A Glimpse of Next-Generation Wireless Enabling Techniques

Presented by
Lajos Hanzo
with Members of Next-Generation Wireless at Southampton

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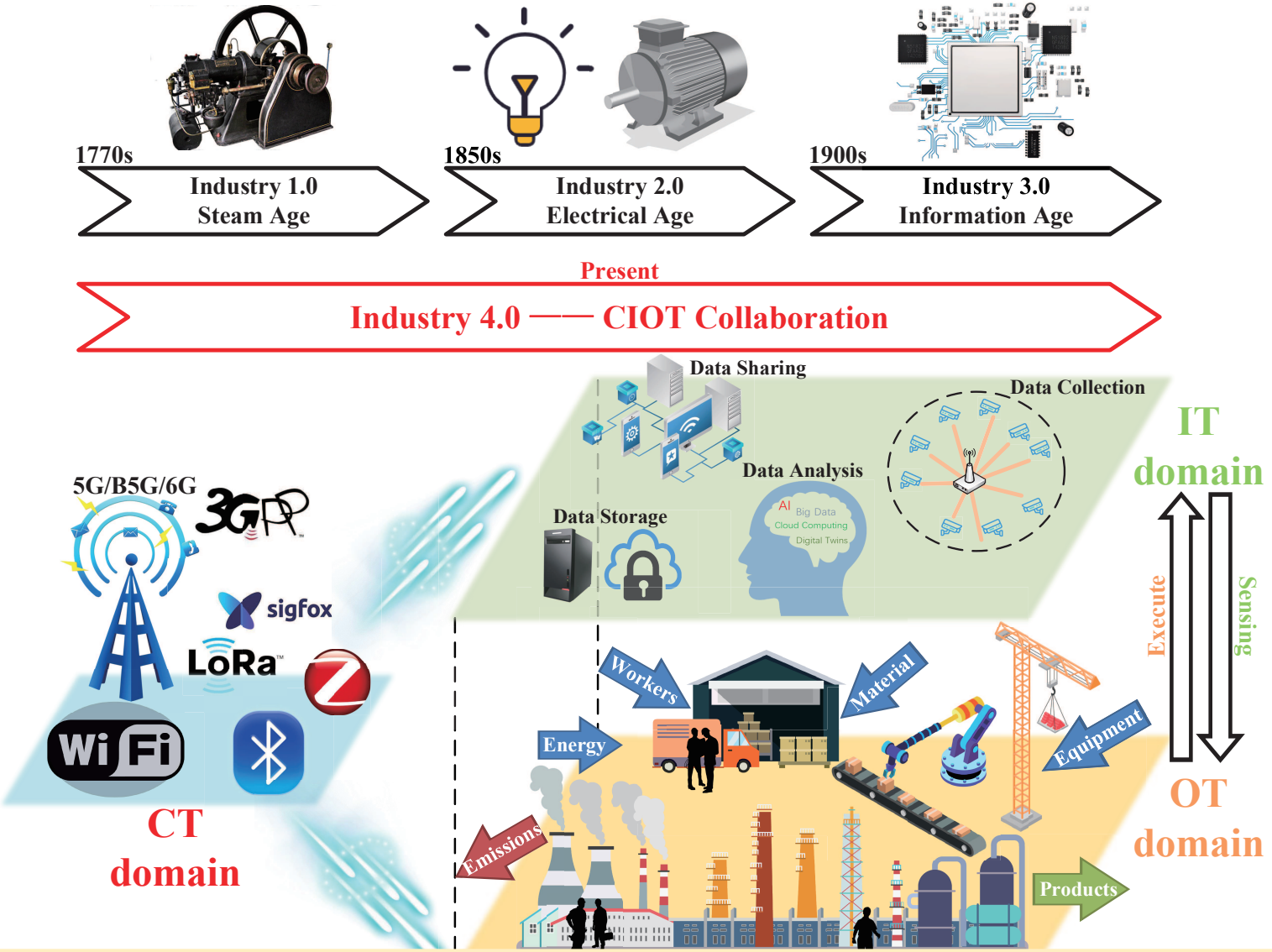
Overview

- **Historic Preamble**
- **The Road to Industry 4.0, the Verticals & Massive Grant-Free Access**
- **The Confluence of the Communications-, Information- & Operations Paradigms**
- **What Will 6G Be?**
  1. 6G Security
  2. 6G Applications: Sensing & SAGIN
  3. 6G Spectrum
  4. Global 6G Coverage
- **From Conflicting Design Trade-offs to Fully-Feldged Pareto-Optimal 6G**
- **The Future?**

Historic Preamble...

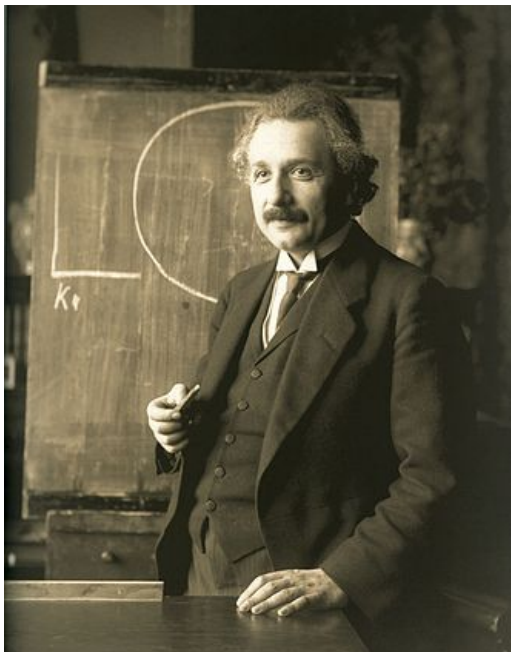
- **Acknowledgements**
- **Promises**
- **Historic Preamble...**

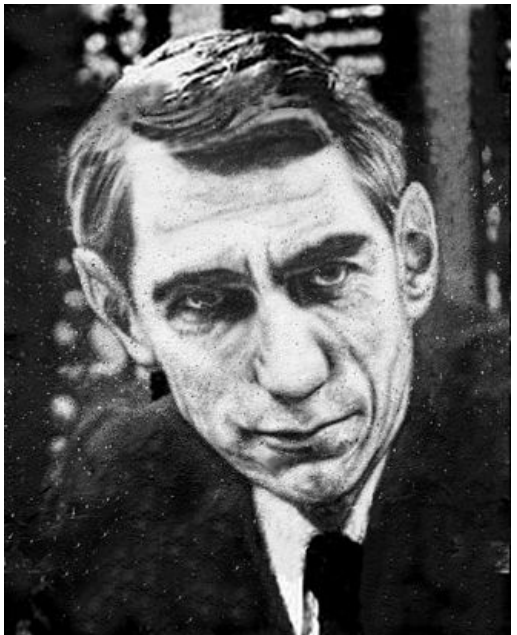
The Road to Industry 4.0 & the Verticals: 1770 - 2021



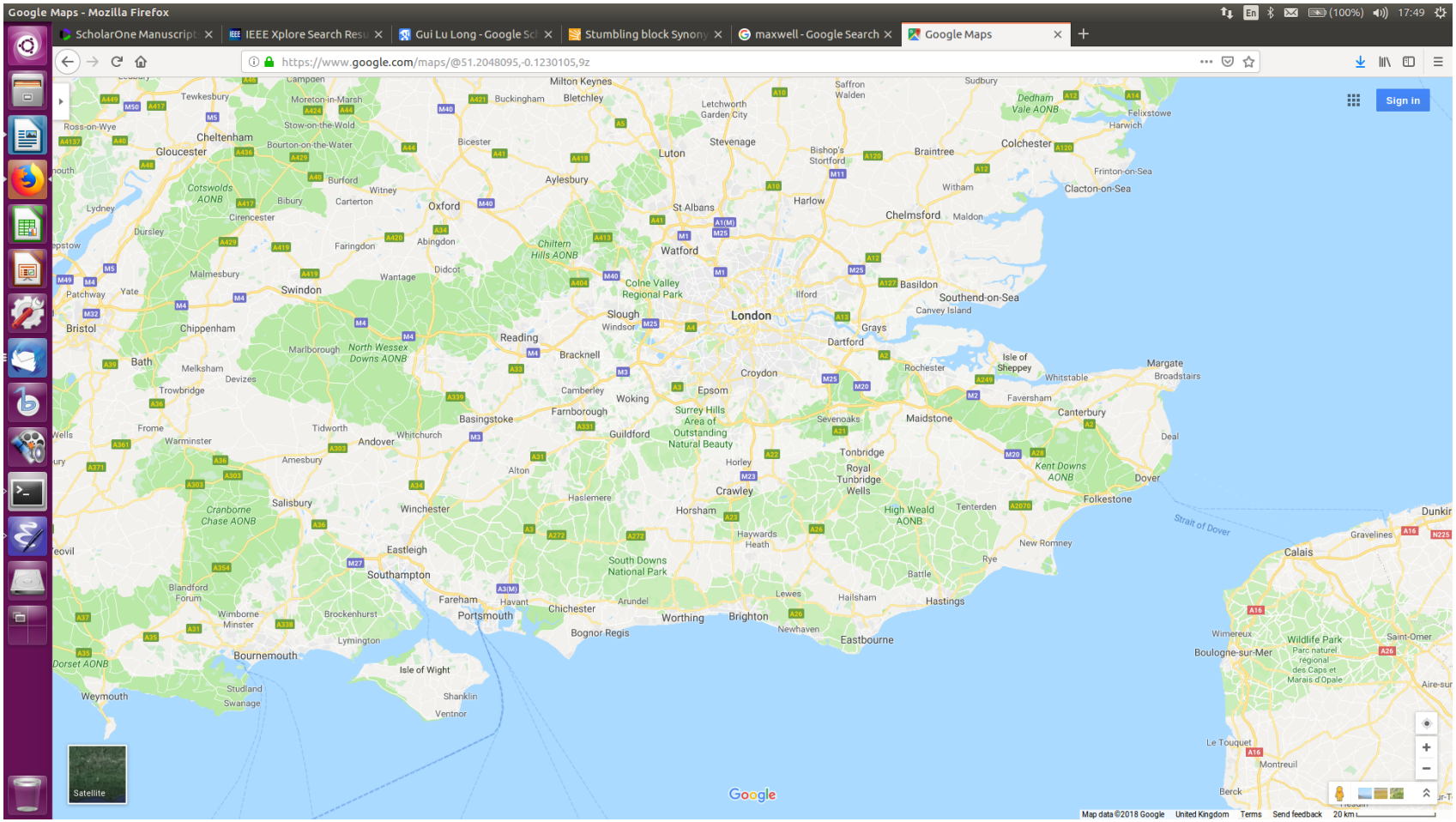
- A Communications-, Information- and Operation Technology Perspective

