

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

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



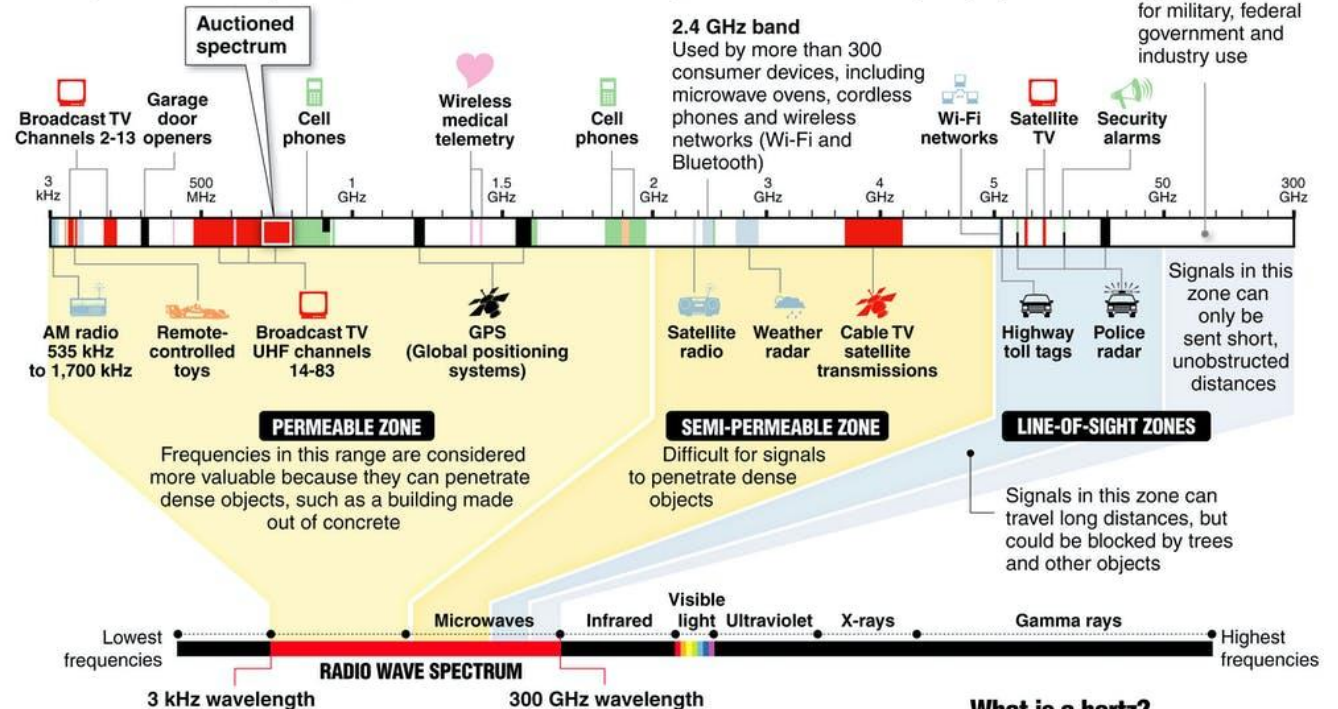
Outline ...

- 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

Inside the radio wave spectrum

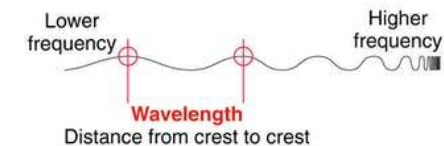
Almost every wireless technology – from cell phones to garage door openers – uses radio waves to communicate. Some services, such as TV and radio broadcasts, have exclusive use of their frequency within a geographic area. But many devices share frequencies, which can cause interference. Examples of radio waves used by everyday devices:



The electromagnetic spectrum

Radio waves occupy part of the electromagnetic spectrum, a range of electric and magnetic waves of different lengths that travel at the speed of light; other parts of the spectrum include visible light and x-rays; the shortest wavelengths have the highest frequency, measured in hertz

Source: New America Foundation, MCT, Howstuffworks.com
Graphic: Nathaniel Levine, Sacramento Bee



What is a hertz?

One hertz is one cycle per second. For radio waves, a cycle is the distance from wave crest to crest

1 kilohertz (kHz) = 1,000 hertz

1 megahertz (MHz) = 1 million hertz

1 gigahertz (GHz) = 1 billion hertz

© 2008 MCT

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

Diversity in 6G

Diverse applications with diverse and challenging requirements

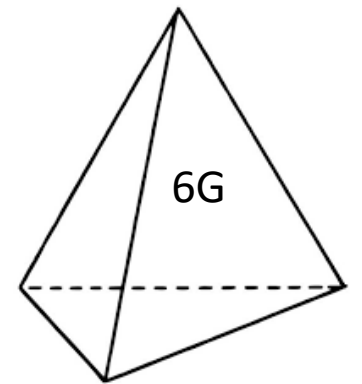


A new dimension to be added:

