Self-Organised Radio and Core Networks: Achieving end-to-end optimal resource utilisation

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Radio Access Network Techniques for 6G

6G Team @ University of Glasgow

CSI Communication, Sensing & Imaging

From 5 to 120+ in 5 years

Multidisciplinary in engineering
Diverse talent from 22 countries

Funded Grants

Involved in £25M+ currently funded portfolio

Active International Collaborations

USA, Middle East, Europe, Italy, France, Holland, China, Brazil, Finland, Nigeria, Pakistan, India, Kazakhstan, Thailand, Singapore, South Africa,

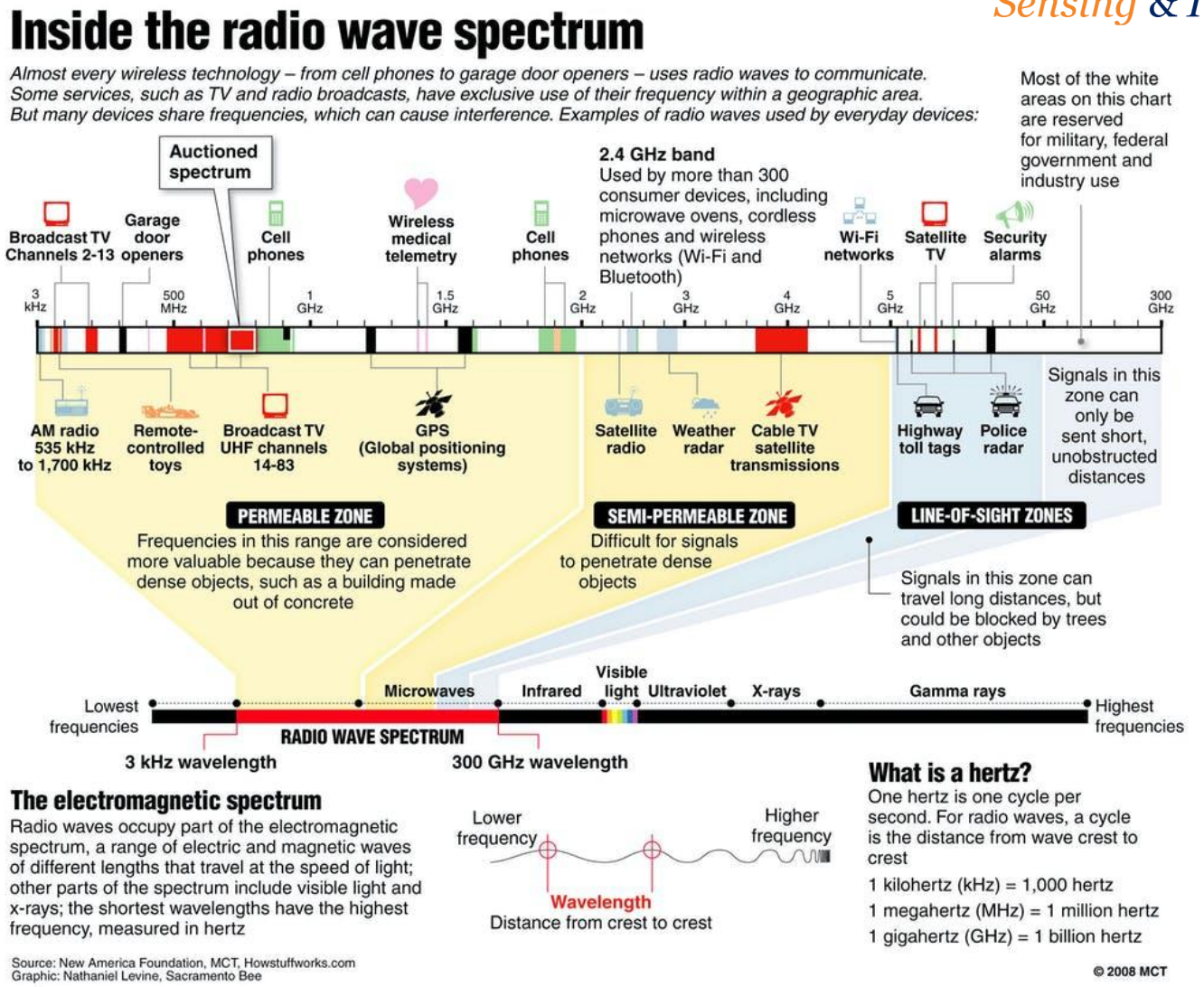
Outputs

300+ outcomes (papers, patents, etc.) every year

Outline …

- Meeting 6G challenges/Key Performance Targets
  - End-to-end RAN, Backhaul and Core
- Existing versus New Spectrum (THz?)
  - Self-organization becoming even more pertinent as spectrum landscape widens
- Estimating the holistic impact
  - Energy/Spectrum/Utilization Efficiency

RAN and Backhaul – both can be wireless



https://theconversation.com/wireless-spectrum-is-for-sale-but-what-is-it-11794

Diversity in 6G

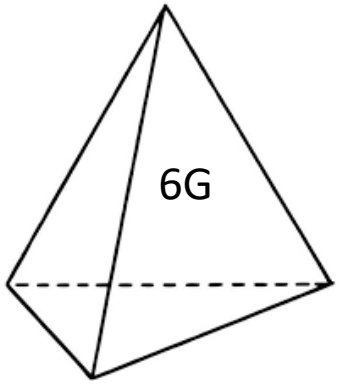
Diverse applications with diverse and challenging requirements

A new dimension to be added:

