

5G-Era and Beyond: *Small Cell Industry Perspectives*

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Chair - Small Cell Forum

BWAC Keynote Address, Mon-09-Nov-2020

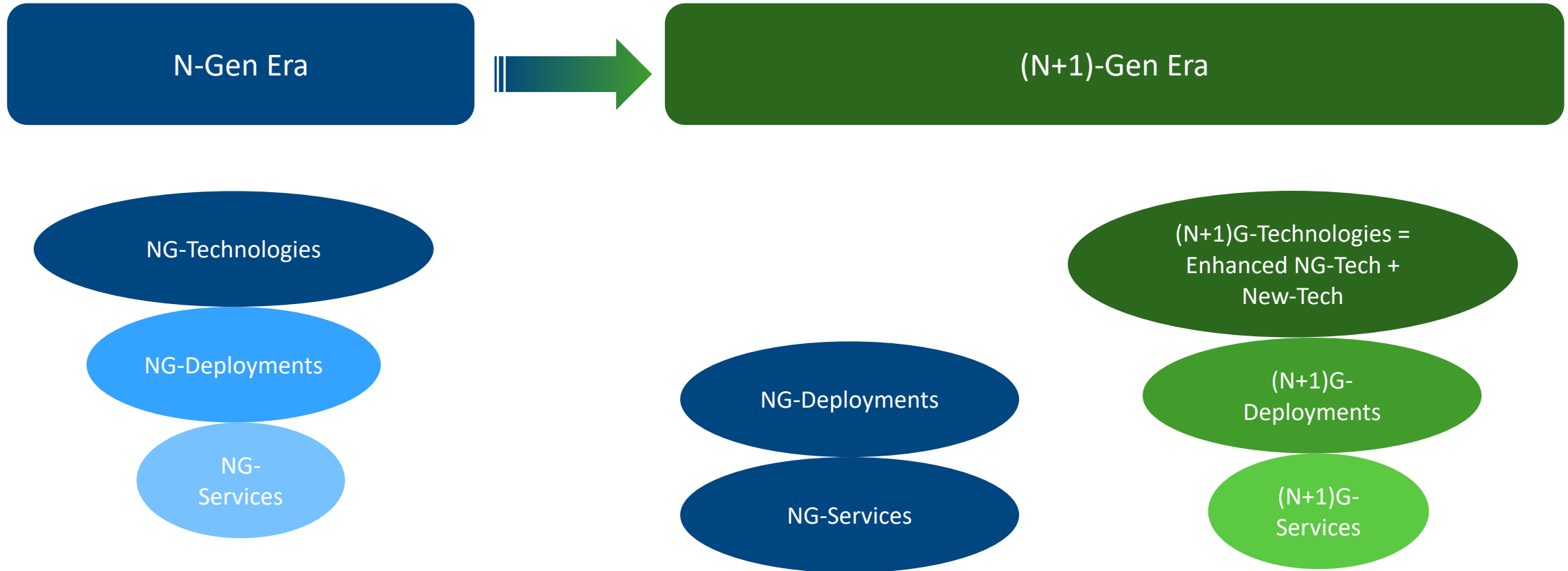


Outline

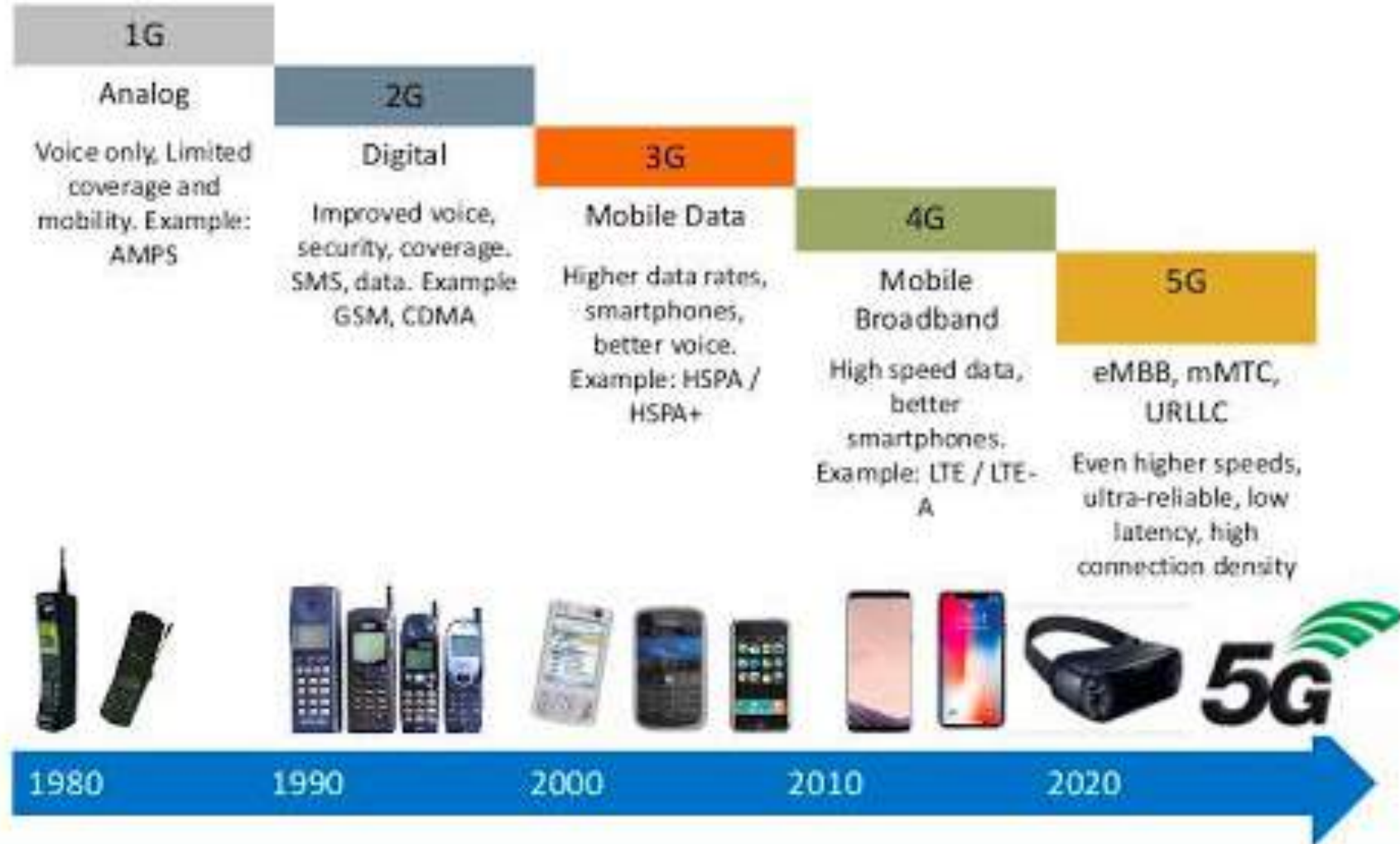
- Evolution to Wireless Generations
- 5G-Era and Small Cells
- Small Cells and Small Cell Networks
 - Disaggregated, virtualized, open RAN/SCNs
- Edge Computing & Small Cells
- Evolving Mobile Ecosystem
 - Neutral Host Networks
- 5G-Era Status & Visions of 6G
- Small Cell Forum



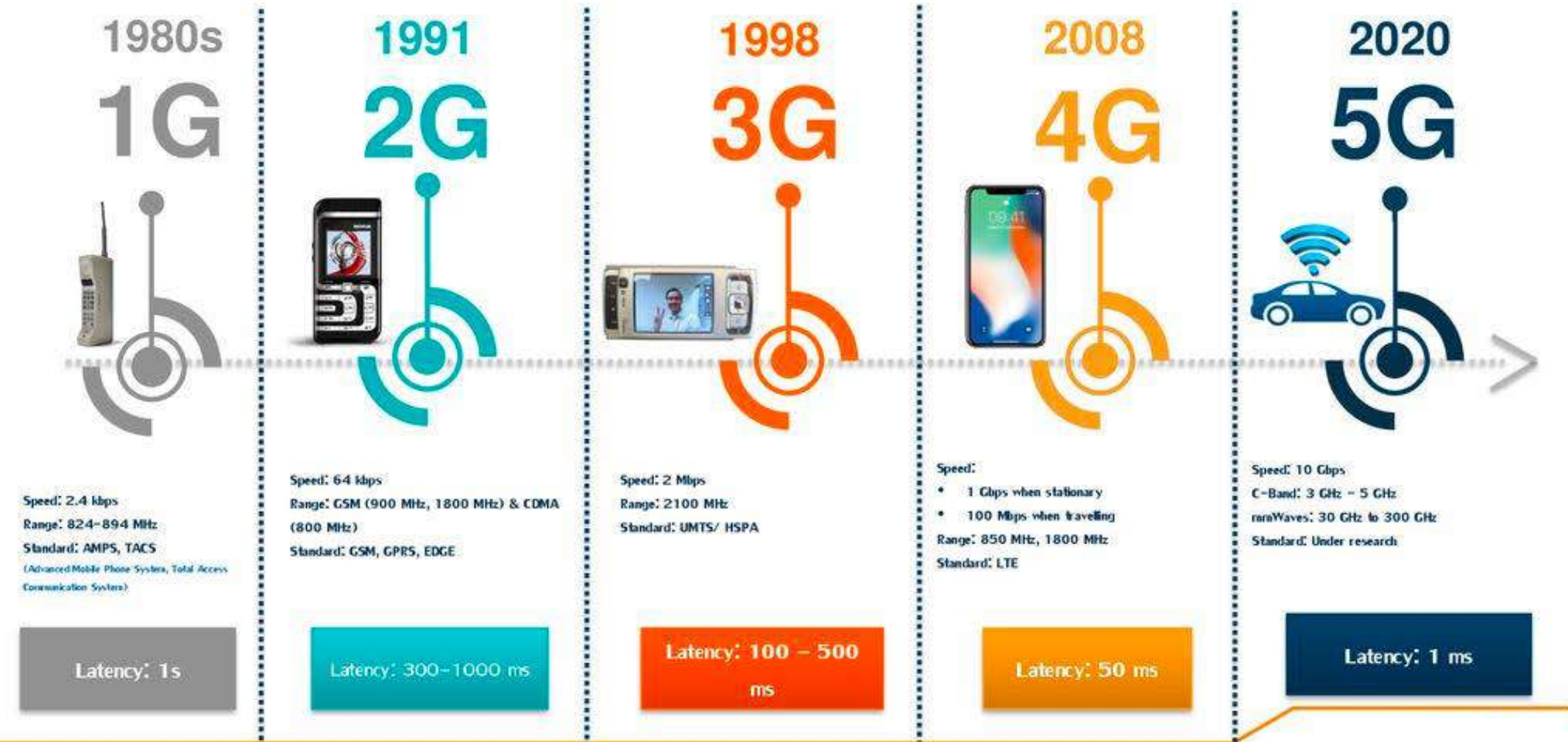
Progression of Wireless Generational Eras