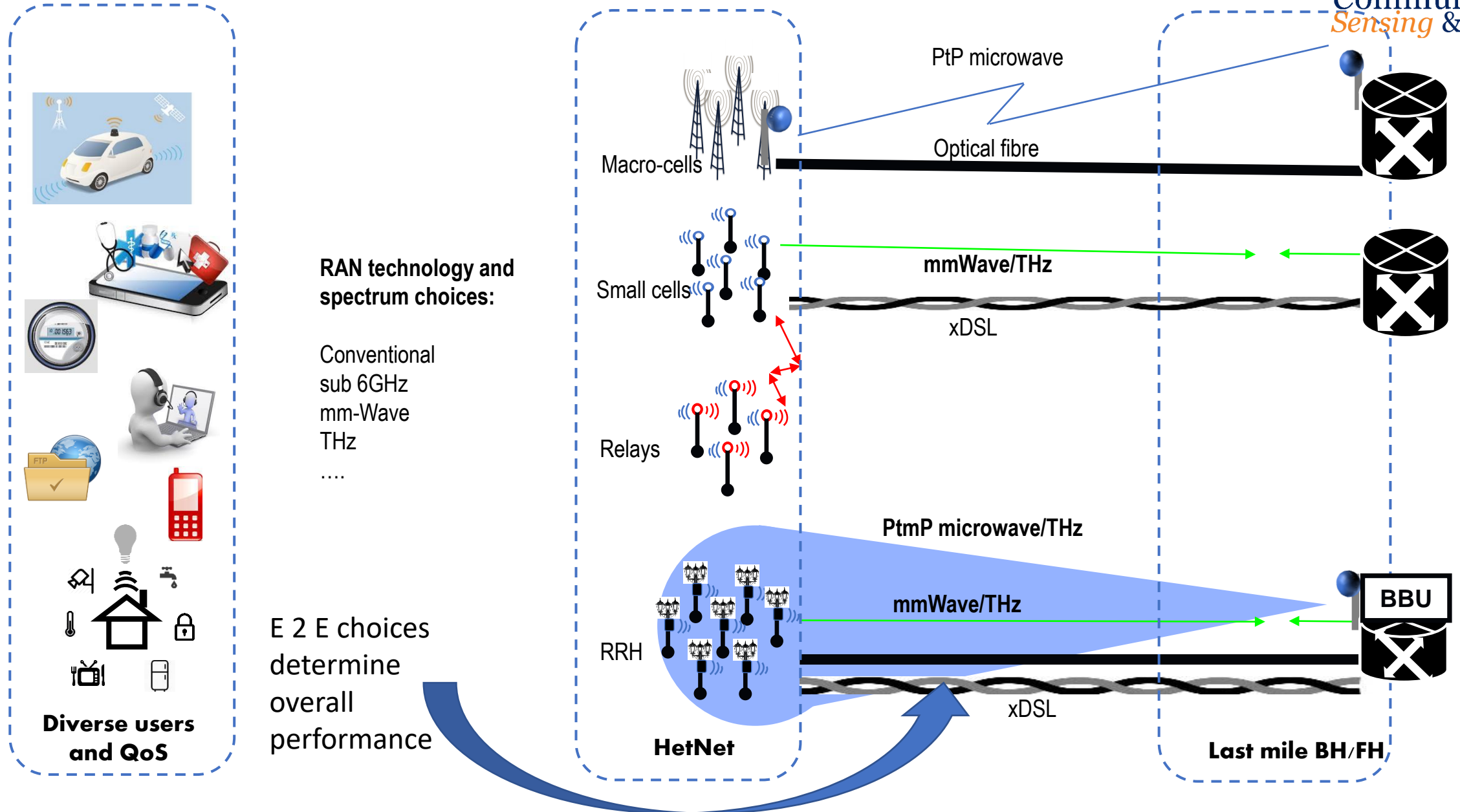
- URLLC
- mMTC
- eMBB

- Ultra Intelligence
- Sustainability and Equitability
- ?

Move further closer to the vertices



6G End-to-end view



User centric cell association



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

Conventional cell association:

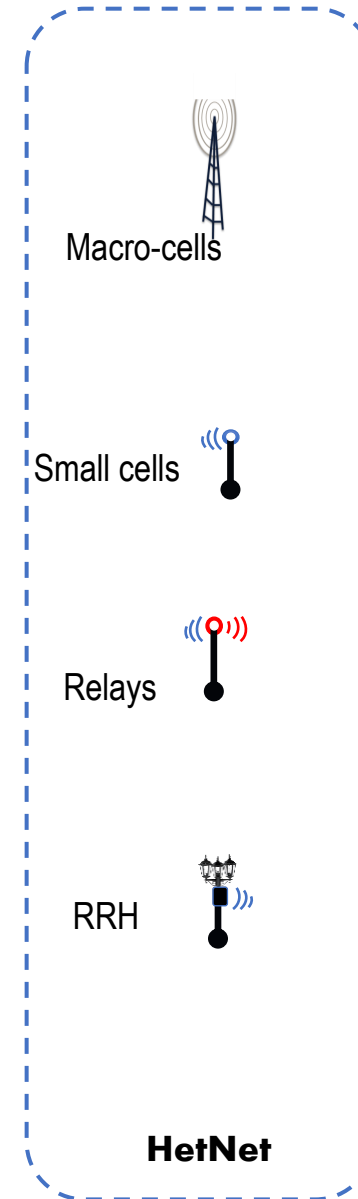
$$R_x = S_x$$

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

Determine $R_x = S_x + \text{CREO}_x$

... and decide cell association using modified rank list

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



Multifarious
Backhaul
options

Learning based dynamic CREO



**Diverse users
and QoS**

$\omega_{i,u}$

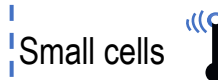
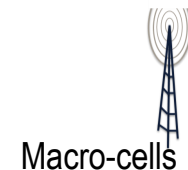
User u 's weightage for i th KPI

Composite CREO

$$R_{s,u} = S_s + \sum_{i=\{\text{Throughput (Tput), Latency (lat), Energy efficiency (EE)}\}} \omega_{i,u} \cdot \beta_{i,s}$$