The Founders of Our Field: 1831 - 2001

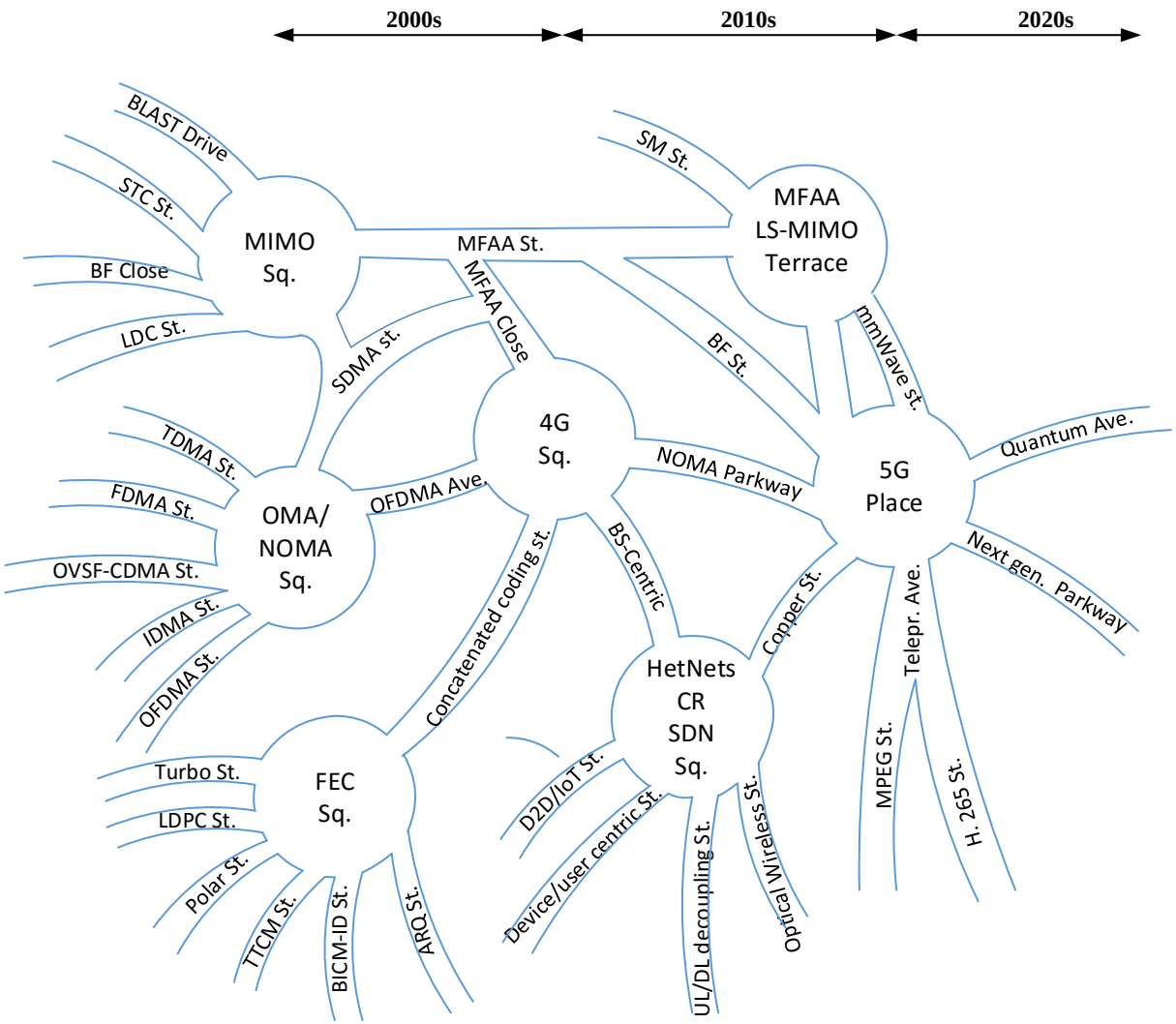




Life Through the Communications Era V 1.0...

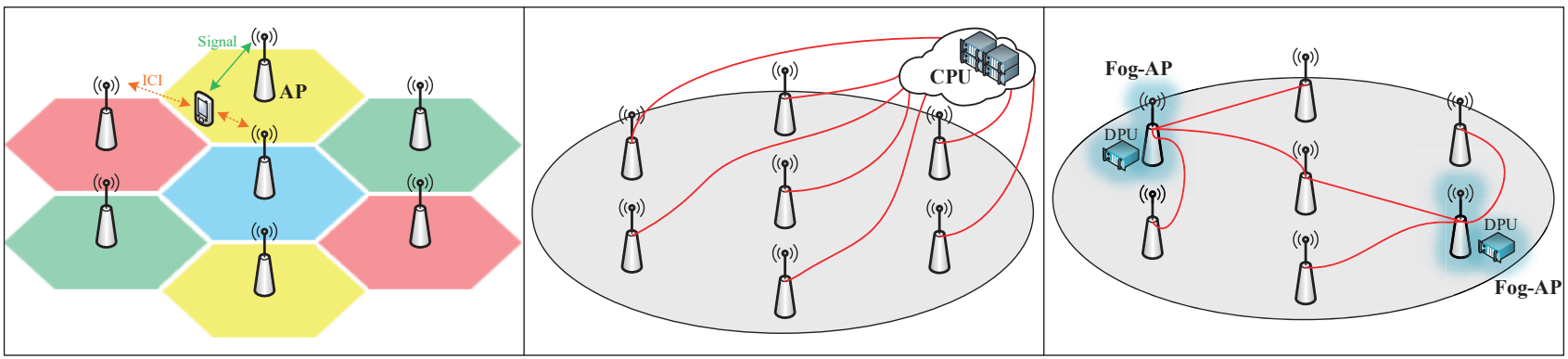


Wireless Generations: 2000 - 2020



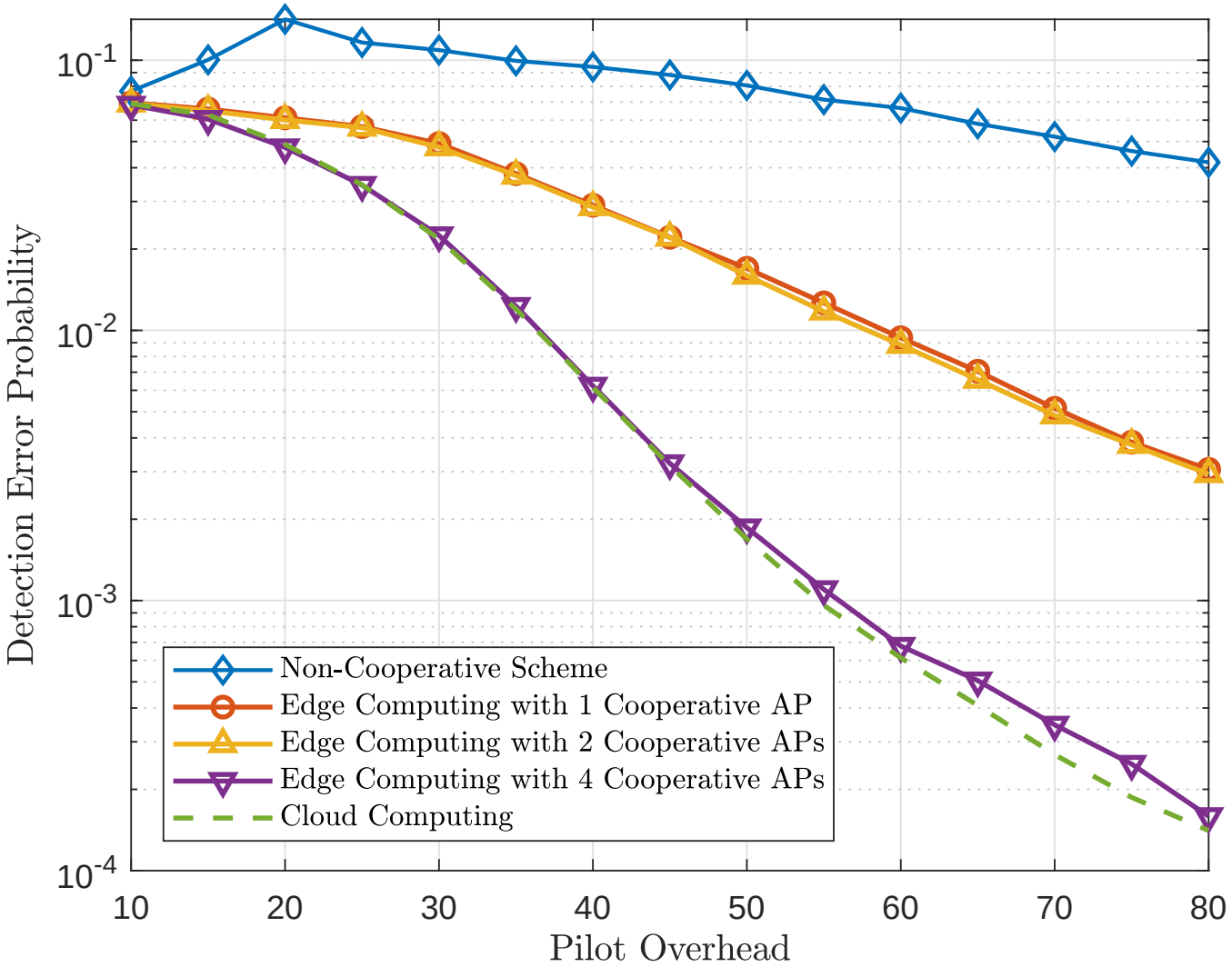
- Liu, Qin, Elkashlan, Ding, Nallanathan & Hanzo: Nonorthogonal Multiple Access for 5G and Beyond, Proceedings of the IEEE, 2017

