6G FLAGSHIP
UNIVERSITY OF OULU

From Best Effort to Resilience – Why now?

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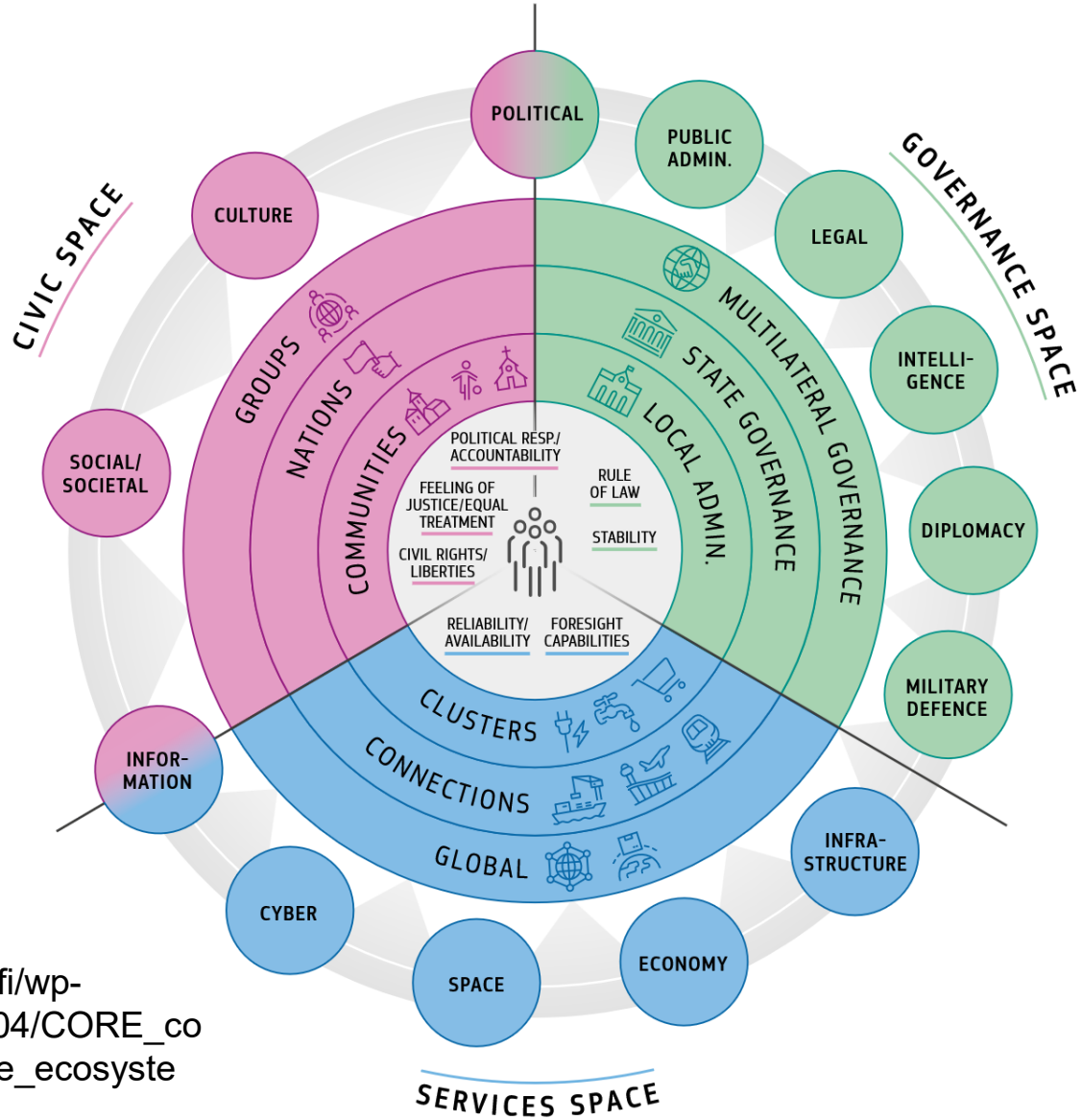
Why should wireless RDI community care about resiliency?


Hmmm ...