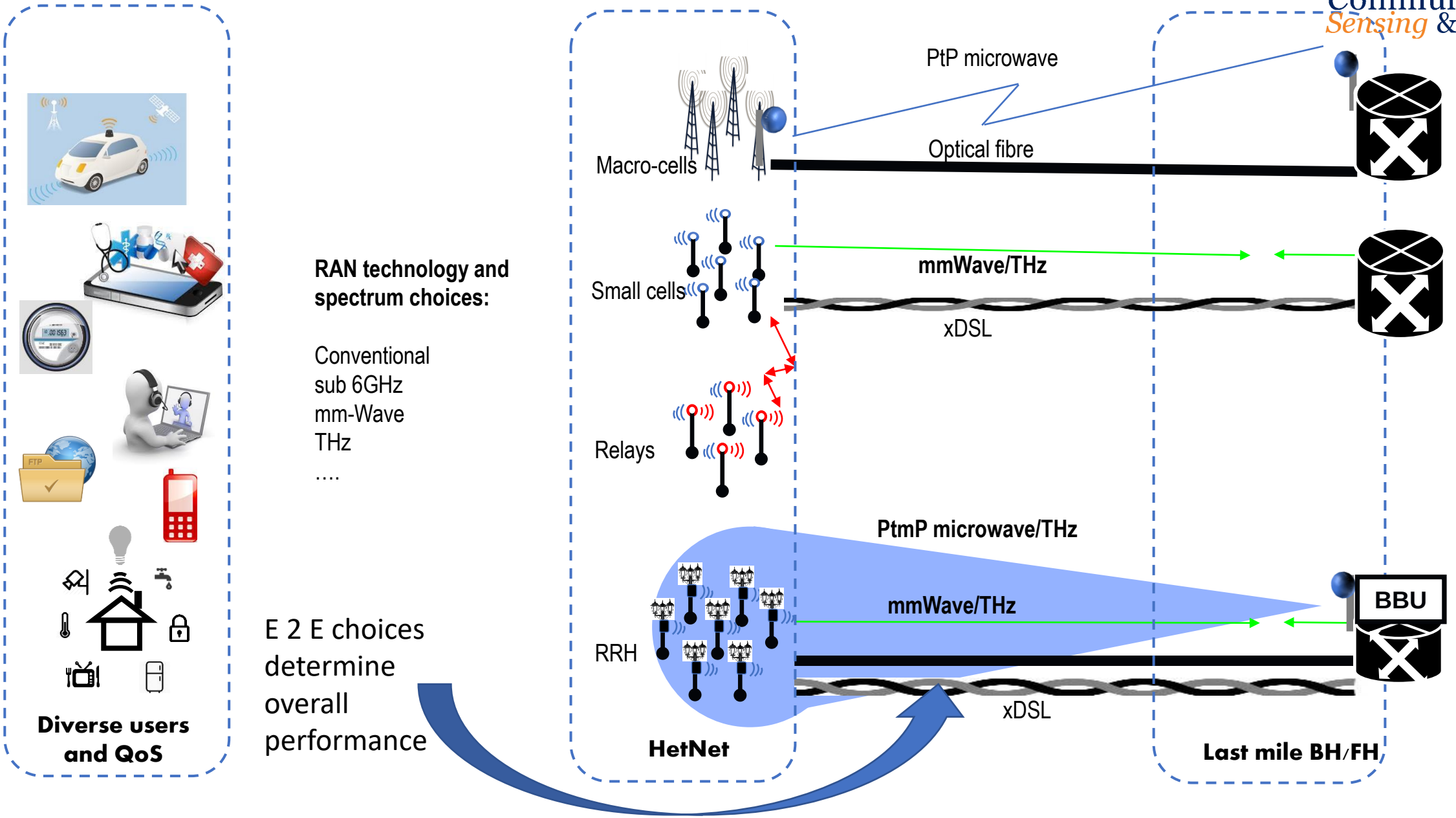
- URLLC
- mMTC
- eMBB

- Ultra Intelligence
- Sustainability and Equitability
- ?

Move further closer to the vertices



6G End-to-end view



User centric cell association

Diverse users and QoS

Let S_x be the physical channel quality (e.g. RSRP)

Conventional cell association:

