

# Toward 6G Network Management and Control in Industrial IoT

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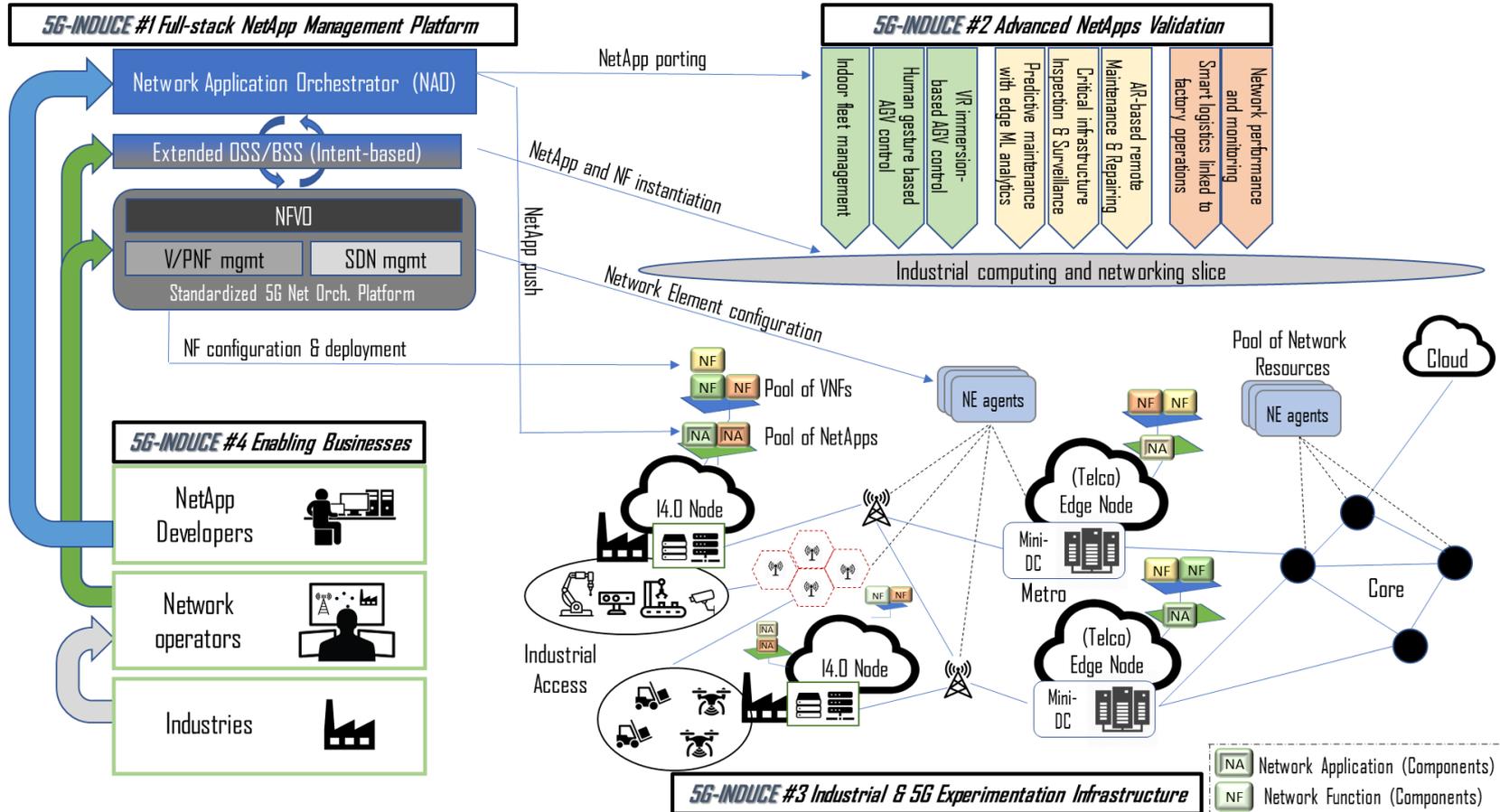
# Beyond 5G: trends in network management and control

- Heterogeneity of vertical applications and of wireless access platforms, along with possibly stringent end-to-end performance requirements pose significant challenges to network management and control paradigms:
  - Architecturally, to ensure a smooth flow of information and ensuing decisions for orchestration, management, and control across the domains of vertical applications, virtual networking abstractions and physical network infrastructure, spanning the cloud/edge/fog continuum
  - Algorithmically, to provide AI/ML as-a-service for autonomous network configuration/adaptation
  - Computationally, to appropriately place, configure and migrate functionalities
  - Sustainability-wise, to trade-off energy consumption and performance to meet desired balance criteria

# Beyond 5G: trends in network management and control

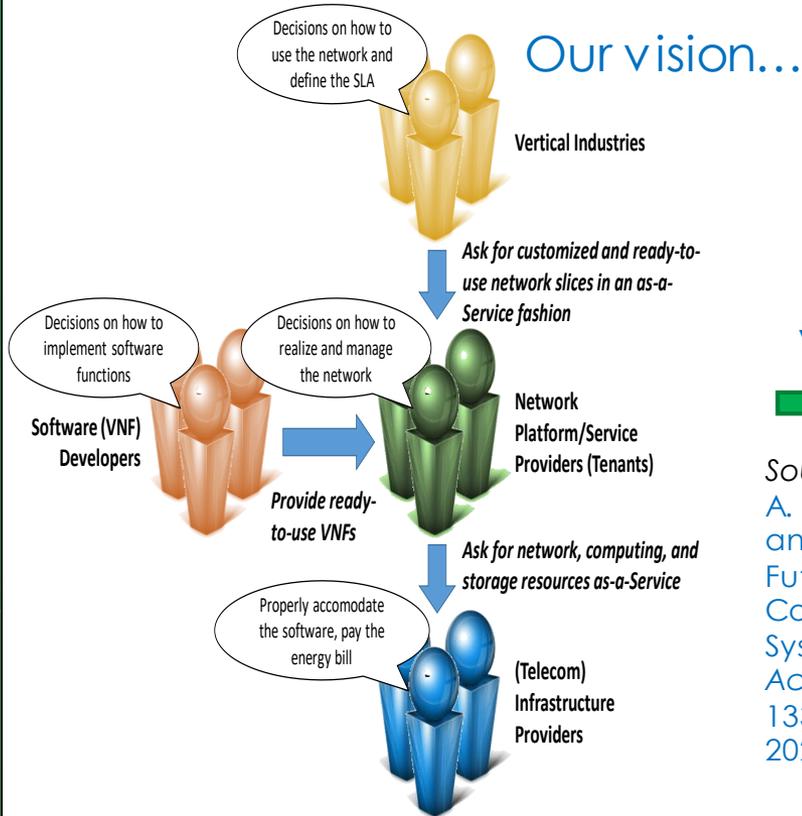
- We address some general aspects, with a special view on Industrial IoT (IIoT) verticals, where these challenges are present, sometimes in conflicting fashion, and with very specific tight characterizations:
  - Very short response times, even below the sub-millisecond range
  - Potentially harsh environments
  - Human-machine interaction
  - Energy consumption constraints, both in terms of field-level devices and of more general network operations

# Architectural separation of concerns



Source: 5G-INDUCE H2020 5G PPP project (2020-2023, 21 partners, CNIT-S2N coordination). 5G-INDUCE targets the development of an open, ETSI NFV compatible, 5G orchestration platform for the deployment of advanced 5G NetApps for Industry 4.0 verticals.