Evolution to 5G

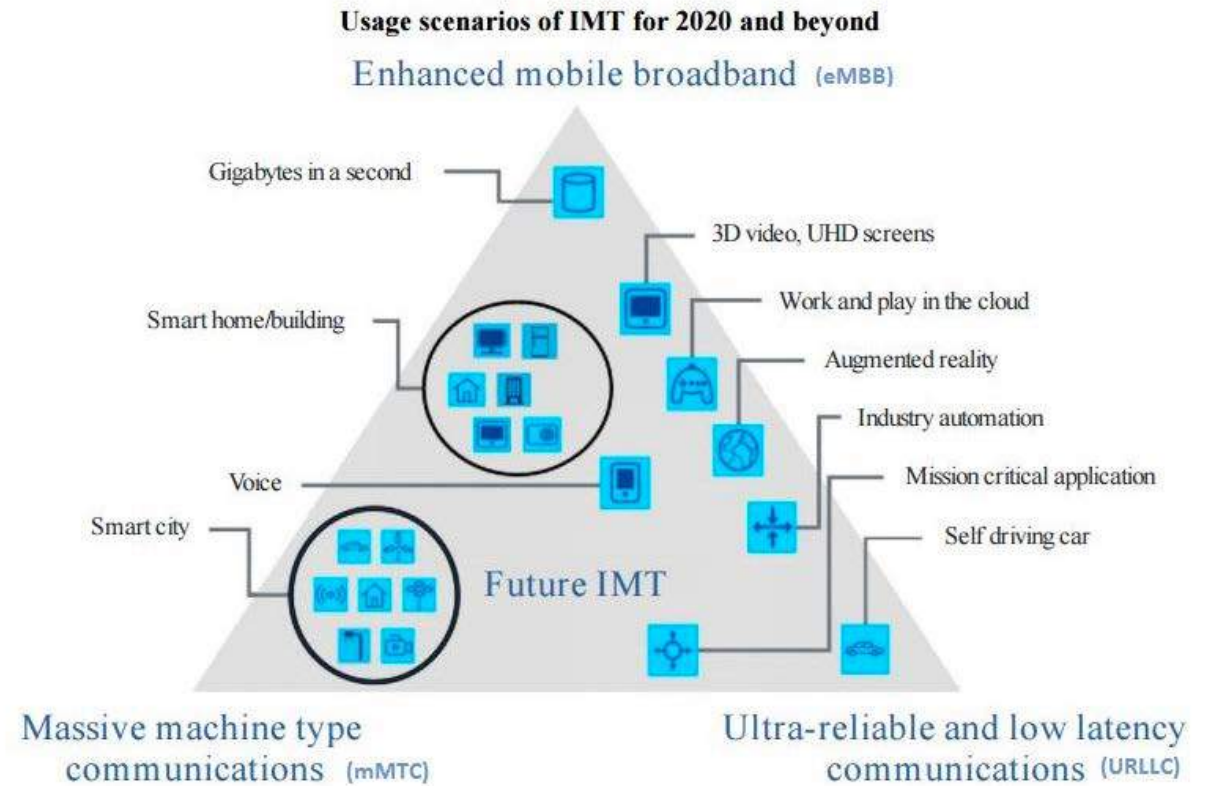
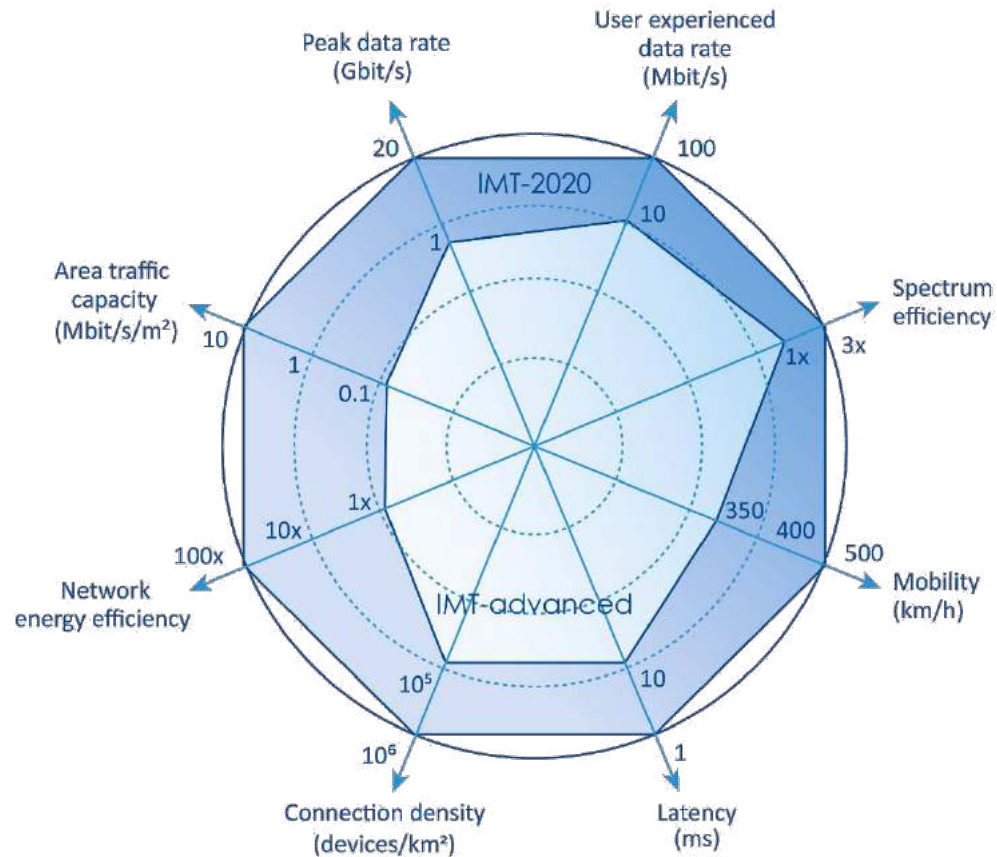


Evolution to 5G



Confidential

5G Requirements & 5G-Era Use Cases



5G-Standards

Radio Network:

- 3GPP-NR
- New Spectra (Licensed, Unlicensed, Shared/Partially-Licensed/Dedicated)
- Multi-Radio-Access Integration

Core Network: 5GPP-5GC

Enabling Technologies

Disaggregated Architectures

Virtualization

Edge Computing

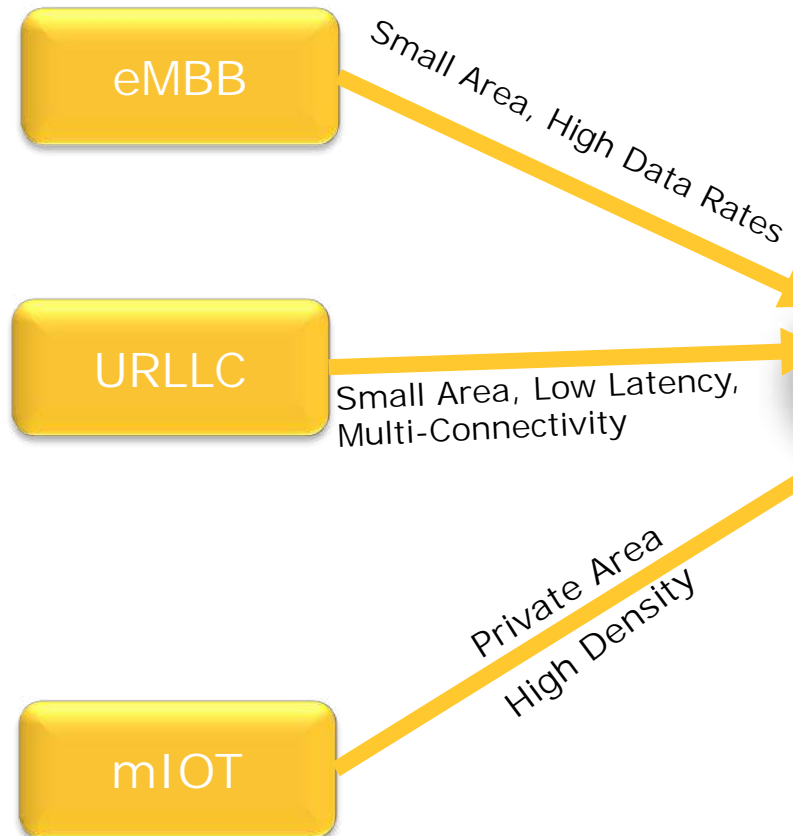
Network Slicing

Energy Efficiency

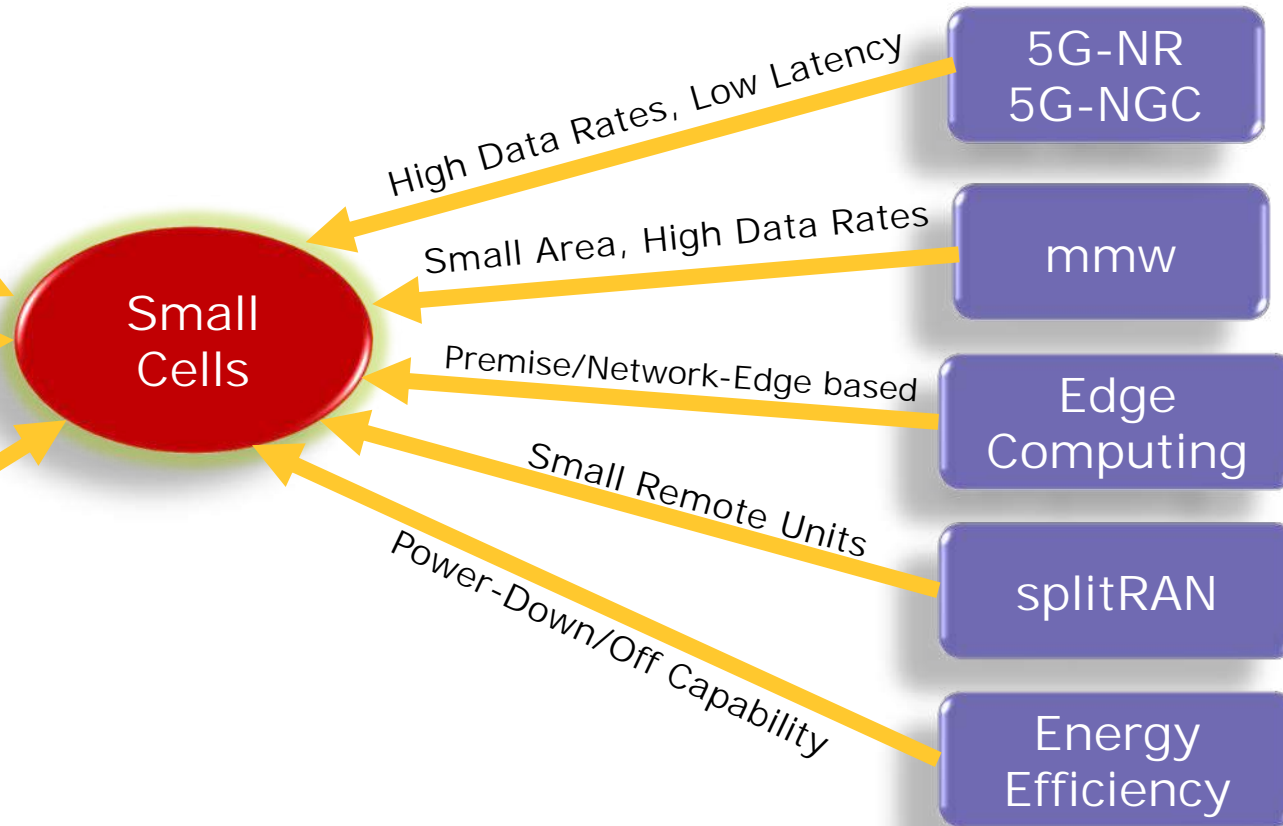
Intelligence (ML/AI)

5G & Small Cells

5G-Era Use Cases



5G-Era Technologies



Small Cells & Small Cell Networks



Small Cell (SC)

A base station that radiates 3GPP defined RF signal with small power & small size, generally with small coverage.