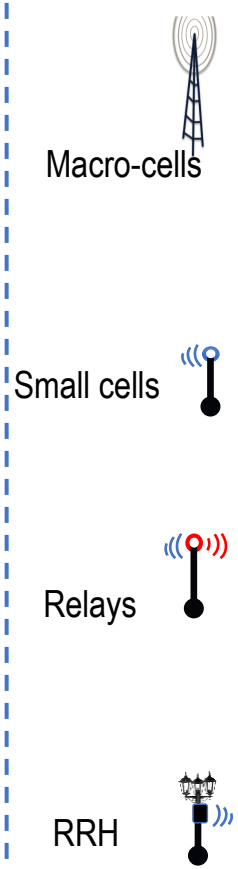
$R_x=S_x$

$$R_M>R_{SC1}\geq R_{SC2}>R_{SC3}$$

Determine $R_x = S_x + \mathbf{CREO_x}$

… and decide cell association using modified rank list

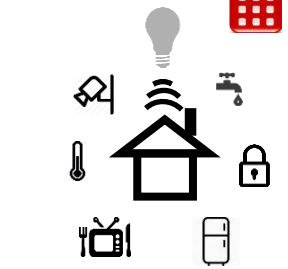
$R_{SC1}\geq R_{SC2}>R_{SC3}\geq R_M$



HetNet

Mutifarious Backhaul options

Learning based dynamic CREO



Diverse users and QoS

$\omega_{i,u}$

User u's weightage for ith KPI

Composite CREO

$$R_{s,u} = S_s + \sum \omega_{i,u} \cdot \beta_{i,s}$$

i ={Throughput (Tput),
Latency (lat),
Energy efficiency (EE)}

$\beta_{i,s}$

AP 's' strength for ith KPI

Macro-cells

Small cells

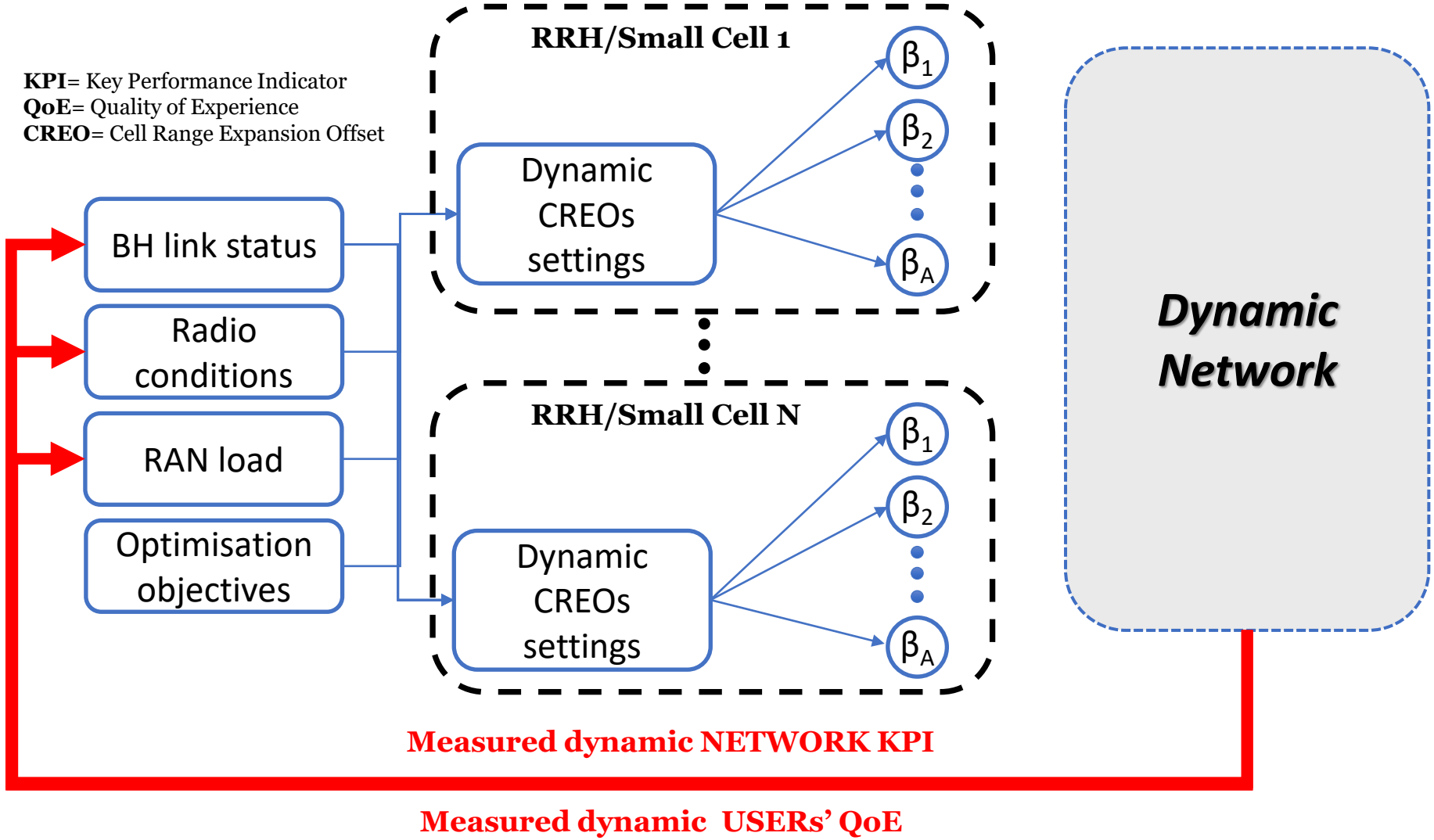
Relays

RRH

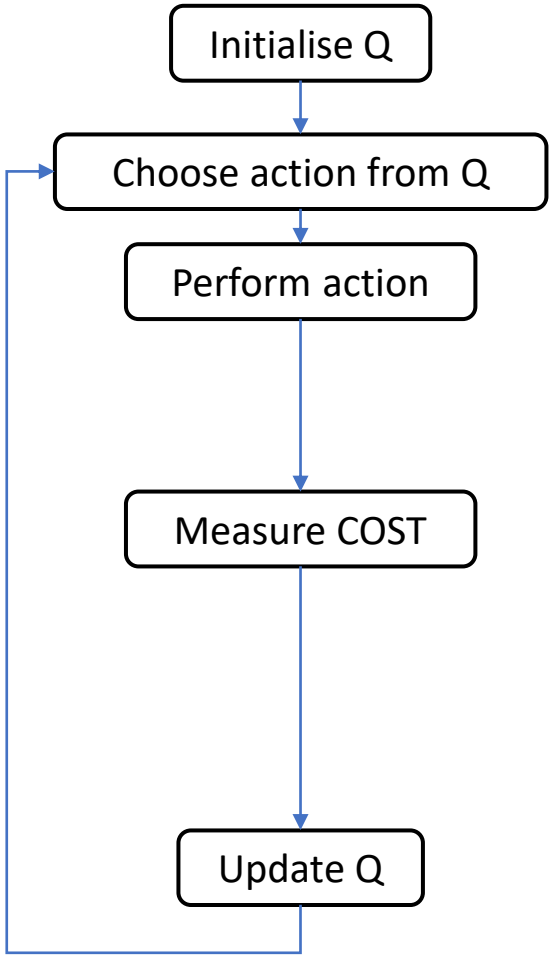
HetNet

Mutifarious Backhaul options

SON Mechanism



SON – Q-learning



Actions are possible settings of CREOs
Selected action is the one that gives the minimum cost

Ultra high cost if backhaul capacity constraint is exceeded,

else, cost is the QoE gap weighed by users' preferences,

else, cost is the difference between backhaul capacity and corresponding constraint