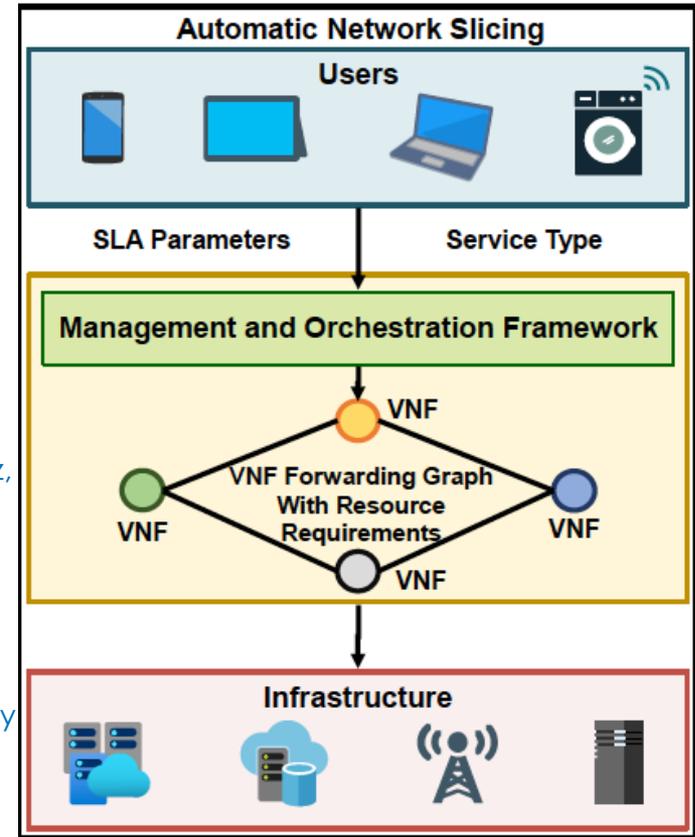
# Toward a more automated network management and control



...in line with



Source: I. F. Akyildiz, A. Kak, S. Nie, "6G and Beyond: The Future of Wireless Communications Systems," *IEEE Access*, vol. 8, pp. 133995-134030, July 2020.



→ **Dynamic resource allocation** – essential aspects:

- New network management & control paradigms
- Energy-efficiency among major **KPIs**, along with performance (**energy-performance tradeoff**)
- Autonomous service deployment capabilities and generation of ensuing network slices and network functions chains

# Role of AI/ML for management and control

In control systems, **Fixed Structure Parametrized Functions** (FSPF – e.g., Neural Networks) are a powerful tool to approximate optimal control techniques in Infinite Dimensional Optimization (IDO), i.e. *functional*, problems.

See: [R. Zoppoli, M. Sanguineti, G. Gnecco, T. Parisini, \*Neural Approximations for Optimal Control and Decision\*, Springer Nature, Cham, Switzerland, 2019.](#)

- Unless applying AI/ML techniques specifically meant to bypass the issue of modeling, we may need to model a VNF in terms of consumption and performance versus load and configuration.
- **In any case, modeling does not prevent the application of AI/ML to the synthesis of complex control strategies.**



**Use models where available to describe the dynamics of the system, and AI/ML to parametrize the functions expressing optimal control strategies as the solution of IDO problems.**

## IIoT scenarios under tight network adaptation time constraints: «fast» and «slow» loops in a hierarchical control architecture

- Sub-millisecond decisions require easily computable control strategies that map local information
- Training/adaptation of parameters of control strategies can be performed at a slower pace
- The presence of multiple time scales suggests a hierarchical structure with multiple control loops, where the coordinator operates by collecting environmental parameters and setting optimization problems over a longer time horizon

# Some takeaways

- Points of attention for further research in the path toward 6G
  - Architectural aspects, perhaps with emphasis to those pertaining to ease the implementation of the low-level management and control chain (low-level APIs; see, e.g., [OneM2M TR-0024-V4.3.0 "3GPP\\_Interworking"](#))
  - Automation and convergence of network management and control
  - Modeling *for* control, where feasible and appropriate
  - Explicit inclusion of energy consumption KPIs, together with
    - Definition of suitable interfaces to convey energy awareness (recent ETSI / ITU-T docs to extend the GAL – Green Abstraction Layer – standard to virtualized environments)
    - Investigation of AI/ML energy requirements
  - Role of AI/ML at different architectural layers
  - Evolution toward Machine Reasoning (role of Bayesian Networks?)

