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What is 5G Architecture?

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Agenda

1. What is Network Architecture?
2. Use cases
3. Requirements
4. Architecture
5. Standards
6. The 5GIC Testbed
7. Slicing

1. What is Network Architecture

What is Network Architecture?

Some language definitions ….

Oxford English Dictionary

Architecture: The complex or carefully designed structure of something

Network: A group or system of interconnected people or things

Wiki: Network architecture:

… the design of a communication **network**. A framework for the specification of a **network's** physical components and their functional organization and configuration, its operational principles and procedures, as well as data formats used in its operation.

CCM.net

Network architecture: refers to the layout of the network, consisting of the hardware, software, connectivity, communication protocols and mode of transmission, such as wired or wireless.

What is the 5GIC?

Based at the University of Surrey (UoS) in the Institute of Communications Systems (ICS)

World's largest academic/industry research partnership & test facility for the development of future 5G Communications.

£58m from industry partners below: Operators, Vendors & Systems providers)

£12m investment from the Higher Education Funding Council.

£5m from Local Enterprise Partnerships to support:

- 5GIC test facilities development
- Step-out 5GIC facilities to SMEs within the region

UK based and with significant international connections to China, Korea & Japan

LEP Board link between 5GIC and China Britain Business Council.

2. Use Case

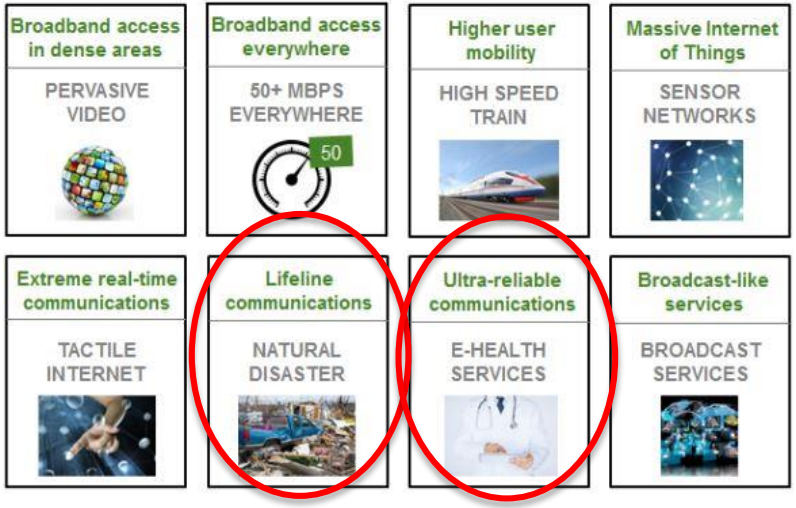
What are the Use Cases for 5G?

Use Cases

Vendor and NGMN Views

2014-2015: Vendors: Ericsson, Huawei, Lucent-Alcatel, NSN & Samsung have all published 5G Whitepapers

Feb 2015: NGMN published their 5G Whitepaper, introducing 8 use case groups proposed by operators.



Use Cases

3GPP SA1/SA2 Next Generation Standards Evolution

Apr 2015: SA1 published the draft Technical Report 22.891 “New Services and Markets Technology Enablers”

- introduced 20 Use Cases (UC) noting Legacy Service provision and defining New Services and Enablers

Aug 2015: SA1 updated the draft 22.891 report as the basis of the “SMARTER initiative.

- SMARTER is (S)ervices (Mar)kets and (T)echnology (E)nablers and the (R)oad to 5G
- added 39 new use cases completing a comprehensive example set of UCs scoping the 3GPP view of next generation, anticipated usage.
- 5GIC drafted eight of these use cases, which in working with Telefonica as our industry Champion partner were all adopted, receiving notable support form other 3GPP lead organisations

Oct 2015: Subsequently SA1/SA2 have agreed several emerging themes for 5G Enhanced Mobile Broadband (MBB)

1. Support for Massive IoT Machine Type Communications (MTC)
2. Flexible Network Operation
3. Critical Communications
4. Enhanced Mobile Broadband

   … as well as supporting Legacy Mobile services

Note:

SMARTER defines

28 Single service use cases (47%)

31 Network Capability Use Cases which each support multiple services (53%)

Use Cases

5GIC Use Case work

Work Area #1 focussed on Context aware, Content aware enablement of 5G to support the 5G UC and includes our Network Architecture work

Submitted 8 of the 59 UC with our partners Telefonica and Huawei.

We have analysed the evolving State of the Art (SOTA) research, Use Case story up to the SMARTER stage and developed our own Network Architecture Research in WA1 to include:

- UC analysis
- Development of an evolved 5G architecture
- Requirements Decomposition for the proposed Architecture

Use Cases

PSC Relevant Use Cases from SMARTER (3GPP22.891)

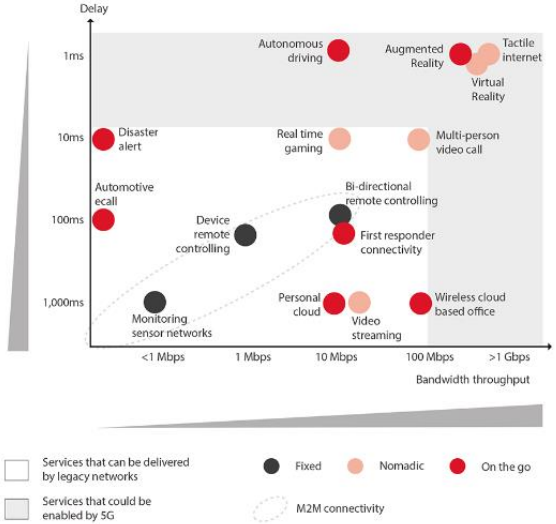
ID	Use Case	Public Safety Relevance	Capability /Service	Throughput per Cell	Latency	Session Setup
2	Network Slicing	The ability to operate slices of the network for different Persistence and QCI groups according to Group Service demand	Capability	N/A	Re-Slice within 5 mins	N/A
3	Lifeline comms (natural disaster)	Basic Emergency Services Communications (Voice, Text and basic rate data during Disasters) D2D Emergency Services, D2D Public	Service	1-10Mbit/s	<100ms	200ms
4	Migration of Services <4G	IMS based Voice and Text	Services			200ms
7	On-demand Networking	Ability to sense an event and adjust network slicing to service (includes emergencies)	Capability	N/A	Detection of condition load >1min	N/A
9	Flexibility and Scalability	Ability to sense an event and adjust network slicing to service (includes emergencies)	Capability			
11, 14, 18	Virtual Presence Tactile Internet Remote Control	360 degree virtual presence for remote support at an emergency Ability to sense touch remotely e.g. Control of robotic High Speed Video imaging systems	Service	N x Gbit/s (Compressed 3D-4k))	5ms	200ms
28	Multiple Concurrent RAT connectivity & RAT selection	Ability to select multiple RAT options concurrently to support a service e.g i) 5G-RF, ii) 5G-mm-Wave, iii)Wi-Fi and iv) LTE and multiplex between to avoid handovers & maximises available connectivity	Capability			

Use Cases

PSC Relevant Use Cases from SMARTER (3GPP22.891)