The Road to Industry 4.0 & the Verticals



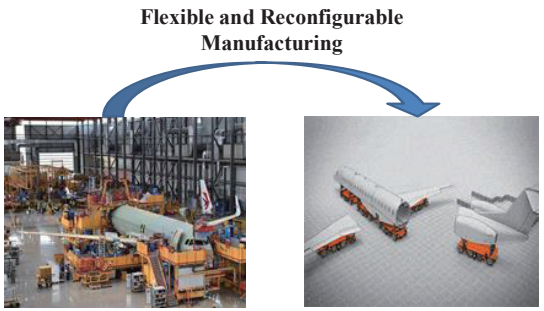
- Processing Paradigms for Grant-Free Access: non-cooperative, cloud & fog architectures ©Wan, Gao, di Renzo & Hanzo

The Road to Industry 4.0 & the Verticals

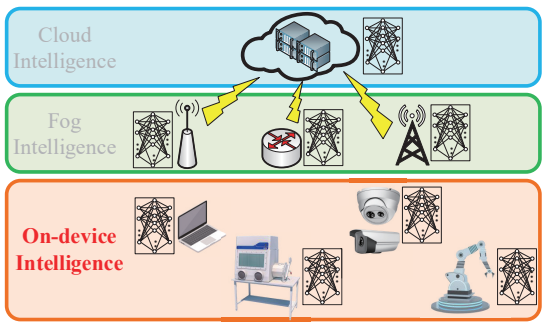


- Detection Probability of Massive Grant-Free Access using the algorithm of ©Ke *et al.* Cloud computing and edge-computing paradigms, IEEE JSAC, March 2021

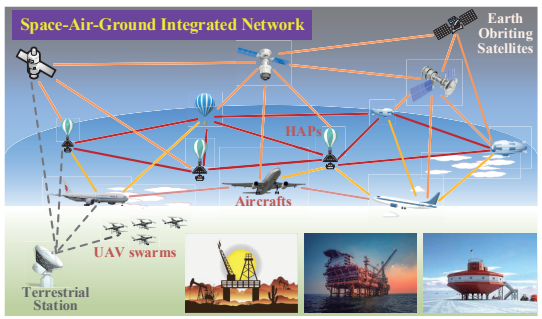
The Road to Industry 4.0 & the Verticals



OT Evolution



IT Evolution

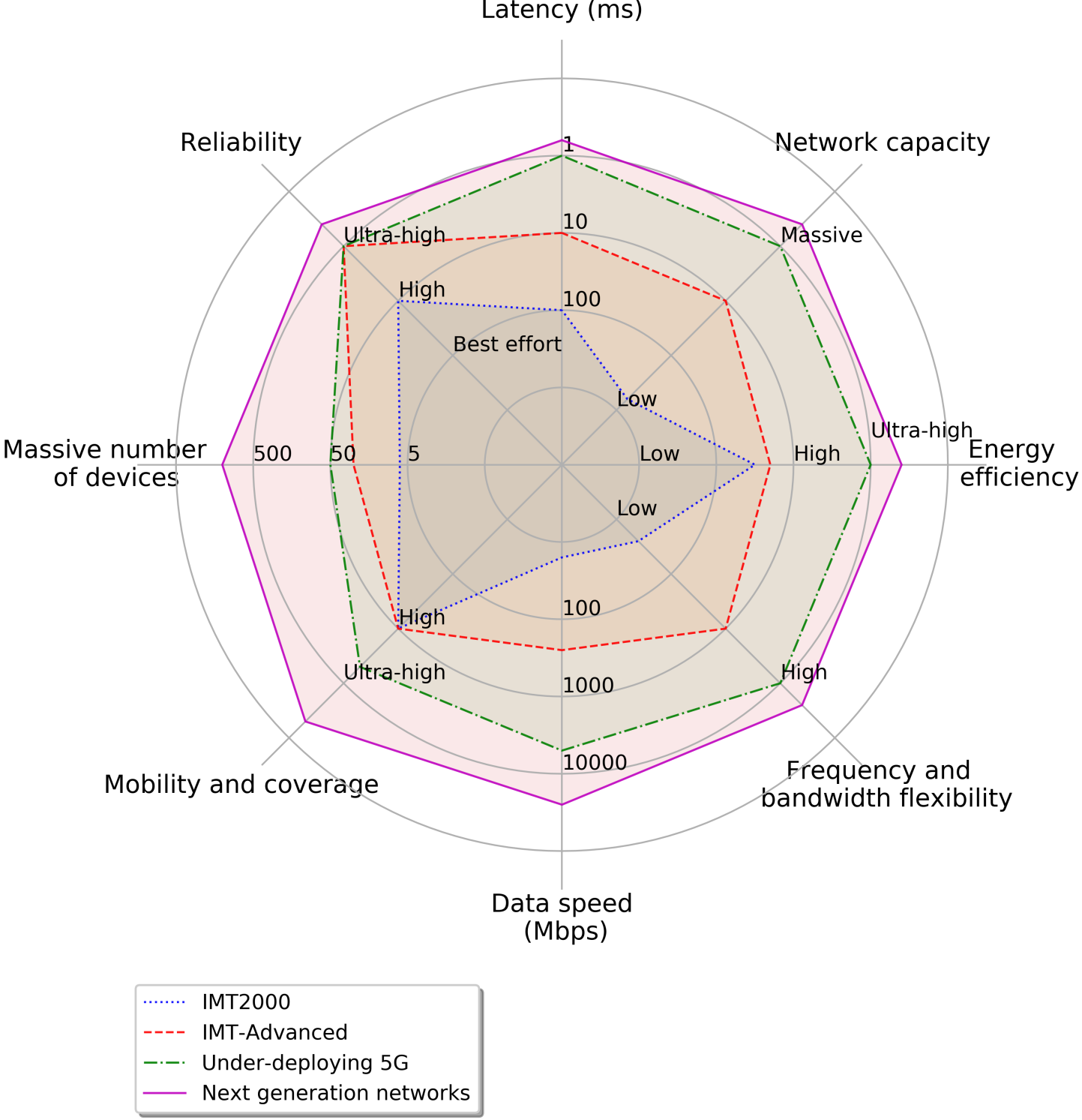


CT Evolution

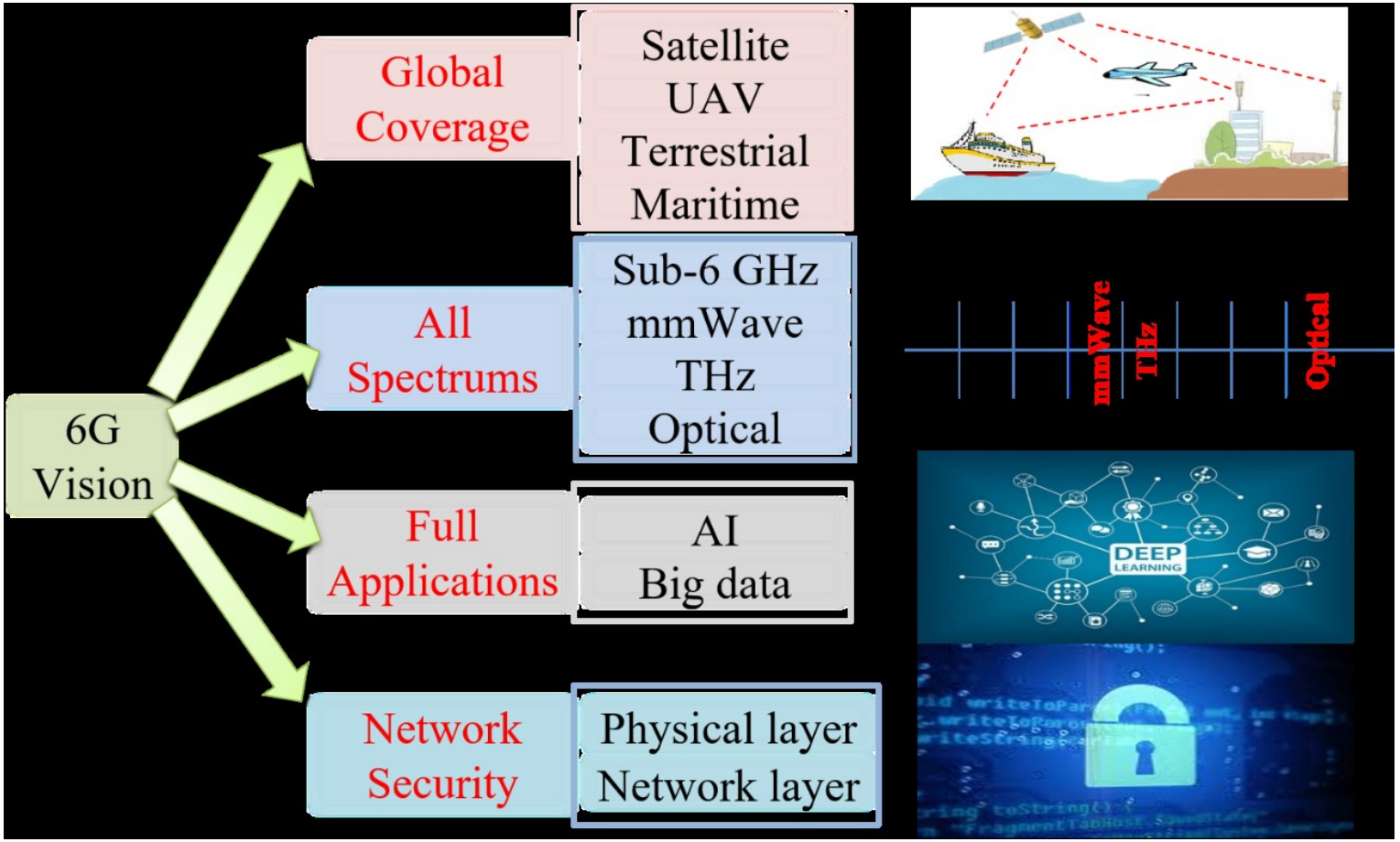
- The Confluence of the Communications-, Information- & Operations Paradigms ©Wan, Gao, di Renzo & Hanzo

A Glimpse Next-Generation Wireless...

