in the frequency range 275-450 GHz has been described.

- WRC 2019 has added a new footnote to the radio regulations, which describes the conditions for the use of the spectrum between 275 and 450 GHz by land mobile and fixed services.

- Totally, 160 GHz of spectrum are now available for THz communications, where no specific conditions are necessary to protect EESS.

- This includes two big contiguous spectrum bands with 44 GHz and 94 GHz bandwidth, respectively.

This provides a sound basis for the future implementation of THz communications. Still, a couple of future regulatory and standardization activities have been identified.

Thank you for your attention!

ご清聴ありがとうございました

For any enquiries please contact:

Thomas Kürner

t.Kuerner@tu-bs.de

This project has received funding from Horizon 2020, the European Union’s Framework Programme for Research and Innovation, under grant agreement No. 814523. ThoR has also received funding from the National Institute of Information and Communications Technology in Japan (NICT).

ThoR and Meteracom Workshops

Hybrid Event !

28. - 30. June 2022

The two projects H2020 EU-Japan ThoR ("ThoR: TeraHertz end-to-end wireless systems supporting ultra high data Rate applications") and DFG FOR 2863 Meteracom (Metrology for Communications) - both of them coordinated by TU Braunschweig - will present their results in two co-located workshops on June 28-30 2022 as a hybrid event at TU Braunschweig. Both events will include invited speakers along with presentations from the projects. The ThoR workshop includes a live demo of a 300 GHz backhaul link between campus buildings as well as a social event.

Register @ https://www.tu-braunschweig.de/ifn/institut/thor-and-meteracom-workshops

Terahertz technology for ultra-broadband and ultra-wideband operation of backhaul and fronthaul links in systems with SDN management of network and radio resources

Funded by the Horizon 2020 Framework Programme of the European Union

H2020-ICT-2019-2
ICT-20-2019-2020: 5G Long Term Evolution
GA no: 871668
Starting date: 01.11.2019
Duration: 36 months

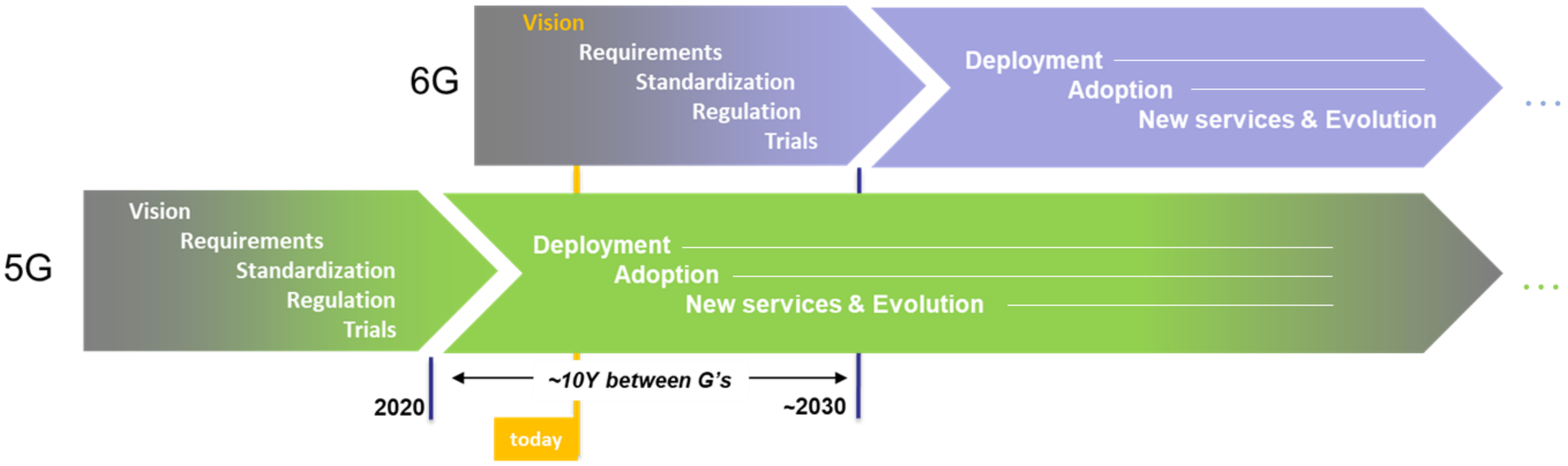
Website: https://ict-teraway.eu/

mmWave & TeraHertz wireless network (transport) applications

Eduardo Yusta Padilla

TELEFONICA I+D – GCTIO office – Core, Transport & platforms group

General context – mobile comm. networks

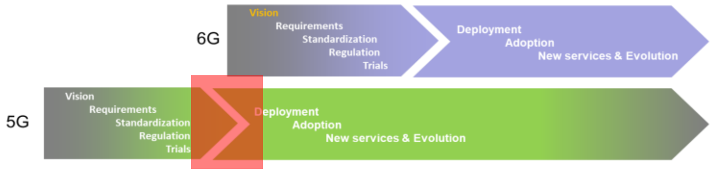


- **Focus on wireless transport applications, but… borders between access & transport becoming diffuse!**
  - mmWave already gaining relevance in 5G. Further relevance in 5G evolution
  - Essential work on THz technology development. Base tech. for future radio access and transport