Climate change causing frequent natural disasters

Cybersecurity attacks increasing

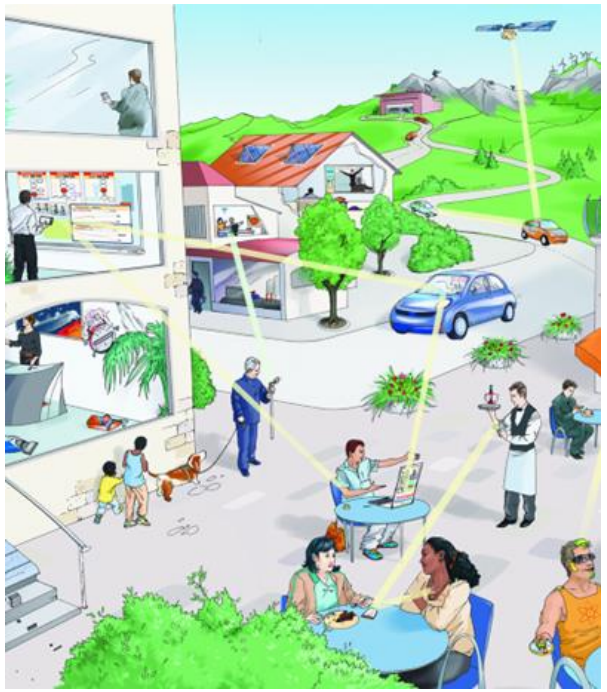
Broad scale of hybrid and hot threaths



https://www.hybridcoe.fi/wp-content/uploads/2023/04/CORE_comprehensive_resilience_ecosystem.pdf

Mobile Technology Visions from 4G to 6G and Beyond

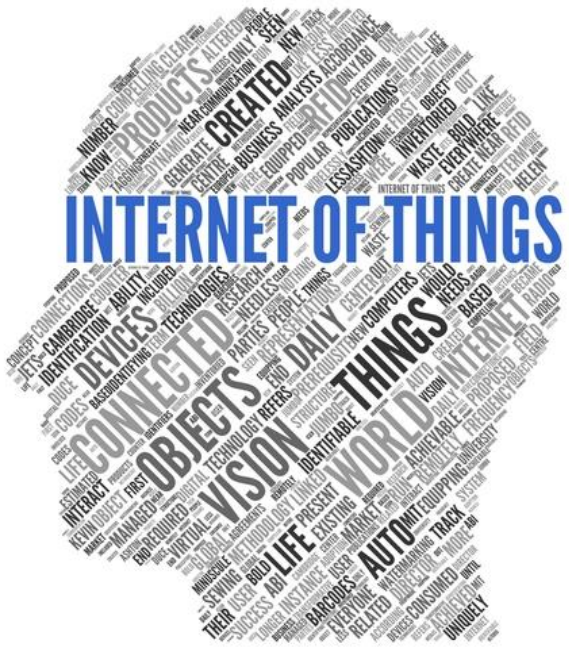
4G



ABC (Always Best Connected)