- **Statement 1: The single-component pure bandwidth, power or delay optimization era is over, let's discover the entire Pareto-front of optimal Industry 4.0 solutions ... Demo?**


Latency (ms)
1
10
100
Network capacity
Massive
Energy
efficiency
Low
Low
Low
Ultra-high
High
Frequency and
bandwidth flexibility
High
100
1000
10000
Data speed
(Mbps)
Mobility and coverage
Ultra-high
High
Massive number
of devices
500
50
5
Reliability
Ultra-high
High
Best effort
IMT2000
IMT-Advanced
Under-deploying 5G
Next generation networks

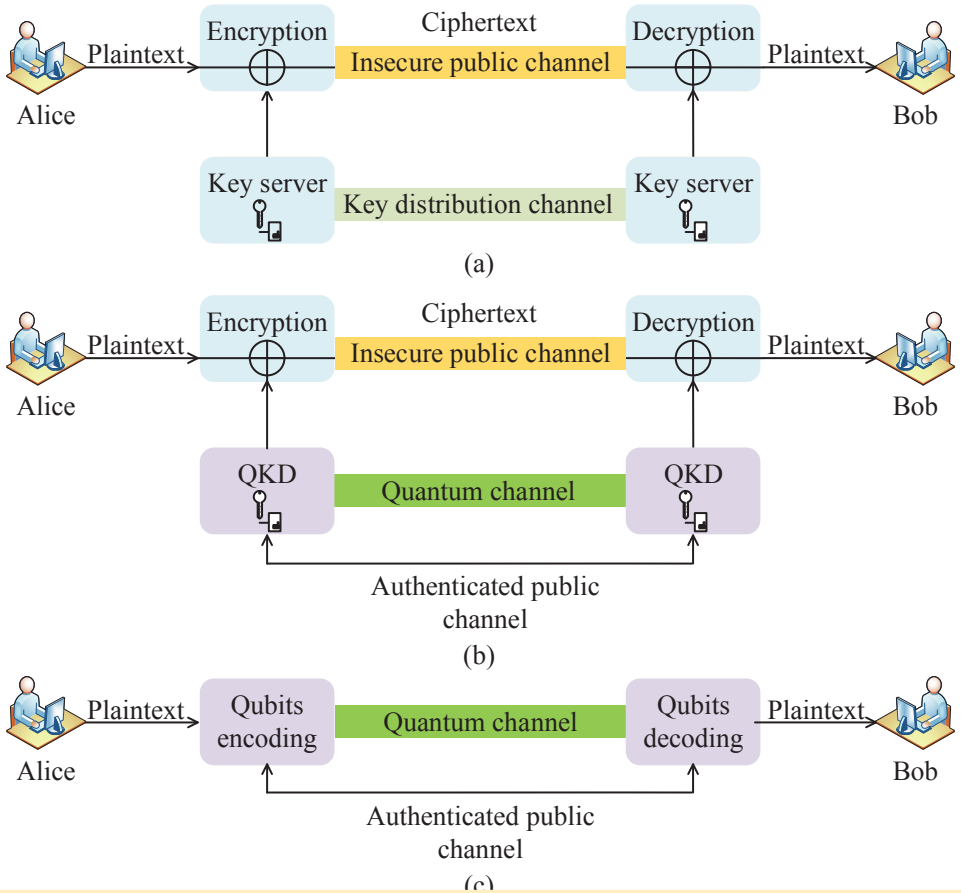
What Will 6G Be?



SOURCE

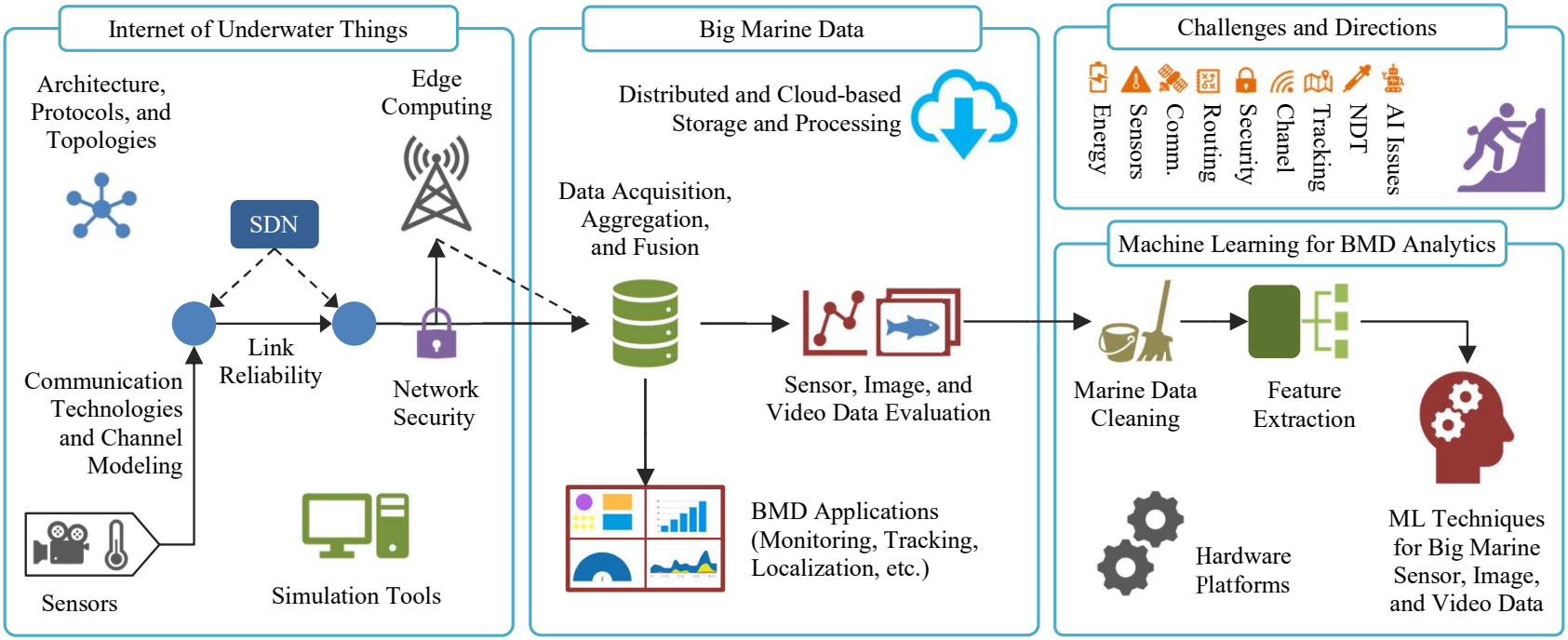
Towards 6G wireless communication networks: Vision, enabling technologies and new paradigm shifts, Science China, 2020 ©You, Wang ... & Hanzo

6G Network Security: Classic & Quantum Cryptography



- Pan, Li, Ruan, Ng and Hanzo: Single-Photon-Memory Two-Step Quantum Secure Direct Communication Relying on Einstein-Podolsky-Rosen Pairs IEEE Access, 2020
- Hosseinidehaj, Babar, Malaney, Ng & Hanzo: Satellite-Based Continuous-Variable Quantum Communications: State-of-the-Art and a Predictive Outlook, IEEE Comms. Surveys & Tutorials, 2018

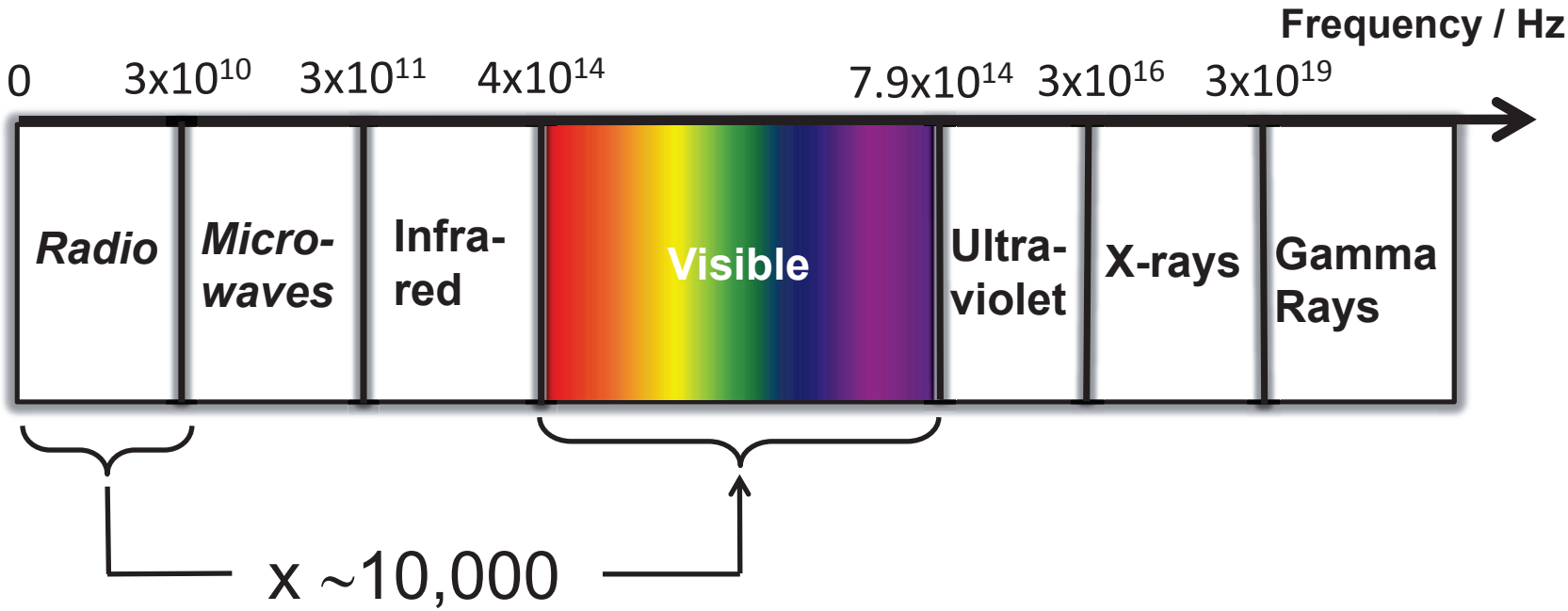
6G Application 1: The Internet of Underwater Things (IoUT), 'Big' Marine Data (BMD) Analytics & AI



