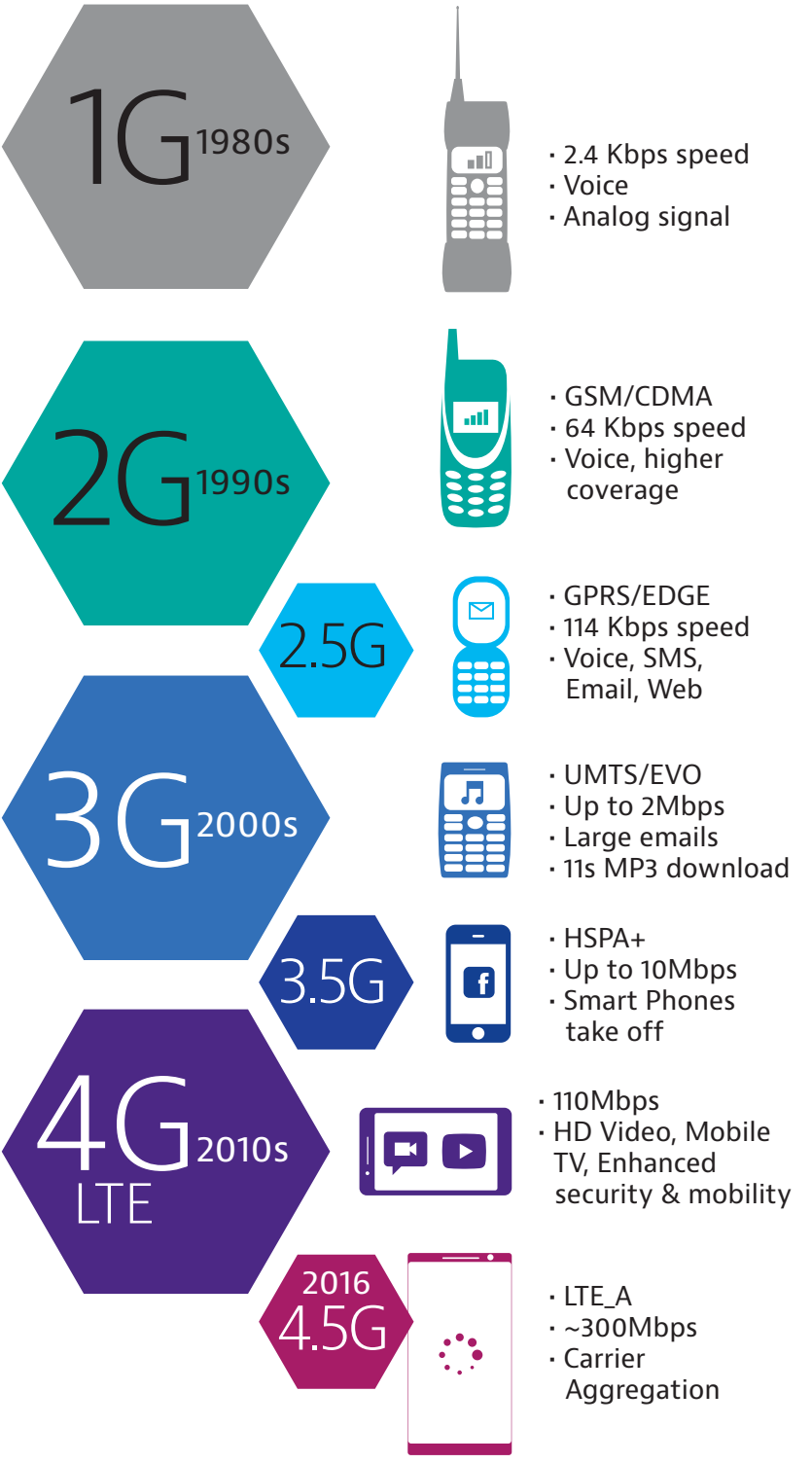
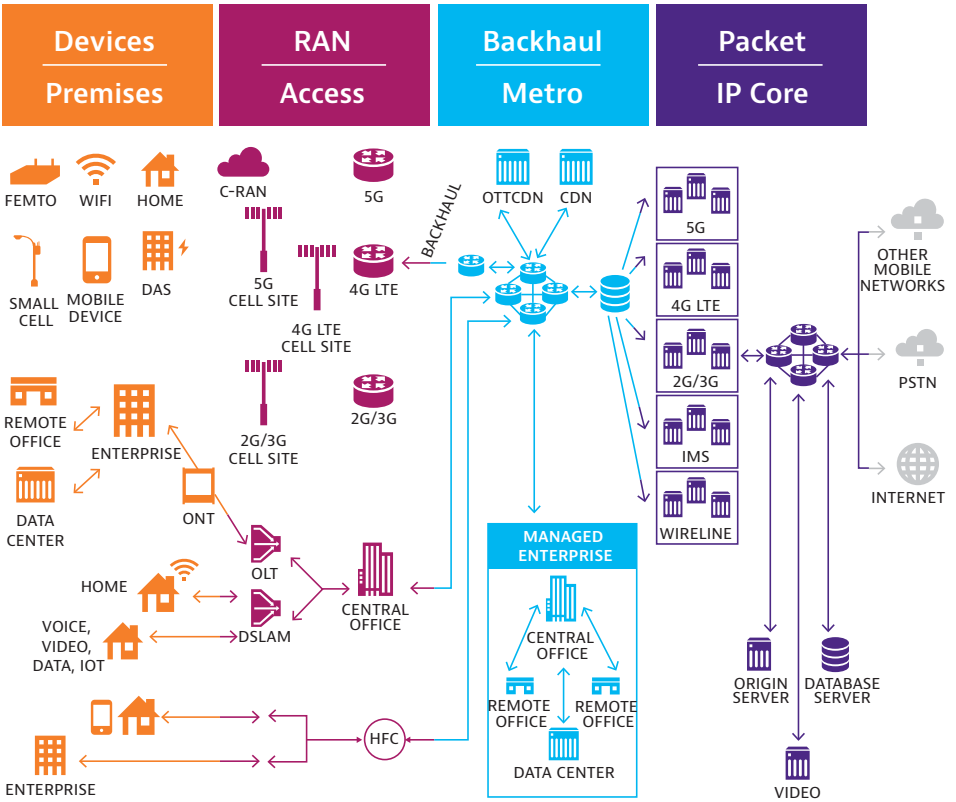
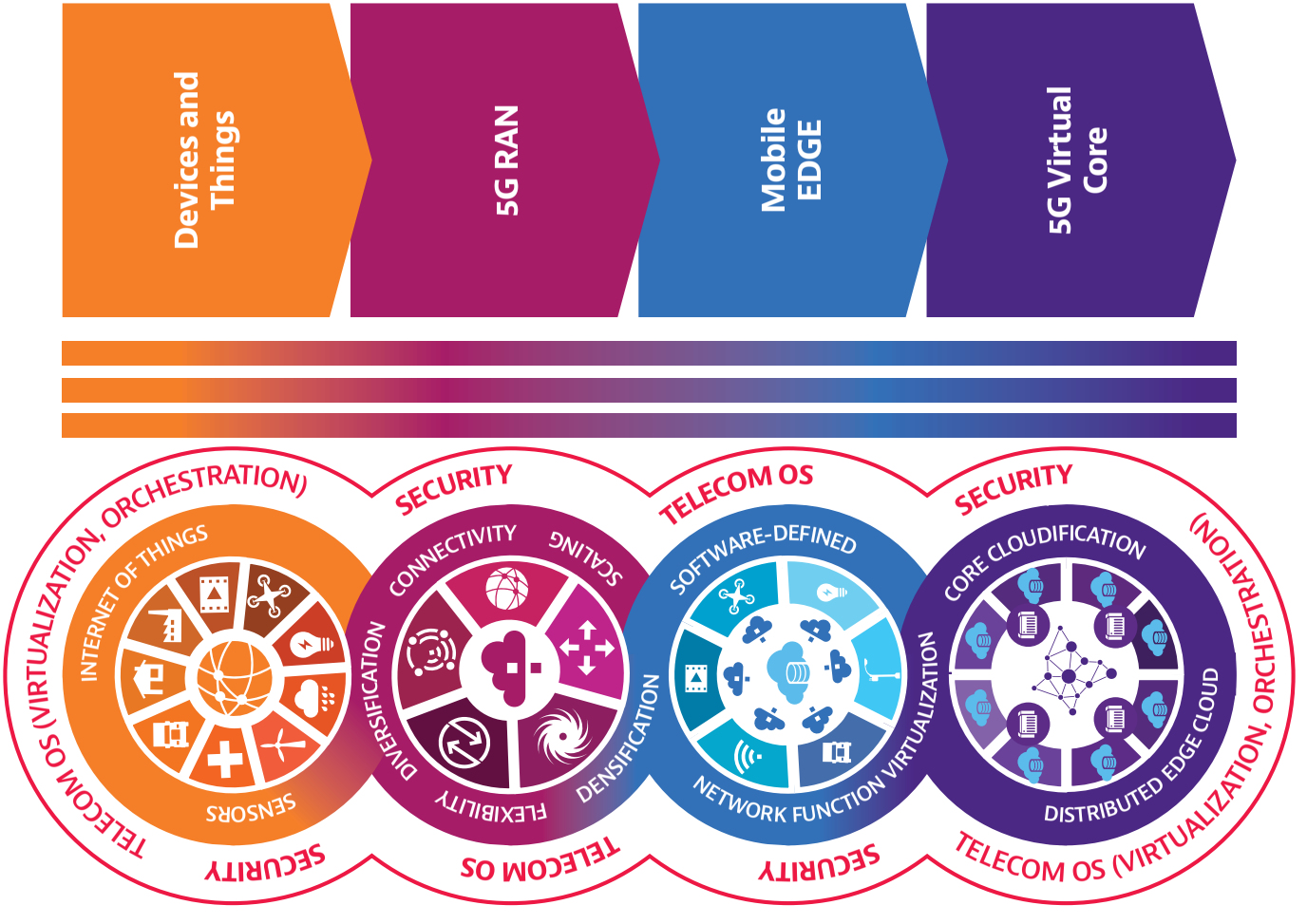
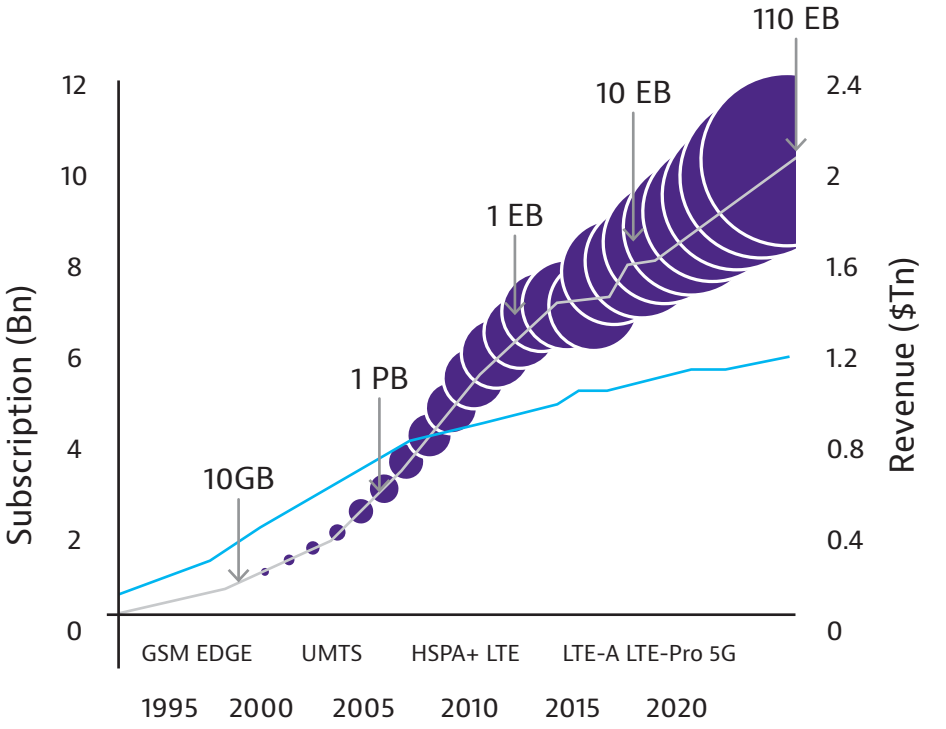
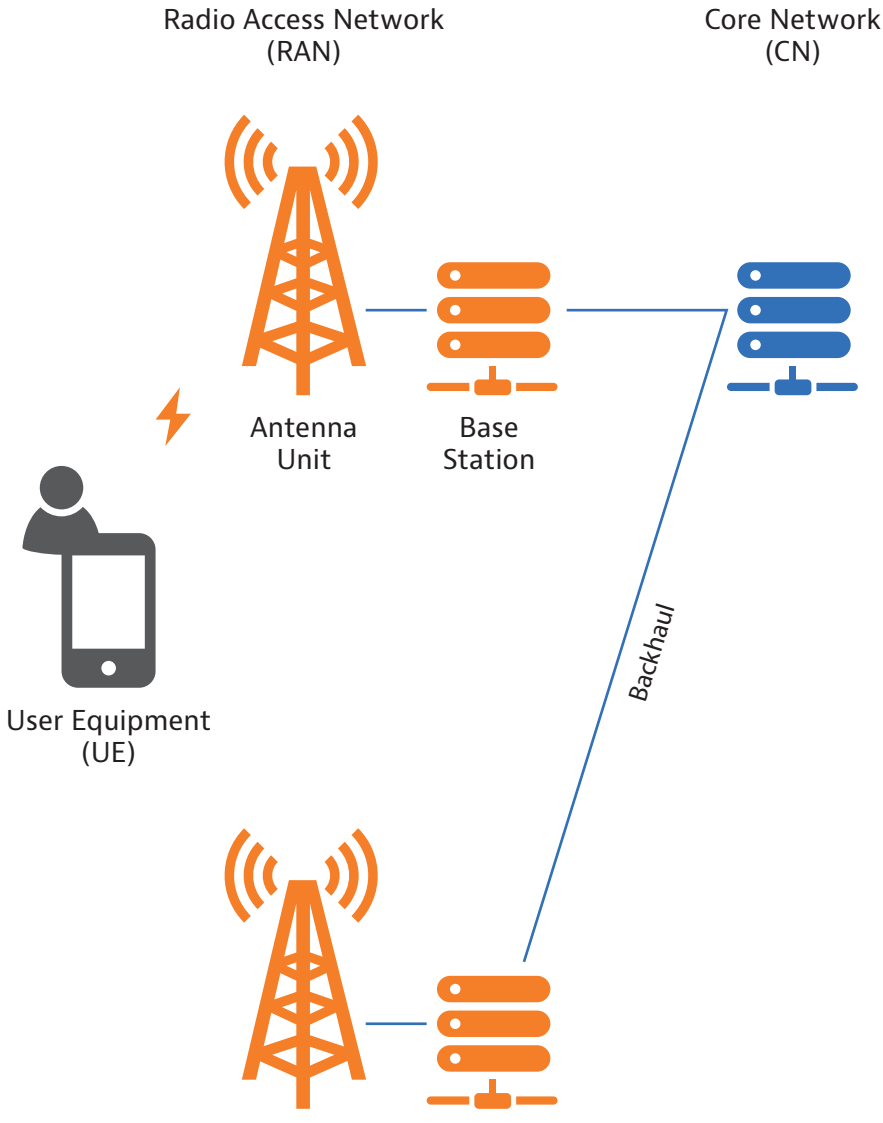