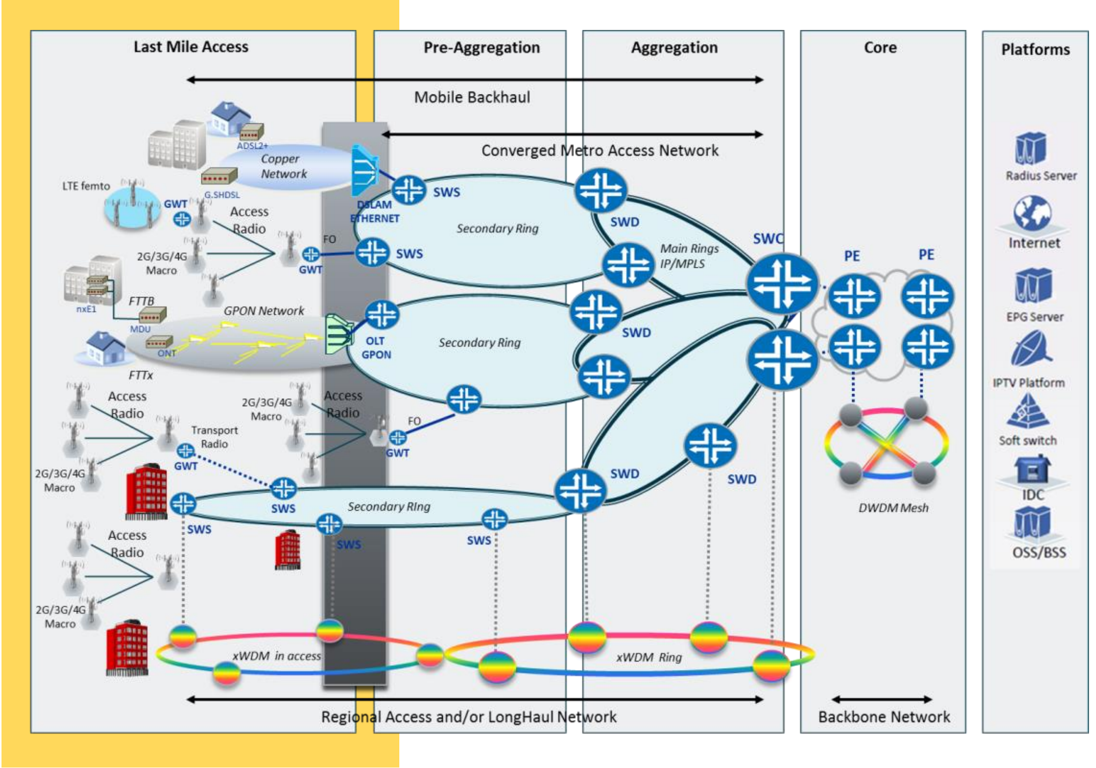
- **Key context for analysis: mobile communication system evolution, primary field of application**
  - Recurrent cycles. Overlap between "N"G evolution and "N+1"G vision, specs and standardization
  - 6G now consolidating target vision, cases and requirements
  - 5G (baseline) – 5G evolution (trends) - 6G (vision)

Wireless transport in communication networks

TERAWAY



- **Main application: Site connectivity**
  - Permanent applications, but also temporal (e.g., events, disaster)
  - Public or private networks (industrial environments)
  - Urban, suburban and rural scenarios
    - Key aspects: range, capacity and availability
    - But also mind form factor, power consumption, installation!
  - Typically, at much higher frequencies than radio access