## From 5G to 6G ecosystem – research questions

**Anastasius Gavras, Eurescom**

**Hanne-Stine Hallingby, Telenor**

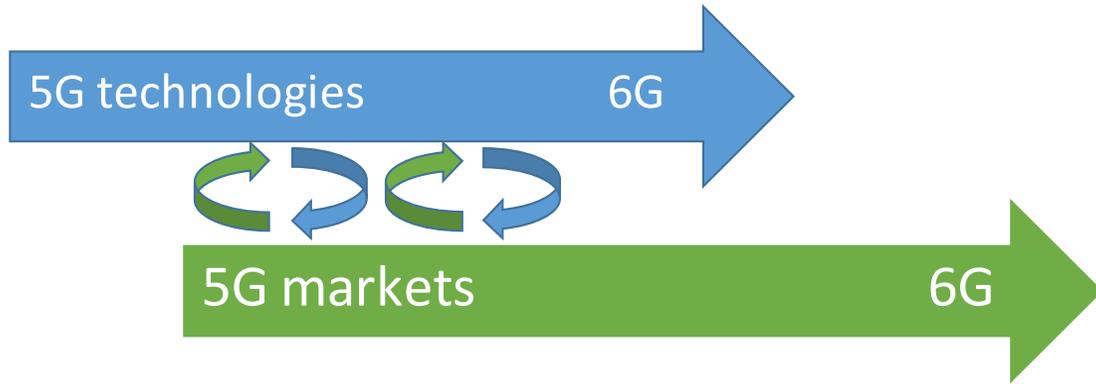
**Håkon Lønsethagen, Telenor**

**Ioanna Mesogiti, COSMOTE**

**Working Group**

**Business Validation, Models and Ecosystems sub-group**

# Technology evolves quickly; markets follow at slower pace

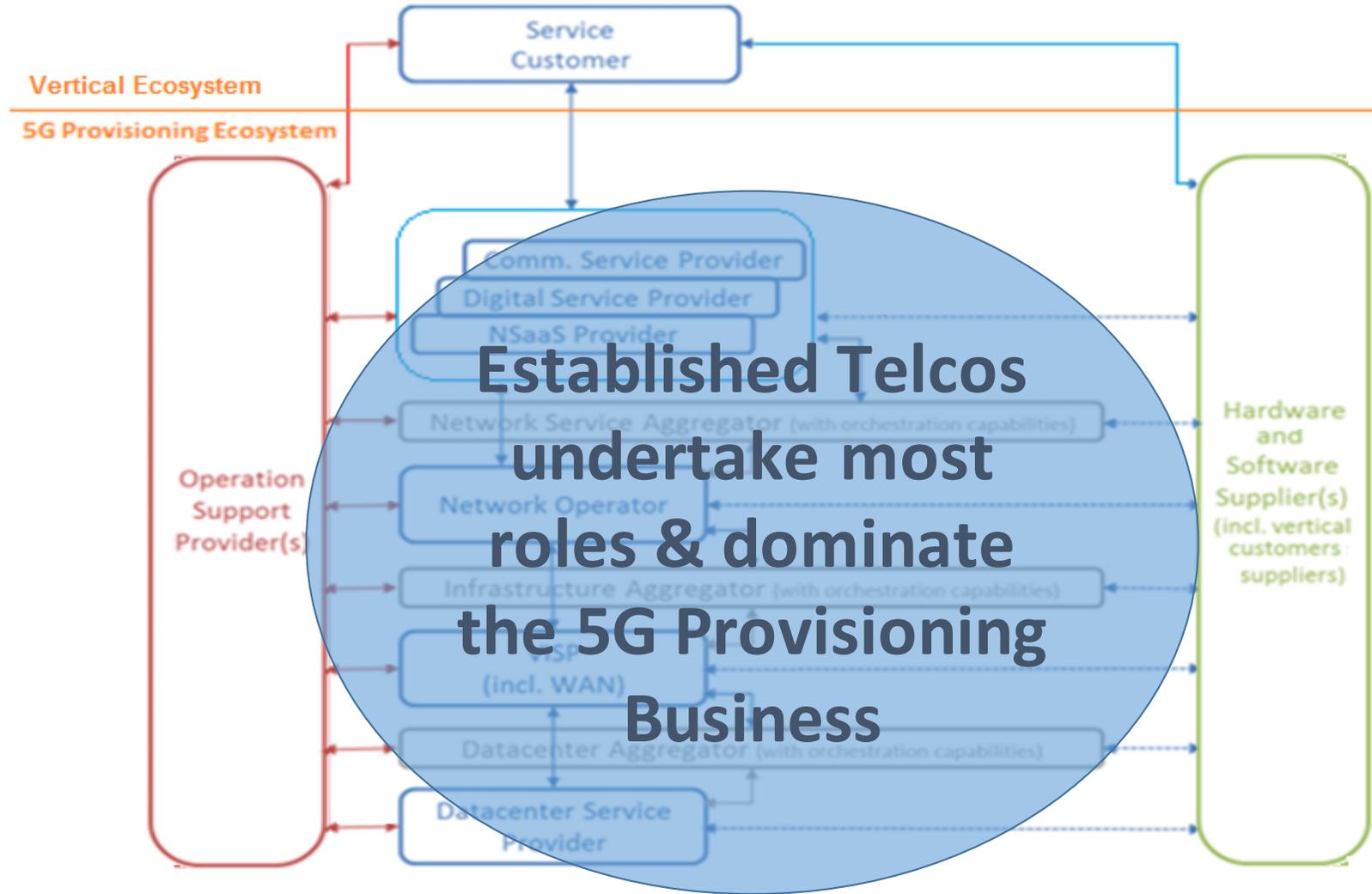


- Markets determine technologies' roadmap and adoption
- Market outlook should motivate applied research to address high impact challenges
- 6G implies building on 5G, yet the business environment is still uncertain concerning fully-fledged 5G deployments

Key question:

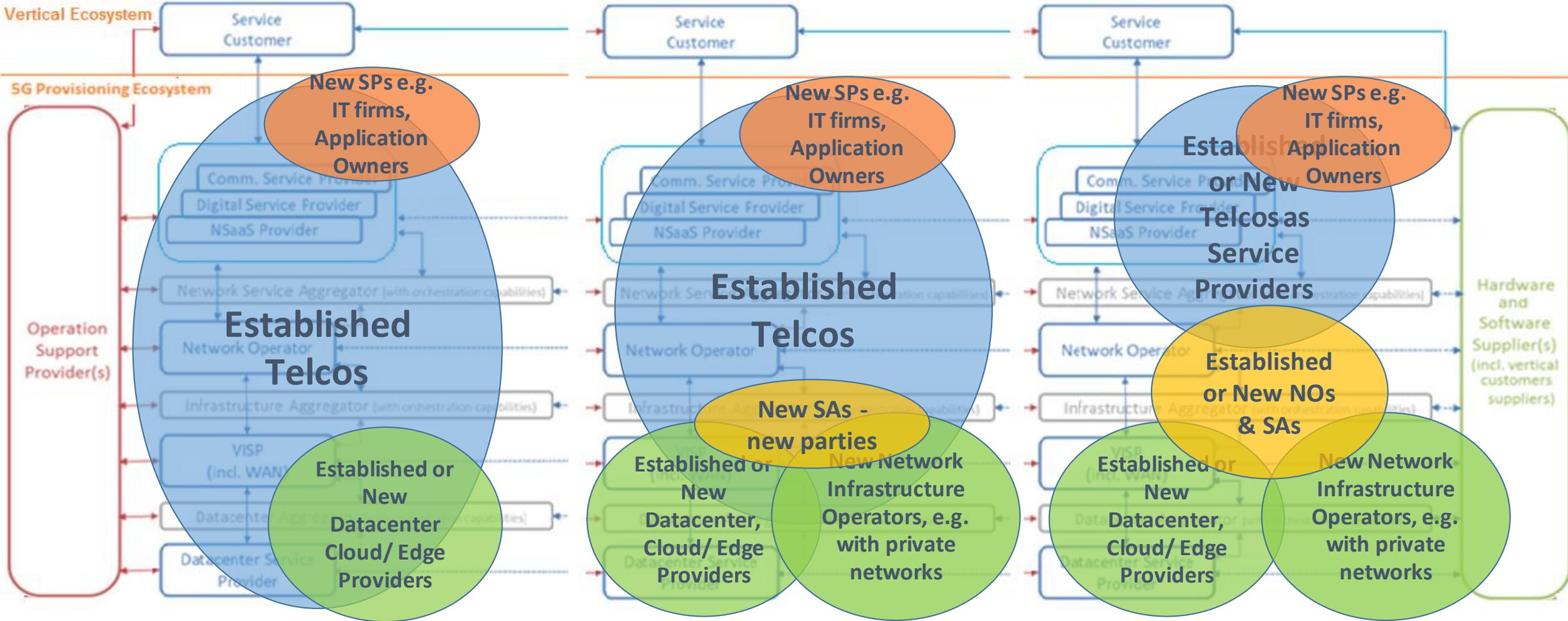
**How to drive 6G technologies with a technology vision, and at the same time develop the market so that it is ready to adopt innovations?**