Vision from 2003

5G



Next 50 billion connected things

2013 vision

6G

6G metaverse and digital twins

2023

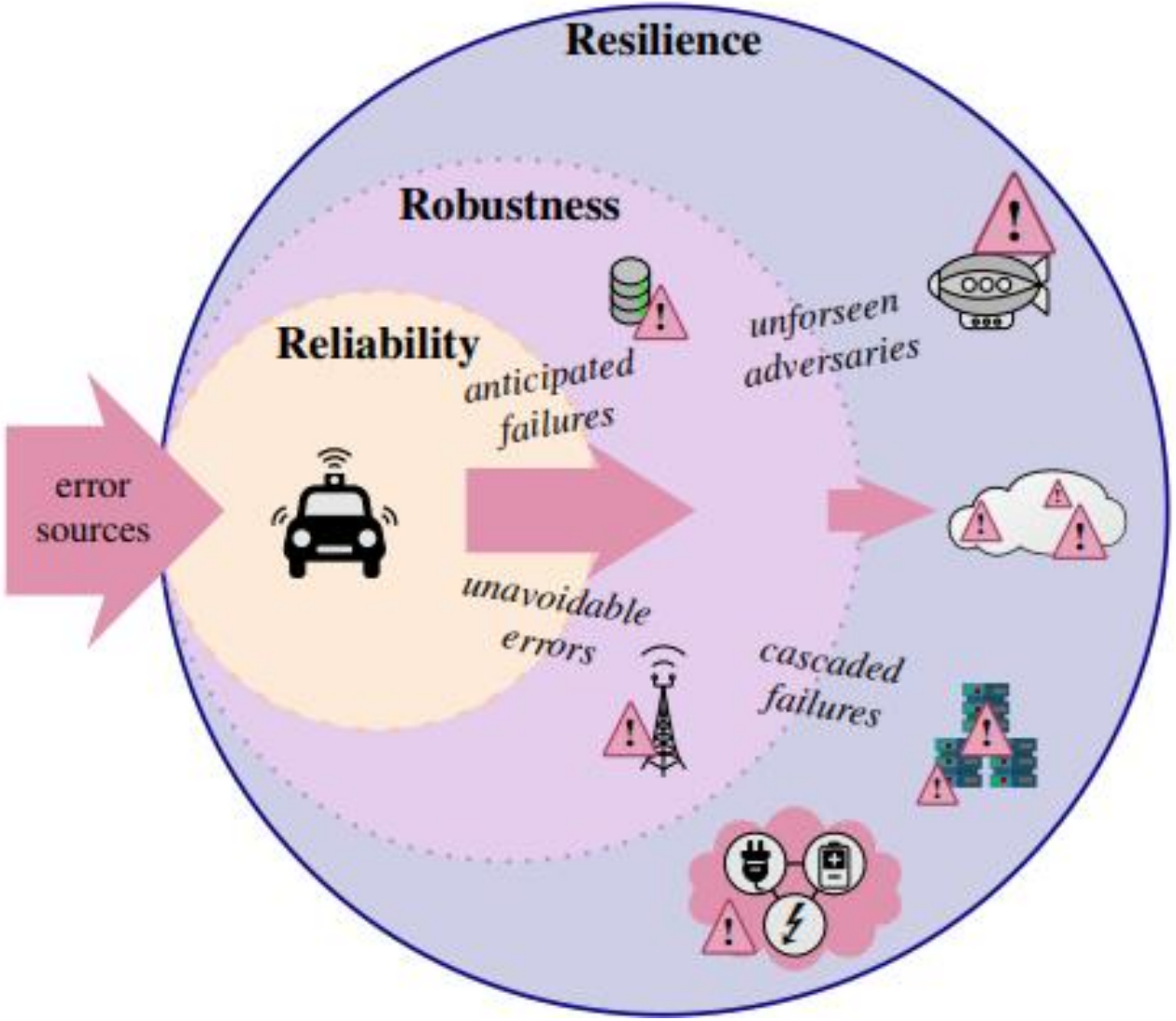
xG

Beyond 6G resilient, sustainable and AI driven society?

Resilience ?

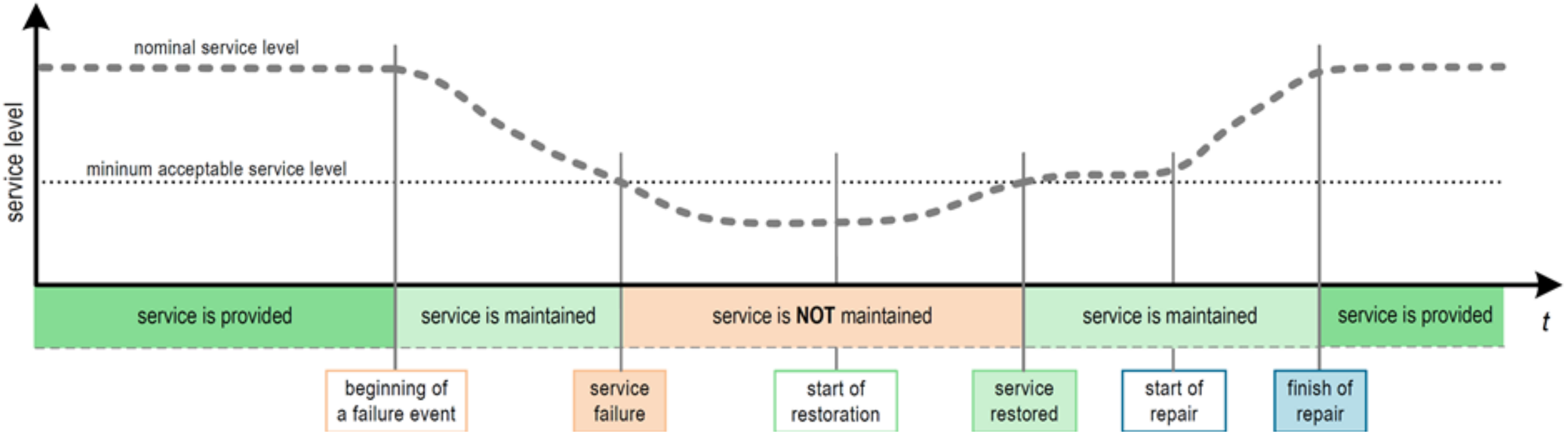
- **Robustness** typically considers the ability to withstand adverse conditions and to accommodate known uncertainties.
- **Reliability** points more toward the long tail of performance, sometimes in the context of transmission rate and latency. For instance, stipulating that a network maintains a 99 percent reliability means that on average one packet out of 100 is lost, within a pre-defined timeframe.
- A **resilient network** would by definition require the system to adapt, recover, and withstand various stressors—whether known or unknown.
- A **resilient network** can effectively balance the notions of high network robustness with high network reliability, all while attempting still to maximize network efficiency.