$\beta_{i,s}$

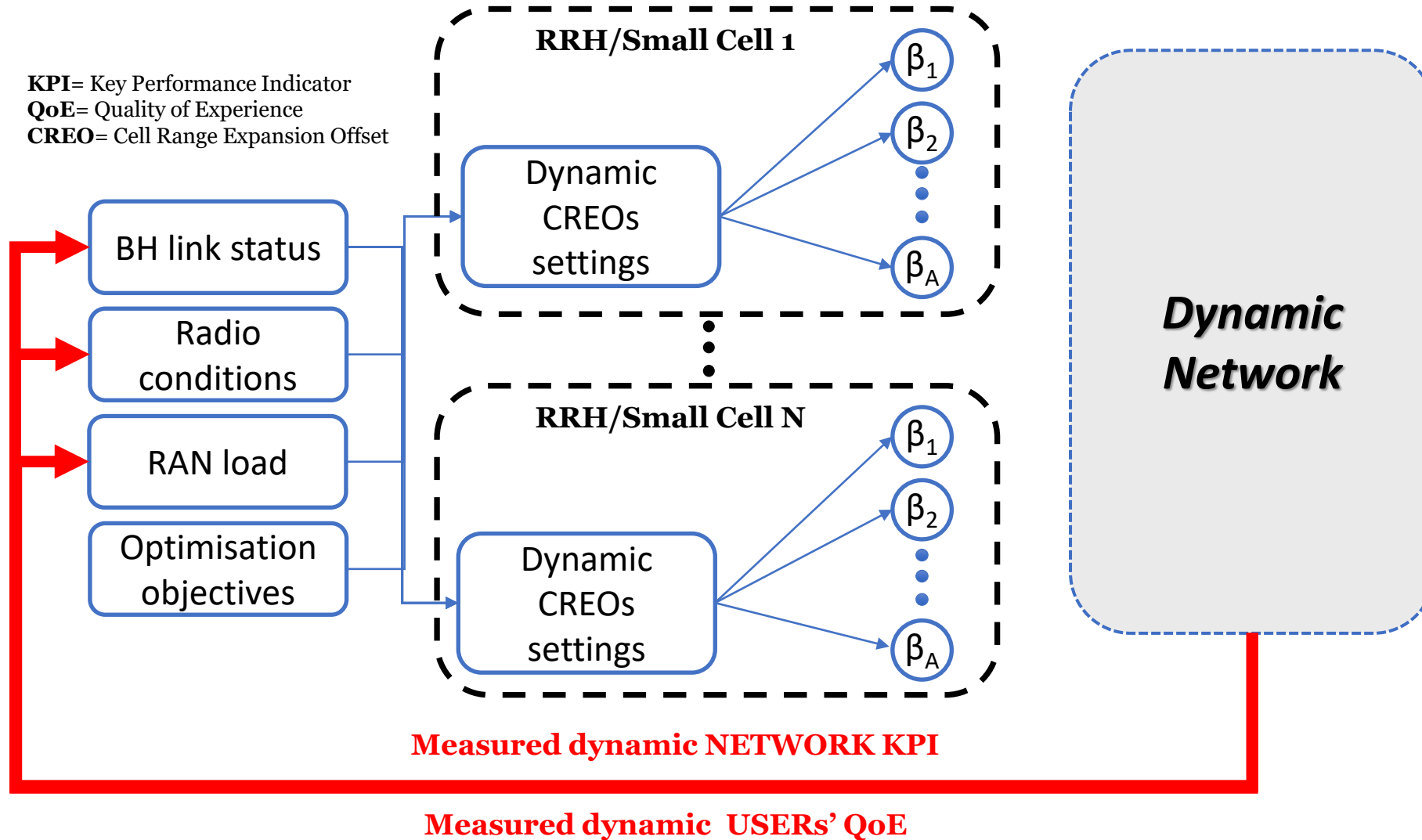
AP ' s ' strength for i th KPI



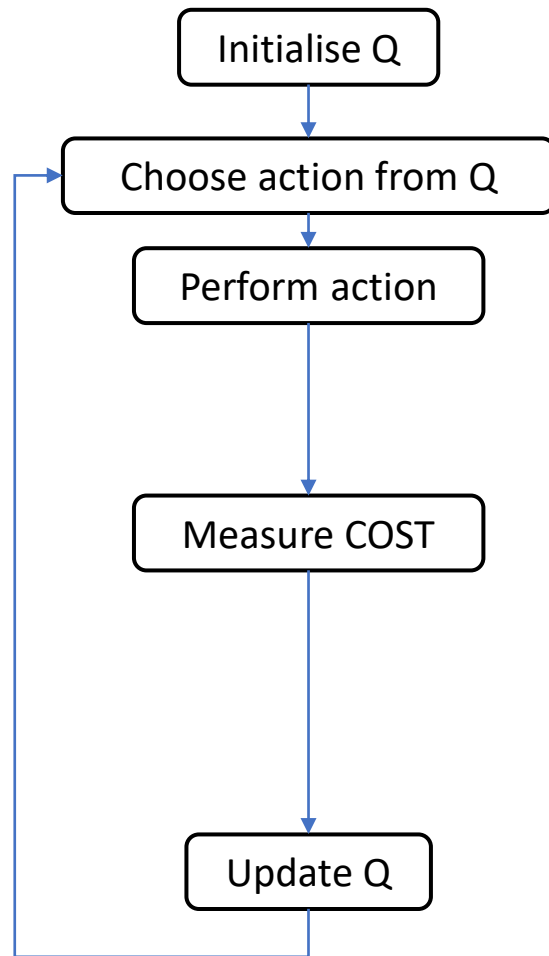
HetNet

**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

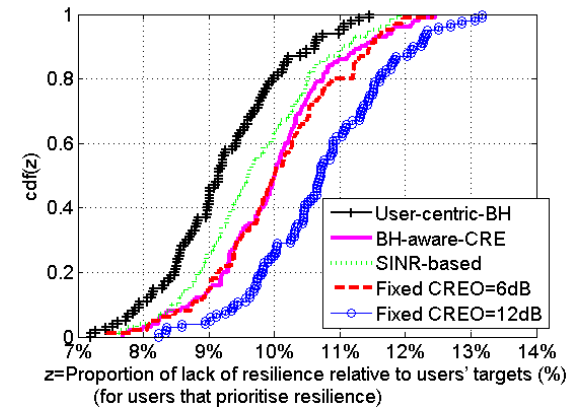
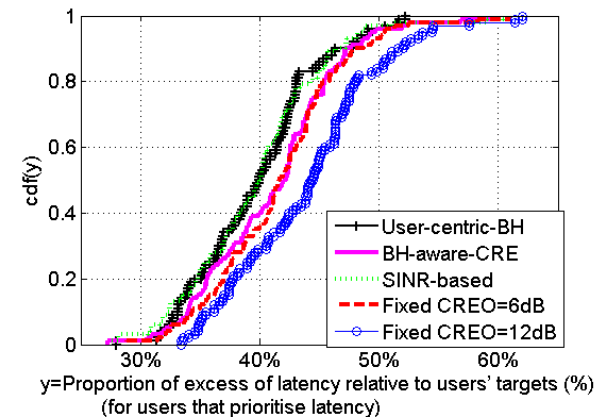
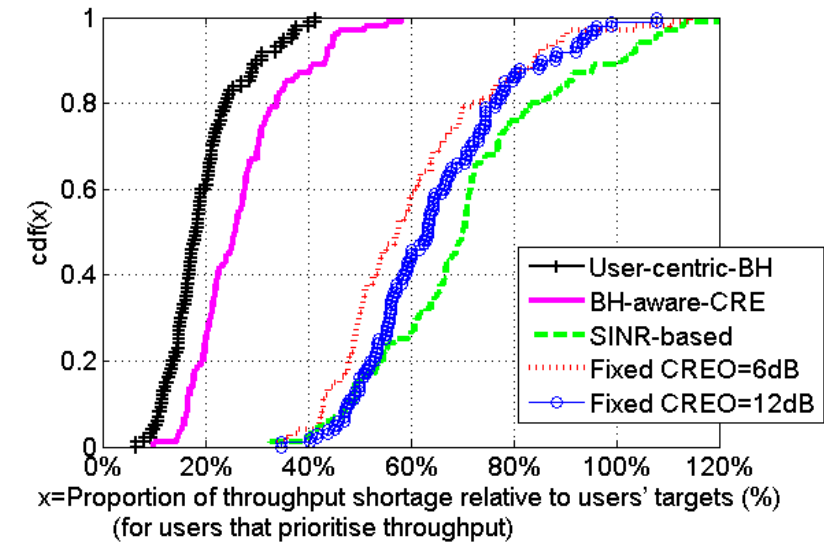
- Glasgow + Surrey + BT Collaboration:
M Jaber, M Imran, R Tafazolli and A Tukmanov