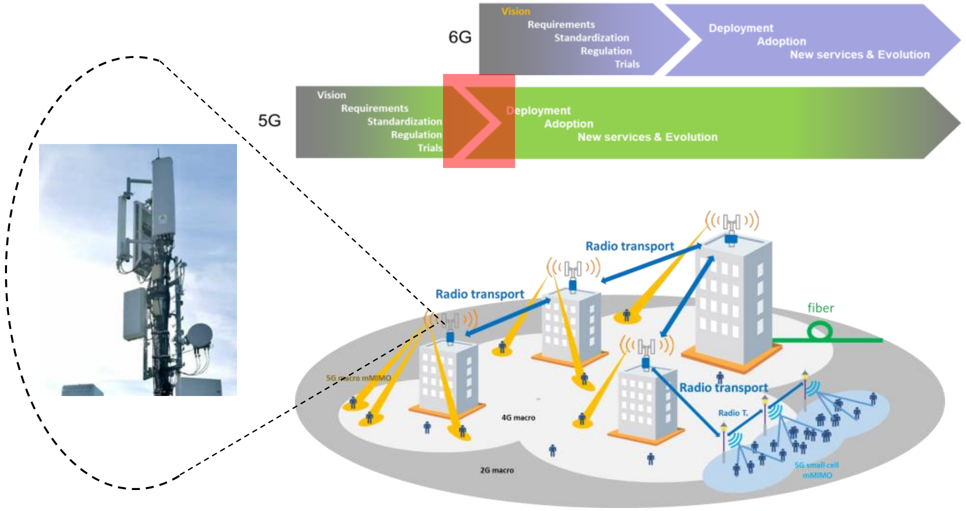


- **Main role → complementing fiber deployment**
  - MNO strategy progressively shifted to fiber. However:
    - Capex-intensive, slow deployment time
  - Flexibility from radio transport as complementary medium
    - Penetration depending on market, environment, MNO

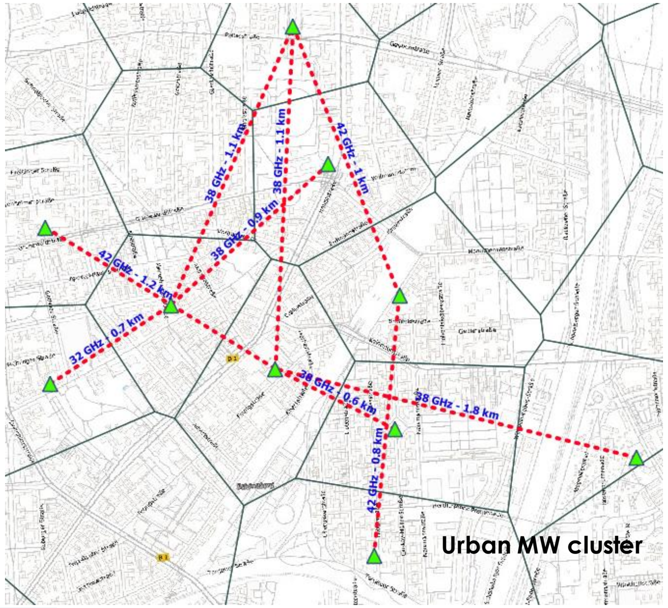
- **Radio transport requirements, heavily linked to access technology, deployment architecture and new service evolution**

Mobile site connectivity

- **Main application of radio transport**
  - Macro / micro / small cell layer
- **Typical tree aggregation structures towards fiber aggregation network**
  - Capacity per site increasing – “legacy” RAT stacking + **5G**
  - #hops to fiber reducing – latency and capacity reasons
- **Suitability of technologies linked to required reach, capacity, availability target and bands/channels available (regulation & licensing!)**
- **Mobile inter-site distance and site capacity linked to environment**
  - Dense environments – hundreds of meters
  - Mid-band w/mMIMO macro layer typical in current 5G deployments

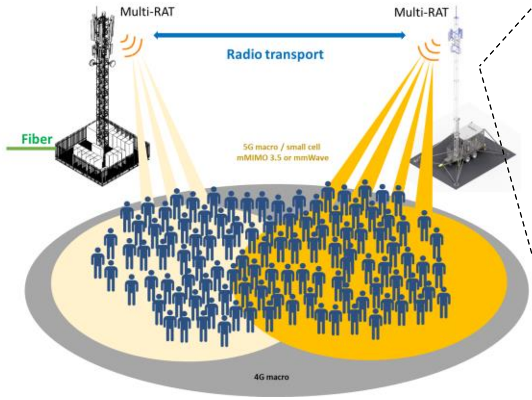


- **Large penetration increase of mmWave products (E-band) linked to 5G deployment**
  - Denser areas where ISD allows for mmWave
  - Combined with traditional MW in other areas requiring larger ISD
  - Per-site 10Gbps dimensioning criterion becoming common for radio transport
    - Cell peak @ mid-band 100MHz TDD RAN w/ mMIMO can exceed 6Gbps
    - Several site transport over a single link (depends on EE and dimensioning)

