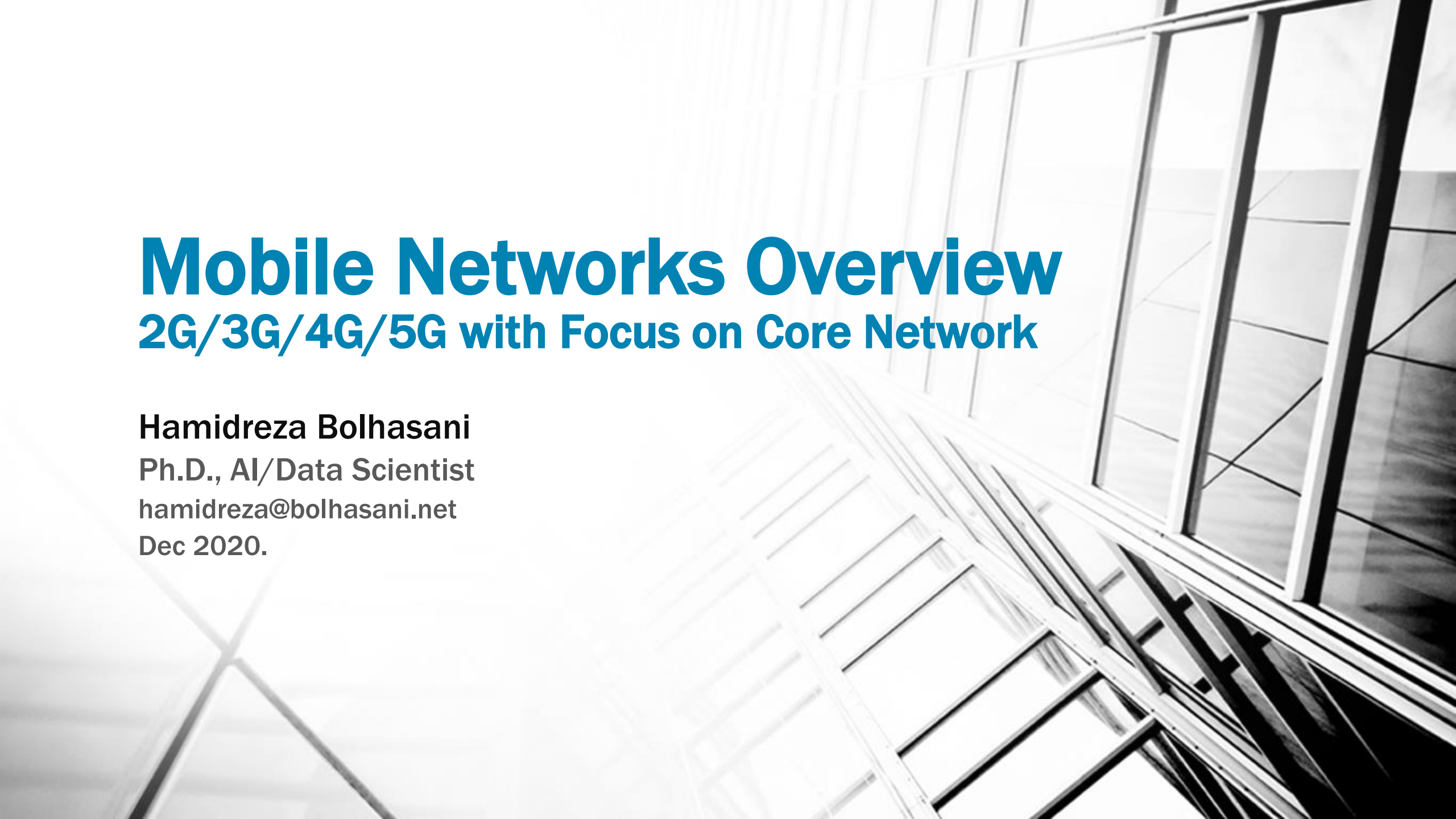
Mobile Networks Overview

2G/3G/4G/5G with Focus on Core Network

Hamidreza Bolhasani
Ph.D., AI/Data Scientist
hamidreza@bolhasani.net
Dec 2020.



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Self Introduction

Founder | Data Scientist (Jul 2020 – Now)
DataBioX

Scientific Reviewer (Jul 2020 – Now)
Elsevier

Visiting Professor (Feb 2021 – Now)
Science and Research Branch of IAU.
Computer Engineering

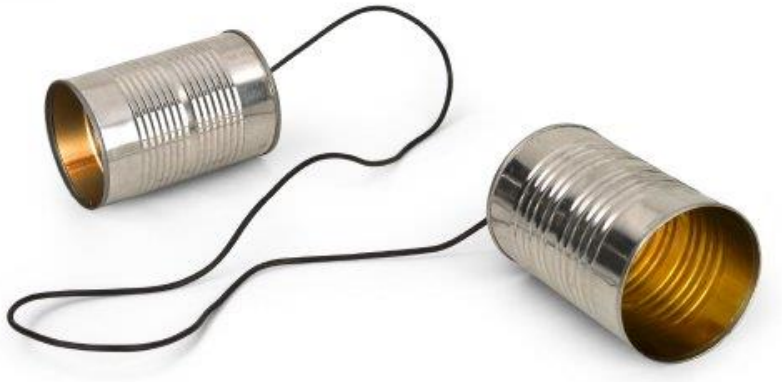
CS/PS IMS Core Network Expert (Jan 2013 – Now)
MCCI (Mobile Communication Company of Iran)

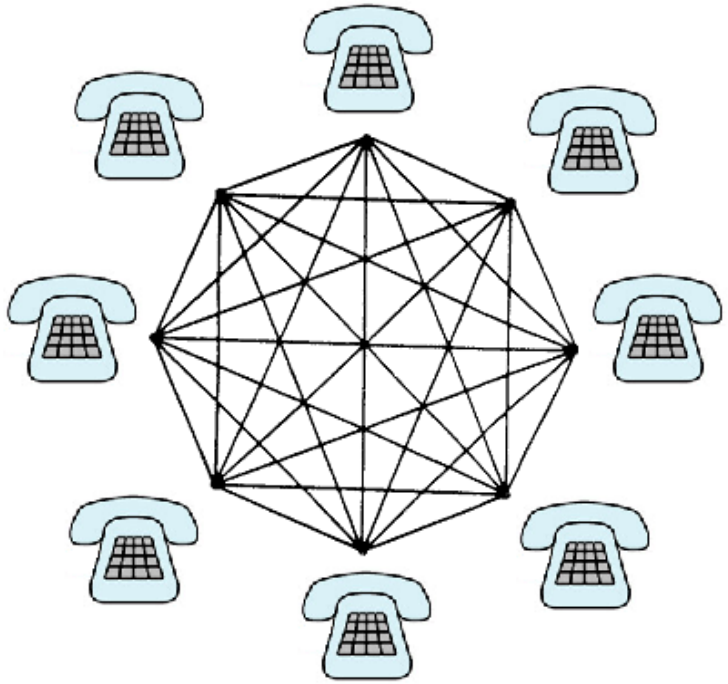
Core Network Consultant (Sep 2014 – Nov 2015)
NAK | World-class telecom managed services company

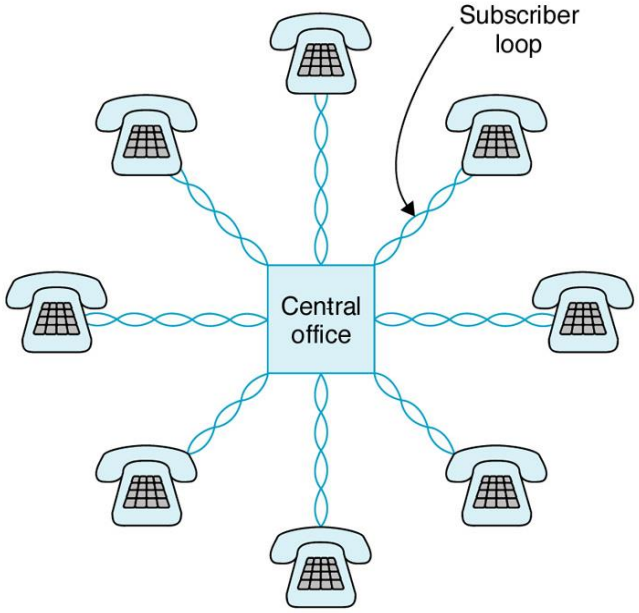
Core Network Engineer (Dec 2010 – Jan 2013)
HUAWEI Technologies Co. LTD.

IP/Network Engineer (Sep 2008 – Nov 2010)
ACECR | Academic Center for Education, Culture and Research

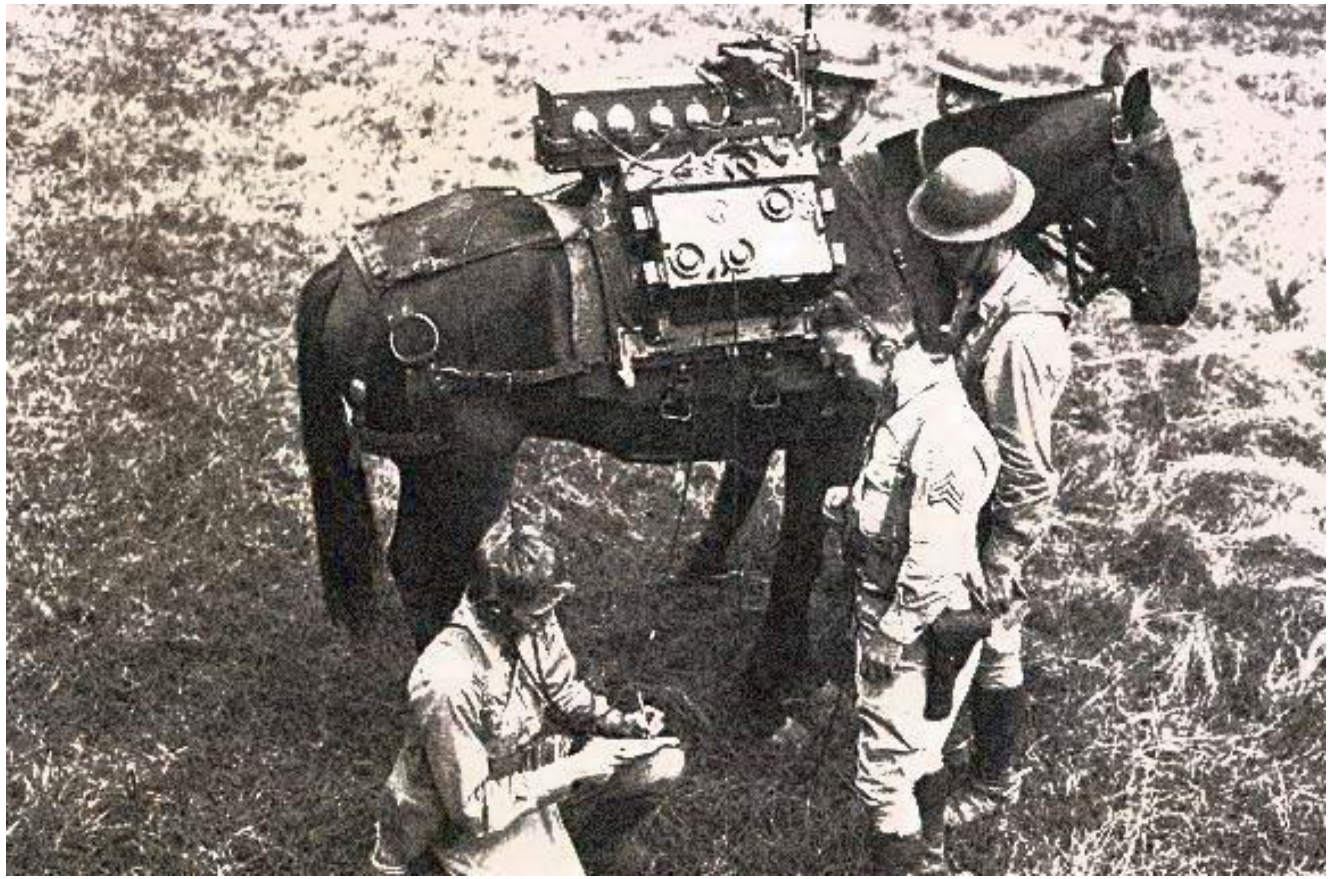
Mobile Networks History







Mobile Networks History



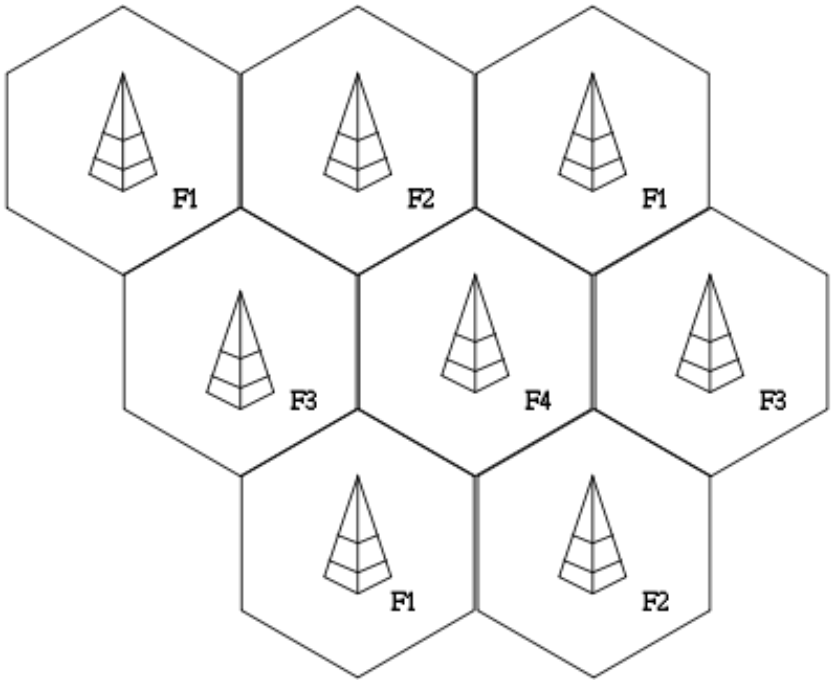
Every new generation of connectivity capability enables fundamental process reinvention

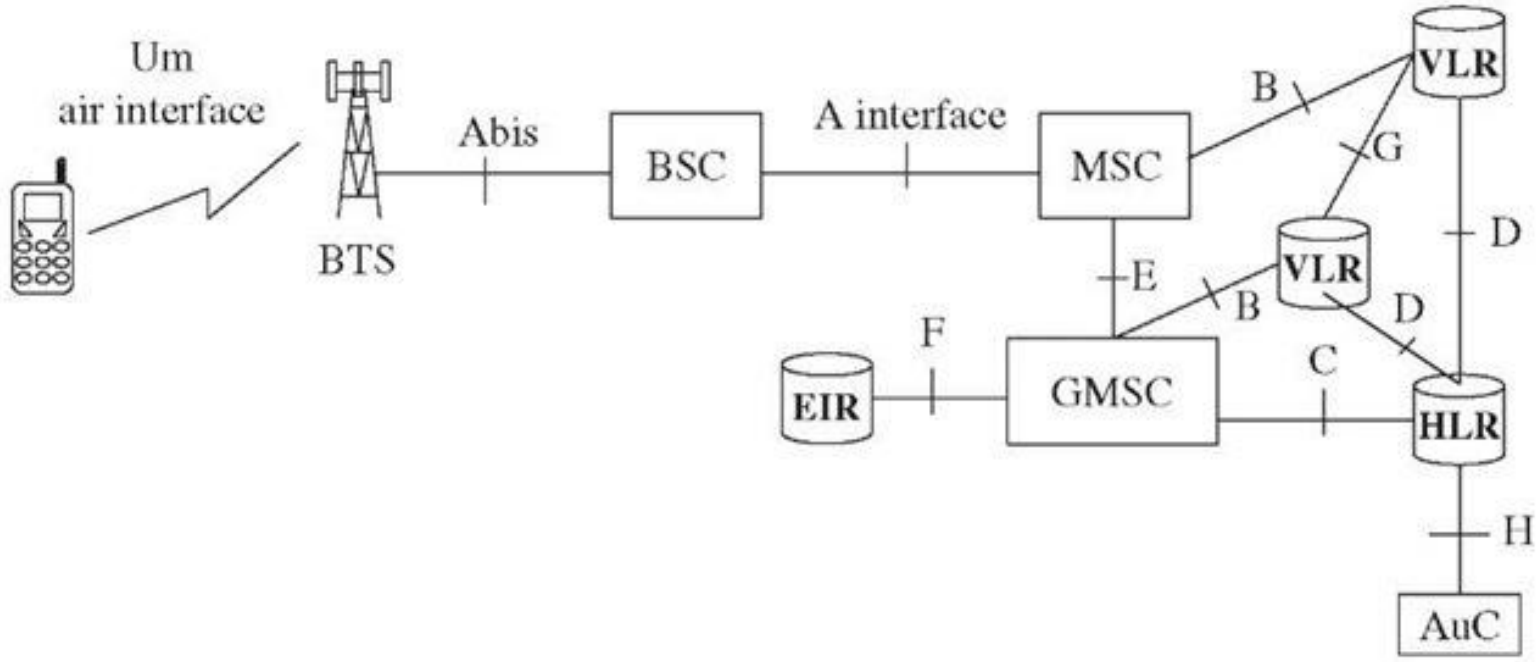
The 5G disruption - from Consumer centric towards Industry & Verticals

1G	2G	3G	4G	5G
1980s Analog Voice	**1990s Digital Voice**	**2000s Mobile Broadband**	**2010s Faster/Better 3G**	**2020s Hyper-connectivity**
▪ Human-to-Human ▪ US vendors had 80% of global handsets and infrastructure markets	▪ Voice and SMS, Low-speed data ▪ US vendors fell to 18% for handsets and to 40% for infrastructure	▪ 2007: Nokia, Motorola, Siemens, Sony, and Ericsson had 67% of global handset market; 2010: they had 26% ▪ Meanwhile, iOS and Android went from 18% OS market share in 2009 to 82% in 2012	▪ IP-Based Network, High-speed Internet, streaming, APPs ▪ Asia accounts for 75% of mobile devices sold ▪ Huawei is #1 infrastructure provider	▪ Interconnected Devices, Sensors and Systems

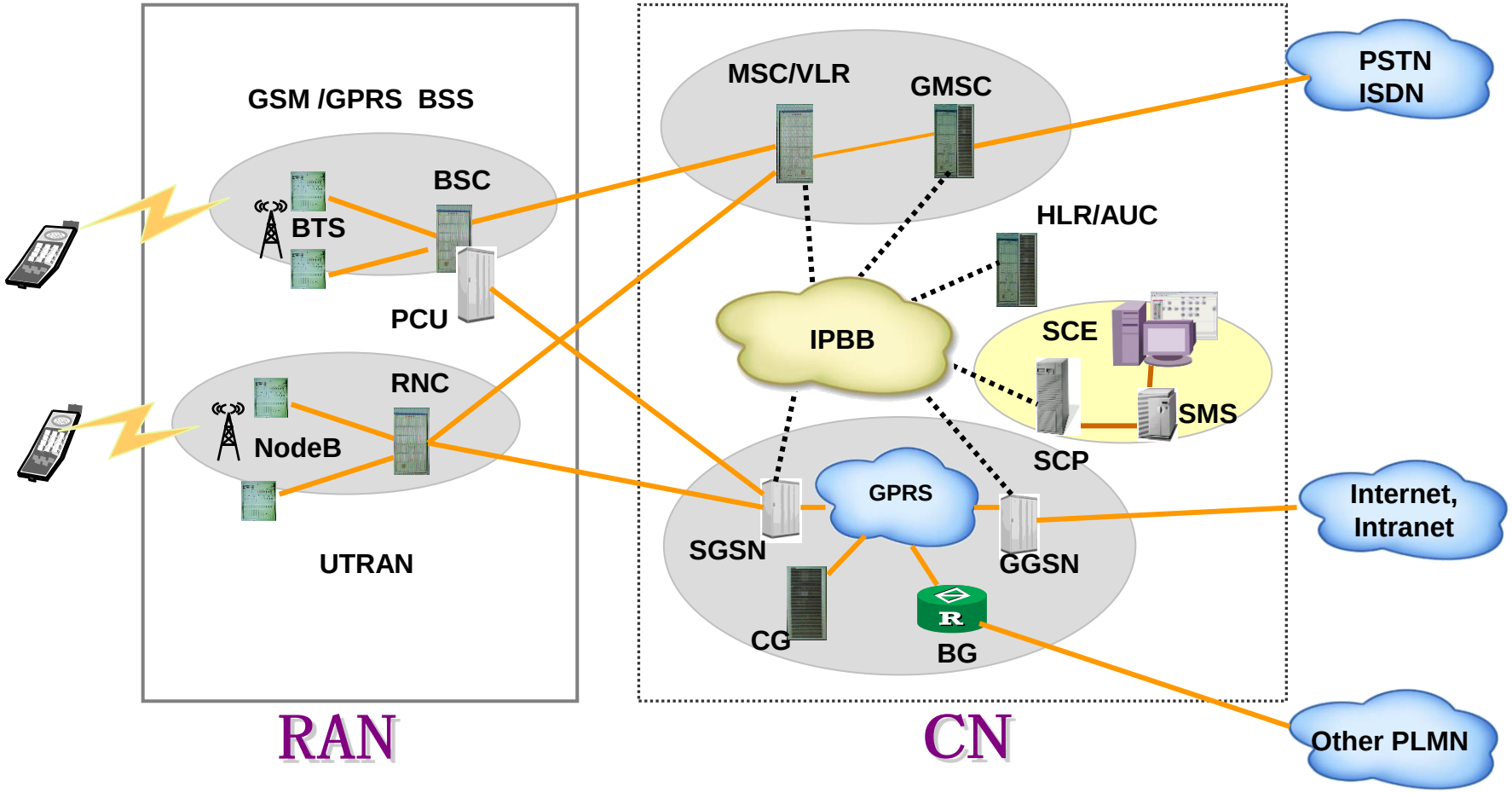
Global System for Mobiles (GSM)

- Cellular Network or Mobile Network is a communication network where the last link is wireless. The network is distributed over land areas called cells, each served by at least one fixed-location transceiver, known as a cell or base station.





2G / 3G Overview



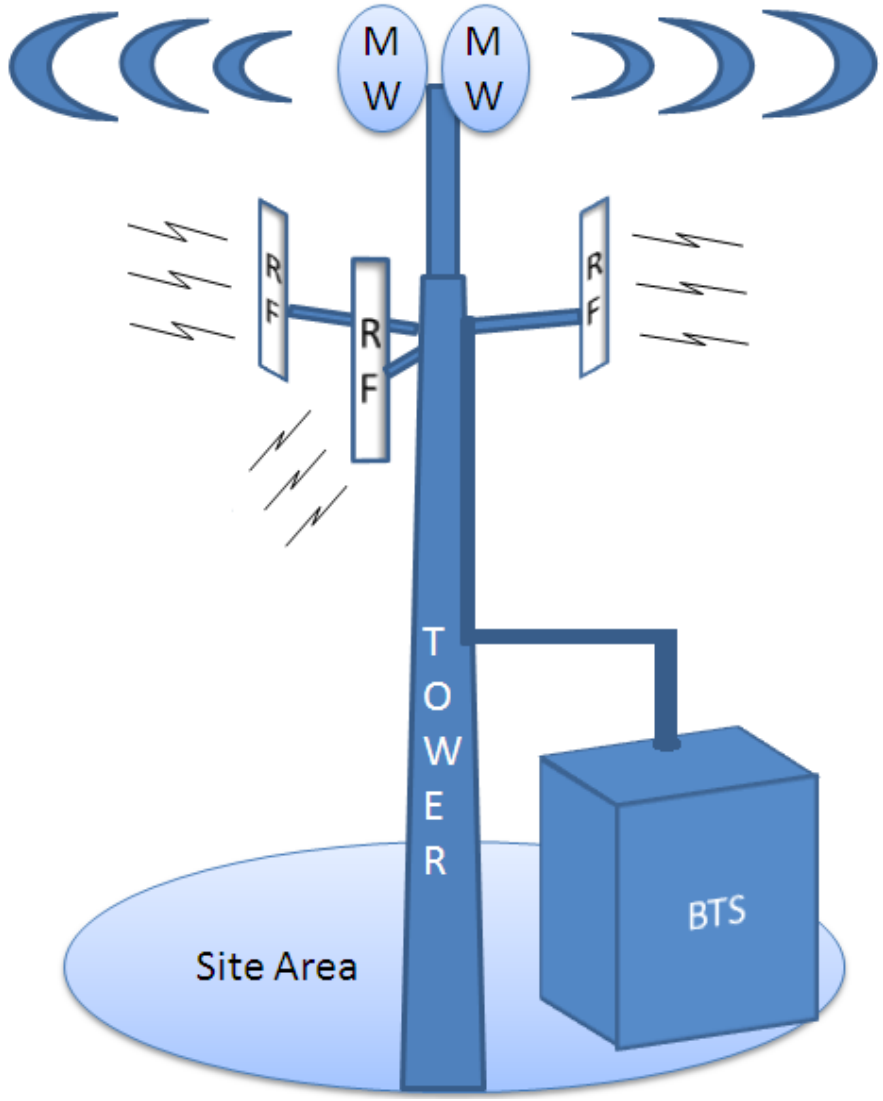
2G Radio

- **BTS (Base Station Transceiver)**

BTS is a piece of equipment that facilitates wireless communication between user equipment (UE) and a network. UEs are devices like mobile phones (handsets), WLL phones, computers with wireless Internet connectivity.

- **BSC (Base Station Controller)**

BSC is a critical mobile network component that controls one or more base transceiver stations (BTS), also known as base stations or cell sites. Key BSC functions include radio network management (such as radio frequency control), BTS handover management and call setup. It also carries transcoding of speech channels.



GSM Frequency Bands

GSM band	*f* (MHz)	Uplink (MHz) (Mobile to Base)	Downlink (MHz) (Base to Mobile)	Channel number	Equivalent LTE band
T-GSM-380	380	380.2 – 389.8	390.2 – 399.8	dynamic	
T-GSM-410	410	410.2 – 419.8	420.2 – 429.8	dynamic	
GSM-450	450	450.6 – 457.6	460.6 – 467.6	259 – 293	31
GSM-480	480	479.0 – 486.0	489.0 – 496.0	306 – 340	
GSM-710	710	698.2 – 716.2	728.2 – 746.2	dynamic	12
GSM-750	750	777.2 – 792.2	747.2 – 762.2	438 – 511	
T-GSM-810	810	806.2 – 821.2	851.2 – 866.2	dynamic	27
GSM-850	850	824.2 – 848.8	869.2 – 893.8	128 – 251	5
P-GSM-900	900	890.0 – 915.0	935.0 – 960.0	1 – 124	
E-GSM-900	900	880.0 – 915.0	925.0 – 960.0	975 – 1023, 0 - 124	8
R-GSM-900	900	876.0 – 915.0	921.0 – 960.0	955 – 1023, 0 - 124	
T-GSM-900	900	870.4 – 876.0	915.4 – 921.0	dynamic	
DCS-1800	1800	1710.2 – 1784.8	1805.2 – 1879.8	811 – 885	3
PCS-1900	1900	1850.2 – 1909.8	1930.2 – 1989.8	512 – 810	2

ISM Bands

Frequency range		Type	Center frequency	Availability	Licensed users
6.765 MHz	6.795 MHz	**A**	6.78 MHz	Subject to local acceptance	FIXED SERVICE & Mobile service
13.553 MHz	13.567 MHz	**B**	13.56 MHz	Worldwide	FIXED & Mobile services except Aeronautical mobile (R) service
26.957 MHz	27.283 MHz	**B**	27.12 MHz	Worldwide	FIXED & MOBILE SERVICE except Aeronautical mobile service
40.66 MHz	40.7 MHz	**B**	40.68 MHz	Worldwide	Fixed, Mobile services & Earth exploration-satellite service
433.05 MHz	434.79 MHz	**A**	433.92 MHz	only in Region 1, subject to local acceptance	AMATEUR SERVICE & RADIOLOCATION SERVICE, additional apply the provisions of footnote 5.280
902 MHz	928 MHz	**B**	915 MHz	Region 2 only (with some exceptions)	FIXED, Mobile except aeronautical mobile & Radiolocation service; in Region 2 additional Amateur service
2.4 GHz	2.5 GHz	**B**	2.45 GHz	Worldwide	FIXED, MOBILE, RADIOLOCATION, Amateur & Amateur-satellite service
5.725 GHz	5.875 GHz	**B**	5.8 GHz	Worldwide	FIXED-SATELLITE, RADIOLOCATION, MOBILE, Amateur & Amateur-satellite service
24 GHz	24.25 GHz	**B**	24.125 GHz	Worldwide	AMATEUR, AMATEUR-SATELLITE, RADIOLOCATION & Earth exploration-satellite service (active)
61 GHz	61.5 GHz	**A**	61.25 GHz	Subject to local acceptance	FIXED, INTER-SATELLITE, MOBILE & RADIOLOCATION SERVICE
122 GHz	123 GHz	**A**	122.5 GHz	Subject to local acceptance	EARTH EXPLORATION-SATELLITE (passive), FIXED, INTER-SATELLITE, MOBILE, SPACE RESEARCH (passive) & Amateur service
244 GHz	246 GHz	**A**	245 GHz	Subject to local acceptance	RADIOLOCATION, RADIO ASTRONOMY, Amateur & Amateur-satellite service

3G Radio

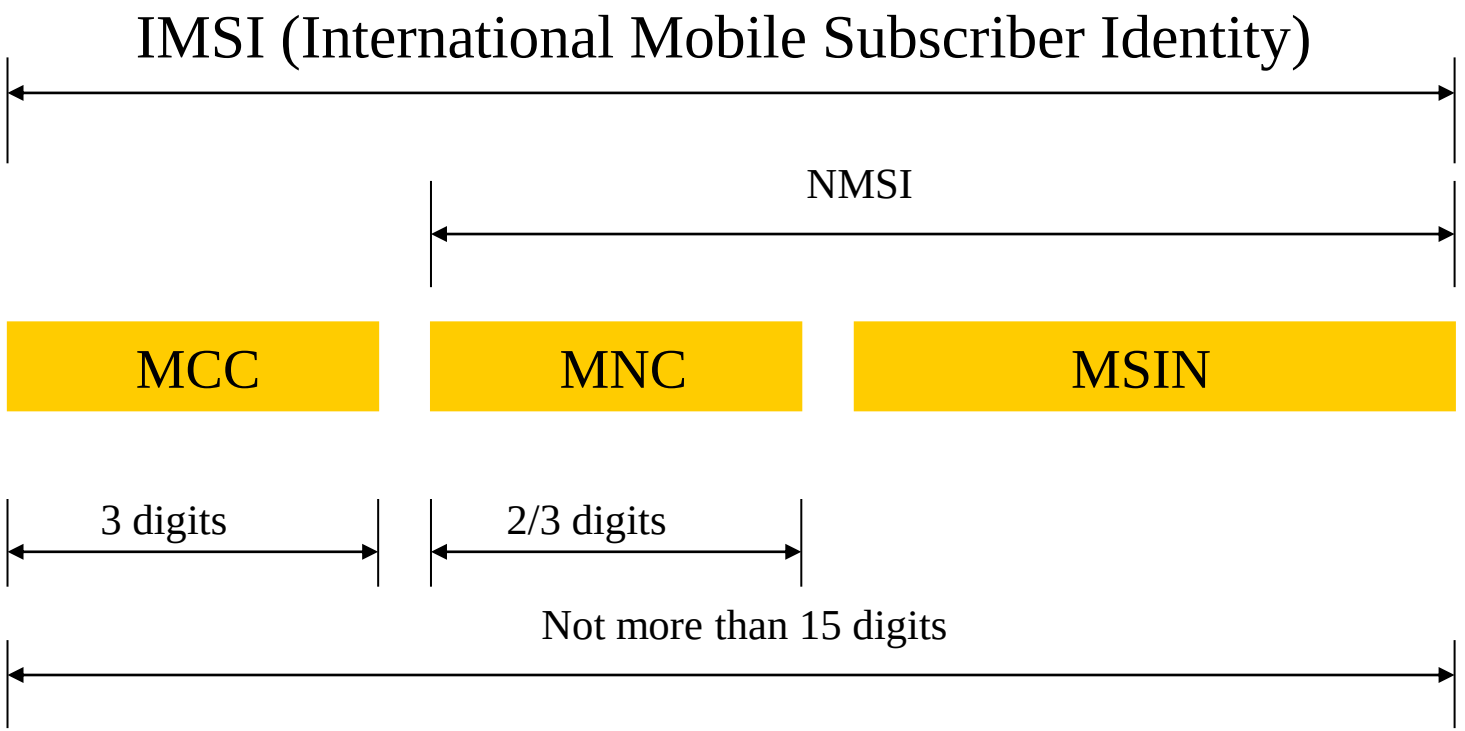
- **NodeB**

  NodeB is a term used in UMTS equivalent to the BTS (base transceiver station) description used in GSM.

- **RNC (Radio Network Controller)**

  RNC is a governing element in the UMTS radio access network (UTRAN) and is responsible for controlling the NodeBs that are connected to it. The RNC carries out radio resource management, some of the mobility management functions and is the point where encryption is done before user data is sent to and from the mobile.