3GPP defined RF signal:
3G, 4G, 5G, Integrated with
Wi-Fi (Wi-Fi calling) etc.

RF frequency:
Licensed (Sub-6, mmw),
Shared (CBRS) or Unlicensed
("Wi-Fi frequencies")

Base Stations:
Integrated or Disaggregated

Small Cell Network (SCN)

A network of small cells
(integrated or
disaggregated)

Small Cell Deployment Scenarios



- Residential
- Indoor enterprise
- Private industrial
- Campus
- Outdoor dense urban
- Outdoor rural



SCN Characteristics & SCF Focus



Small Power
(often Small Coverage)

Small Size

Low cost

\$ \$ \$

Light touch



Scalable (Numbers & Features)



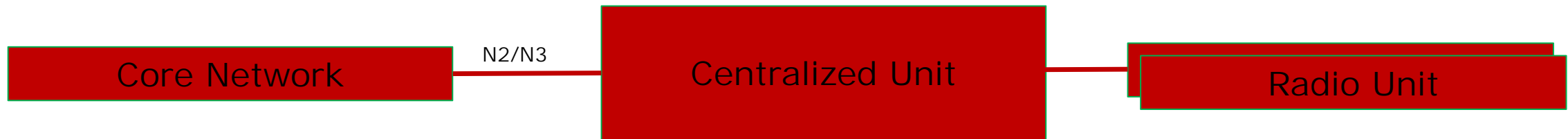
Distributed & Centralized/Disaggregated Small Cell Network Architectures



Distributed SCN Architecture



Centralized/Disaggregated SCN Architecture



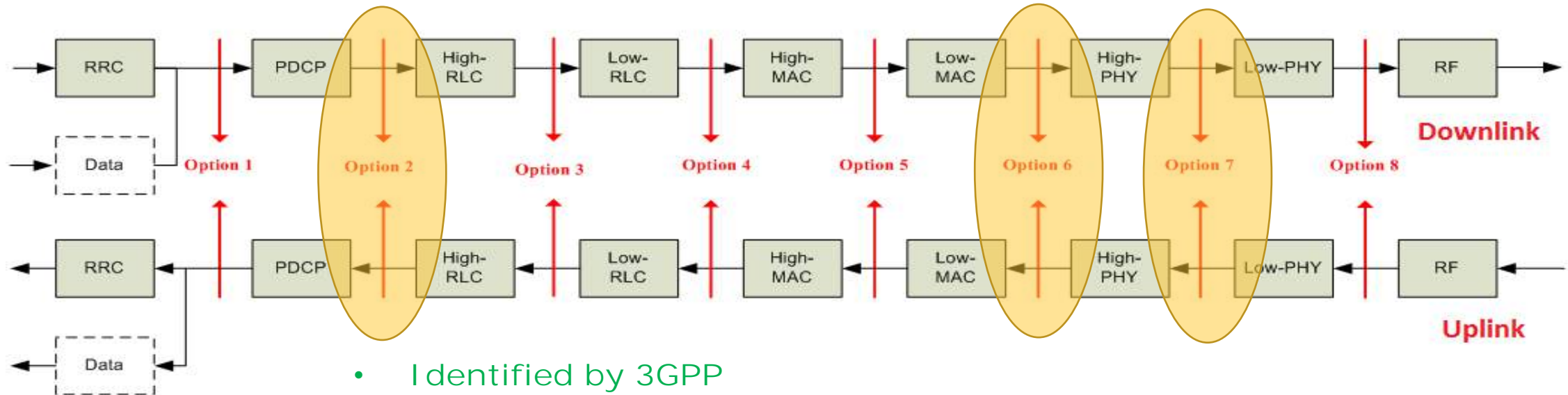
Disaggregation Options



All-In-One gNB

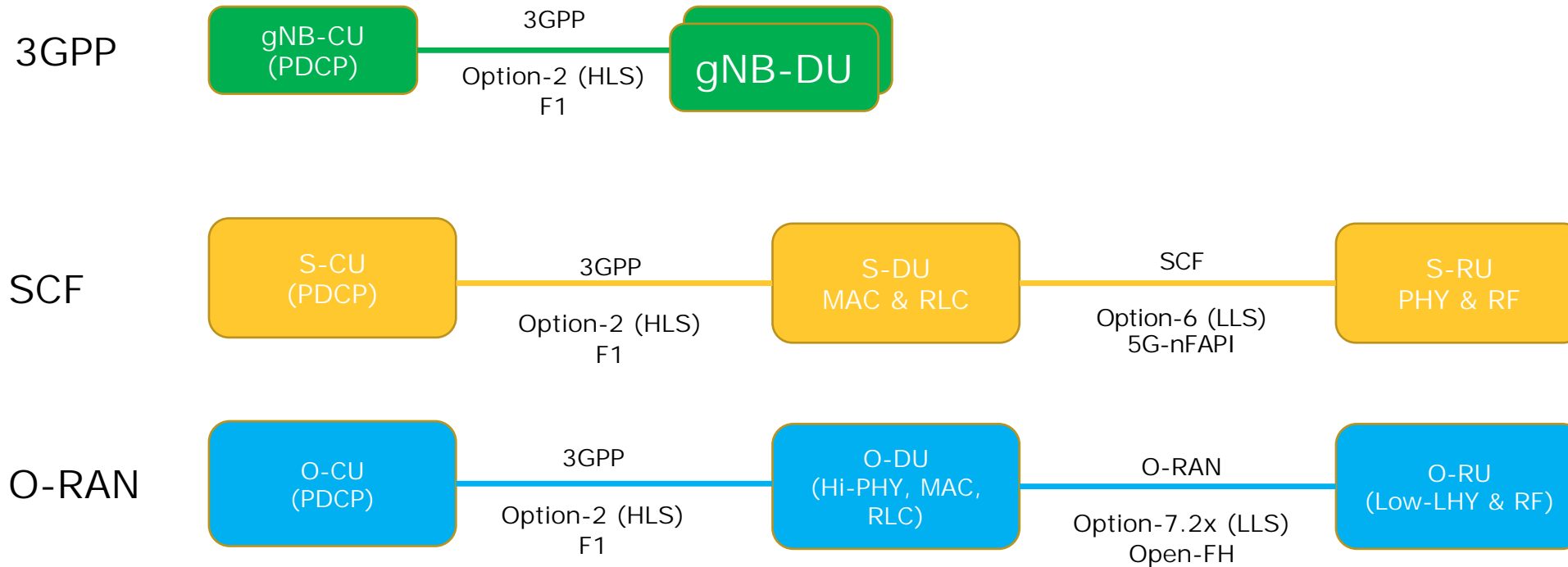
Centralized Unit

Radio Unit



- Identified by 3GPP
- Standardization:
 - High Layer Split: Option-2: 3GPP
 - Low Layer Split: Option-6: SCF
 - Low Layer Split: Option-7.2x: O-RAN

Commercially pursued Disaggregated Architectures





Easing SC Deployments

Siting, Best Practices, Lobbying with Regulators

[SCF 190, 195] Small Cell Siting Challenges (with 5G-Americas)

[SCF 183] Global Best Practices for Local Councils

[SCF 186] Deployment Guidelines for Latin America (with GSMA)

[SCF 012] Small Cell Installation Classes with GSMA

Deployment Challenges



- Time & Cost to deploy a small cell.
- Site and equipment approvals;
- Fees negotiations with the city or other landlord;
- Deployment, provisioning and maintenance
- Appropriate backhaul and power
- Conformance to the city's aesthetic and environmental regulations.

SCF & GSMA work on Siting

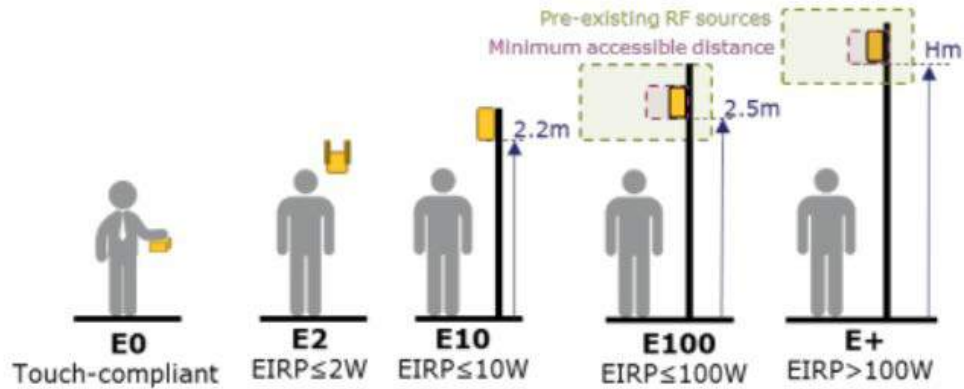
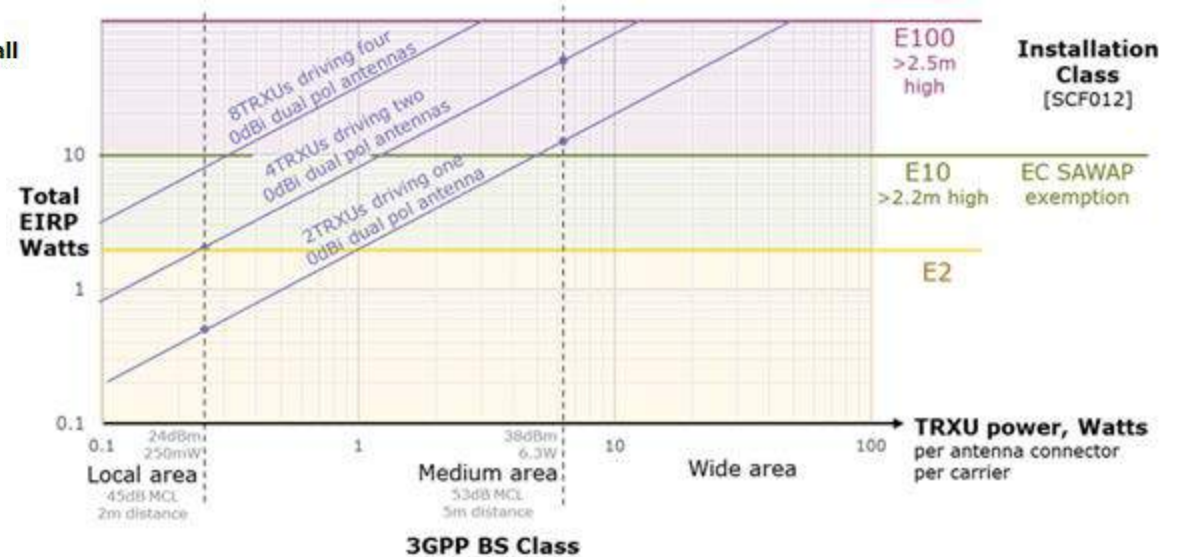


Figure 14 Installation classes simplify deployment rules needed for RF compliance of small cell sites

SCF012 Small Cell Installation Classes with GSMA

Simplified EU installation rules and EC adopted implementation regulation for the Small Area Wireless Access Point light deployment regime



SCF & 5GA Recommendations for rules to address siting challenges



Key challenge	SCF Recommended solutions
Streamlining the regulatory approval for small cell equipment	Standard industry classifications of equipment with common documentation of compliance and conformity to be used when defining related policies; some of these classes can be exempt from approval process or to light regulatory regime.
Scaling the planning application process to support large numbers of cells	Common rules on which equipment classes can be exempt or subject to fast track approval; batch process for groups of cells, to decrease the approval time and reduce workload of local administrations.
Securing sufficient suitable sites with power and backhaul	Simplified common frameworks to ease the opening up the access to street furniture and other existing assets. Census of available assets per municipality. Open access to administrative buildings.
Cost of installation	Adopt simplified rules of installation that would enable non-skilled workers to deploy (based on classes of equipment and complexity of installation). Reduce administrative charges (e.g. installation, operation, periodical revision taxes).
Radiofrequency compliance	Follow international recommendations for installation classes and provide information
Administrative complexity	Single executive to coordinate all approvals (e.g., in a smart city program) Streamlined paperwork and filing to minimize the approval processes and reduce the workload of the administration.