# Stakeholders and Roles of Service Provisioning in 5G Era – Initial Stage

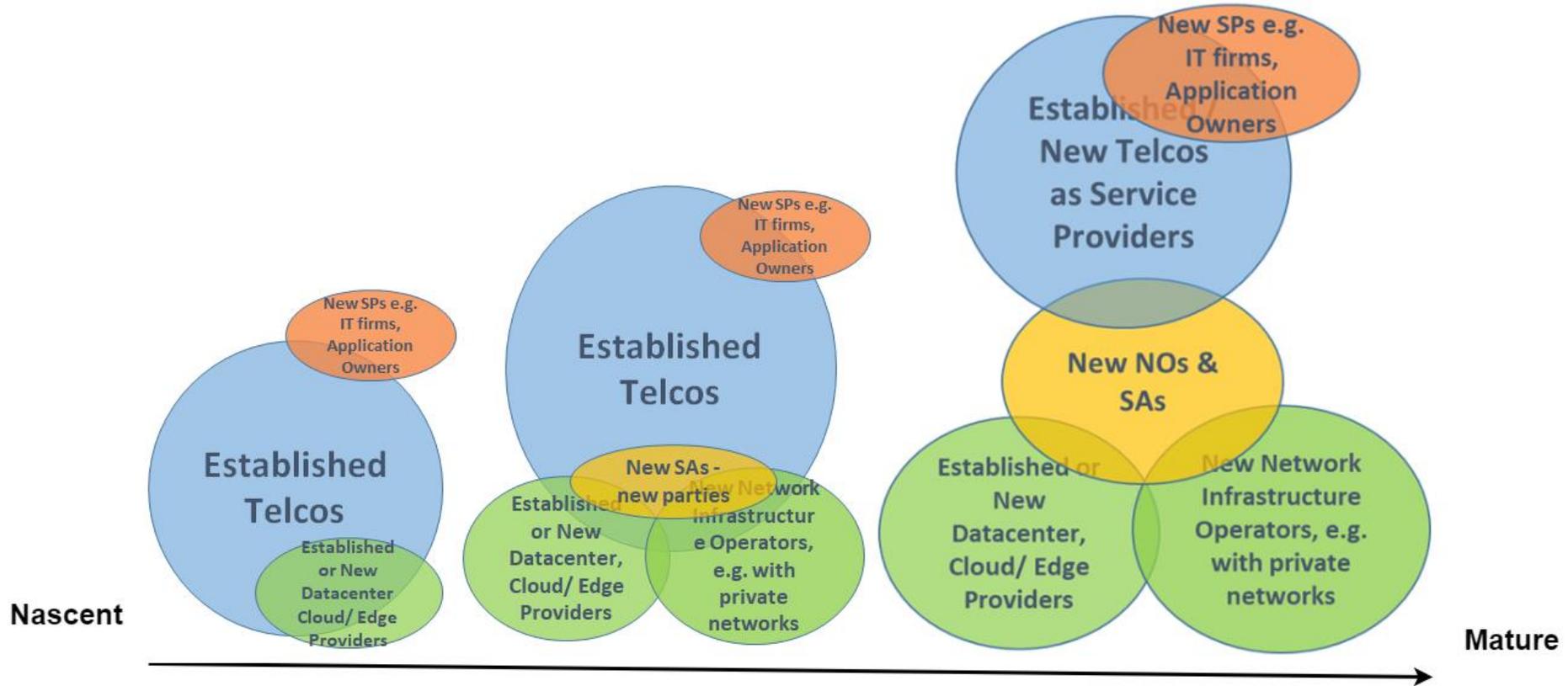




# Potential Formulations of Developed 5G Provisioning Ecosystems

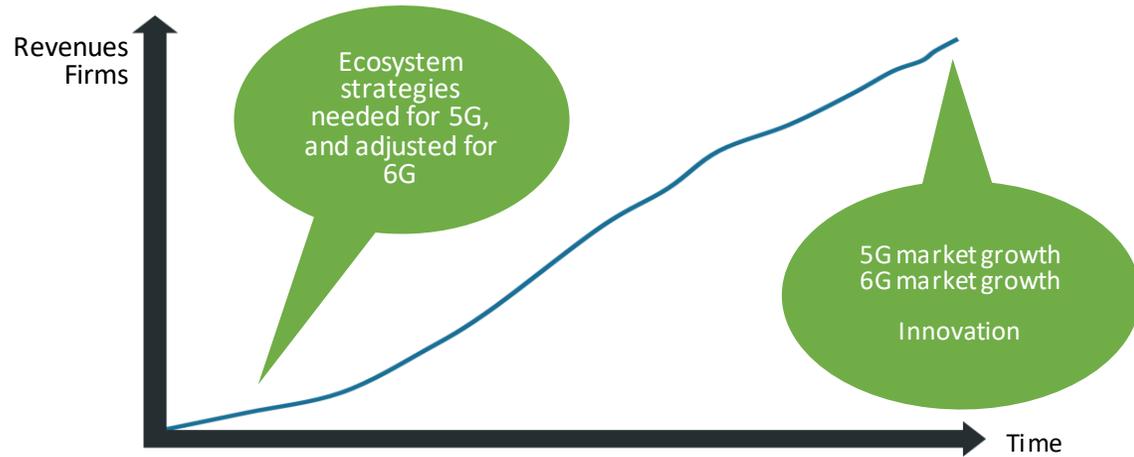


# Pathways of Growth for 5G Provisioning Ecosystems as Baseline for 6G



<b>Size</b>	<b>Small</b>	<b>Large</b>
<b>Actors</b>	<b>Few</b>	<b>Many</b>
<b>Roles</b>	<b>Needed roles start to emerge</b>	<b>Roles Settled</b>
<b>Central Role</b>	<b>Not settled</b>	<b>Platform role</b>
<b>Relationships</b>	<b>Sparcely Connected</b>	<b>Well Connected A few central roles</b>

# 5G and 6G ecosystems grow from small to large



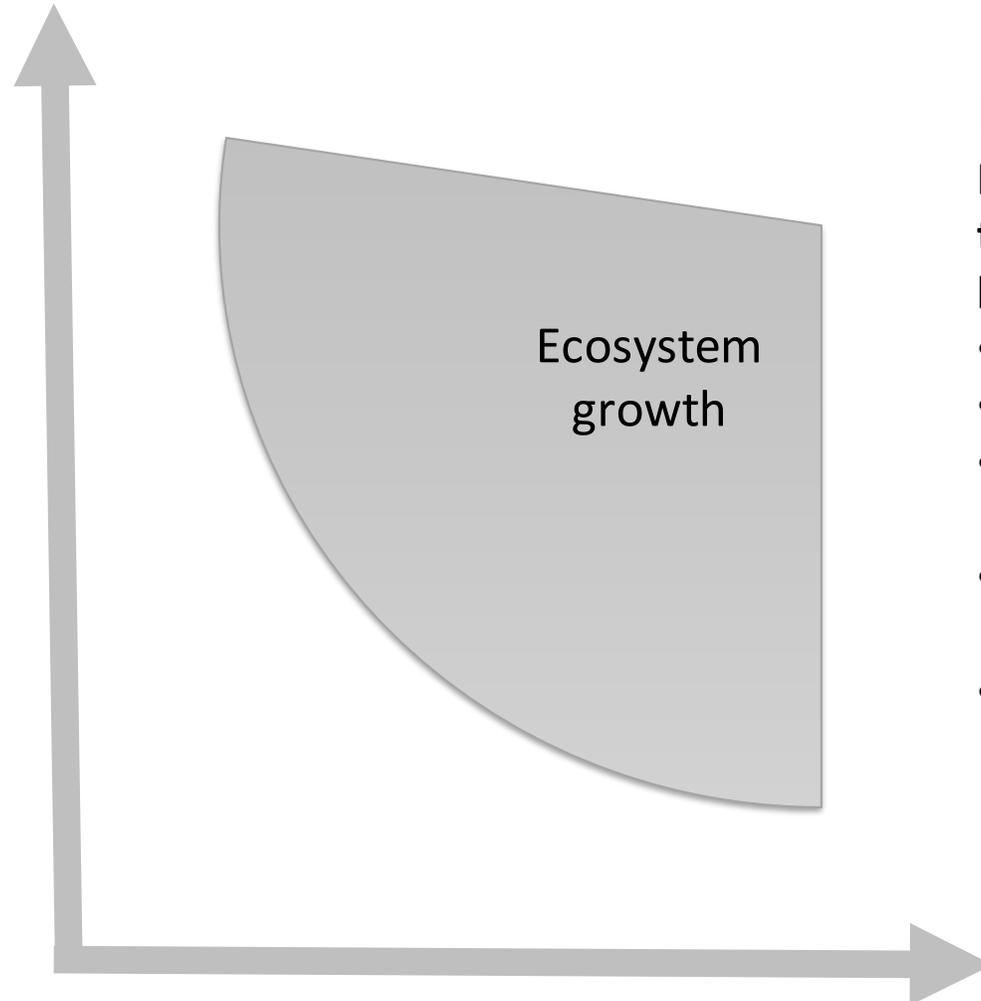
- The ecosystem approach as means to maximize growth and foster innovation can be considered appropriate for 6G
- The ecosystem characteristics, promises, and challenges continue into the 6G era
- Address challenges and consider technology advancements facilitating and fostering ecosystem strategies
- Make it *easy to innovate* and deliver jointly
- Make it *attractive* for actors *to join* an ecosystem

# Strategies for growing Ecosystems

## Make it attractive

### Decrease risk from collaboration

- Clear roles
- Trust in central actors who drive ecosystem
- Predictability in how roles are filled
- Predictability in revenue sharing between roles
- System for sanctions may exist



## Make it easy

### Increase ability to innovate through access to APIs and learning effects

- Available APIs
- Smooth developer journeys
- Developer kits, documentation, communities
- Trust and engagement towards firm providing APIs
- Clear and shared understanding of distribution of IPR and knowledge for firms' value proposition