$$\max_B T(B)$$

$$T(B) = \sum_{c=1}^{N} T_c(B_c) = \sum_{c=1}^{N}\sum_{u=1}^{U} T_{u,c}$$

$$K_c - T_c(B_c) \cdot O_c < 0$$

$$\sum_{u=1}^{U} \left| \frac{Q'_{u,a} - Q_{u,a}}{Q_{u,a}} \right| > \theta_a$$

$$K_c - T_c(B_c) \cdot O_c$$

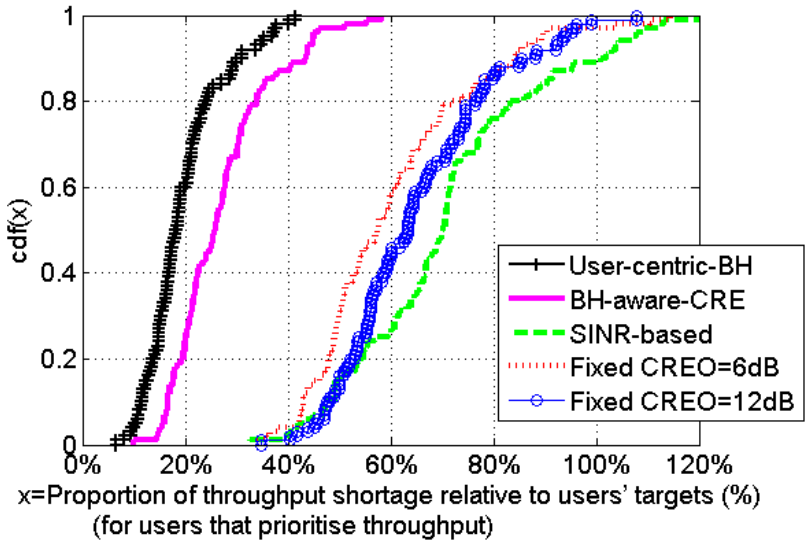
User Centric Improvement

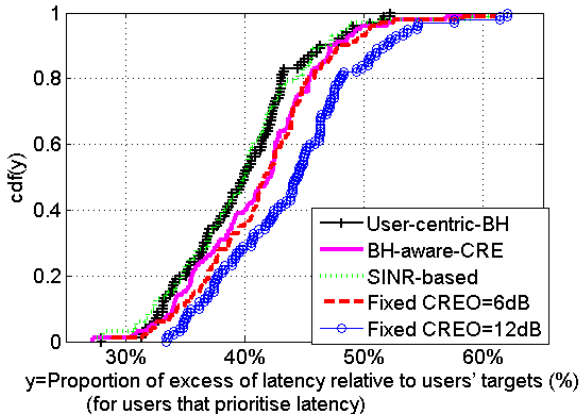
- Glasgow + Surrey + BT Collaboration:

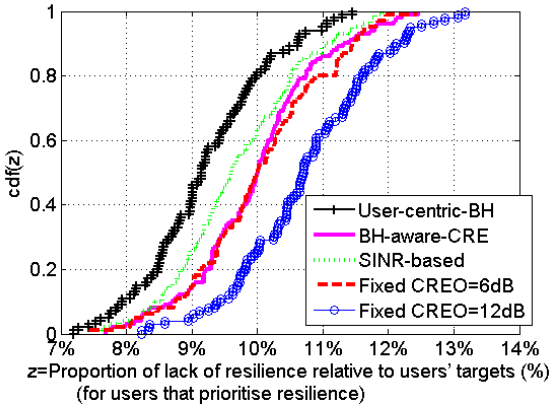
M Jaber, **M Imran**, **R Tafazolli** and **A Tukmanov**

IEEE Transactions on Wireless Communications, 17(5), pp. 3095-3110
doi:10.1109/TWC.2018.2806456

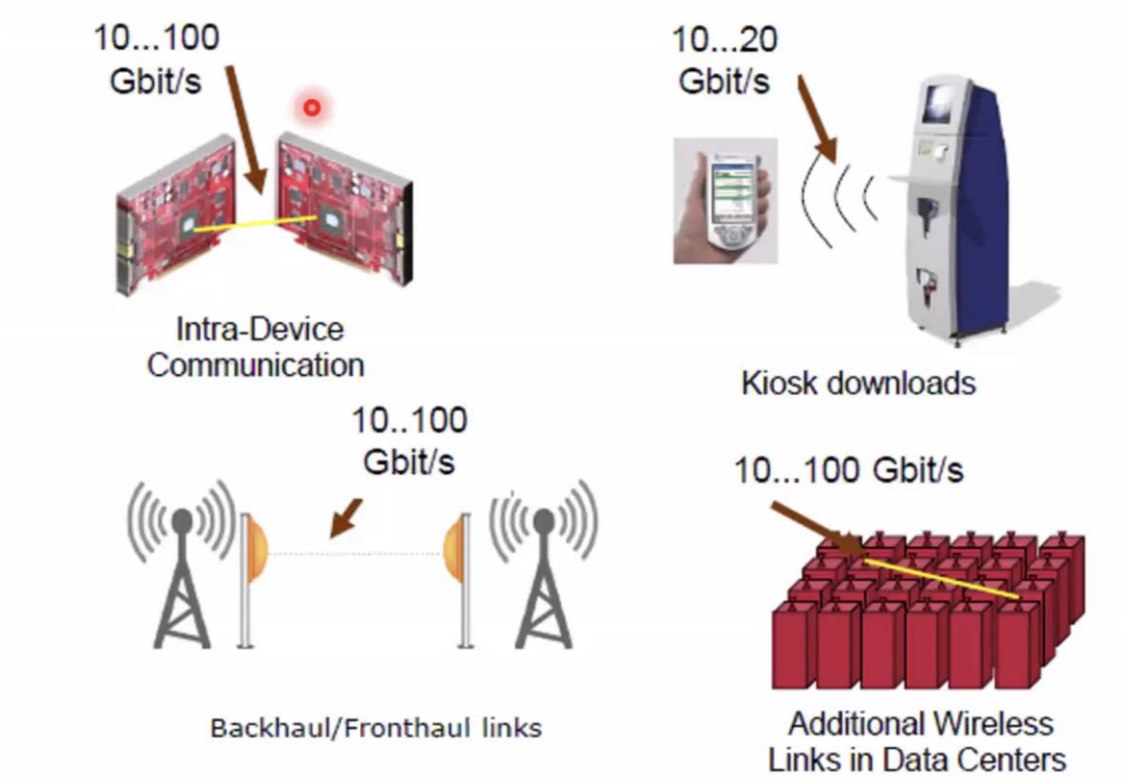
IEEE Access, Vol.4, pp.2314-2330;
doi:10.1109/ACCESS.2016.2566958