Figure 15 Summary of recommended solutions to facilitate small cell siting. Source: 5GA/SCF 2017



Edge computing and small cell networks



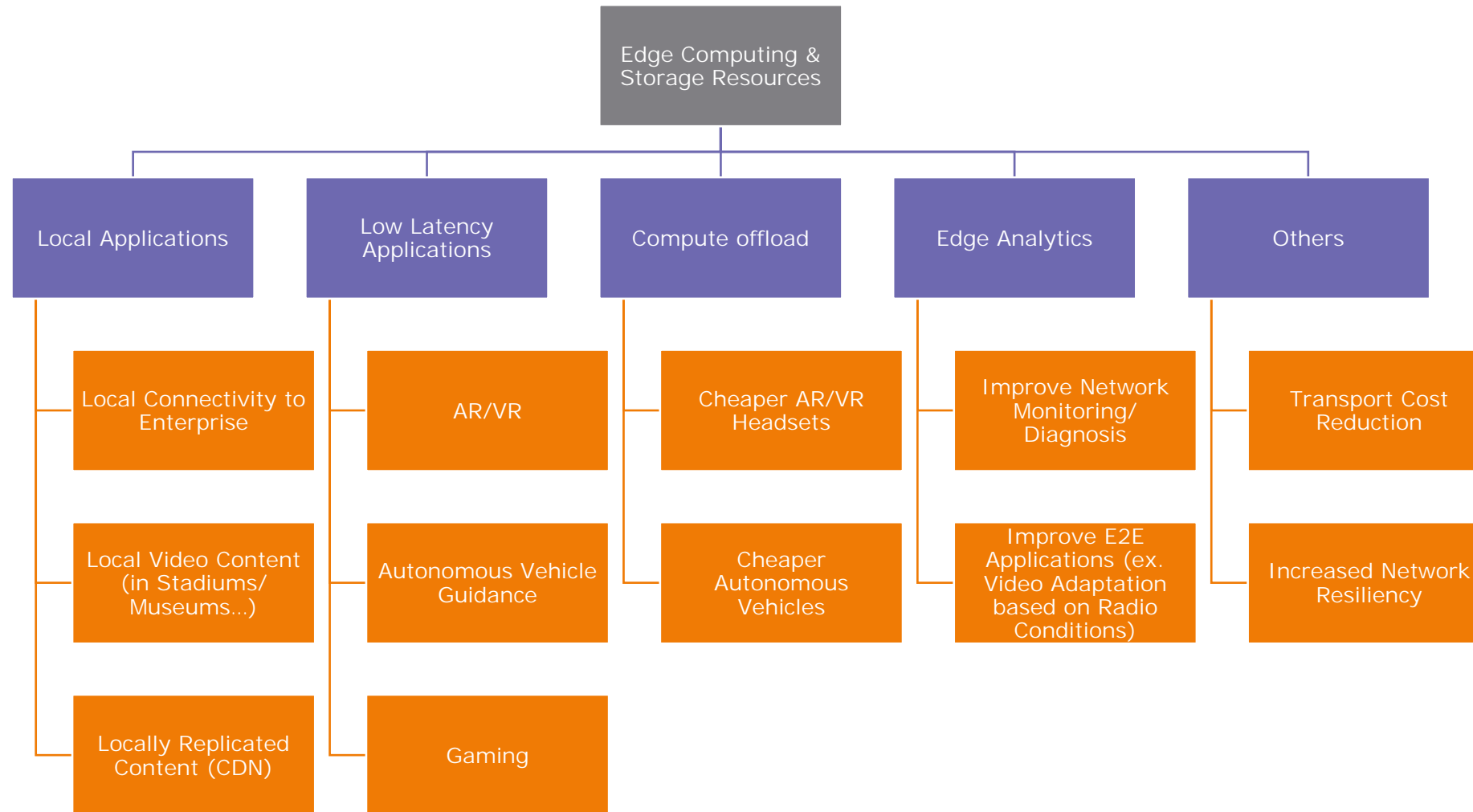
Editors



Key contributors



Benefits of edge computing



Industry segments for edge computing



Industry segment	Industry examples	Edge computing application
Automation & Industry 4.0	<ul style="list-style-type: none">• Factory floor• Logistics and warehousing	<ul style="list-style-type: none">• Edge network for internal communications, automation, IoT• Edge applications: video, logistics, warehousing, automation, etc.
Worksite industries	<ul style="list-style-type: none">• Mining, agriculture, remote oil/gas	<ul style="list-style-type: none">• Extend wireless IoT networks to remote/temporary locations and removing black spots in coverage• Edge applications: video, local communications, automation, alarms
Mission critical services	<ul style="list-style-type: none">• Electricity, power plants	<ul style="list-style-type: none">• Critical communications, High availability• Edge computing for local communications, automation, alarms
Enterprise/venue services	<ul style="list-style-type: none">• Airports, stadiums, hospitals, ports	<ul style="list-style-type: none">• Private network for employees. Data privacy & public network for visitors• Edge computing for local communications, videos, local applications, automation
Public safety	<ul style="list-style-type: none">• Patrol, first responders	<ul style="list-style-type: none">• Private network for emergency situations. Portable communications• Edge computing for communications, video, body camera feeds, drone video feeds