Source

- Internet of Underwater Things and Big Marine Data Analytics, by Jahanbakht, Xiang, Hanzo & Rahimi, ResearchGate, IEEE Comms. Surveys & Tutorials

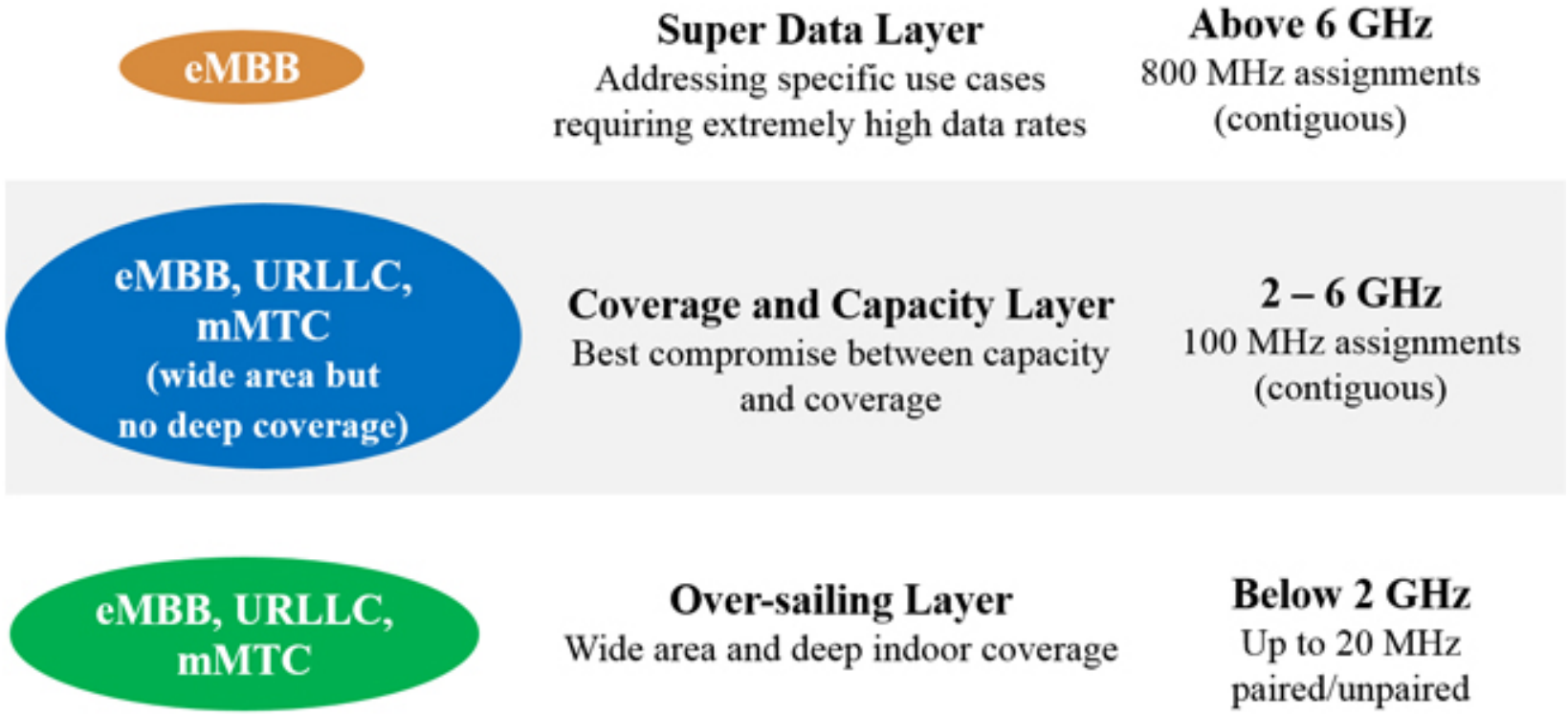
6G Cognitive Spectrum Sharing ©H. Haas



SOURCE

L. Hanzo, H. Haas, S. Imre, D. O'Brien, M. Rupp, and L. Gyongyosi, "Wireless myths, realities and futures" *Proceedings of the IEEE*, vol. 100, pp. 1853 –1888, 13 2012,

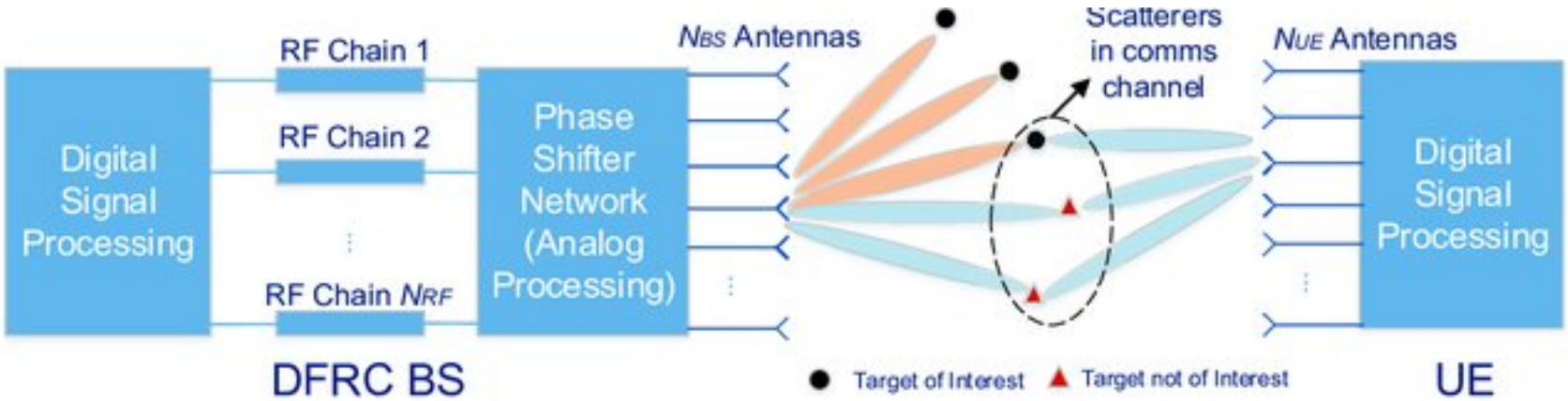
Spectrum Sharing



SOURCE

4G & 5G Spectrum Sharing: Efficient 5G Deployment to Serve Enhanced Mobile Broadband and Internet of Things Applications by Wan, Guo, Wu, Bi, Yuan, Elkashlan & Hanzo, IEEE VTM, 2018

6G Spectrum Sharing in Joint Sensing & Communication: 1/ Joint Waveform Design (PAPR, ACF, CCF); 2/ MIMO; 3/ Synchronization; 4/ ML in the Face of Uncertainty