Terminologies - IMSI



MCC：Mobile Country Code

MNC：Mobile Network Code

MSIN：Mobile Station Identification Number

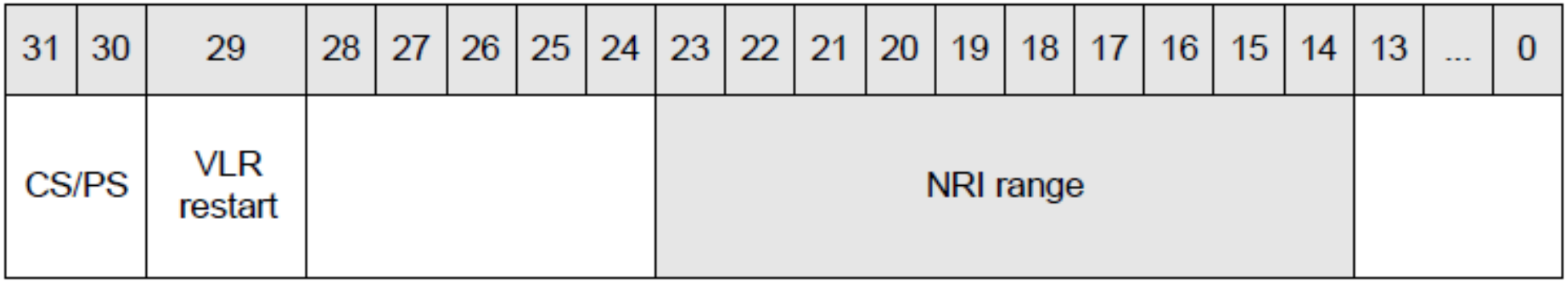
NMSI：National Mobile Station Identity

IMSI

- IMSI: International Mobile Subscriber Identity
- IMSI is a unique identifier allocated to each mobile subscriber
- Its code type is E.212
- IMSI can be saved in SIM, HLR and VLR and can be transferred through MAP and Wireless interface.
- IMSI has almost 15 digits (0-9) such as 43211xxxxxxxxxx

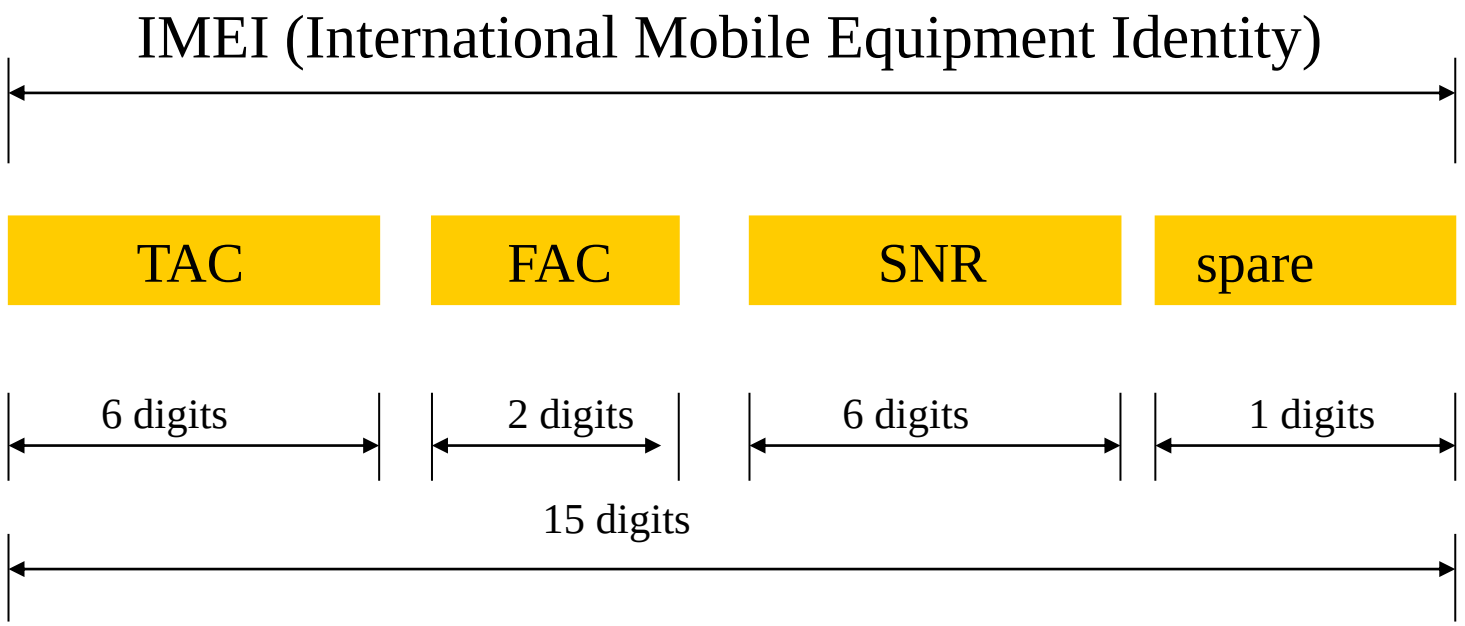
TMSI

- TMSI: Temporary Mobile Subscriber Identity
- In order to ensure subscriber identity confidentiality, the VLR (Visiting Location Register) and SGSN (Serving GPRS Support Node) may allocate TMSI to visiting mobile subscribers.



Bits 31-30	CS/PS service indicator
Bit 29	VLR restart count
Bits 23-n (n⩾14)	NRI
Other bits	User IDs

IMEI



TAC：Type Approval Code

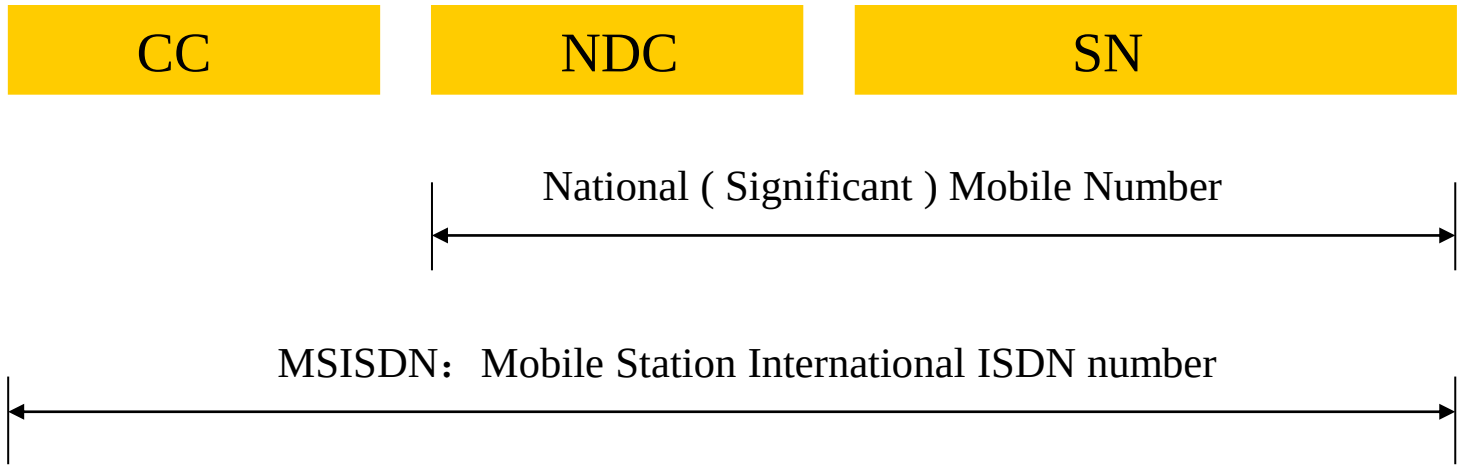
FAC：Final Assembly Code

SNR：Serial Number

spare：Standby bit

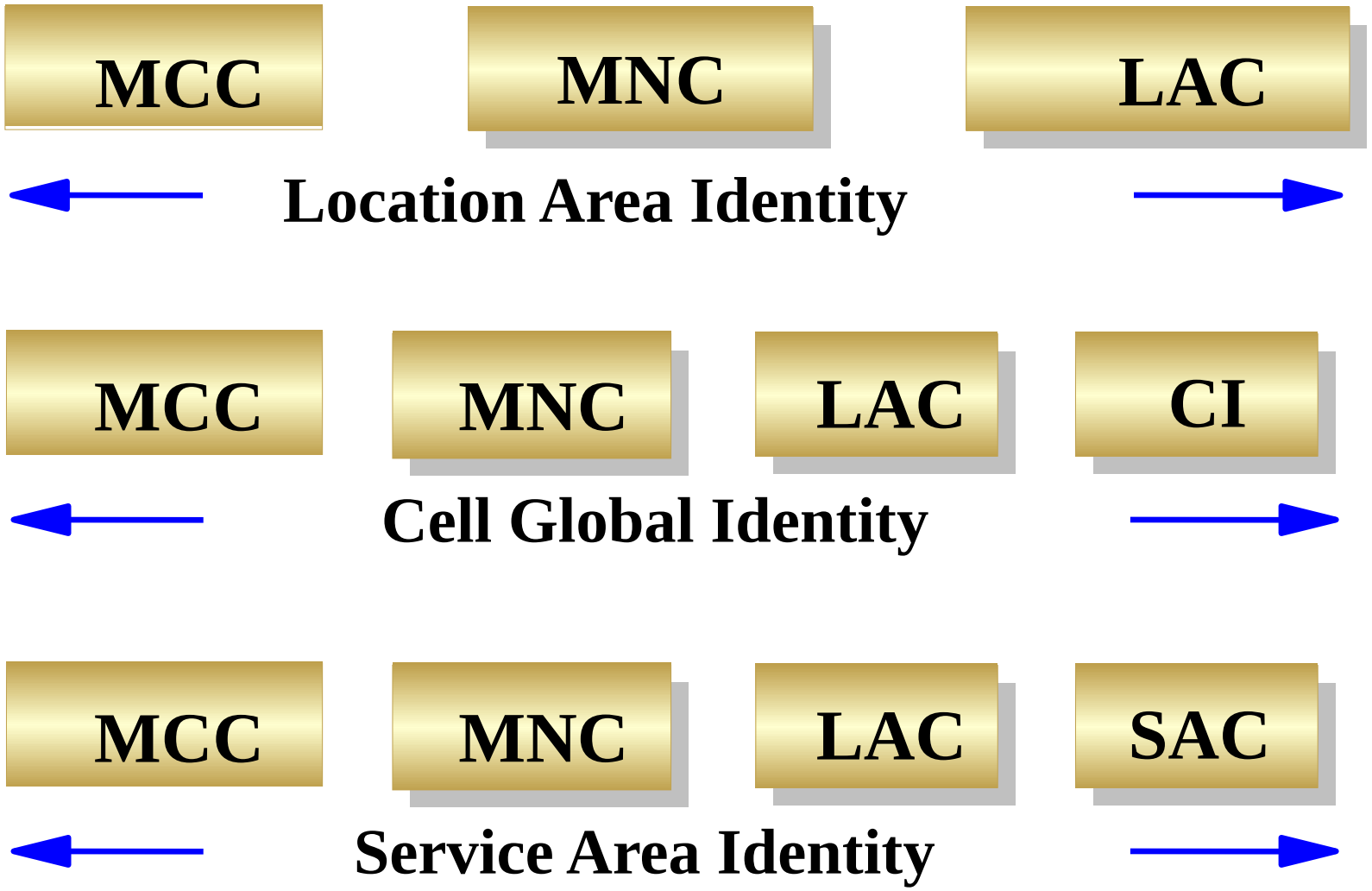
Example:490547403767335

MSISDN



CC： Country Code, China Country Code is 86
NDC： National Destination Code
SN： Subscriber Number

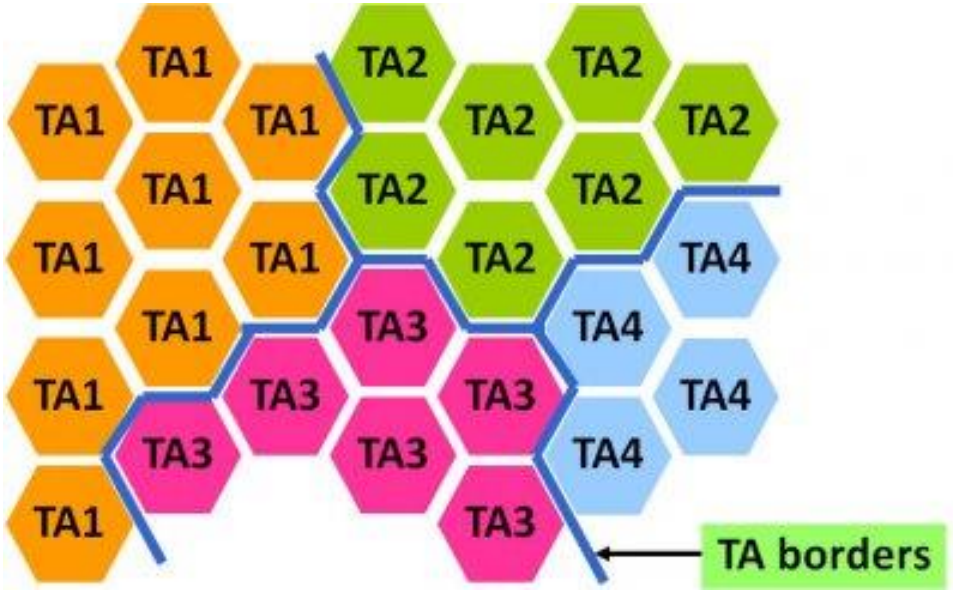
LAI / GCI / SAI


MCC
MNC
LAC
Location Area Identity
MCC
MNC
LAC
CI
Cell Global Identity
MCC
MNC
LAC
SAC
Service Area Identity

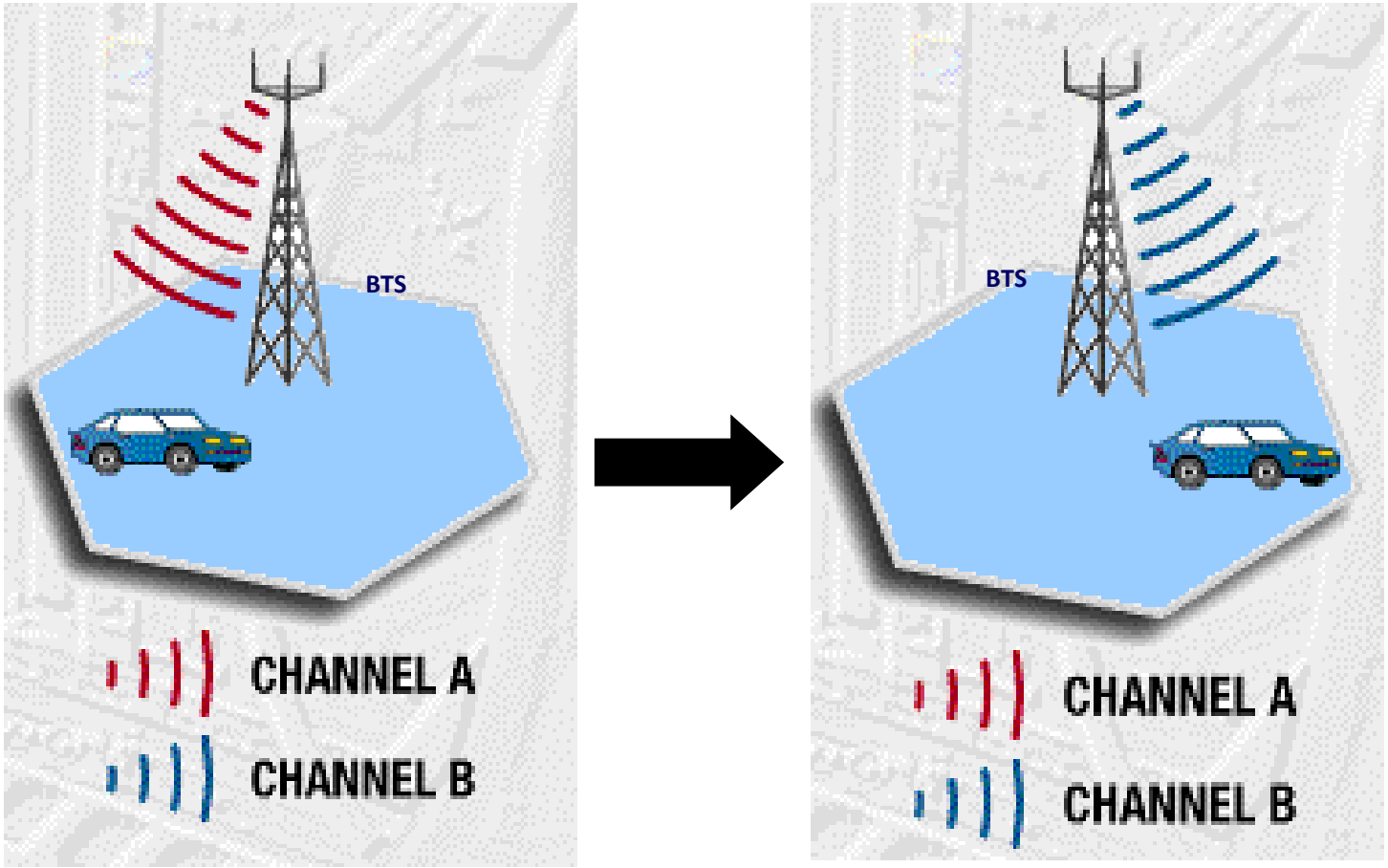
TAI / TAC

MCC **MNC** **TAC**

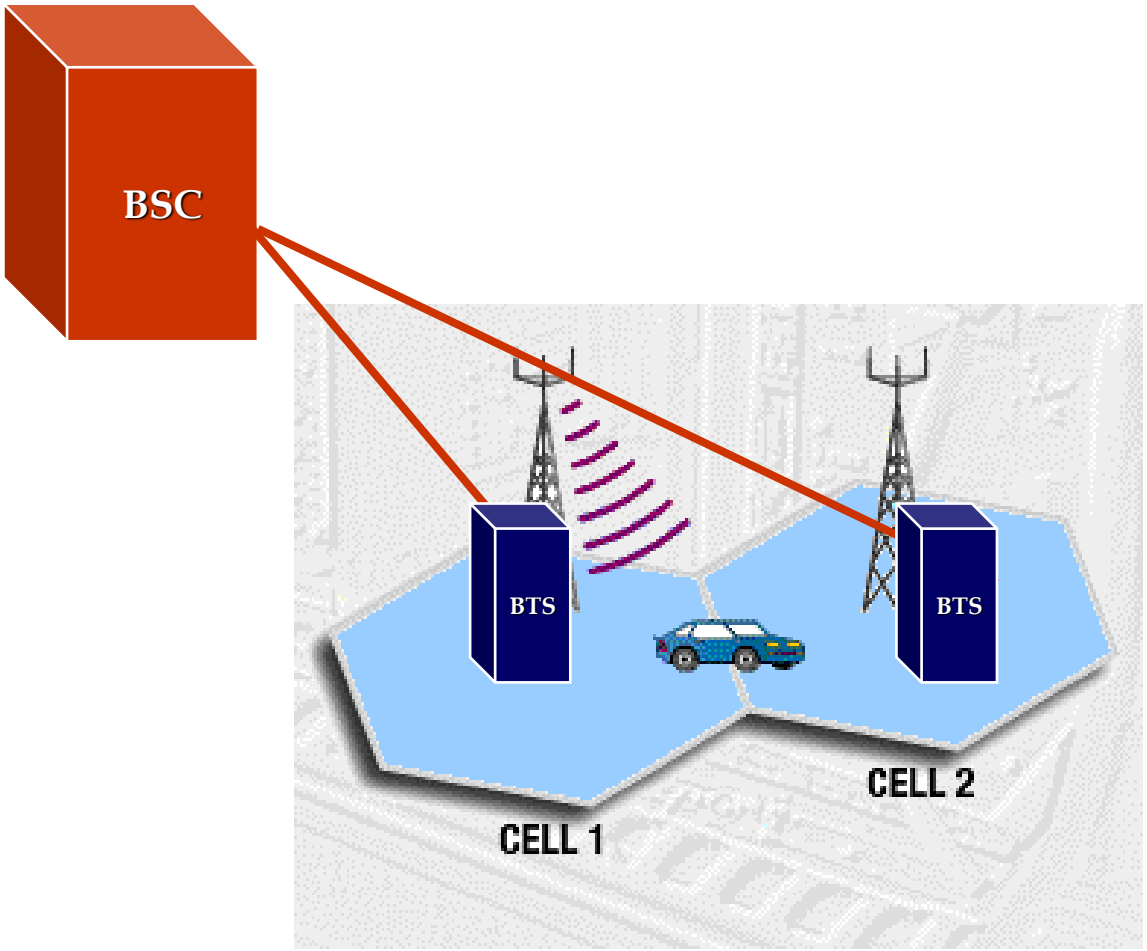
Tracking Area Identity



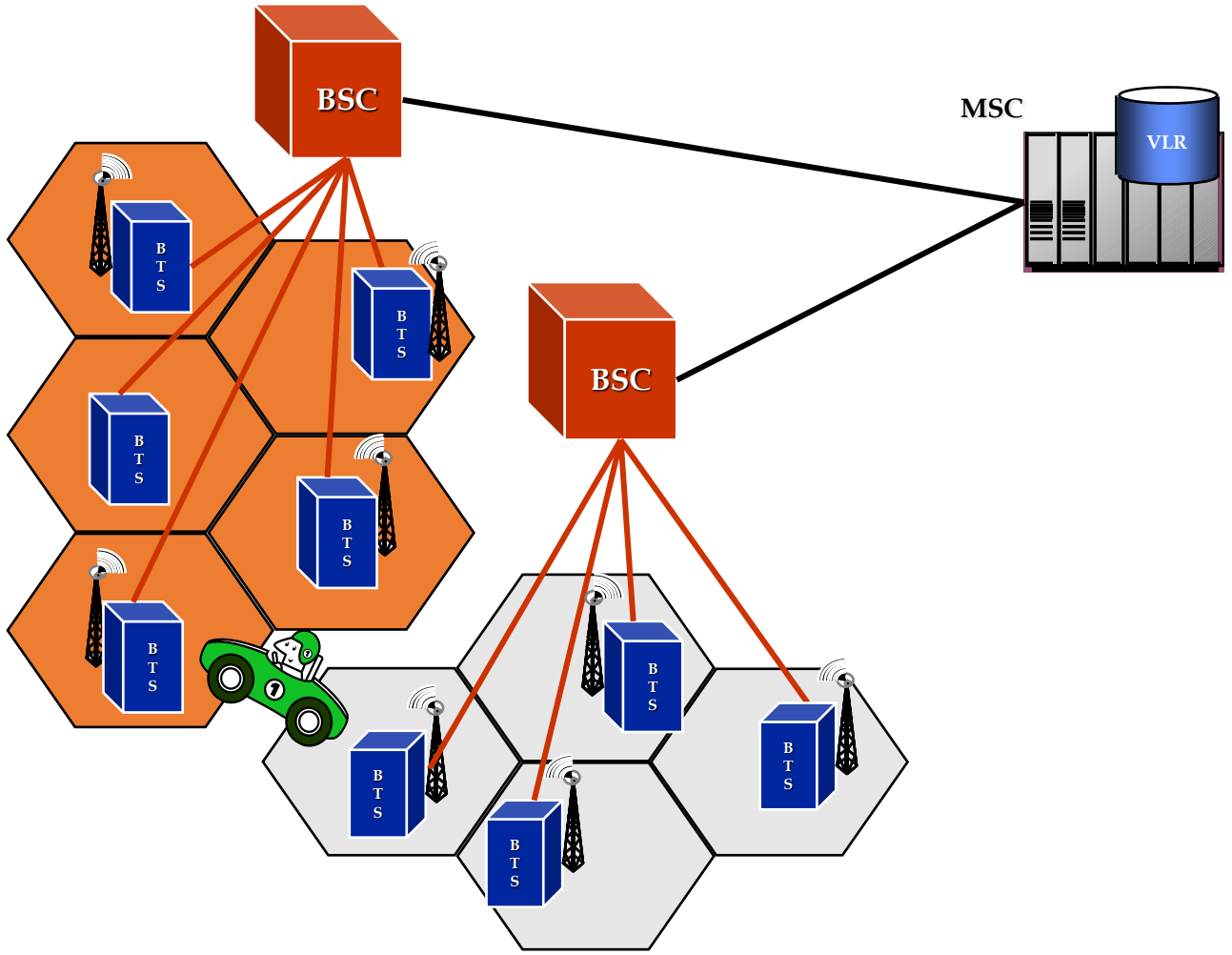
Intra-Cell Handover



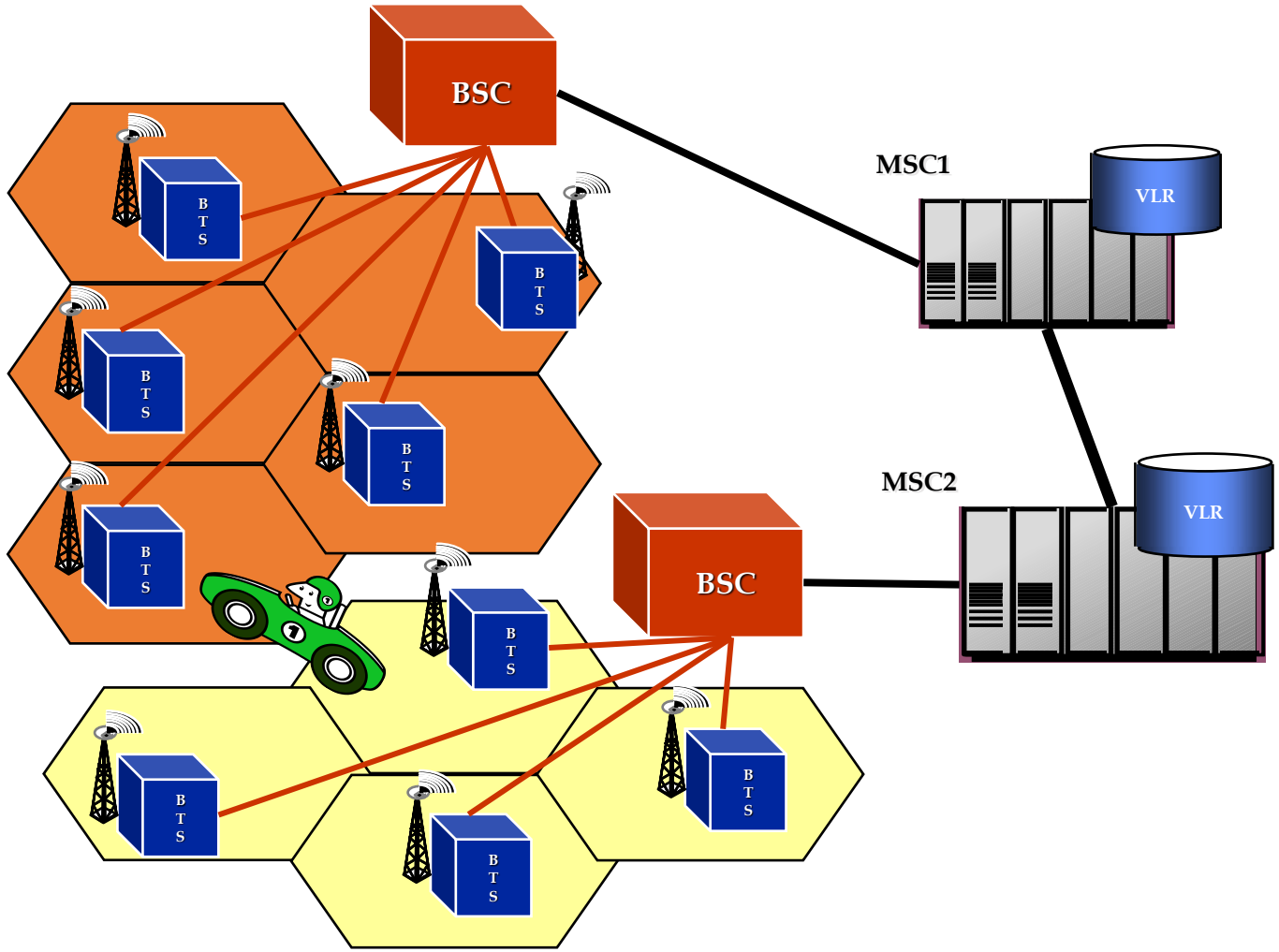
Inter-Cell Intra-BSC Handover



Inter-BSC Intra-MSC Handover



Inter-BSC Inter-MSC Handover



2G / 3G Core Network (CN)

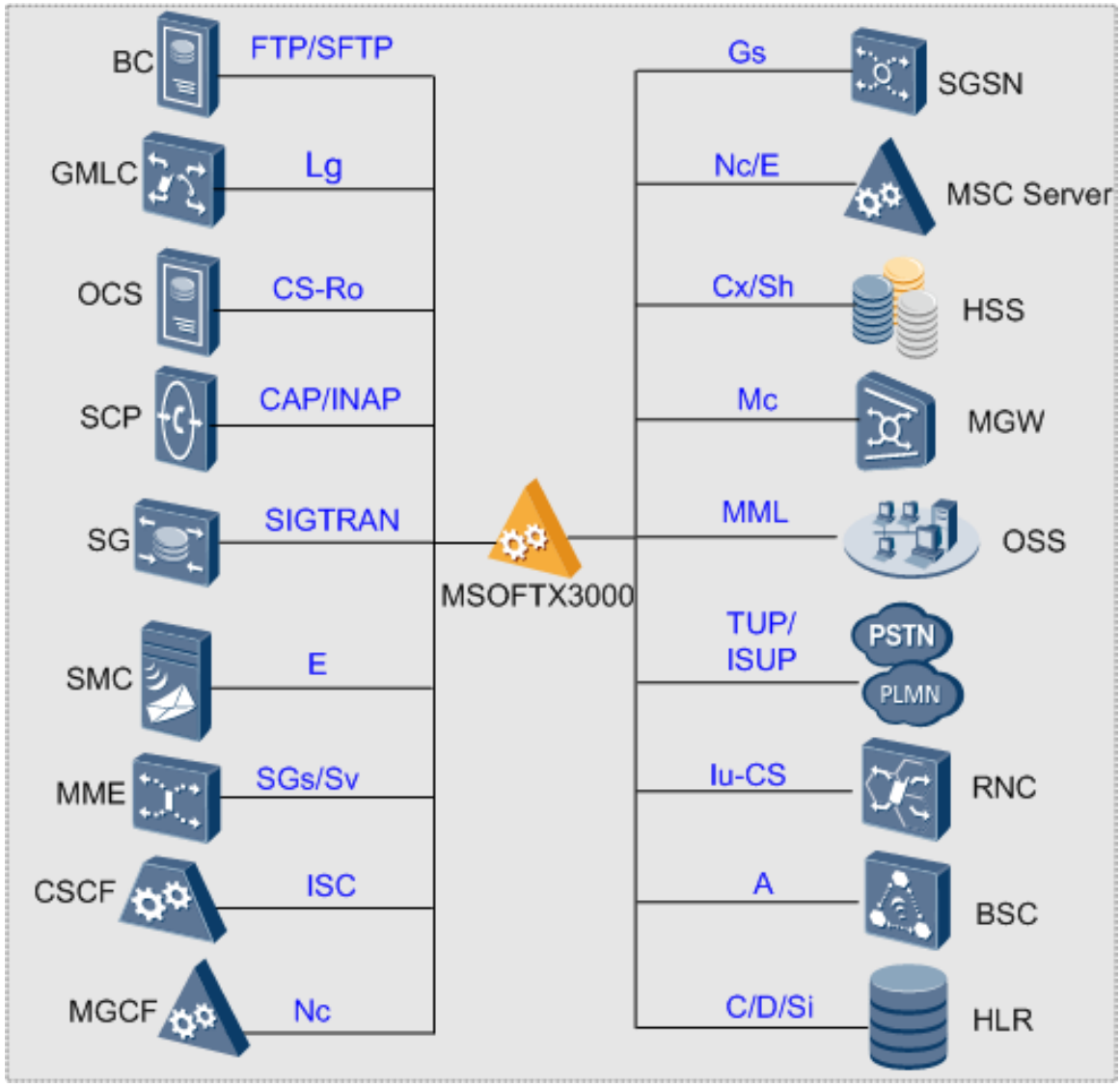
- **Core Network** is split into **CS domain** and **PS domain**. CS domain is based on original GSM network. PS domain is based on original GPRS network.

- **CS domain**: used to provide Circuit-switched service. Network mode can support TDM, ATM and IP. Physical entities include switching equipment (such as MSC/VLR, GMSCs, HSS), and inter-working equipment (IWF).

- **PS domain**: used to provide Packet-switched service. Network mode is IP. Physical entities include SGSN, GGSN, CG , BG etc.

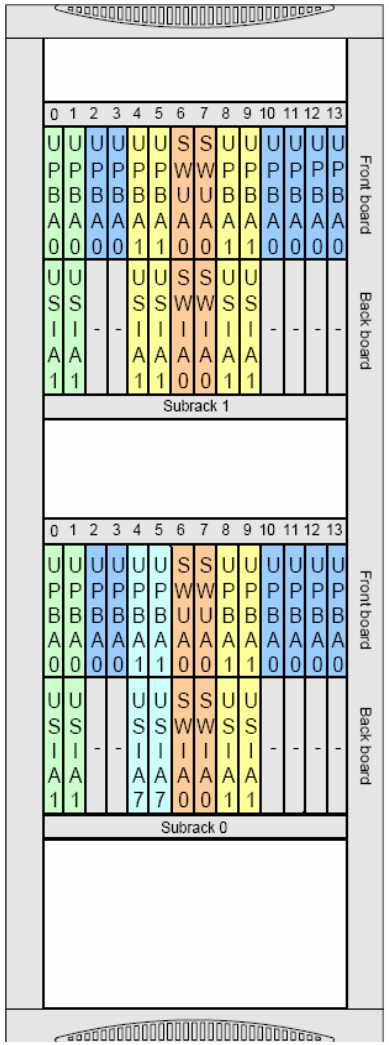
2G / 3G Core Network (CN)

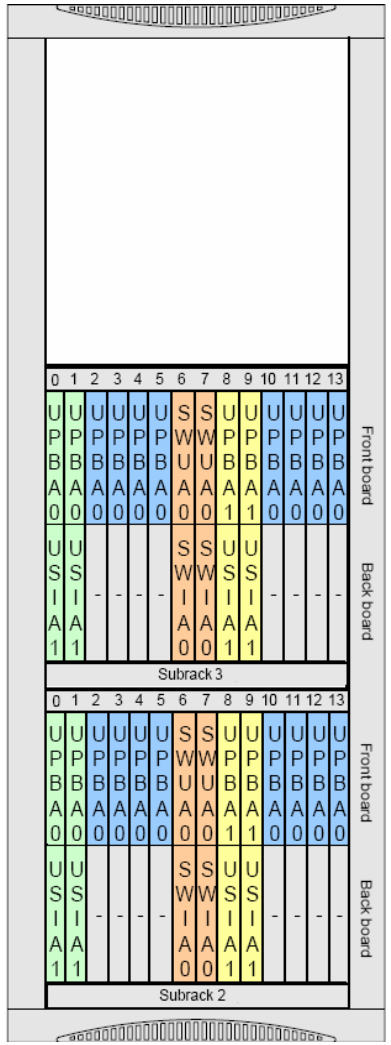
- Function entity shared by CS domain and PS :
  - **MSC Server**: Control layer, to realize MM (Mobility Management), CM (Call Control), MGC (Media Gateway Control).
  - **MGW**: Bearer layer, to realize the exchange of voice and media flow, and provide all kinds sources, such as TC, EC, play announcement and receive DTMF.
  - **SG**: To realize signaling transfer from MTP (SS7 transmission layer) to SCTP/IP (SIGTRAN).