Enterprise/Venue

Enterprise/Venue Premises

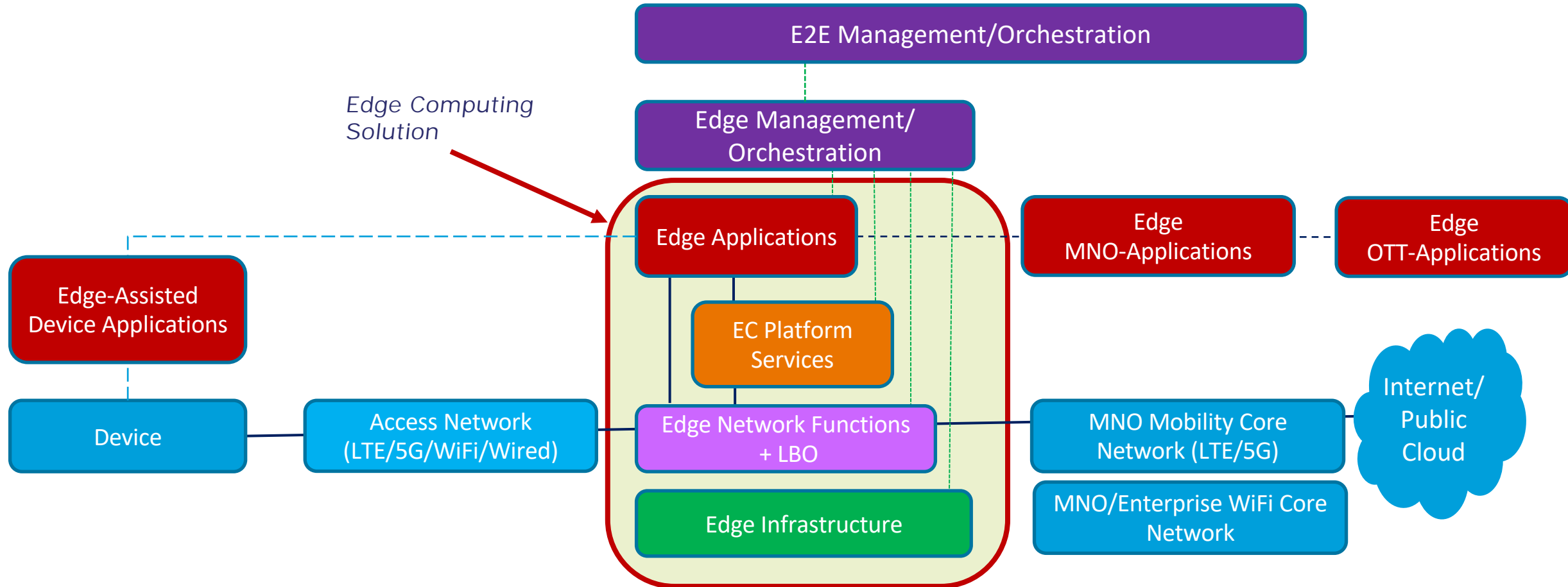
MNO

Cell-Tower/Small-Cell

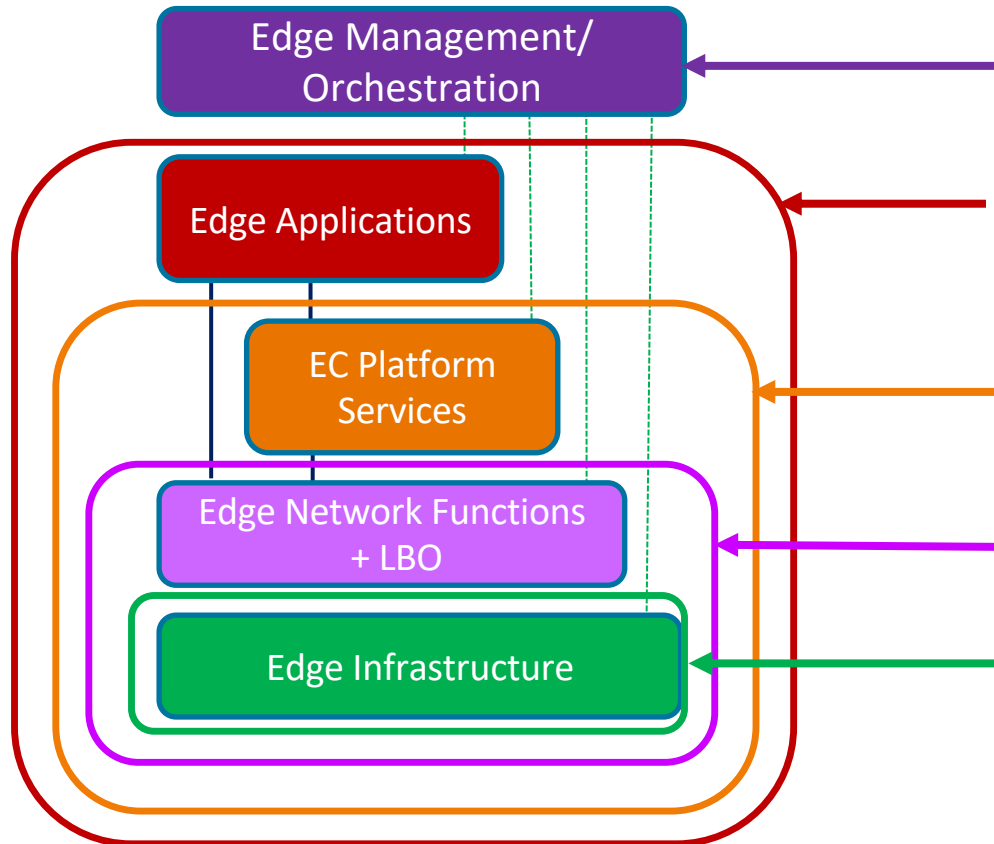
Local Aggregation Center

Regional Center

EC framework

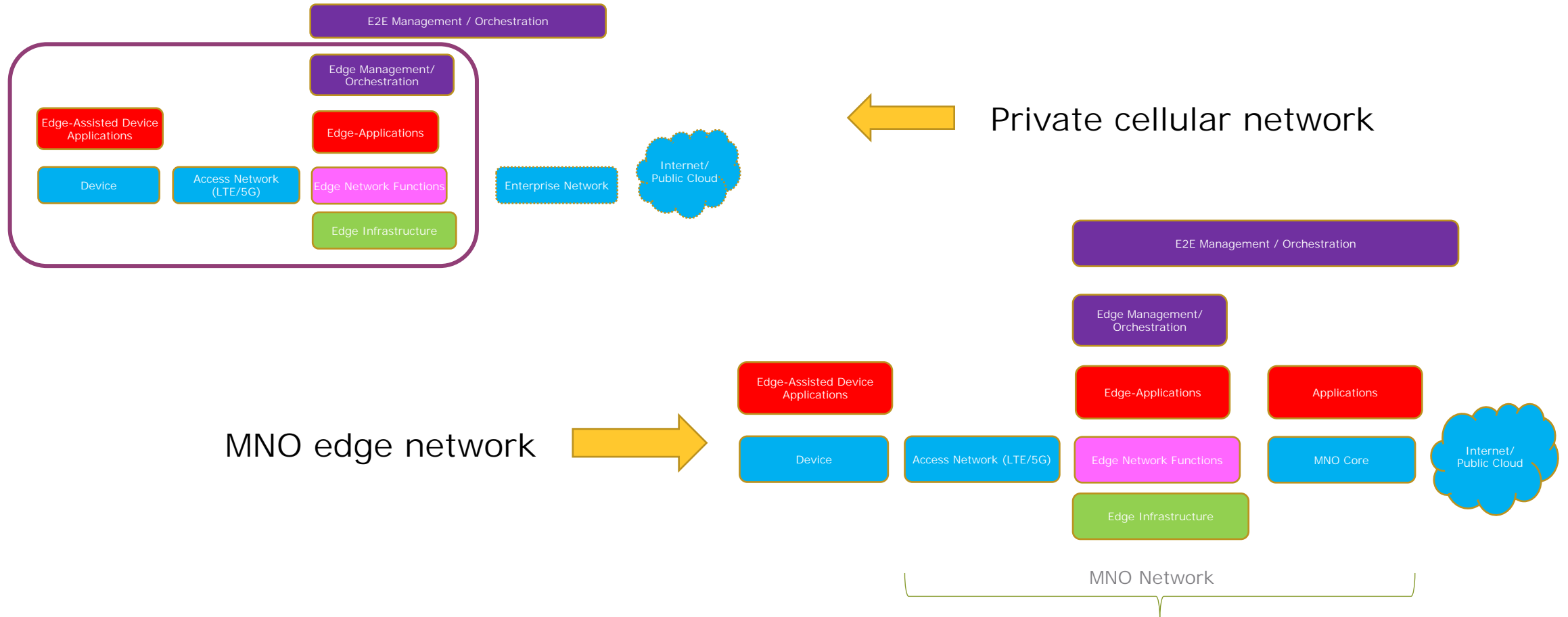


Service offerings enabled by EC

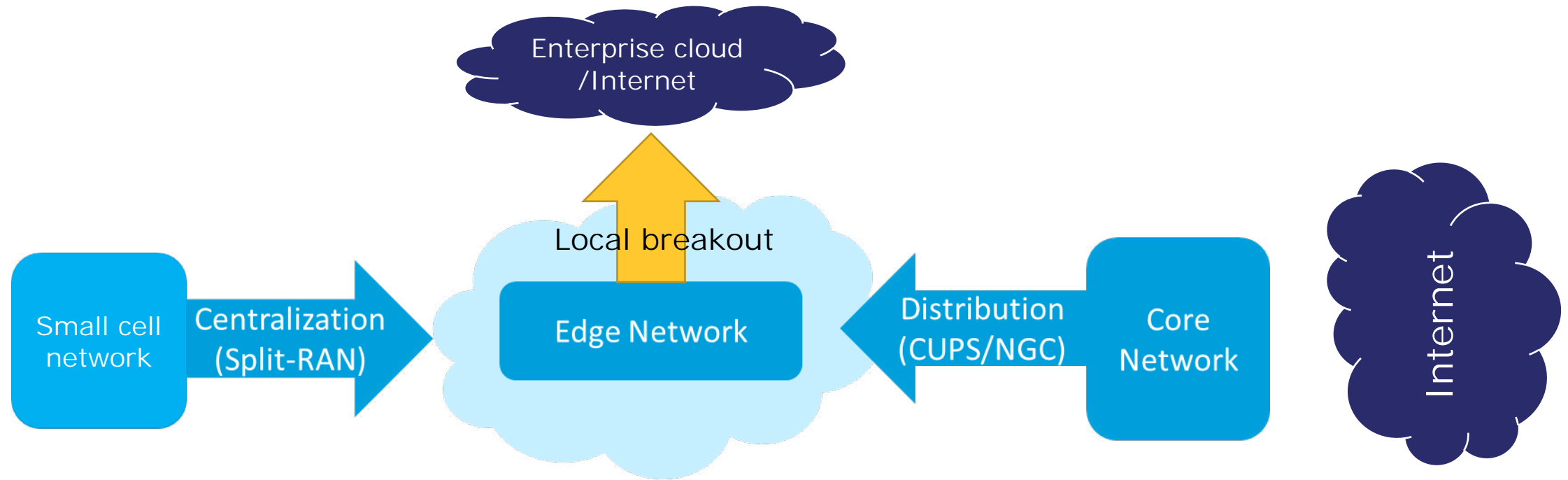


- **Managed services**
 - *Offering:* Deployment, operational management
- **SaaS – Software as a service**
 - *Offering:* Applications
- **PaaS – Platform as a service**
 - *Offering:* Radio, Network & Application APIs; Video, Security, AI/ML Analytics
- **NaaS – Network as a service**
 - *Offering:* Distributed core, centralized RAN & local breakout functions; network APIs
- **IaaS – Infrastructure as a service**
 - *Offering:* COTS hardware + virtualization software environment (VMs/containers)

EC Deployment Use Cases



Edge Network

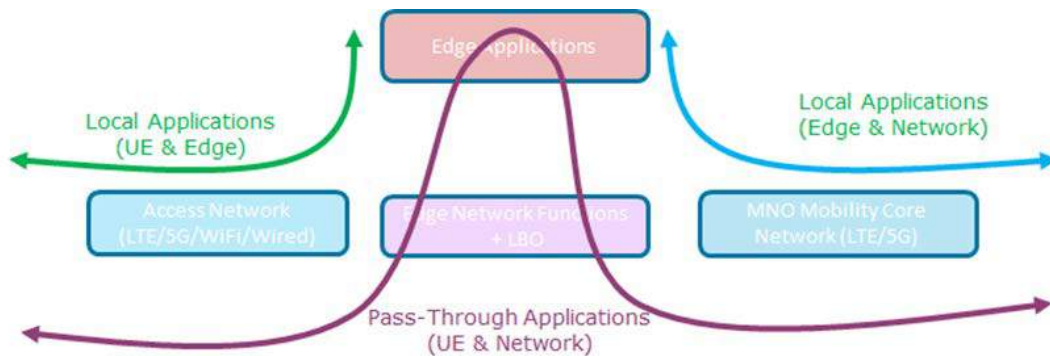


Edge Network Functions: CU of Split-RAN, UPF of Distributed-Core, Local Breakout...

EC Applications



Traffic flow-based application types



Examples – UE & Edge Applications

- LBO to enterprise
- AR/VR
- Autonomous Vehicle Assist
- Presence & Tracking
- Robotic Control
- Security