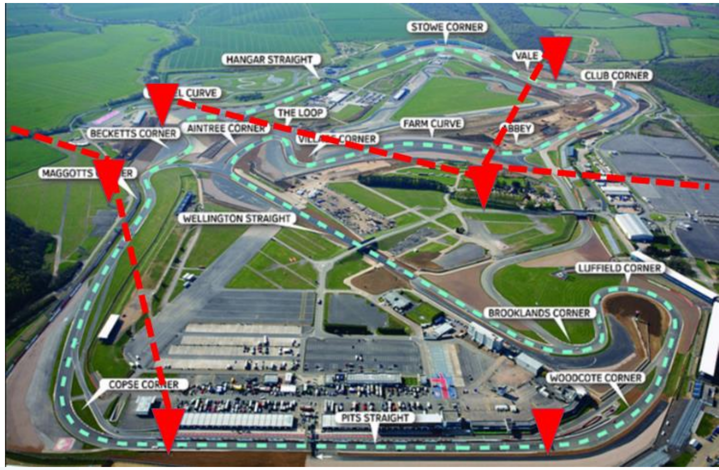


Temporal site connectivity scenarios

- **Ad-hoc temporal aggregation networks, diverse applications**
  - Outdoor events (festivals, fairs, sporting events, …)
  - Emergency / disaster recovery
- **Specific infrastructure for RAN + transport**
  - Transportable Cell on Wheels or semi-permanent infrastructure
  - Stand-alone transport or complement to fiber-based RAN solutions



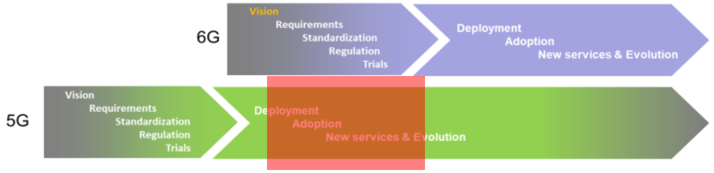
- **Outdoor events in many cases similar to dense environments**
  - Very large capacity density (users, activity factors, service mix…)
  - Aggregation topology towards fiber
  - Multiple sites, multi-RAT stacking, low ISD
  - However, larger relevance of SWAP, installation/configuration simplicity
- **Emergency/disaster recovery**
  - Deployment time and flexibility become essential factors
  - Other aspects like extended reach might become more relevant than capacity, imposing practical limits for link frequencies
- **Both fixed and temporal applications of relevance for industrial environments**

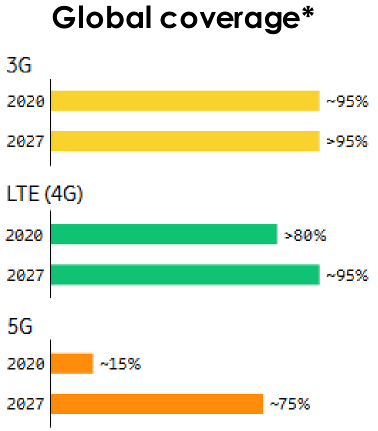


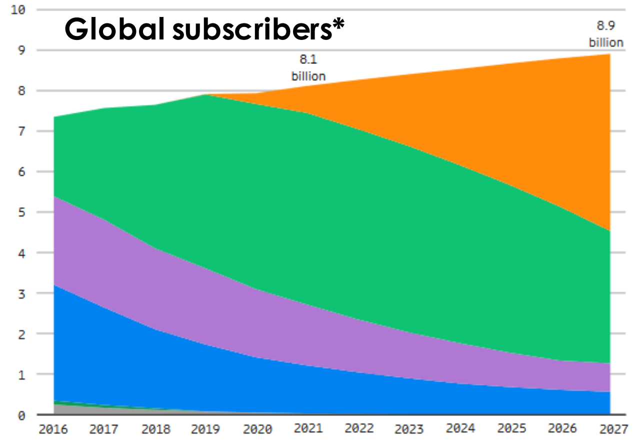
5G evolution, key trends for radio transport

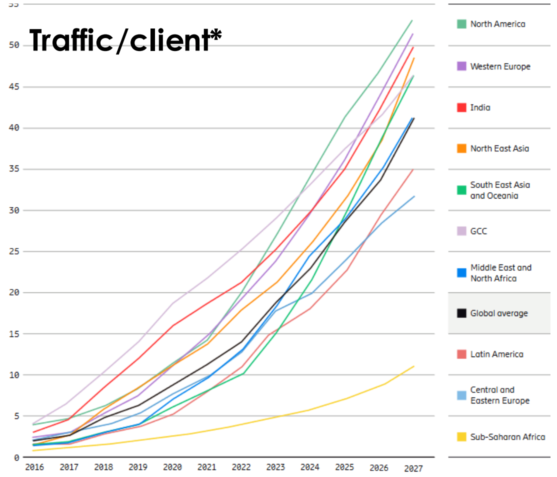
- **5G adoption**
  - Coverage and capacity rollout evolution
  - Device availability, price points (handsets and specific devices)
  - Commercial models favoring adoption
  - Newer applications (eMBB) leveraging on new 5G capabilities
  - **5G user and traffic (per user / per site) growth**