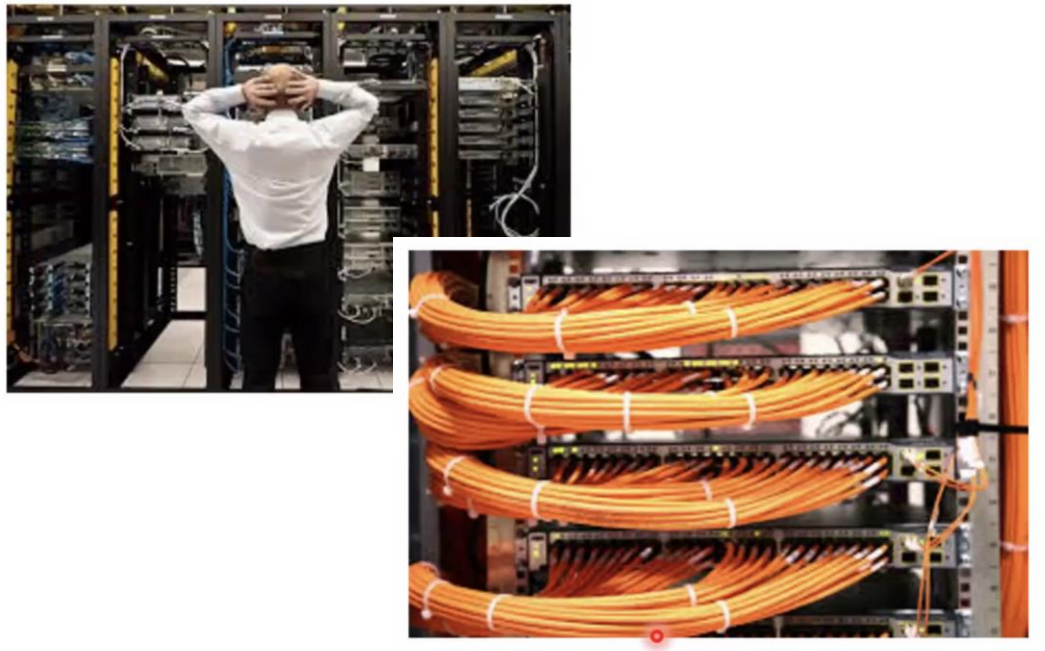






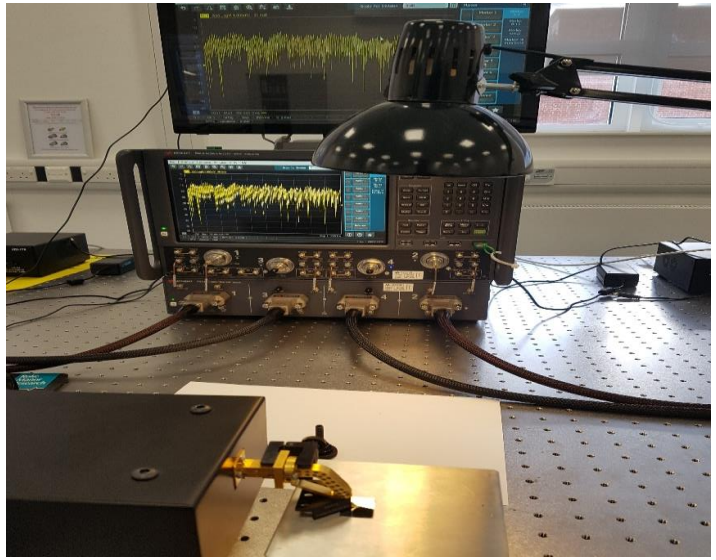
Exploring New Spectrum Opportunities



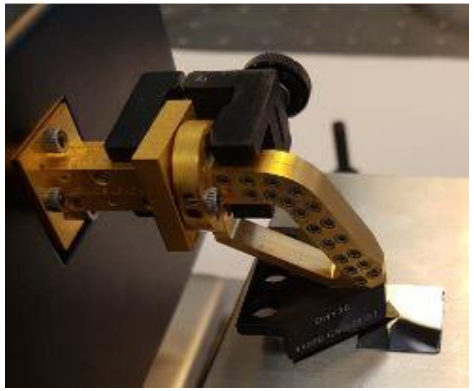


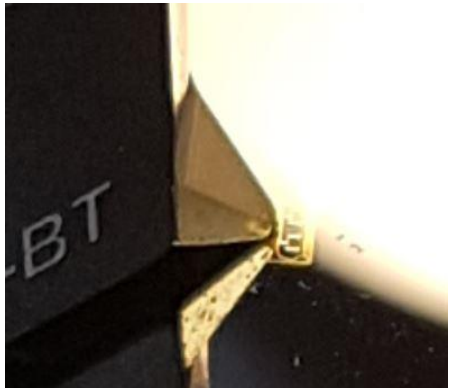
Source: https://standards.ieee.org/standard/802_15_3d-2017.html