# Identified Challenges to drive Research Topics in 6G Ecosystems

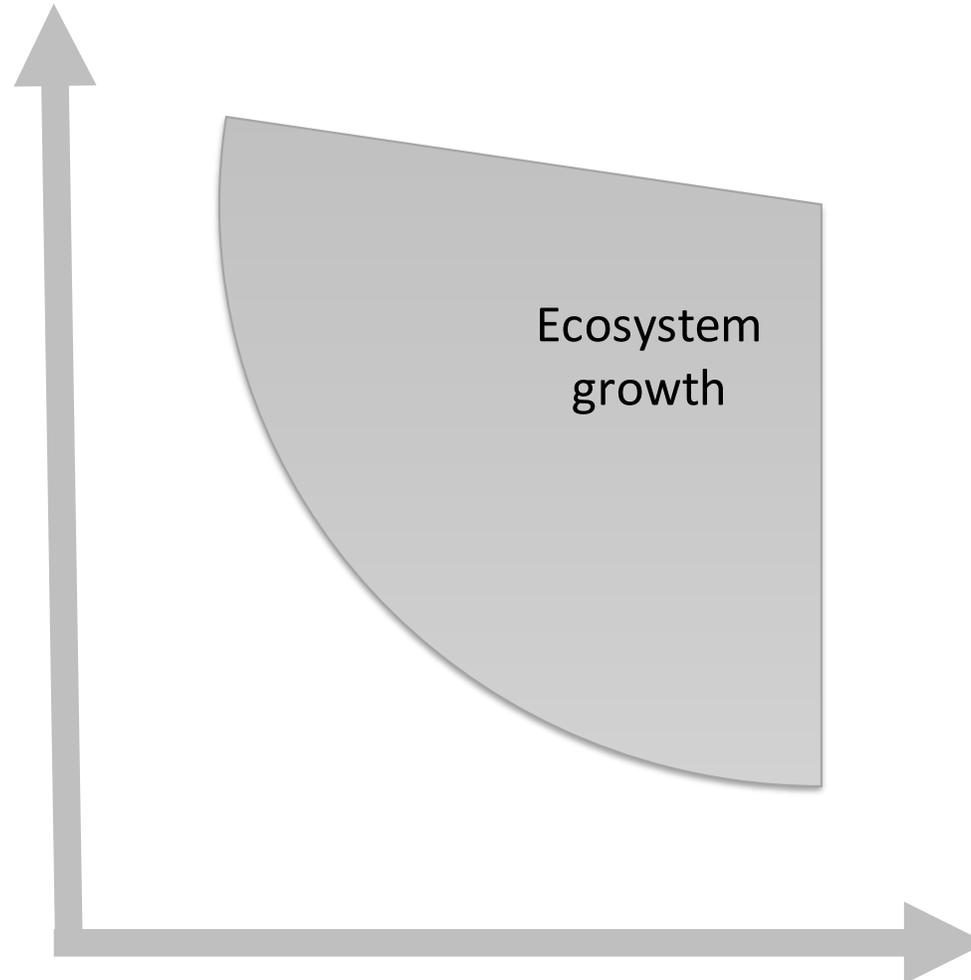
## Make it attractive

### *Provisioning Perspective:*

- Ecosystem governance
- Manage legacy from 5G
- Increase trust and decrease perceived risks
- Stage investments
- Securing investment by balancing profits regarding open SW and IPR

### *End-User Perspective:*

- Engage with end-users
- Provide end-to-end SLAs over multiple layers



## Make it easy

### *Technical:*

- Openness of interfaces
- Service and network accessibility
- Interoperability
- Align technical interfaces with business interactions and agreements

### *Market – Policies:*

- Mobilize actors
- Foster Ecosystem Policies
- Stable regulatory environment

# The benefits of 6G experimental infrastructures

## Make it attractive

- Roles
- Benefits and risks for all roles
- Trust
- Formulation of 6G ecosystems
- Governance mechanisms



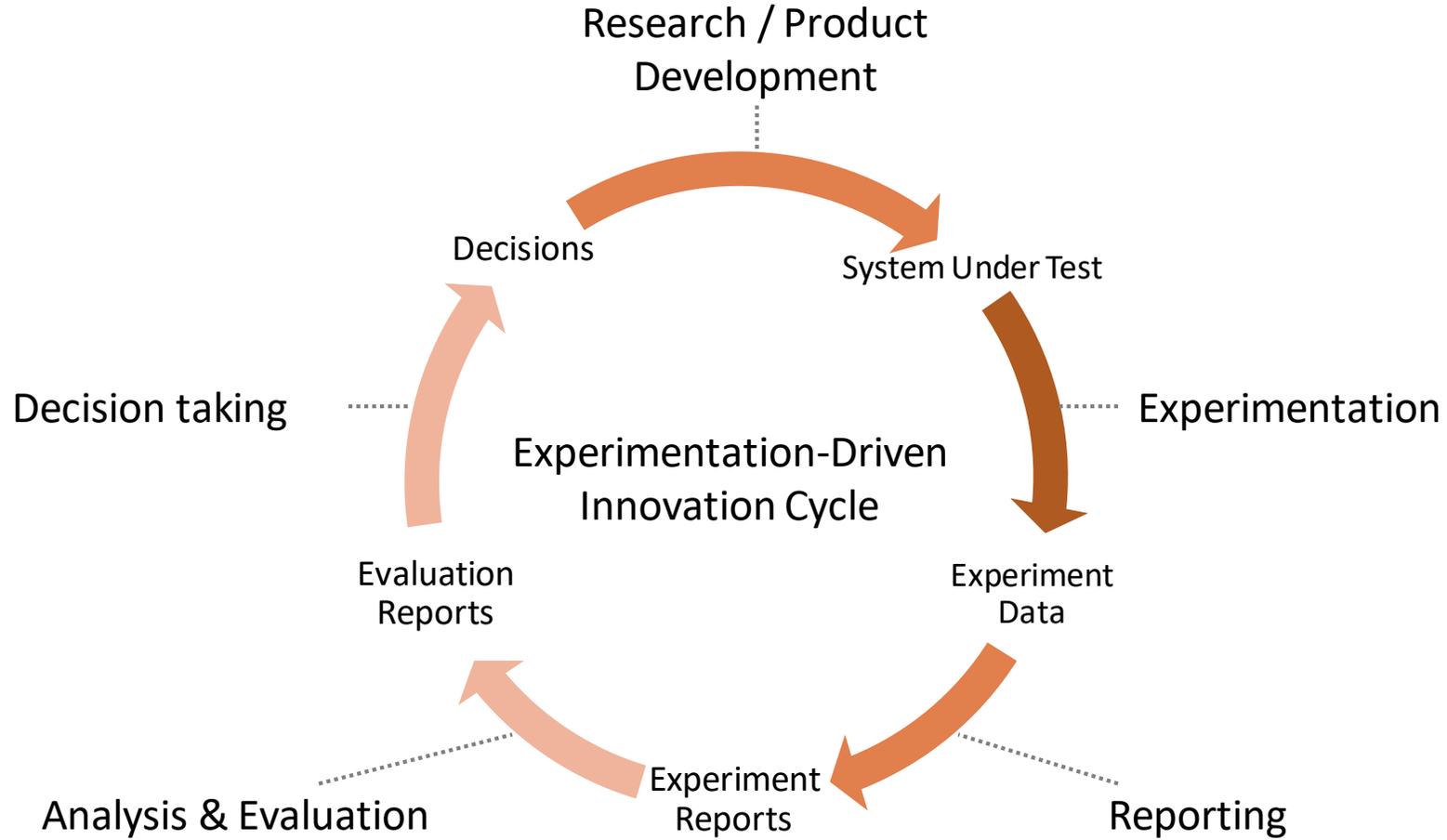
## Make it easy

- Enabling structures
- Evaluation of technology
- Validation of impact
- Knowledge building and sharing
- Significance of openness and accessibility

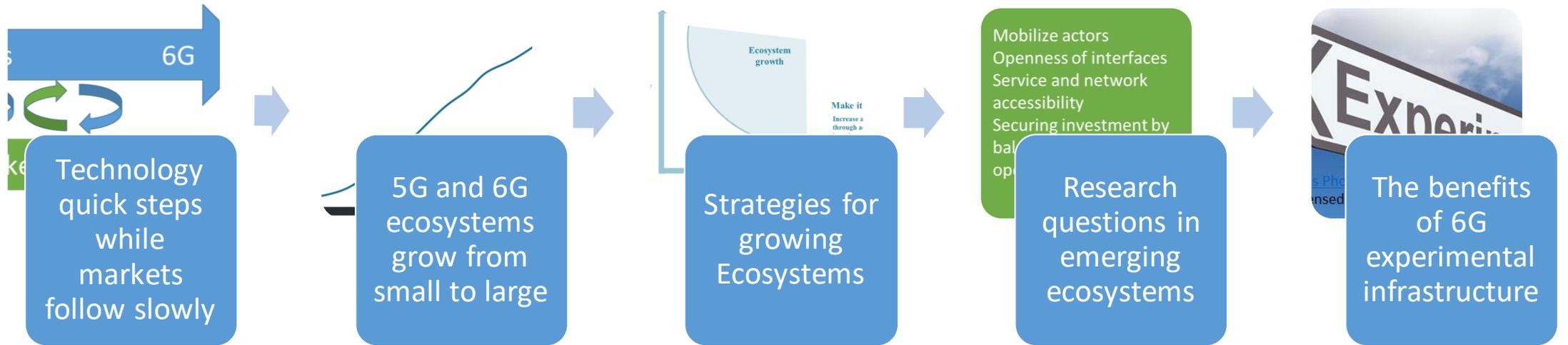
# Aspects for consideration in 6G Experimental Infrastructure