IEEE Transactions on Wireless Communications, 17(5),
pp. 3095-3110

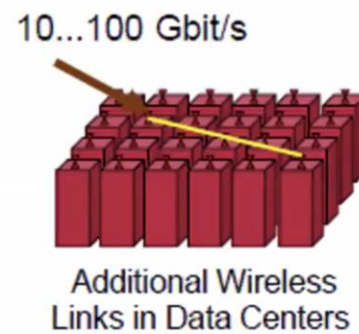
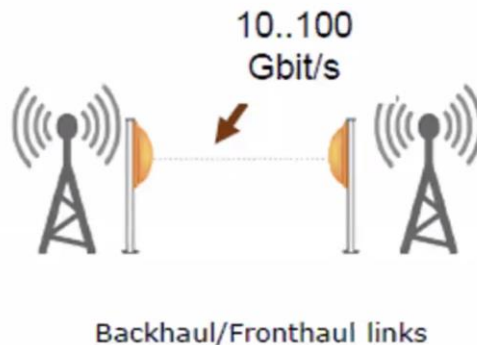
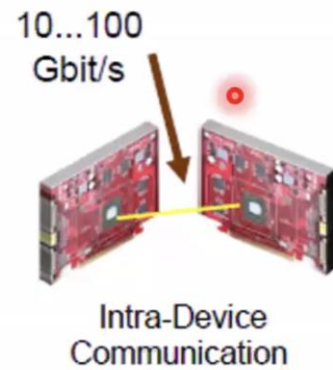
doi:[10.1109/TWC.2018.2806456](https://doi.org/10.1109/TWC.2018.2806456)

IEEE Access, Vol.4, pp.2314-2330;

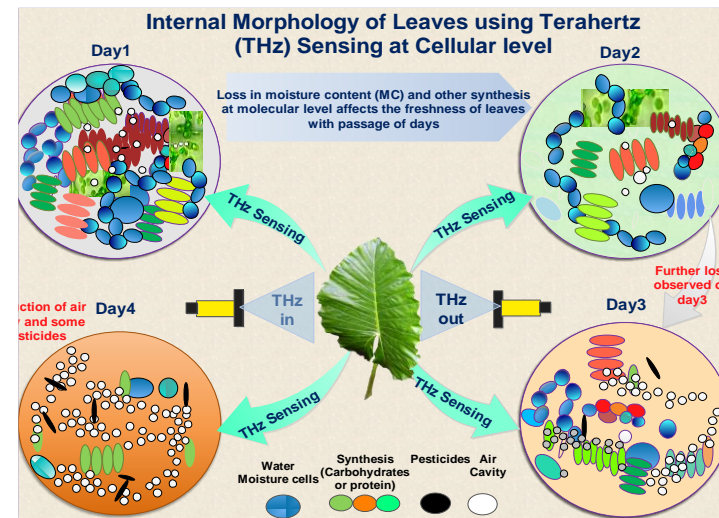
doi:[10.1109/ACCESS.2016.2566958](https://doi.org/10.1109/ACCESS.2016.2566958)