1G 1980s
· 2.4 Kbps speed
· Voice
· Analog signal
2G 1990s
· GSM/CDMA
· 64 Kbps speed
· Voice, higher coverage
2.5G
· GPRS/EDGE
· 114 Kbps speed
· Voice, SMS, Email, Web
3G 2000s
· UMTS/EVO
· Up to 2Mbps
· Large emails
· 11s MP3 download
3.5G
· HSPA+
· Up to 10Mbps
· Smart Phones take off
4G 2010s LTE
· 110Mbps
· HD Video, Mobile TV, Enhanced security & mobility
2016 4.5G
· LTE_A
· ~300Mbps
· Carrier Aggregation

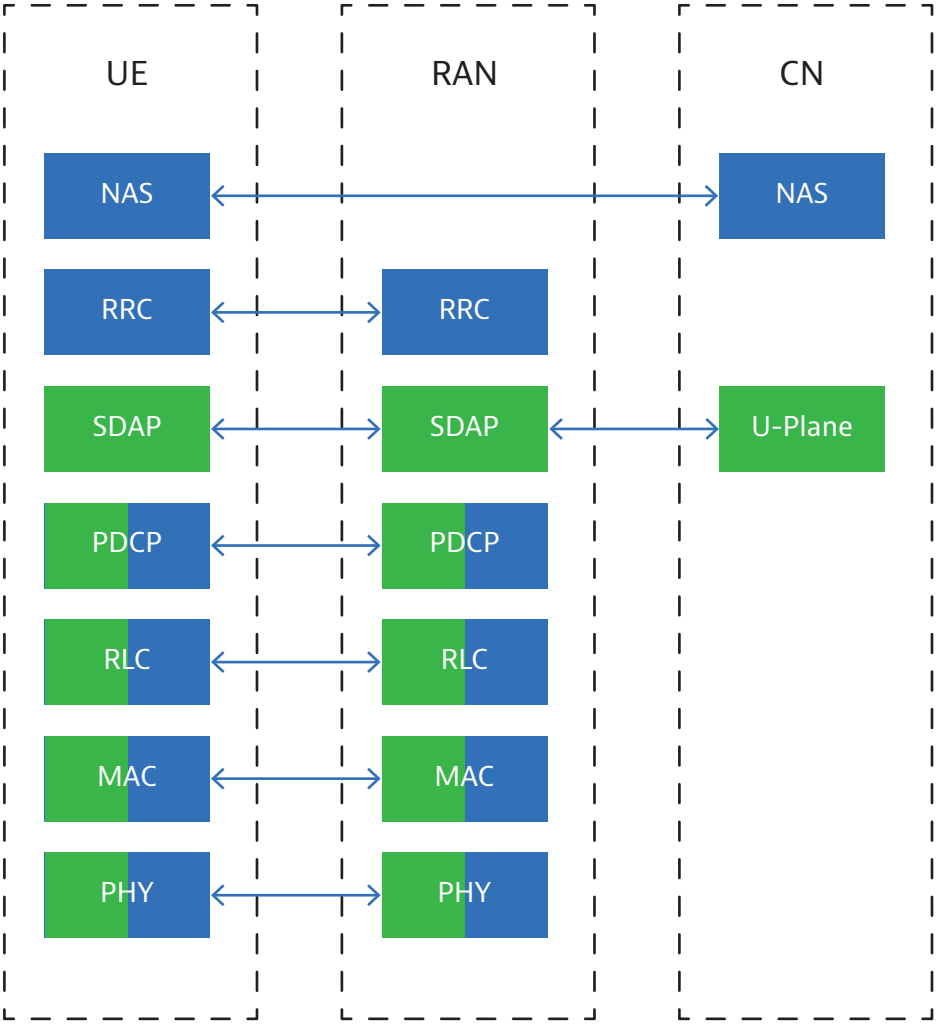

Devices
Premises
RAN
Access
Backhaul
Metro
Packet
IP Core
FEMTO
WIFI
HOME
SMALL CELL
MOBILE DEVICE
DAS
C-RAN
5G CELL SITE
4G LTE CELL SITE
2G/3G CELL SITE
5G
4G LTE
2G/3G
BACKHAUL
OTTCDN
CDN
5G
4G LTE
2G/3G
IMS
WIRELINE
OTHER MOBILE NETWORKS
PSTN
INTERNET
REMOTE OFFICE
ENTERPRISE
DATA CENTER
ONT
OLT
DSLAM
HOME
VOICE, VIDEO, DATA, IOT
CENTRAL OFFICE
MANAGED ENTERPRISE
CENTRAL OFFICE
REMOTE OFFICE
REMOTE OFFICE
DATA CENTER
HFC
ENTERPRISE
ORIGIN SERVER
DATABASE SERVER
VIDEO

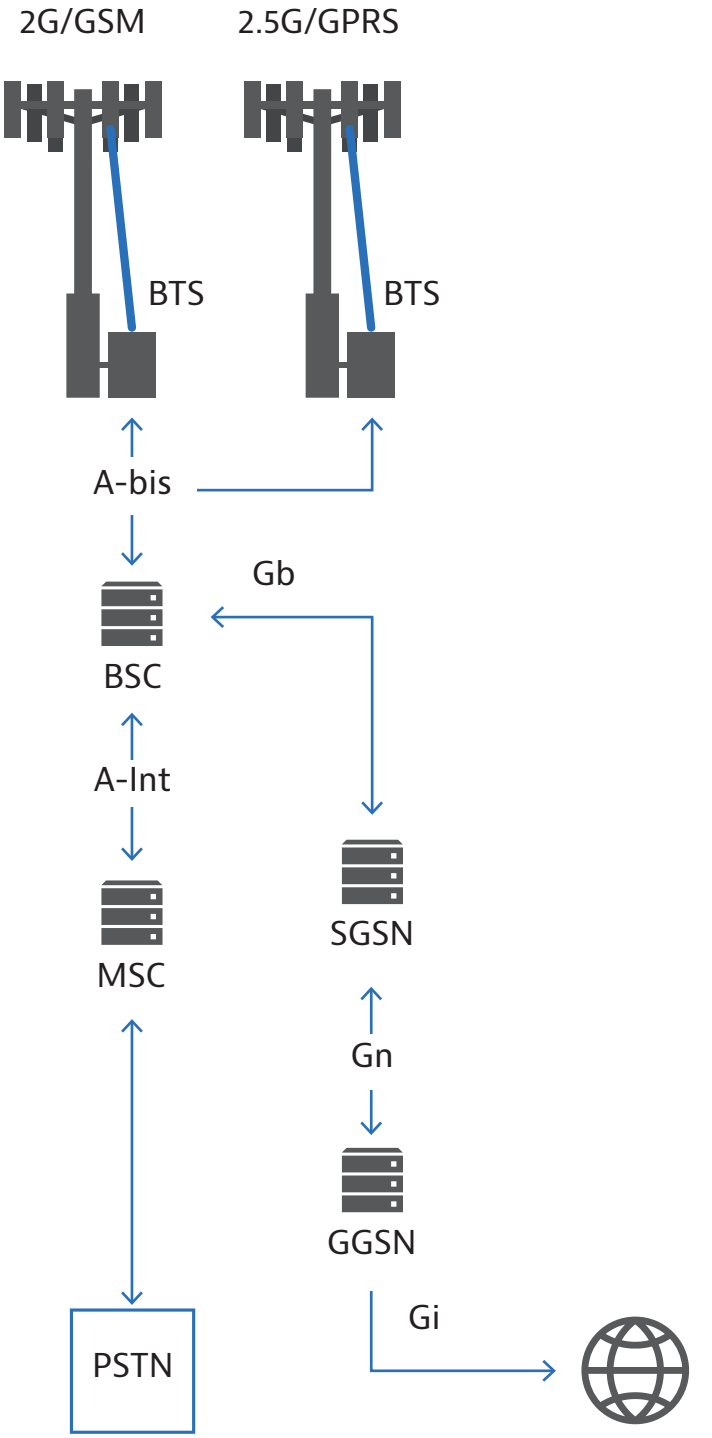

Devices and Things
5G RAN
Mobile EDGE
5G Virtual Core
INTERNET OF THINGS
SENSORS
TELECOM OS (VIRTUALIZATION, ORCHESTRATION)
SECURITY
CONNECTIVITY
SCALING
DIVERSIFICATION
FLEXIBILITY
DENSIFICATION
SECURITY
TELECOM OS
SOFTWARE-DEFINED
NETWORK FUNCTION VIRTUALIZATION
SECURITY
TELECOM OS
CORE CLOUDIFICATION
DISTRIBUTED EDGE CLOUD
SECURITY
TELECOM OS (VIRTUALIZATION, ORCHESTRATION)

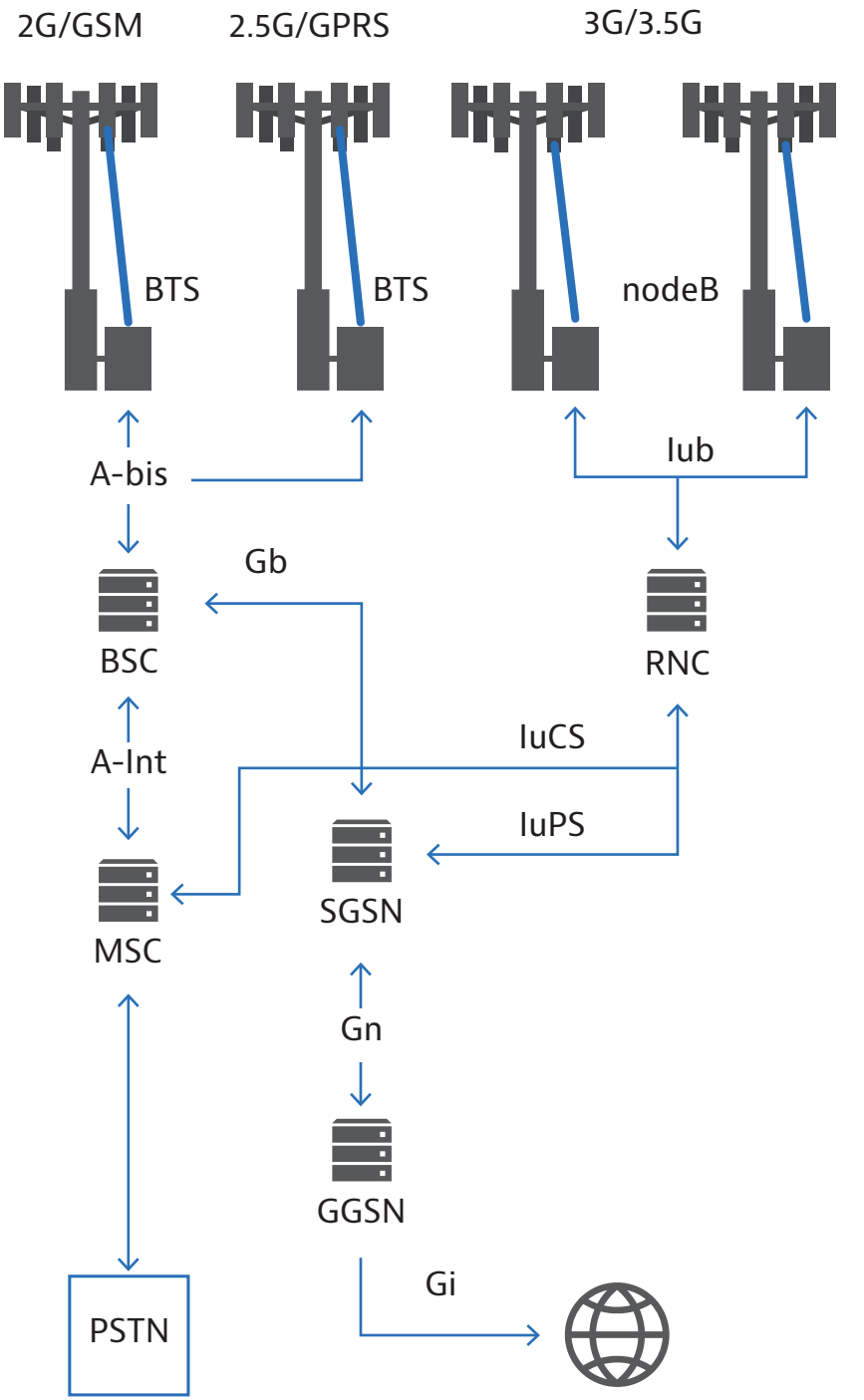
Global Mobile Radio Subscription, Data, & Revenue Growth