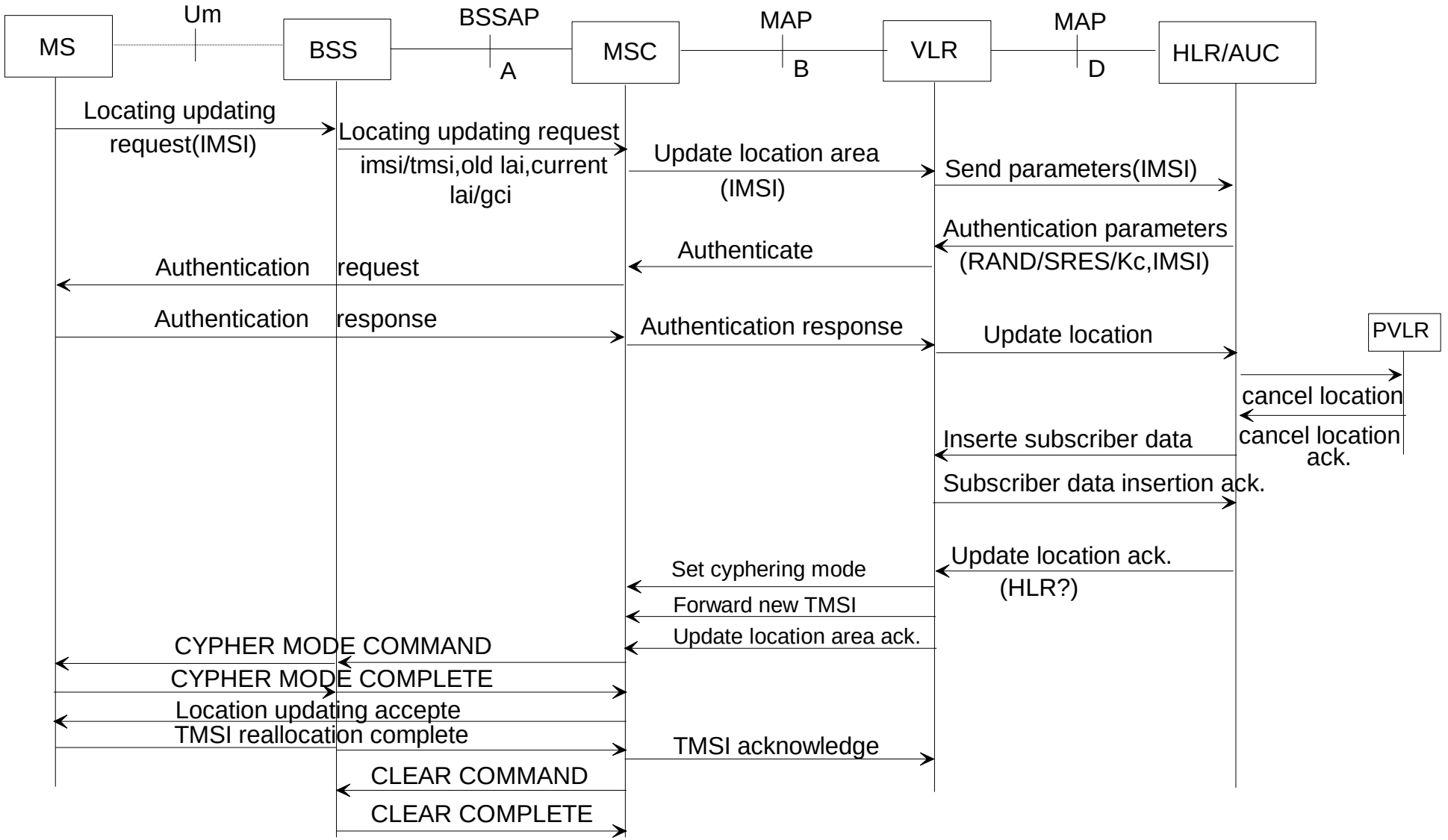
2G / 3G Core Network (CN)

- **HLR/HSS**: To realize mobile subscriber management and location information management.
- **VLR**: To deal with all kinds of data information of current mobile subscriber.
- **AUC**: To store authentication information of mobile subscriber.
- **EIR**: To store IMEI data of mobile subscriber.
- **SMS**: Short Message Center.

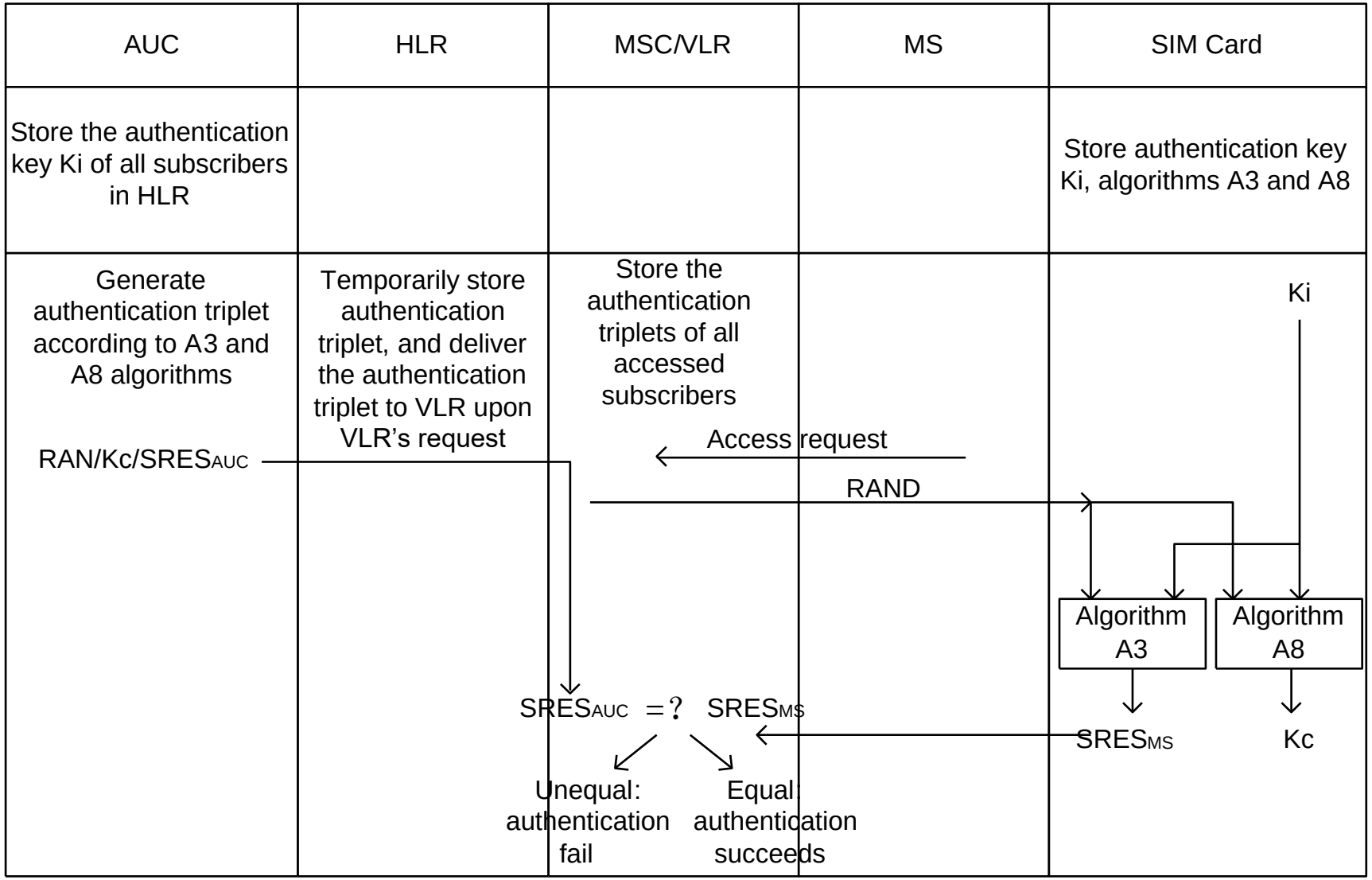




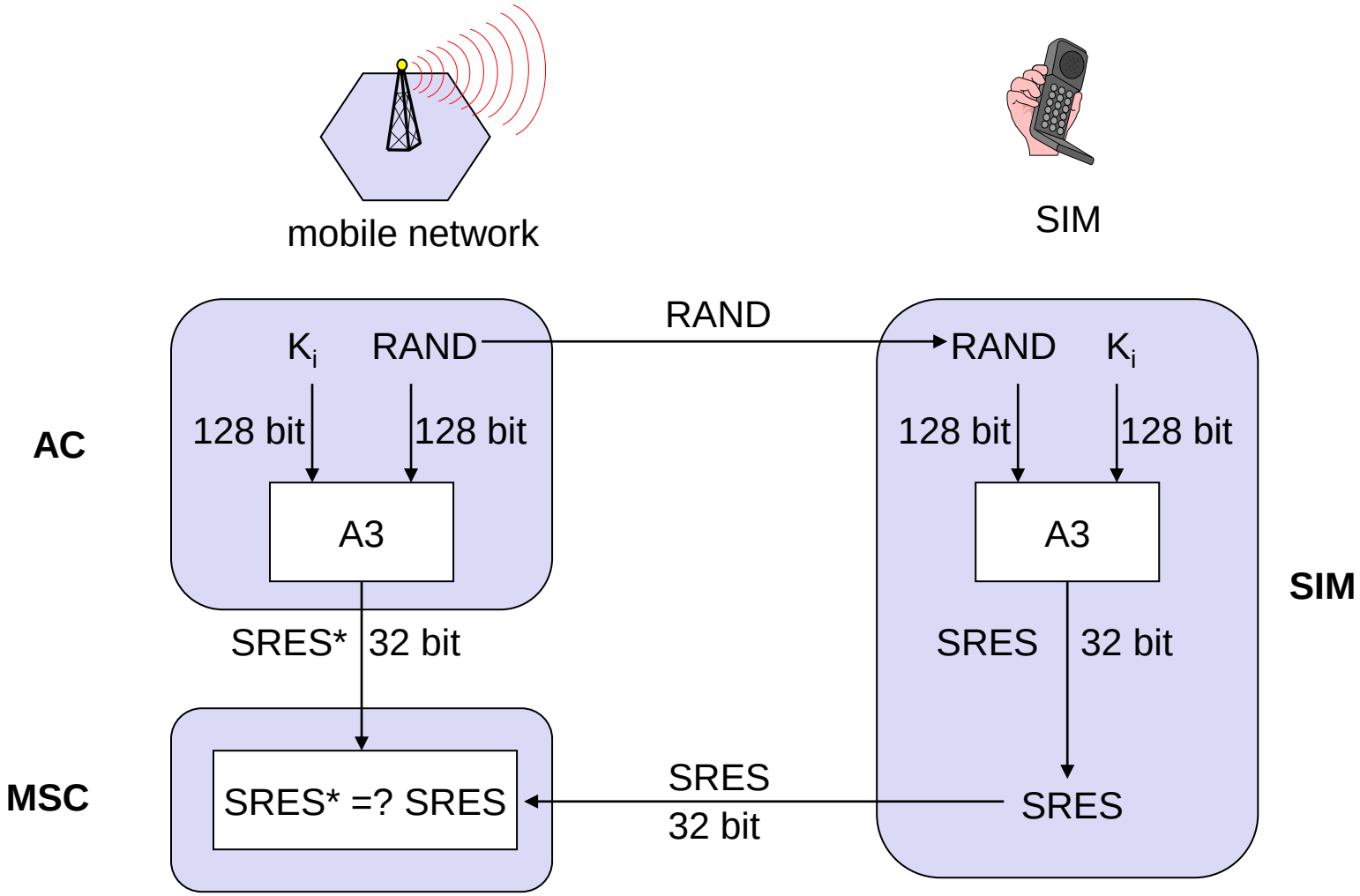
Scenario #1 Location Update



Scenario #1 Location Update / Authentication

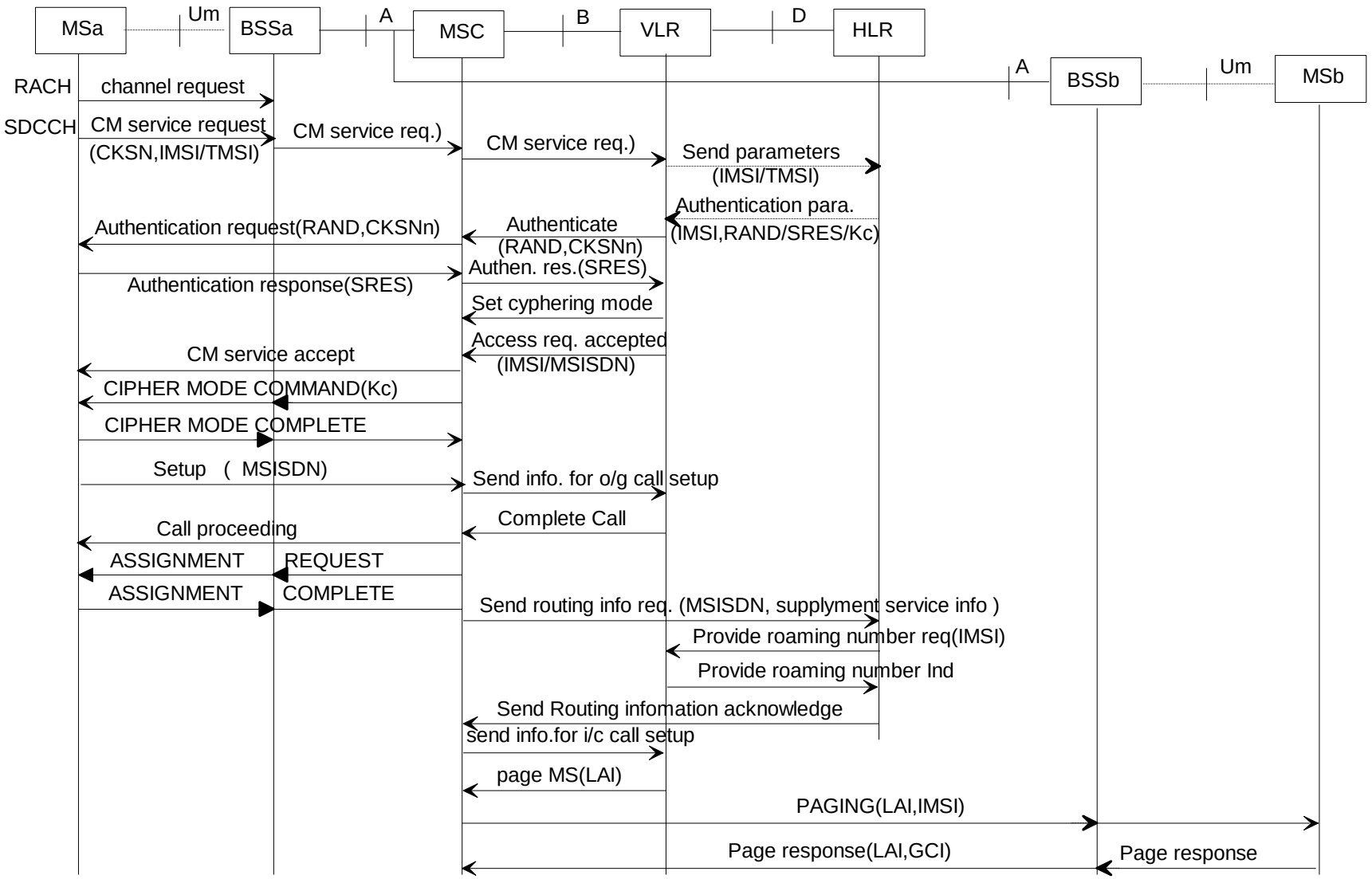


Scenario #1 Location Update / Authentication

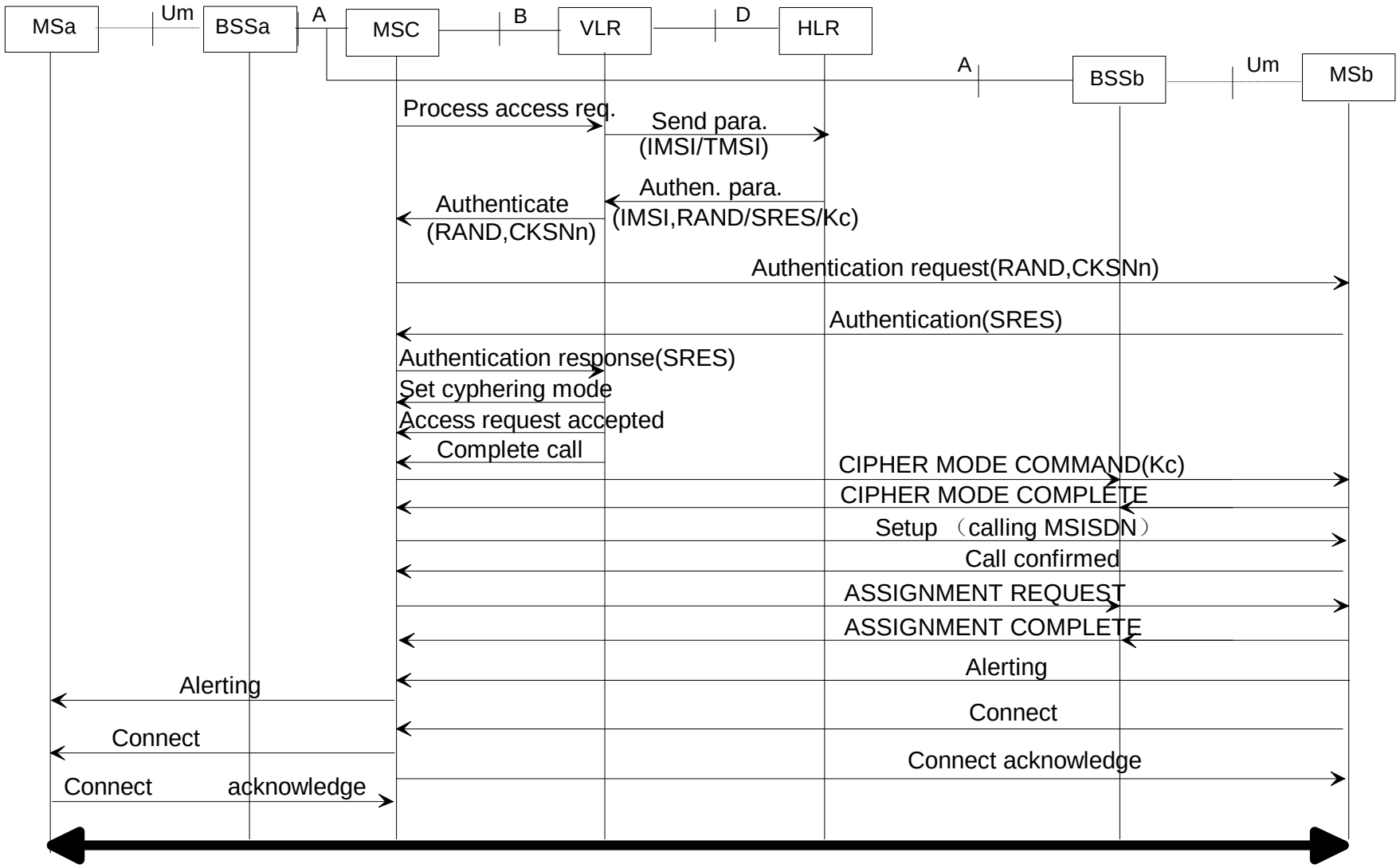


K_i: individual subscriber authentication key SRES: signed response

Scenario #2 Call Flow (1/2)



Scenario #2 Call Flow (2/2)



Scenario #2 Call Flow / Real (1/5)

No.	TimeStamp	Msg Interface	Msg Type
1	2020-11-30 12:28:47.067	>TRC MI FROM SGS	SERVICE REQUEST
2	2020-11-30 12:28:49.377	>TRC MI FROM IU	RN MM CM SERVICE REQUEST
3	2020-11-30 12:28:49.385	<TRC MI TO IU	RN N CONNECT RES
4	2020-11-30 12:28:49.385	<TRC MI TO IU	COMMON ID
5	2020-11-30 12:28:49.401	<TRC MI TO IU	RN MM AUTHENTICATION REQUEST
6	2020-11-30 12:28:50.097	>TRC MI FROM IU	RN MM AUTHENTICATION RESPONSE
7	2020-11-30 12:28:50.098	<TRC MI TO IU	SECURITY MODE COMMAND
8	2020-11-30 12:28:50.457	>TRC MI FROM IU	SECURITY MODE COMPLETE
9	2020-11-30 12:28:50.913	>TRC MI FROM IU	RN CC SETUP
10	2020-11-30 12:28:50.934	<TRC MI TO IU	RN CC CALL PROCEEDING
11	2020-11-30 12:28:50.935	<TRC MI TO CAP	TC INVOKE REQ
12	2020-11-30 12:28:50.935	<TRC MI TO CAP	TC BEGIN REQ
13	2020-11-30 12:28:51.045	>TRC MI FROM CAP	TC CONTINUE IND
14	2020-11-30 12:28:51.045	>TRC MI FROM CAP	TC INVOKE IND
15	2020-11-30 12:28:51.179	>TRC MI FROM CAP	TC CONTINUE IND
16	2020-11-30 12:28:51.179	>TRC MI FROM CAP	TC INVOKE IND
17	2020-11-30 12:28:51.179	>TRC MI FROM CAP	TC CONTINUE IND
18	2020-11-30 12:28:51.179	>TRC MI FROM CAP	TC INVOKE IND
19	2020-11-30 12:28:51.218	<TRC MI TO C D F	MAP OPEN REQ
20	2020-11-30 12:28:51.218	<TRC MI TO C D F	MAP SEND ROUTING INFORMATION REQ
21	2020-11-30 12:28:51.218	<TRC MI TO C D F	MAP DELIMITER REQ
22	2020-11-30 12:28:51.333	>TRC MI FROM C D F	MAP OPEN CNF
23	2020-11-30 12:28:51.333	>TRC MI FROM C D F	MAP SEND ROUTING INFORMATION CNF
24	2020-11-30 12:28:51.333	>TRC MI FROM C D F	MAP CLOSE IND
25	2020-11-30 12:28:51.335	<TRC MI TO CAP	TC INVOKE REQ
26	2020-11-30 12:28:51.335	<TRC MI TO CAP	TC BEGIN REQ
27	2020-11-30 12:28:51.376	>TRC MI FROM CAP	TC END IND
28	2020-11-30 12:28:51.376	>TRC MI FROM CAP	TC INVOKE IND
29	2020-11-30 12:28:51.554	<TRC MI TO H248	ADD REQ
30	2020-11-30 12:28:51.642	>TRC MI FROM H248	ADD REPLY
31	2020-11-30 12:28:51.569	<TRC MI TO IU	RN RAB ASSIGNMENT REQUEST
32	2020-11-30 12:28:51.686	<TRC MI TO H248	ADD REQ
33	2020-11-30 12:28:51.686	>TRC MI FROM H248	NTFY REQ
34	2020-11-30 12:28:51.686	<TRC MI TO H248	NTFY REPLY

Scenario #2 Call Flow / Real (2/5)

No.	TimeStamp	Msg Interface	Msg Type
35	2020-11-30 12:28:51.834	>TRC MI FROM H248	ADD REPLY
36	2020-11-30 12:28:51.759	<TRC MI TO BICC	TO BICC TYPE IAM
37	2020-11-30 12:28:52.749	>TRC MI FROM IU	RN RAB ASSIGNMENT RESPONSE
38	2020-11-30 12:28:52.999	>TRC MI FROM C D F	MAP PROVIDE SUBSCRIBER INFO IND
39	2020-11-30 12:28:53.010	<TRC MI TO C D F	MAP PROVIDE SUBSCRIBER INFO RSP
40	2020-11-30 12:28:53.010	<TRC MI TO C D F	MAP CLOSE REQ
41	2020-11-30 12:28:53.365	>TRC MI FROM C D F	MAP PROVIDE ROAMING NUMBER IND
42	2020-11-30 12:28:53.389	<TRC MI TO C D F	MAP PROVIDE ROAMING NUMBER RSP
43	2020-11-30 12:28:53.389	<TRC MI TO C D F	MAP CLOSE REQ
44	2020-11-30 12:28:53.660	>TRC MI FROM BICC	FROM BICC TYPE IAM
45	2020-11-30 12:28:53.785	<TRC MI TO SGS	PAGING REQUEST
46	2020-11-30 12:28:54.847	>TRC MI FROM SGS	SERVICE REQUEST
47	2020-11-30 12:28:54.896	<TRC MI TO H248	ADD REQ
48	2020-11-30 12:28:55.040	>TRC MI FROM H248	ADD REPLY
49	2020-11-30 12:28:55.050	<TRC MI TO BICC	TO BICC TYPE APM
50	2020-11-30 12:28:55.139	>TRC MI FROM BICC	FROM BICC TYPE APM
51	2020-11-30 12:28:55.185	>TRC MI FROM BICC	FROM BICC TYPE APM
52	2020-11-30 12:28:55.330	<TRC MI TO H248	MOD REQ
53	2020-11-30 12:28:55.292	<TRC MI TO H248	MOD REQ
54	2020-11-30 12:28:55.446	>TRC MI FROM H248	MOD REPLY
55	2020-11-30 12:28:55.446	>TRC MI FROM H248	NTFY REQ
56	2020-11-30 12:28:55.446	<TRC MI TO H248	NTFY REPLY
57	2020-11-30 12:28:55.372	<TRC MI TO BICC	TO BICC TYPE APM
58	2020-11-30 12:28:55.400	>TRC MI FROM H248	MOD REPLY
59	2020-11-30 12:28:55.400	>TRC MI FROM H248	NTFY REQ
60	2020-11-30 12:28:55.400	<TRC MI TO H248	NTFY REPLY
61	2020-11-30 12:28:55.408	<TRC MI TO BICC	TO BICC TYPE APM
62	2020-11-30 12:28:55.488	>TRC MI FROM BICC	FROM BICC TYPE APM
63	2020-11-30 12:28:55.508	>TRC MI FROM H248	NTFY REQ
64	2020-11-30 12:28:55.508	<TRC MI TO H248	NTFY REPLY
65	2020-11-30 12:28:55.512	<TRC MI TO BICC	TO BICC TYPE ACM
66	2020-11-30 12:28:55.678	<TRC MI TO H248	MOD REQ
67	2020-11-30 12:28:55.818	>TRC MI FROM H248	MOD REPLY
68	2020-11-30 12:28:55.818	>TRC MI FROM H248	NTFY REQ

Scenario #2 Call Flow / Real (3/5)

69	2020-11-30 12:28:55.818	<TRC MI TO H248	NTFY REPLY
70	2020-11-30 12:28:55.764	>TRC MI FROM BICC	FROM BICC TYPE ACM
71	2020-11-30 12:28:55.770	<TRC MI TO IU	RN CC ALERTING
72	2020-11-30 12:28:56.004	>TRC MI FROM BICC	FROM BICC TYPE CPG
73	2020-11-30 12:29:01.749	>TRC MI FROM IU	RN RR PAGING RESPONSE
74	2020-11-30 12:29:01.749	<TRC MI TO IU	RN N CONNECT RES
75	2020-11-30 12:29:01.760	<TRC MI TO IU	COMMON ID
76	2020-11-30 12:29:01.773	<TRC MI TO IU	SECURITY MODE COMMAND
77	2020-11-30 12:29:01.900	>TRC MI FROM IU	SECURITY MODE COMPLETE
78	2020-11-30 12:29:01.930	>TRC MI FROM CAP	TC N L CANCEL IND
79	2020-11-30 12:29:01.901	<TRC MI TO IU	RN CC SETUP
80	2020-11-30 12:29:02.261	>TRC MI FROM IU	RN CC CALL CONFIRMED
81	2020-11-30 12:29:02.300	<TRC MI TO H248	ADD REQ
82	2020-11-30 12:29:02.408	>TRC MI FROM H248	ADD REPLY
83	2020-11-30 12:29:02.421	<TRC MI TO IU	RN RAB ASSIGNMENT REQUEST
84	2020-11-30 12:29:02.516	>TRC MI FROM H248	NTFY REQ
85	2020-11-30 12:29:02.516	<TRC MI TO H248	NTFY REPLY
86	2020-11-30 12:29:03.401	>TRC MI FROM IU	RN RAB ASSIGNMENT RESPONSE
87	2020-11-30 12:29:03.449	>TRC MI FROM IU	RN CC ALERTING
88	2020-11-30 12:29:03.449	<TRC MI TO BICC	TO BICC TYPE CPG
89	2020-11-30 12:29:03.552	>TRC MI FROM BICC	FROM BICC TYPE CPG
90	2020-11-30 12:29:03.557	<TRC MI TO H248	MOD REQ
91	2020-11-30 12:29:03.740	>TRC MI FROM H248	MOD REPLY
92	2020-11-30 12:29:16.602	>TRC MI FROM IU	RN CC CONNECT
93	2020-11-30 12:29:16.602	<TRC MI TO BICC	TO BICC TYPE ANM
94	2020-11-30 12:29:16.657	>TRC MI FROM BICC	FROM BICC TYPE ANM
95	2020-11-30 12:29:16.663	<TRC MI TO IU	RN CC CONNECT
96	2020-11-30 12:29:16.713	<TRC MI TO H248	MOD REQ
97	2020-11-30 12:29:16.758	>TRC MI FROM H248	MOD REPLY
98	2020-11-30 12:29:16.766	<TRC MI TO IU	RN CC CONNECT ACKNOWLEDGE
99	2020-11-30 12:29:16.873	<TRC MI TO H248	MOD REQ
100	2020-11-30 12:29:16.907	>TRC MI FROM IU	RN CC CONNECT ACKNOWLEDGE
101	2020-11-30 12:29:16.941	>TRC MI FROM H248	MOD REPLY
102	2020-11-30 12:29:26.889	>TRC MI FROM IU	RN CC DISCONNECT

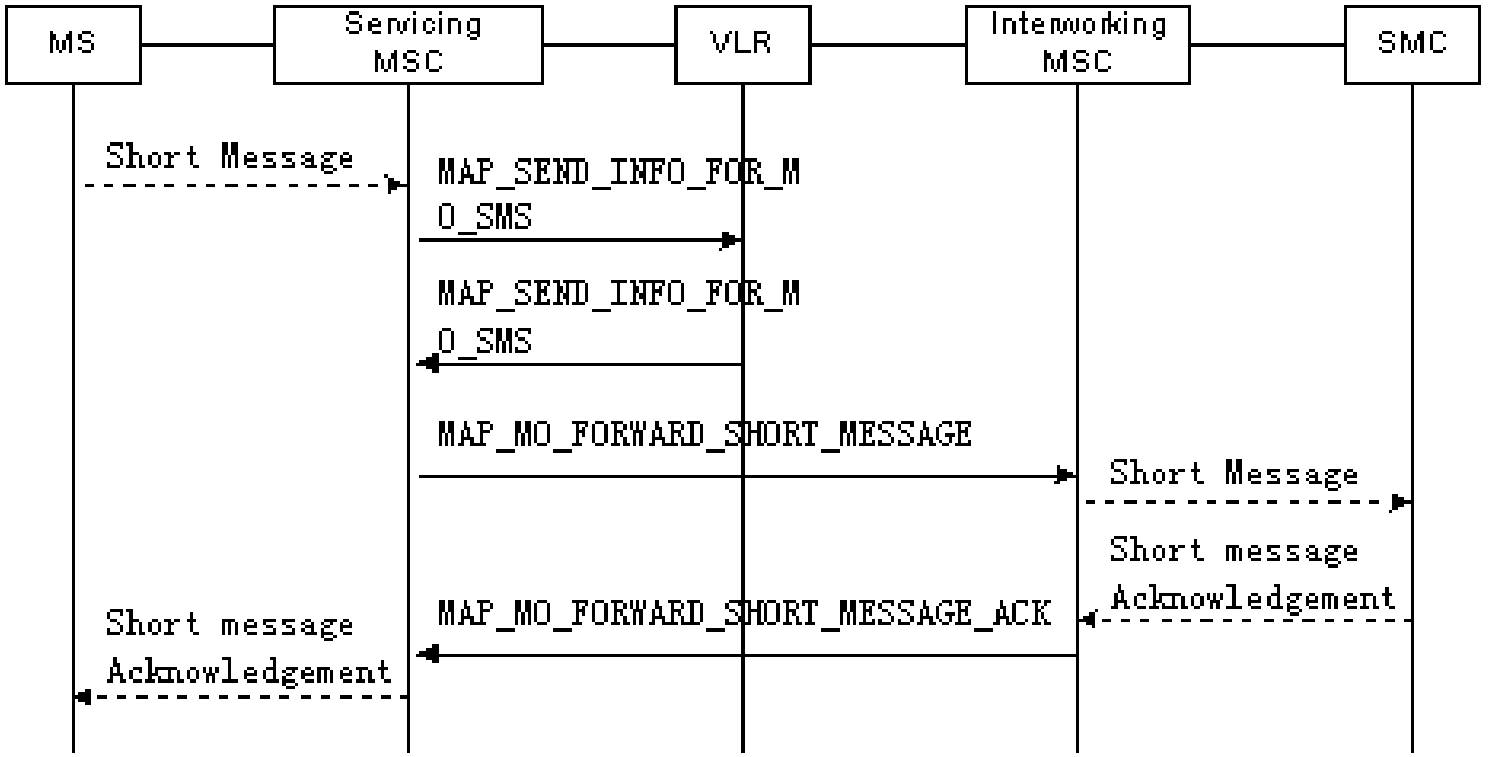
Scenario #2 Call Flow / Real (4/5)

No.	TimeStamp	Msg Interface	Msg Type
103	2020-11-30 12:29:26.889	<TRC MI TO IU	RN CC RELEASE
104	2020-11-30 12:29:26.889	<TRC MI TO BICC	TO BICC TYPE REL
105	2020-11-30 12:29:26.938	>TRC MI FROM BICC	FROM BICC TYPE RLC
106	2020-11-30 12:29:27.010	<TRC MI TO H248	SUB REQ
107	2020-11-30 12:29:27.050	>TRC MI FROM H248	SUB REPLY
108	2020-11-30 12:29:27.071	>TRC MI FROM IU	RN CC DISCONNECT
109	2020-11-30 12:29:27.071	<TRC MI TO IU	RN CC RELEASE
110	2020-11-30 12:29:27.071	<TRC MI TO CAP	TC INVOKE REQ
111	2020-11-30 12:29:27.071	<TRC MI TO CAP	TC CONTINUE REQ
112	2020-11-30 12:29:27.071	<TRC MI TO CAP	TC INVOKE REQ
113	2020-11-30 12:29:27.071	<TRC MI TO CAP	TC CONTINUE REQ
114	2020-11-30 12:29:27.122	>TRC MI FROM BICC	FROM BICC TYPE REL
115	2020-11-30 12:29:27.122	<TRC MI TO BICC	TO BICC TYPE RLC
116	2020-11-30 12:29:27.128	<TRC MI TO CAP	TC INVOKE REQ
117	2020-11-30 12:29:27.128	<TRC MI TO CAP	TC CONTINUE REQ
118	2020-11-30 12:29:27.162	>TRC MI FROM IU	RN CC RELEASE COMPLETE
119	2020-11-30 12:29:27.276	<TRC MI TO H248	SUB REQ
120	2020-11-30 12:29:27.171	<TRC MI TO IU	IU RELEASE COMMAND
121	2020-11-30 12:29:27.316	>TRC MI FROM H248	SUB REPLY
122	2020-11-30 12:29:27.244	>TRC MI FROM CAP	TC END IND
123	2020-11-30 12:29:27.244	>TRC MI FROM CAP	TC INVOKE IND
124	2020-11-30 12:29:27.348	>TRC MI FROM IU	RN CC RELEASE COMPLETE
125	2020-11-30 12:29:27.355	<TRC MI TO IU	IU RELEASE COMMAND
126	2020-11-30 12:29:27.371	>TRC MI FROM IU	IU RELEASE COMPLETE
127	2020-11-30 12:29:27.520	<TRC MI TO H248	SUB REQ
128	2020-11-30 12:29:27.608	>TRC MI FROM H248	SUB REPLY
129	2020-11-30 12:29:28.650	>TRC MI FROM IU	IU RELEASE COMPLETE
130	2020-11-30 12:29:28.726	<TRC MI TO H248	SUB REQ
131	2020-11-30 12:29:28.766	>TRC MI FROM H248	SUB REPLY
132	2020-11-30 12:29:28.820	>TRC MI FROM IU	RN MM LOCATION UPDATING REQUEST
133	2020-11-30 12:29:28.820	<TRC MI TO IU	RN N CONNECT RES
134	2020-11-30 12:29:28.828	<TRC MI TO IU	COMMON ID
135	2020-11-30 12:29:28.888	<TRC MI TO L	MAP OPEN REQ
136	2020-11-30 12:29:28.888	<TRC MI TO L	MAP NOTE MM EVENT REQ