Exploring New Spectrum Opportunities



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



Managing Existing Spectrum Better

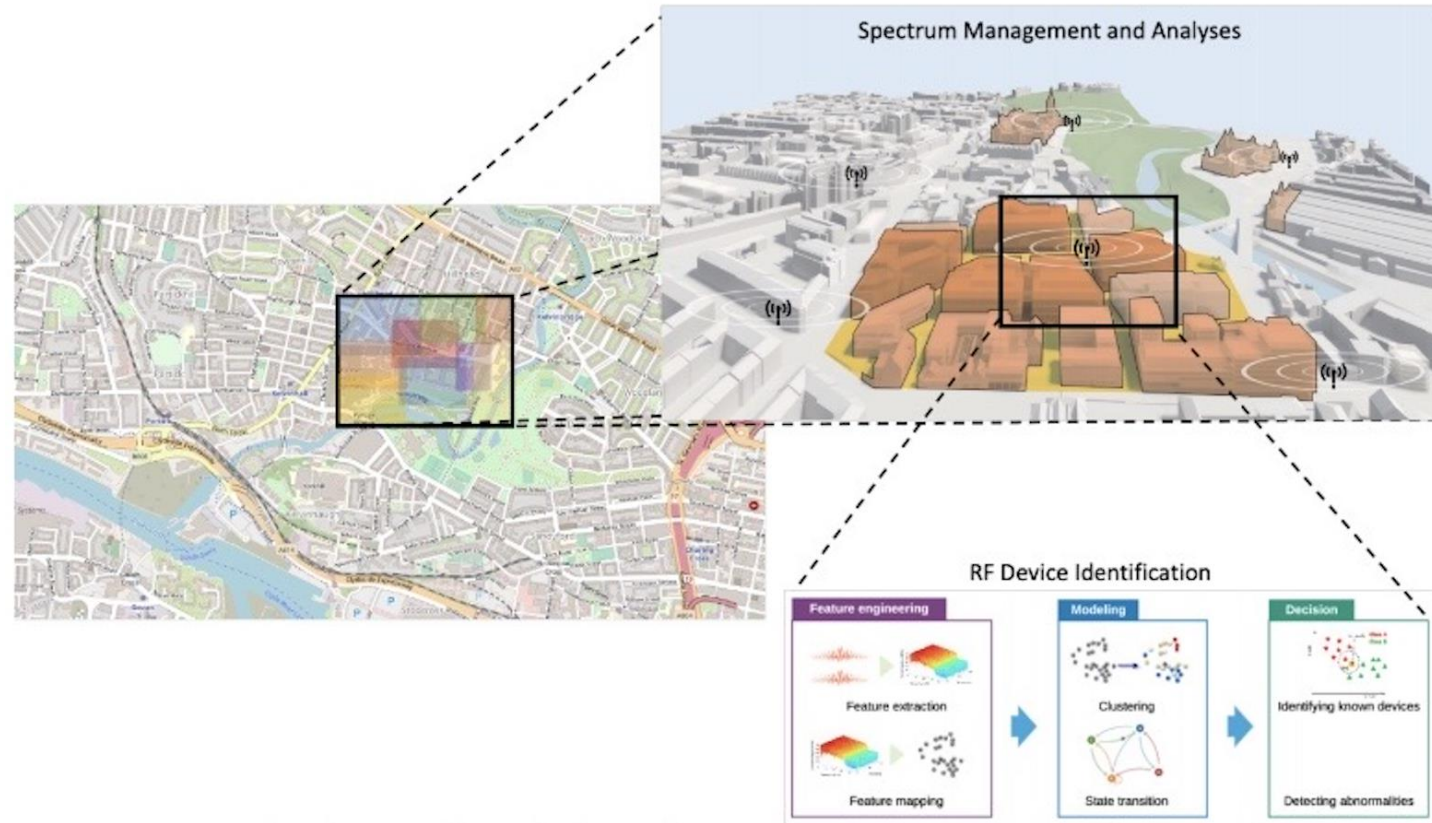


Fig. Geographical areas and RF landscape for RF device identification and shared spectrum management at University of Glasgow's smart campus