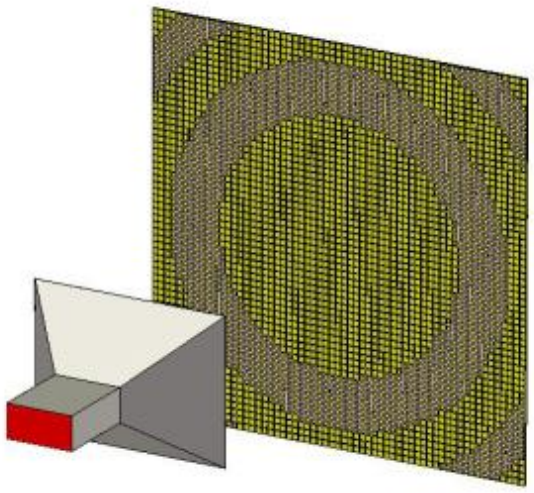
THz Research areas

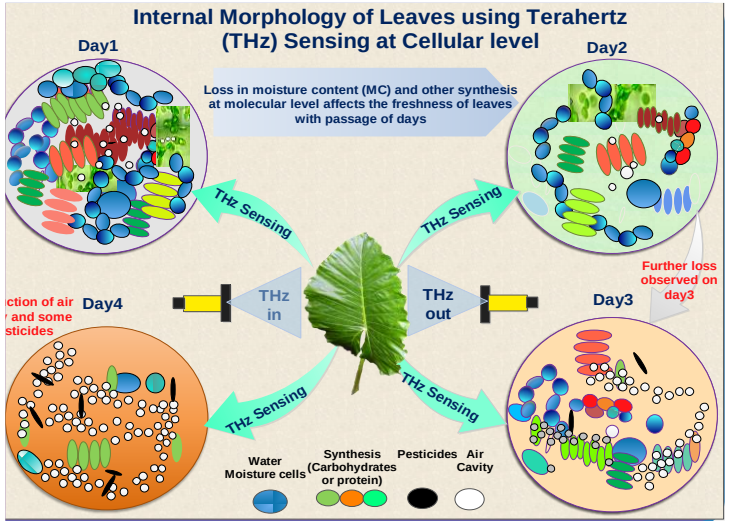


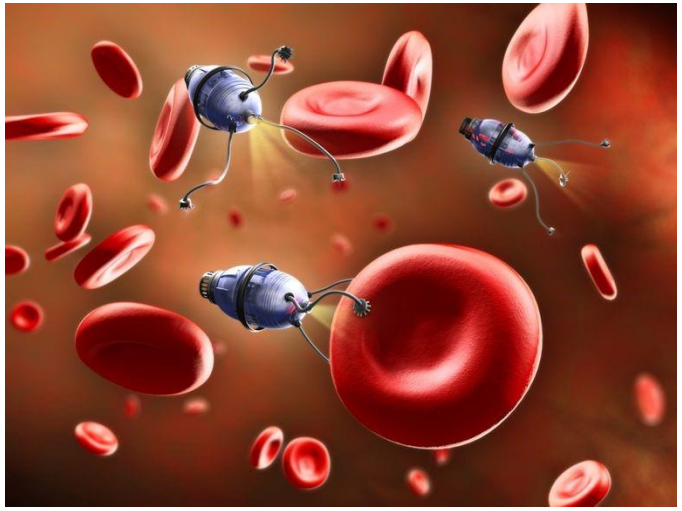
Sources, Waveguides and Antennas











Managing Existing Spectrum Better

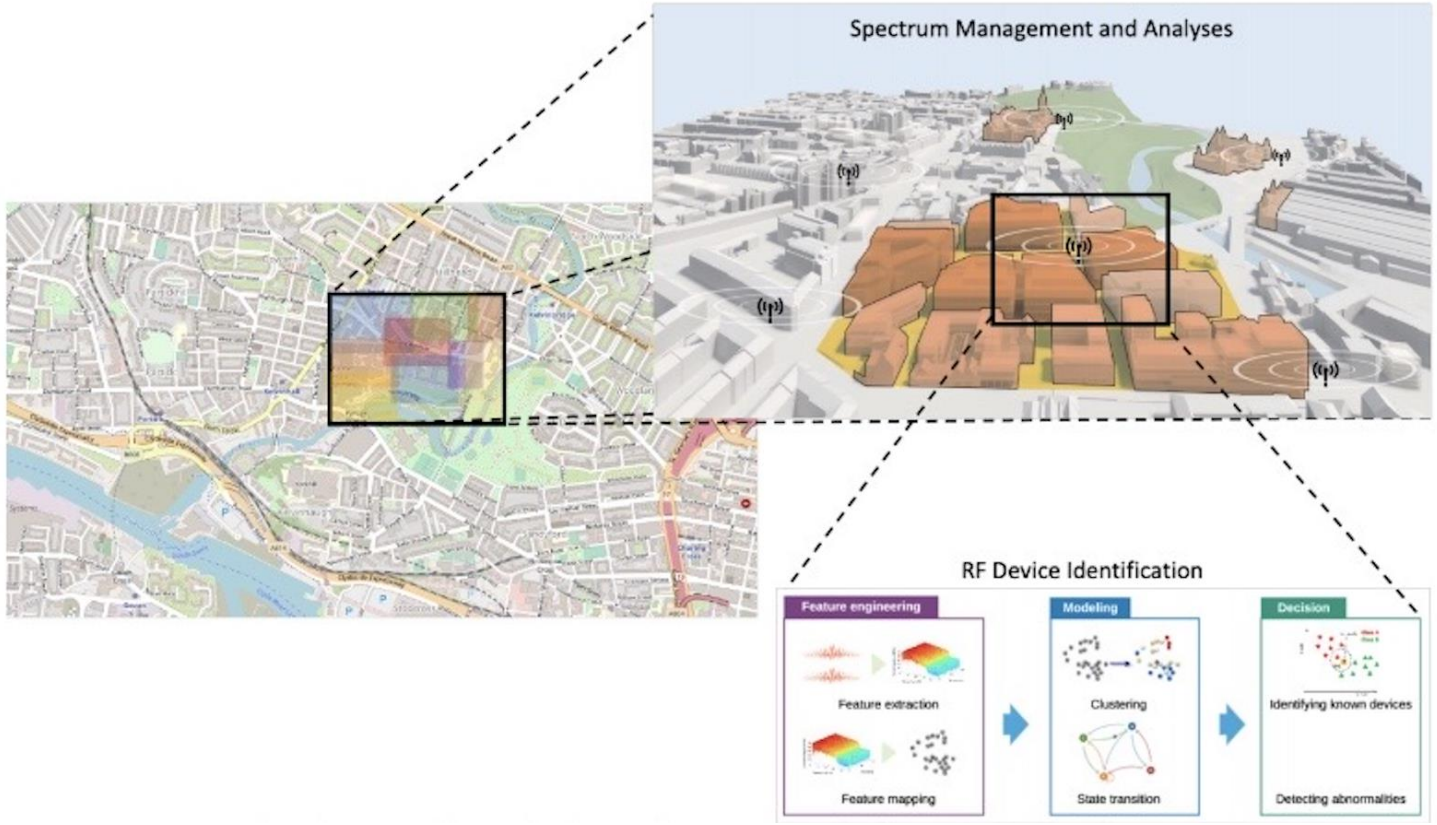


Fig. Geographical areas and RF landscape for RF device identification and shared spectrum management at University of Glasgow's smart campus