Resilience ?



Robert-Jeron Reifert, Yasemin Karacora, Christina Chaccour, Aydin Sezgin, and Walid Saad (2024), “Resilience and Criticality: Brothers in Arms for 6G”, arXiv:2412.03661v1 [cs.IT] 4 Dec 2024

Resilience ?



J. Rak, "Resilient Routing in Communication Networks - A Systems Perspective", Springer, 2024

Total Paradigm Change

From

Best effort → Resilience

Societal Sustainability

- It is not only about 6G, but also all existing generations and upcoming versions

Resilience ≠ 6G

Resilience ≈ Societal Sustainability

1€ ≈ 4€

R. Jungwirth, et al., “Hybrid threats: a comprehensive resilience ecosystem”, Publications Office of the European Union, Luxembourg, 2023, doi:10.2760/37899, JRC129019.
S. Hallegatte, J. Rentschler, J. Rozenberg, “Lifelines: The Resilient Infrastructure Opportunity”, Sustainable Infrastructure Series. Washington, DC, World Bank 2019. doi:10.1596/978-1-4648-1430-3

Need

1) Mobile cellular networks are **central part of society's critical infrastructures.**

2) Critical infrastructures are **strongly intertwined**.

- Especially critical is intertwining of electrical networks, mobile cellular networks and GPS.

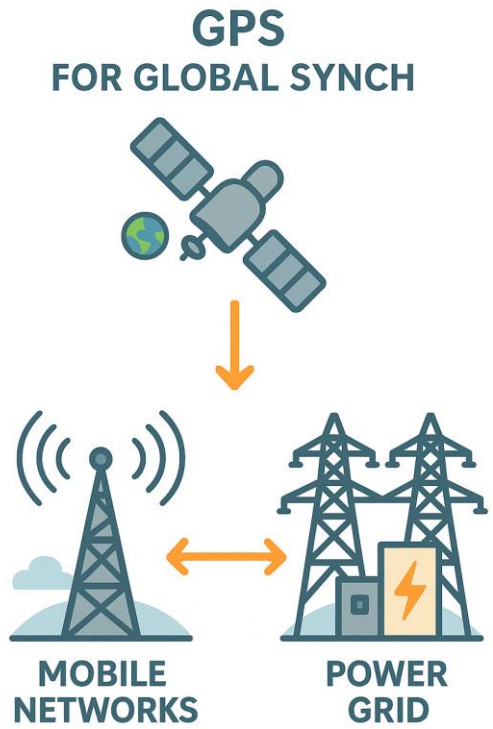
3) Resilience will be one of the **key drivers of central ICT-technologies** in the foreseen future,.

4) Standardisation and regulation of mobile cellular systems has not paid enough attention to the matter.

- Requires large international effort and mutual regulatory and standardisation efforts.

5) Strong resilience open new business oppotunities.

⇒ The European goal should be to achieve opinion leadership in developing and applying resilient mobile cellular technologies.



OOKLA Ookla Research™ Articles

The April 28th event highlights concerns about the critical need for resilience and continuity of service for telecom providers

Power outages triggered a rapid, severe, and sustained decline in mobile performance across all operators in Spain and Portugal on April 28, with impacts peaking in the mid-afternoon as backup batteries became depleted.

Opportunities

- Resilience improvement creates new **business opprtunities** for many wireless verticals
- On top of business opportunities, public authorities system resilience affect directly to **national security**
  - E.g. Finland will start using mobile cellular as backbone of public authorities communications by 2028 which entails a security risk if their operational capacity cannot be ensured under
- Being active now ensures that that central **IPRs can be claimed** while devoloping wireless systems forward.

Sector	Market Size 2023/2024	CAGR (%)	Market Size 2032/2033
Military Wireless Communications	$33.12B	7.2%	$60.2B
Other Government Wireless Systems	$27.4B	21.25%	$155.2B
Intelligent Transportation Systems	$38.8B	6.6%	$73.8B
Vehicle-to-Vehicle (V2X)	$0.6B	51.6%	$38.5B
Wireless Healthcare Technologies	$227B	17.4%	$1,035B
Industrial Private Networks	$3.5B	25.3%	$29.7B

Resilience of Mobile Networks – Examples of Actions

Short term actions (NOW)

- **National strategies** against 4G & 5G network failures natural disa power outages al attac
- **national ming** and other orms of operator collaborations

Medium term actions (2-3y)

- Make sure 3GPP **standardization** ta resilience serio a clear roadm
- **Differe ration mo** needed for stem (normal ue, mild malfunctions, serious malfunctions, total network failure)

Long term actions (5-10y)

- Prepare mobile network to survive from total power outage at least to offer
  - critical comms. for pu ities
  - carrying emerge ages
- How sh s backup batt e used in total outage?
- w could mesh networking between user terminals be allowed in power outage?
- How could AI be utilized to enable **resilient-by-design 6G**?