- **5G SA implementation**
  - Network transformation enabling 5G evolution
  - Higher relevance of services outside eMBB
    - Expansion of connected devices
    - Newer requirements for communication technologies
  - New services for verticals (Slicing)



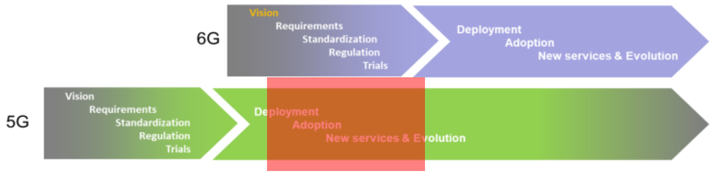






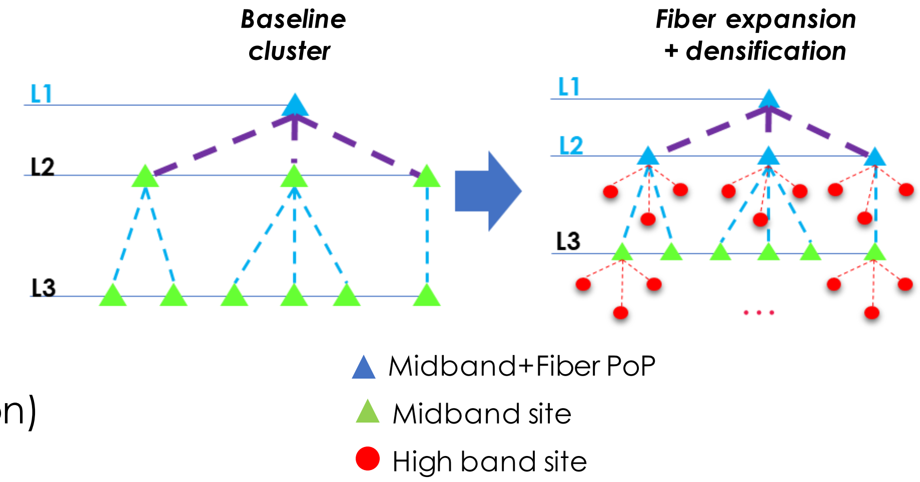
*source: Ericsson mobility report

5G evolution, key elements for radio transport



THROUGHPUT!

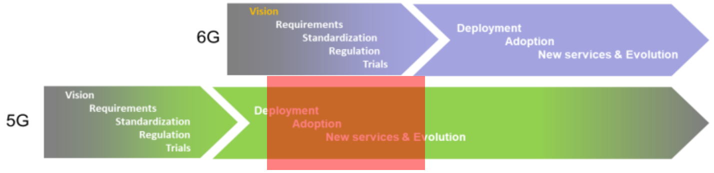
- **Radio access evolution**
  - Potential mid-band frequency expansion (e.g., 6-7GHz band)
  - High-band frequencies (26-28GHz and higher on consideration)
    - Theoretical **peaks beyond 10Gbps** (e.g., 800MHz BW)
    - **FWA** site connectivity **as additional use case** relevant for radio transport
    - Access and transport might merge in some cases (IAB)
  - Potential densification on top of existing site grid
    - **Lower ISD**, mmWave RAN with range challenges, **opportunity for high throughput wireless transport**
    - Street level deployments, **SWAP gains relevance**
  - Site simplification and radio virtualization
    - Higher penetration of RAN centralization scenarios
    - Low layer RAN splits in centralized scenarios → **many 10`s to 100+ Gbps!**