ID	Use Case	Public Safety Relevance	Capability /Service	Throughput per Cell	Latency	Session Setup
31	Connectivity Everywhere	Providing a global wide area control plane service for 5G	Capability			
35	Context Awareness to support network elasticity	This is the CA driven, ANO use case where User Profile information can be collected securely and privately to enable the network to support rapid network reconfiguration to support user changing traffic and mobility load patterns (5GIC)	Capability			
50	Low-delay speech coding	Reduce d speech coding delays for applications requiring live voice from 20-40ms today towards only 10ms one way in 5G timeframe.	Service	<1Mbit/s	10ms	200ms
52	Wireless Self-Backhauling	To allow for low cost backhaul and ad-hoc backhaul for emergencies.				
55	High Accuracy Enhanced Positioning (ePositioning)	ePositioning for 95% of service are to 1m accuracy indoor and outdoor	Capability			
59	Massive Internet of Things M2M and device identification	Enables the ability to build an IoT system that automatically detects emergencies and disasters	Service	100kbit/s to 1Mbit/s	10ms	10-30ms

3. Requirements



Source: GSMA Intelligence, 2015

GSMA says: 5G needs to:

- be faster,
- have lower latency
- support many more diverse markets to be cost effective

…. for example integrated PPDR

Requirements

Performance and Capability Summary

Overair Rates

LTE-A 2xCA, Cat4 today 75/150Mbit/s user
2xCA, 4x4 MIMO Cat5 600Mbit/s DL/cell

5G RF Wide Area 10-10Mbit/s /user, 1Gbit/s/cell
RF Small cell 0.1-NxGbit/s /user, 10Gbit/s/cell
mm Wave: (as RF small Cell or higher)

Monitoring

5G cost effective IoE
mobile-IoT + legacy-IoT

Self Organising Networks

LTE-A RAN optimisation
5G + Automatic Cluster Organisation driving Network Slicing
+ Demand Attentive Networking

Automation

LTE-A >100ms
5G ~1ms
(supports Auto-Drive)

Access

LTE-A 50ms
5G 10ms

Apps

5G Work with the network
& connected Cloud/ IoE
(with User plane control)

COMMS

Wi-Fi
5G Mobile (RF)
PtP (mm Wave)
(simultaneous
multi-RAN connection)

Cloud

Seamless cloud storage
and IaaS, AaaS

User/ DEVICES

5G SoftSIM
extensible User Profiles
Predictive capabilities
80% Autonomous signalling

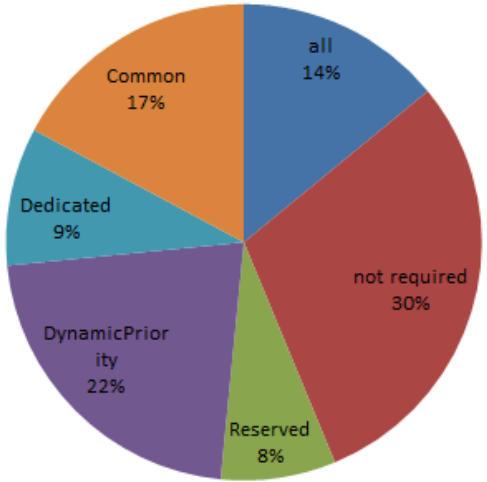
Requirements

Key Requirements for 5G Architecture

Goal	Capability (5GIC proposals)
Lower Latency	Reduce # functional nodes traversed per ETE path. 5GIC propose a Flat Distributed Cloud (FDC) arch. with less Tunnelling.
More Efficient Signalling	ETE context aware Memory-Full signalling solution with including: Signalling Context Caching/IE Codebook compression. Extend Rel-14 IoT RRC context caching across multiple subscriber types according to grouping for Mobility, Locale etc.
Common, Sliceable Nwk. Arch. supporting Multiple RAN Arch options	Common Nwk Arch. sliceable according to service groups deployed & mapped to multiple RAN architecture options: C-RAN (Campus, UD areas), D-RAN(Rural areas) and H-RAN
Extended ETE Control and User plane Separation	Extend Rel-14 Dual Connectivity approach to become able to connect to totally different RAT(a) for CP services as compared to that for UP services with ability to bond multiple UP streams together and maintain during Handover
Evolved SON and OAM to Enable Network Slicing	Adopt SDN/NFV implementation approach and define standard Orchestration/Topology control interface for Mobile adoption (& add Nwk Level SON algorithms such as: Automatic Cluster Organisation (ACO)
Network Context Enablement	Extend Subscriber Data Management (SDM) to provide distinct, but related SIM, User Profile and Device Management Expose UsrP and Device Mgt interfaces to the User to enable context awareness t drive QoE
Multi-Option IoT Support	The 5G System Shall provide 'built-in' support for the Internet of Things' (IoT)
Much improved Content Management Services	Fully adopt MEC principles and empower with ICN/CCN for Predictive content management algorithms to realise real reductions in data volume shipped over the network for better QoE

Requirements

Network Slicing Capability



DIVERSE !

In order to support “Flexible Network Operations”

Network Slicing has been proposed by many of the SMARTER use cases.

5GIC identify a network slicing approach where resources are able to be assigned as follows:

Reserved	Resources are always reserved for services of this type to use whether active or not (8%) e.g. Safety Critical applications or usually deployed UAVs, AVs
Dedicated	Resources are dedicated to these use cases for the duration of the session (9%) e.g. Disasters, Temporarily deployed UAVs, Tactile Internet, Remote Precision Control
Dynamic	Resources for these UC are not dedicated but given pre-emptive priority for each session and may throttle or displace other lower priority services on service request, but operate at lower Priority than dedicated services, e.g. Real-Time & Gaming
Common	Services on this slice of the network get access to the remaining resources of the network after the other resource slices are served, everything else

Note:

70% of the use cases in SMARTER require Slicing

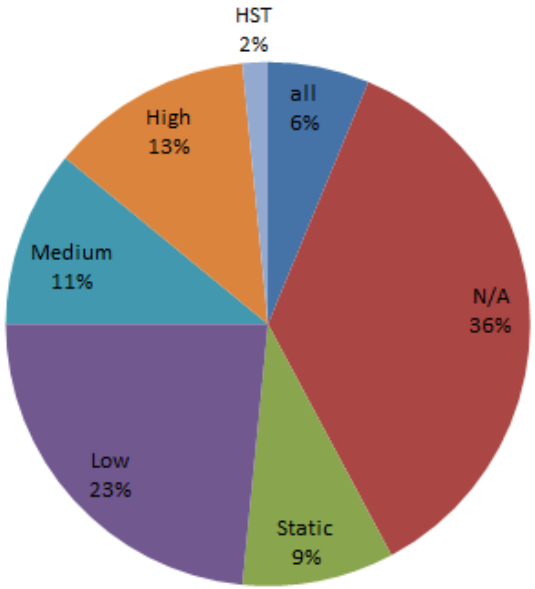
14% are capabilities that require support of all Slicing options

Each Slice may have to support multiple QoS, but Slicing is more about the nature of the R&A of the resource than QoS parameters.

41% of the SMARTER use cases require improved security (IDoT, Separate UsrP control etc.)