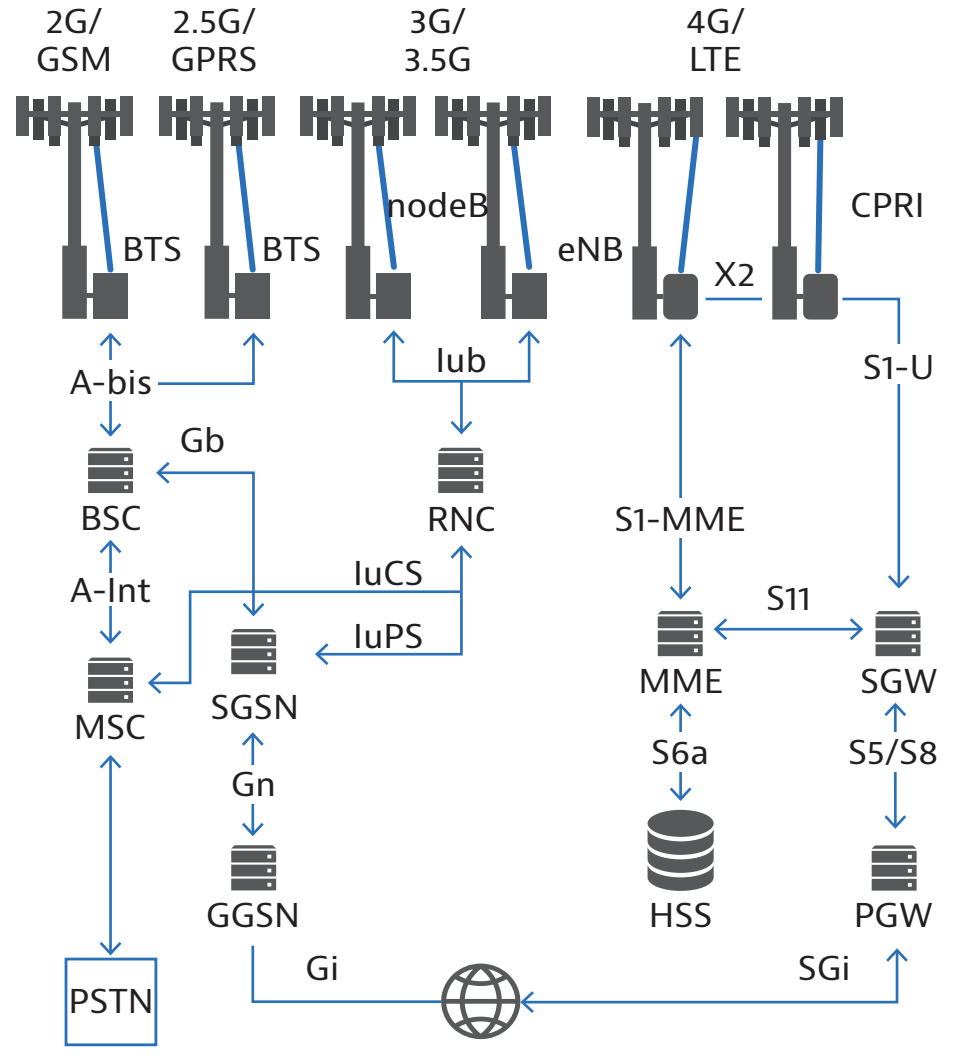


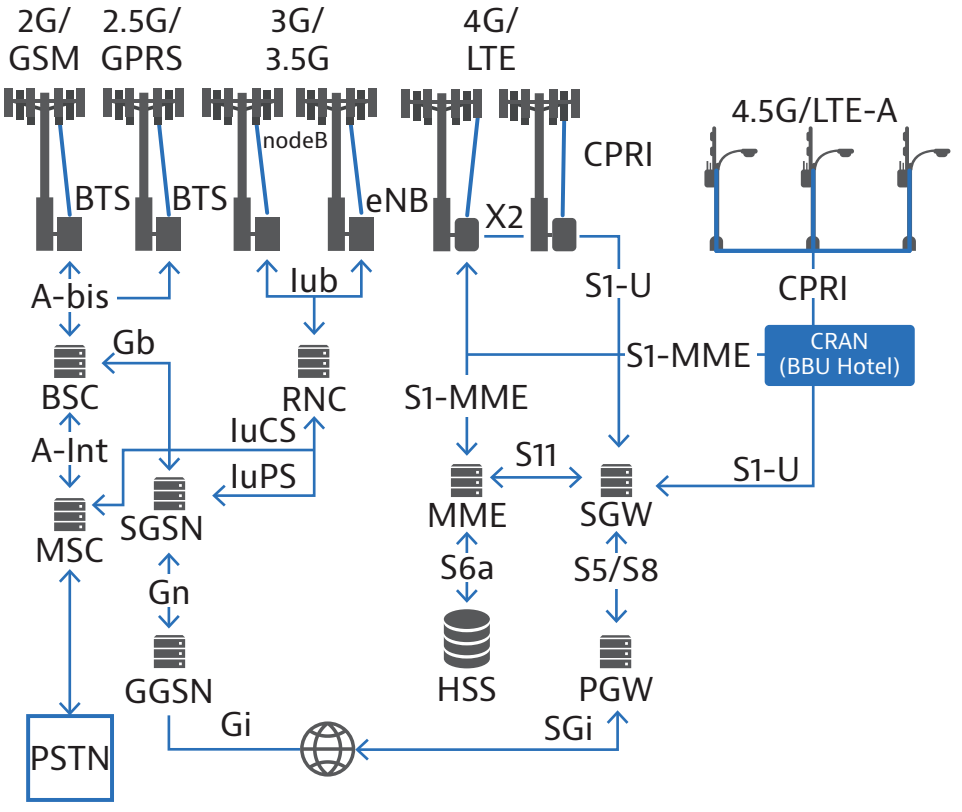

Radio Access Network
(RAN)
Core Network
(CN)
Antenna
Unit
Base
Station
Backhaul
User Equipment
(UE)


UE
RAN
CN
NAS
NAS
RRC
RRC
SDAP
SDAP
U-Plane
PDCP
PDCP
RLC
RLC
MAC
MAC
PHY
PHY

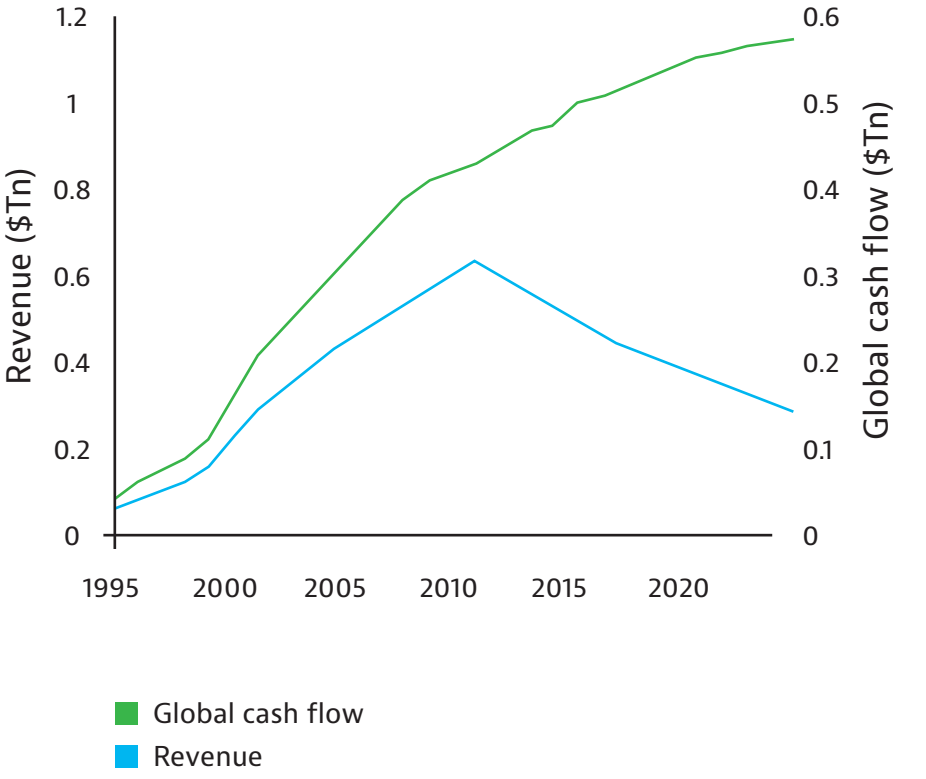

2G/GSM
2.5G/GPRS
BTS
BTS
A-bis
Gb
BSC
A-Int
MSC
SGSN
Gn
GGSN
Gi
PSTN

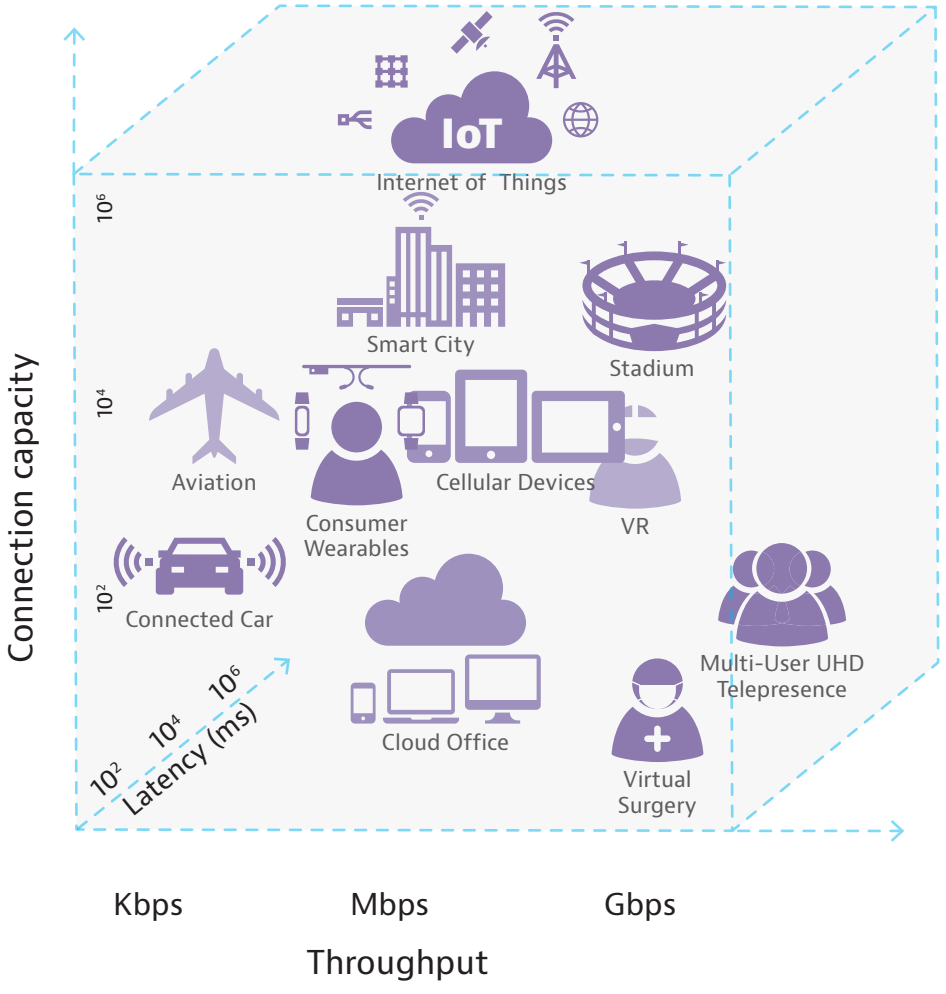

2G/GSM
2.5G/GPRS
3G/3.5G
BTS
BTS
nodeB
A-bis
Iub
Gb
BSC
RNC
A-Int
IuCS
IuPS
SGSN
MSC
Gn
GGSN
PSTN
Gi

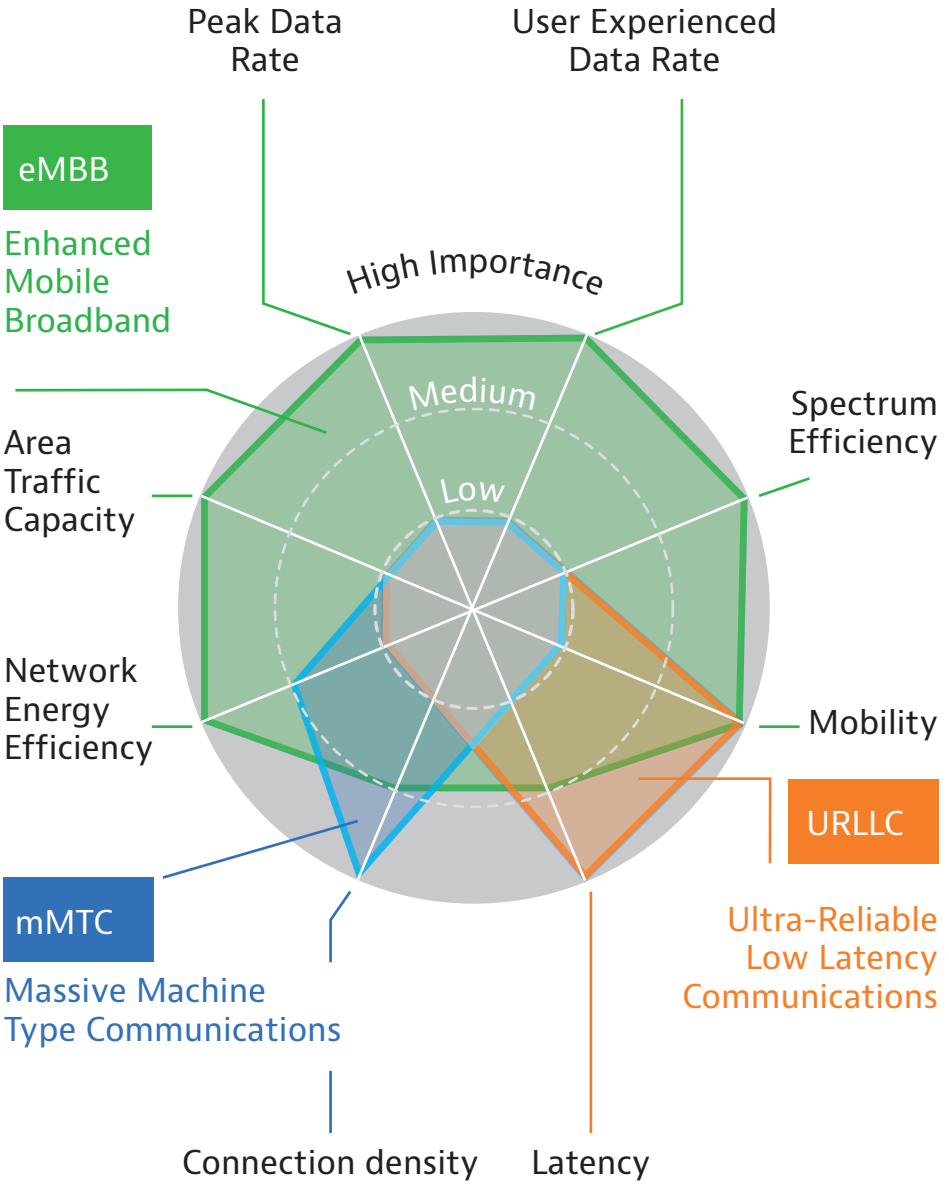

2G/
GSM
2.5G/
GPRS
3G/
3.5G
4G/
LTE
BTS
BTS
nodeB
eNB
X2
CPRI
A-bis
Iub
S1-U
Gb
BSC
RNC
S1-MME
A-Int
IuCS
IuPS
S11
MME
SGW
SGSN
MSC
S6a
S5/S8
Gn
HSS
PGW
GGSN
Gi
SGi
PSTN

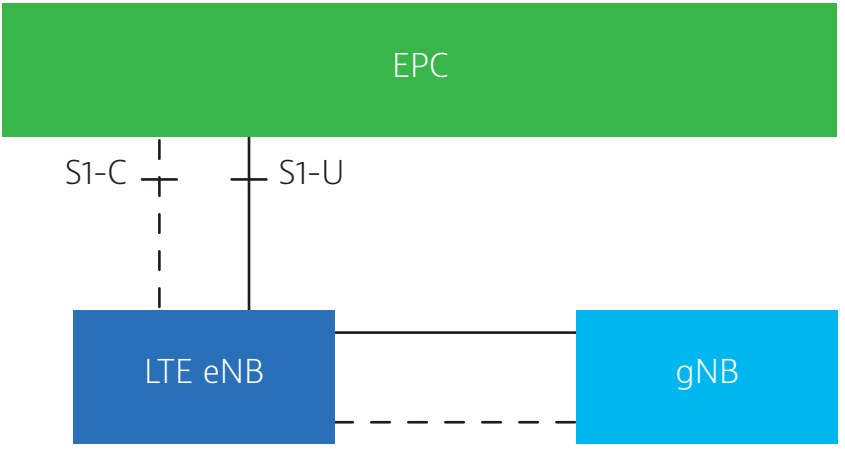

2G/
GSM
2.5G/
GPRS
3G/
3.5G
4G/
LTE
4.5G/LTE-A
nodeB
CPRI
BTS
BTS
eNB
X2
A-bis
Iub
S1-U
CPRI
Gb
S1-MME
CRAN
(BBU Hotel)
BSC
RNC
S1-MME
IuCS
A-Int
S11
S1-U
IuPS
MME
SGW
MSC
SGSN
S6a
S5/S8
Gn
HSS
PGW
GGSN
Gi
SGi
PSTN