- The motivation for experimentation infrastructures is guided by the need to trial and evaluate service concepts, technologies, system solutions and business models to the point, where the risks associated with launching them in the market is minimised.
- How do experimentation infrastructures enable the formulation of the 6G ecosystem?
  - Which structures better enable the evaluation of technology benefits from the perspective of all business roles?
  - Which structures enable validation of technology impact on various sectors, the environment, data etc.?
  - Can experimentation infrastructures become a governance mechanisms and drive 6G innovations?

# Experimentation-driven innovation



# Summary



# 5G ecosystems white paper

## 5G - Business Ecosystems

- What it is
- Ecosystem strategies
- Two 5G ecosystems

## The 5G Provisioning Ecosystem

- Roles in the 5G provisioning ecosystem
- Formulation of 5G provisioning ecosystem
- Challenges in the development of 5G ecosystems

## The 5G vertical ecosystem

- Roles in the 5G vertical ecosystem
- 5G vertical ecosystem examples

## Challenges for the 5G ecosystems



## 5G ecosystems

2021

Date: 2020-09-09

Version: 1.0

DOI 10.5281/zenodo.5094340

URL <http://doi.org/10.5281/zenodo.5094340>

<http://doi.org/10.5281/zenodo.5094340>

# Societal Needs and Value Creation

## New subgroup under the 5G-IA/6G-IA (SNS)

- New SG within 6G-IA Vision and Societal Challenges WG
- The plan for the SG is to:
  - *Establish itself as a forum for value-based discussions on 6G with focus on societal challenges*
  - *Start preparation of a White Paper on key 6G problems and solutions from a societal angle*
    - *Scope: What will 6G bring? Focus on value-add for people. Enabled services and expected impact, definition of KVIs*
    - *Cite use cases from existing sources, analyse in KVI framework [What it gives]*
    - *Break down KVIs into clear requirements/capabilities for networks [What it takes]*
- Contact: Gustav Wikström, Ericsson Research ([gustav.wikstrom@ericsson.com](mailto:gustav.wikstrom@ericsson.com))

# Scope of group – What does 6G bring?

- 6G use case visions, enabled by 6G and related / adjacent technology
  - New opportunities that 6G opens – new types of services and applications
  - Perspectives and benefits for verticals and consumers – human factor



Vertical evolution

Service revolution

Human in the center



Clear value-add

- ICT for sustainability – how 6G can enable reduced footprint in other sectors, how digital inclusion can be addressed, how societal challenges can be addressed
  - Also account for footprint cost of ICT solutions (but not how to minimize this)
  - Societal added values (saved lives, etc.) – human factor
  - Find what can be addressed, and how much
  - Define clear KVIs



Environmental enabling effect

Socio-economical enabling effect



# 6G FOR SOCIETY



Tommy Svensson  
Chalmers U.



Patrik Rugeland  
Ericsson Research



Andreas Wolfgang  
Qamcom



Gustav Wikström  
Ericsson Research



Third Visions for Future Communications Summit  
Strengthening the Path Towards 6G

24-25th November 2021  
Lisbon, Portugal

# SWEDISH 6G WORKSHOP



## 6G FOR SOCIETY 2021



**CHALMERS**  
UNIVERSITY OF TECHNOLOGY



**ERICSSON**



Hexa-X



**IEEE** IEEE Sweden VT/COM/IT Chapter  
Vehicular Technology/ Communications/Information Theory



**IEEE ComSoc**  
IEEE Communications Society



**WIRELESS WORLD**

**RESEARCH FORUM**

# Background



- The development towards 6G, with the European research initiative [Hexa-X](#), is ramping up.
- 6G will be naturally placed in a context of society striving towards sustainability, and it is key to understand how 6G would fit in and enable such a transformation.
- As societies become more reliant on wireless connectivity, the trustworthiness of the communication system is essential, and the digital inclusion of everyone is critical, especially in a post-pandemic society.
- In October, the Swedish Hexa-X members **Chalmers**, **Ericsson**, and **Qamcom** organized an [online workshop](#) to discuss how 6G can contribute to societal targets of **sustainability**, **trustworthiness**, and **digital inclusion** in three dedicated sessions following an opening session on the state of **6G research and vision**.
- Invited presenters joined from academia, industry, and Swedish public sector and shared their view on what the relevant societal challenges and possibilities are for wireless networks going towards 2030.

# 6G and society? 6G for society!

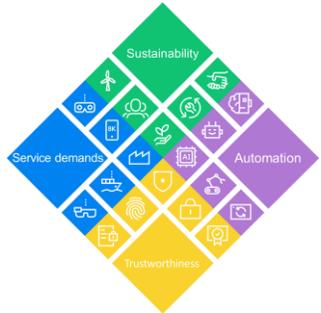


- 6G should not just be integrated into society, it should aim at solving important challenges
- **Sustainability challenge:**  
how can environmental footprints be reduced and how do we enable the SDGs?
- **Digital inclusion challenge:**  
how do we bring the digital benefits to as many as possible?
- **Trust challenge:**  
how can critical and sensitive services be ensured in a digital society?



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## 6G vision and key values



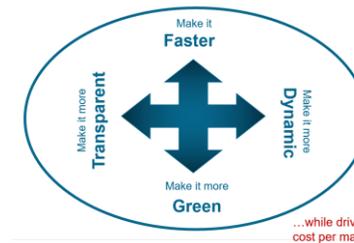
### Expectations on 5G & 6G

- Spectrum
  - Even higher speeds and lower latency!
  - Low speed and low energy consumption, if any?
- SCEF, NEF and so on... APIs is crucial going forward
- Being on the Edge! Lower latency and energy consumption by handling data close to the customer
- Fixed and mobile convergence taken one step further with SD-WAN, Edge and so on...
- Roaming - How to handle complex use cases when not in home network? Commercial or technical question?



### My six "provocations" ...

- Governance
- Geopolitics
- Human integrity
- Inclusion
- Accountability
- Rhythms & temporalities



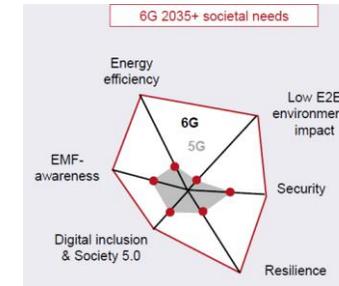
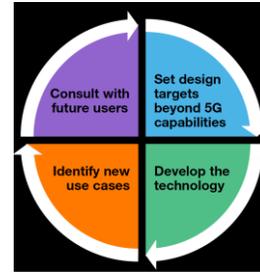
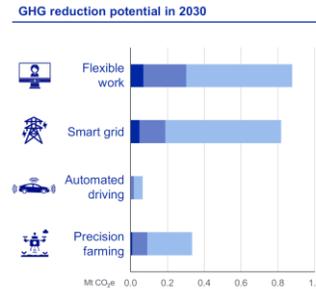
...while driving down the cost per managed bit



- 6G: more of everything, but should enable advanced new use cases
  - Common trends: immersive interaction, integrated intelligence, further automation
  - 6G must address future challenges and not add to them!