1. National regulation
2. 6G standardisation
3. Research & IPR

Public authorities will abandon their private mobile network in Finland by 2028 and start using a commercial 4G & 5G network.
How do we ensure reliable service delivery under stress?

Questions to be addressed

1. Technology: What fundamental changes in network architecture are required to ensure resilience in 6G compared to previous generations? What new redundancy mechanisms can 6G introduce to ensure seamless failover during network outages? How do we define resiliency?

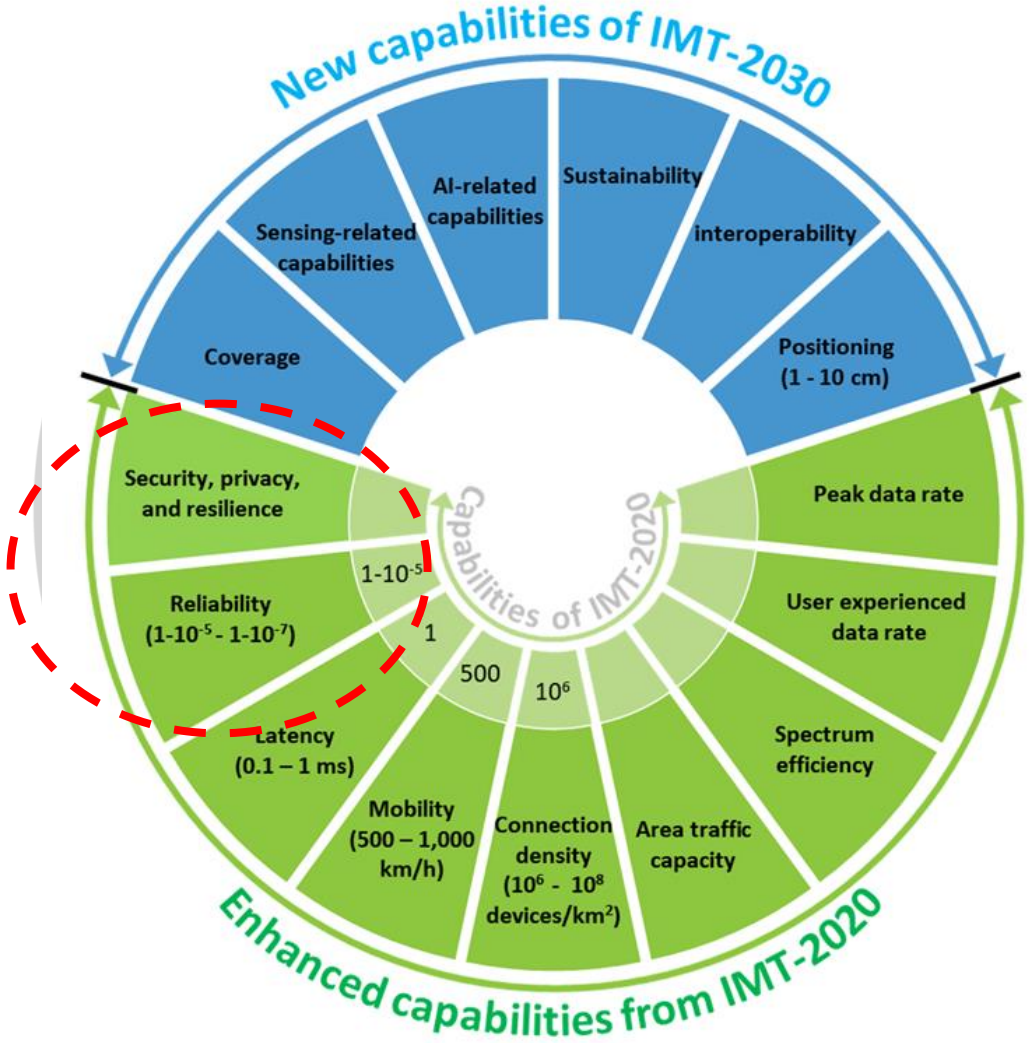
2. Interdependencies of critical infrastructures: Given that 6G will integrate deeply with energy grids, healthcare, and industrial automation, how can we ensure cross-sector resilience when a failure in one system could cascade across multiple domains? How can 6G networks remain operational during power grid failures or extreme weather events, especially in critical infrastructure applications?

3. Softwarization: How can we secure 6G networks, particularly with the increasing adoption of Open RAN and software-defined networking, which introduce new vulnerabilities e.g. via new supply chains or cloud based architecture?