Requirements

Mobility Support



DIVERSE !

5G needs to be responsive to Mobility

9% static use cases (IoT support now much more prevalent)

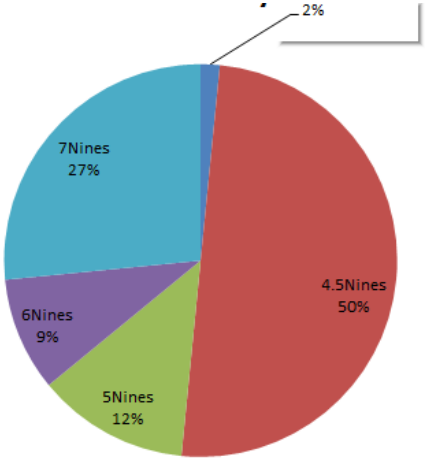
23% Low - Pedestrian <6km/hr
11% Med - DU/SU vehicular, 7 to 65km/hr
13% High - Motorway, low speed drones, AV, UAV 66 to 130km/hr
2% HST - High Speed Trains , 130 to 500km/hr

6% of the use cases are capabilities that require the graduates support of all of the speed ranges required e.g. we expect slicing to be ab le to be applied over all speed/mobility cases.

Requirements

VERY DIVERSE !

Availability Support



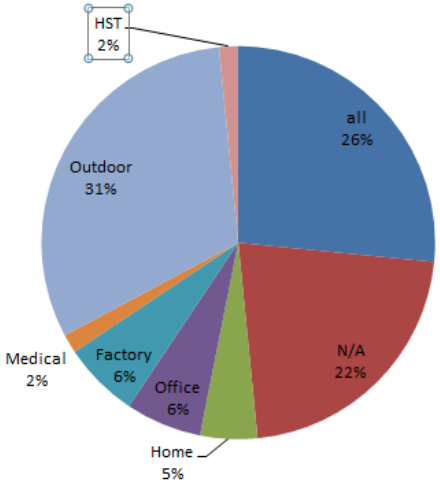
50% of the UC do not need any greater availability than today & 4.5Nines (99.995%, 26m18s/yr)

12% need 5 Nines (99.999%, 5m15s/yr

9% need 6Nines=99.9999%, 32s/yr

27% need 7Nines=99.99999&, 3.2s/yr

Locale Support



31% of UC are outdoor

26% of the UC capabilities need to support all locales.

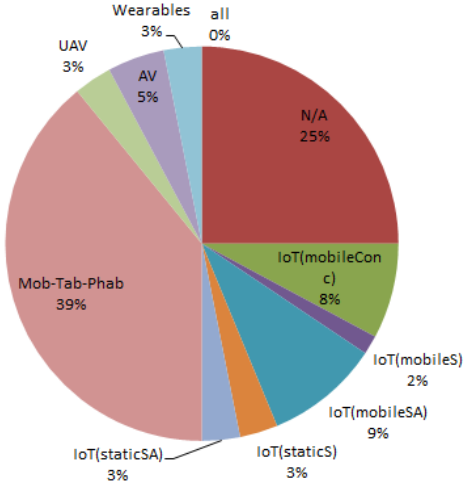
22% of UC are locale independent

6% of UC are Factory applicable

6% of UC are Office applicable

5% home and 2% Medical

Device Type



39% of UC apply to the Mobile/ Tablet/ Phablet group

25% of the UC apply to IoT type devices

8% of the UC are autonomous devices (UAV/ AV)

3% of the UC are applicable to wearables

25% of the UC are not mobile device type specific and apply equally to all device types

Requirements

Safety Critical Requirements

Network Slicing

- Persistence based services as well as Priority & QoS to accommodate DIVERSE UC at same time

Automatic cell Cluster Organisation

- SON to drive Slicing

Wide area coverage separate Control Plane radio service

- always 1-10Mbit/s user plane available
- can be reserved for Safety Critical applications

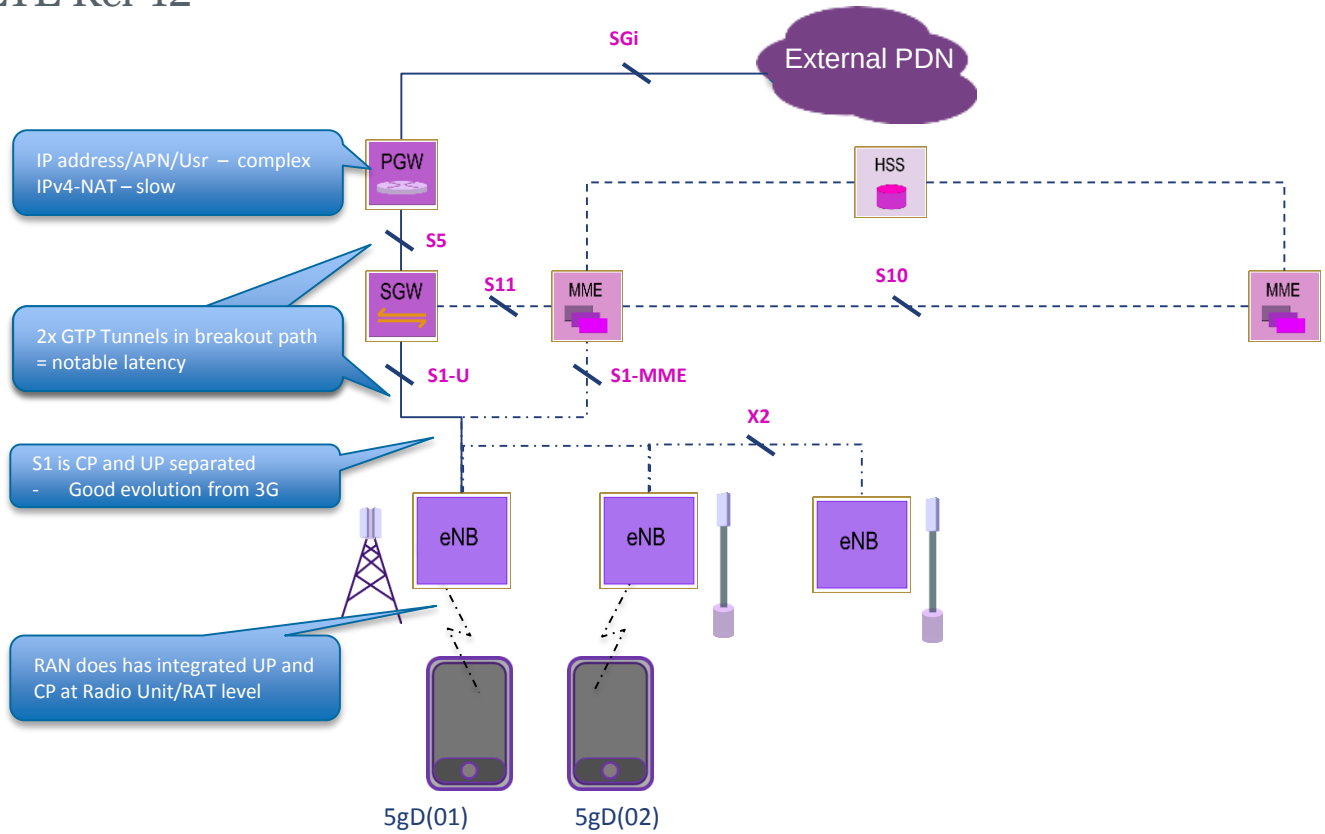
Network becomes demand, priority and persistence attentive which enables whole spectrum to be shared, but slices reserved at RAN and CN for wide area Safety Critical services.