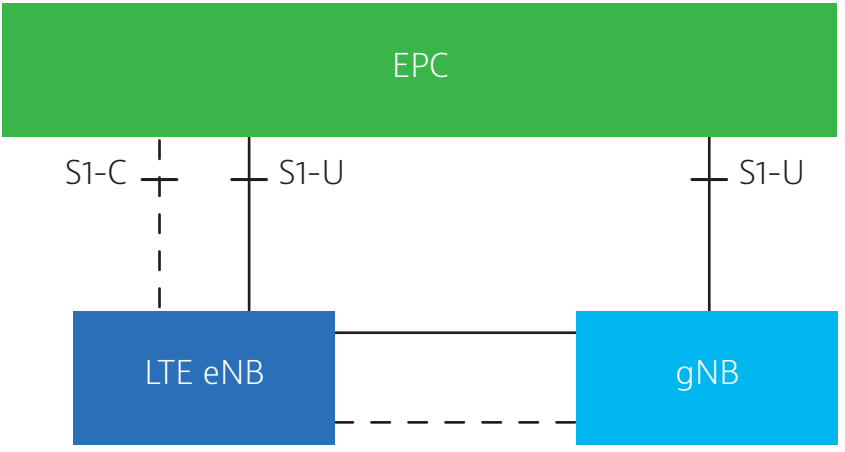
Key economic idicators

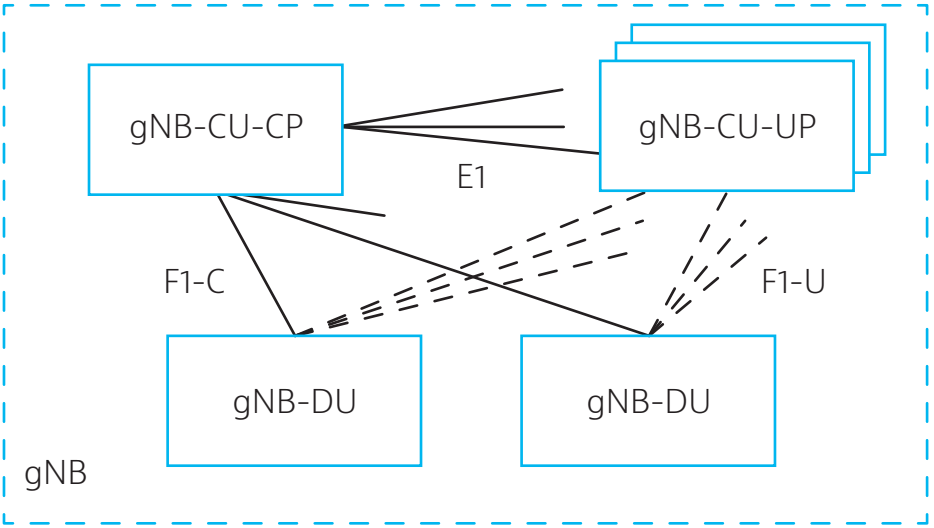


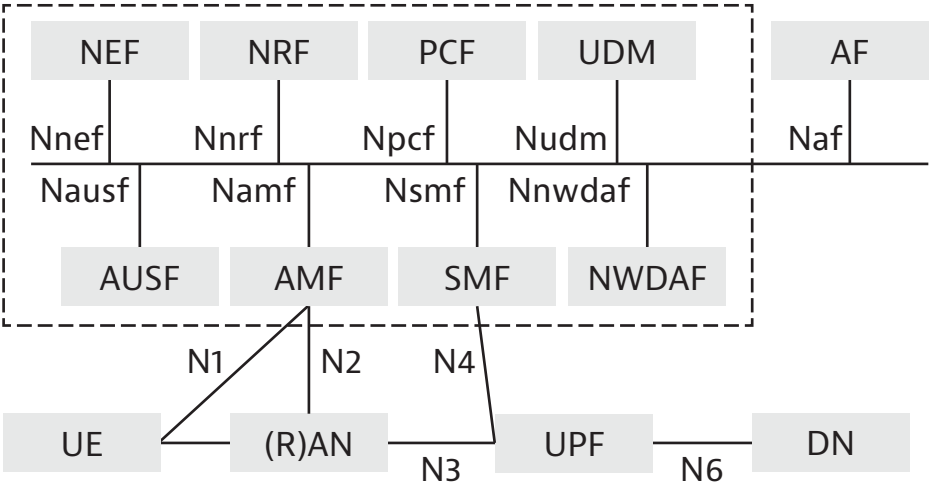

IoT
Internet of Things
Smart City
Stadium
Aviation
Consumer Wearables
Cellular Devices
VR
Connected Car
Cloud Office
Multi-User UHD Telepresence
Virtual Surgery
Connection capacity
10^6
10^4
10^2
10^2 10^4 10^6 Latency (ms)
Kbps
Mbps
Gbps
Throughput


Peak Data Rate
User Experienced Data Rate
eMBB
Enhanced Mobile Broadband
High Importance
Medium
Low
Area Traffic Capacity
Spectrum Efficiency
Network Energy Efficiency
Mobility
URLLC
Ultra-Reliable Low Latency Communications
mMTC
Massive Machine Type Communications
Connection density
Latency