4. Standards and regulation: Should resilience be mandated in 6G standardization efforts (e.g., within 3GPP, ITU, and ETSI), and how can regulatory bodies enforce such requirements? Should governments set the minimum resilience requirements for 6G networks, and if so, how should compliance be incentivized or enforced?

5. Business considerations: Is there a business case for resilience in 6G, or will it always be seen as an additional cost with limited short-term returns? Will resilience become a key differentiator for mobile operators in the 6G era, and how can they market it as a competitive advantage?

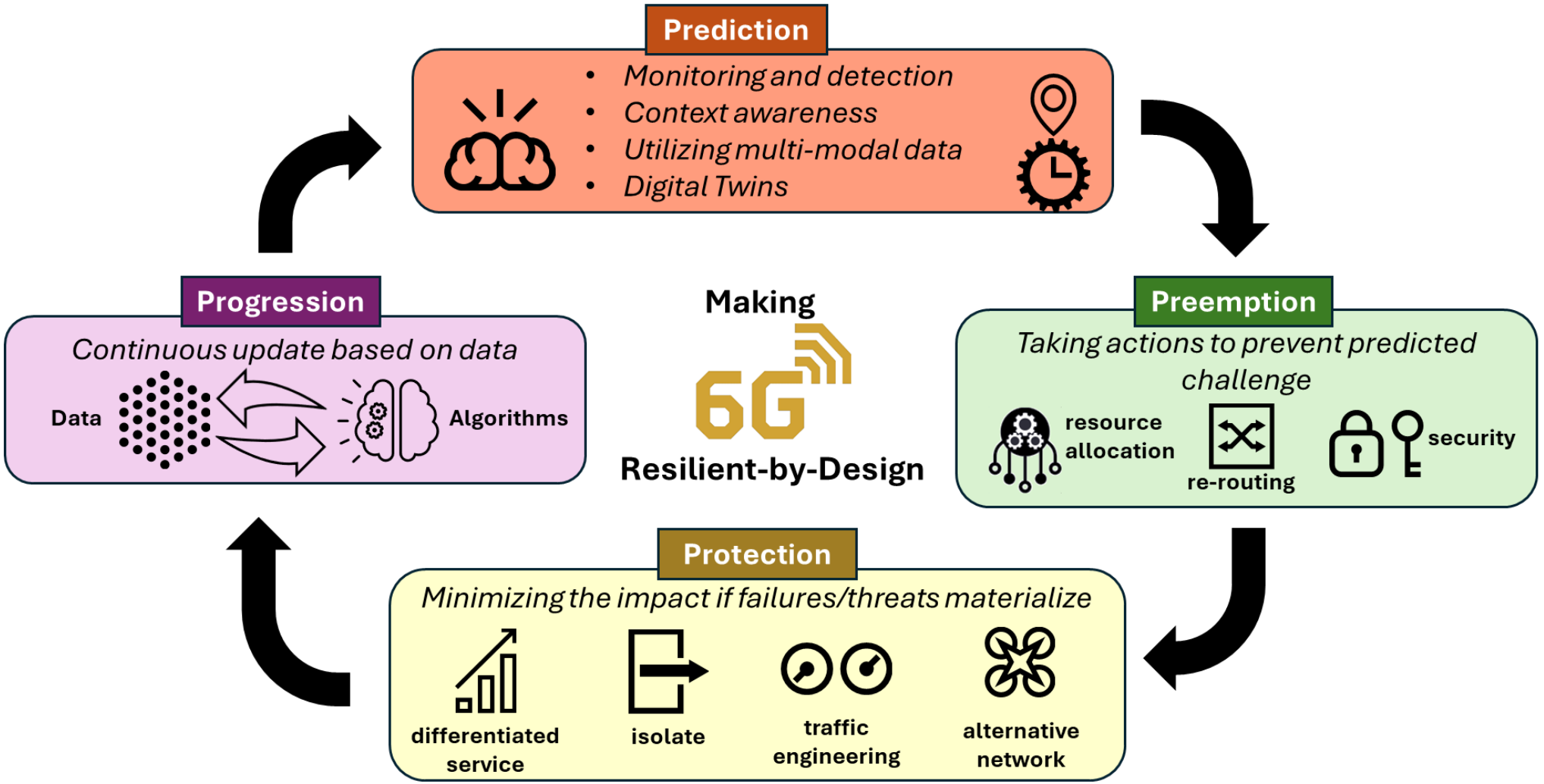
How To Address Resilience in IMT-2030 Requirements and 3GPP



Quality-of-Resilience features

- ITU-T Recommendation G.827 (Digital networks – Quality and availability targets)
- Service level definitions
- Fault localization and related parameters
- Network recovery parameters (Mean Time to Failure, Mean Up Time, Mean Down Time, etc. etc.)