4. Architecture

The 5GIC view on 5G architecture evolution

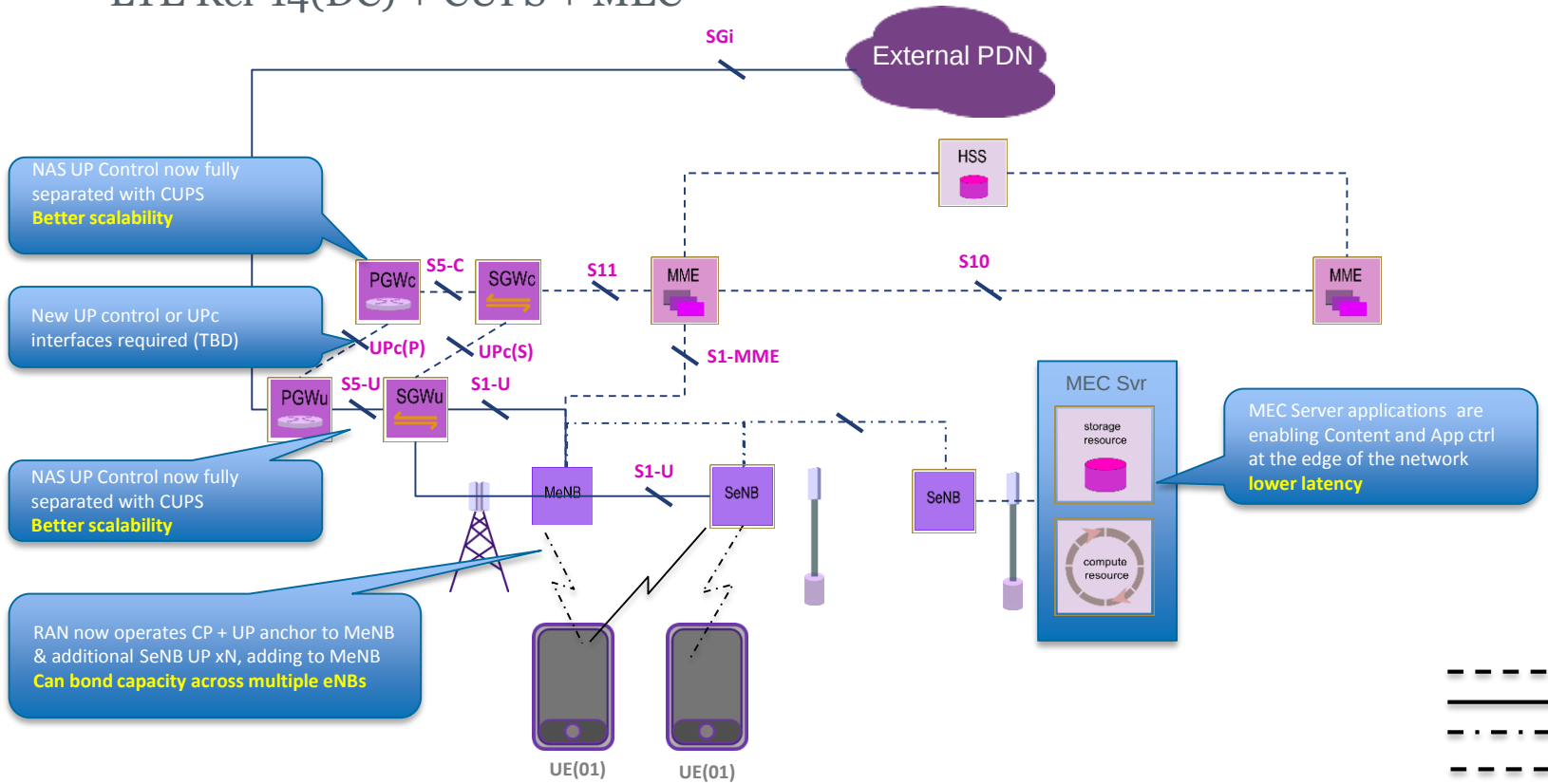
Architecture

LTE Rel-12



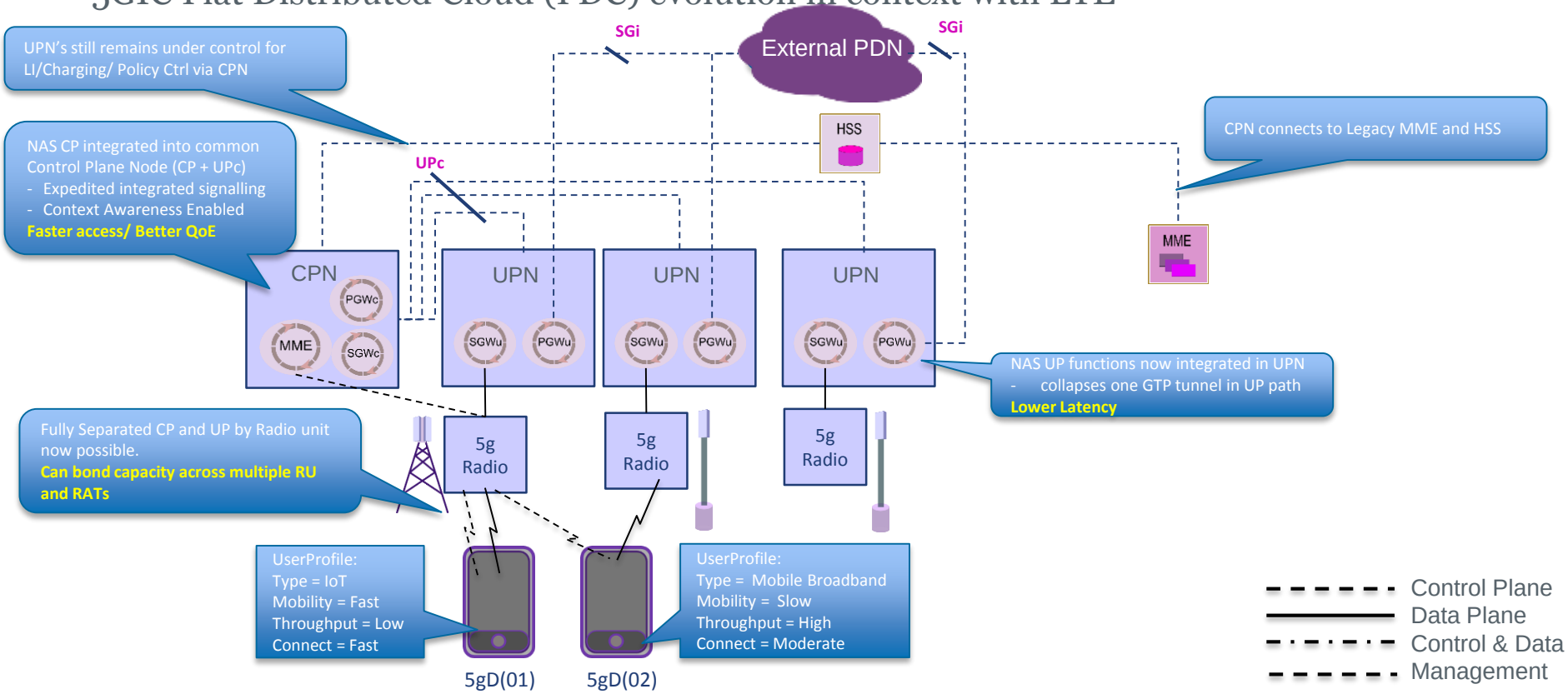
Architecture

LTE Rel-14(DC) + CUPS + MEC



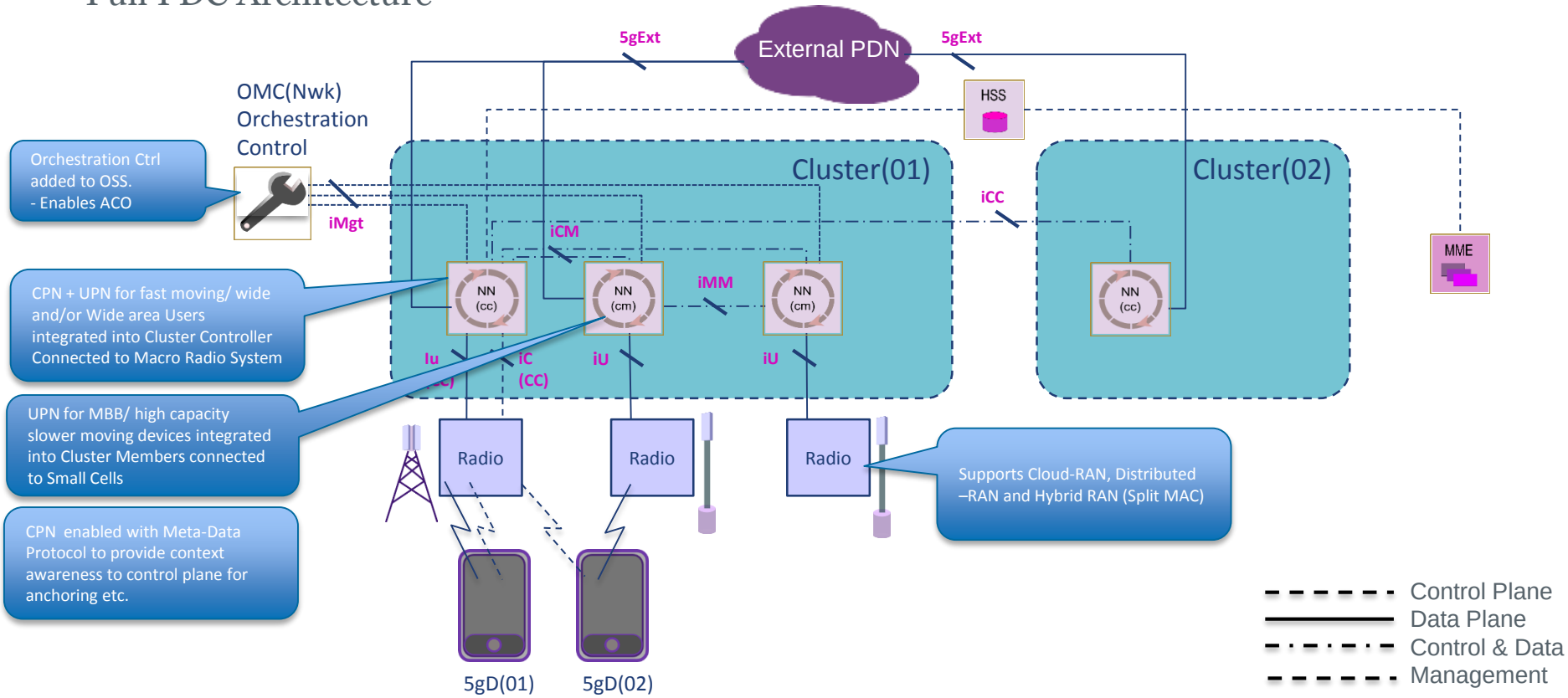
Architecture

5GIC Flat Distributed Cloud (FDC) evolution in context with LTE



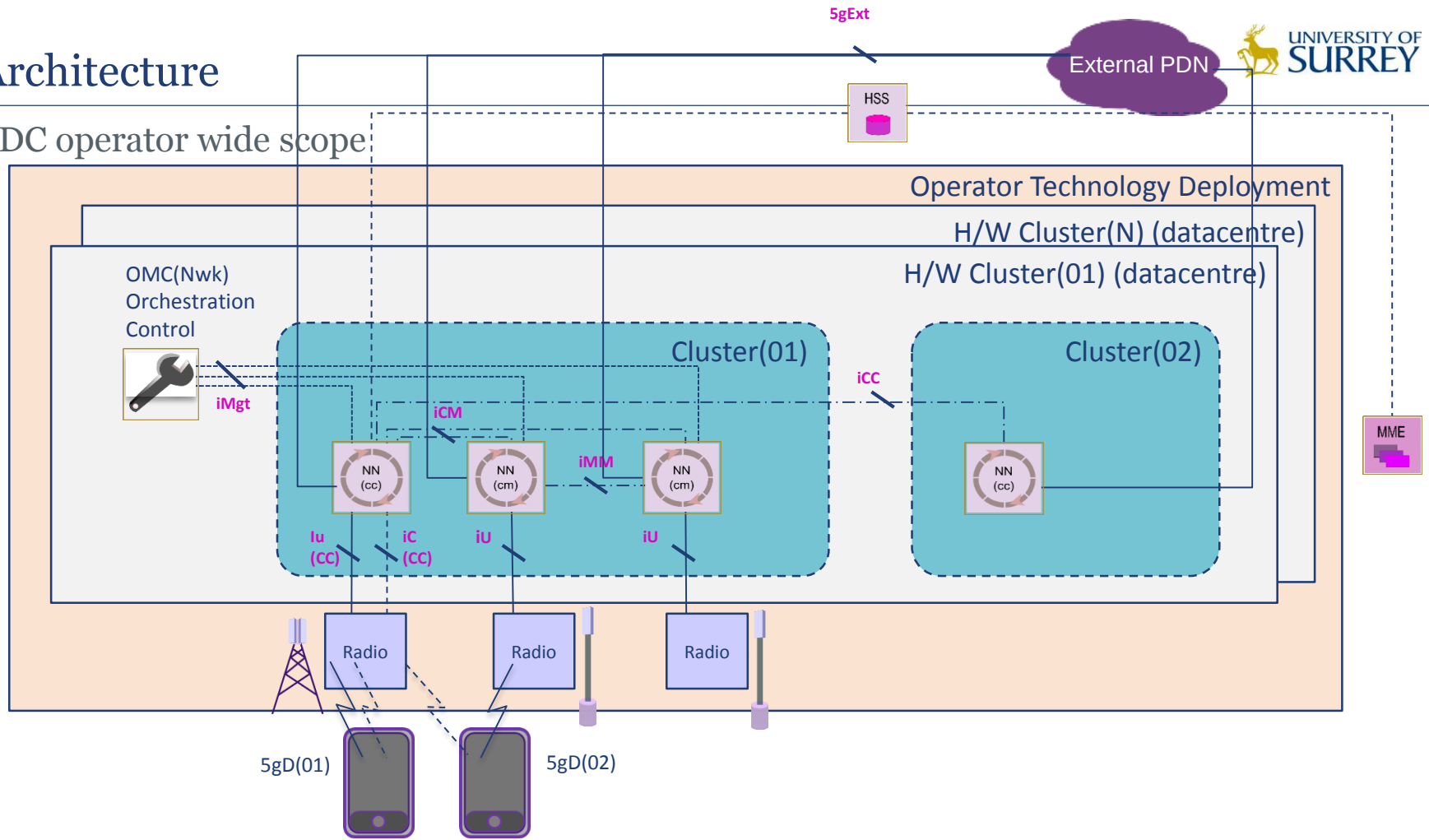
Architecture

Full FDC Architecture



Architecture

FDC operator wide scope



5. Standards

5G Architecture topics needing short term market focus

Standards: WRC15 update

Band	WRC 15 Additions	WRC15 Harmonisation Scope	Start (GHz)	End (GHz)	WRC Proposed Usage	5GIC Proposed Usage
UHF	No		0.610	0.694/ 0.698	High range mobile services.	Global Control Plane, Critical Communications, Wide area MBB and IoT
UHF	Scope Extended	Expanded from Regional APAC to Global	0.694	0.790	To improve the reach of critical mobile broadband services.	Global Control Plane, Critical Communications, Wide area MBB and IoT
L-Band	New		1.427	1.518	Coverage and Capacity expansion	?
C-Band	New	Global harmonisation	3.4	3.6	Dense Urban Mobile	5G MBB
C-Band	Previously available	Regional harmonisation	3.3	3.4	Dense Urban Mobile	5G MBB
C-Band	Previously available	Regional harmonisation	3.6	3.7	Dense Urban Mobile	5G MBB
K-Band, +	New announcement	26GHz+			To be decided at WRC19, anticipate 5G dense MBB	5G MM wave

Standards

5G Architecture Key Progressions?

1. Progress CUPS (Rel-14) towards fully separated CP and UP at RAN & CN level (**Faster Access**)
   - towards FDC-like Next Generation Architecture definition.
2. Support ongoing adoption of NAS signalling optimisation (**Faster Signalling response**)