SOURCE

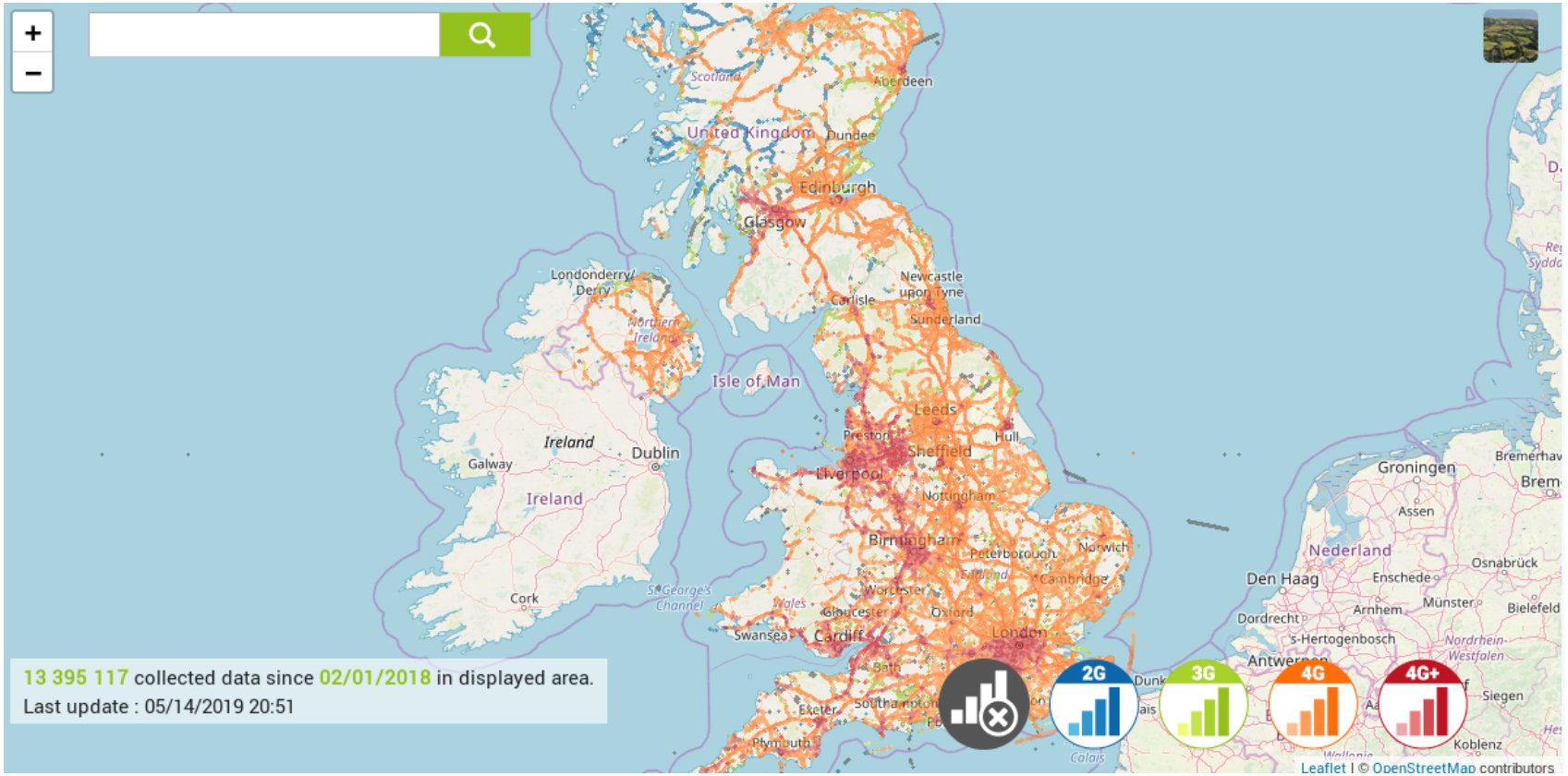
- Joint Radar and Communication Design: Applications, State-of-the-Art, and the Road Ahead, ©IEEE Liu, Masouros, Petropulu, Griffiths & Hanzo IEEE TCOM, 2020
- Mobile Radio Communications by Steele & Hanzo, 1999, Chapter 2, Bello Functions

Multi-Component Pareto Optimization: Bandwidth, BER, Delay, Power & Complexity, etc

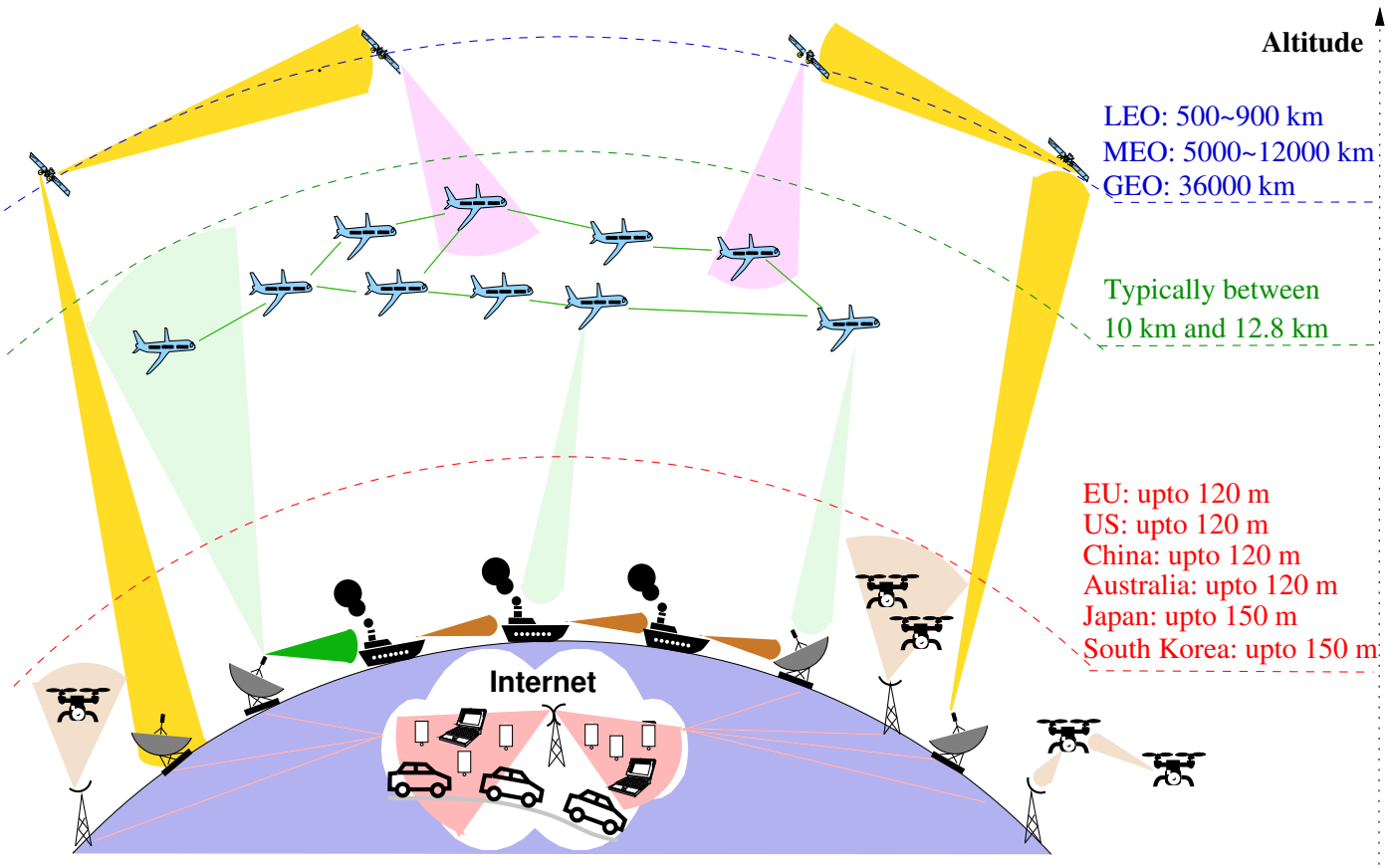
SOURCE

- Alanis, D.; Botsinis, P.; Babar, Z.; Ng, S.X.; Hanzo, L.: Non-Dominated Quantum Iterative Routing Optimization for Wireless Multihop Networks, IEEE Access
- Alanis, D. ; Botsinis, P. ; Soon Xin Ng ; Hanzo, L.: Quantum-Assisted Routing Optimization for Self-Organizing Networks: IEEE Access, Volume: 2, 2014, pp 614 - 632
- Thirty Years of Machine Learning: The Road to Pareto-Optimal Wireless Networks, ©Wang, Jiang, Zhang, Ren, Chen & Hanzo IEEE COMST, 2020

2G, 3G & 4G Coverage Maps



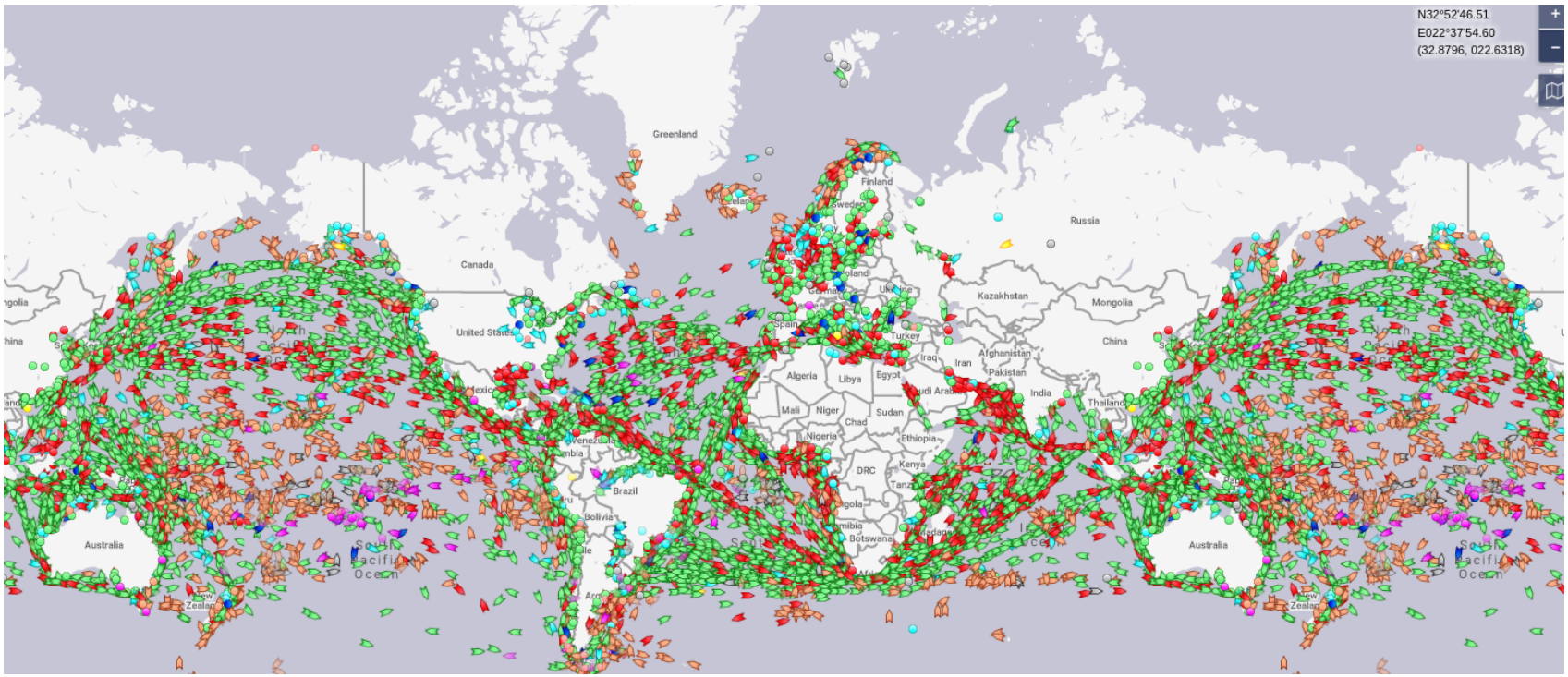
Application 2: Space, Air Ground Integrated Network (SAGIN)