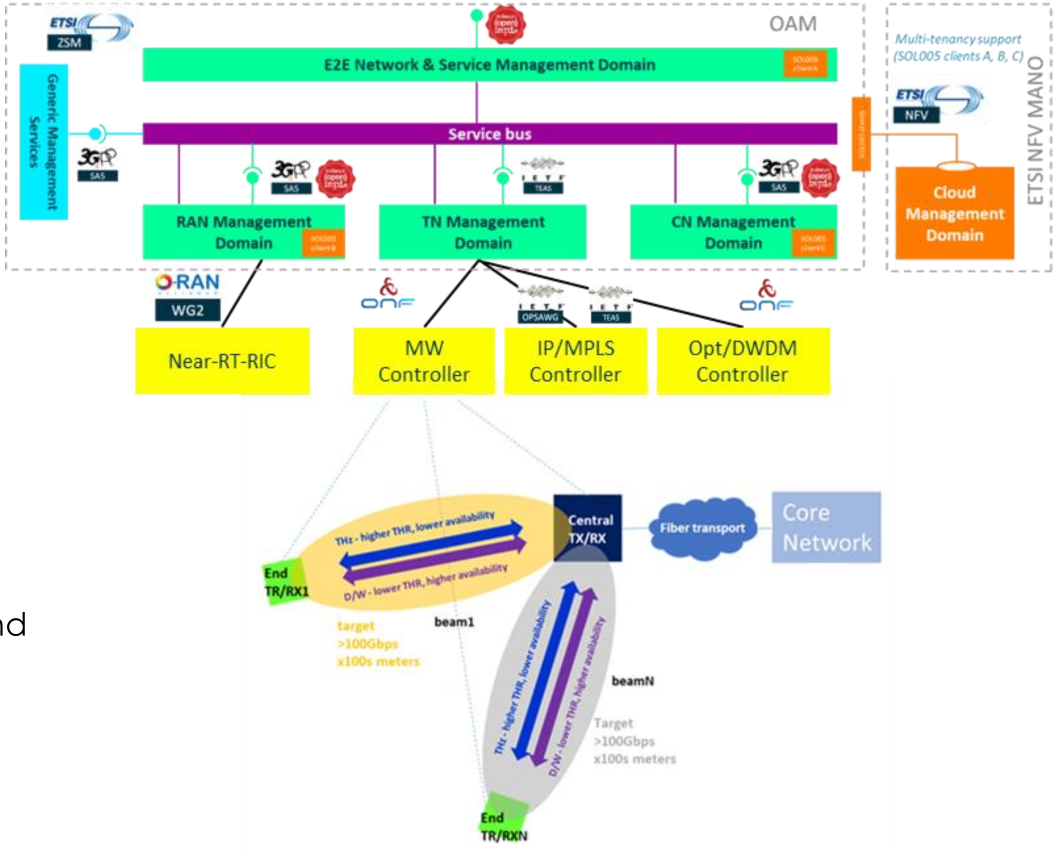
- **Evolution of "baseline" mmWave products…**
  - E-band might get progressively to 30-50Gbps (multi-channel and MIMO)
  - W-band providing extra spectrum, products closer in concept to E-band
  - D-band targets 10's to 100Gbps (multi-channel, IF BW and band fragmentation)

- **100Gbps wireless transport and beyond → large relevance of THz!**

5G evolution, key elements for radio transport

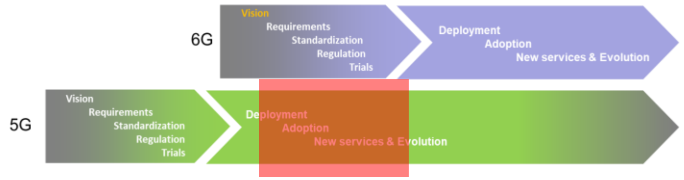


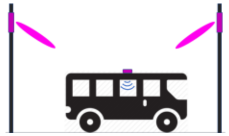
- **5G evolution → impact on applications aside raw throughput**
  - **Site densification**
    - **Multi-beam point to multipoint (star)**, steps towards mesh topologies…
    - End site equipment integration & radio layer coordination, larger radio virtualization and BB pooling
    - Deployment flexibility / HW reusability – **tunability and beam steering**
  - **New services ("non eMBB") and slicing**
    - Latency: critical services stringent requirements in RAN centralization scenarios. **Minimize processing delay/jitter** on top of radio propagation.
    - High availability: **multi-band wireless tunable** transport
    - Slicing support: **multi-band / multi-channel**, provision of differentiated resources to meet SLAs/Os
  - **Network automation & orchestration**
    - **Hierarchical control architectures**
    - Domain agnostic management, **standard interfaces/protocols/models**
    - Pillar for AI-driven autonomous network (efficiency, optimization, healing) and slicing support



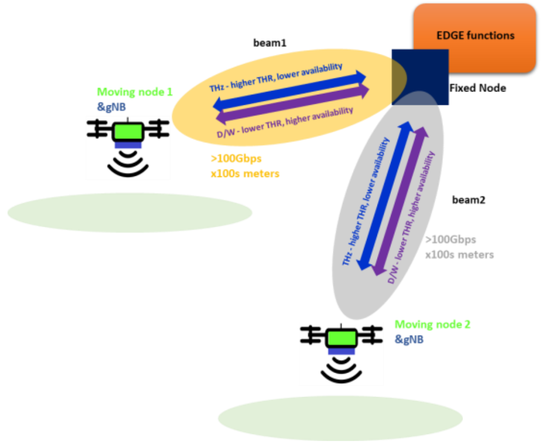
5G evolution: connectivity to moving objects

- **Wireless high throughput connectivity to moving objects (UAVs, V2X)**
  - UAVs → Many verticals and use cases: surveillance, infrastructure monitoring, video, …
  - UAVs cases so far mainly 5G assisted (moving object managed by RAN access) but…
    - Demanding applications might need dedicated data channels (avoid cell capacity impact)
    - 5G channel quality might not be enough at heigh in all areas for specific applications
  - High throughput connectivity to vehicles hosting RAN nodes/relays (e.g., bus)