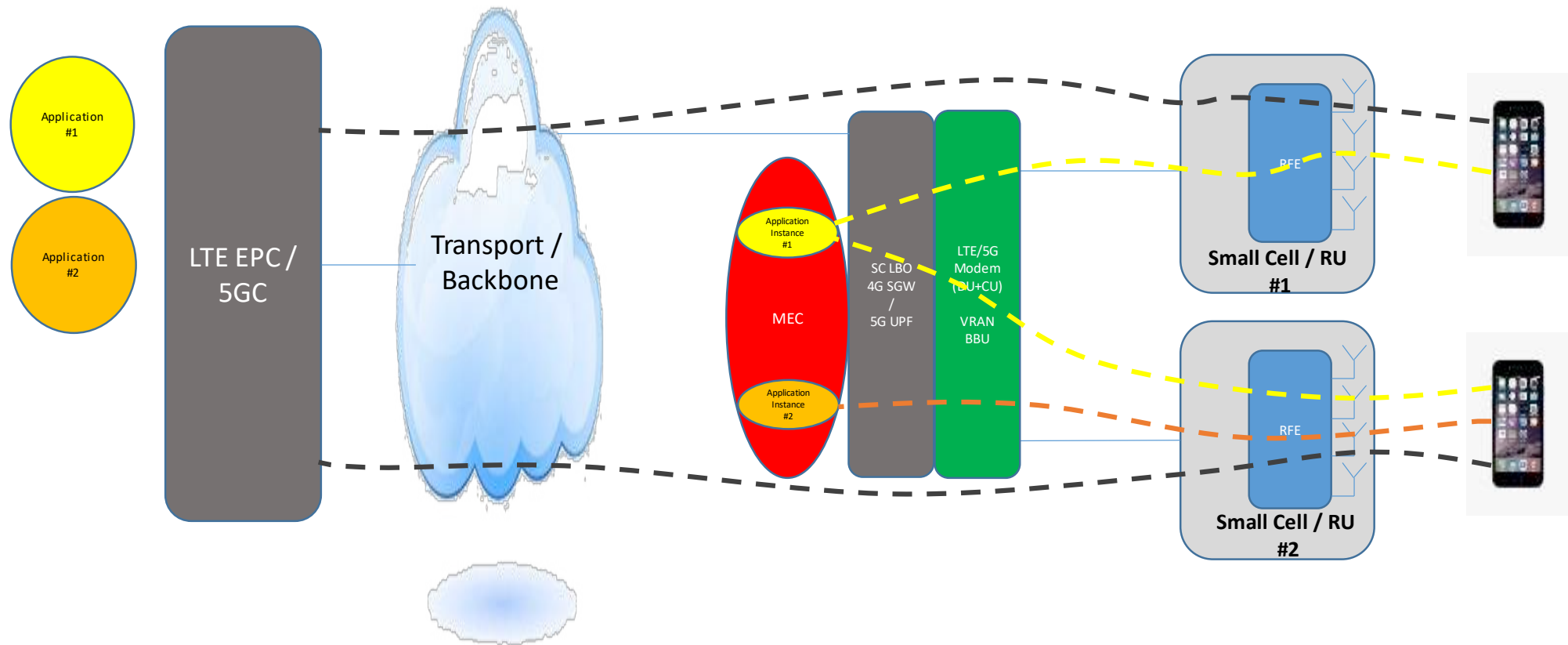
Examples – Pass Through Applications

- Video Compression/Optimization
- Security
- Content Caching
- IOT Gateways

Examples – Edge & Network Applications

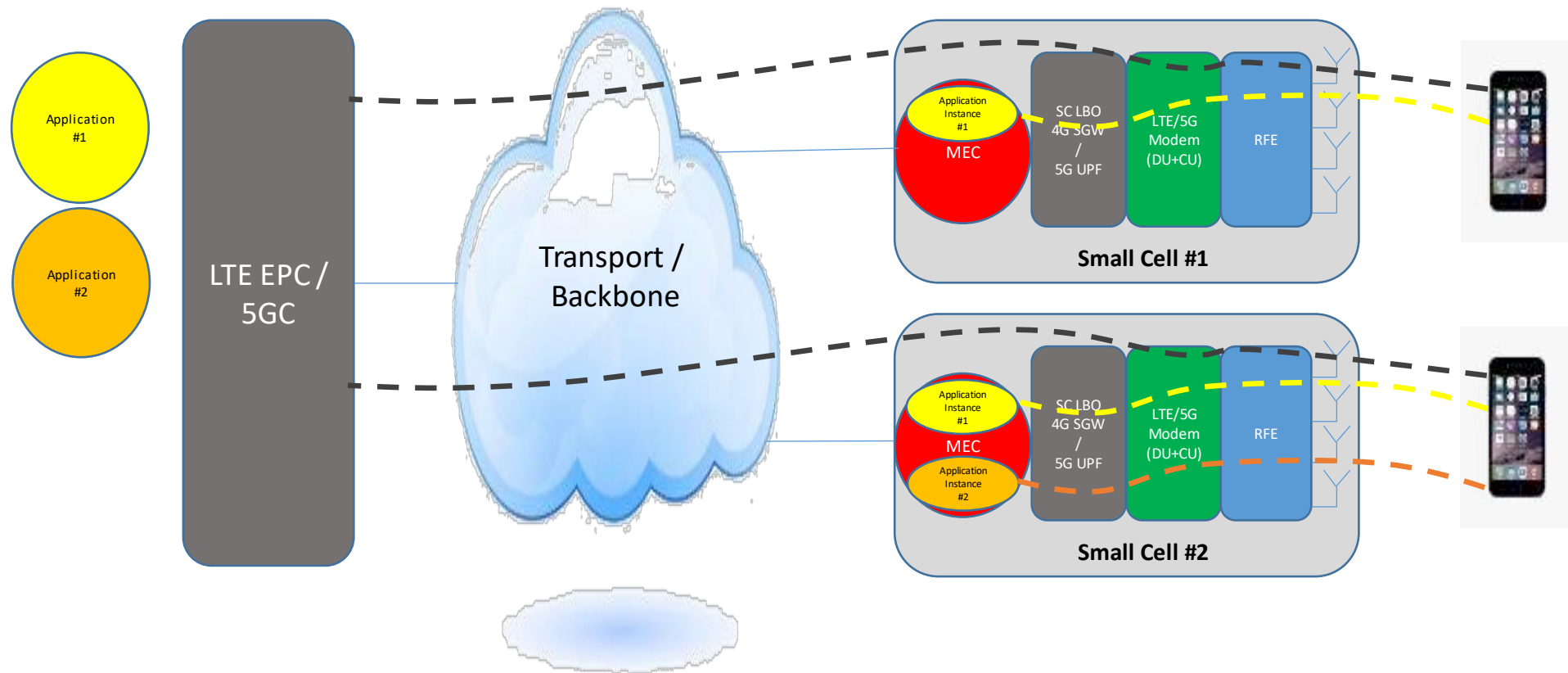
- Network Analytics & Management

EC & SCN Integration Options (1/2)



EC platform integrating Disaggregated SCNs

EC & SCN Integration Options (2/2)

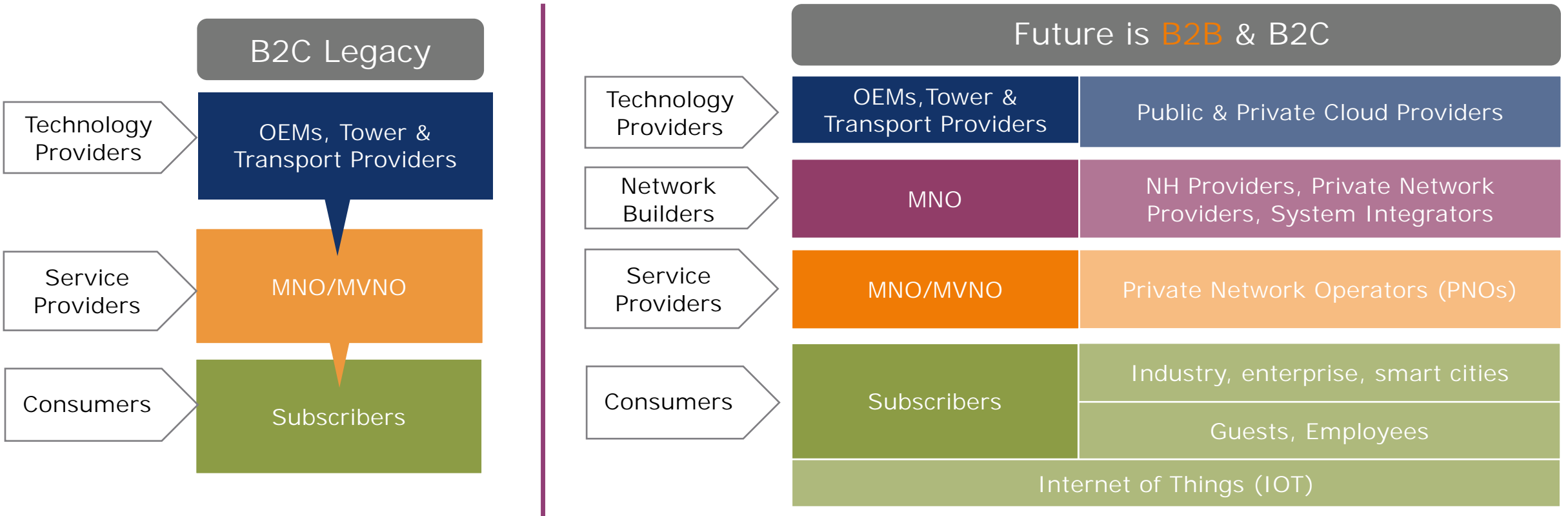


SC integrating lightweight EC

EC – Industry Forum Landscape (ETSI-MEC view)

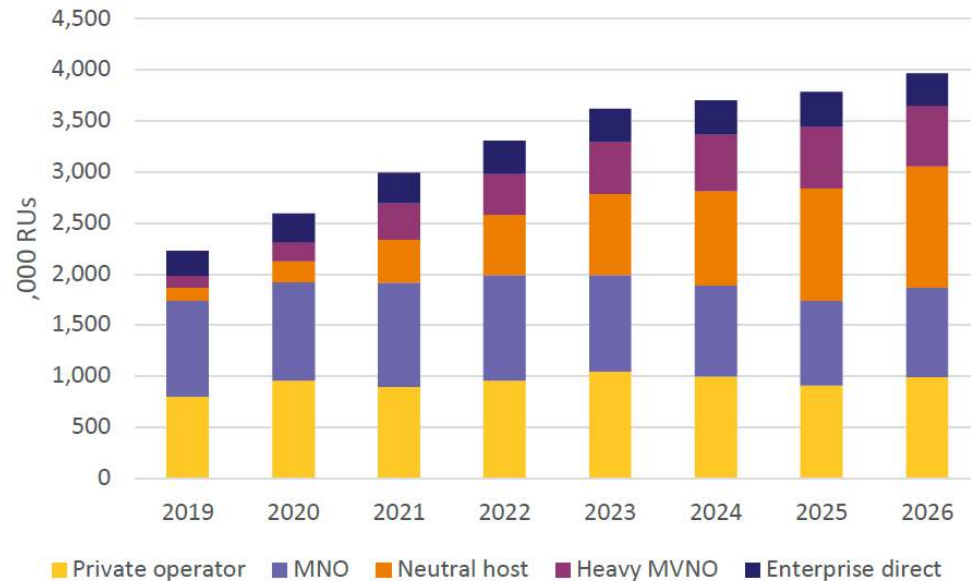


Evolving mobile ecosystem



New players, new business relationships & new opportunities

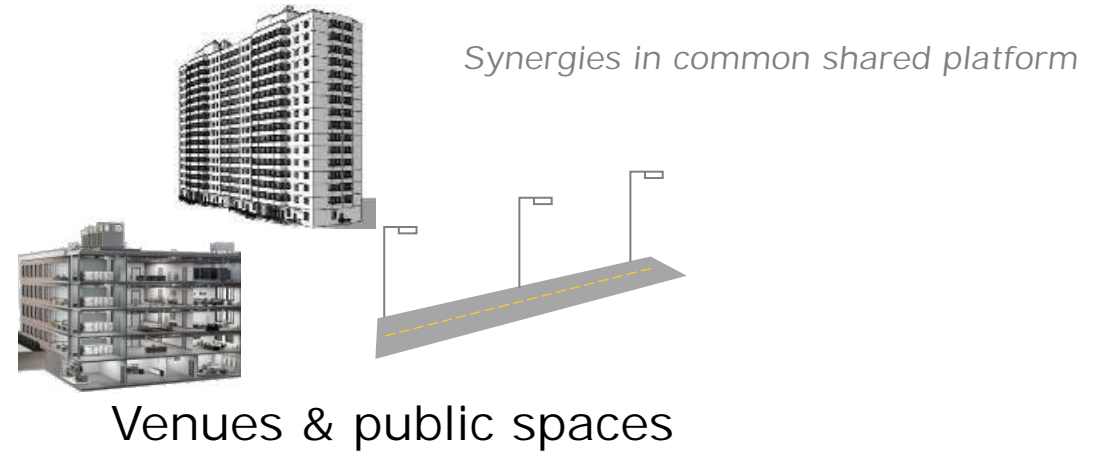
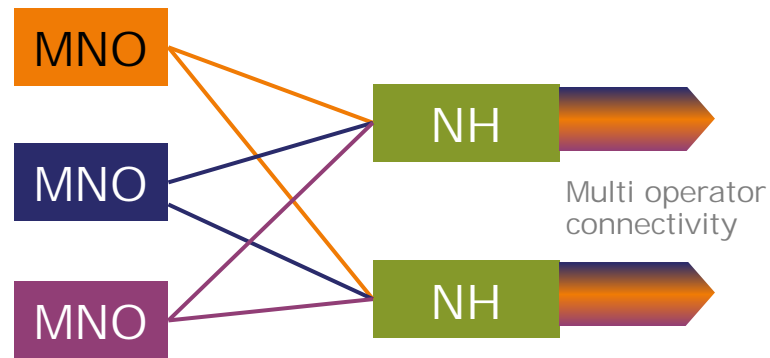
Diversification of small cell deployers



Small Cell Deployers

- MNO
- Heavy MVNO
- Neutral Host
- Private Operator
- Enterprise Direct

Neutral Hosts' Technology Requirements



- Venues are willing to fund infrastructure deployment provided it is multi-operator. Neutral hosts are brokering these arrangements.
- Historically, MNOs selected RAN equipment and Neutral hosts use RAN agnostic DAS, or separate MNO-selected small cells.
- CBRS and JOTS change this and put RAN ownership within the control of neutral hosts.