SOURCE

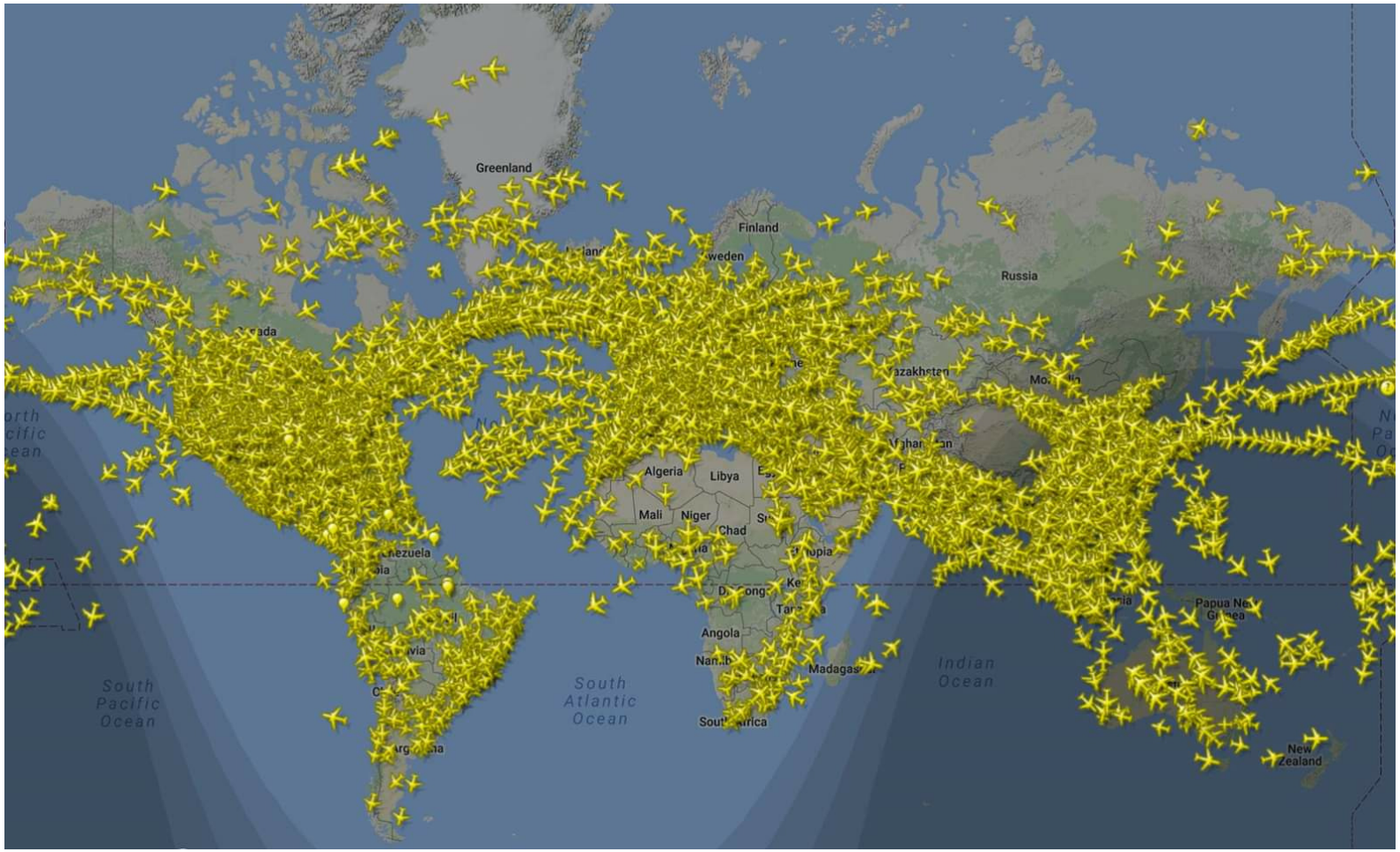
- Aeronautical Ad Hoc Networking for the Internet-Above-the-Clouds, Zhang, Chen, Zhong, Wang, Zhang, Zuo, Maunder & Hanzo, Proc. of the IEEE'19

Application 2: SAGIN Snap-Shot of Ships



Green: Cargo; Blue: Cruise; Red: Tanker; Yellow: Fishing;

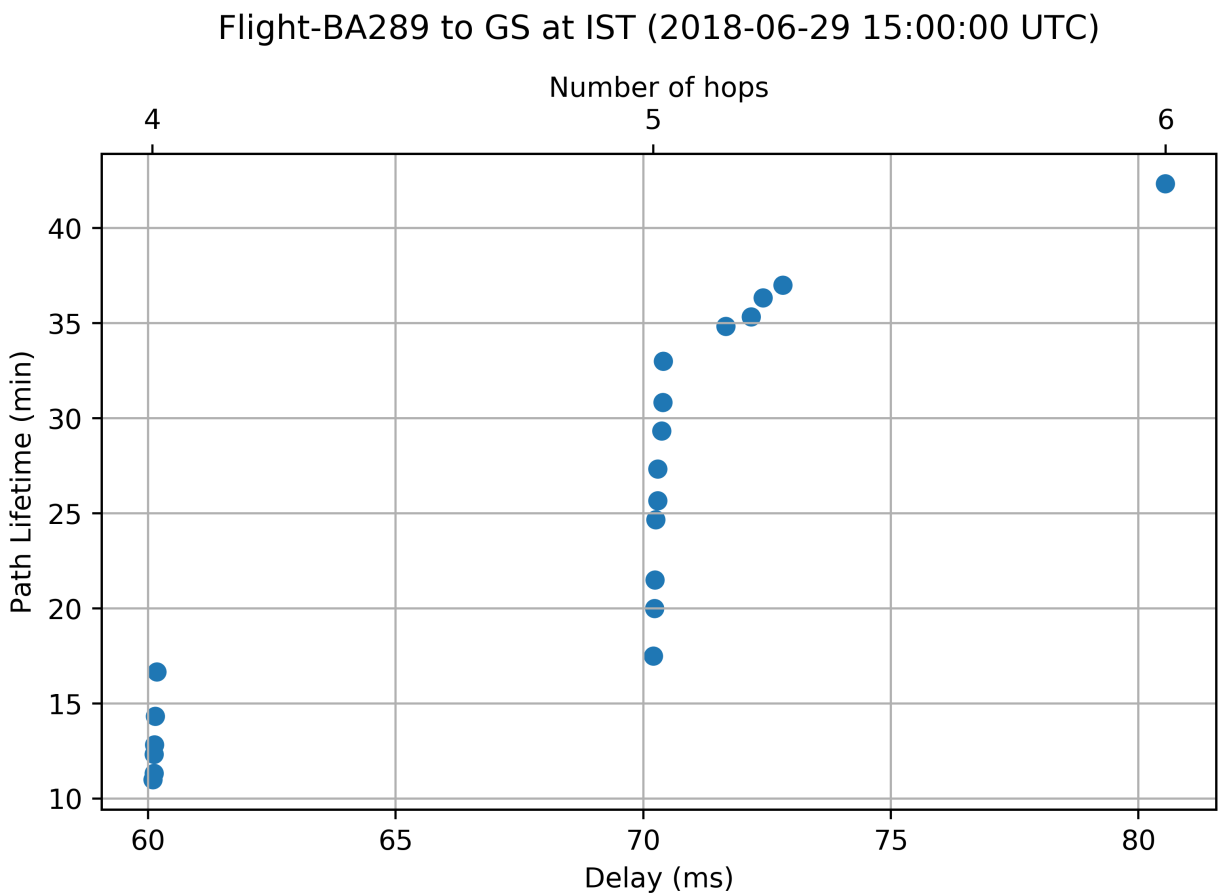
Application 2: SAGIN Snap-Shot of Planes