Spectrum landscape Glasgow testbed

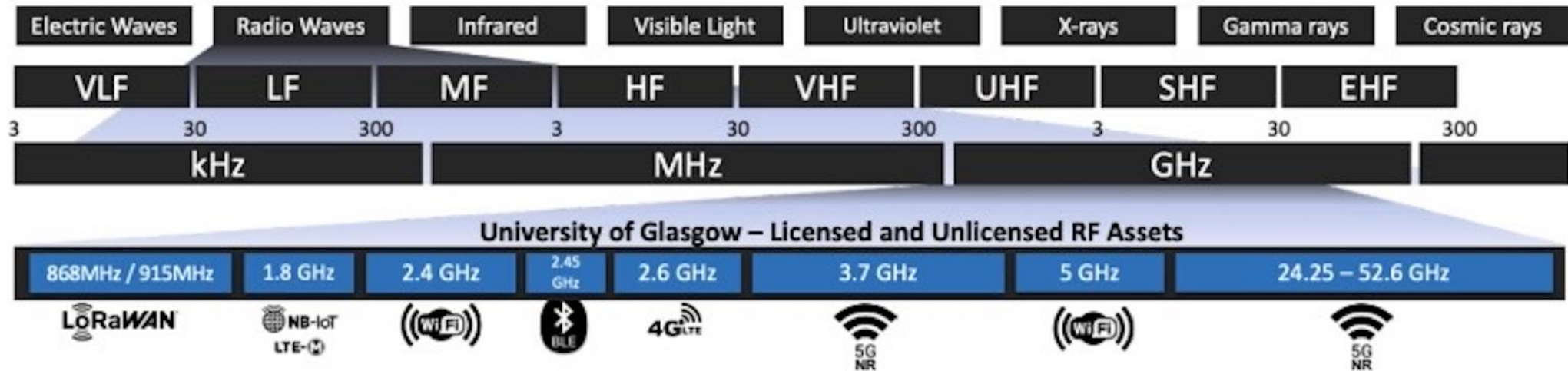


Fig. Licensed and unlicensed RF assets at the University of Glasgow

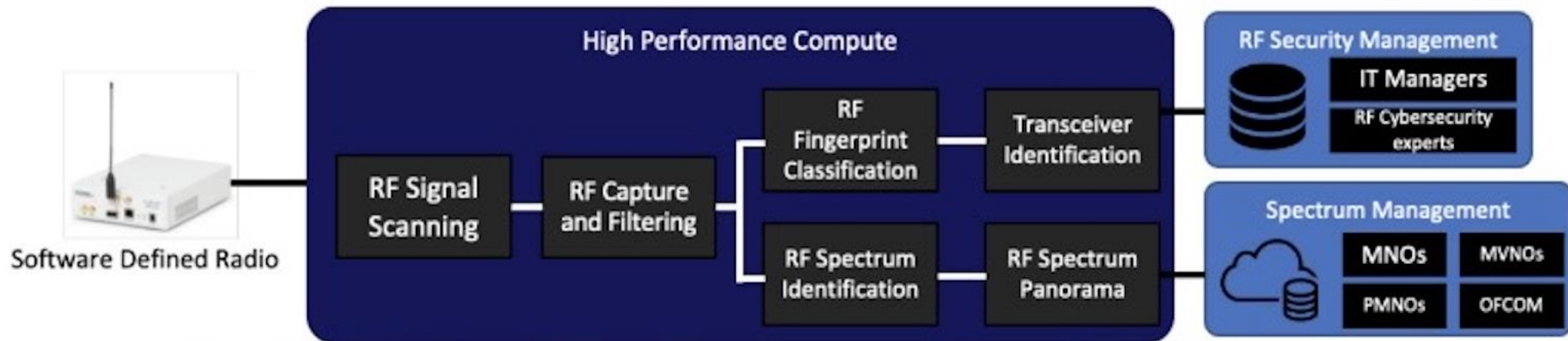
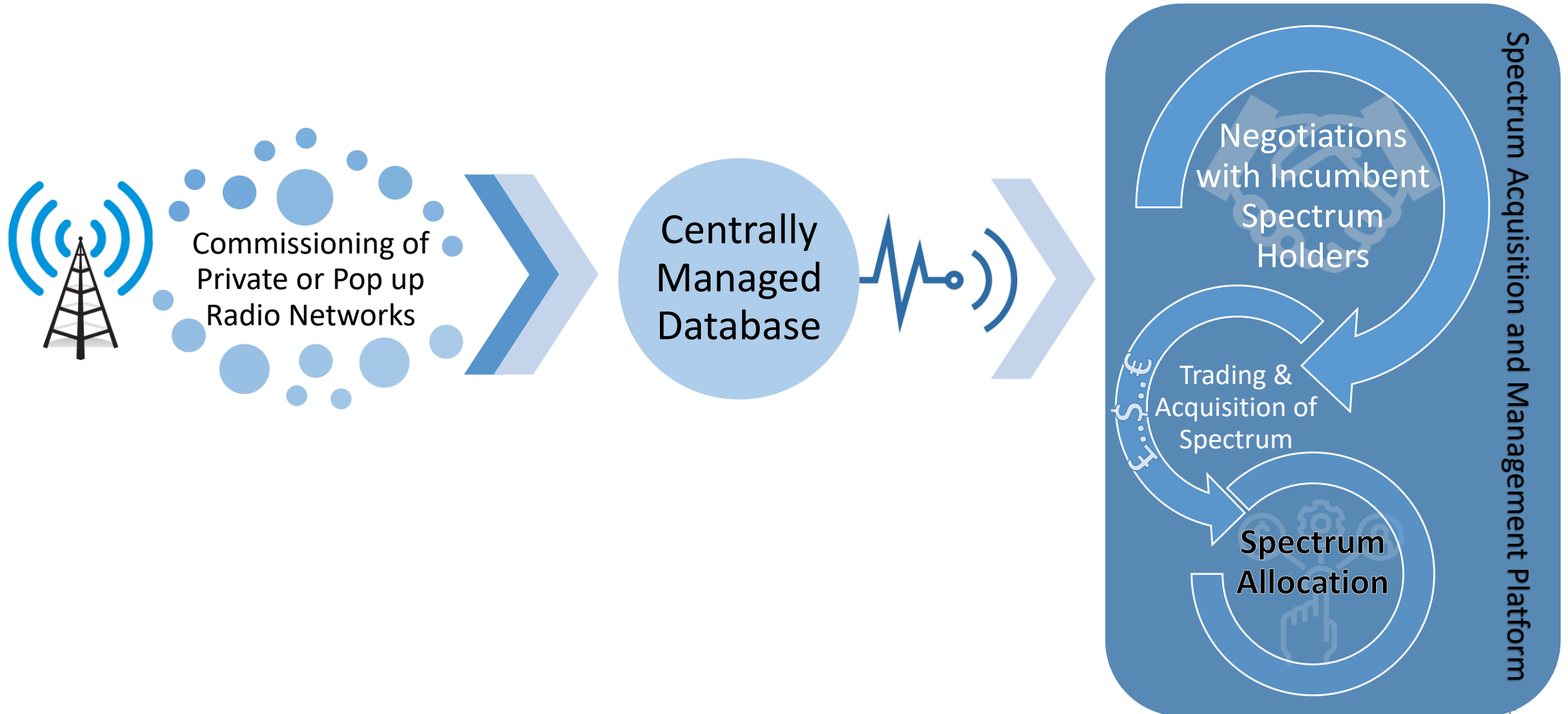