EPC
S1-C
S1-U
LTE eNB
gNB


EPC
S1-C
S1-U
S1-U
LTE eNB
gNB


gNB-CU-CP
gNB-CU-UP
E1
F1-C
F1-U
gNB-DU
gNB-DU
gNB



NEF
Network Exposure Function

NRF
Network Repository Function

PCF
Policy Control Function

UDM
Unified Data Management

AF
Application Function

AUSF
Authentication Server Function

AMF
Access & Mobility Management Function

SMF
Session Management Function

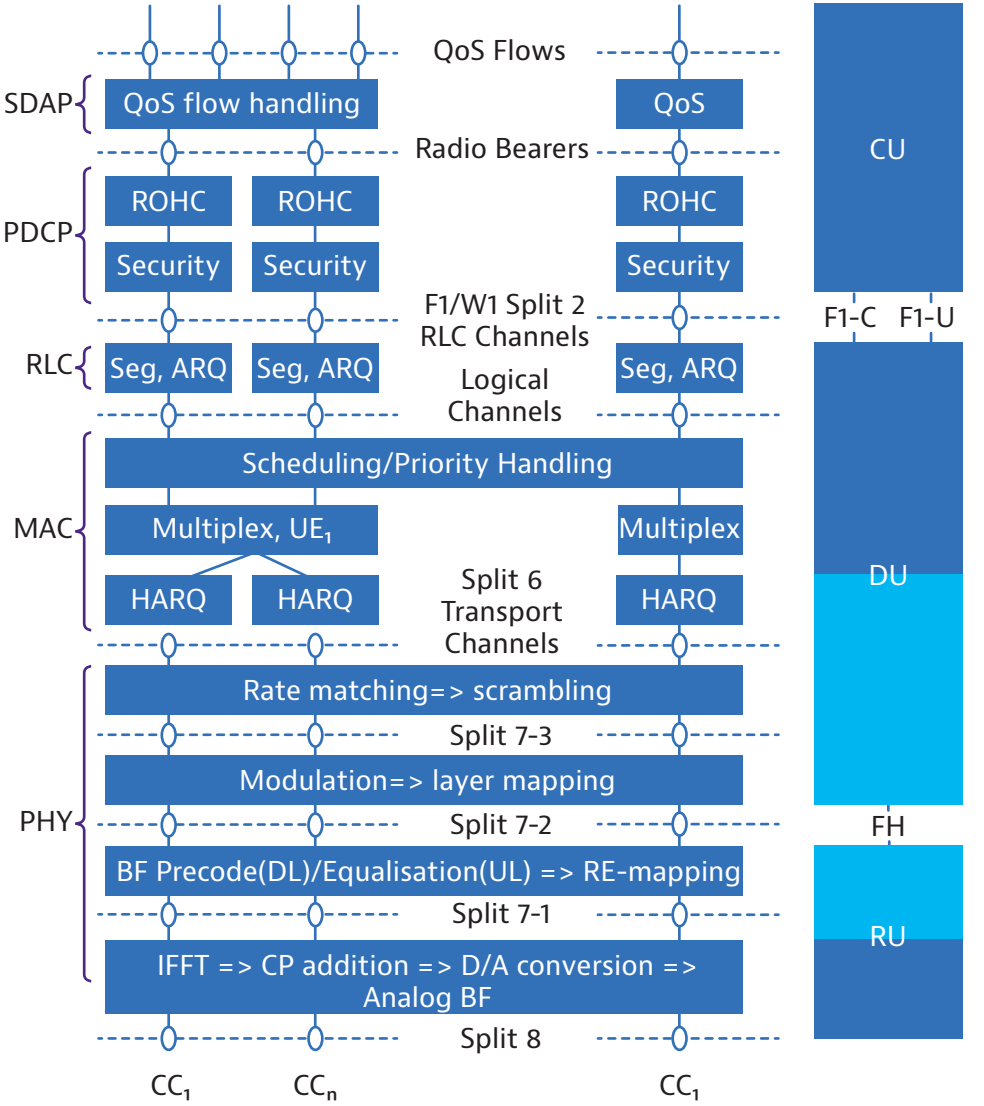
NWDAF
Network Data Analytics Function

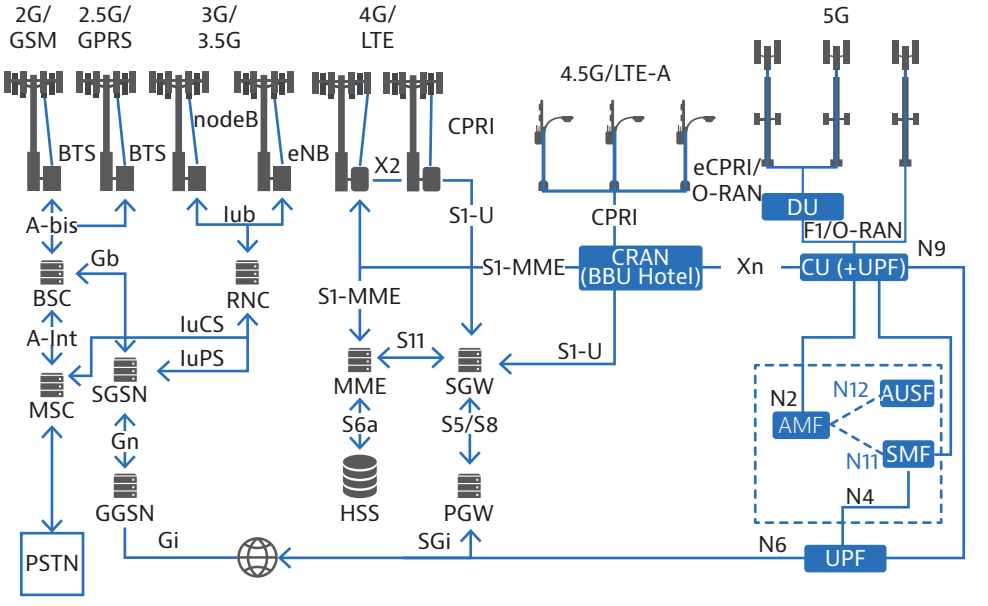
UE
User Equipment

RAN
Radio Access Network

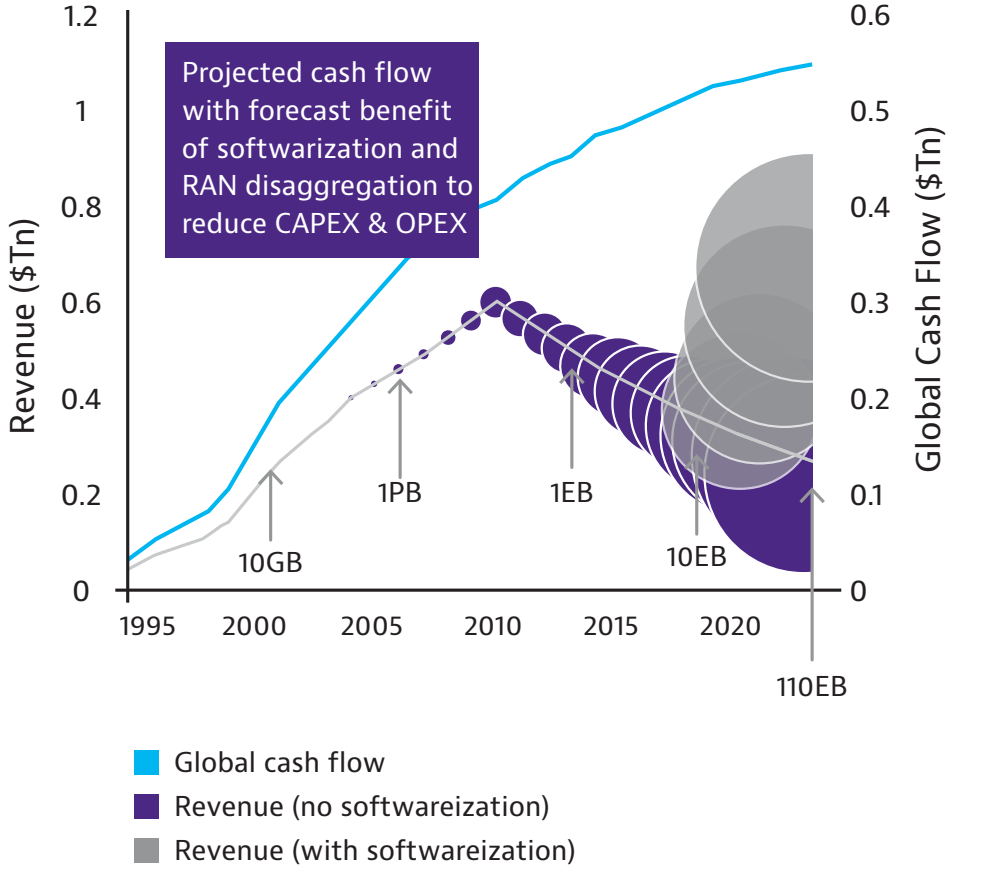
UPF
User Plane Function

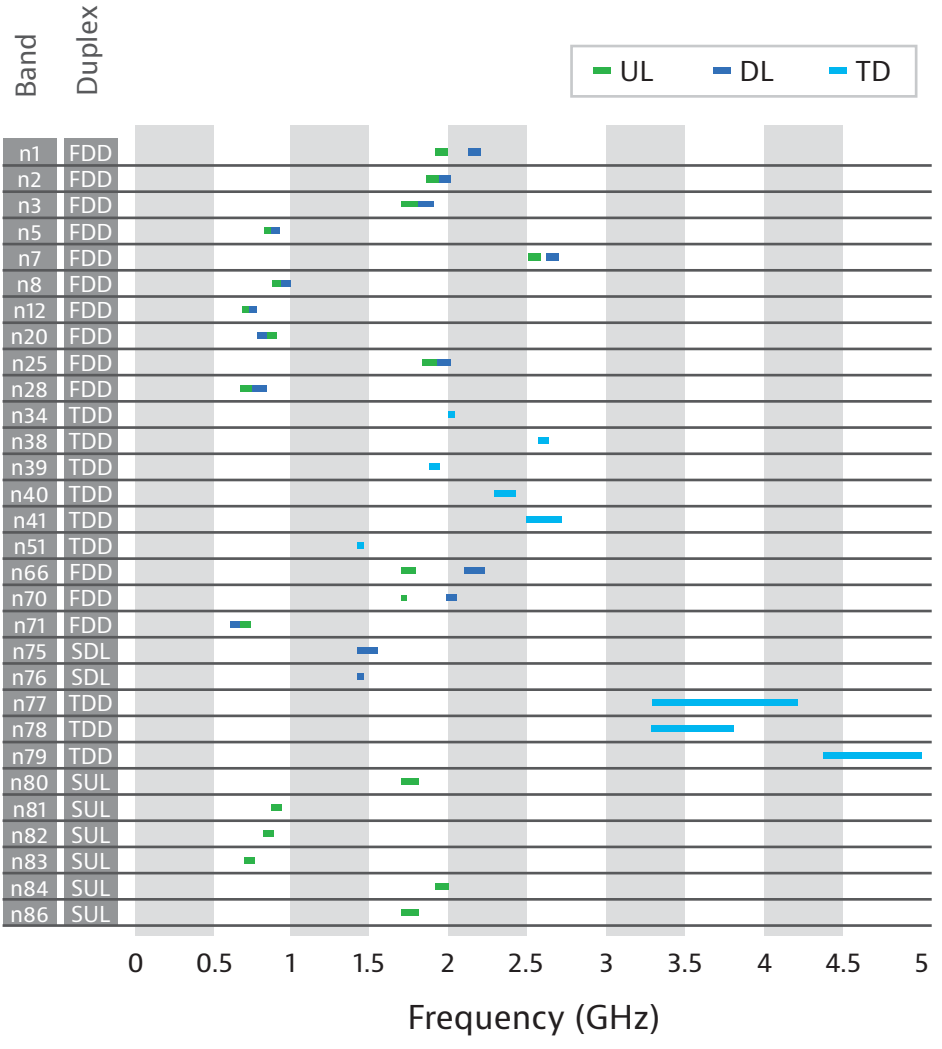
DN
Data Network

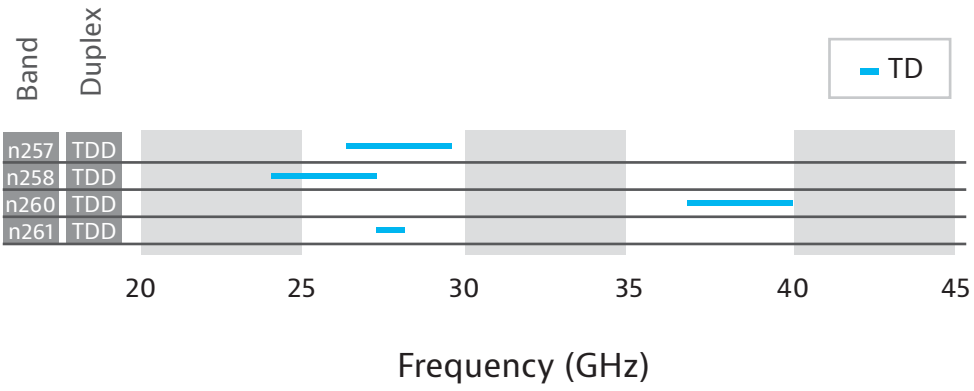

QoS Flows
SDAP
QoS flow handling
QoS
Radio Bearers
CU
PDCP
ROHC
ROHC
ROHC
Security
Security
Security
F1/W1 Split 2
RLC Channels
F1-C
F1-U
RLC
Seg, ARQ
Seg, ARQ
Seg, ARQ
Logical
Channels
Scheduling/Priority Handling
MAC
Multiplex, UE1
Multiplex
DU
HARQ
HARQ
HARQ
Split 6
Transport
Channels
Rate matching=> scrambling
Split 7-3
Modulation=> layer mapping
PHY
Split 7-2
FH
BF Precode(DL)/Equalisation(UL) => RE-mapping
Split 7-1
RU
IFFT => CP addition => D/A conversion =>
Analog BF
Split 8
CC1
CCn
CC1


2G/
GSM
2.5G/
GPRS
3G/
3.5G
4G/
LTE
4.5G/LTE-A
5G
BTS
BTS
nodeB
eNB
X2
CPRI
eCPRI/
O-RAN
A-bis
Iub
S1-U
CPRI
DU
F1/O-RAN
N9
Gb
BSC
RNC
S1-MME
CRAN
(BBU Hotel)
Xn
CU (+UPF)
S1-MME
IuCS
A-Int
IuPS
S11
S1-U
MME
SGW
N2
N12
AUSF
AMF
SGSN
MSC
S6a
S5/S8
N11
SMF
Gn
N4
GGSN
HSS
PGW
Gi
SGi
N6
UPF
PSTN

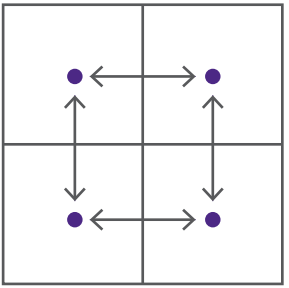
Key economic indicators
(bubble volume = data/month)



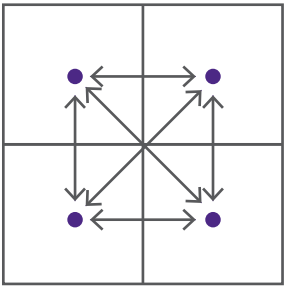

Band
Duplex
UL
DL
TD
n1 FDD
n2 FDD
n3 FDD
n5 FDD
n7 FDD
n8 FDD
n12 FDD
n20 FDD
n25 FDD
n28 FDD
n34 TDD
n38 TDD
n39 TDD
n40 TDD
n41 TDD
n51 TDD
n66 FDD
n70 FDD
n71 FDD
n75 SDL
n76 SDL
n77 TDD
n78 TDD
n79 TDD
n80 SUL
n81 SUL
n82 SUL
n83 SUL
n84 SUL
n86 SUL
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
Frequency (GHz)


Band
Duplex
TD
n257
TDD
n258
TDD
n260
TDD
n261
TDD
20
25
30
35
40
45
Frequency (GHz)

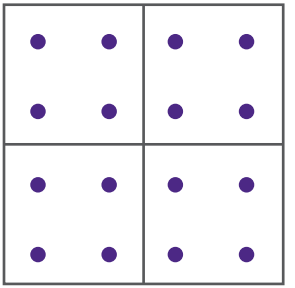
π/2-BPSK



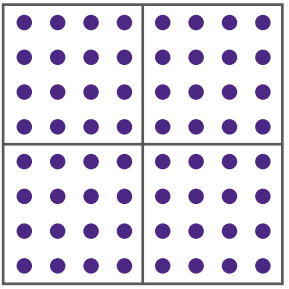
QPSK



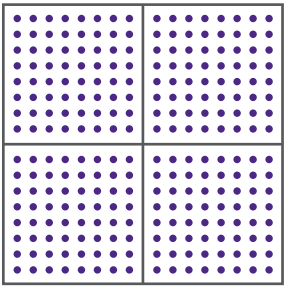
16QAM

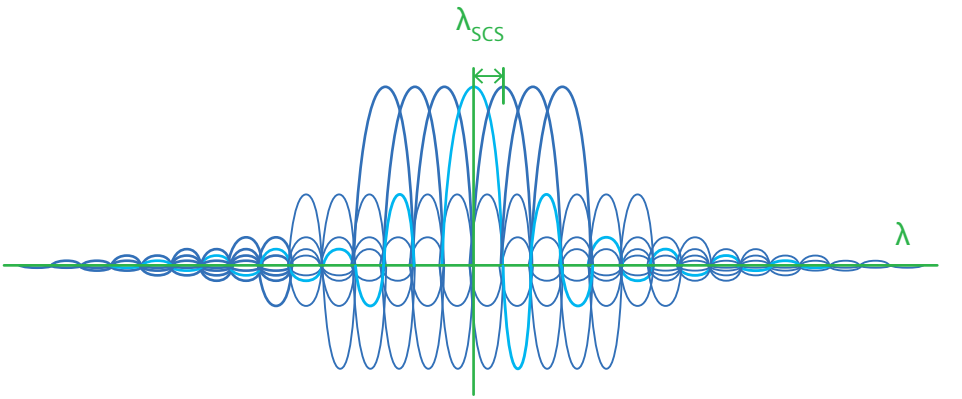


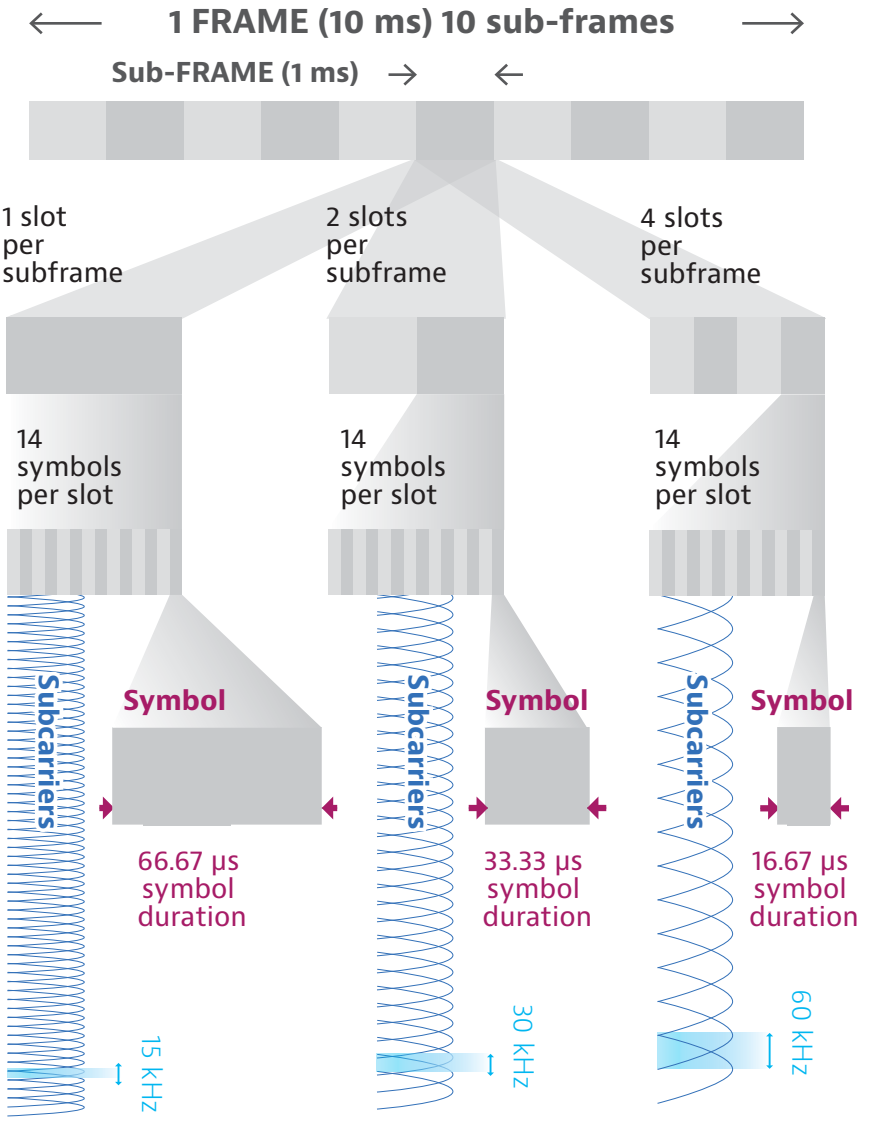
64QAM



256QAM



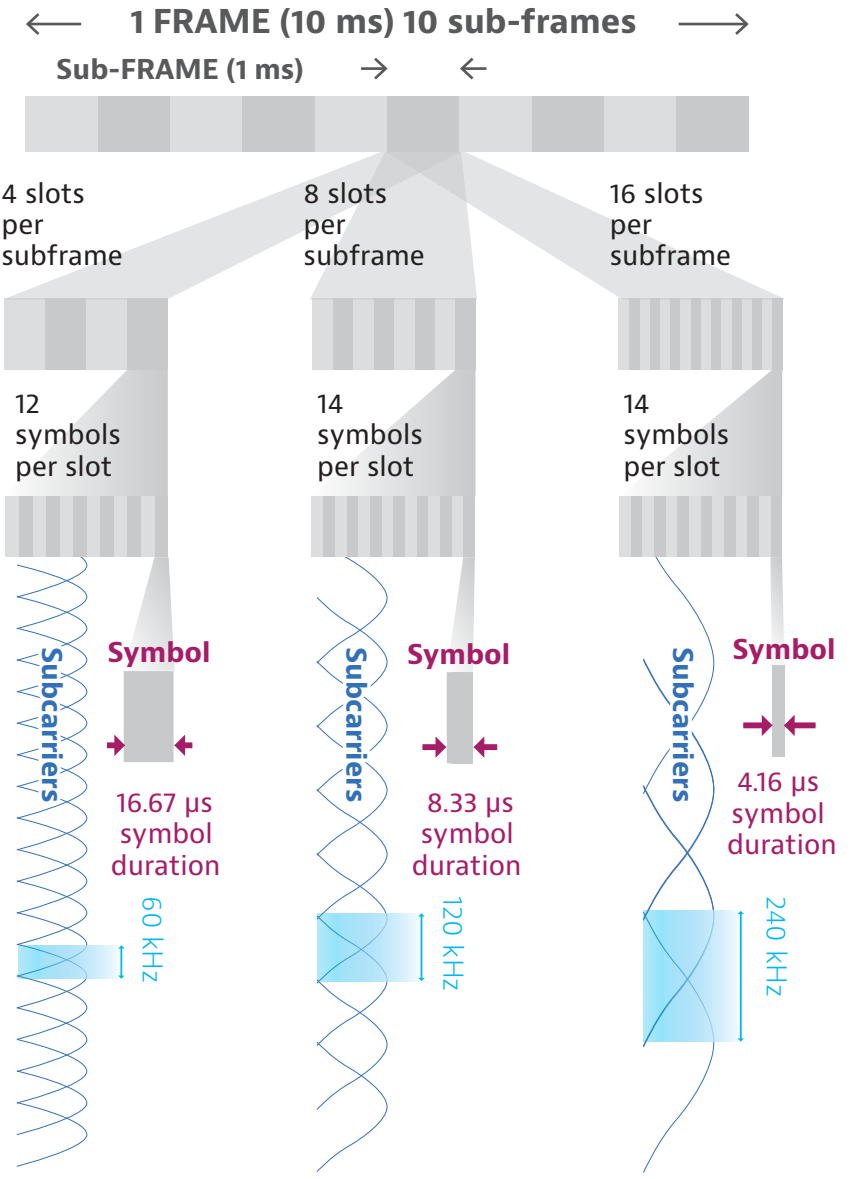

λscs
λ



Numerology µ = 0
Normal CP
15 KHz subcarrier spacing (SCS)
66.67 µs symbol duration

Numerology µ = 1
Normal CP
30 KHz subcarrier spacing (SCS)
33.33 µs symbol duration

Numerology µ = 2
Normal CP
60 KHz subcarrier spacing (SCS)
16.67 µs symbol duration