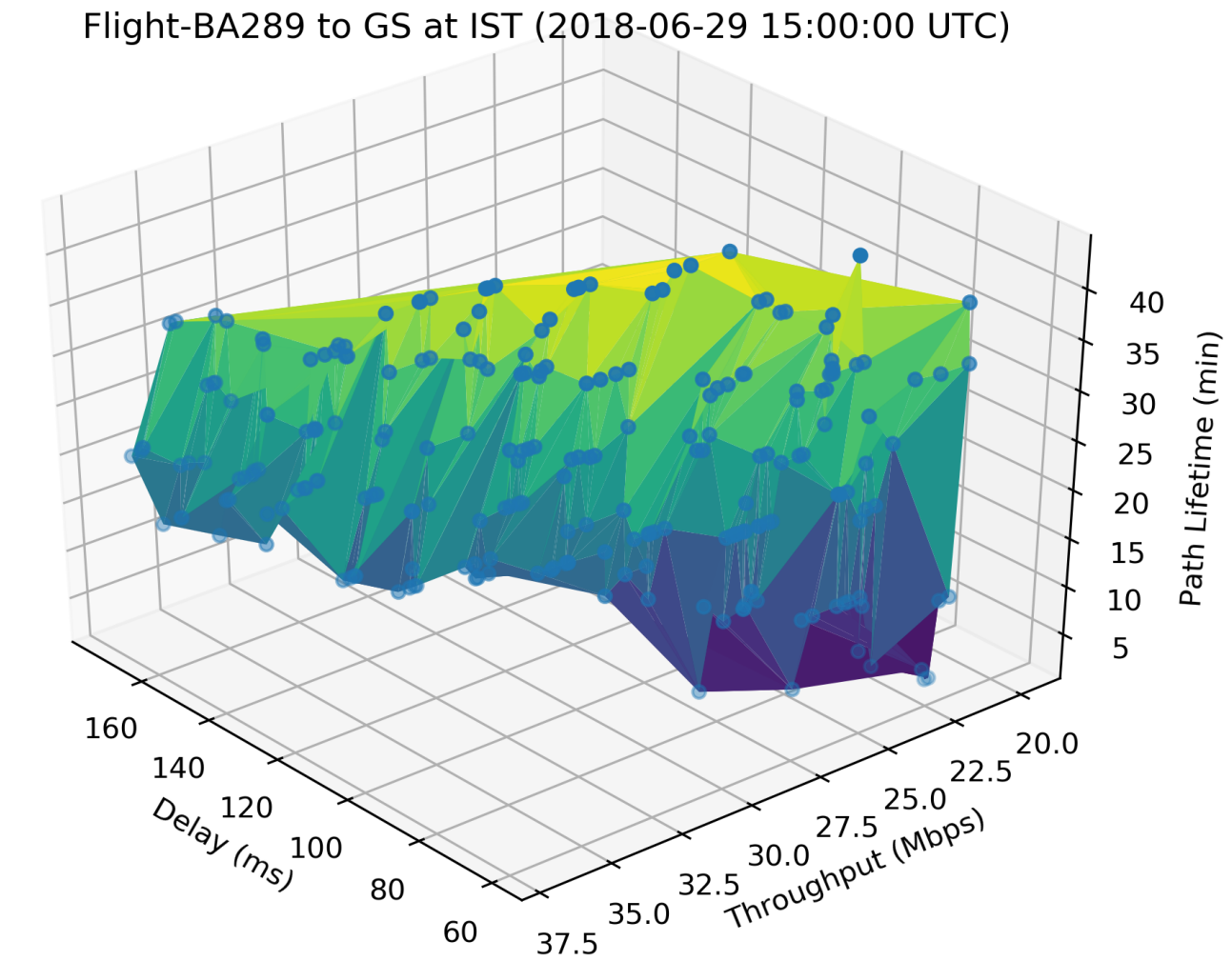
SOURCE

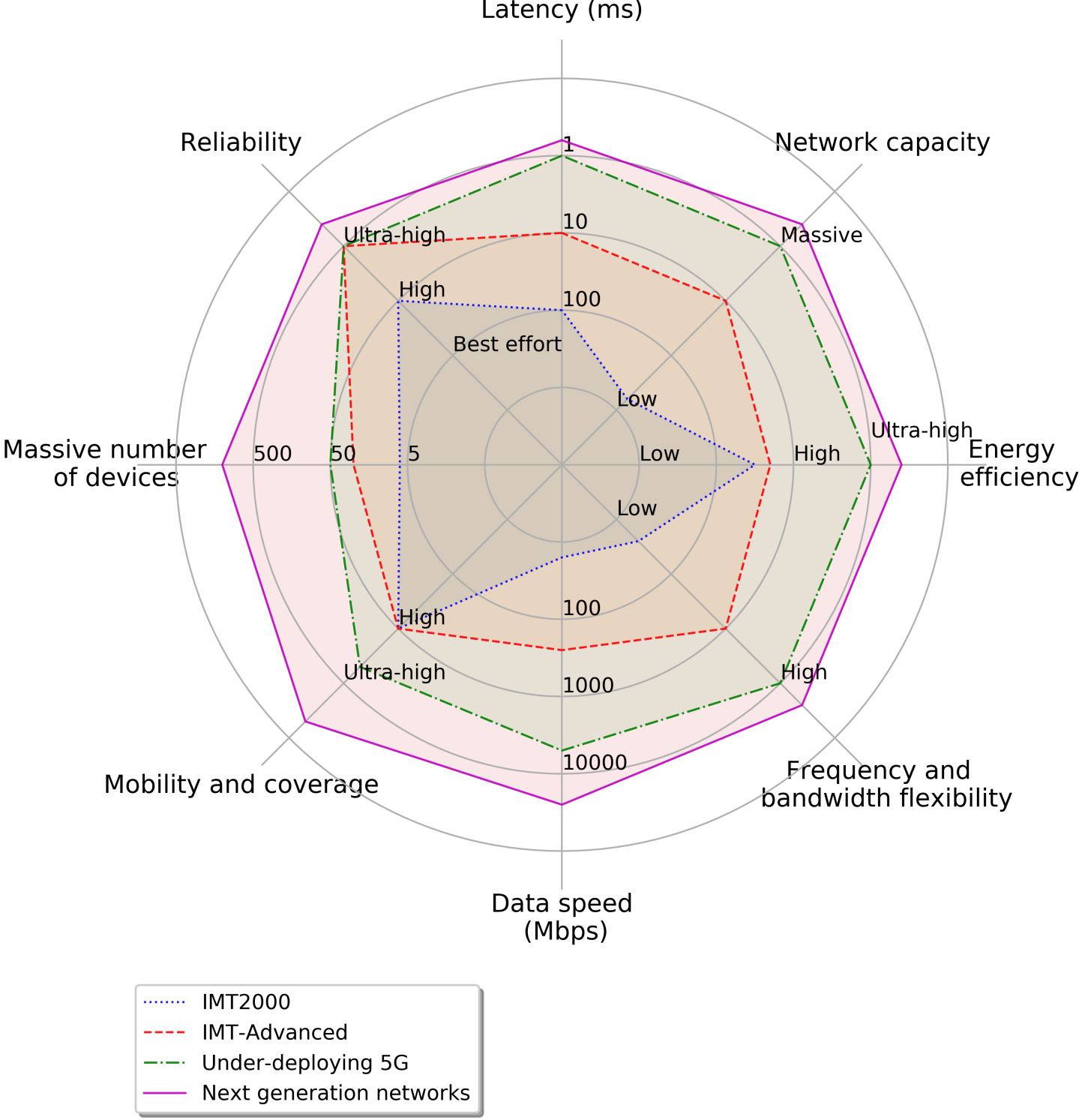
- Aeronautical Ad Hoc Networking for the Internet-Above-the-Clouds, Zhang, Chen, Zhong, Wang, Zhang, Zuo, Maunder & Hanzo, Proc. of the IEEE'19

Pareto-front **MCOF=f[Delay, Path-Lifetime] ©Dong Liu**

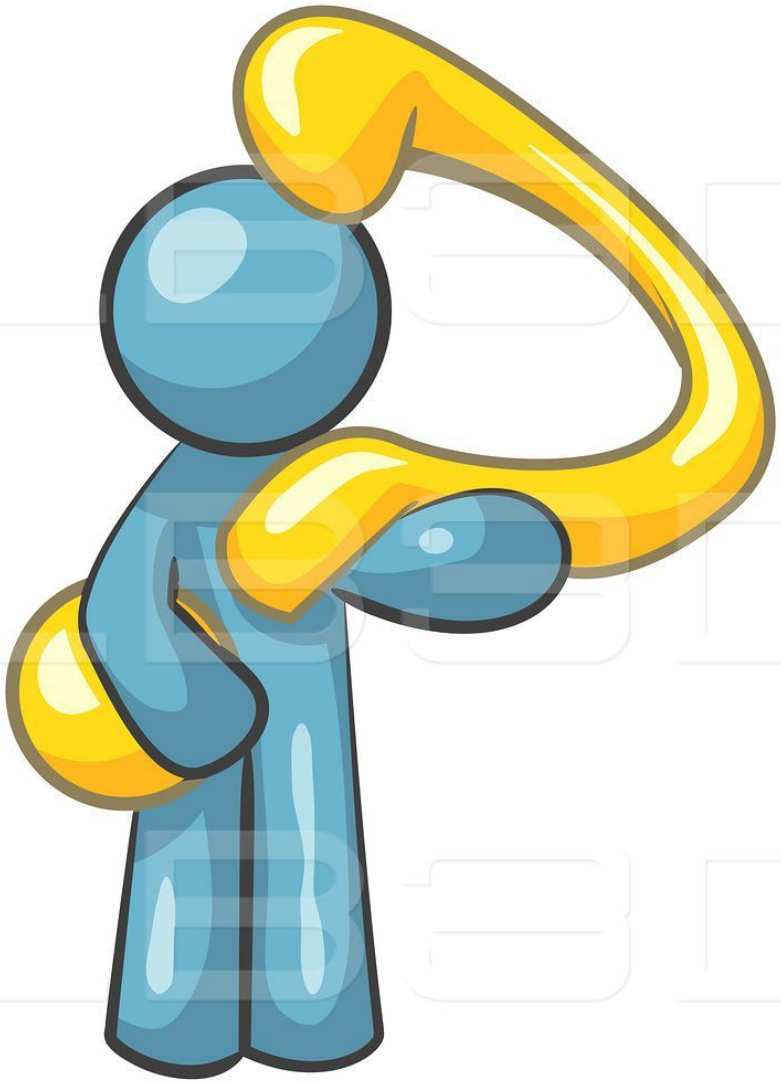


3D Pareto-front **MCOF=f[Throughput, Delay, Path-Lifetime ©Dong Liu]**




Latency (ms)
1
10
100
Network capacity
Massive
Low
Energy
efficiency
Ultra-high
High
Low
Frequency and
bandwidth flexibility
High
1000
10000
Data speed
(Mbps)
100
High
Mobility and coverage
Ultra-high
5
50
500
Massive number
of devices
Low
Reliability
Ultra-high
High
Best effort
IMT2000
IMT-Advanced
Under-deploying 5G
Next generation networks

Wireless Futures... ©CCBY



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