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## Sustainability

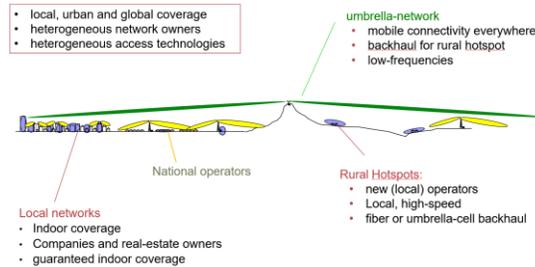
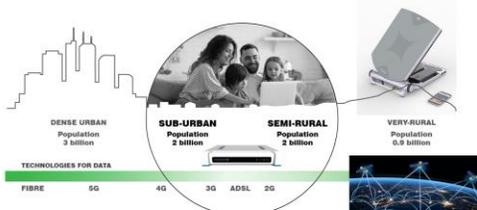


- Develop 6G requirements in line with the UN SDGs, avoid cherry picking, involve innovative SMEs
- Aim for Sufficiency rather than Efficiency design metrics for 6G
- Innovation in circular material flows and modular HW-SW design with flexible design borders
- Digitalization show potential for large Indirect effects, beware of Rebound effects
- Foster Sustainability mind-set within key actor organizations, the educational system could help

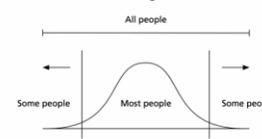
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## Digital inclusion

4 billion underserved, only 15% terrestrial coverage



"If we understand what the extremes are, the middle will take care of itself" (Dan Formosa, PhD, Smart Design, from the documentary Objectified)



In the margins, among "Extreme users" and "Extreme scenarios", there are plenty of information, inspiration and innovation.  
Ex.: 8 80 Cities, <https://www.880cities.org>

Digital ethics?

- Rapid technology development and increasingly complex systems make risk assessment and evaluation difficult ahead of full-scale deployment
- There is no strong ethical tradition among engineers and computer scientists (compared to e.g. healthcare and journalism)
- How will so-called Lawful Interception be implemented in 6G, and what are the implications?



- 6G has the opportunity to bridge the digital divide, instead of widening it
- It's not primarily a technical problem – rather political, economic, societal challenge
- Will require concerted efforts from R&D, industry and regulators to make it happen
- We shouldn't wait for 6G to address digital inclusion, we can start now!

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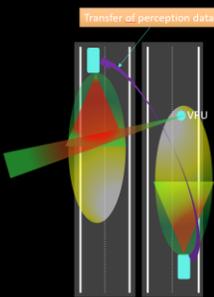
## Trustworthiness

**6G – the challenge**

- ✓ How does this fit into the development process and legal framework currently applied in safety critical applications?
- ✓ Does 6G guarantee reliability?
- ✓ Who takes responsibility for cyber security?

Today a car is an isolated system.

With 6G, will there be a single safety system consisting of autonomous cars/robots and infrastructure?



### 6 Generalizations

1. Not everything will be new, need to work with legacy
2. Even security improvements can create security problems
3. We underestimate the human factor
4. Moving targets are unavoidable
5. Security and privacy have a perception problem
6. Trustworthy systems: need to talk more about HOW

Limitless connectivity  
for good and bad guys!



The asymmetric dilemma:

The defenders need to succeed every time -  
the attackers only need to succeed once!



- In order for 6G be perceived trustworthy by other ecosystems collaboration is needed
- Security problem becomes more difficult with the increased attack surface
- Reliability/Robustness and Security go hand in hand

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## Conclusion

- Useful to collect problem descriptions from partners in society
- Critical eyes of academia healthy for seeing beyond market logic
- No sharp recipes yet but common understanding of challenges
- Need to reflect society challenges in 6G requirements

# SWEDISH 6G WORKSHOP

Thank you!  
/co-organizers



Tommy Svensson  
Chalmers U.



Patrik Rugeland  
Ericsson Research



Andreas Wolfgang  
Qamcom



Gustav Wikström  
Ericsson Research

**6G FOR SOCIETY 2021**



# How to create societal value-compatible telecommunication architectures?

Holger Karl –  
based on and with input from panel discussion at NetSys 2021

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## What to research?

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- Telecommunication systems need to work around the world
- Economy of scale mandates one solution
  
- They span across vastly different legal, social, ethical systems, regulatory approaches
  
- **Option 1:** One solution as intersection of all regulations
  - Most restrictive system; perhaps commercially most viable
  - Might be compatible with only subset of countries
    - **Danger:** freer countries are pushed towards more restrictive system
  
- Not just OTT, also telcos themselves

### Networks and software

Holger Karl,  
Research School Fall  
Retreat 2021  
Slide 2

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## What to research?

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- **Option 2:** Architecture that can adapt to different regulations
  - Transparently! Make decisions, tradeoffs explicit
    - E.g., censorship
  - Make borderlines explicit; explain negotiations, tussles
  
- Possible approach: One architecture with “value plugins”?

### **Networks and software**

Holger Karl,  
Research School Fall  
Retreat 2021  
Slide **3**

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## Why is it important?

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- Isn't it obvious that values are at stake?
  - Censorship, misinformation, ...
- Hope: Increase trust in infrastructure
- **Challenges**
  - How to communicate to laypeople?
  - How to make that auditable?
  - "Explainable architectures"?
  - ...

### **Networks and software**

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## Previous indications of potential?

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- Not too many
- It runs counter to state interests and business interests

### **Networks and software**

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Slide **5**

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## Impact on other areas?

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- Tons of impact:
  - Business models of telcos and OTT
  - Security, privacy, ...



# 5G Network Functionality Exposure for Industrial Sectors

Dr. Fiona Williams, Ericsson Germany

Dr. Gergely Seres, Ericsson Hungary

November 25, 2021

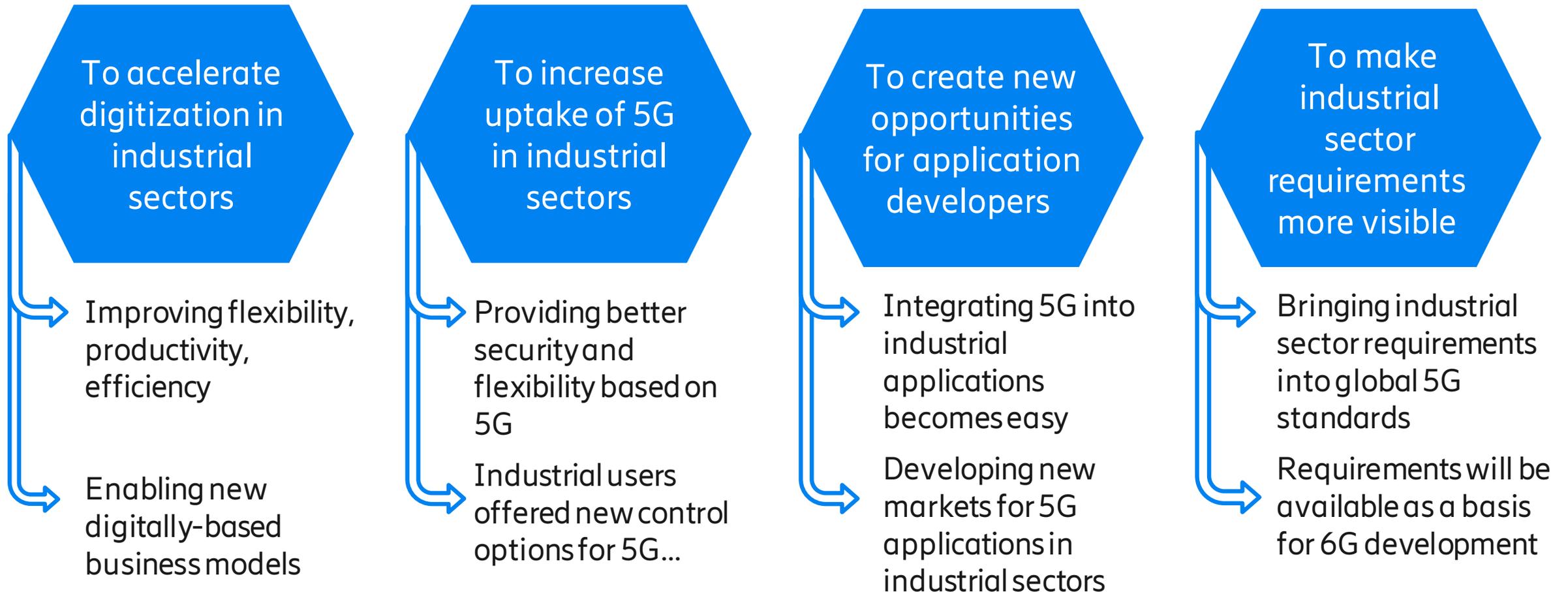
# New network functionality exposure APIs for **simplicity** for industrial sector users!