   - context/ memory-full IE caching/ predictive signalling e.g. PrMM
3. Support reduction of Tunnelling/Encapsulation (**Lower Latency**)
4. Support of IP protocol evolution across 3GPP/IETF/ETSI-ISG next generation protocols (ETSI ISG)
5. Common Network architecture able to support multiple RAN architecture options
   - C-RAN, D-RAN and Hybrid RAN (MAC variants) (**RAN Flexibility**)
6. Definition of User Profile as parallel SDM functionality to make network context-aware
   - with separate ID validation to SIM (**Better QoE**)
7. Definition of Mobile Orchestration/Topology control interface for SDN/NFV adoption (**RAN Flexibility**)
8. RRC evolution for multiple concurrent RAT support, faster access and “connectionless” group access method (**Faster Access**) (Rel-14)
9. Evolve architecture for massive IoT connectivity
   - multiple IoT type support and massive #connections support as evolved MAC (**Enables Metering and Emergency Sensing**)

6. 5GIC Testbed

5GIC Test-bed

Research Targets

Demonstrate Ultra-Dense, 4G-LTE-Advanced deployment

- Build campus 4G network
- Understand the constraints of commercial 4G equipment today
- Develop optimisation techniques to manage Ultra-Dense Networks (e.g. manage interference, sectored small-cells)
- Propose optimisation/evolutions for 5G

Demonstrate and validate 5G Campus ETE research network

- Selectively upgrade components to 5G ETE
- Demonstrate 5G Ultra-Dense Radio Cluster technology
- Demonstrate 5G Context Aware, Flat Distributed Cloud Network,
- Illustrate user benefits with Application & Performance demonstrations

5GIC Test-bed

Goals and Metrics

General