Spectrum landscape Glasgow testbed

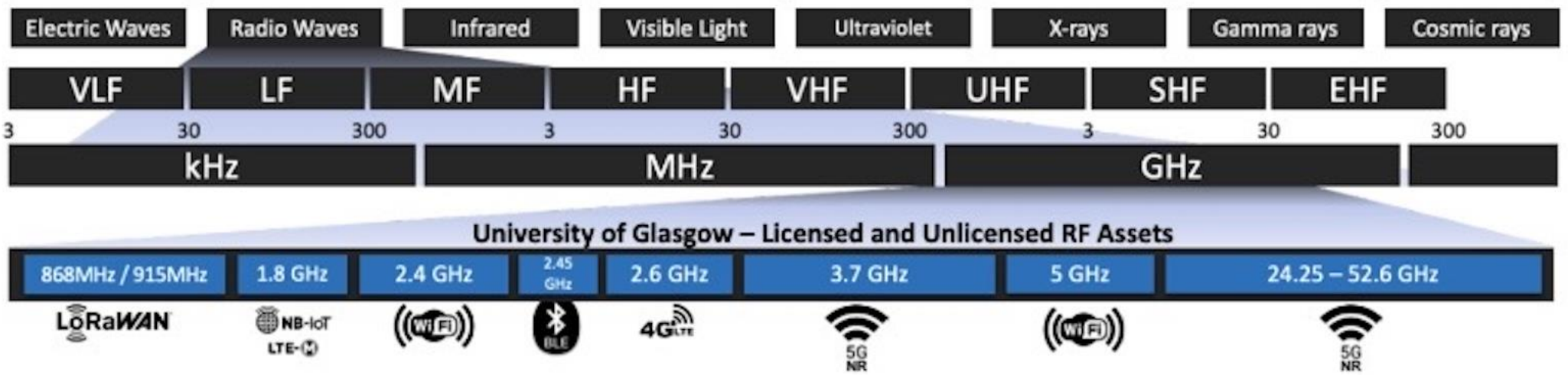


Fig. Licensed and unlicensed RF assets at the University of Glasgow

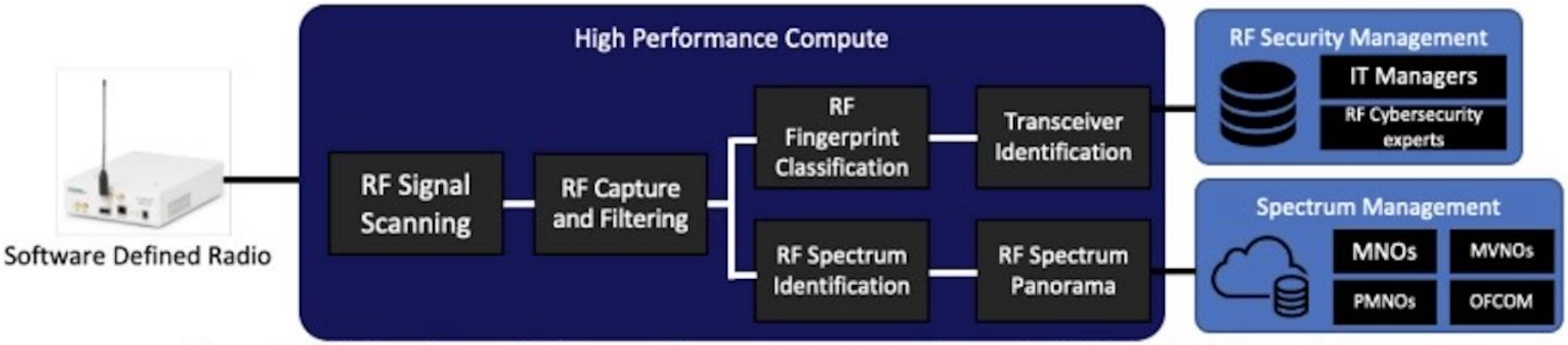
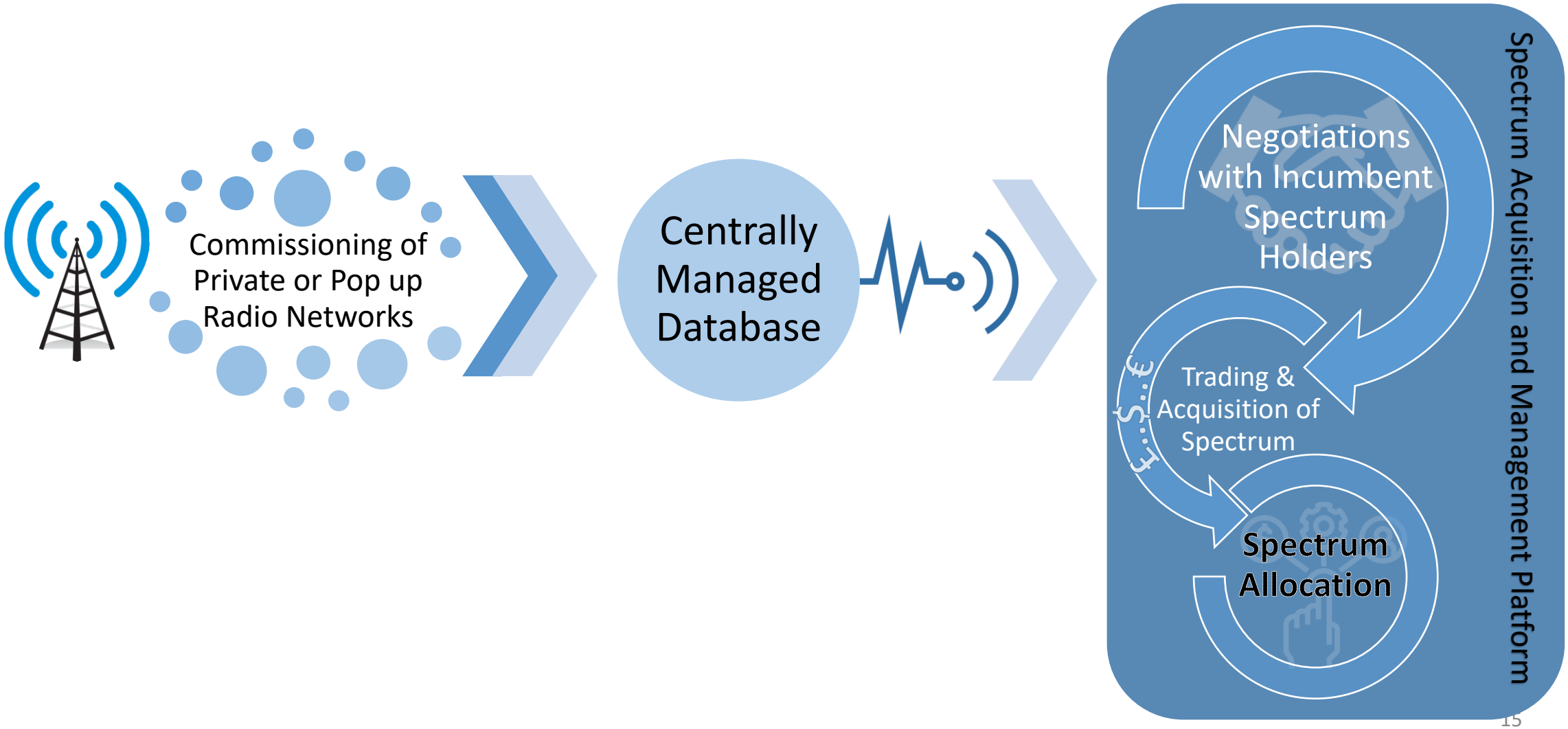