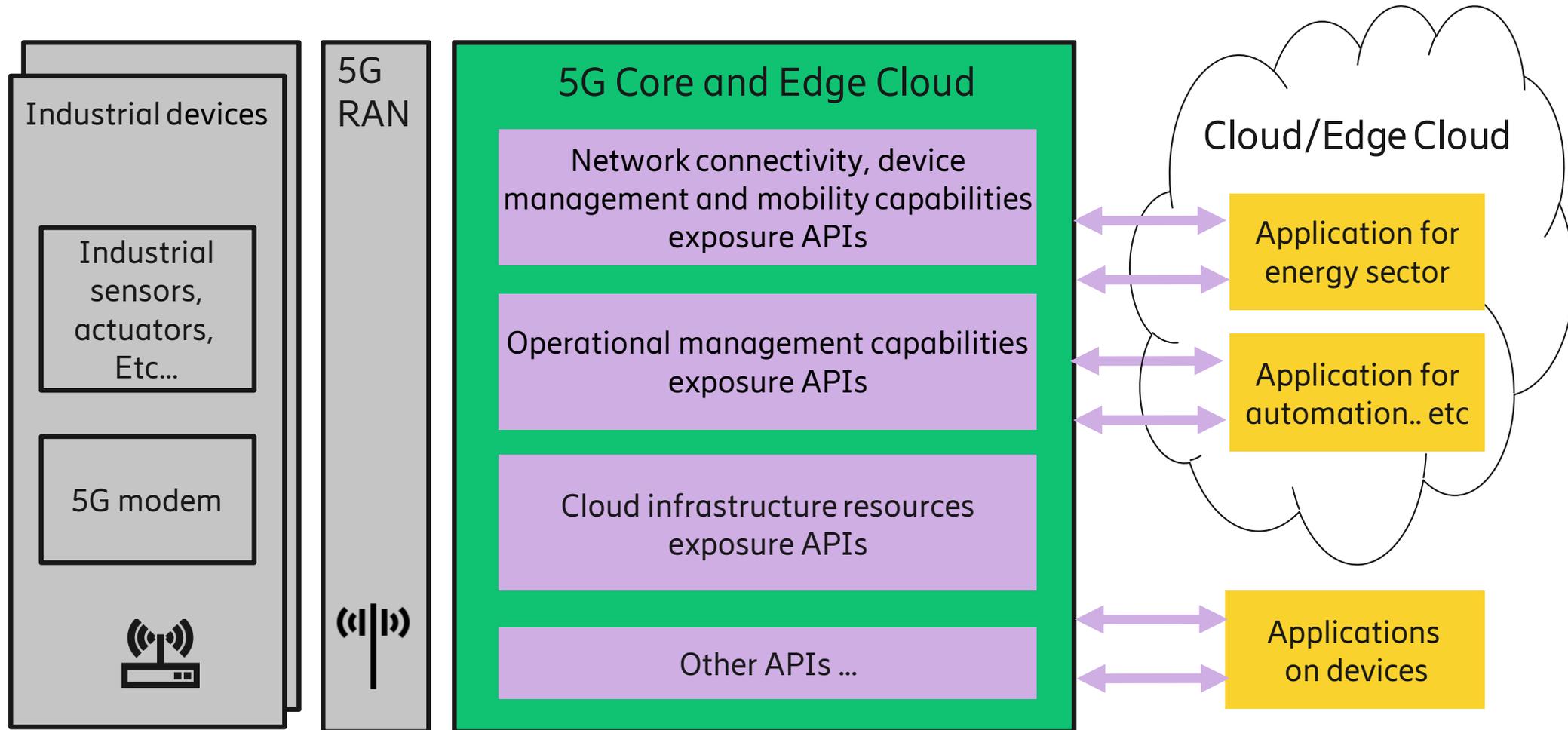
- Why do industrial sectors need tailored network exposure APIs?
- What are network exposure APIs?
- What research is needed?
- How will results impact 5G & 6G?
- How will the results make 5G & 6G easier to use?



# Why do industrial sectors need tailored network exposure APIs?



# What are network exposure APIs?



# What research is needed?

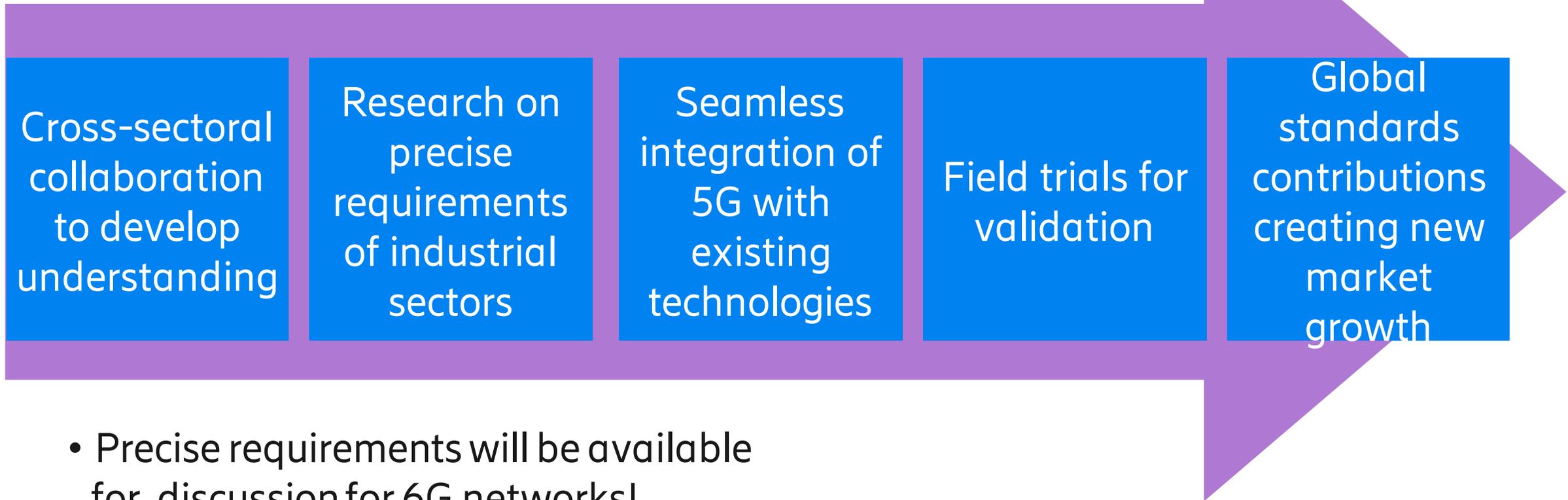


- Investigation of the API requirements of industrial sectors
- Research on automation of current manual tasks around building and reconfiguring industrial systems
- Integration of 5G wireless access into existing IT/Operational Technology systems
- Prototyping of new API functionality
- Organisation of field trials to validate the new functionality with industrial sector actors
- Preparation of standards input on the new API functionality and the requirements

# How will results impact on 5G and 6G?



- New functionality can be added to current 5G networks!



- Precise requirements will be available for discussion for 6G networks!

# How will the results make 5G & 6G easier to use for industrial sector users? ☰

- Industrial sector users will be able to **quickly start using 5G** without spending time learning about the detail of 5G networks!
- The effort required to integrate 5G networks with industrial IT systems, IoT platforms, automation tools and IoT devices will **significantly decrease!**