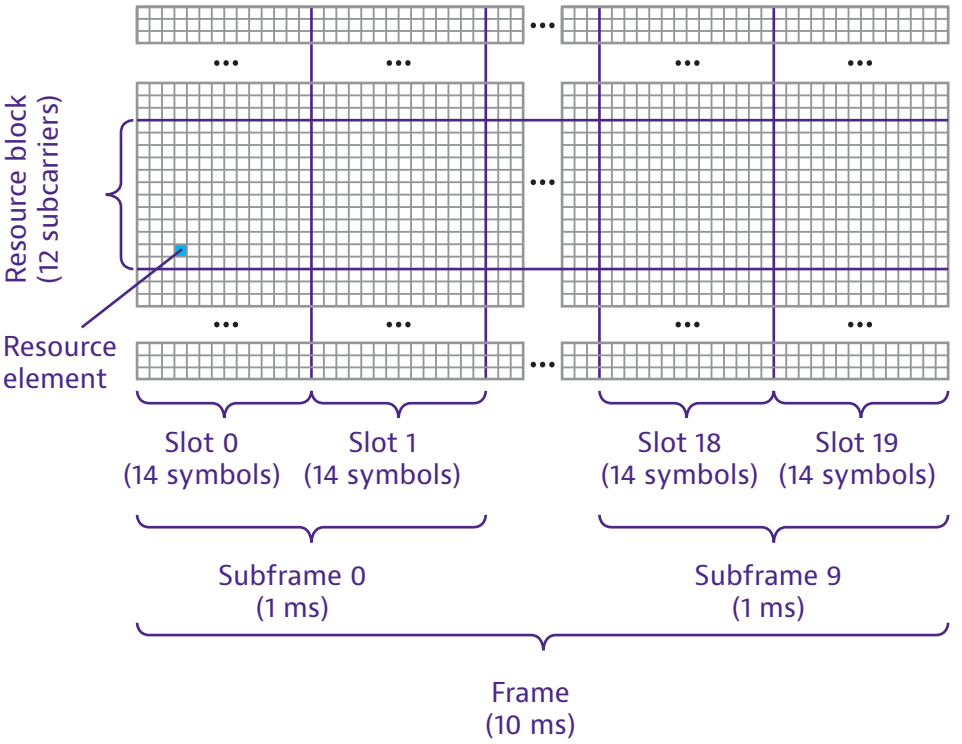
Numerology µ = 2
Extended CP
60 KHz subcarrier spacing (SCS)
16.67 µs symbol duration

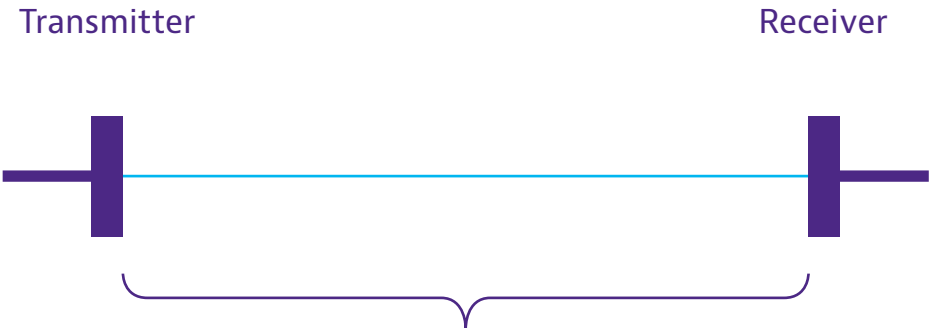
Numerology µ = 3
Normal CP
120 KHz subcarrier spacing (SCS)
8.33 µs symbol duration

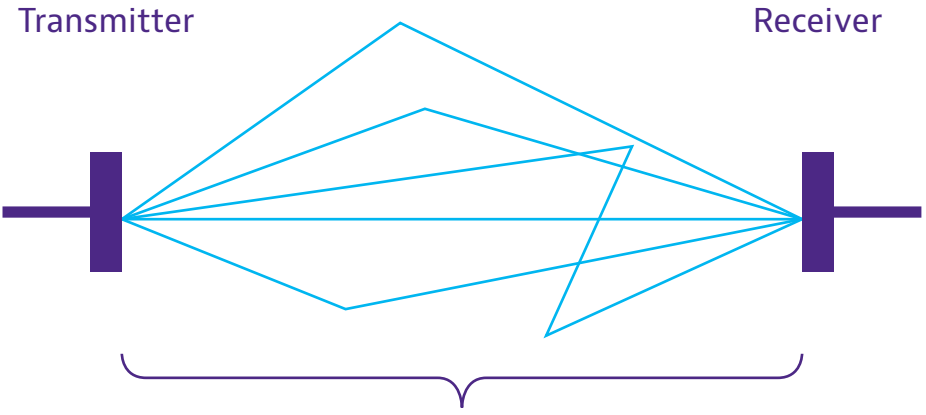
Numerology µ = 4
Normal CP
240 KHz subcarrier spacing (SCS)
4.16 µs symbol duration

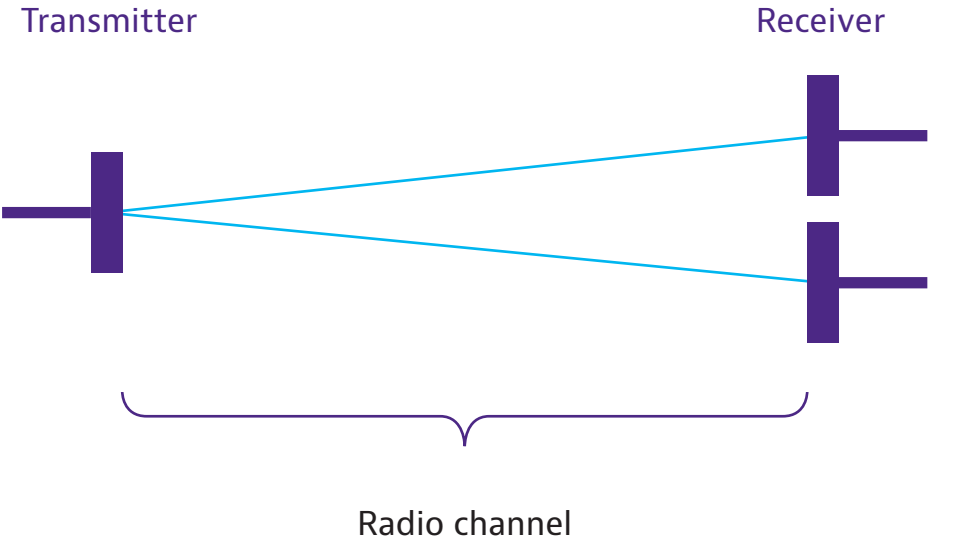
Numerology 1

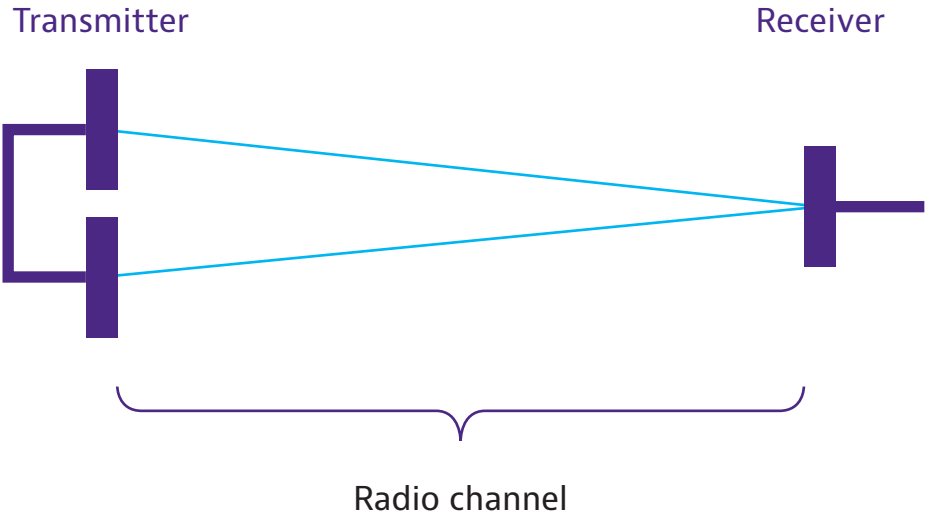
30 KHz subcarrier spacing

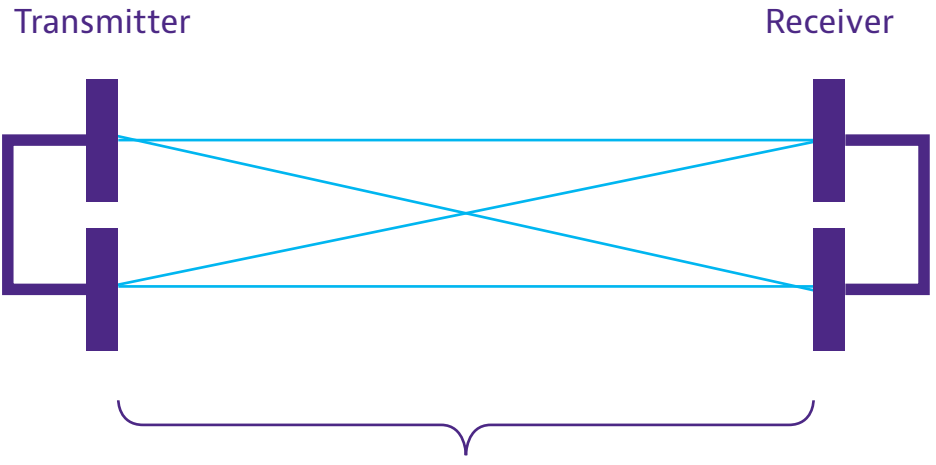


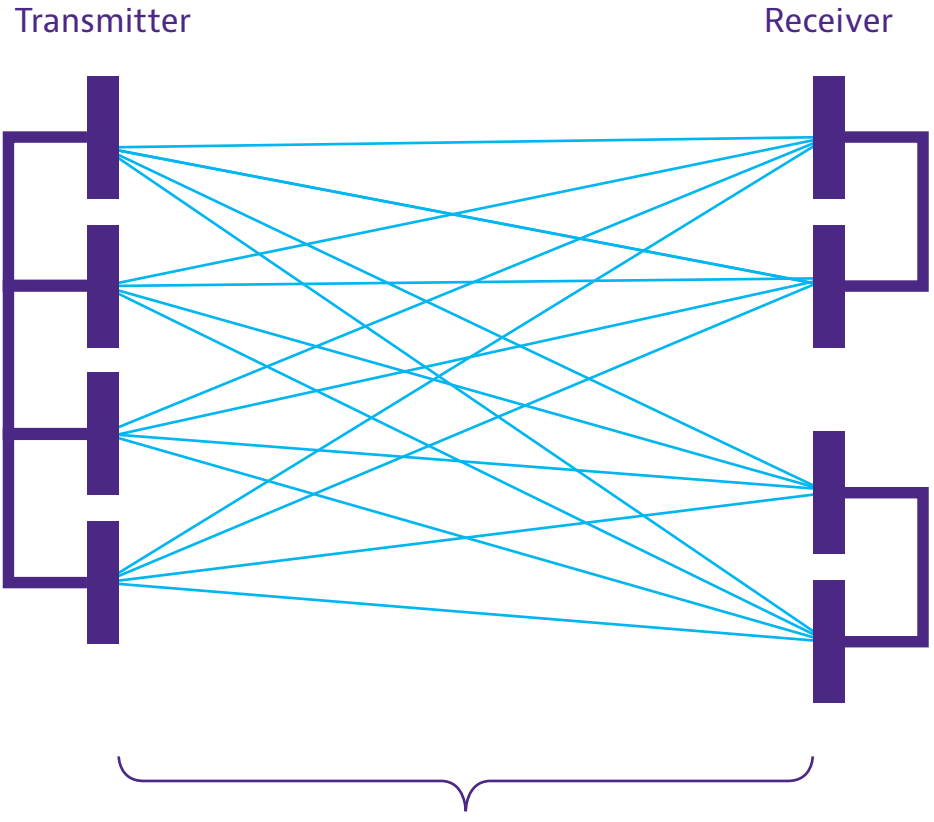

Transmitter
Receiver
Radio channel

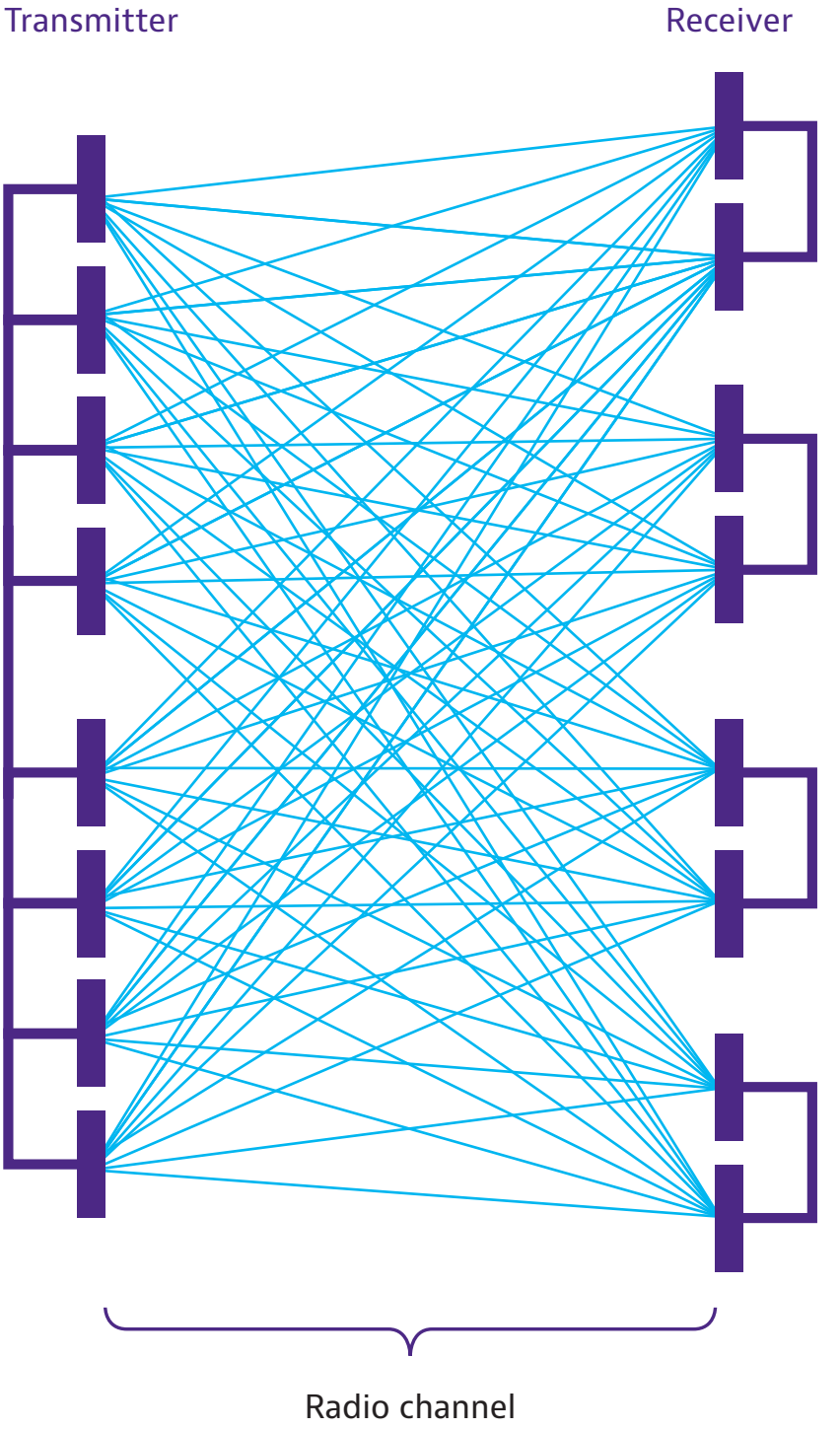

Transmitter
Receiver
Complex radio channel

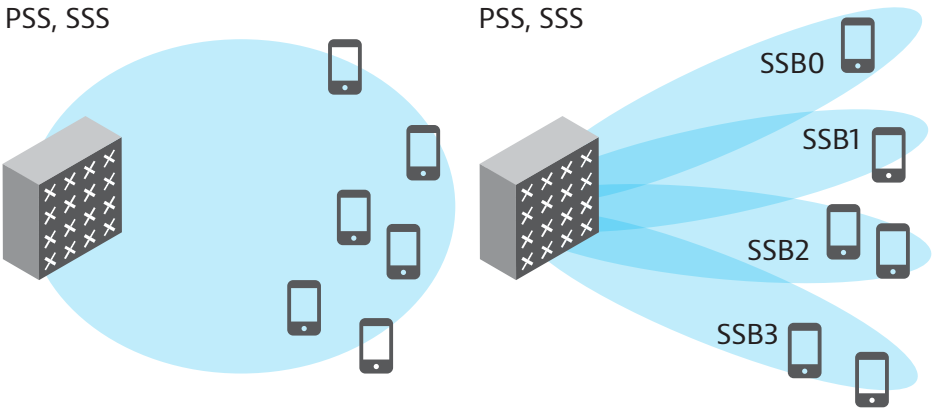

Transmitter
Receiver
Radio channel


Transmitter
Receiver
Radio channel


Transmitter
Receiver
Radio channel


Transmitter
Receiver
Radio channel


Transmitter
Receiver
Radio channel



Channel State Indicator-Reference Signal (CSI-RS) on 32 ports

Channel State Indicator-Reference Signal (CSI-RS) on 8 ports each

Synchronization Signal Block (SSB)