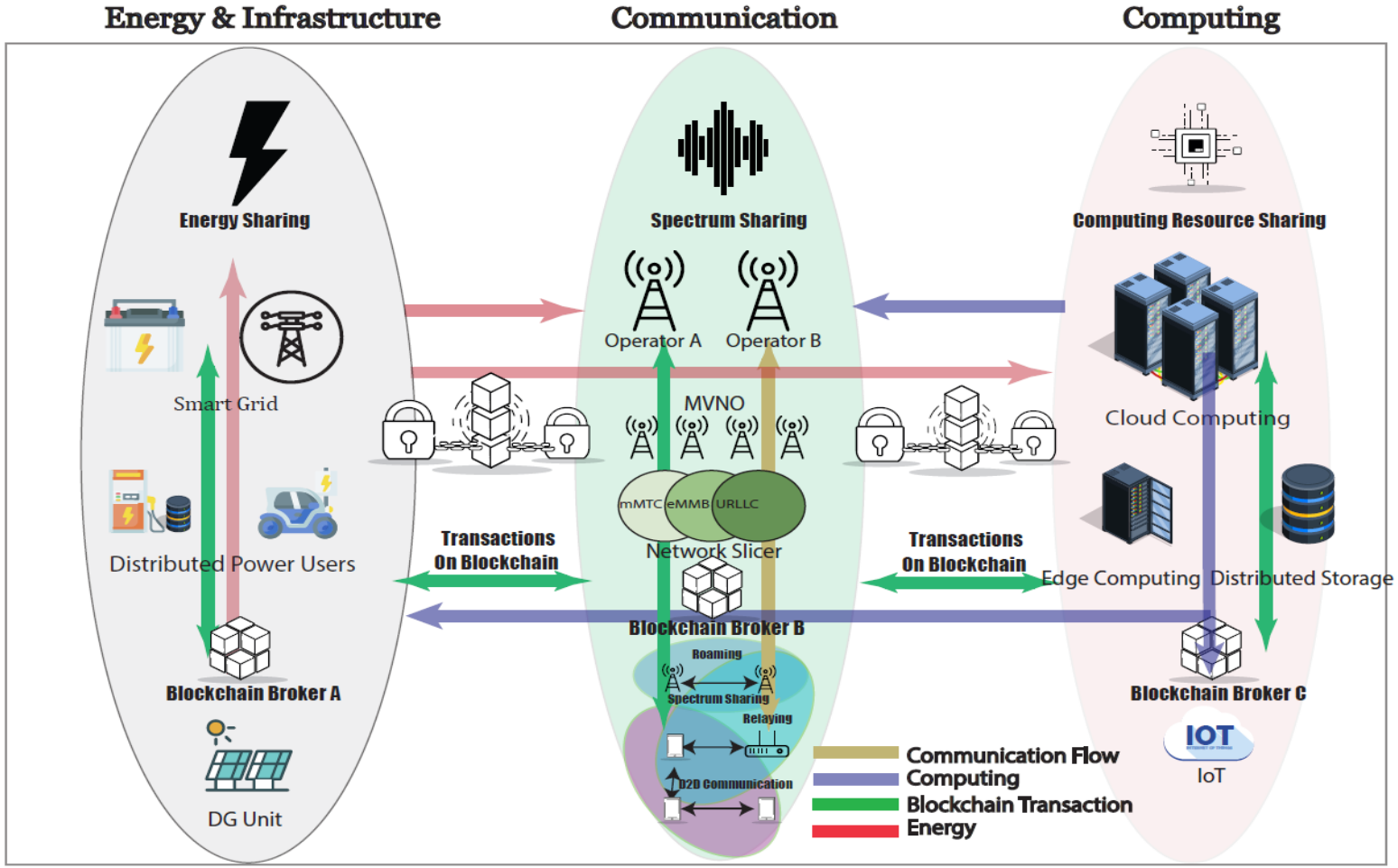
Fig. RF scanning and spectrum and security management framework

Dynamic spectrum portal …



Block-chain for spectrum trading

Fair, reliable and real-time trading platform



Our Beep-trace Framework

Conclusion Summary

- Self-organized networking to ensure end-to-end mapping of user requirements with wireless link capabilities can ensure better user experience on following KPIs
  - Throughput – around 20% more users satisfied;
  - Latency – around 8% more users satisfied;
  - Resilience – around 2% more users satisfied
  - Energy efficiency – most energy efficient links selected
- This may be at the cost of sacrificing some global metrics
- Need to optimize conventional spectrum used for wireless comms
- Need to explore and efficiently use the new spectrum e.g. THz/VLC

Success is a group achievement …

Sincere appreciation of contributions from colleagues, students and external supporters!

Thank you

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