What is the approach to Resilient-by-design?



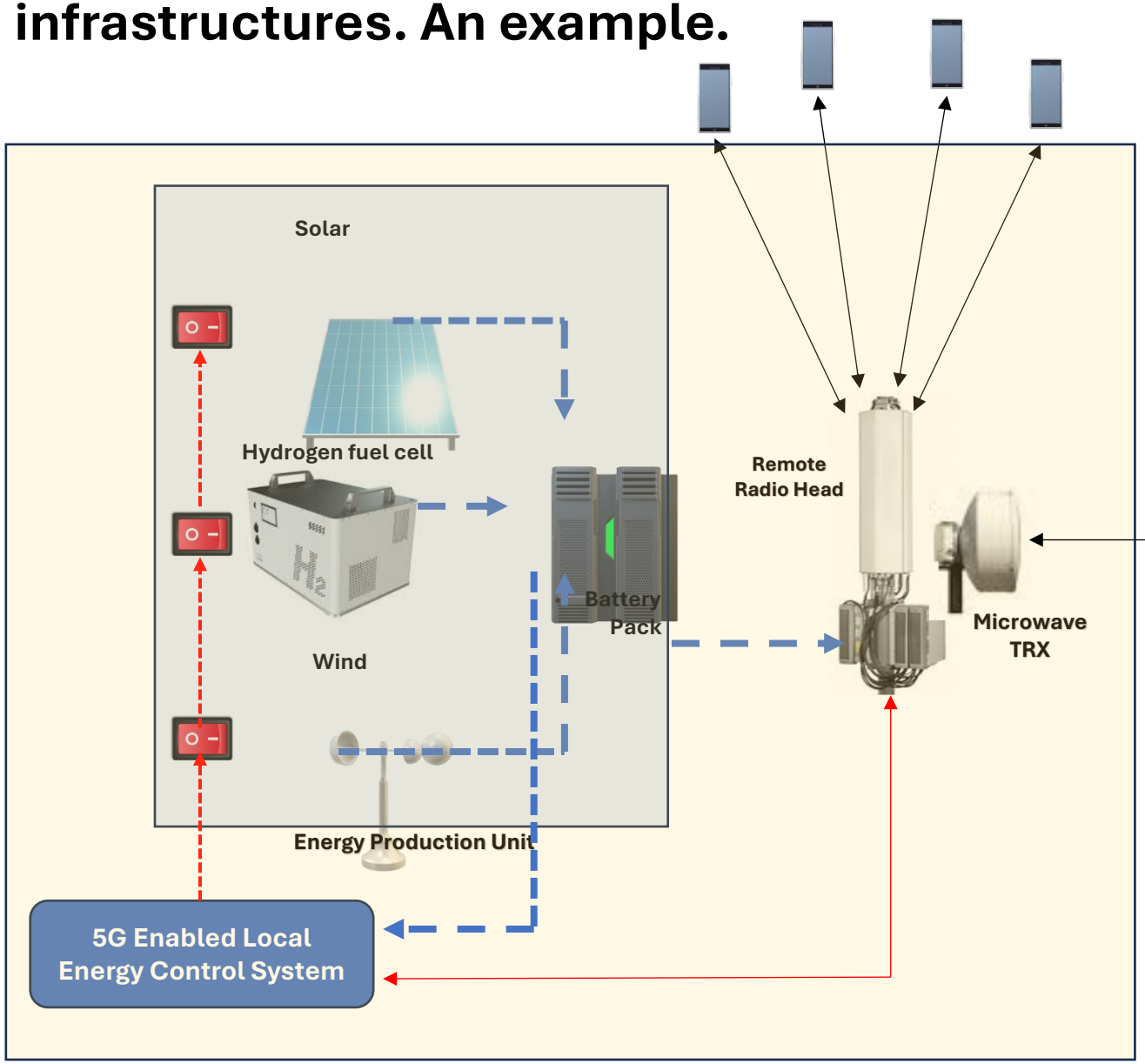
How to deal with intertwined critical infrastructures. An example.