- High capacity cells using 5G PHY and Massive Network MIMO techniques
- Cost-Effective Ultra-Dense, Multiple-Concurrent-Access RAN: (i) RF, ii) mm-Wave and iii) Wi-Fi
- Flat Distributed Cloud (FDC) Network
- Validate User and Access Profiling driving user-tailored-service provision
- Demonstrate efficient, cost effective and flexible IoT communications options
- Show 5G apps that demonstrate broadband high speed video and mobile cloud information exchanges
- Automatic network and resource re-organisation (Network-SON)

User KPIs

- Massive throughput per user for many users per cell (N x Gbit/s per user)
- Low Latency access and operation (~10ms idle to active, ~1ms connection re-load, intra-net packet latency of <1-5ms)
- Efficient use of Caching of (100% for common content)
- HTTP based request/response times (50% to 100% better than LTE-A)

Network KPIs

- High capacity per cell (10Gbit/s)
- Indoor and outdoor massive network MIMO (8 to 128 branch) and low cost multi-branch antenna systems/radio (8/16)
- Scaled massive connection capability per cell (130,000+users)

5GIC Test-bed: Ultra-Dense Campus Test-bed

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University of Surrey Outdoor Campus

Macro BS
RRH
Umbrella Cell
Small Cell
FAP
Ultra-Dense Cluster(1)
AP
ATI
Ultra-Dense Cluster(2) (AY Building)
Ultra-Dense Cluster(3)

Vodafone Reading Test Centre

LTE Core (H/W)
MME
HSS
SGW
PGW
VPN Tunnel

5GIC Comm's Room

C-RAN Baseband Units
Operations & Maintenance
LTE Soft-Core
MME
HSS
SGW
PGW
5G Soft-FDC Core
CM
CC
PPE

5GIC Indoor Deployment

LTE pRRH
picoRRH's (x6, pico-LTE TDD)
LTE Femto
Femto Radios (x6, LTE FDD)
Wi-Fi AP
Access Points (x6, 802.11ac)

