6G RESEARCH VISIONS WEBINAR SERIES :

Remote and Rural Area Connectivity Challenges and Solutions from the Spectrum perspective

Prof. Abdelaali CHAOUB

Associate Professor | VoIP/5G/B5G Consultant

National Institute of Posts and Telecommunications (INPT), Morocco

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Agenda I

1. Towards a flexible use of spectrum is remote areas
2. Cognitive radio and coexistence
3. Hybrid horizontal and vertical spectrum sharing
4. Spectrum aggregation and Multi-connectivity schemes
5. Utilizing unlicensed bands
6. Integrated access and backhaul (IAB)
7. Optical wireless communications (OWC)
8. Final Remarks

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- ★ Spectrum : the lifeblood of the telecommunication market.
- ★ Remote areas connectivity : beyond traditional urban connectivity ⇒ connecting the unconnected and the under-connected (e.g. ubiquity over the 3 dimensions).
- ★ Lack of favorable spectrum : a serious impediment to broadband connectivity in those areas.
- ★ Two options to increase the available spectrum portion :
  - ➥ Spectrum sharing/reuse/optimization, huge potential.
  - ➥ Introducing new bands (e.g. millimeter and terahertz), but poor coverage.

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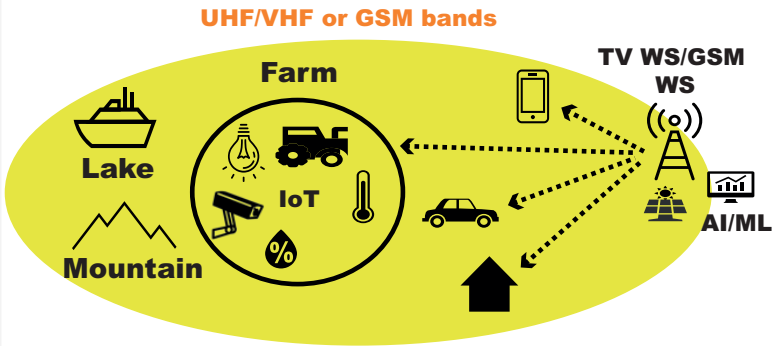
Cognitive radio and coexistence

- ★ Sub-6 GHz frequencies remain critical for remote connectivity thanks to their favourable propagation properties and wide reach.
- ★ Crowded bands : fully assigned and very hard to be freed up.
- ★ Sparse distribution of remote/rural users may result in spectrum holes.
- ★ Leveraging white spaces (e.g. TV, radar and GSM bands) and inter/intra-operator spectrum sharing can increase spectrum availability ⇒ **connectivity beyond the rural households to more distant locations like farms and wilderness areas**.

Some challenges and research directions :

- ➥ Radio awareness (e.g. spectrum sensing, geolocation databases and radio environment maps).
- ➥ Protection against unauthorized transmissions.
- ➥ Parallel sensing and transmission (e.g. innovative sensing and/or interference cancellation).

awareness



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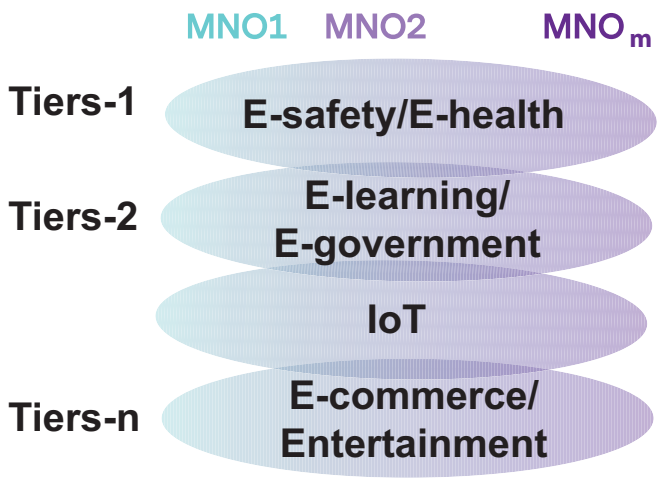
Hybrid horizontal and vertical spectrum sharing

- ★ **Horizontal spectrum sharing** : sharing by operators of the same priorities.
- ★ **Vertical spectrum sharing** : coexistence of stakeholders with various priorities.
- ★ Licensed shared access (LSA, in Europe) and spectrum access system (SAS, in US) are mature examples with 2-tiers and 3-tiers of users, respectively.
- ★ Evolve to include n-tiers of users/services belonging to m different MNOs/incumbents ⇒ **low-cost spectrum access and promoting local content providers (e.g. farming, mining, education, health and safety)**.

Some challenges and research directions :

- ➥ Interference management and mitigation.
- ➥ Database management of various actors (e.g. incumbents, local licenses and authorized operators).
- ➥ QoS/QoE guarantees for all stakeholders.
- ➥ Extremely accurate radio environment maps.