Energy Flows

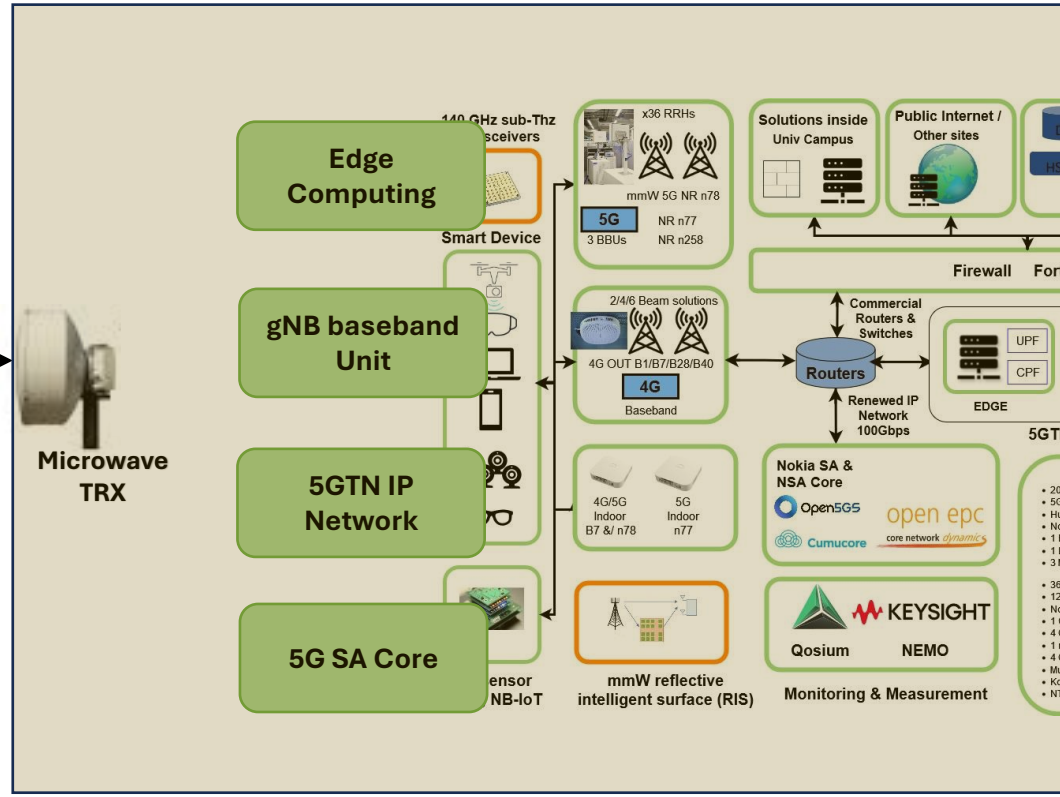
Wireless Data Flow

Wireless Control Flow

Wired Control Flow



Remote Unit Powered By Renewable Energy Sources



5G test Network (5GTN)

XXX

5GTN Resource Consum

Join the 6G Resilience White Paper Community!

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- 40+ Renowned Experts
- 18 Leading Universities and Research Centers

Scan the QR code and register now!

Shape the future of resilient wireless networks.

6G Resilience White Paper - Registration

1 Vision and motivation

1.1 A new paradigm for 6G
1.2 Responding to global challenges
1.3 The research frontier
1.4 From performance to resilience

2 Mobile technologies in critical infrastructures

2.1 Evolution and impact of mobile cellular networks
2.2 The digital device
2.3 Edge cloud continuum
2.4 Intelligent systems for enhanced network resilience
2.5 Interplay between mobile networks and other sectors
2.6 The challenges ahead

3 Mobile network resilience definition

3.1 What is resilience?
3.2 Resilience in wireless networks
3.3 Case studies
3.4 Key insights and perspectives

4 Architectures for resilience

4.1 Resilient architecture foundations
4.2 Programmable and AI-native networks
4.3 Edge-native and localized networks for resilience
4. 4 Multi-access integration
4.5 Summary and architectural guidelines for resilient 6G

5 Technological enablers towards resilience

5.1 Networking techniques
5.2 Artificial intelligence methods and algorithms
5.3 Security & trust designs
5.4 Outlook: toward comprehensive resilience in 6G

6 Techno-economics of resilience 6G system

6.1 Resilience forces - trends and uncertainties
6.2 Techno-economic lenses to explore resilience in 6G
6.3 Business model for resilience design in 6G
6.4 Recommendations – business and regulatory aspects

6G Resilience Summit

Shape the future of resilient wireless networks.

When: 18 – 19 November 2025, Tuesday and Wednesday

Where: Hotel Lasaretti, Oulu, Finland.

6G Resilience Summit

What to Expect

- ✓ Launch of the 6G Resilience White Paper
- ✓ Keynotes & Talks by Government Leaders, Regulators, Academics, and Industry Pioneers
- ✓ Engaging Discussions on Resilience Theory, Architectures, Technological Enablers, and Techno-Economic Aspects of Resilient 6G

https://www.6gflagship.com/6g-resilience-summit/

More than wireless.

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