5GIC Test-bed: Technical & Economic Roadmap Goals

7. Slicing Examples

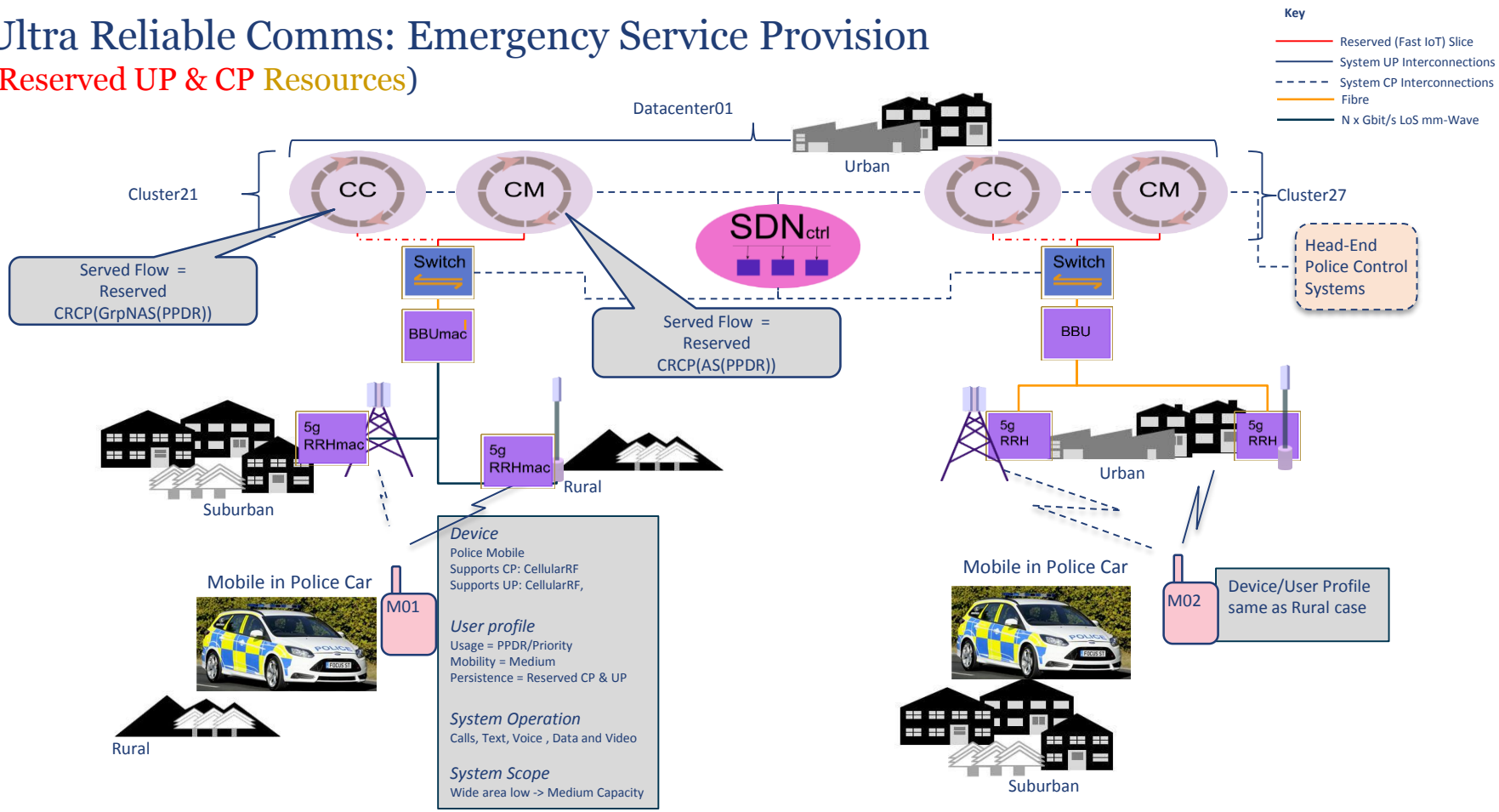
For 5G use cases, “one size does not fit all”

5G must be a holistic network!

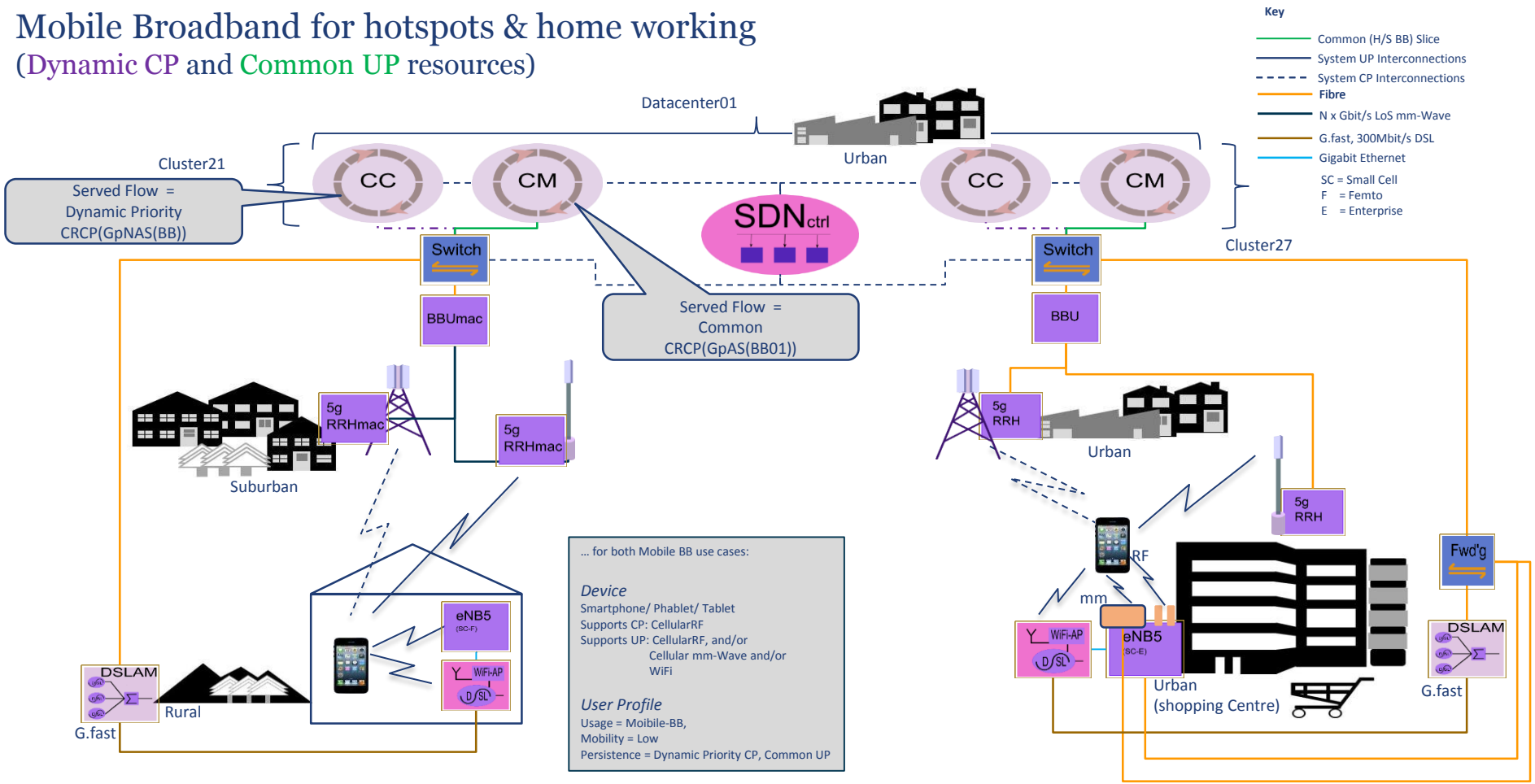
- *fed with Context Aware, User Profile input*
- *triggered with SON*
- *Demand attentive, Context Aware and Network Slicing*