Scenario #2 Call Flow / Real (5/5)

132	2020-11-30 12:29:28.820	>TRC MI FROM IU	RN MM LOCATION UPDATING REQUEST
133	2020-11-30 12:29:28.820	<TRC MI TO IU	RN N CONNECT RES
134	2020-11-30 12:29:28.828	<TRC MI TO IU	COMMON ID
135	2020-11-30 12:29:28.888	<TRC MI TO L	MAP OPEN REQ
136	2020-11-30 12:29:28.888	<TRC MI TO L	MAP NOTE MM EVENT REQ
137	2020-11-30 12:29:28.888	<TRC MI TO L	MAP DELIMITER REQ
138	2020-11-30 12:29:28.888	<TRC MI TO IU	SECURITY MODE COMMAND
139	2020-11-30 12:29:28.956	>TRC MI FROM L	MAP OPEN CNF
140	2020-11-30 12:29:28.956	>TRC MI FROM L	MAP NOTE MM EVENT CNF
141	2020-11-30 12:29:28.956	>TRC MI FROM L	MAP CLOSE IND
142	2020-11-30 12:29:28.998	>TRC MI FROM SGS	LOCATION UPDATE REQUEST
143	2020-11-30 12:29:29.060	<TRC MI TO SGS	LOCATION UPDATE ACCEPT
144	2020-11-30 12:29:29.060	<TRC MI TO SGS	MM INFORMATION REQUEST
145	2020-11-30 12:29:29.060	>TRC MI FROM IU	SECURITY MODE COMPLETE
146	2020-11-30 12:29:29.060	<TRC MI TO IU	RN MM INFORMATION
147	2020-11-30 12:29:29.060	<TRC MI TO IU	RN MM LOCATION UPDATING ACCEPT
148	2020-11-30 12:29:29.118	>TRC MI FROM SGS	TMSI REALLOCATION COMPLETE
149	2020-11-30 12:29:29.240	>TRC MI FROM IU	RN MM TMSI REALLOCATION COMPLETE
150	2020-11-30 12:29:29.240	<TRC MI TO IU	IU RELEASE COMMAND
151	2020-11-30 12:29:29.337	>TRC MI FROM IU	IU RELEASE COMPLETE

Scenario #3 SMS MO

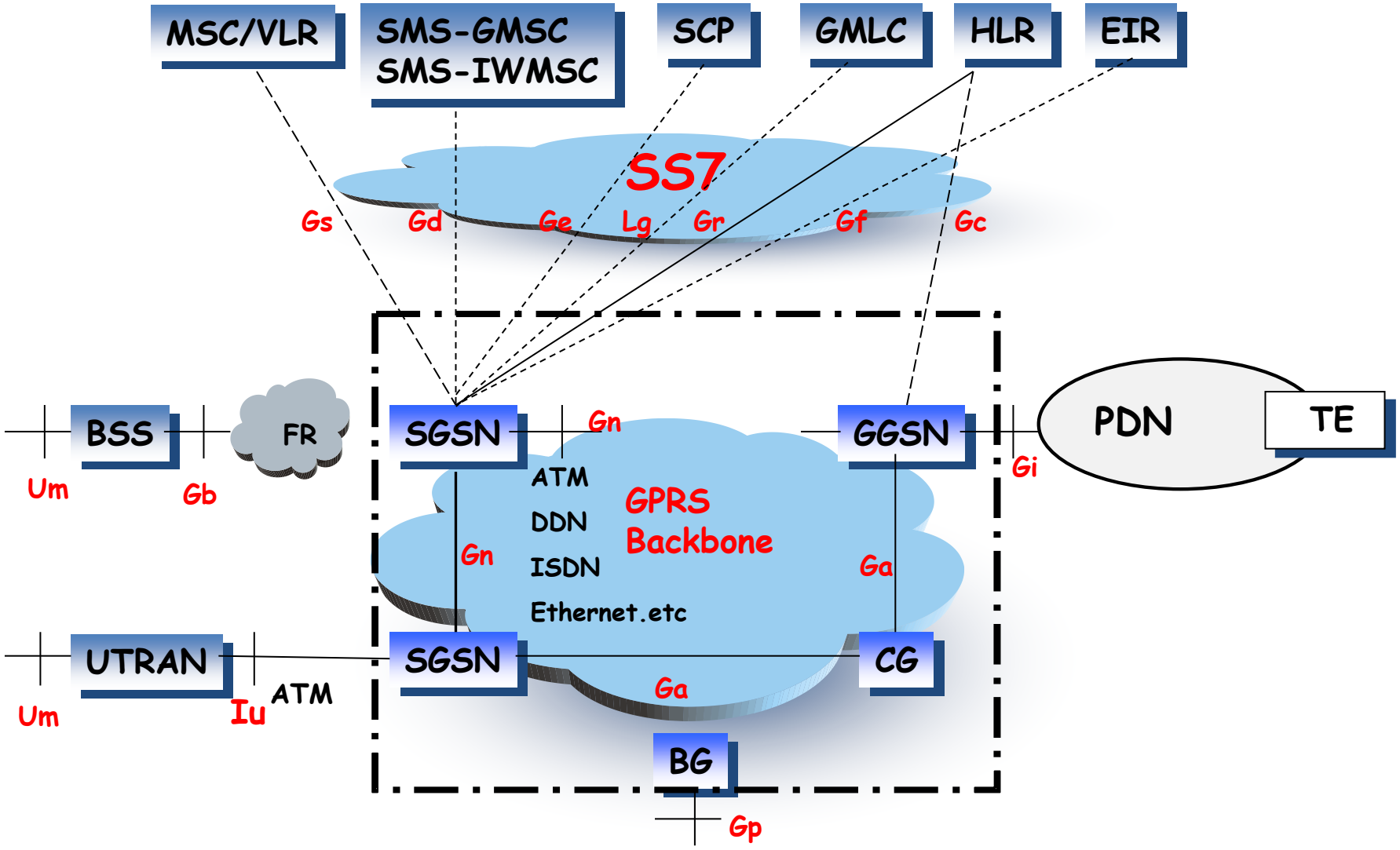


1	2020-11-30 12:24:23.907	>TRC MI FROM SGS	UPLINK UNITDATA
2	2020-11-30 12:24:23.929	<TRC MI TO SGS	DOWNLINK UNITDATA
3	2020-11-30 12:24:23.941	<TRC MI TO E G	MAP OPEN REQ
4	2020-11-30 12:24:23.941	<TRC MI TO E G	MAP MO FORWARD SHORT MESSAGE REQ
5	2020-11-30 12:24:23.942	<TRC MI TO E G	MAP DELIMITER REQ
6	2020-11-30 12:24:24.186	>TRC MI FROM E G	MAP OPEN CNF
7	2020-11-30 12:24:24.185	<TRC MI TO SGS	DOWNLINK UNITDATA
8	2020-11-30 12:24:24.186	>TRC MI FROM E G	MAP MO FORWARD SHORT MESSAGE CNF
9	2020-11-30 12:24:24.186	>TRC MI FROM E G	MAP CLOSE IND
10	2020-11-30 12:24:24.255	>TRC MI FROM SGS	UPLINK UNITDATA
11	2020-11-30 12:24:24.265	<TRC MI TO SGS	RELEASE REQUEST

GPRS Network Structure

- What is GPRS?
  - ⇨ General Packet Radio Service
- Why GPRS?
  - ⇨ In order to provide the data service out the scope of the fixed network
- GPRS network classification
  - ⇨ GSM GPRS
  - ⇨ UMTS GPRS
- GPRS network background
  - ⇨ GSM GPRS network reuse the existed GSM network
  - ⇨ UMTS GPRS network just change the RAN side

GPRS Network Structure



GPRS Network Structure

- Some Abbreviation
  - ⇨ GPRS: General Packet Radio Service
  - ⇨ BSS: Base Station Subsystem
  - ⇨ UTRAN: UMTS Terrestrial Radio Access Network
  - ⇨ SGSN: Service GPRS Support Node
  - ⇨ GGSN: Gateway GPRS Support Node
  - ⇨ CG: Charging Gateway
  - ⇨ BG: Bordering Gateway
  - ⇨ PDN: Packet Data Network

GPRS Network Structure

- Important Entity Function __ SGSN
  - ⇨ Mobility management
    - − The mobility management functions are used to keep track of the current location of an MS within the PLMN or within another PLMN.
  - ⇨ Session management
    - − Session Management (SM) function manages the PDP context of MS.
  - ⇨ Routing and transfer
    - − SGSN performs routing and forwarding of service data between MS and GGSN.
  - ⇨ Charging
    - − SGSN can generate, store, convert and send CDRs.
  - ⇨ Lawful Interception
  - ⇨ NTP

GPRS Network Structure

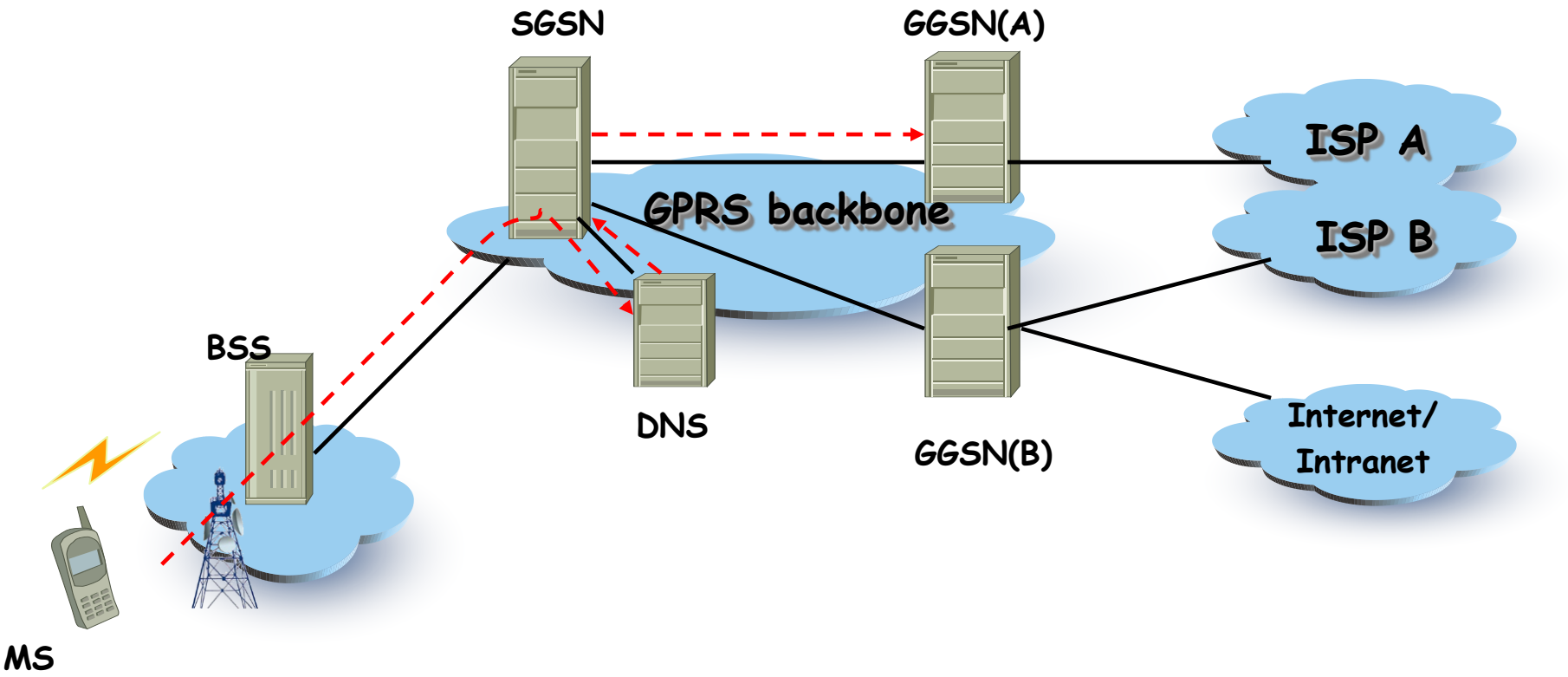
- Important Entity Function __ GGSN
  - ⇨ Session management
    - − Session Management (SM) function manages the PDP context of MS.
  - ⇨ Routing and transfer
    - − GGSN performs routing and forwarding of service data between MS and internet.
  - ⇨ Charging
    - − GGSN can generate, store, convert and send CDRs.
  - ⇨ Dynamic IP allocation
  - ⇨ Service management
    - − Manage APN

GPRS Network Structure

- Important Entity Function __ CG
  - ⇨ Real-time collection of GPRS bills
  - ⇨ Temporary storage and buffering of GPRS bills
  - ⇨ Pre-processing of GPRS bills
  - ⇨ Sending GPRS bills to the billing center

GPRS Network Structure

- Important Entity Function | DNS

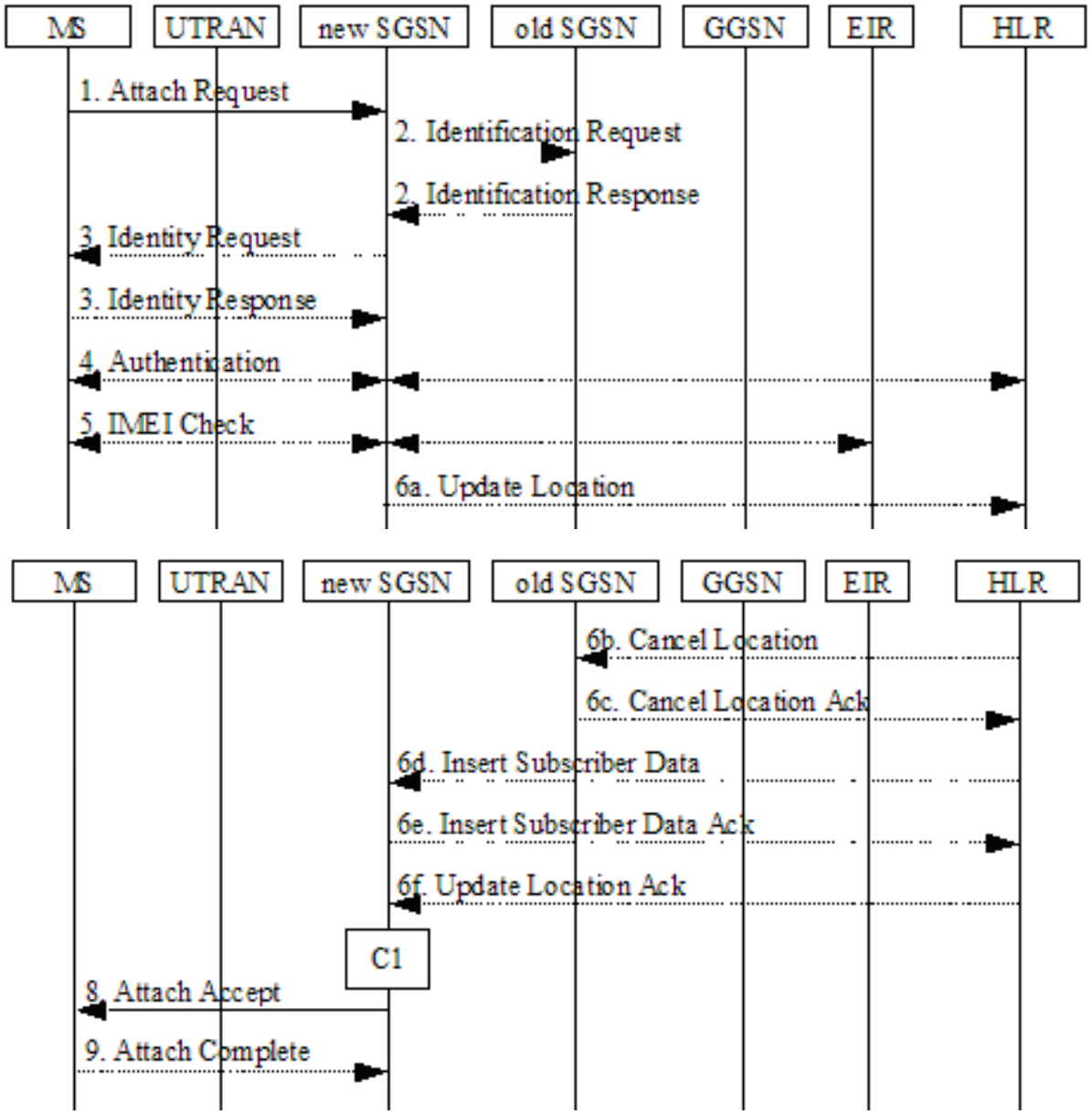


⇨ Resolve the APN to a GGSN IP in the PDP active procedure

⇨ Resolve the RAI to a SGSN IP in the inter-SGSN RAU procedure

⇨ Resolve the RNCID to a SGSN IP in the relocation procedure (UMTS)

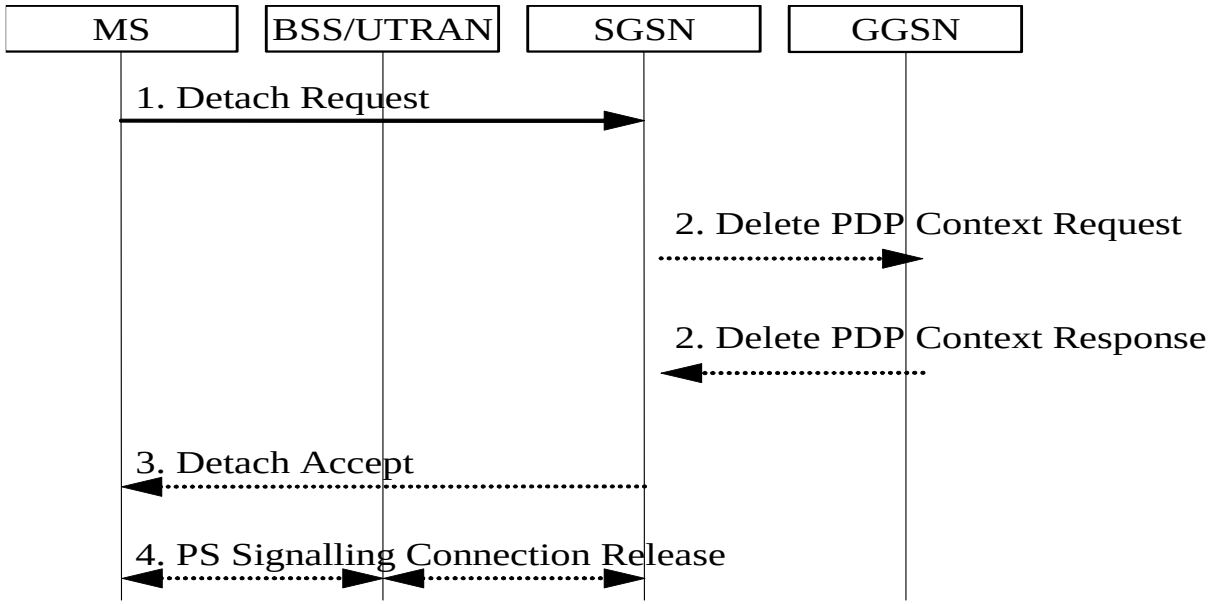
Attach Procedure



Reject Causes by GPRS Network

Cause in attach reject	Actions in PS domain	Actions in CS domain
Illegal MS	The MS shall set the GPRS update status to GU3 ROAMING NOT ALLOWED The SIM/USIM shall be considered as invalid for GPRS services until switching off or the SIM/USIM is removed	If the MS is IMSI attached, the MS shall in addition set the update status to U3 ROAMING NOT ALLOWED, shall delete any TMSI, LAI and ciphering key sequence number
Illegal ME		
GPRS services not allowed	The MS shall set the GPRS update status to GU3 ROAMING NOT ALLOWED; The SIM/USIM shall be considered as invalid for GPRS services until switching off or the SIM/USIM is removed.	no effect
GPRS services not allowed in this PLMN	shall set the GPRS update status to GU3 ROAMING NOT ALLOWED	
PLMN not allowed	shall set the GPRS update status to GU3 ROAMING NOT ALLOWED), shall reset the GPRS attach attempt counter and shall change to state GMM-DEREGISTERED	The MS shall perform a PLMN selection
Location area not allowed		
Roaming not allowed in this location area		
No Suitable Cells In Location Area	shall set the GPRS update status to GU3 ROAMING NOT ALLOWED	The MS shall search for a suitable cell in another location area in the same PLMN

Detach Procedure



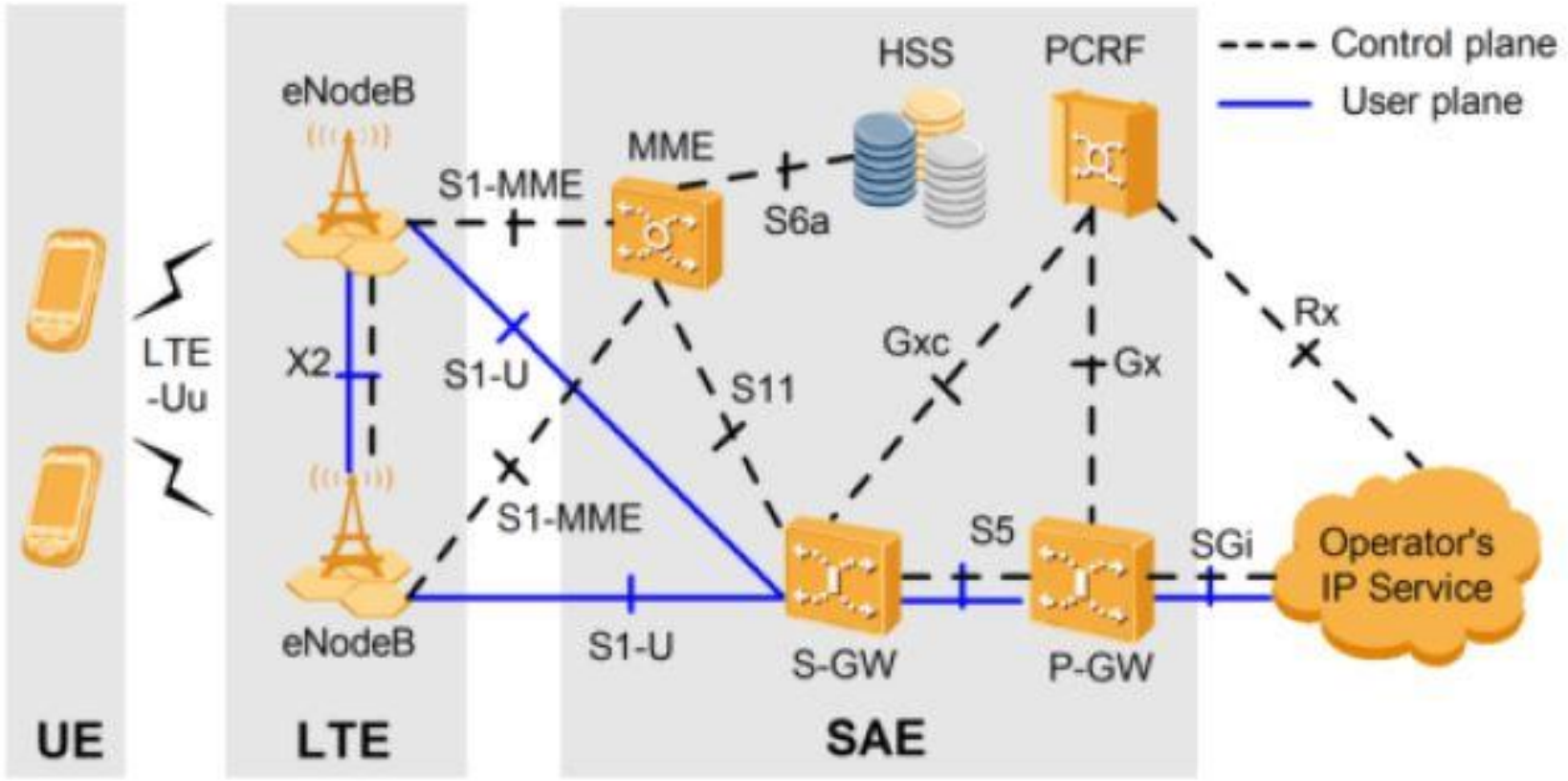
Detach type							
			bit4	bit3	bit2	bit1	
			power off	detach tye			

4G/LTE

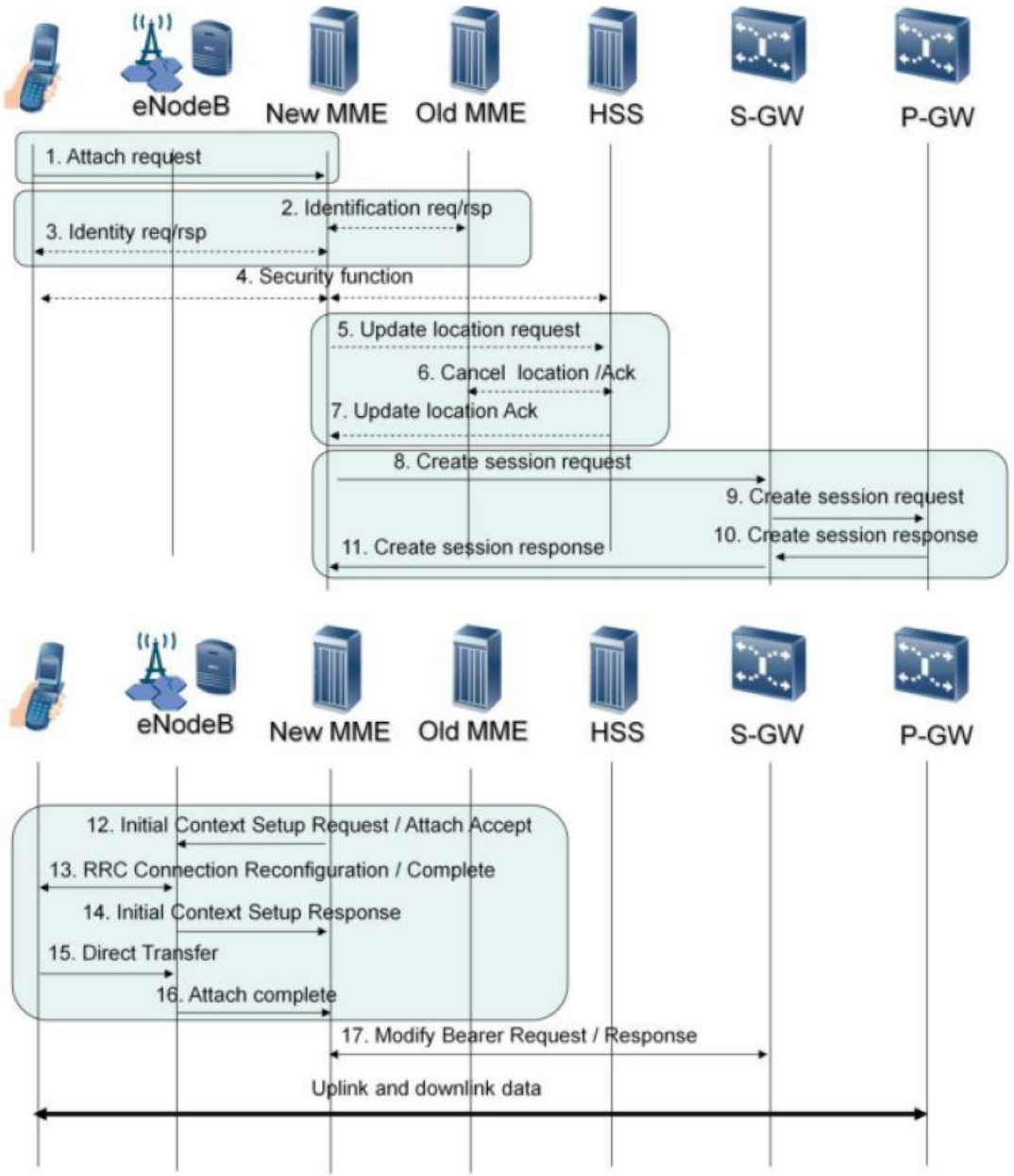
1.PS core network only support non-real time services.
2. Voice services are carried in the CS domain.
3. Low efficiency of routes in forwarding data due to the over-layered networks.
4. Incapability of supporting multiple radio access systems

1. The all-IP network contains the PS. Voice services are jointly provided by the PS and the IP Multimedia Subsystem (IMS).
2. Flattened network architecture.
3. Support of the multiple access technologies.
4. High data transmission rate: downlink 100 Mbit/s and uplink traffic 50 Mbit/s.

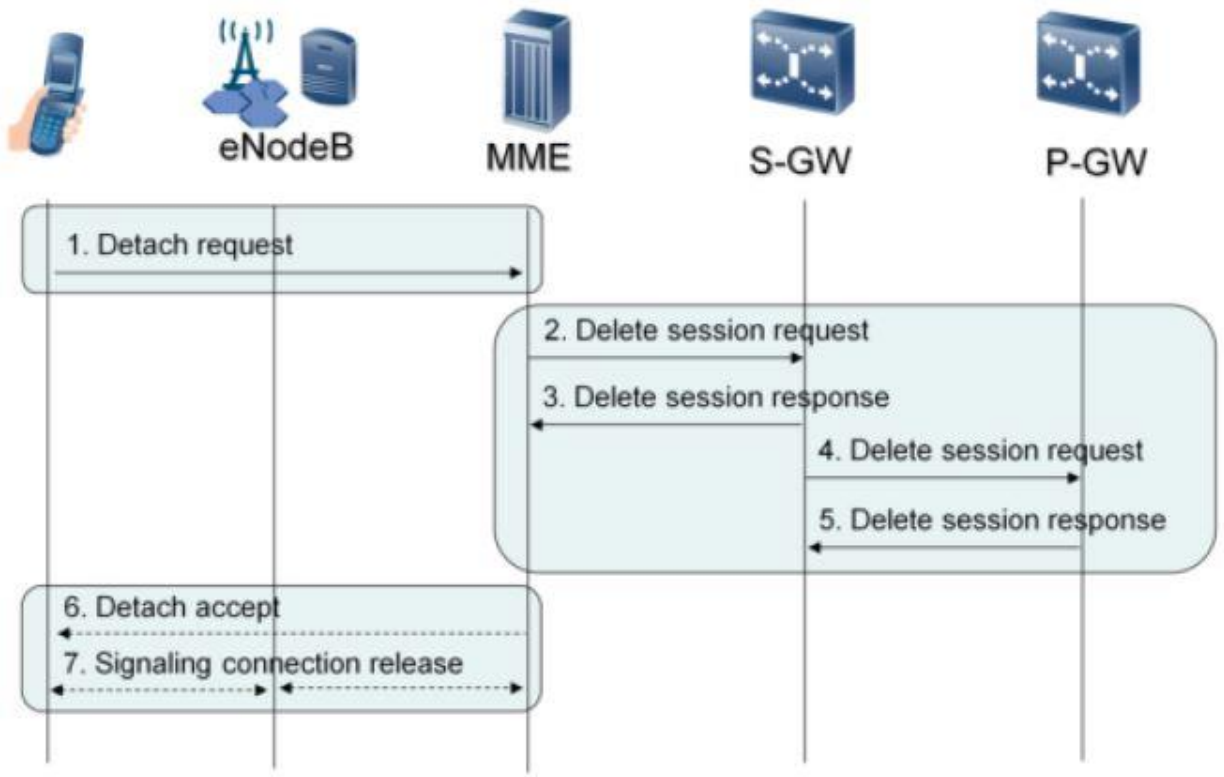
4G/LTE


Control plane
User plane
HSS
PCRF
eNodeB
MME
S1-MME
S6a
LTE
-Uu
X2
S1-U
S11
Gxc
Gx
Rx
S1-MME
S5
SGi
Operator's
IP Service
eNodeB
S1-U
S-GW
P-GW
UE
LTE
SAE

4G/LTE Attach

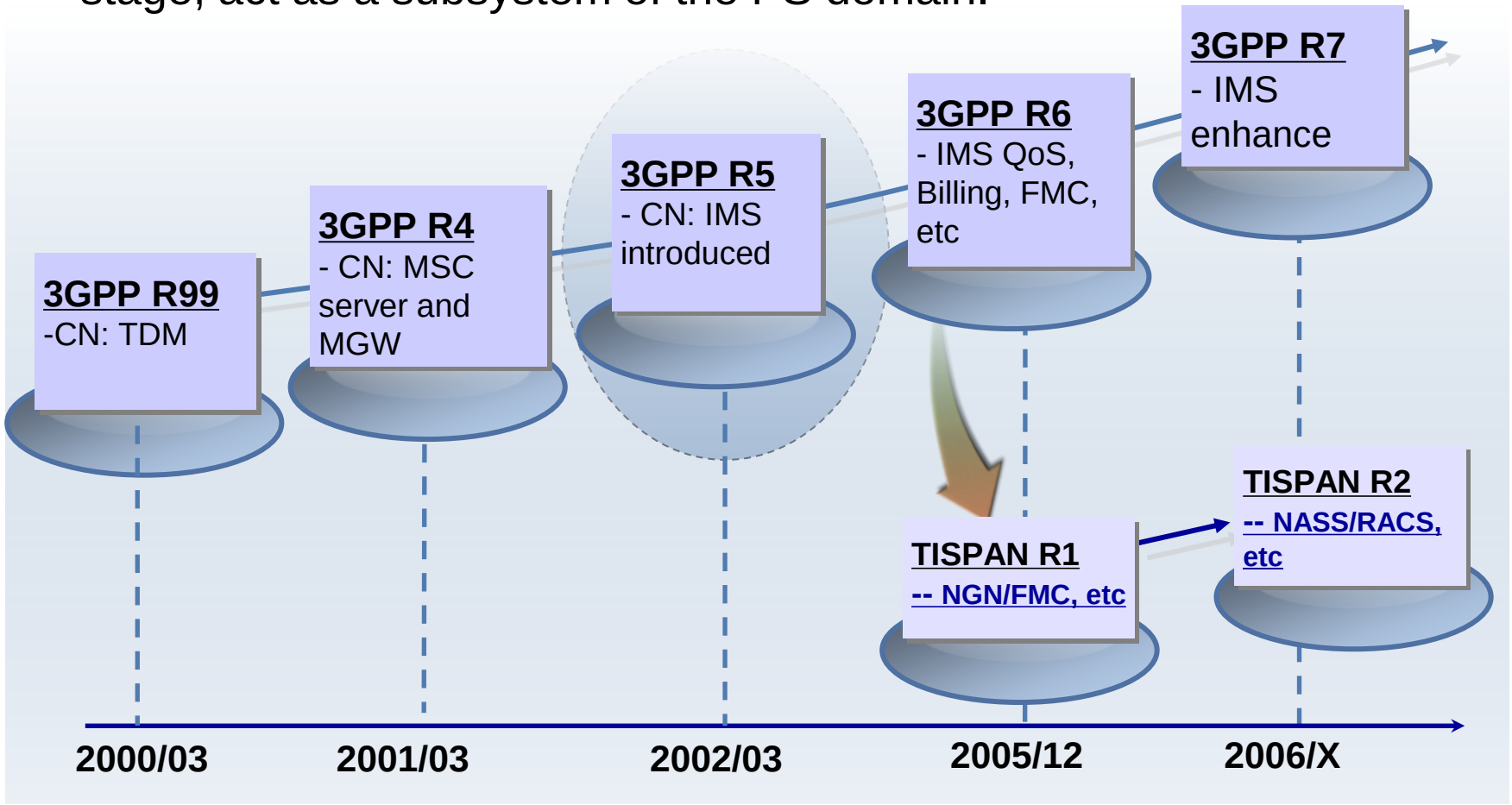


4G/LTE Detach



History of IMS

- The IMS is introduced as part of 3GPP specifications at the **R5** stage, act as a subsystem of the PS domain.