Channel Quality Indicator (CQI)

Channel Quality Indicator (CQI)

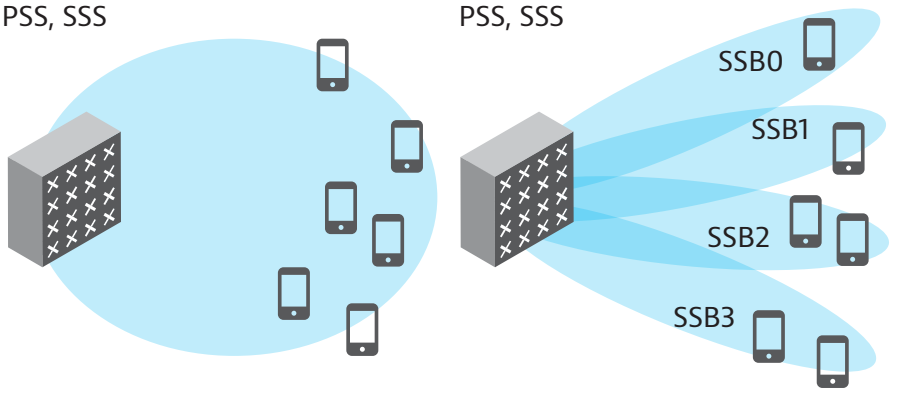
Rank Indicator (RI)

Rank Indicator (RI)

Precoding Matrix Indicator (PMI)

Precoding Matrix Indicator (PMI)

Channel State Indicator-Reference Signal Resource Indicator (CRI)



Channel State Indicator-Reference Signal (CSI-RS) on 32 ports

Channel State Indicator-Reference Signal (CSI-RS) on 8 ports each

Synchronization Signal Block (SSB)

Channel Quality Indicator (CQI)

Channel Quality Indicator (CQI)

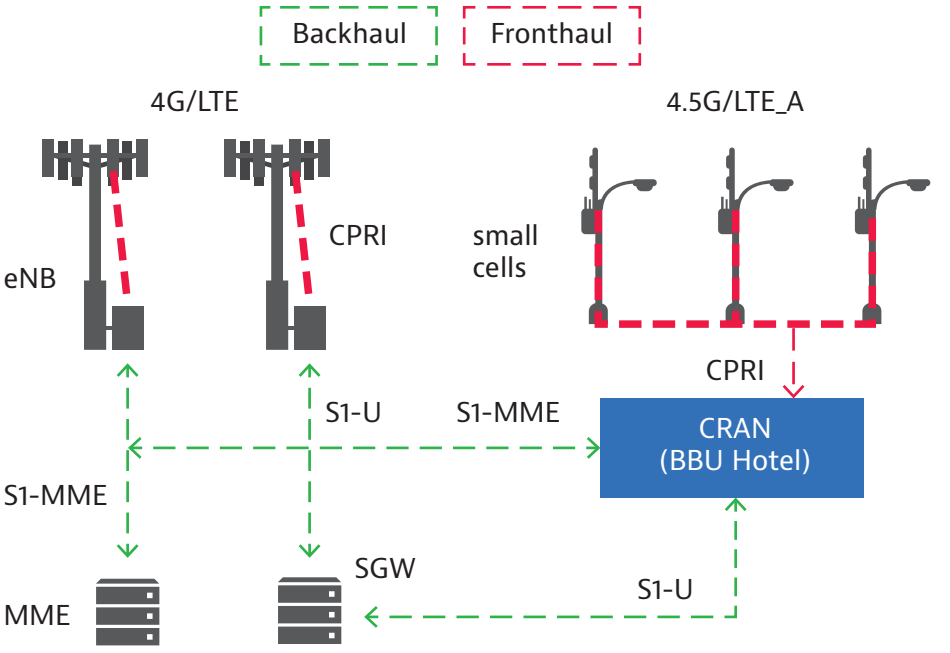
Rank Indicator (RI)

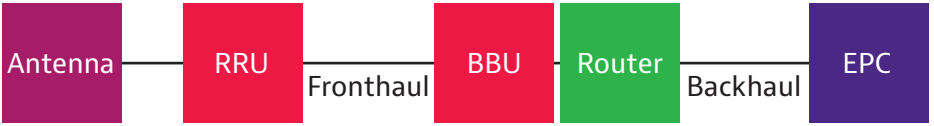
Rank Indicator (RI)

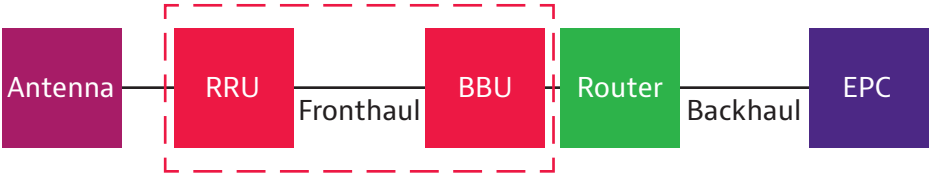
Sounding Reference Indicator (SRS)

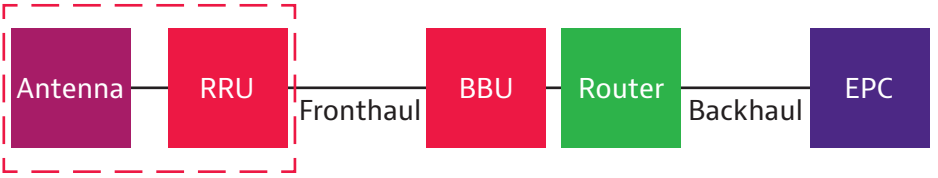
Sounding Reference Indicator (SRS)

Channel State Indicator-Reference Signal Resource Indicator (CRI)

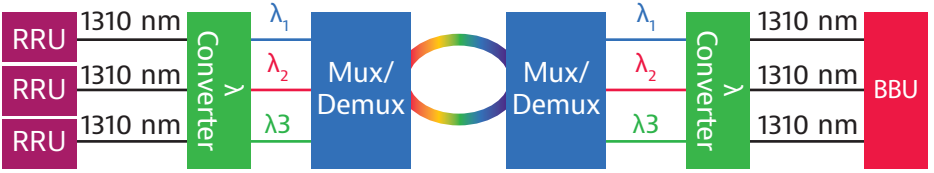

Backhaul
Fronthaul
4G/LTE
4.5G/LTE_A
eNB
CPRI
small
cells
CPRI
S1-U
S1-MME
CRAN
(BBU Hotel)
S1-MME
SGW
S1-U
MME

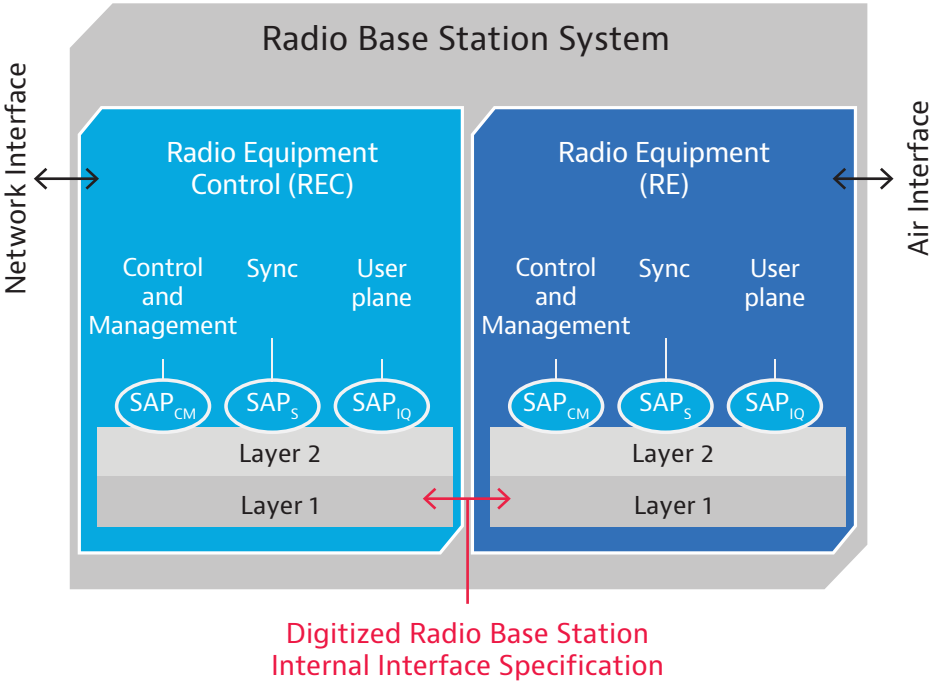

Antenna
RRU
Fronthaul
BBU
Router
Backhaul
EPC

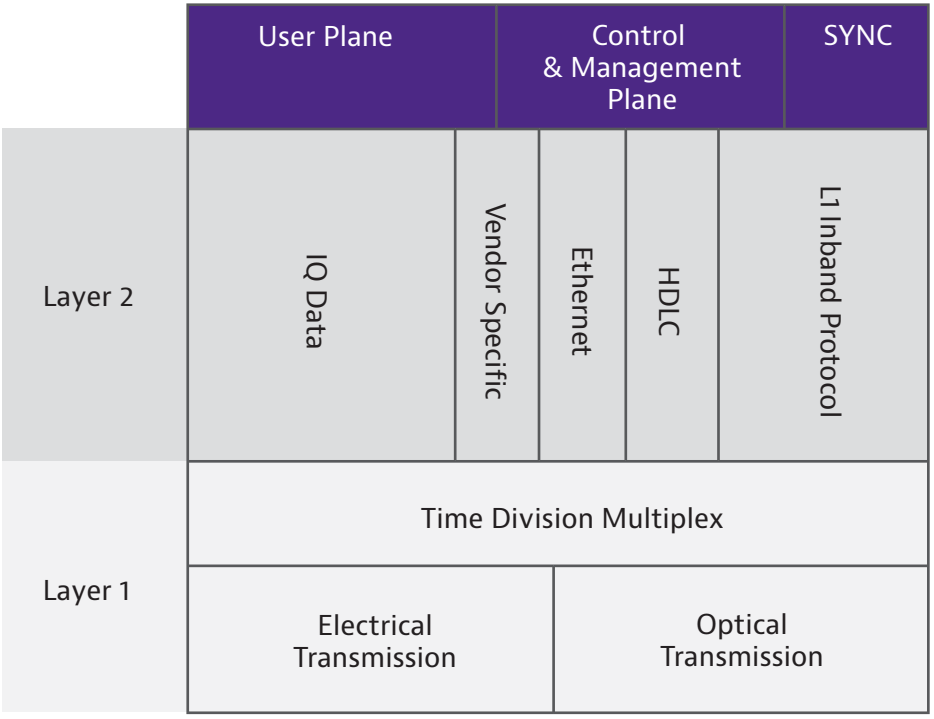

Antenna
RRU
Fronthaul
BBU
Router
Backhaul
EPC

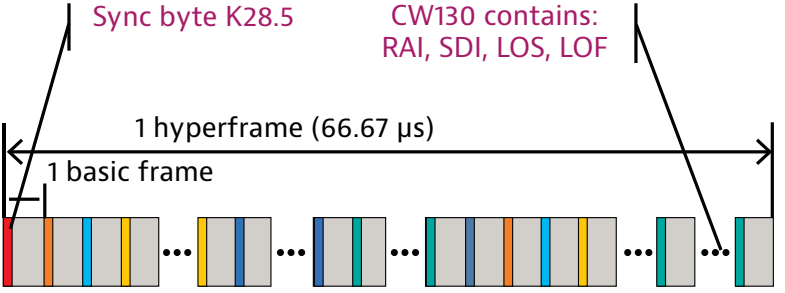

Antenna
RRU
Fronthaul
BBU
Router
Backhaul
EPC


RRU
RRU
RRU
λ1
λ2
λ3
Mux/
Demux
Mux/
Demux
λ1
λ2
λ3
BBU

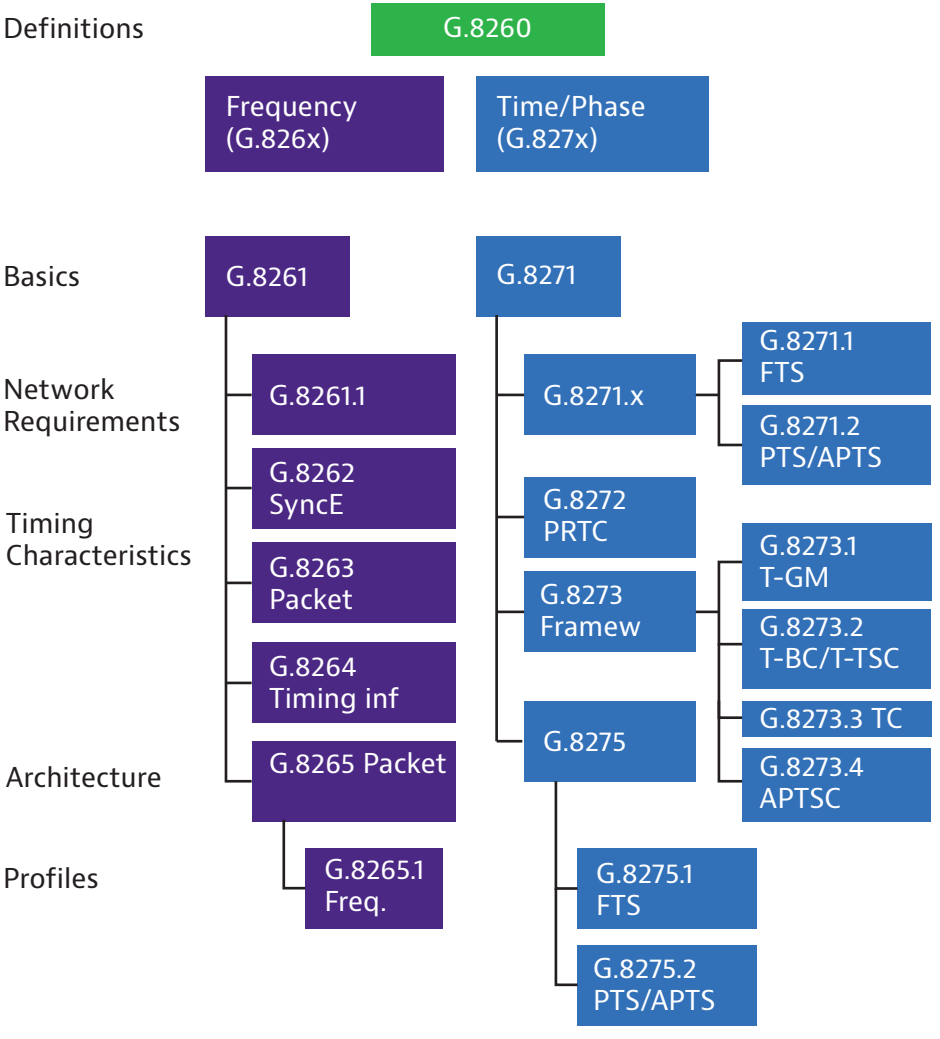

RRU
RRU
RRU
1310 nm
1310 nm
1310 nm
λ Converter
λ1
λ2
λ3
Mux/ Demux
Mux/ Demux
λ1
λ2
λ3
λ Converter
1310 nm
1310 nm
1310 nm
BBU