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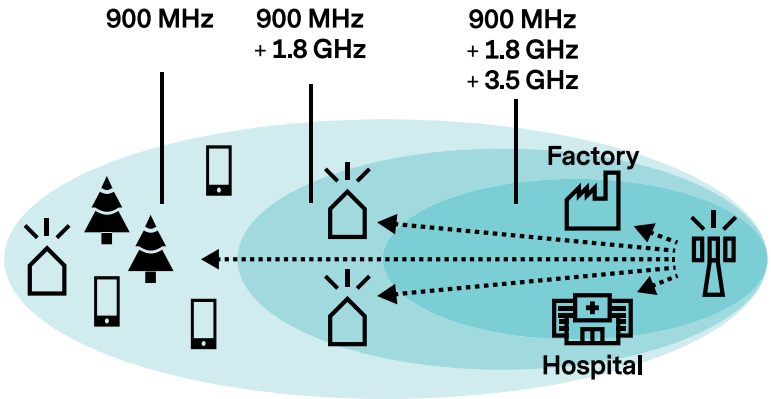
Spectrum aggregation

- ★ Situation awareness : combines frequencies above and below 6 GHz (same TX).
- ★ Using advanced spectrum/carrier aggregation the resource scheduling unit in 6G systems can choose the optimal frequency combination(s) according to service requirements, device capabilities, and network conditions.
- ★ A scalable bandwidth that maintains service continuity in case of connectivity loss in one or many bands ⇒ **better service resilience in remote/rural areas**.

Some challenges and research directions :

- ➥ Overcoming complexity of TX-RX circuits operating in such heterogeneous bands.
- ➥ Need for extremely agile antennas.
- ➥ Enhanced and flexible UL and DL split : UL on a given set of frequencies, DL on same or different set of frequencies.

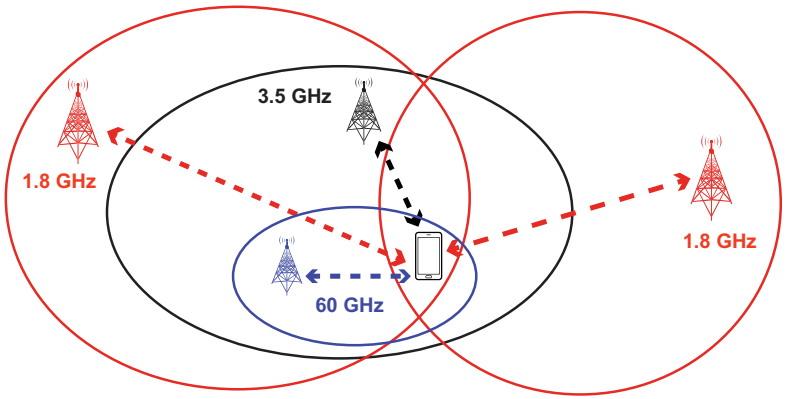


Multi-connectivity schemes

- ★ Remote streams split over multiple radio access technologies (RATs) and bands.
- ★ Exploiting diversity and pervasiveness of some technologies (e.g. WIFI, TV and HetNets).
- ★ Ideal for both standalone and non-standalone deployments.
- ★ In 6G, various RATs and a scalable aggregation can be envisioned at various protocol and/or architecture levels from the radio link up to the core network ⇒ **seamless mobility, load-balancing and fault tolerance in hard-to-reach areas**.

Some challenges and research directions :

- ➥ More complexity reported at the edge of the network (i.e. UEs and base stations).
- ➥ Coordinated resource scheduling, handover and beam directions.



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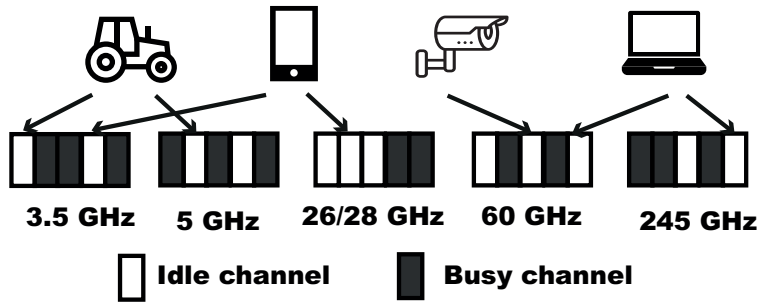
Utilizing unlicensed bands

- ★ FCC has recently released 1.2 GHz in the precious 6 GHz bands to expand the unlicensed spectrum. Other MM and THz bands can follow.
- ★ Hybrid spectrum sharing solutions can adaptively orchestrate network operations in the licensed and unlicensed bands.