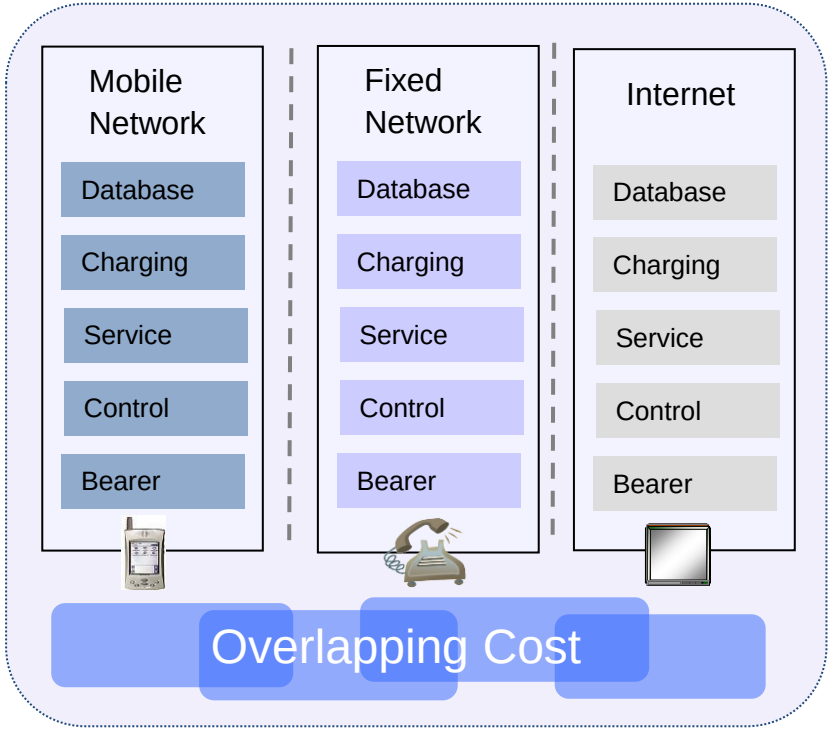
IMS Motivations

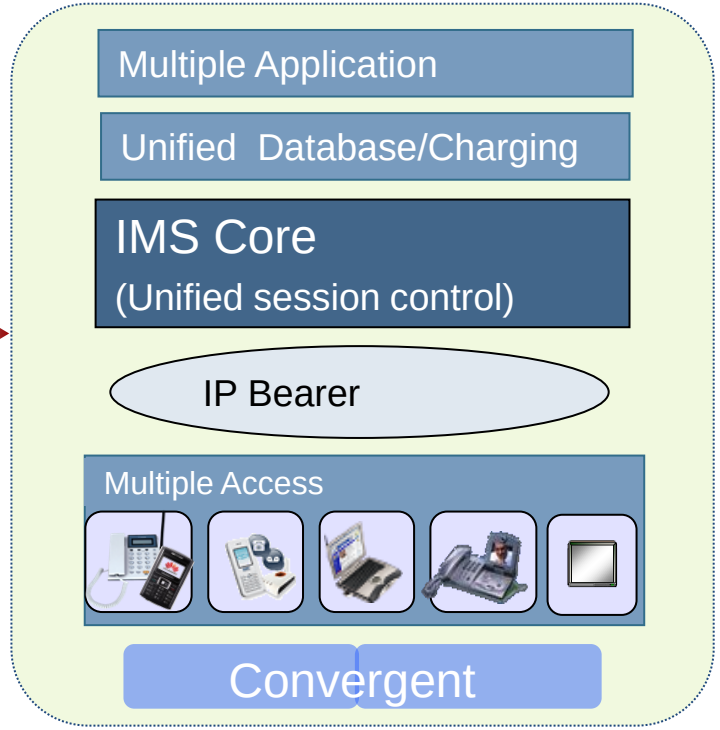
Legacy Core Network Arch.

- Vertical network, overlap in hardware, service and database
- Separated user and service
- Difficult to decrease OPEX/CAPEX

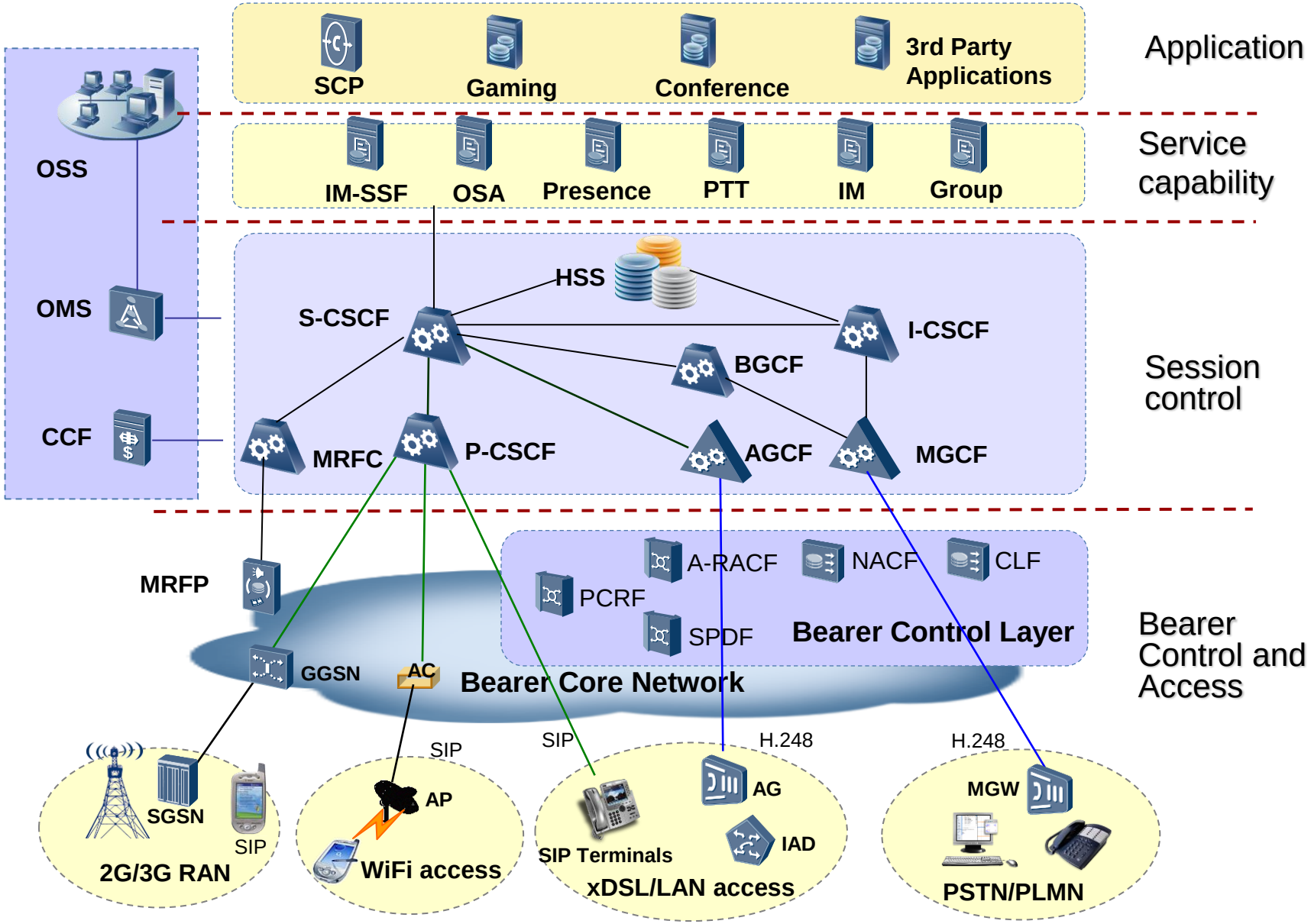
Converged Multi-service Arch.

- Horizontal network, converge fixed, mobile and data service network
- Unified database and service
- Access independent



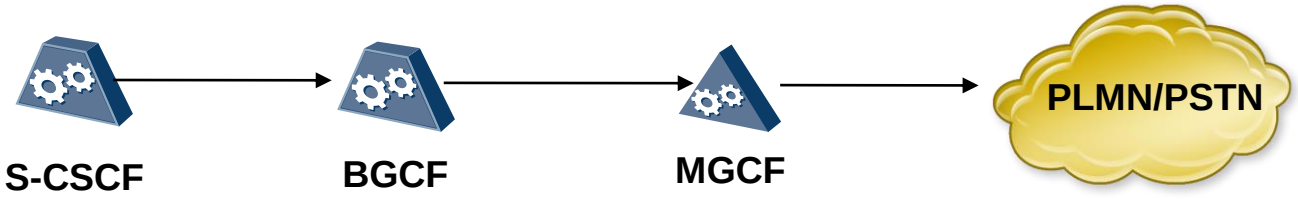


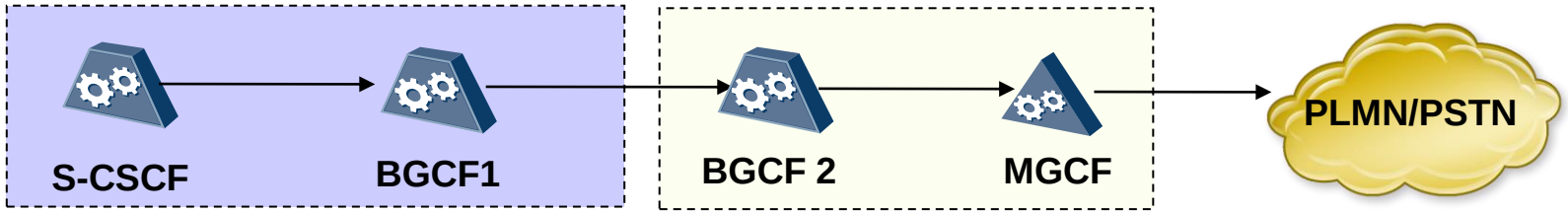
IMS Network Architecture



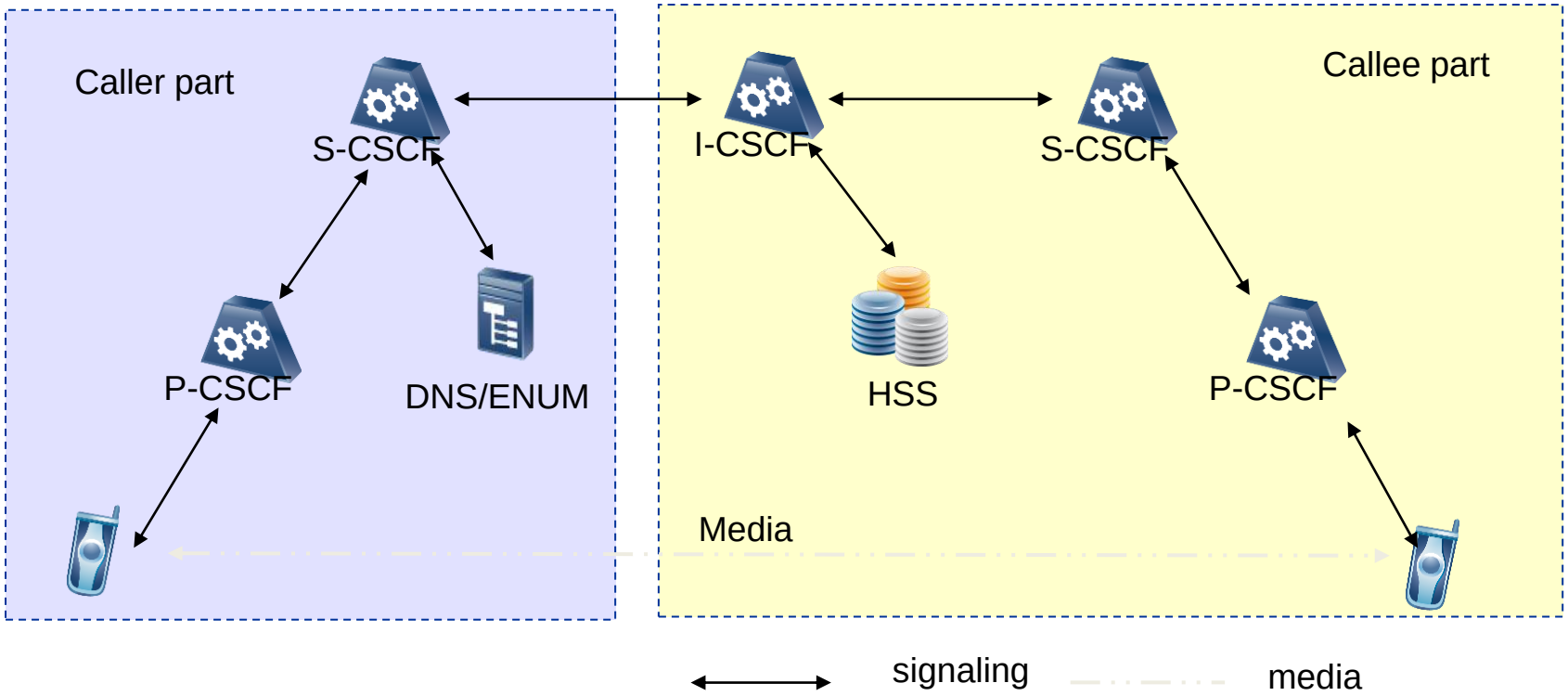
IMS Network Entities

Function	NE	Function	NE
Call control	P – CSCF	Network interworking	MGCF
	I – CSCF		IM – MGW
	S – CSCF		BGCF
User management	HSS	Media resource	MRFC
	SLF		MRFP



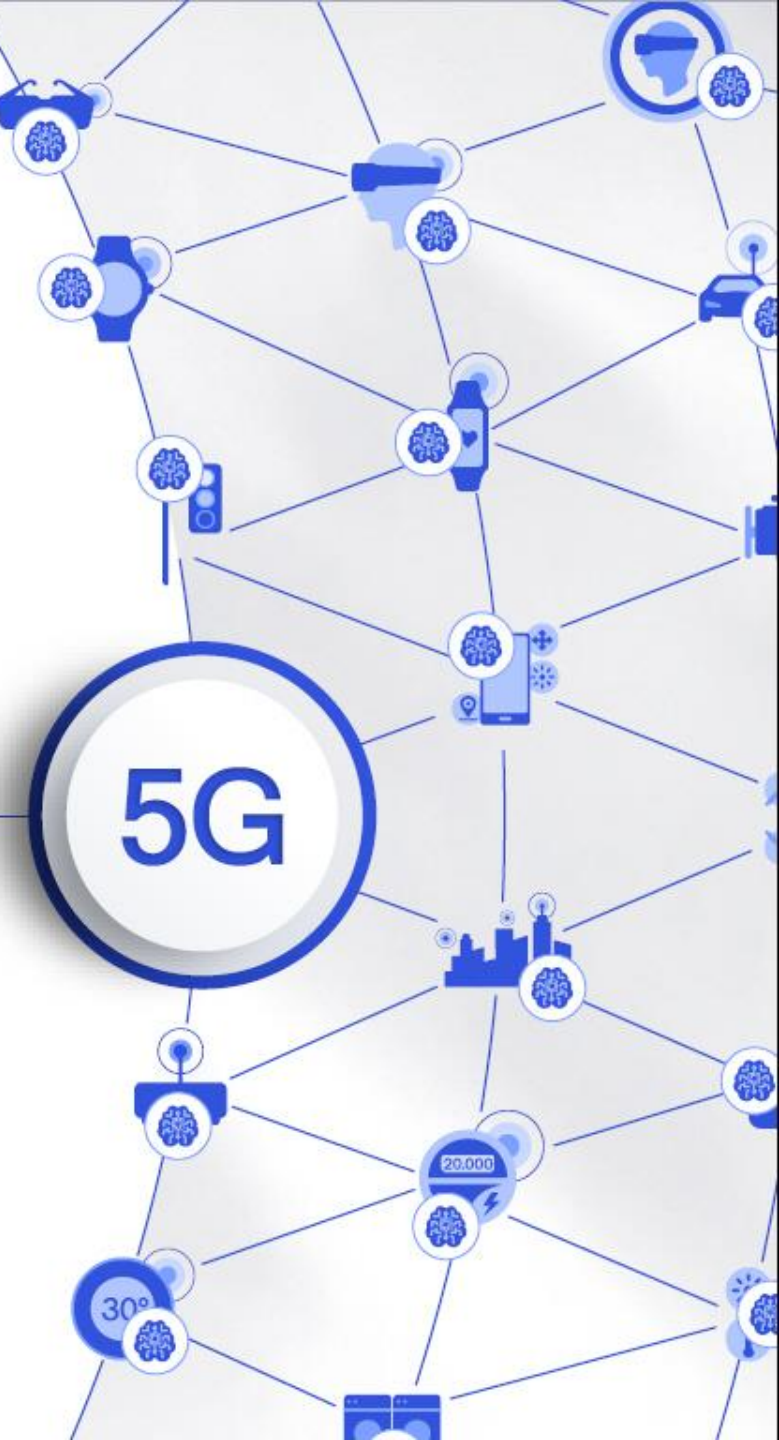


IMS Call Procedure (Simple Model)



What is 5G?

Making 5G a reality in 2019



Industry-leading R&D

5G interoperable global standards

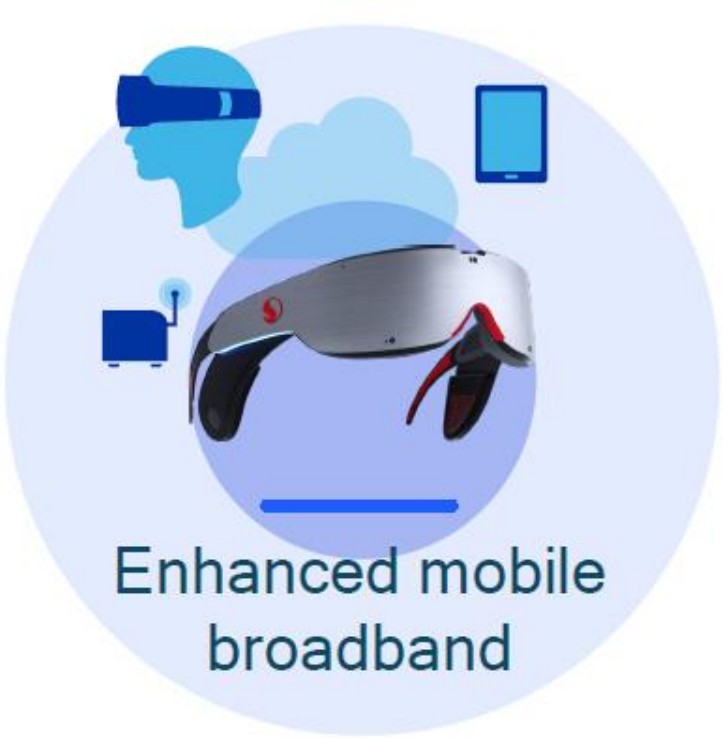
End-to end system prototypes and test beds

Commercial chipsets: Qualcomm® Snapdragon™ X50 5G modem

Commercial networks and products

Our vision for 5G is a unifying connectivity fabric

Delivering always-available, secure cloud access



Enhanced mobile broadband

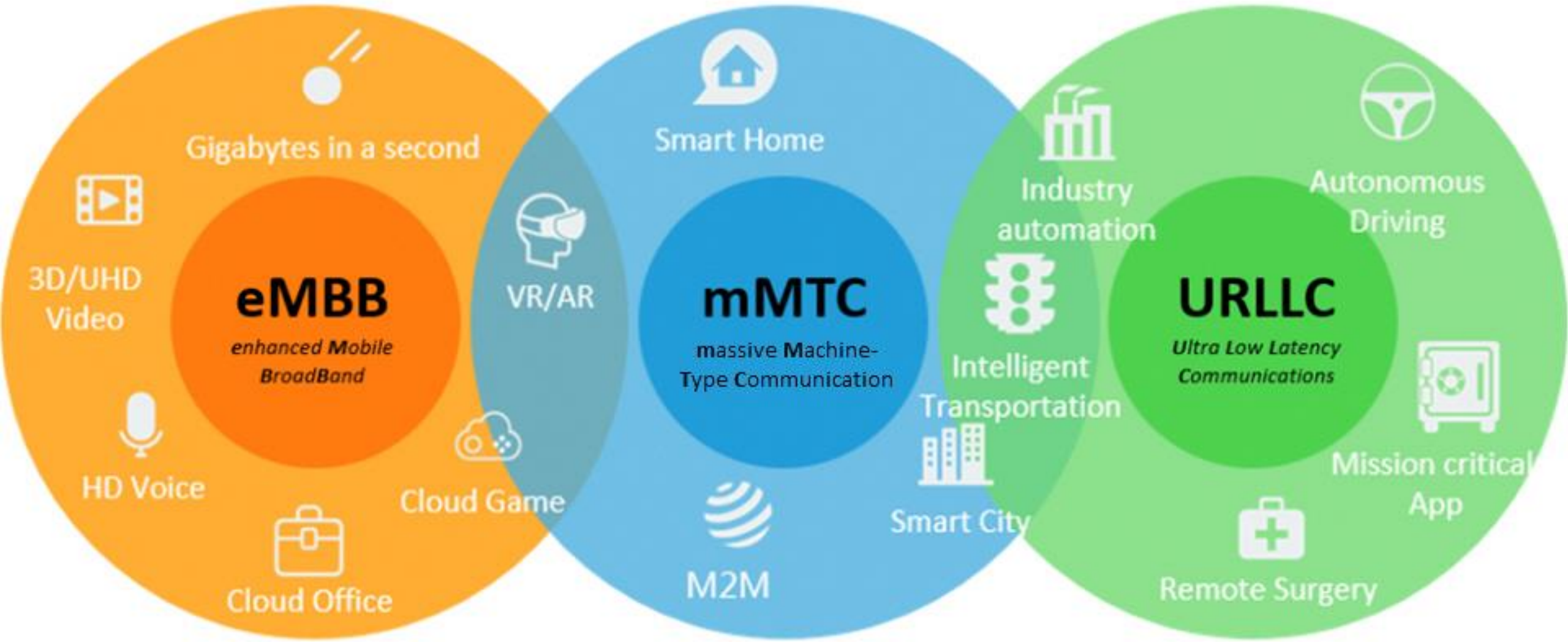
Mission-critical services

Massive Internet of Things

Unifying connectivity platform for future innovation

Convergence of spectrum types / bands, diverse services, and deployments,
with new technologies to enable a robust, future-proof 5G platform

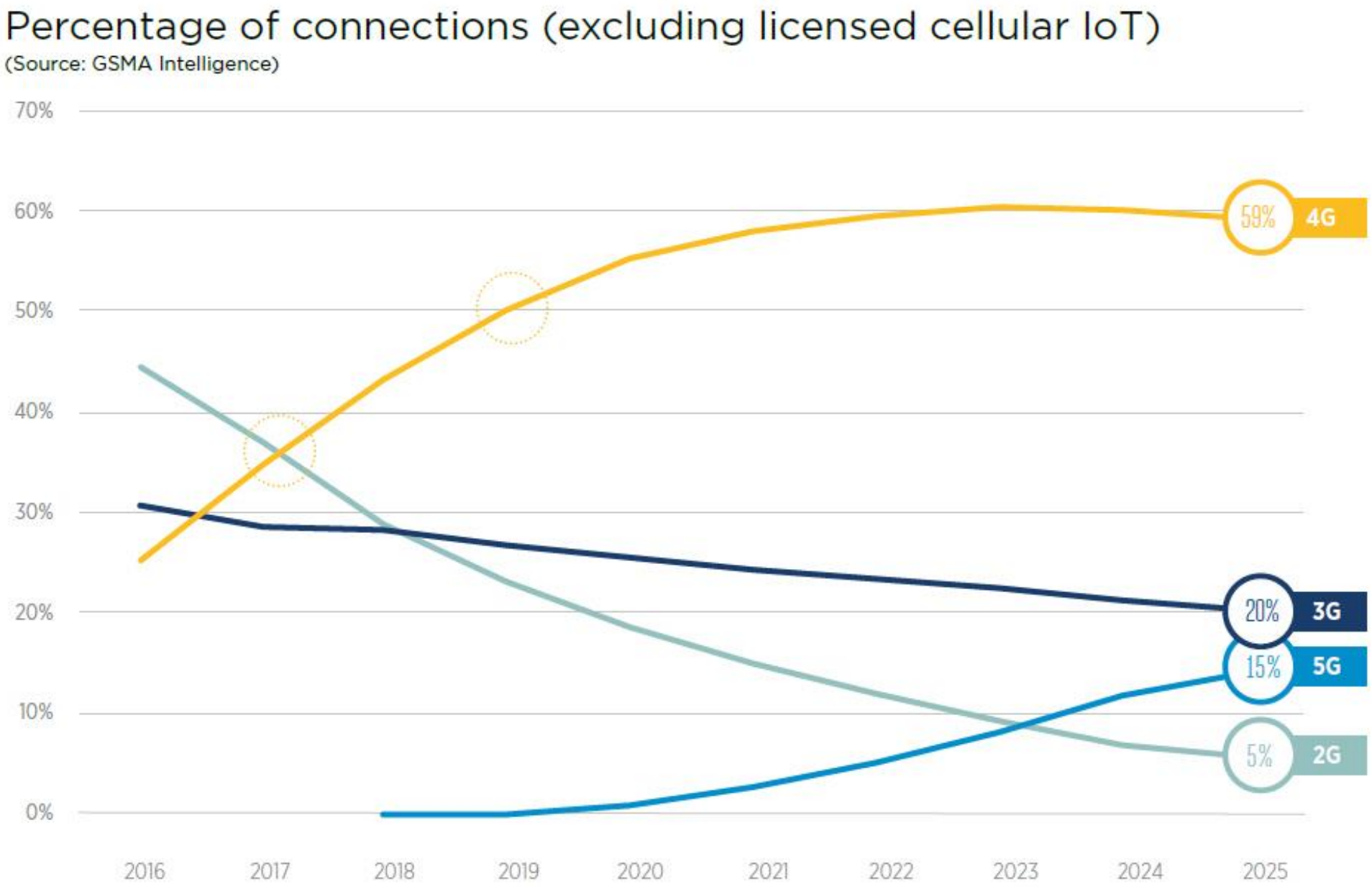
5G – Primitives



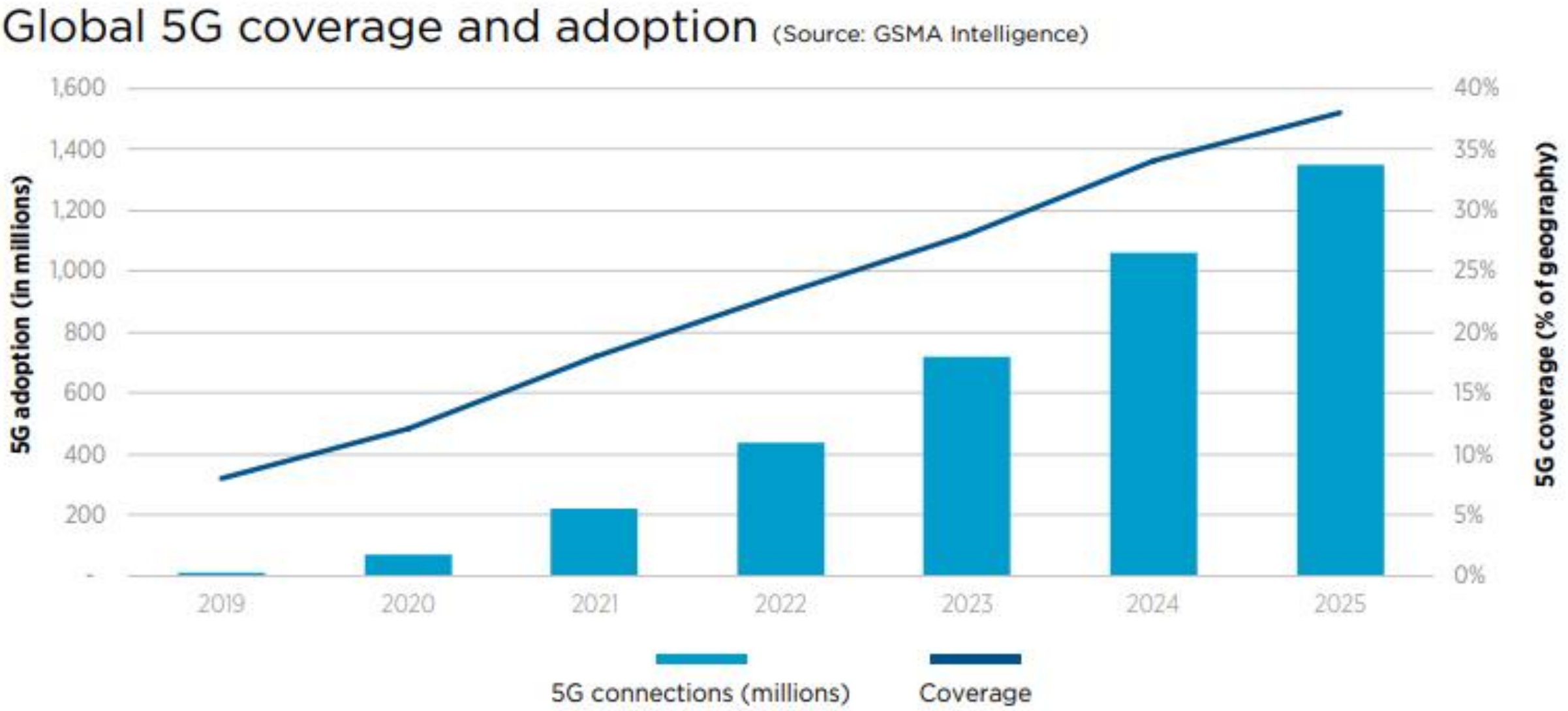
5G – Near Future

European Commission

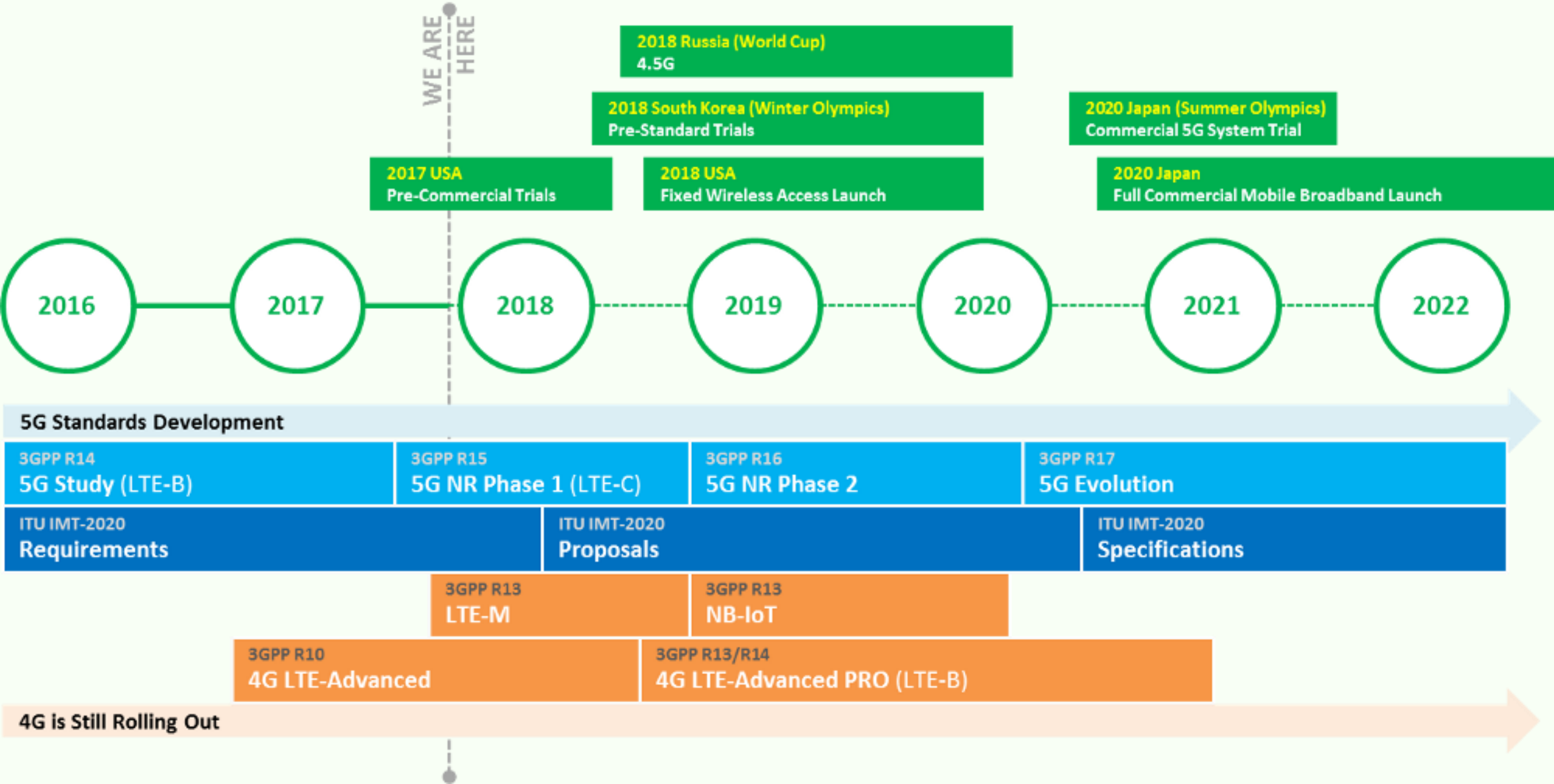
2G → 5G Roadmap



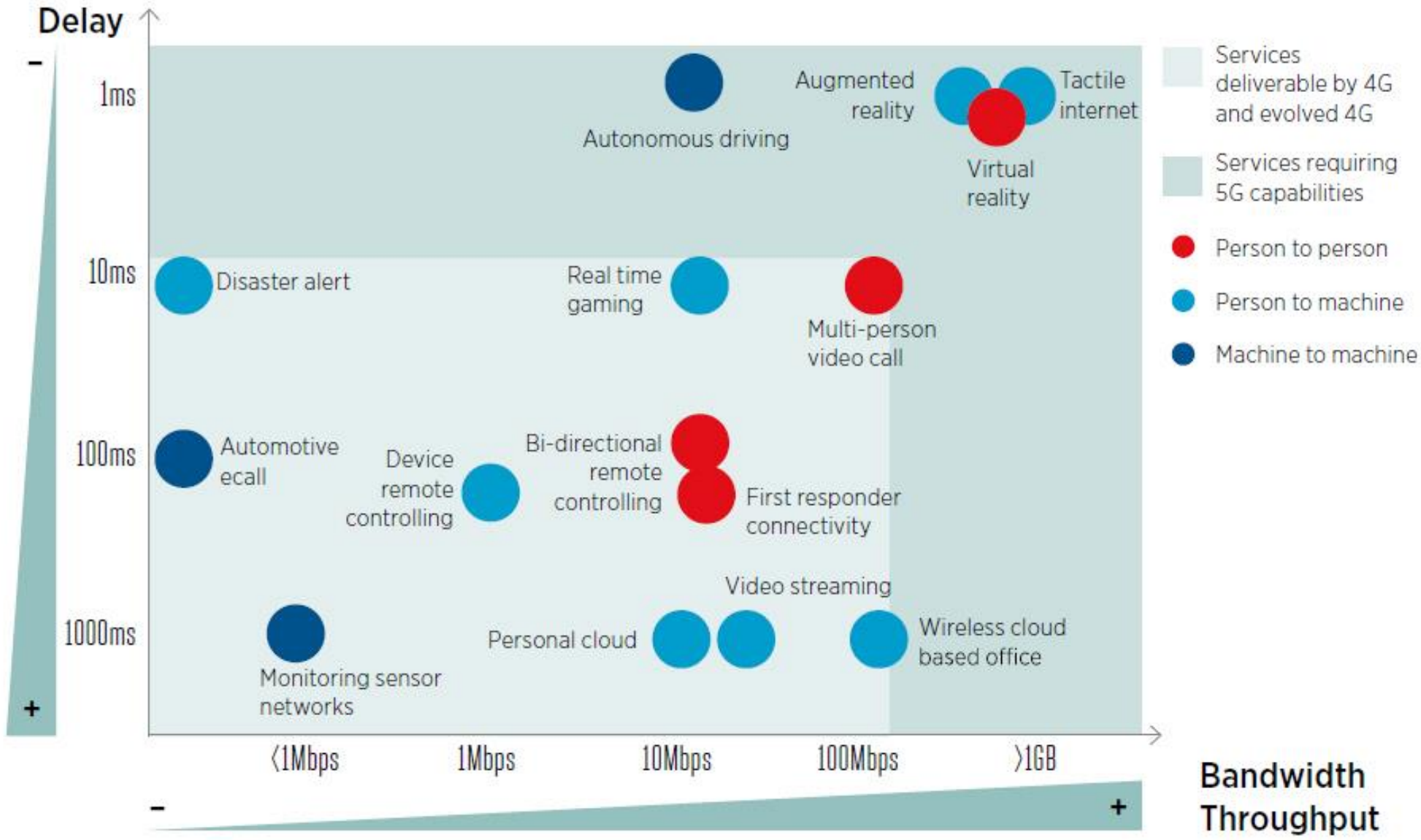
Towards → 5G


Global 5G coverage and adoption (Source: GSMA Intelligence)
5G adoption (in millions)
1,600
1,400
1,200
1,000
800
600
400
200
-
40%
35%
30%
25%
20%
15%
10%
5%
0%
5G coverage (% of geography)
2019
2020
2021
2022
2023
2024
2025
5G connections (millions)
Coverage