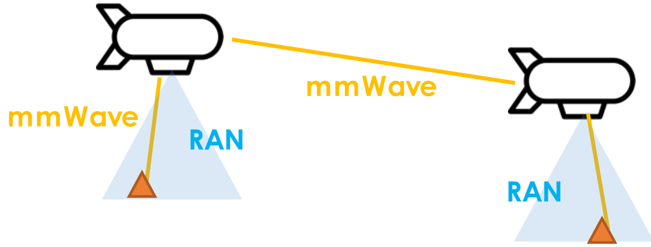


- **Ad-hoc mobile coverage provision via moving objects (UAVs)**
  - Dynamic network deployment: Outdoor event traffic offloading, emergency / disaster recovery,…
  - On board gNB simplification (SWAP-autonomy) → BB centralization → large throughput
  - Services on top of mobile coverage (e.g., surveillance, video), NaaS leveraging on slicing



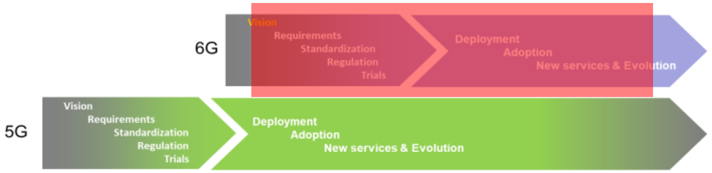
Main challenges → mobility support / speed, range & availability, SWAP (UAV autonomy!)
Beamforming/steering, positioning,… requirements "on top" of traditional applications

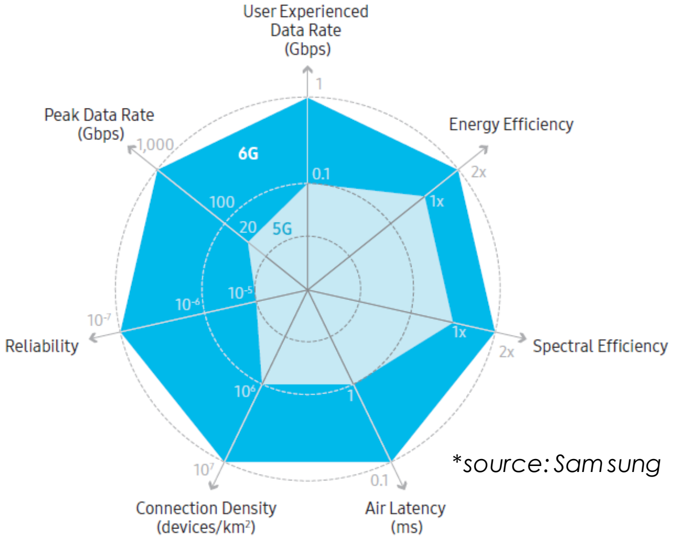
- **5G NTN – TN integration → HAPs and satellite mmWave applications**
  - mmWave V/E-band already in ISLs (V-band) and inter-HAP or gateway links (E-band). FSO also part of experiences
  - Range/availability challenges for mmWave/THz/FSO, especially in the gateway link (tens of km)
  - Stratospheric operational conditions (h~20km) also presents relevant challenges



6G – some vision aspects

- **Target services (end users/verticals) with large impact in requirements**
  - Immersive XR, digital twins, holograms…
  - Large multipliers for peak and UE throughputs, but also in computing requirements
  - Also large impact on E2E latency linked to XR, and reliability in critical services (e.g industry, medical)
- **Massive increase of connected devices**
  - Robots, UAVs, wearables, XR, holographic, sensors…
- **Automation & AI driven**
  - E2E orchestration, standard-based open control architectures
  - Distribution of intelligence device – network
  - Dynamic optimization, energy efficiency, self-healing, predictive management
- **Flexible network architecture**
  - Cloud/SW-based. Network function and resource (e.g caching, processing) dynamic distribution
- **Social impact and sustainability and development targets**
  - Energy efficiency and greenhouse emission reduction (remote work, education,…)
  - Larger relevance of NTN integration. Coverage extension, ubiquity and service continuity.