Some challenges and research directions :

- ➥ Harmonious operation with lower bands (i.e. MM/THz bands requires LOS).
- ➥ Control and listening mechanisms (e.g. LBT) need to be more cooperative and distributed to avoid misleading spectrum occupancy.
- ➥ The management of uncoordinated competing users in unlicensed bands.



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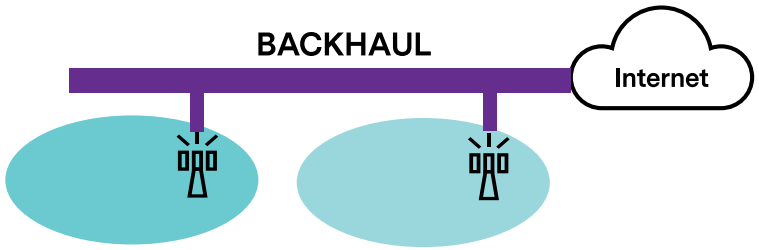
Integrated access and backhaul (IAB)

- ★ Multiplexing the access and backhaul data within the same bands ⇒ **no need for additional hardware and/or spectrum license costs.**
- ★ Replace fiber-like infrastructures ⇒ **lower complexity : facilitates site installation in rural areas where cable buildout is difficult and costly.**
- ★ More potential at mmWaves to exploit a larger bandwidth.

Some challenges and research directions :

- ➥ Optimal and dynamic resource scheduling between RAN and backhaul.
- ➥ High number of hops (can be combined with other technologies or sub-6 GHz).
- ➥ Ideal if endowed with self-configuring easier-to-deploy capabilities.



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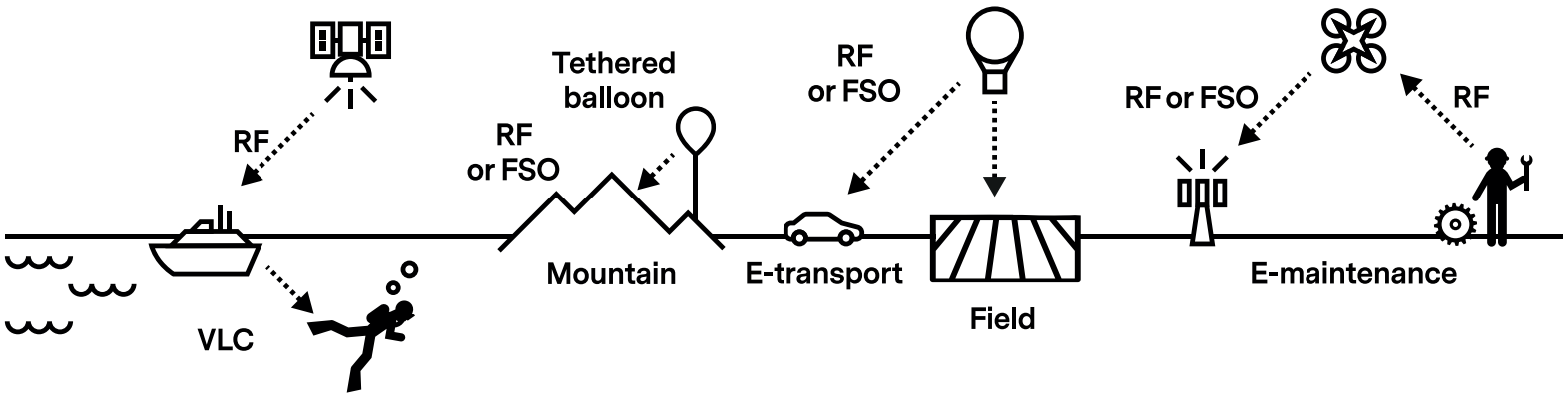
Optical wireless communications (OWC)

- ★ Free space optical (FSO) communications and visible light communications (VLC) are two popular examples of OWC.
- ★ License-free operation, full-duplex mode, huge available spectrum and robustness against interference ⇒ **VLCs to boost the throughput in indoor, fronthaul and underwater environments, FSOs as backhaul solutions in remote areas**.



Some challenges and research directions :

- ➥ OWC very sensitive to TX-RX misalignment.
- ➥ Handover management in cellular deployments.
- ➥ Need for new protocols at various layers (different from their RF counterparts).

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- ★ Local, flexible and pluralistic spectrum sharing/licensing could be the way forward to boost the remote market.
- ★ Supported by software-defined technology embedded into off-the-shelf multi-vendor hardware ⇒ big potential for digital inclusion.
- ★ Stakeholders cooperation (e.g. MNOs, regulators, vendors and manufacturers).
- ★ AI/ML techniques provide cognitive capabilities for an optimal (prudent, resp) use of licensed (shared, resp) spectrum.
- ★ SS should be expanded to include the higher bands (e.g. MM and THz waves).
- ★ The timing is perfect to impact 6G requirements specifications such that these important issues are considered into the design process from the very beginning.

THANK YOU FOR YOUR ATTENTION