2G → 5G Roadmap



5G Motivations

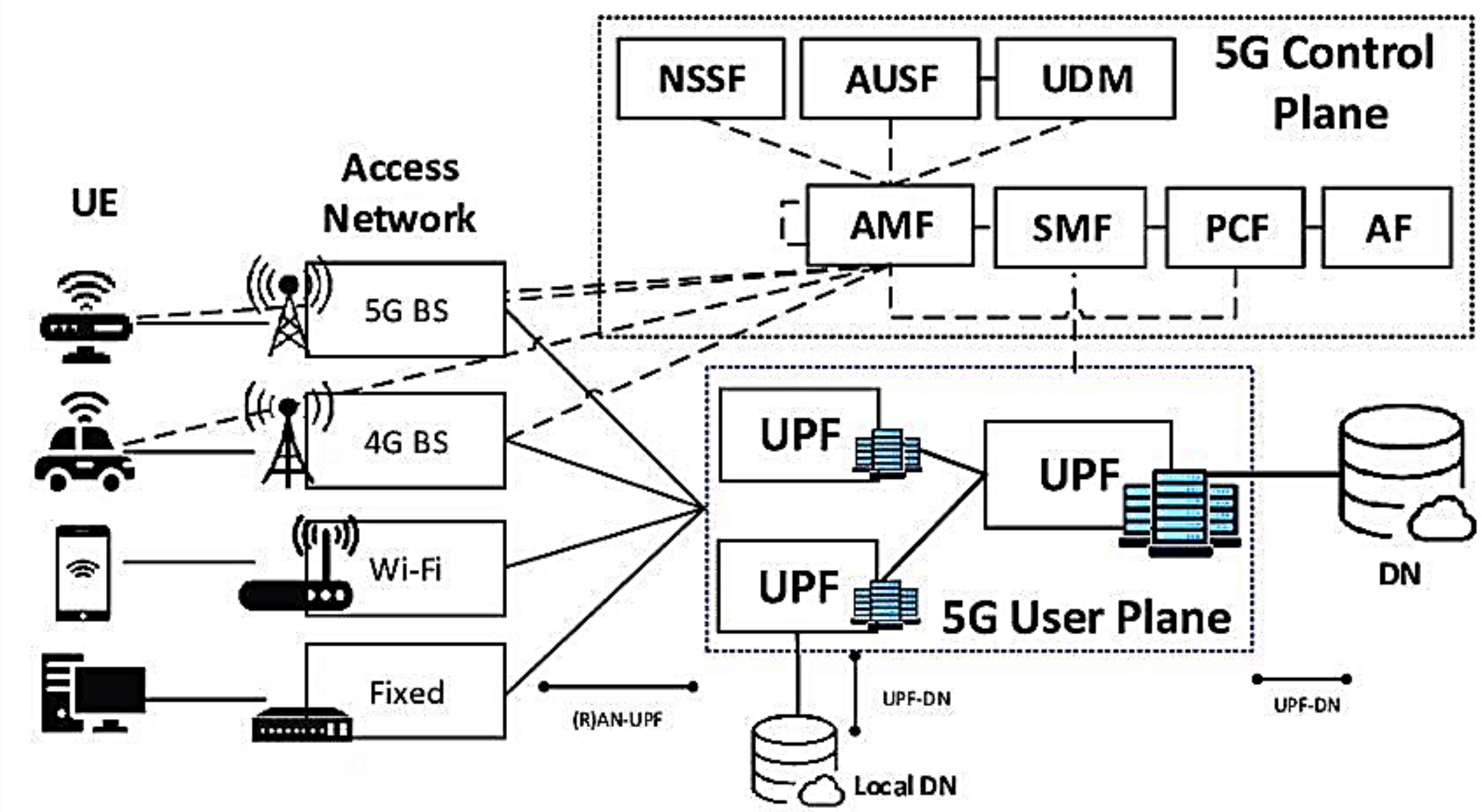


5G IMT-2020

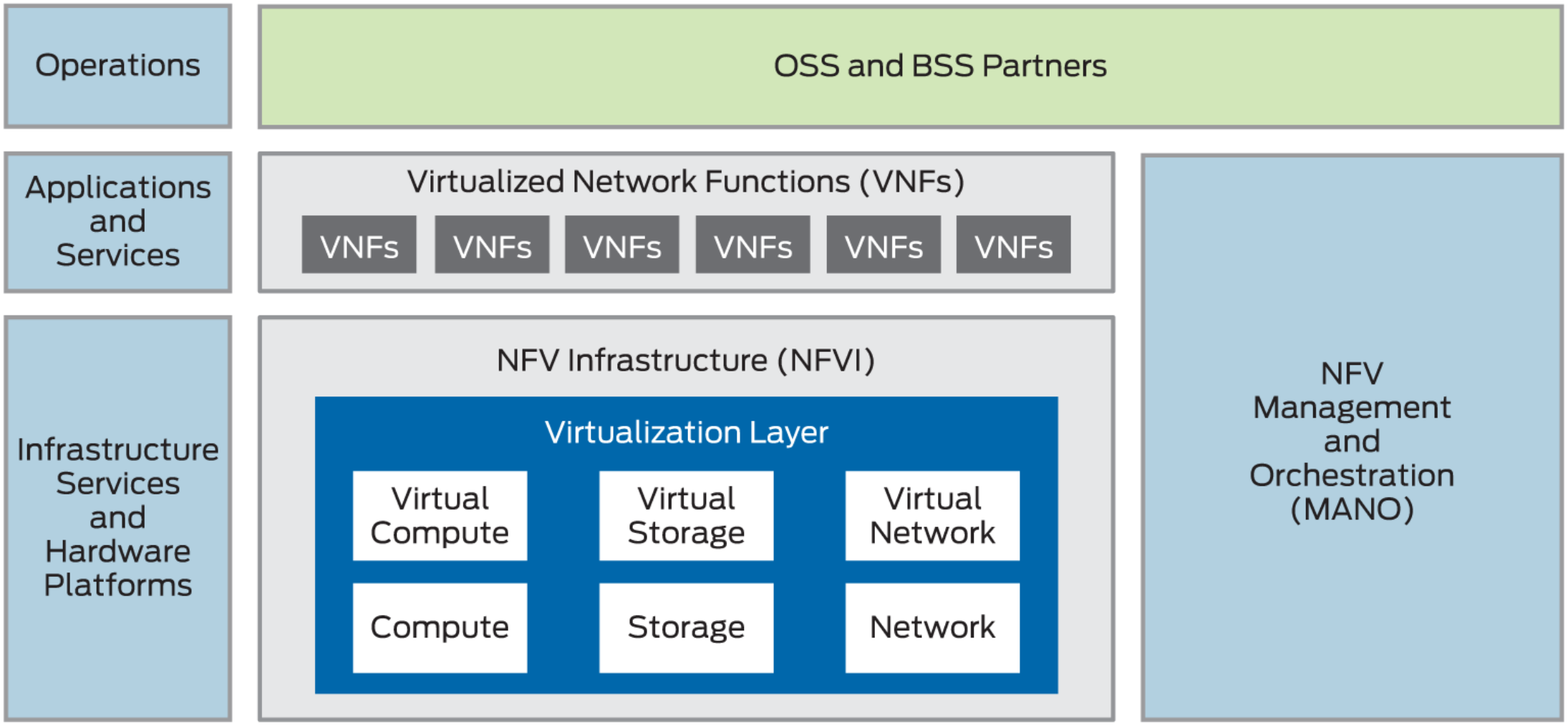
Use Cases	Key Performance Indicator	Specification
Enhanced Mobile Broadband (eMBB)	Data Rate	10-20Gbps peak
		100 Mbps whenever needed
		10000x more traffic
	Mobility Speed	500km/h
	Use Scenario	Marco and small cells
	Network Energy efficiency	Network energy saving by 100 x
Massive Machine Type Communications (mMTC)	Connection Density	$2 \times 10^5 - 10^6/km^2$
	Coverage	Long Range
	Data rate	1-100 kbps
	Battery Life	10 years
	Cost	M2M ultra low cost
	Access method	Asynchronous access
Ultra-Reliability and Low Latency Communications (URLLC)	Latency	<1ms air interface latency
		5 ms E2E latency
	Reliable and Available	99.9999%
	Data Rate	50 kbps – 10 Mbps
	Mobility	High speed mobility

5G – Primitives

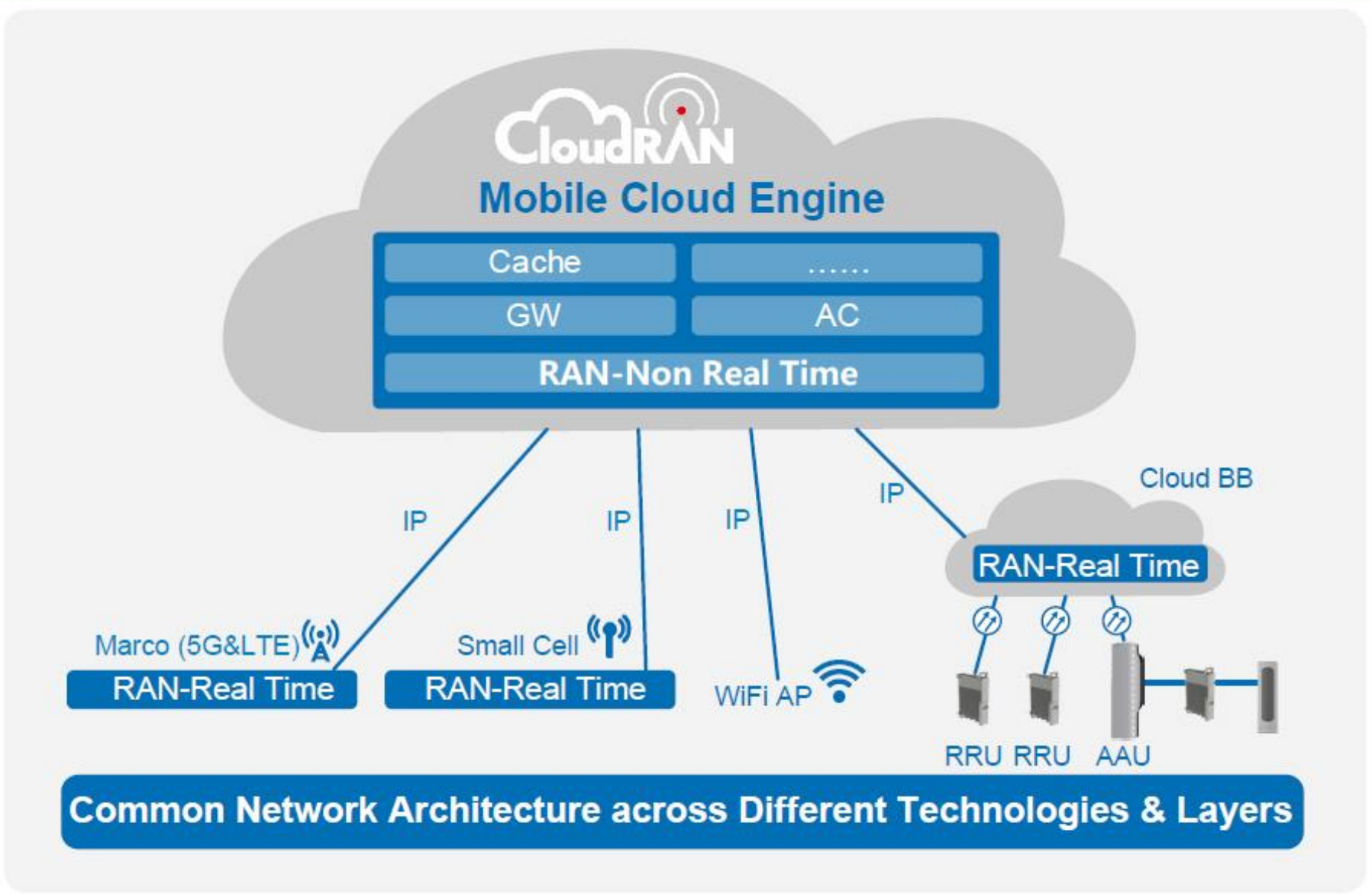
5G – Network Architecture



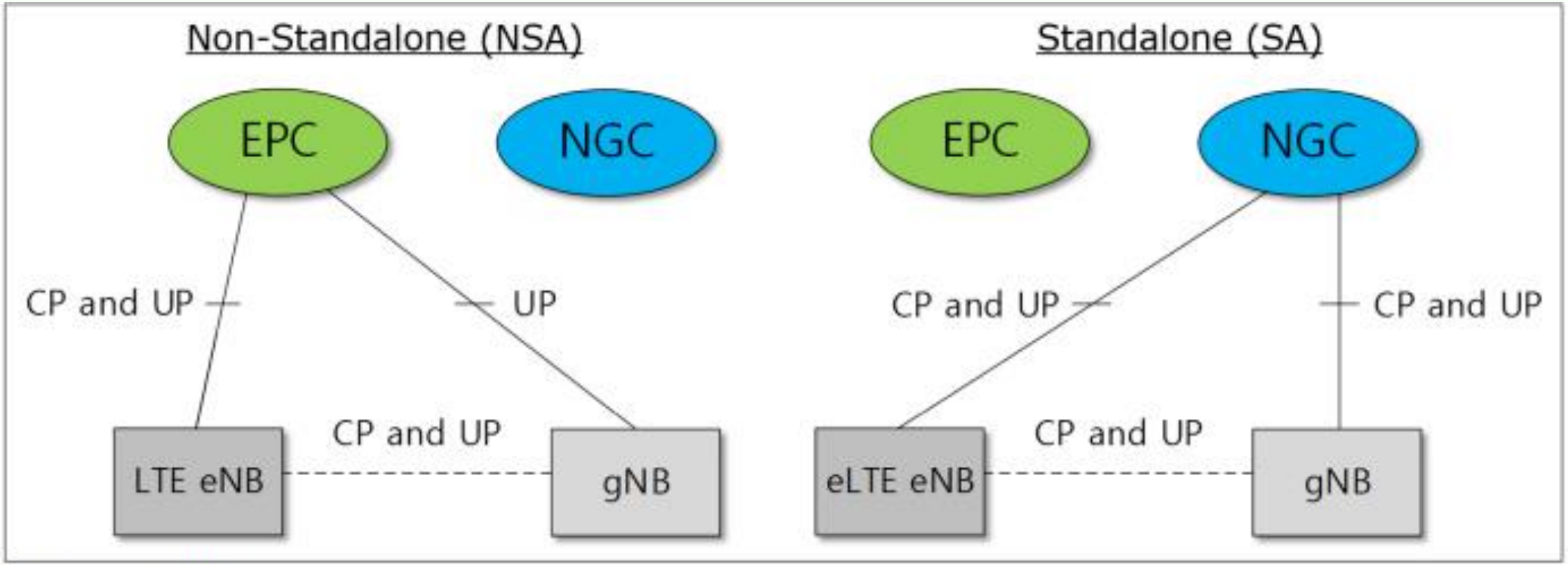
NFV-Network Function Virtualization



5G-CRAN Cloud RAN

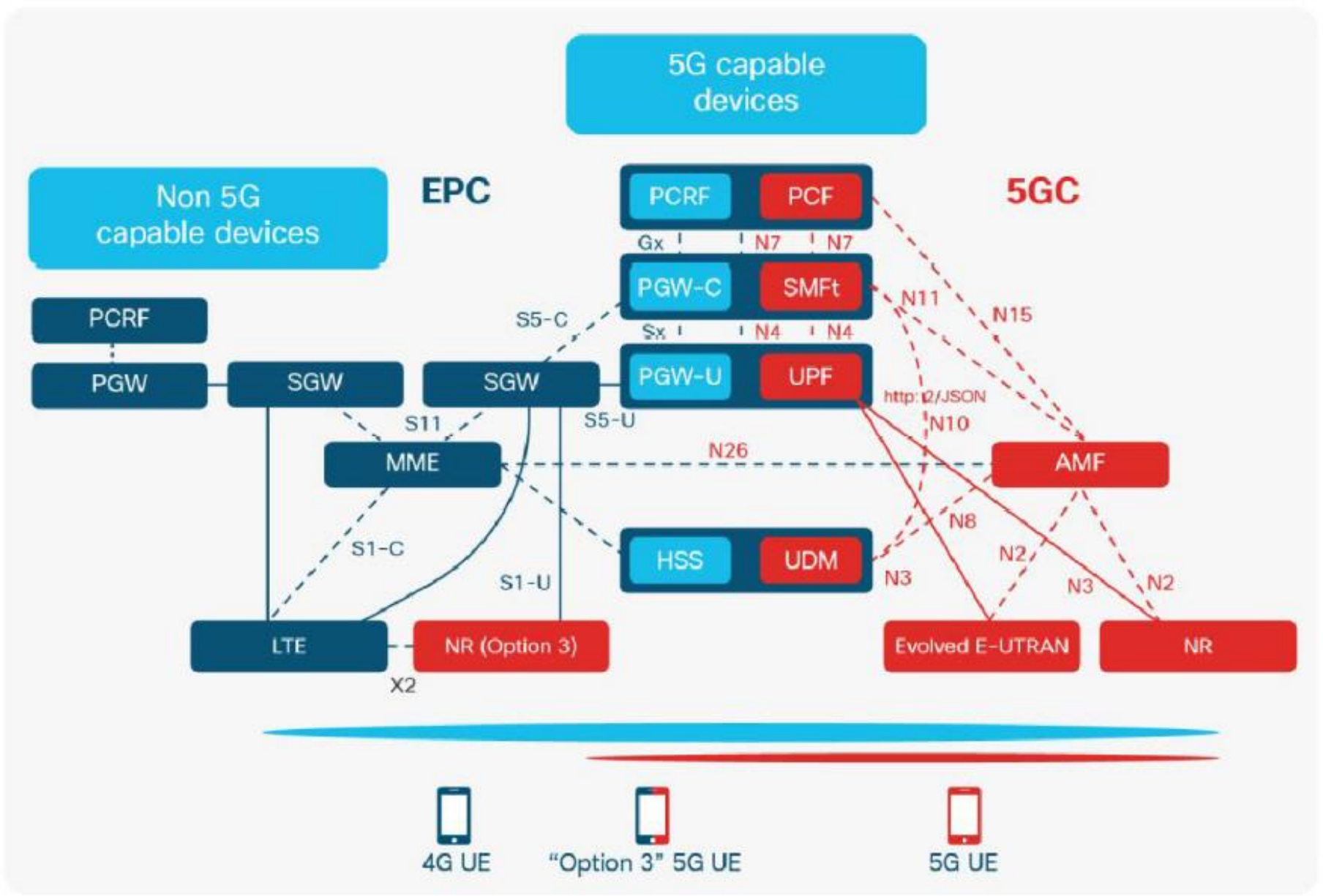


5G – Interoperable Network



Source: 3GPP

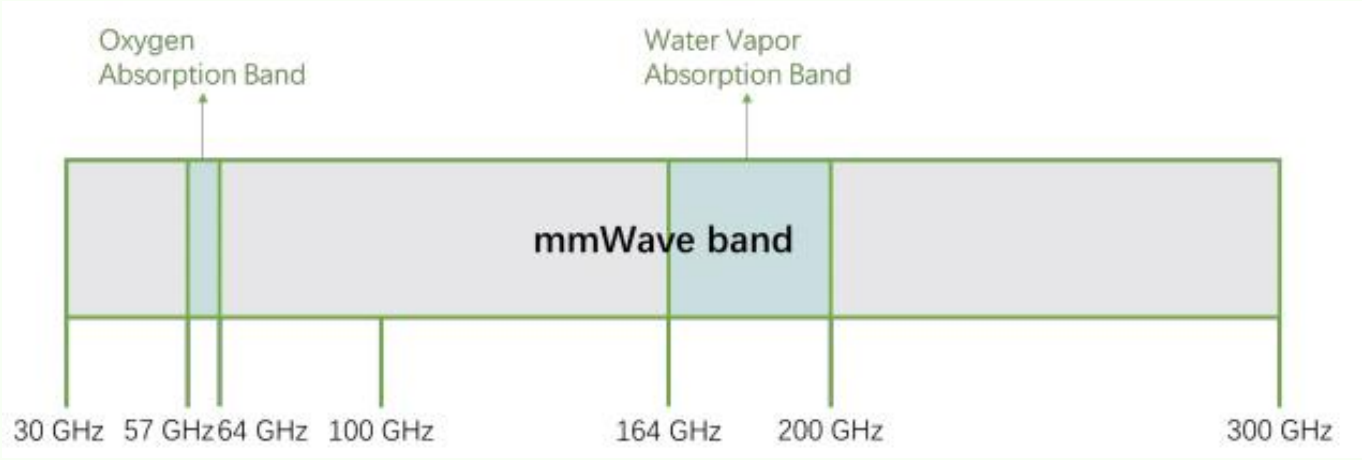
5GC – Interoperable Network

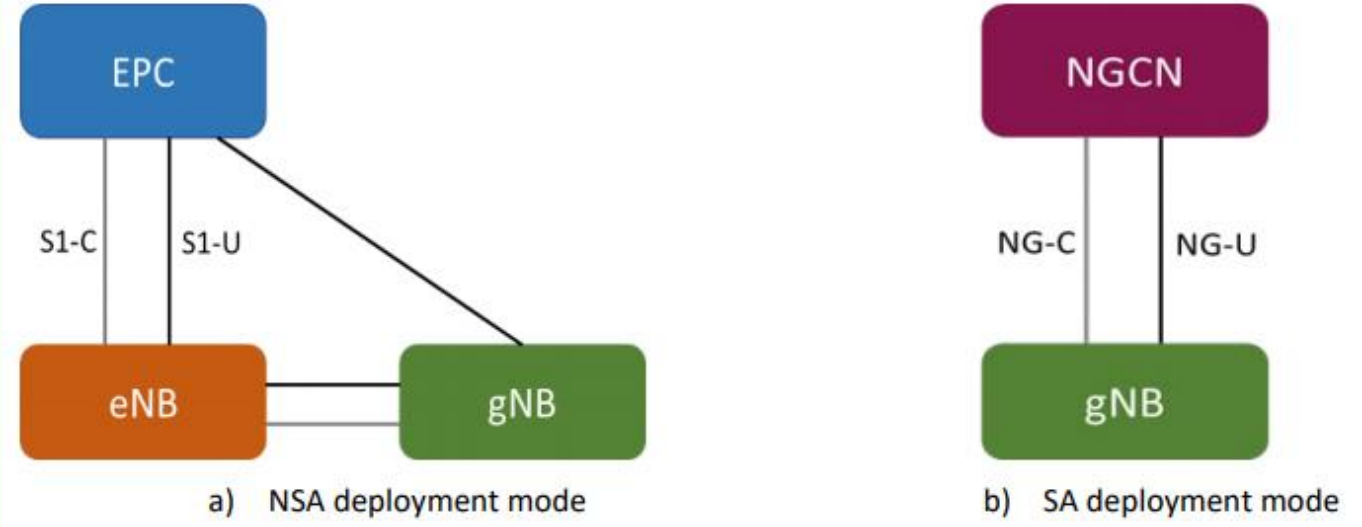


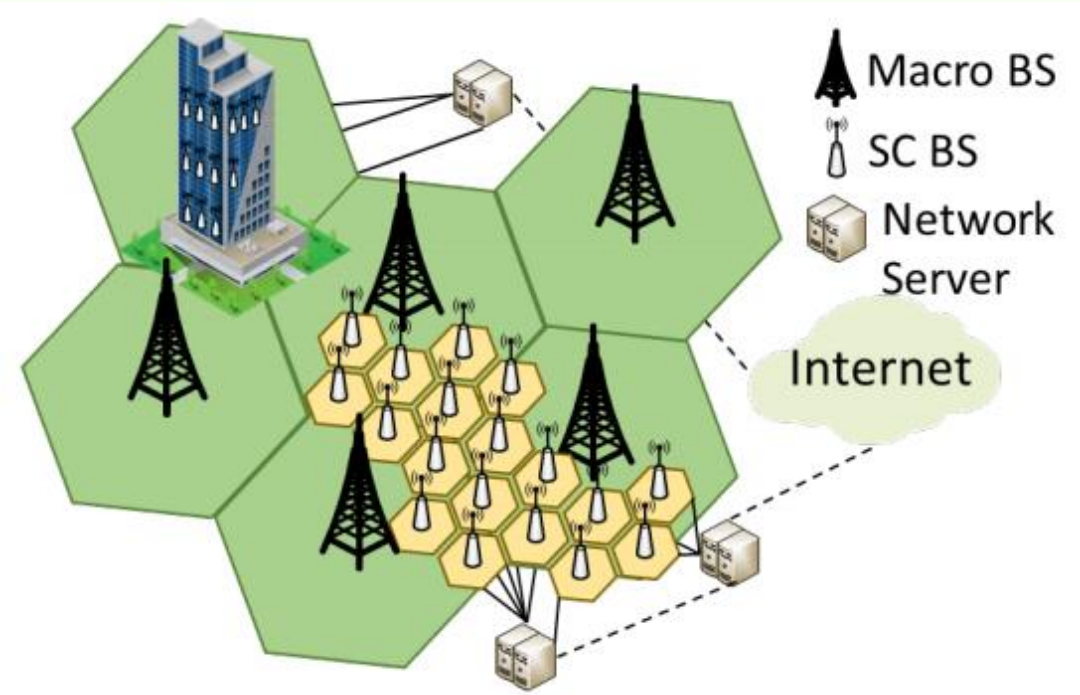
5GNR – New Radio

Source: Heavy Reading

5GNR – New Radio

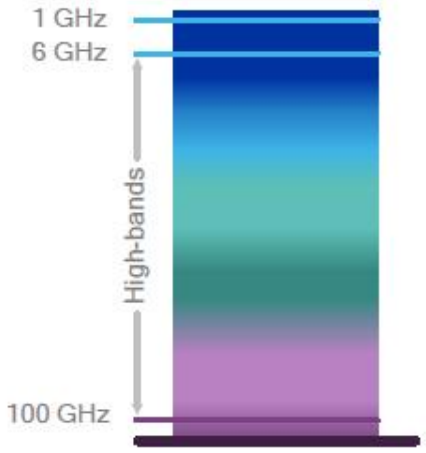






5G NR mmWave is capable of delivering massive capacity

Exploiting higher bands and more flexible use of available bandwidth

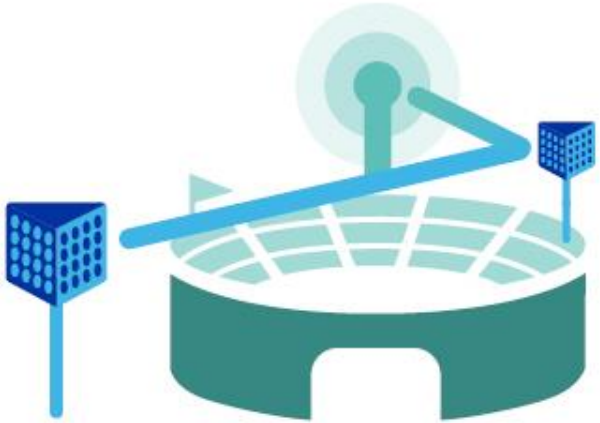


Large bandwidth

Leveraging higher spectrum bands (e.g., at 28 GHz) previously not available to LTE

Flexible capacity

Adapting to network traffic needs with dynamic UL / DL switching, enabled by new self-contained TDD design

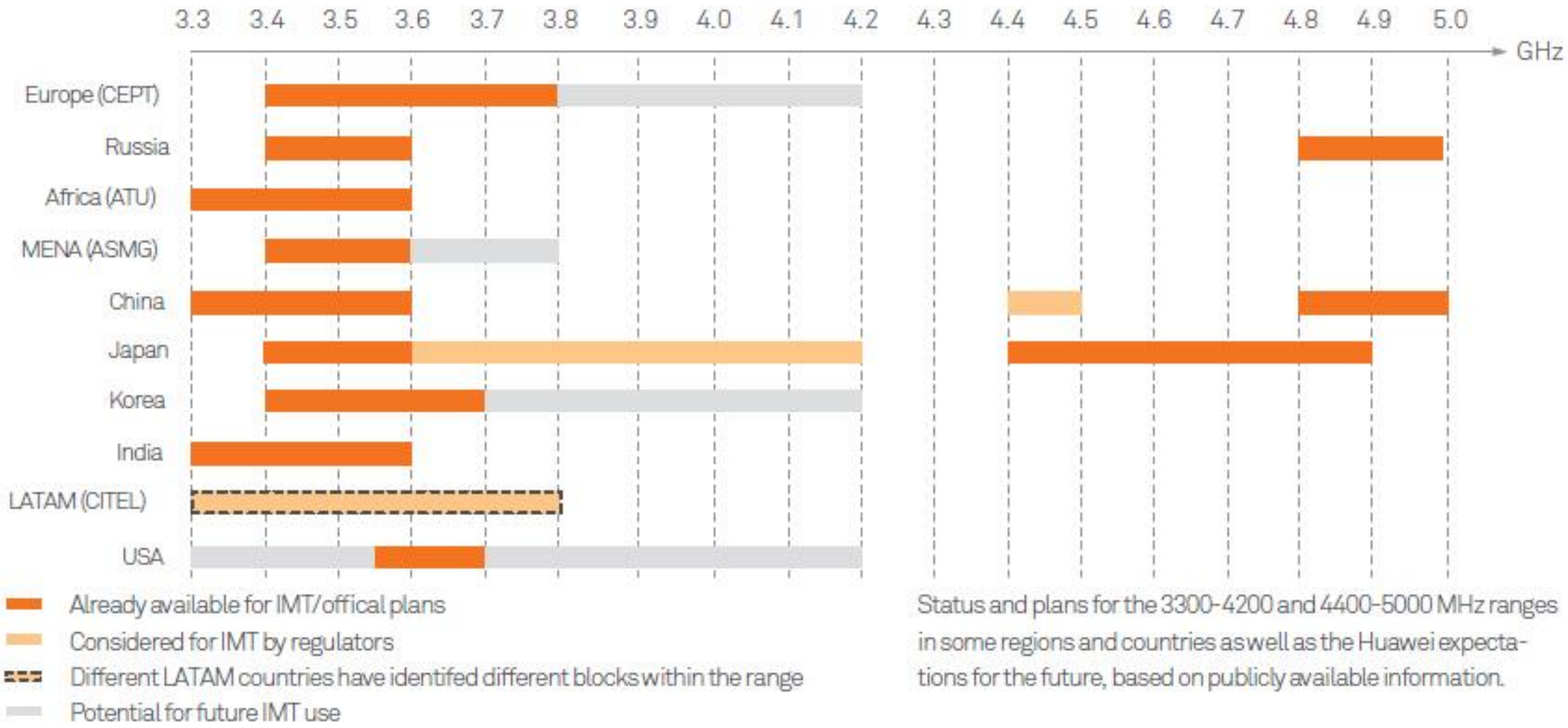


Small cell densification

Enabling easy / low-cost deployment of small cells with integrated access and backhaul

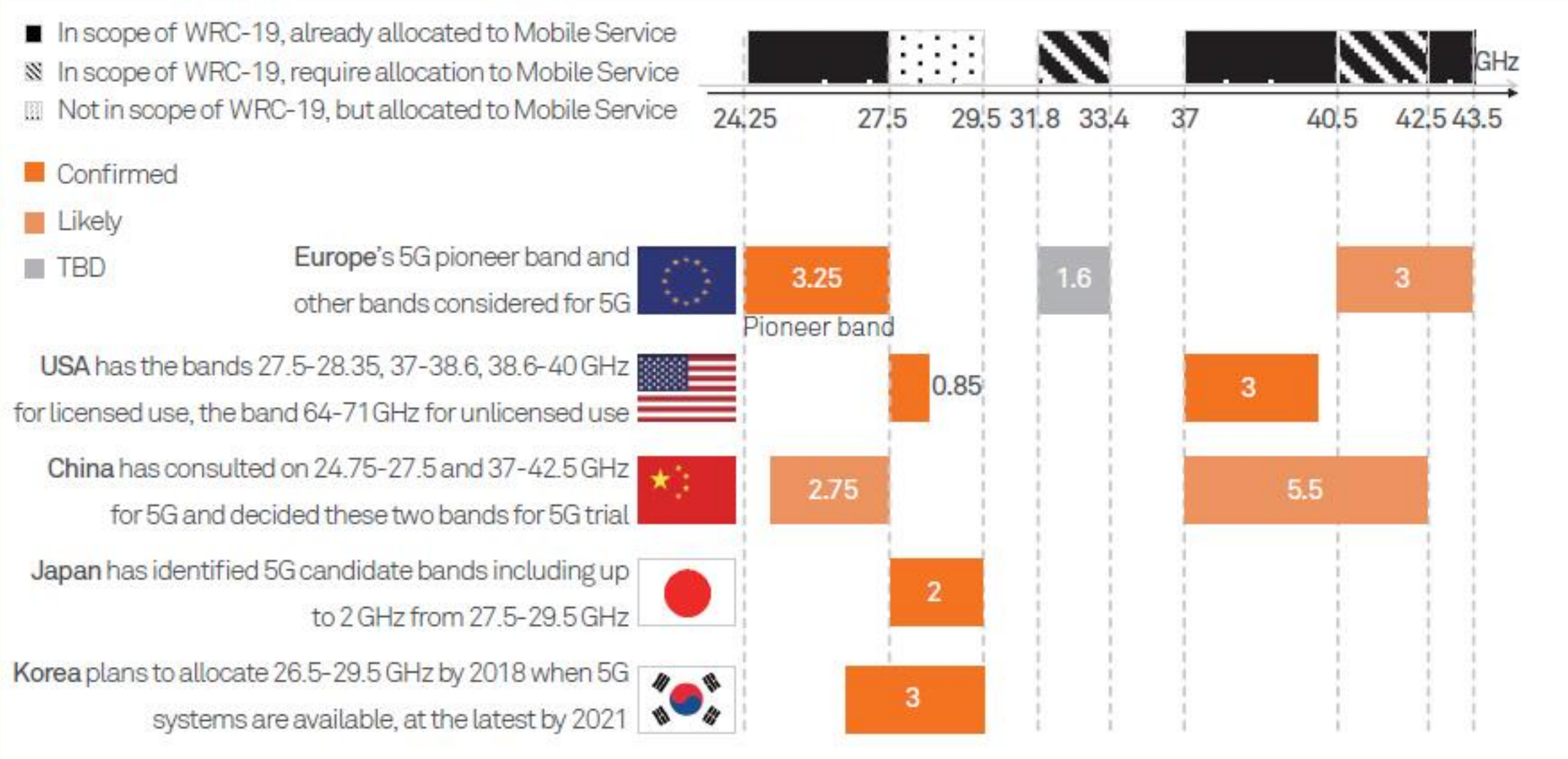
Simultaneous connectivity with spectrum bands below 6GHz (Gigabit LTE or 5G NR) ensures a seamless, ubiquitous user experience

5G Spectrum – mmWave



Status and plans for the 3300-4200 and 4400-5000 MHz ranges in some regions and countries as well as the Huawei expectations for the future, based on publicly available information.