Neutral Host Network Domains



Source: JOTS NHIB

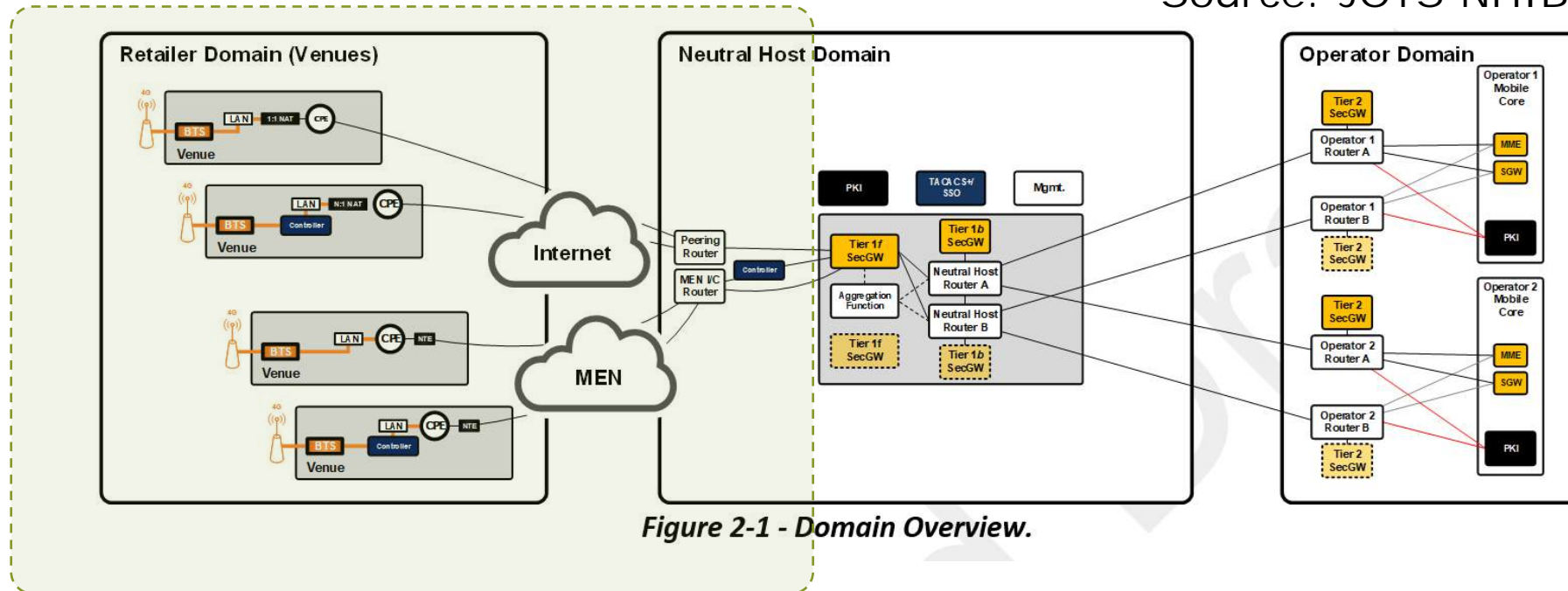


Figure 2-1 - Domain Overview.

SCF NH technology requirements elaborates on use cases, architectures and requirements for the NH and retail domains

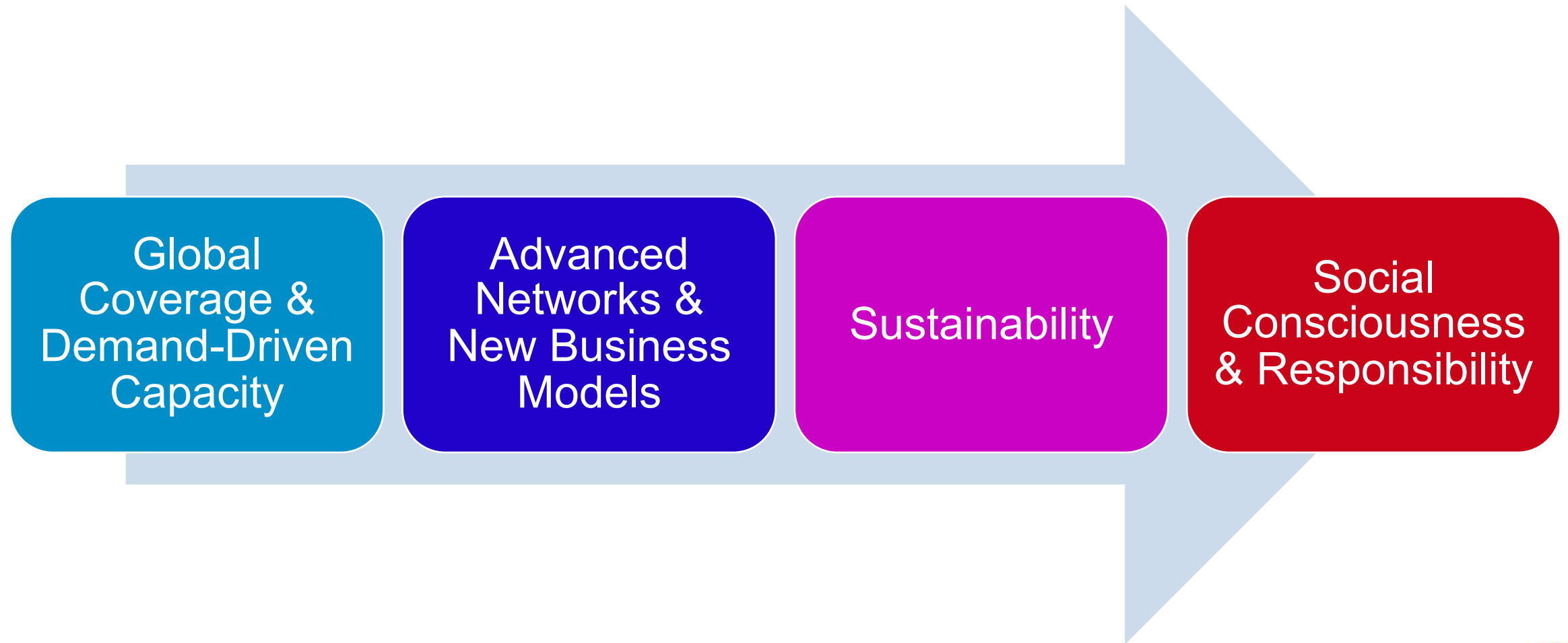
Focus of JOTS NHIB is on common security architecture for multiple MNOs connecting with a neutral host

5G-Era Technologies: Current Status

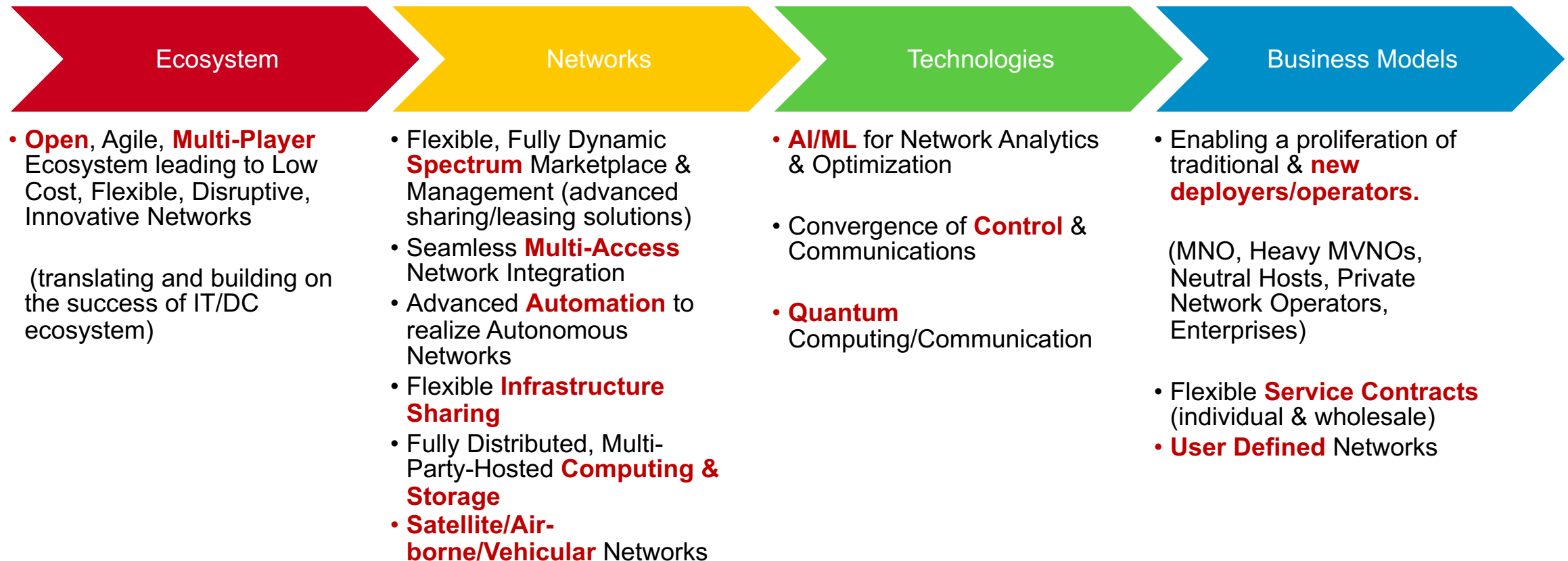
Drivers	Current Status
eMBB	✓✓✓ mid-band vs. mmw spectrum: coverage vs. speed
UR-LLC	✓✓ LLC (with Edge Computing) ✓ UR
mIoT	✓✓
Network Densification	✓✓
Private Cellular Networks	✓ Dedicated/Shared vs. MNO spectrum, PNO-MNO Interpoertability
Core Technologies	Current Status
3GPP 5G-NR	✓✓✓
3GPP 5G-NGC	✓✓✓ SA deployments lagging
Auxiliary Technologies	Current Status
Virtualized Networks	✓✓ Core ✓ RAN ✓✓ Management/IT
Open Networks	✓✓ Core ✓ RAN ✓✓ Management/IT
Edge Computing	✓✓ Enterprise Environments ✓ MNO/MSO Networks
Network Slicing	✓
Shared Spectrum	✓ CBRS in US
Shared Infrastructure	✓ Neutral Host players