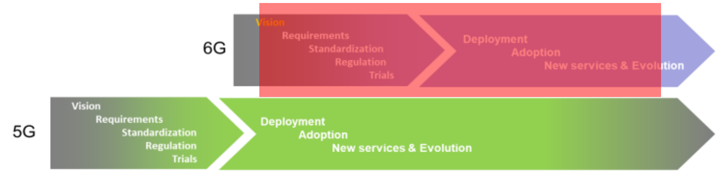




*source: Samsung

6G access→ low / mid / high-band mix. Midband and high-band expansion. **High bands >100GHz under consideration**
As access moves to higher frequencies → THz becomes key in wireless transport to complement fiber

6G – Wireless transport applications evolution



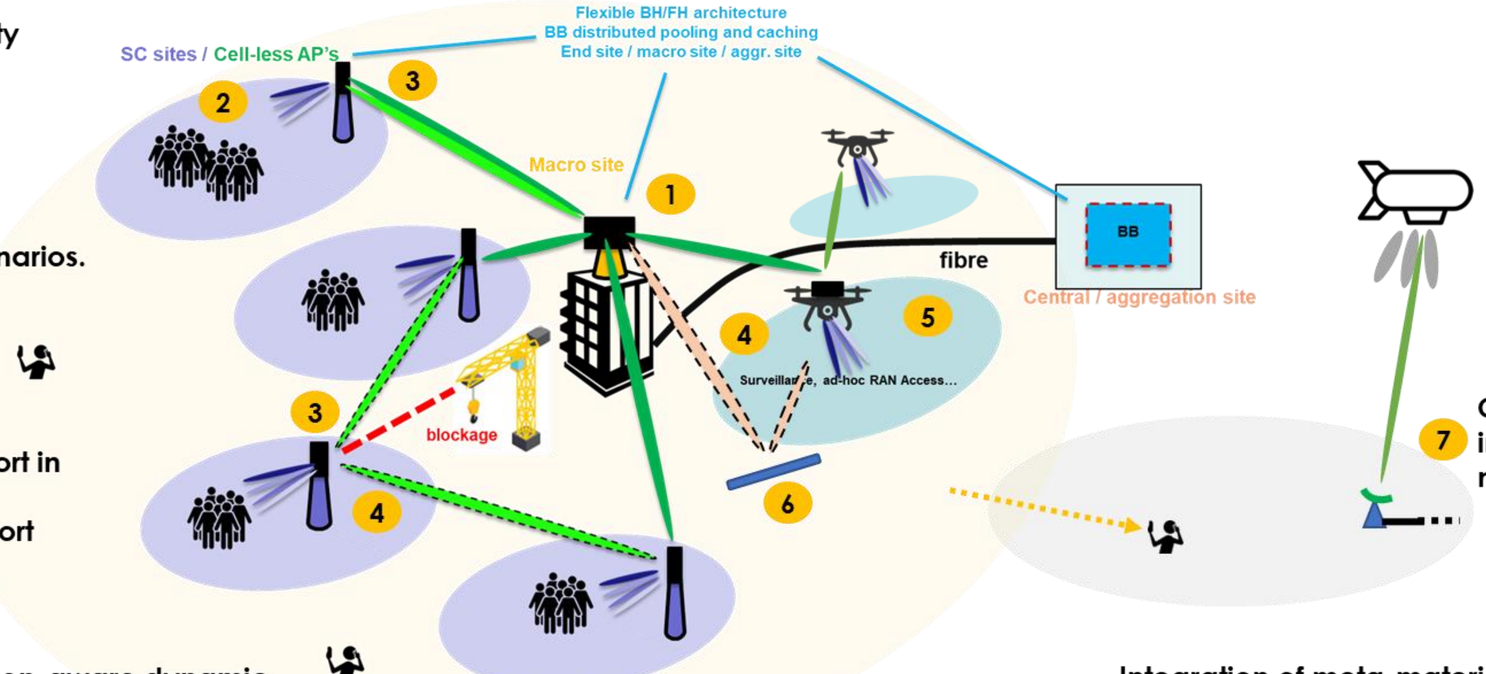
E2E multi-domain control & orchestration architecture, sliceable network

IA based network with open interfaces and protocols leveraging automation. Energy efficiency, self-healing & performance optimization

1 Large-scale mMIMO in THz transport – reach & site density
Multi-band tunable transport

2 Potential Integration of THz access/transport in denser scenarios.
Cell-less IAB architectures

3 Multi beam THz transport in macro/SC sites – AP's
Meshed network support



7 Coverage extension integrating NTN networks

4 Location-aware dynamic topology management exploiting THz-band capabilities

6 Integration of meta-materials/RIS in network topology
Moving elements, NLoS

5 Dynamic integration and support of moving objects by Wireless transport
Wide / fast beamforming / steering

Thank you!

Q&A?

For more info, visit TERAWAY website: ict-teraway.eu/

Funded by the Horizon 2020 Framework Programme of the European Union under under G.A No 871668 and it is an initiative of the Photonics Public Private Partnership

Session B

Network architecture for mmWave & TeraHertz communications

Session C

Photonics-enabled wireless transceivers

THANK YOU

For more info, visit TERAWAY website: ict-teraway.eu/

Funded by the Horizon 2020 Framework Programme of the European Union under under G.A No 871668 and it is an initiative of the Photonics Public Private Partnership