5G Spectrum – mmWave



5G Spectrum – mmWave

Europe

2018-2019 Trial

- 3.4 -3.8 GHz
- eMBB, IoT

USA

2017-2018 Trial

- 28 and 39 GHz
- Fixed Wireless Access, eMBB

China

2017 Trial, 2019 Commercial

- 3.4-3.6 and 4.8-5 GHz; uplink sharing with sub-2 GHz
- eMBB, NB-IoT

Korea

2017 Trial, 2019 commercial

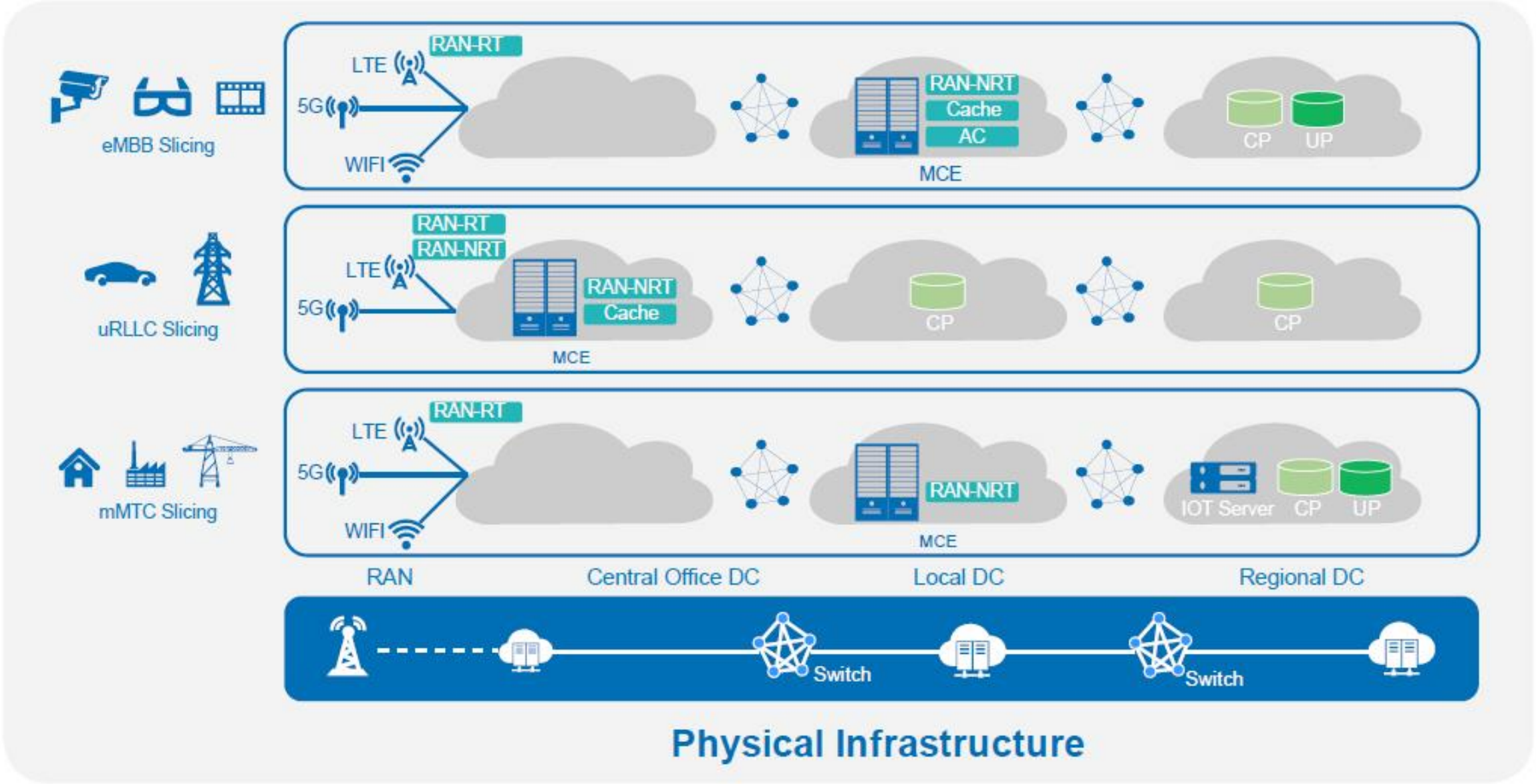
- 28 GHz, 3.4-3.7 GHz
- eMBB

Japan

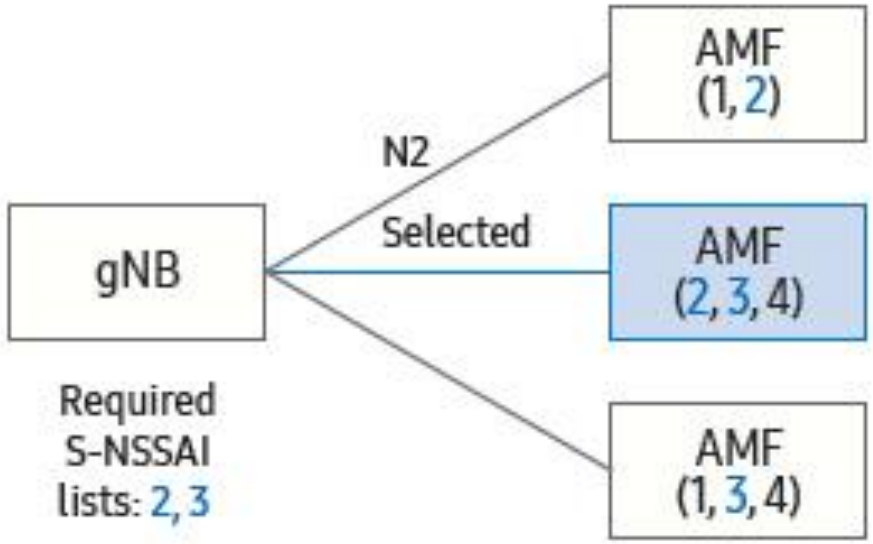
2017 Trial, 2020 Commercial

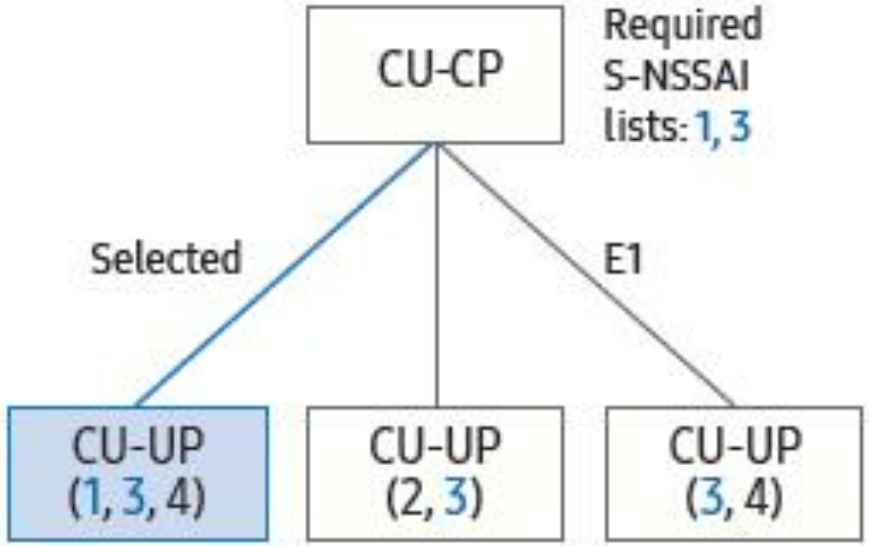
- 3.6-4.2 and 4.4-4.9 GHz, and 28 GHz
- eMBB

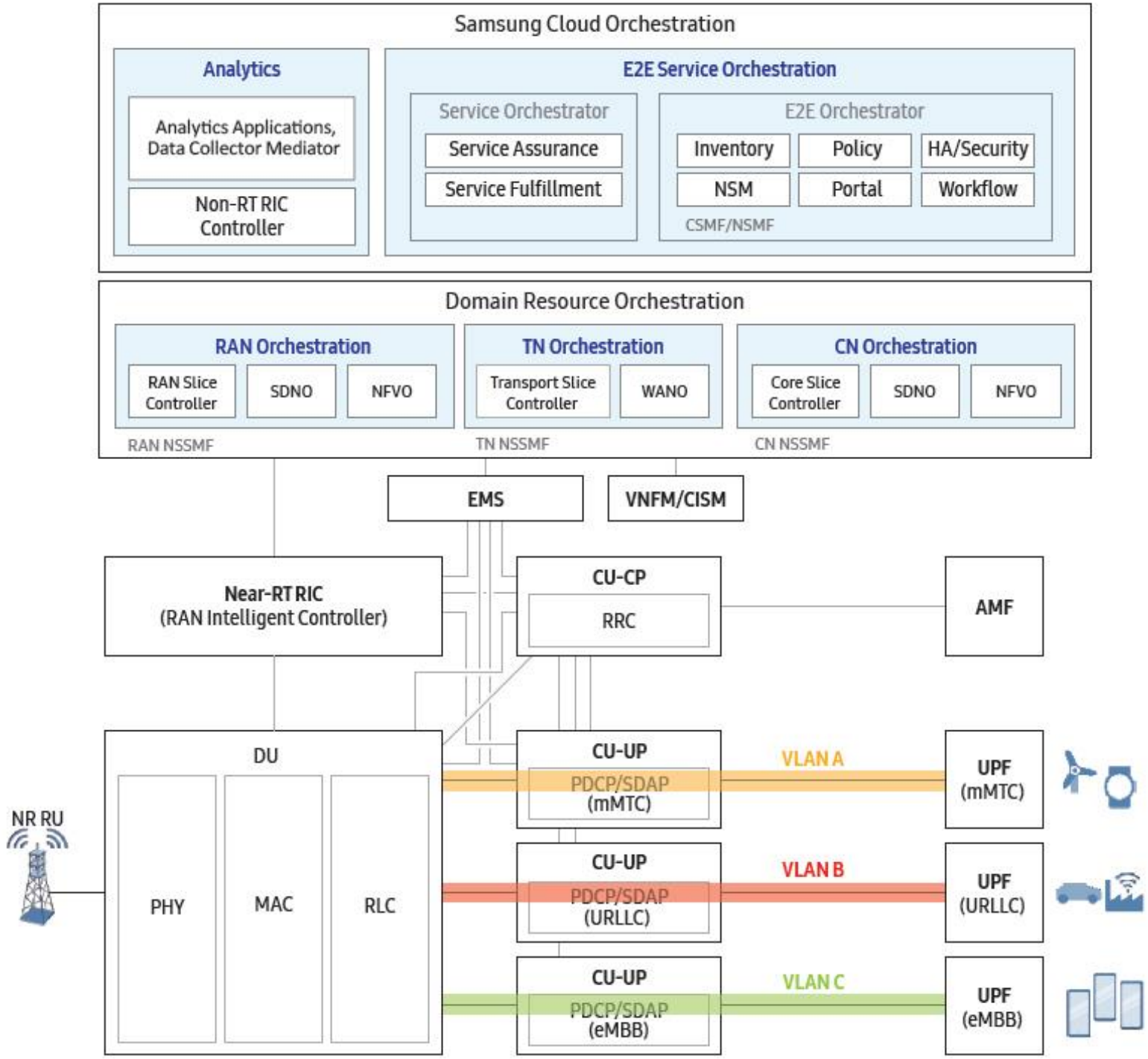
5G Network Slicing



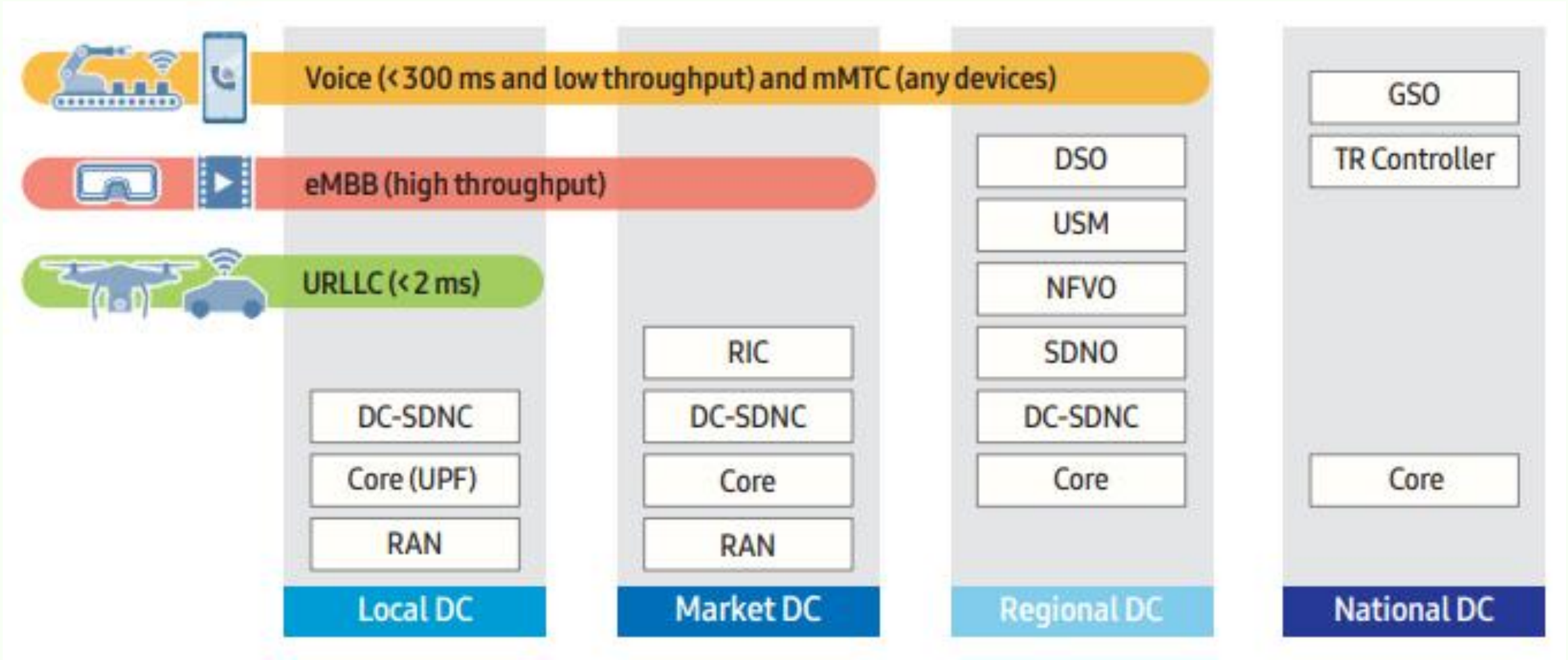
5G Network Slicing



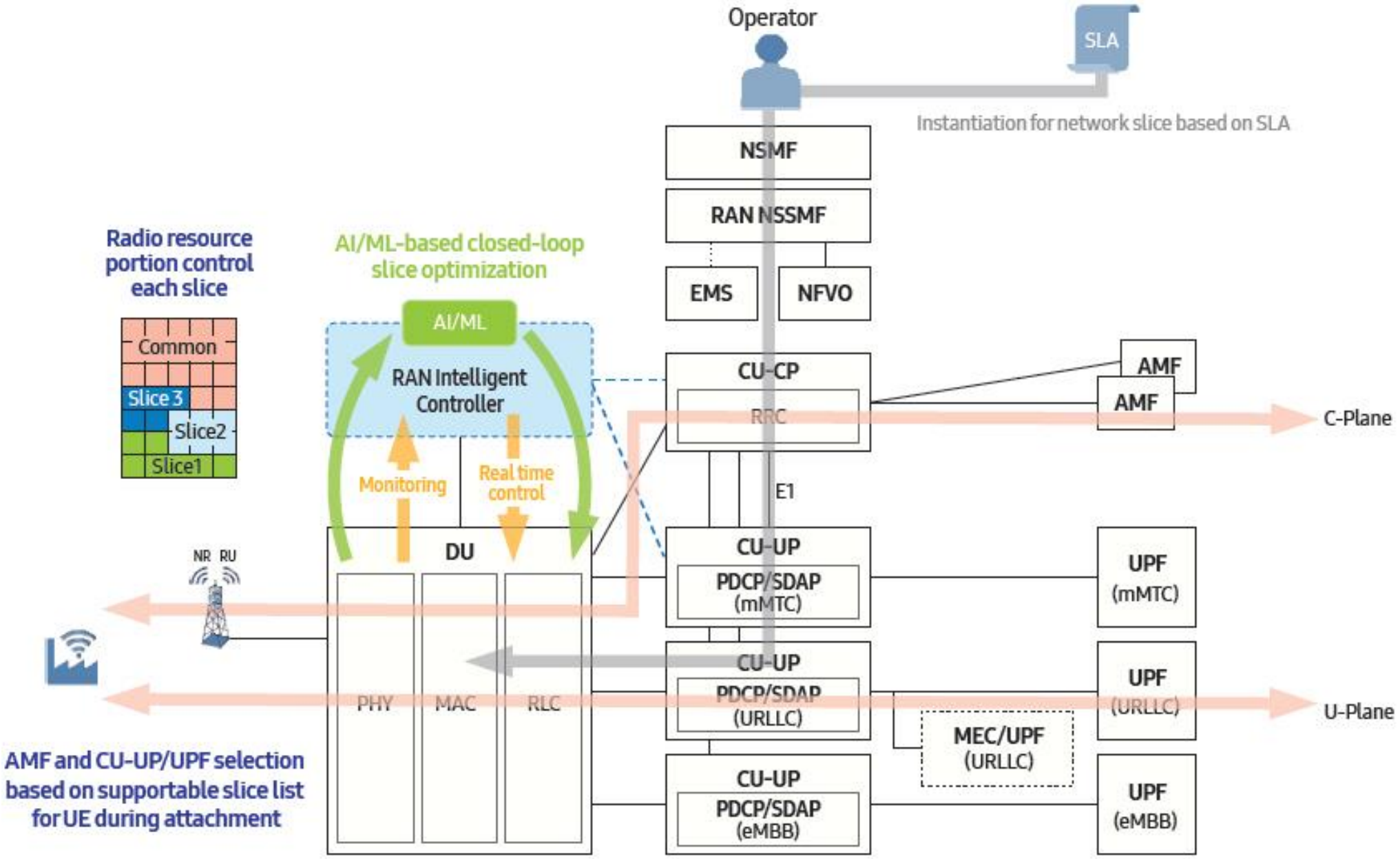




5G Network Slicing

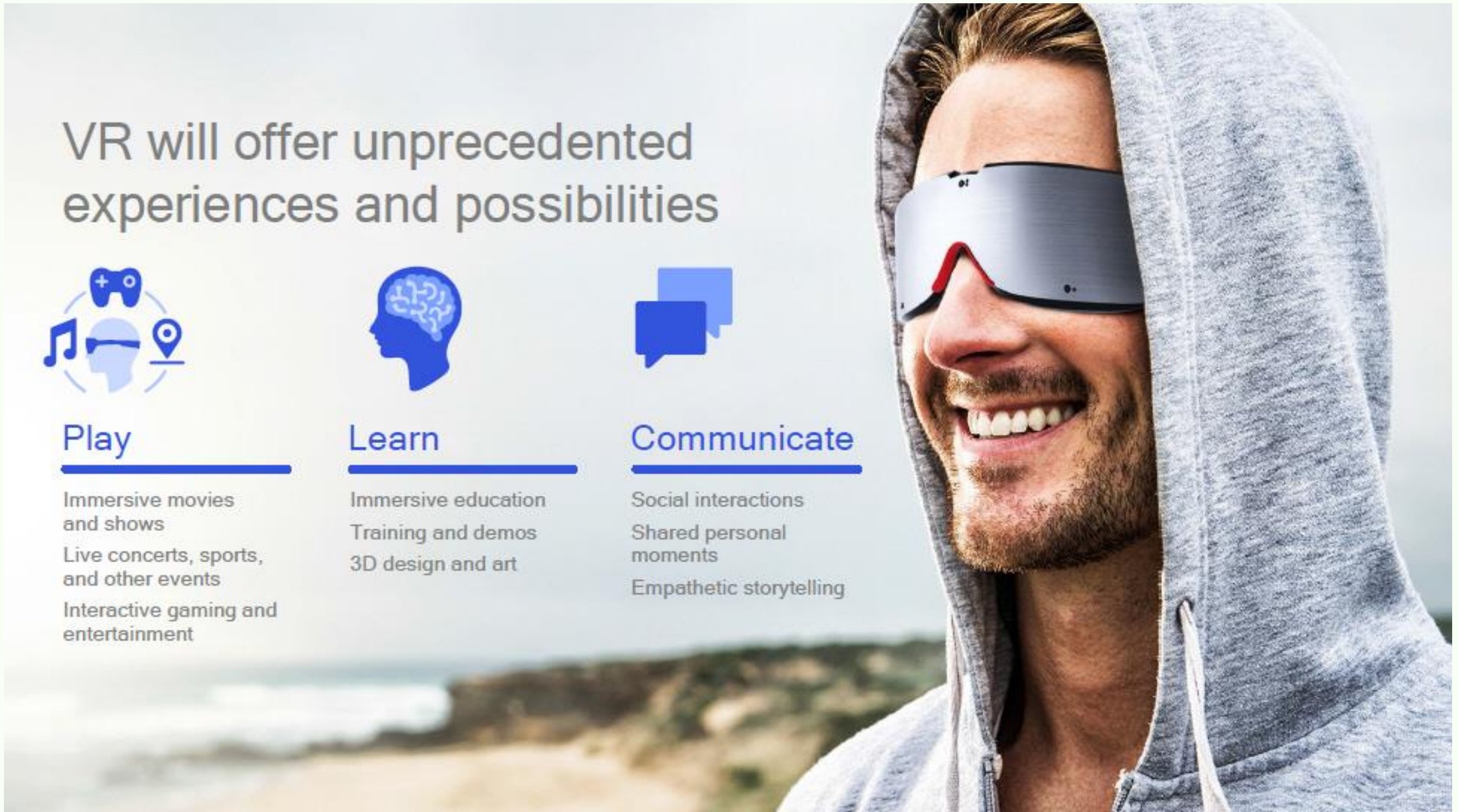


5G Network Slicing




Automotive video streaming
High uniformity
Crowded event sharing
Extreme capacity
5G
Essential for
next-gen AR / VR
experiences
6 DoF immersive content
High throughput, low latency
*6 DoF: Six degrees of freedom
Remote control / Tactile Internet
Low latency

5G & AR / VR


VR will offer unprecedented experiences and possibilities
Play
Immersive movies and shows
Live concerts, sports, and other events
Interactive gaming and entertainment
Learn
Immersive education
Training and demos
3D design and art
Communicate
Social interactions
Shared personal moments
Empathetic storytelling

A glimpse into the future – sleek and stylish XR glasses

How do we get there?

VR and AR will push connectivity requirements

More capacity, lower cost

Increased throughput per user as quality of immersion improves, and more simultaneous usage

Low latency

Reduces throughput requirements, buffering requirements, and lag for interactive content like tactile Internet and 6 DoF*

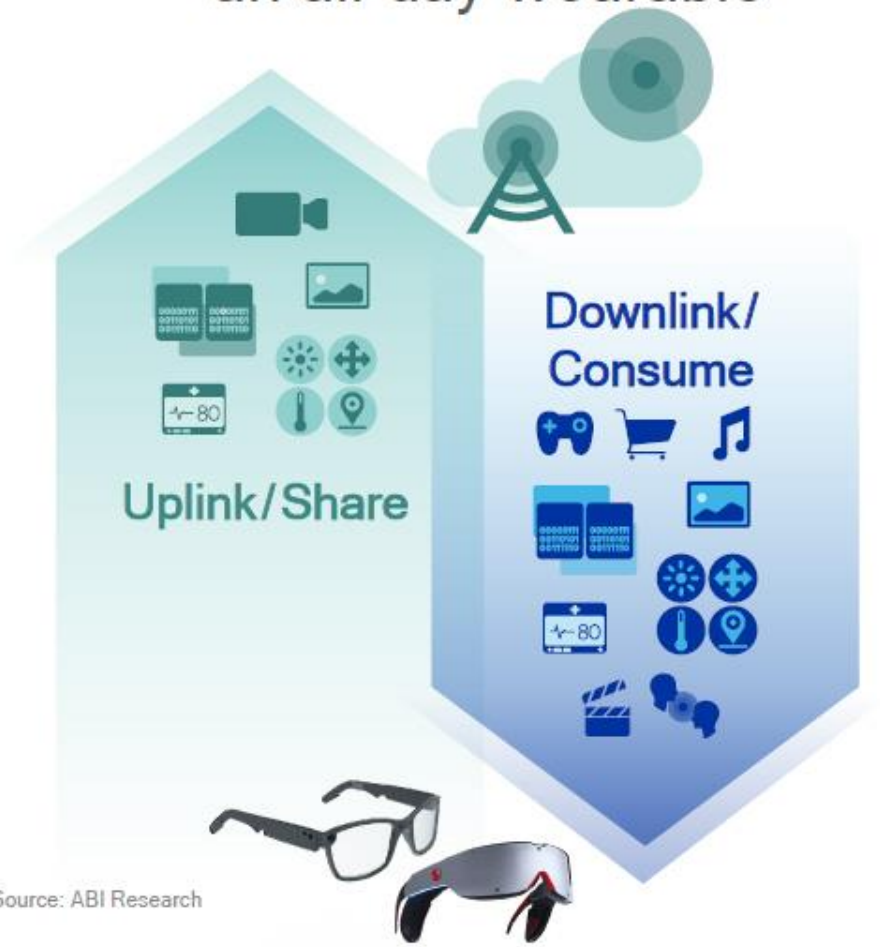
Uniform experience

Full immersion everywhere requires consistent throughput, even at the cell edge

*6 DoF: Six degrees of freedom

VR and AR require efficient increase in wireless capacity

Constant up/download on an all-day wearable



Source: ABI Research

Richer visual content

- Higher resolution, higher frame rate
- Stereoscopic, High Dynamic Range (HDR), 360° spherical content, 6 DoF

2 Mbps
Video conferencing

5 to 25 Mbps
Two-way telepresence

50 to 200 Mbps
Next-gen 360° video (8K, 90+ FPS, HDR, stereoscopic)

Bandwidth

1 Mbps
Image and workflow downloading

2 to 20 Mbps
3D model and data visualization

10 to 50 Mbps
Current-gen 360° video (4K)

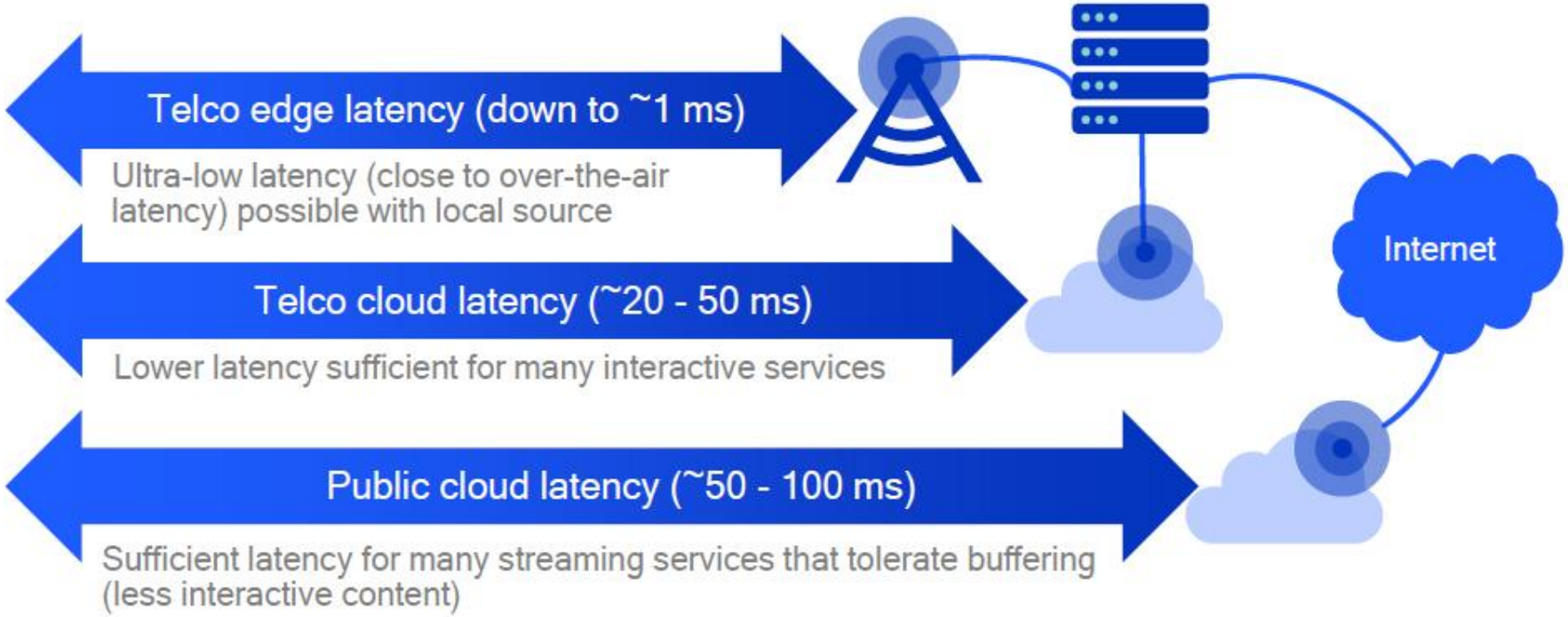
200 to 5000 Mbps
6 DoF video or free-viewpoint

Critical for immersive experiences

Low wireless latency is critical for immersion

The air interface is one component of the overall end-to-end latency

Motion to Photon (MTP) latency below 15 ms generally avoids discomfort – processed on the device[1]



1 Specific use cases, e.g. local edge content, may allow some processing to be intelligently split over the air-interface

5G enhanced mobile broadband

is required to take VR/AR experiences to the next level

Extreme throughput—with Multi-Gbps

Ultra-low latency—down to 1 ms

Uniform experience—even at cell edge

Gigabit LTE

Ubiquitous coverage with Wi-Fi and Gigabit LTE, the anchor of the 5G broadband experience