Ultra Reliable Comms: Emergency Service Provision

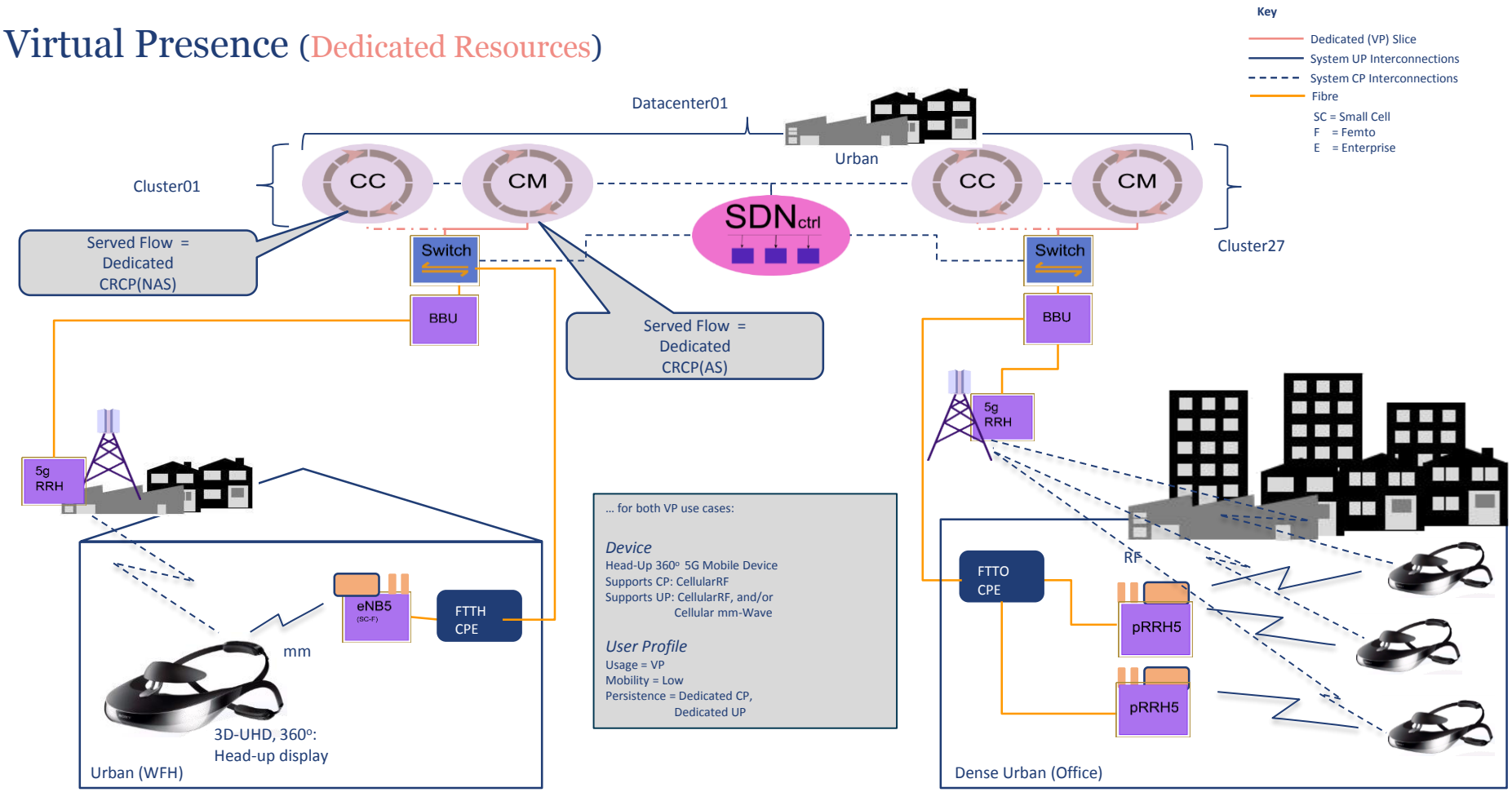
(Reserved UP & CP Resources)



Mobile Broadband for hotspots & home working
(Dynamic CP and Common UP resources)



Virtual Presence (Dedicated Resources)



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Public Safety Communication Europe

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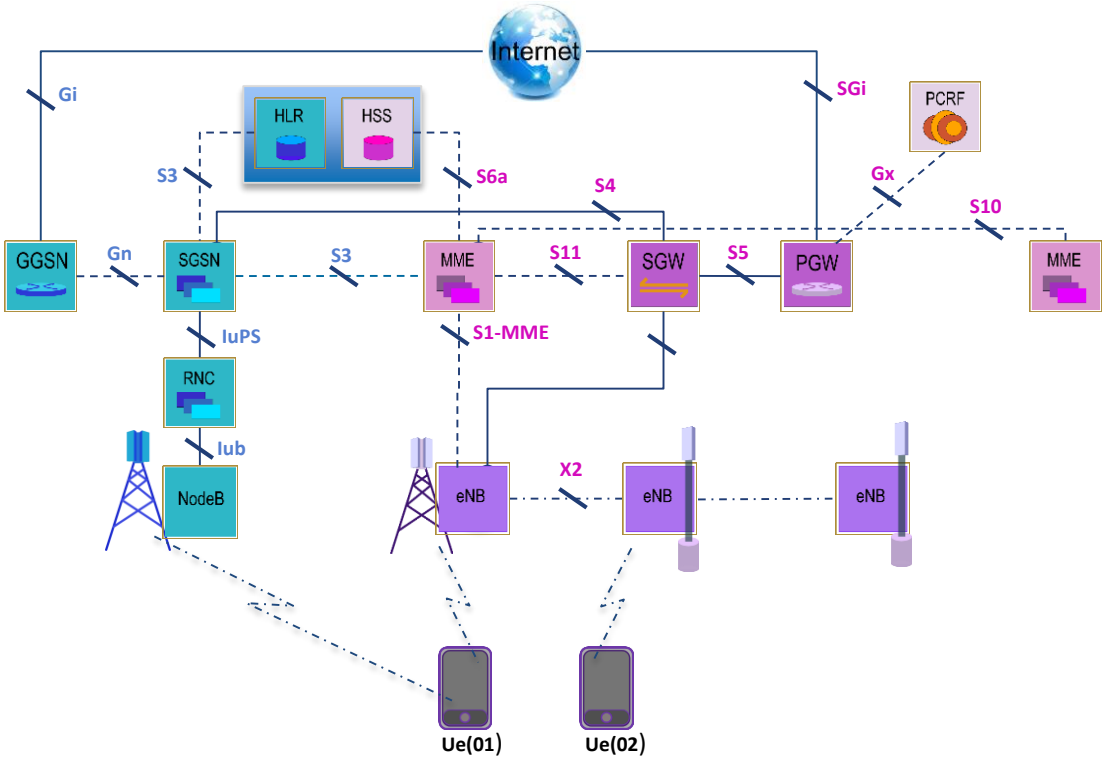
... any questions?

Architecture

LTE Rel-12 (& Legacy UMTS)



Key

Control Plane

Data Plane

Control & Data

Management