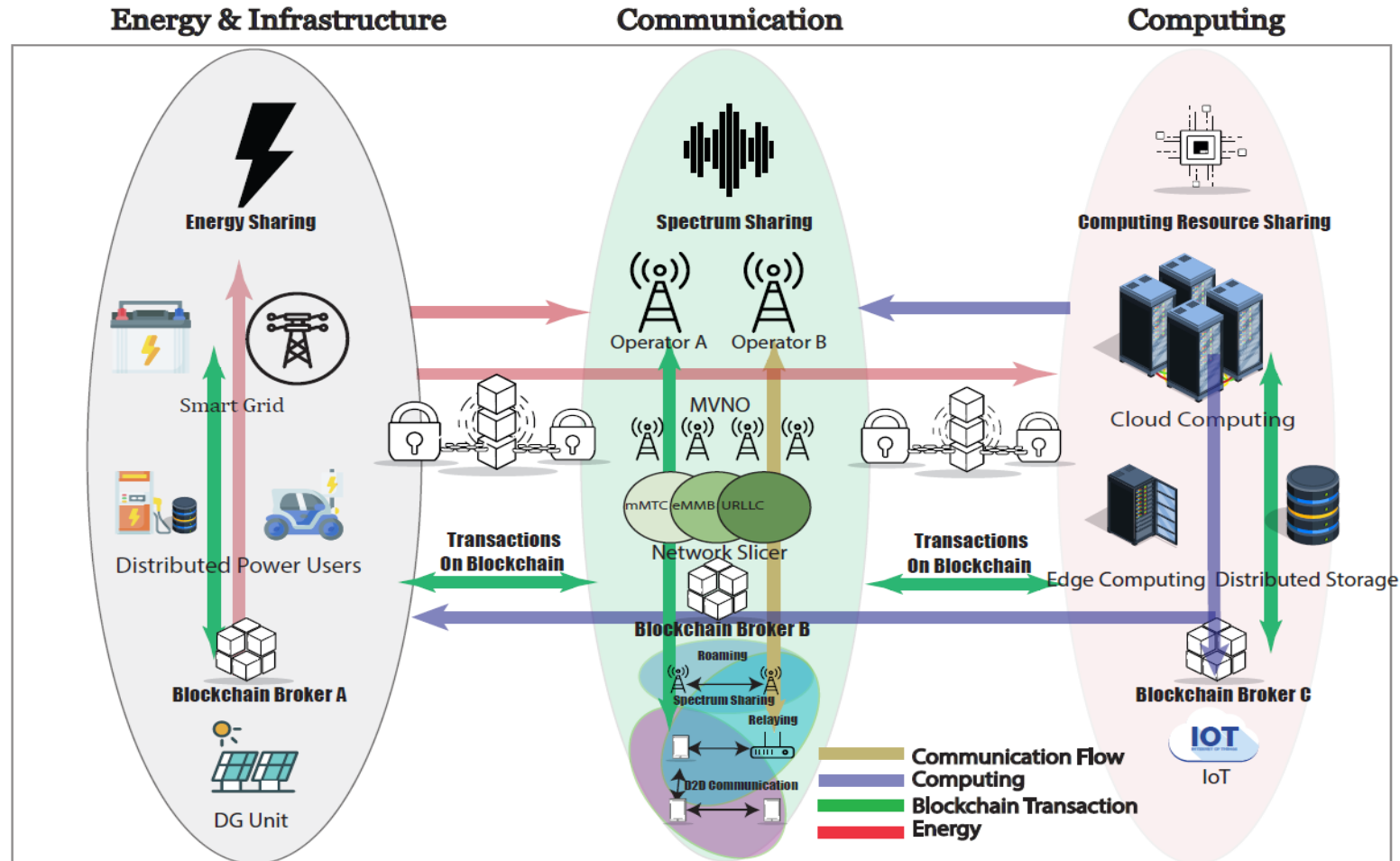
Fig. RF scanning and spectrum and security management framework

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

An aerial photograph of Glasgow, Scotland, featuring the University of Glasgow's main building with its prominent Gothic spire. The city's dense urban landscape, including residential areas and modern buildings, is visible in the background under a blue sky with scattered clouds.

Success is a group achievement ...

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

Thank you

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