5G & AR / VR

AR will serve a broad spectrum of roles in daily life

Applicable across ages, genders, and activities

Children Playing

Kids chasing virtual characters in more interactive and immersive games

Young Adults Exploring

A young man exploring Rome and seeing the Colosseum as originally built

Families Communicating

Families virtually brought together with life-like communication

Professionals Working

Architects collaborating on a shared design to improve efficiency

Fitness Enthusiasts Thriving

Group running with a virtual trainer to motivate them

6 DoF* content

Next-gen video for more immersive experiences (move freely around)

Requirements

- Tradeoff between throughput and latency
- 5-20 ms latency requires 400-600 Mbps, while 1-5 ms latency requires 100-200 Mbps

*6 DoF: Six degrees of freedom

Social sharing at crowded venues

Massive simultaneous content upload through social media

12.5
Tbps / km²
upload capacity

Assumptions: 1: 50,000 fans are simultaneously streaming in a 0.1 km² stadium, 2: Each video is 4K 360° video @ 25 Mbps. Minimum 50 Mbps uplink is one of the IMT-2020 requirements, along with 10 Tbps/km² downlink area density (example for uplink)

Remote control and tactile Internet

Reduced latency for better interactivity and expanded use cases

End-to-end latency requirements

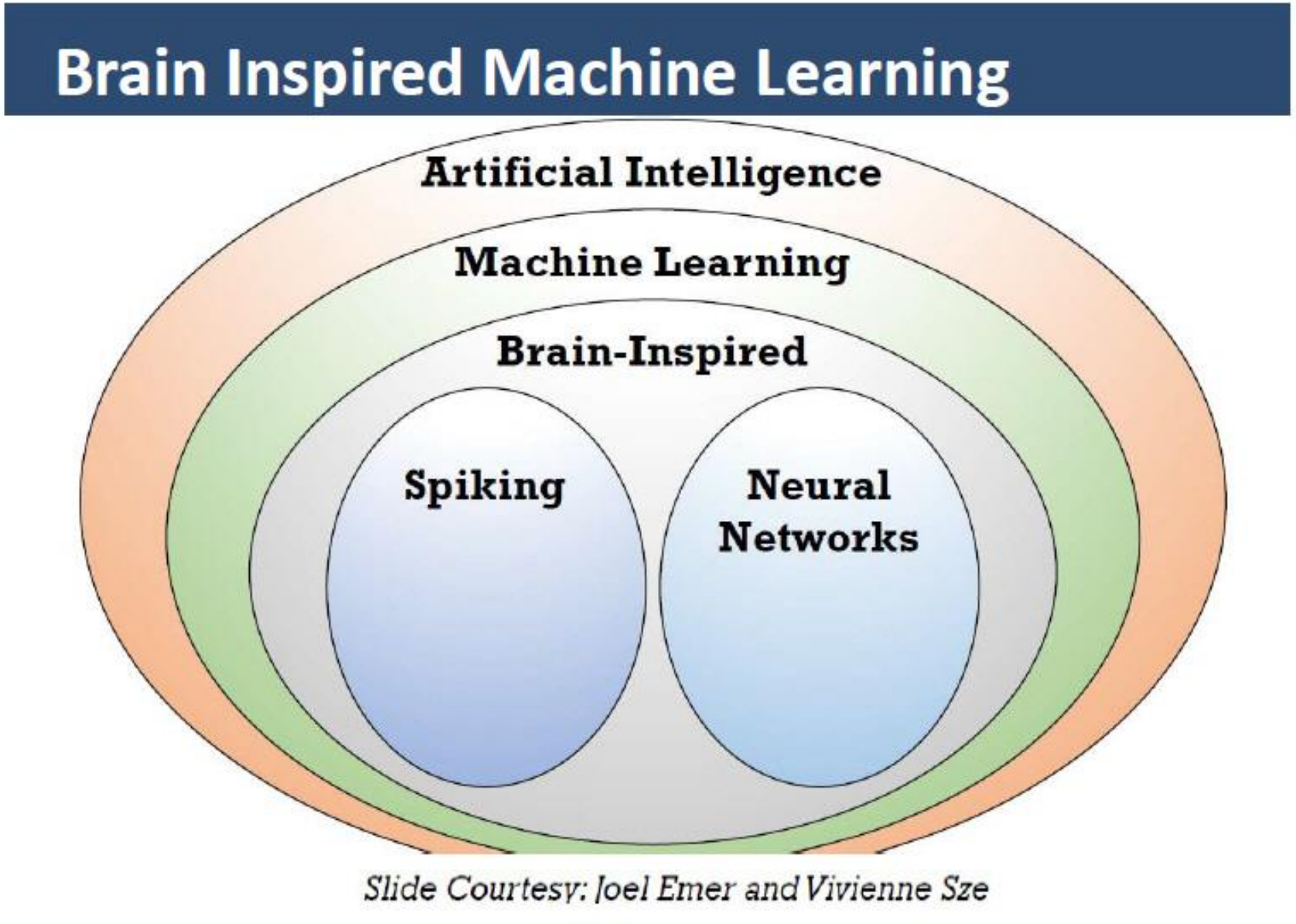
- Interactive remote experiences often ranging from 40 ms to 300 ms (includes transport latency)
- Feedback below 5 ms will enable novel uses of multi-sensory remote tactile control

5G & Artificial Intelligence (AI)

"Machine learning is a field of computer science that gives computers the ability to learn without being explicitly programmed."

Arthur L. Samuel, 1959

5G & Artificial Intelligence (AI)

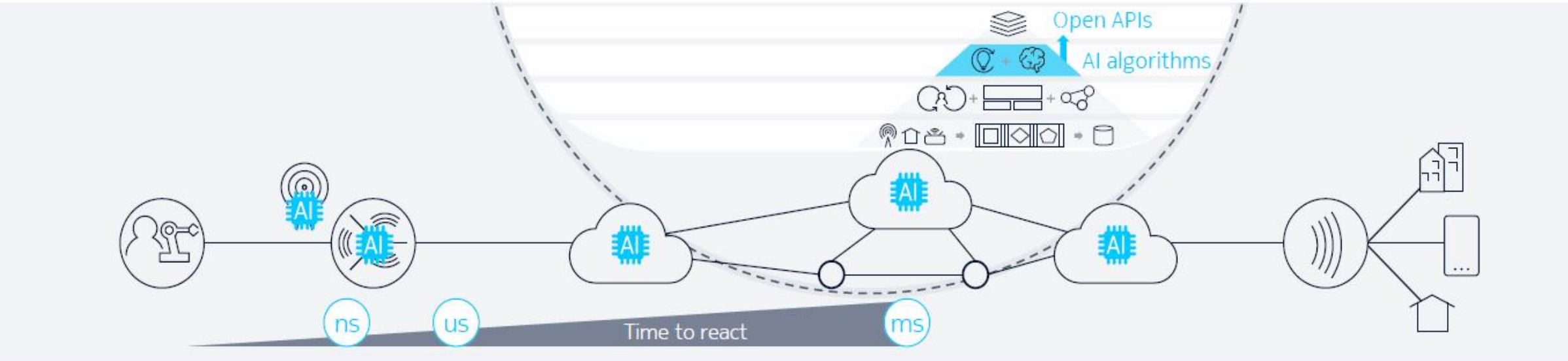


Embedding AI into the Architecture

Powerful

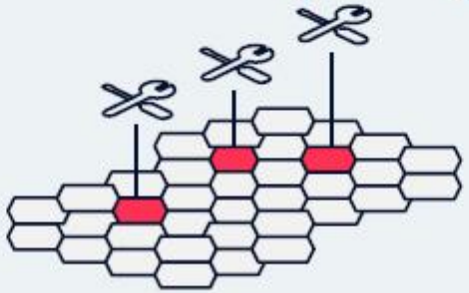
Intelligent

Open



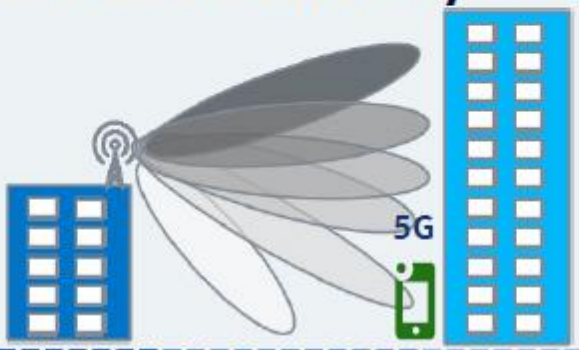
What can AI do for Networks?

Fully automated management of network complexity

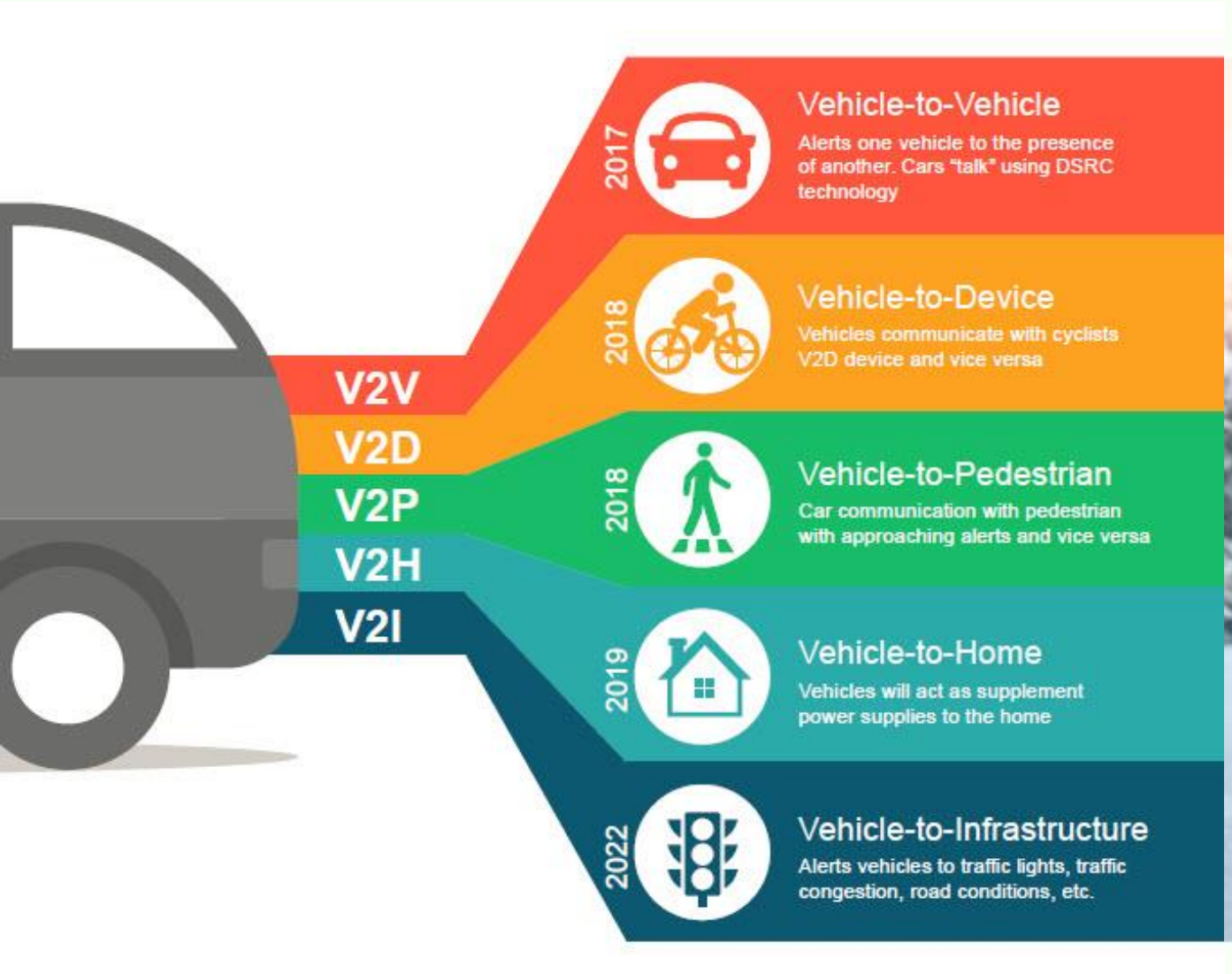


Individual network element optimized to its specific operating environment

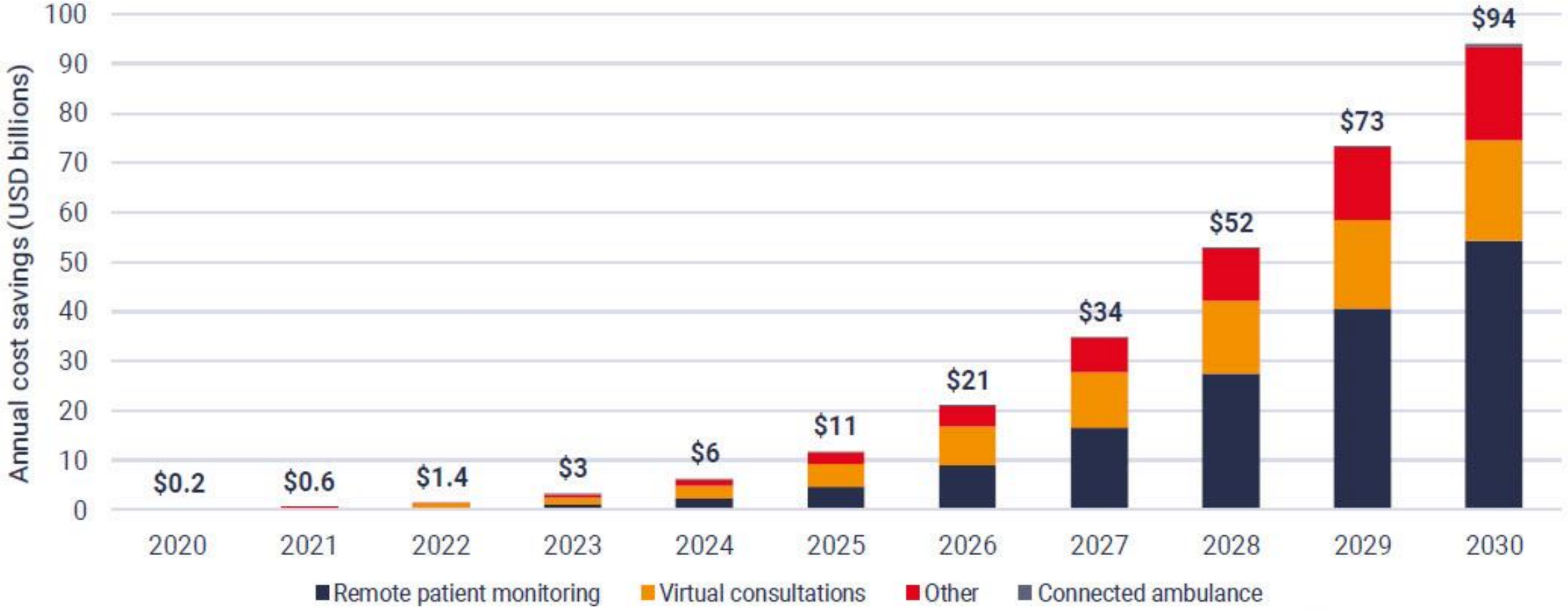
Cover all network technology generations - 2G to 5G and beyond



5G & V2X / Connected Cars



5G & Health



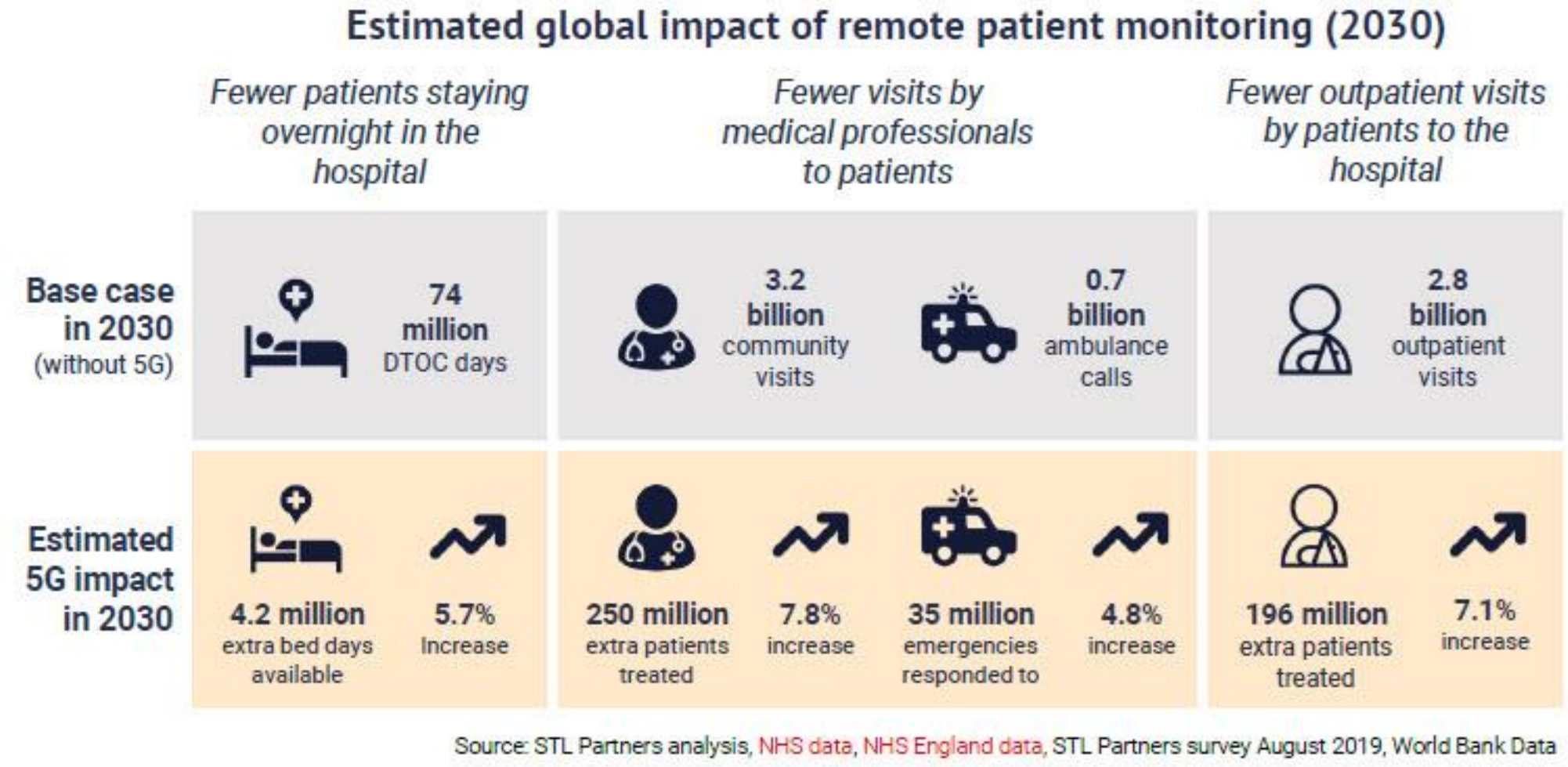
Source: STL Partners analysis

5G & Health

Use case		Benefits	Why 5G?
Advanced predictive maintenance	Using dozens of sensors to give an accurate, real-time representation of the status of a machine to perform predictive and preventative maintenance	Reduce downtime Reduce spend on maintenance Reduce machine replacement rate	Capacity Reliability Device costs
Remote patient monitoring	Real-time streaming, monitoring and analysis of patient data from e-health devices and wearables	Reduce transfer delays Increase hospital throughput Increase emergency turnover	Device density Bandwidth MMTC
Augmented reality	Using augmented reality headsets to train/guide medical professionals, or create an immersive/ purposefully distracting experience for patients	Reduce maintenance resources Reduce spend on training Improve patient experience	Bandwidth Ultra-low latency
HD virtual consultations	HD video streaming between doctor and patient (e.g. for a routine appointment) or primary care and specialist doctor (e.g. for a referral appointment)	Increase patient throughput Reduce cost of appointments Cut "Did not attend" rates	Low-latency Bandwidth Reliability
Connected ambulance	Real-time streaming of patient data/information (sensors + HD video) between ambulances and the hospital	Reduce ambulance handover times Increase emergency department turnover	Ultra-low latency Bandwidth Reliability
Inventory management devices	Using light 5G sim devices (e.g. smart phone) to scan, track and manage inventory stores in hospitals or pharmacies	Reduce inventory costs Increase human productivity	Device costs Capacity

Source: STL Partners

5G & Health


Estimated global impact of remote patient monitoring (2030)
Fewer patients staying overnight in the hospital
Fewer visits by medical professionals to patients
Fewer outpatient visits by patients to the hospital
Base case in 2030 (without 5G)
74 million DTOC days
3.2 billion community visits
0.7 billion ambulance calls
2.8 billion outpatient visits
Estimated 5G impact in 2030
4.2 million extra bed days available
5.7% Increase
250 million extra patients treated
7.8% increase
35 million emergencies responded to
4.8% increase
196 million extra patients treated
7.1% increase
Source: STL Partners analysis, NHS data, NHS England data, STL Partners survey August 2019, World Bank Data

5G & Health

Medical students and patients 'enter' an operating theatre

Neurosurgery taught via Virtual Reality

Report: Mark Nicholls

Virtual Reality (VR) technology is aiding trainee surgeons to practise complex procedures in a simulated setting, rather than learning skills on real patients. VR is also helping to demystify neurosurgery in that it enables medical students and patients to 'enter' and experience a neurosurgical operating theatre. Alex Alamri, a trainee neurosurgeon at Barts Health NHS Trust in London, UK, said hands-on experience of brain surgery in an operating theatre is not always straightforward for medical students. The Barts Health Trust surgeons have been working on the project with Fundamental VR, a London-based firm that has developed a VR system to allow trainees to conduct virtual surgeries. Haptic feedback, which recreates the sense of touch to the user,

undergone neurosurgery to share their experiences to help other patients and their families, as well as healthcare professionals, understand neurosurgical decision-making processes.

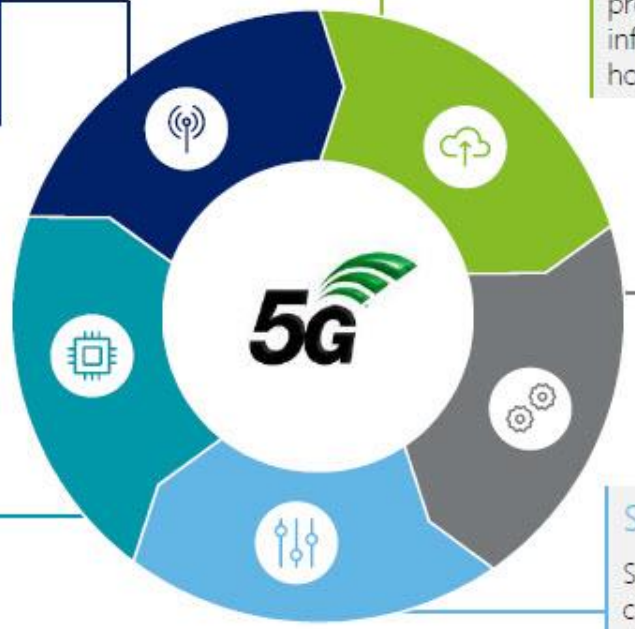
wider public audience.

'We stitched in head mounted GoPro views, so that the public could see exactly what a consultant neurosurgeon sees when they operate,' he

5G technology ecosystem

The 5G technology ecosystem has the potential to accelerate innovation, leverage Open RAN/vRAN and create synergies between the different stakeholders to support several 5G related use cases

5G Technology Ecosystem



Mobile Network Operators

MNOs are providers of connectivity and are expected to focus beyond that, 5G value chain, leading to the creation of new business models and innovation

Hyperscalers

Hyperscalers are companies, typically platform and cloud providers, that have an infrastructure designed for horizontal scalability

Systems Integrators

System integrators are companies specialized in the process of integrating the physical and virtual elements that compose 5G networks

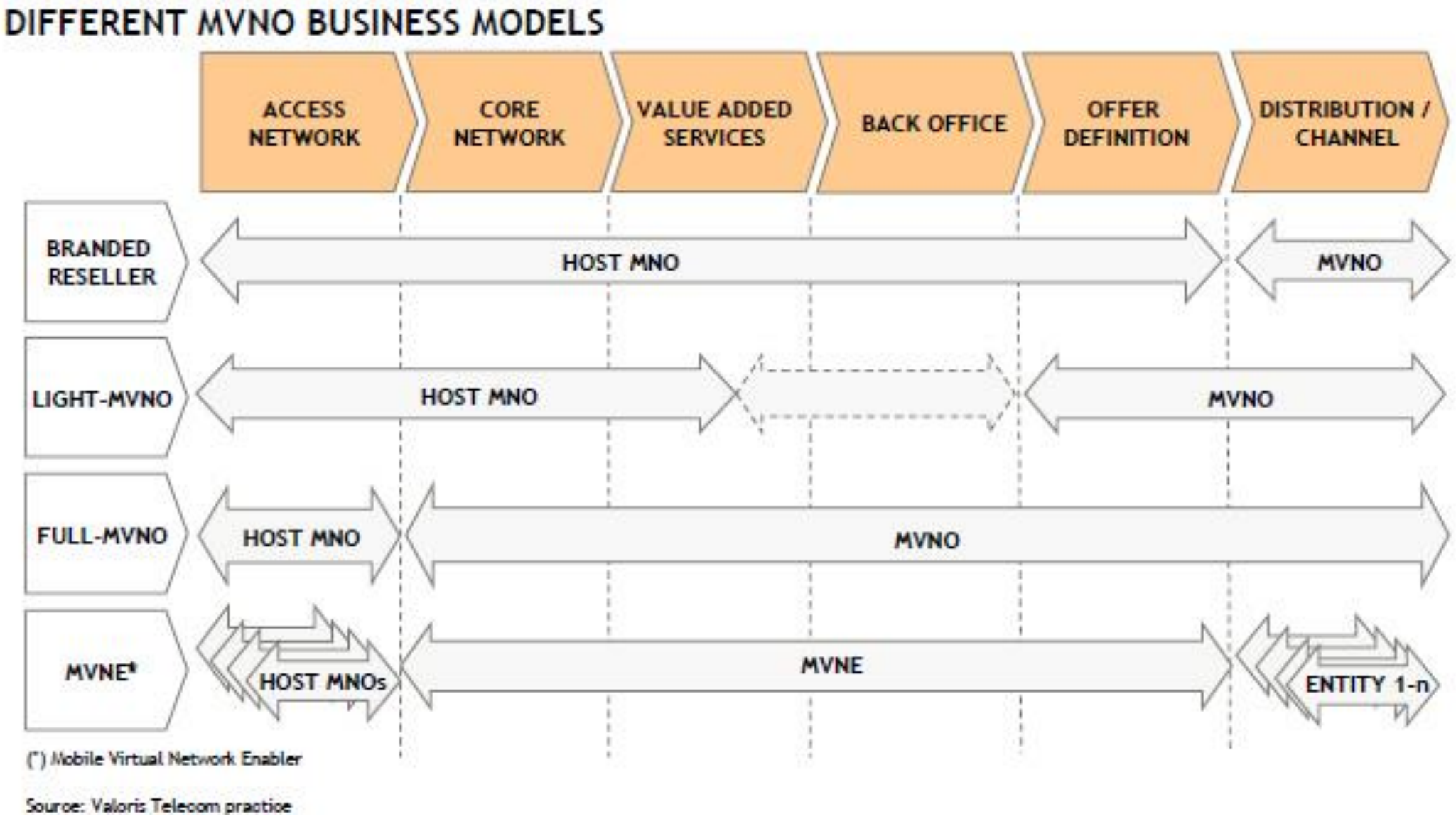
Equipment Manufacturers

Equipment manufacturers include all the hardware providers, from network equipment (e.g. radio units) to the end devices (e.g. smartphones)

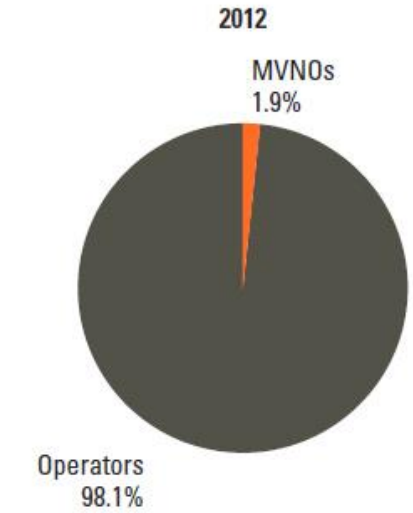
Software Vendors

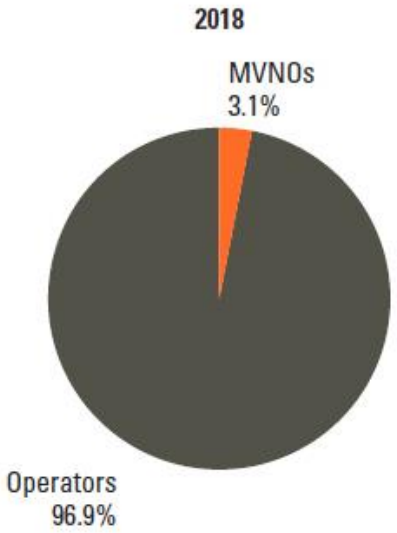
Software vendors are the companies responsible for developing, for instance, vRAN software and the virtualization platforms

MVNOs role in 5G Market



MVNOs role in Telecom Market

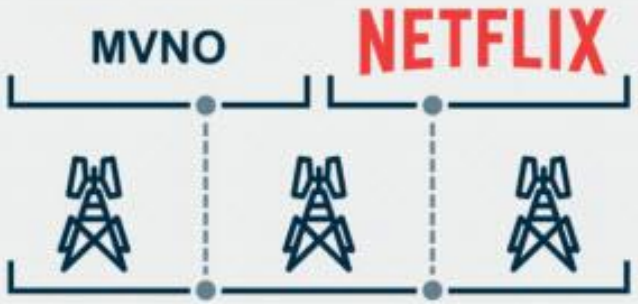




MVNOs role in 5G Market

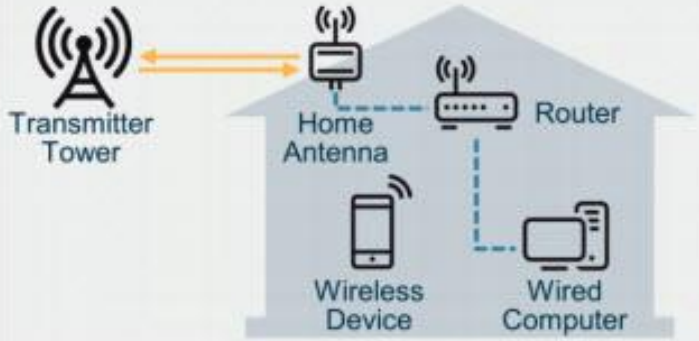
Connectivity Boost for B2C

5G Infrastructure-as-a-Service



Connected Car

Fixed-wireless Access

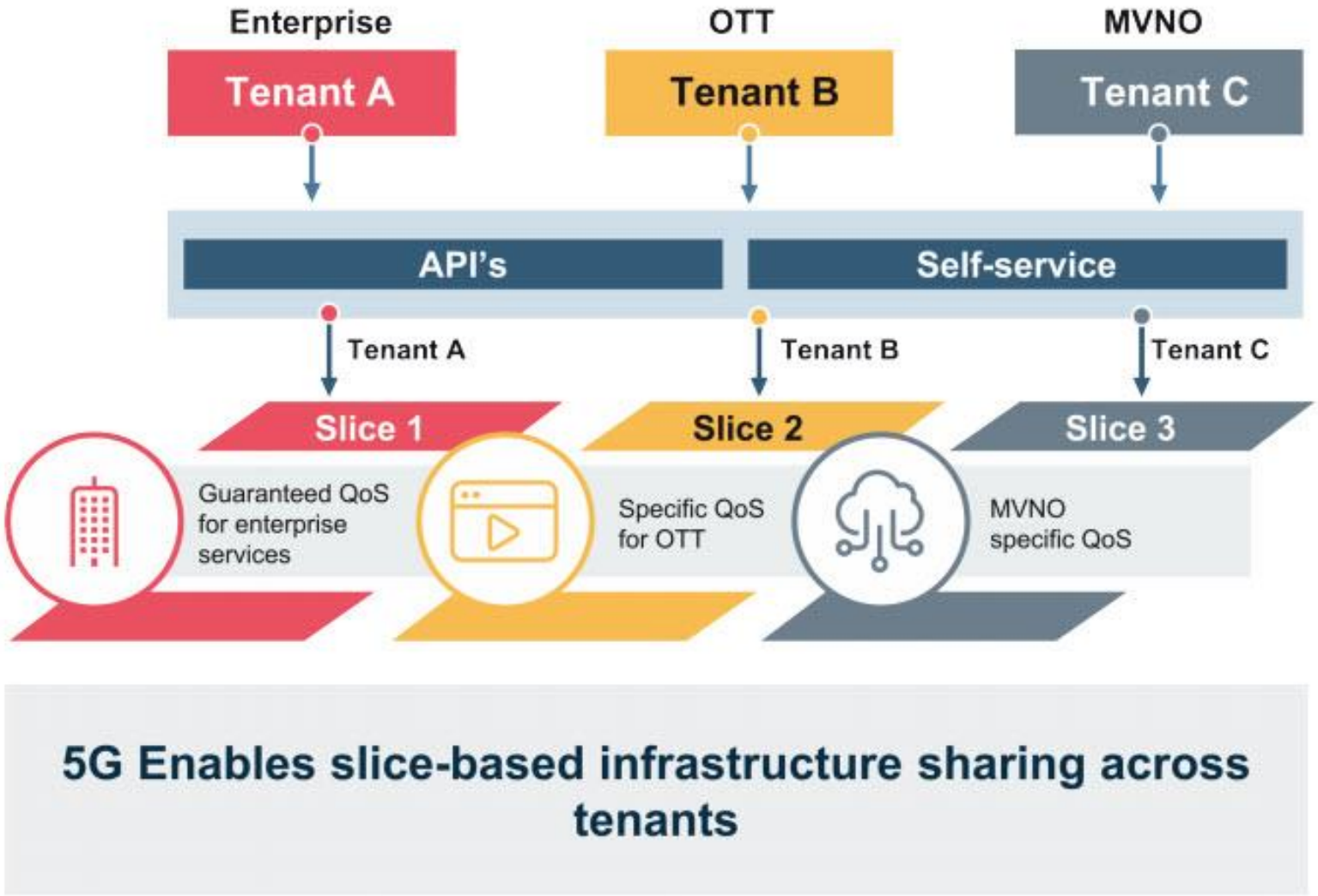


Fixed-like Enterprise Services

Industry 4.0

Source: Inform 2018

MVNOs role in 5G Market



Source: digital tmforum

Thanks!

Hamid Reza Bolhasani
Hamidreza@Bolhasani.net

Dec 2020