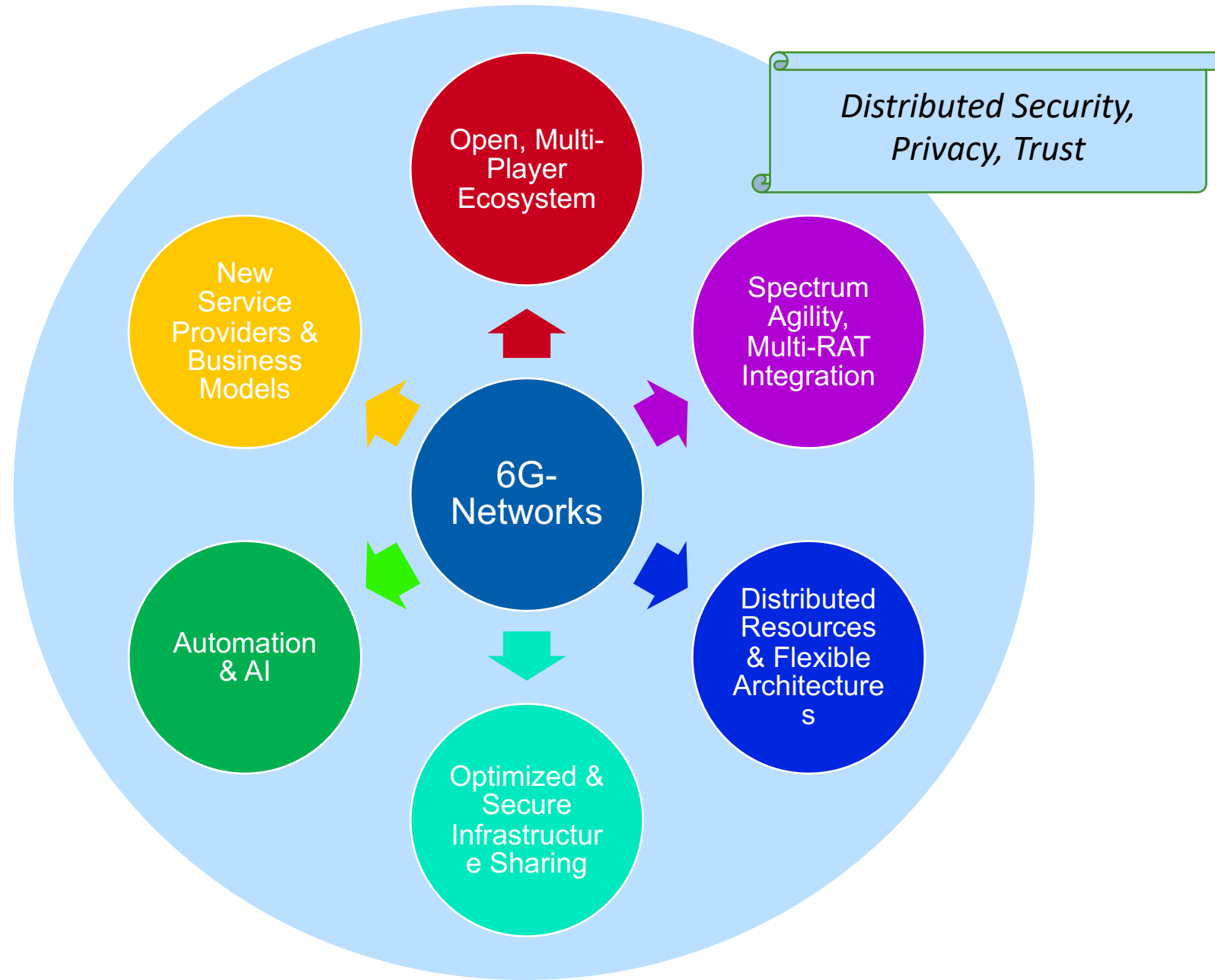
6G-Era: Drivers



6G-Era Requirements: Advanced Network Solutions & New Business Models



6+1 Dimensions of 6G-Networks



6G-Enhanced Performance

KPI	5G	6G
Peak data rate	20 Gb/s	1 Tb/s
Experienced data rate	0.1 Gb/s	1 Gb/s
Peak spectral efficiency	30 b/s/Hz	60 b/s/Hz
Experienced spectral efficiency	0.3 b/s/Hz	3 b/s/Hz
Maximum bandwidth	1 GHz	100 GHz
Area traffic capacity	10 Mb/s/m ²	1 Gb/s/m ²
Connection density	10 ⁶ devices/km ²	10 ⁷ devices/km ²
Energy efficiency	not specified	1 Tb/J
Latency	1 ms	100 μs
Reliability	1-10 ⁻⁵	1-10 ⁻⁹
Jitter	not specified	1 μs
Mobility	500 km/h	1000 km/h

© 6G Flagship

6G-Key Open Problems

New Enablers



New frequency bands
Large bandwidths



Quantum
Technology



MEC



Higher accuracy
(mm and cm)



Compact form
factor



Smart
metasurfaces



AI & machine
learning



Roll, pitch, yaw



Dense arrays



High speed Tbps,
Low latency sub-ms

Applications & Opportunities



Sensing / imaging



Robot localization



Object recognition



Context awareness



Joint comm
and radar



Big data analytics and
modeling of signals



Radar capabilities



Low power
Directional transmission



AR / VR / MR



Sensor fusion



Localization and sensing
for future eHealth

Challenges



High hardware
power consumption



Limitations in
hardware



Dark spots and
blockage



Increased Interference
from new services



Short range
at THz



Heat problem due to
very small size of THz
elements & hardware

6G-Spectrum Range

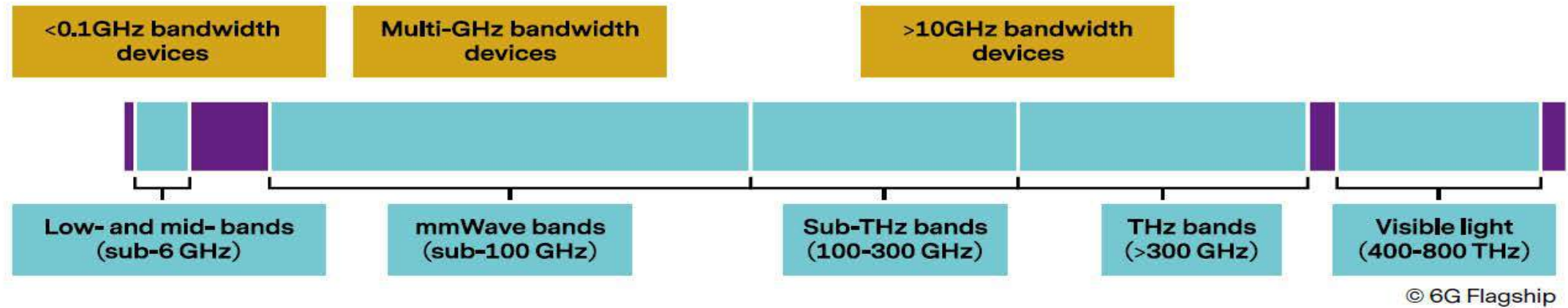


Figure 3: Potential spectrum regions for 6G.

6G-Key Open Research Topics

Summary of key open problems		
Challenges	Potential 6G solutions	Open research topics
Stable service quality in coverage area	User-centric cell-free massive MIMO	Scalable synchronization, control, and resource allocation
Coverage improvements	Integration of a spaceborne layer, ultra-massive MIMO from tall towers, intelligent reflecting surfaces	Joint control of space and ground-based APs, real-time control of IRS
Extremely wide bandwidths	Sub-THz, VLC	Hardware development and mitigation of impairments
Reduced latency	Faster forward error correcting schemes, wider bandwidths	Efficient encoding and decoding algorithms
Efficient spectrum utilization	Ultra-massive MIMO, waveform adaptation, interference cancellation	Holographic radio, use-case-based waveforms, full-duplex, rate-splitting
Efficient backhaul infrastructure	Integrated access and backhauling	Dynamic resource allocation framework using space and frequency domains
Smart radio environment	Intelligent reflecting surfaces	Channel estimation, hardware development, remote control
Energy efficiency	Cell-free massive MIMO, suitable modulation techniques	Novel modulation methods with limited hardware complexity
Modeling or algorithmic deficiencies in complex and dynamic scenarios	ML-/AI-based model-free, data-driven learning and optimization techniques	End-to-end learning/joint optimization, unsupervised learning for radio resource management

Standardization Path to 6G



Small Cell Forum



- Members: Operators, OEMs, infrastructure vendors, system integrators
- Work program driven by Operators, Board & Steering Group

Board



Nick Thompson
AT&T



Andrew Conway
BAI Communications



Piercarlo Giannattasio
Cellnex



Mark Reudink
Crown Castle



Paul Trubridge
Dense Air



Ravi Sinha
Jio



Randy Cox
Nokia



Caleb Banke
Qualcomm

Leadership



Prabhakar Chitrapu
Chair
Small Cell Forum

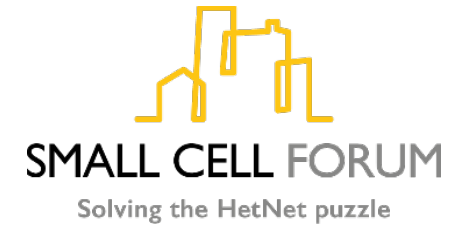


Sue Monahan
CEO
Small Cell Forum



Richard Kennedy
COO & Marketing
Small Cell Forum

SCF's value proposition



Enabling Disruption & Innovation in RAN

- Unlike Macro-Cellular Networks, SCNs have always been more open to new & disruptive players.
- SCF has enabled such players by developing open-SCN Solutions
- Due to the fundamental aspects of SCs, SC-ecosystem has the potential to be as vibrant as Wi-Fi ecosystem, while being an integral part of the macro-mobile-networks!

Fostering Open-ness in Small Cell Solutions

- Open-RAN Solutions
 - Iuh → 3GPP
 - TR-196 → BBF
 - FAPI (3G, 4G, 5G) → SC HW & SW Vendors, OAI, O-RAN..
 - Split-Option-6 5G-nFAPI Interface → OAI, O-RAN, ...

Fostering US Competitiveness of Silicon Vendors

- FAPI enables mix&match of Silicon Vendors and SW vendors
- Driving towards Open-Silicon supporting various Split-Options for Disaggregated SCN architectures

SCF's value proposition



Engaging Regulators

- US, UK, EU
- Lobby for Ease of Deployment of Small Cells

Engaging Enterprises

- 5G-Era is a lot about enabling various Verticals
- EAC, engagement with Healthcare, Hospitality, Property Management, Transportation...

Collaborative Approach

- 3GPP, BBF, O-RAN, OAI, ETSI-MEC, WBA, MEF, 5GA,...

SCF's value proposition



SMALL CELL FORUM

Solving the HetNet puzzle

Trusted Supplier of Information

- 100s White Papers with over 16,000 downloads (2019) and numerous Press Coverages
- Specifications/Standards
- Best Practices for Industry
- Information to Regulators

SCF would be happy to collaborate in areas of mutual interest !

<https://www.smallcellforum.org/>

References and Follow-ups



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Contact memberservices@smallcellforum.org to get involved the product definition work item [238] due to complete in June
- 6. Market survey of products and architectures** Caroline Gabriel, SCF
Contact caroline@rethinkresearch.biz to take part in the 5G small cell products and architectures survey, described here:
<https://www.smallcellforum.org/blog/scf-launches-initiative-to-revise-the-small-cell-product-definition>
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