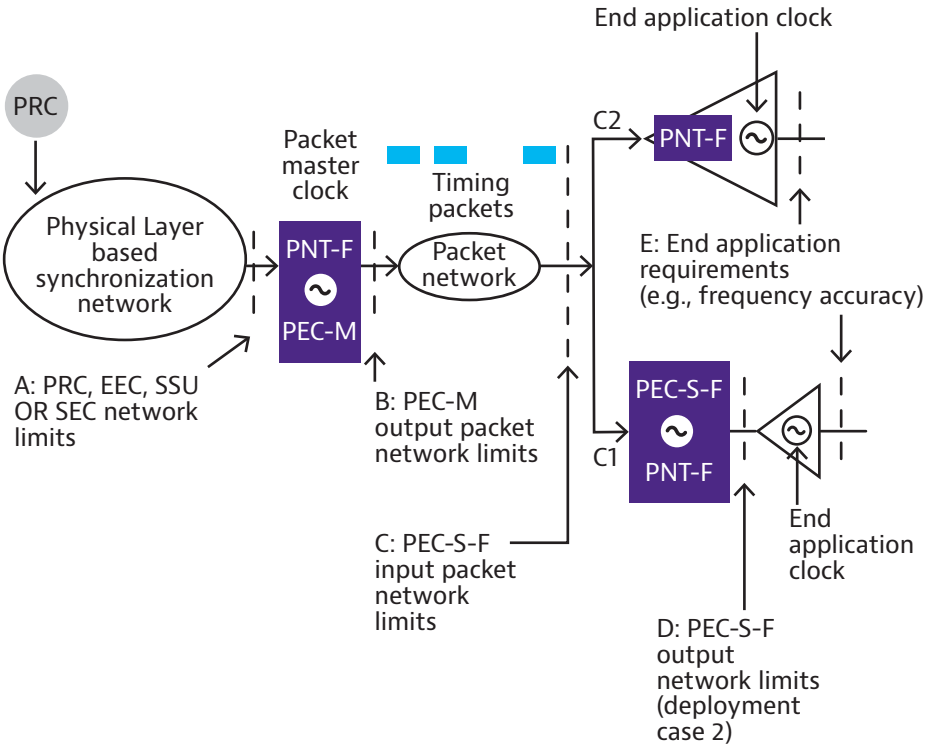

Radio Base Station System
Network Interface
Air Interface
Radio Equipment Control (REC)
Radio Equipment (RE)
Control and Management
Sync
User plane
SAP CM
SAP S
SAP IQ
Layer 2
Layer 1
Digitized Radio Base Station Internal Interface Specification

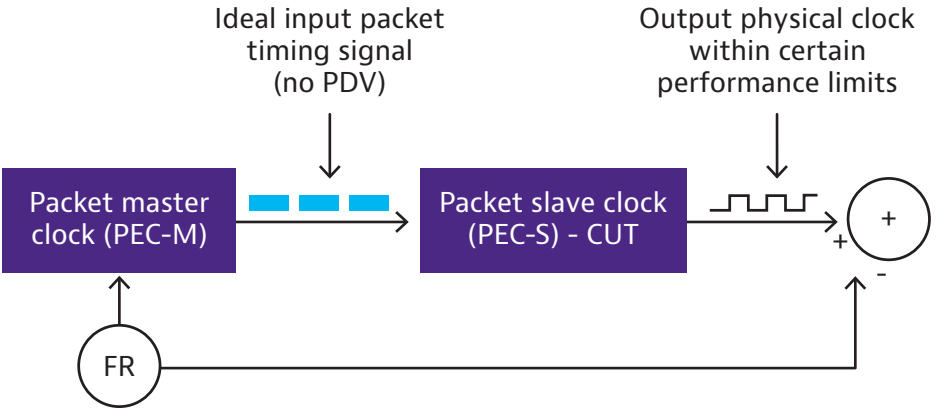

User Plane
Control & Management Plane
SYNC
Layer 2
IQ Data
Vendor Specific
Ethernet
HDLC
L1 Inband Protocol
Layer 1
Time Division Multiplex
Electrical Transmission
Optical Transmission

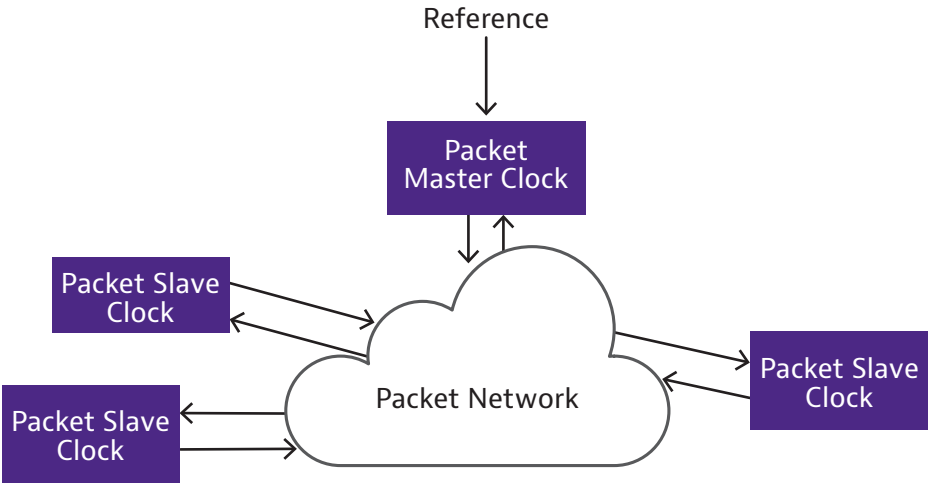


Index of control word X=0	1	2	3		15	16		p-1	p		63	64	65	66	67		127		255	
Index of subchannel Ns=0	1	2	3		15	16		p-1	p		63	0	1	2	3		63		63	
Index of control word within subchannel Xs=0	0	0	0		0	0		0	0		0	1	1	1	1		1		3	

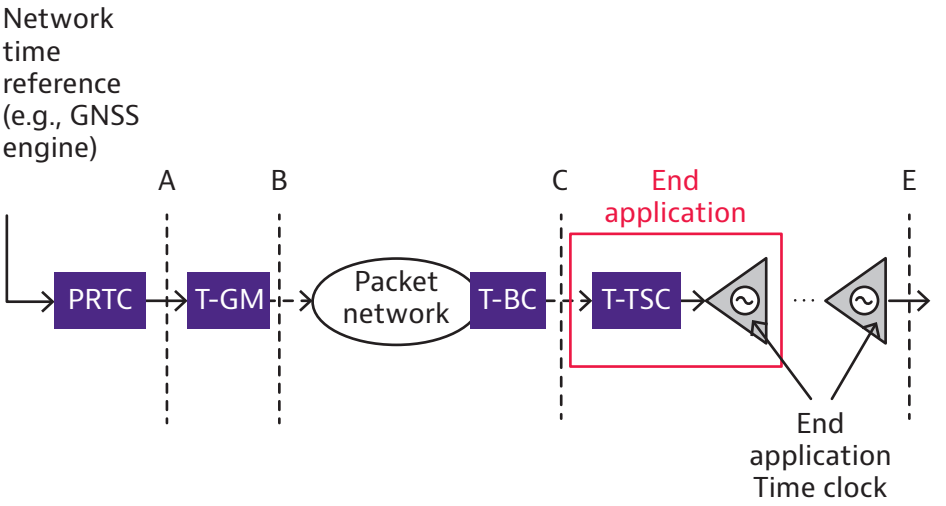

Definitions
G.8260
Frequency (G.826x)
Time/Phase (G.827x)
Basics
G.8261
G.8271
Network Requirements
G.8261.1
G.8271.x
G.8271.1 FTS
G.8271.2 PTS/APTS
Timing Characteristics
G.8262 SyncE
G.8272 PRTC
G.8263 Packet
G.8273 Framew
G.8273.1 T-GM
G.8273.2 T-BC/T-TSC
G.8273.3 TC
G.8273.4 APTSC
G.8264 Timing inf
G.8275
Architecture
G.8265 Packet
Profiles
G.8265.1 Freq.
G.8275.1 FTS
G.8275.2 PTS/APTS


End application clock
PRC
Packet master clock
Timing packets
C2
PNT-F
Physical Layer based synchronization network
PNT-F
PEC-M
Packet network
E: End application requirements (e.g., frequency accuracy)
A: PRC, EEC, SSU OR SEC network limits
B: PEC-M output packet network limits
PEC-S-F
PNT-F
C1
End application clock
C: PEC-S-F input packet network limits
D: PEC-S-F output network limits (deployment case 2)

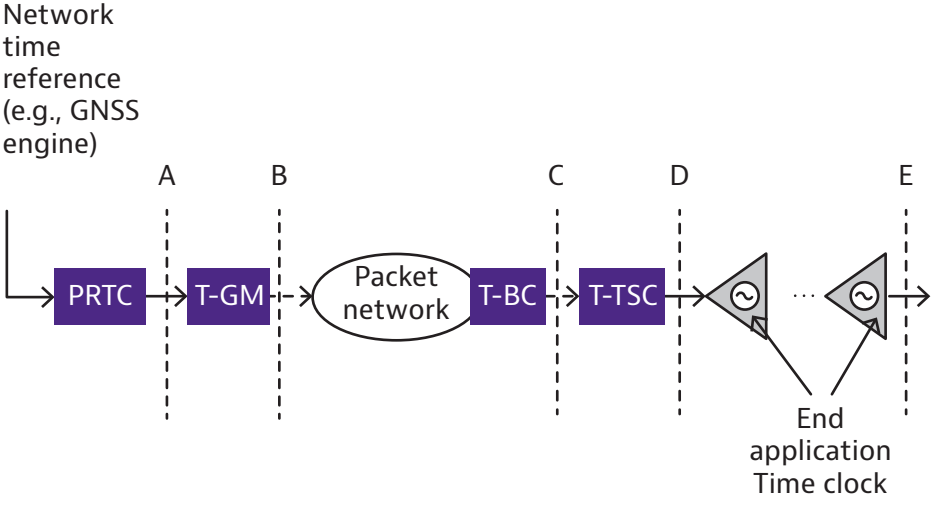

Ideal input packet timing signal (no PDV)
Output physical clock within certain performance limits
Packet master clock (PEC-M)
Packet slave clock (PEC-S) - CUT
+
+
-
FR

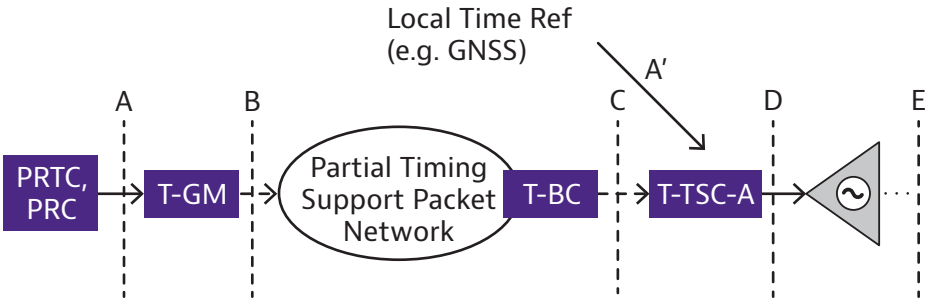

Reference
Packet
Master Clock
Packet Slave
Clock
Packet Network
Packet Slave
Clock
Packet Slave
Clock

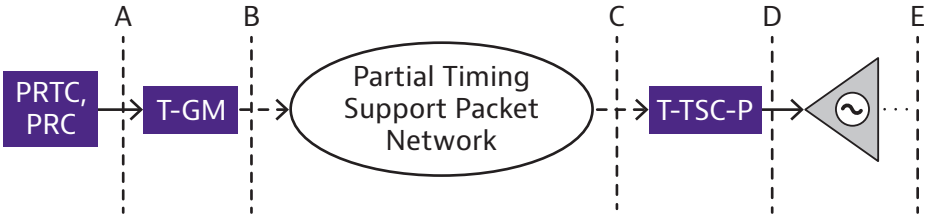
Deployment Case 1

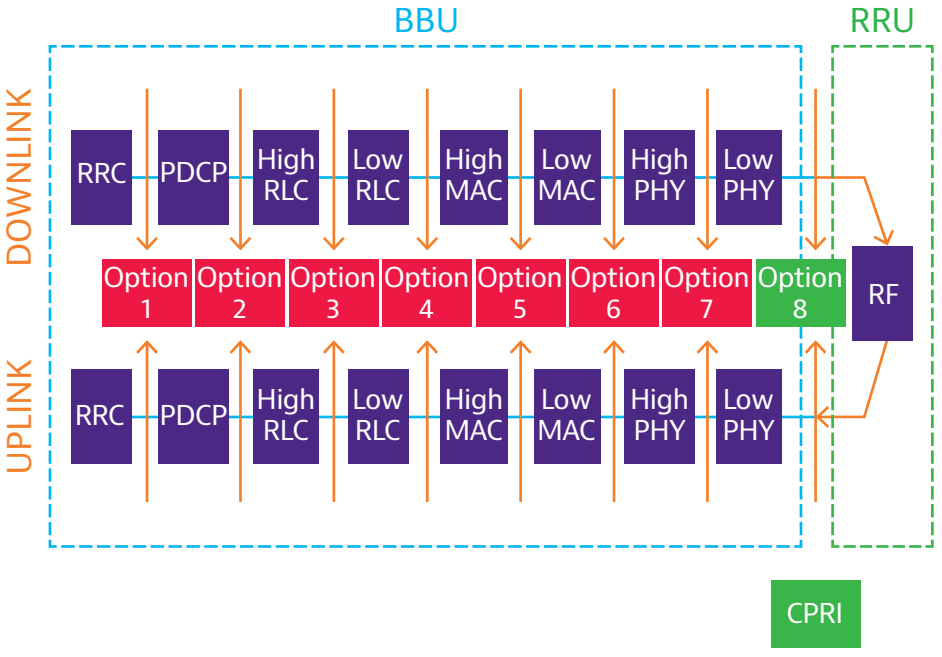


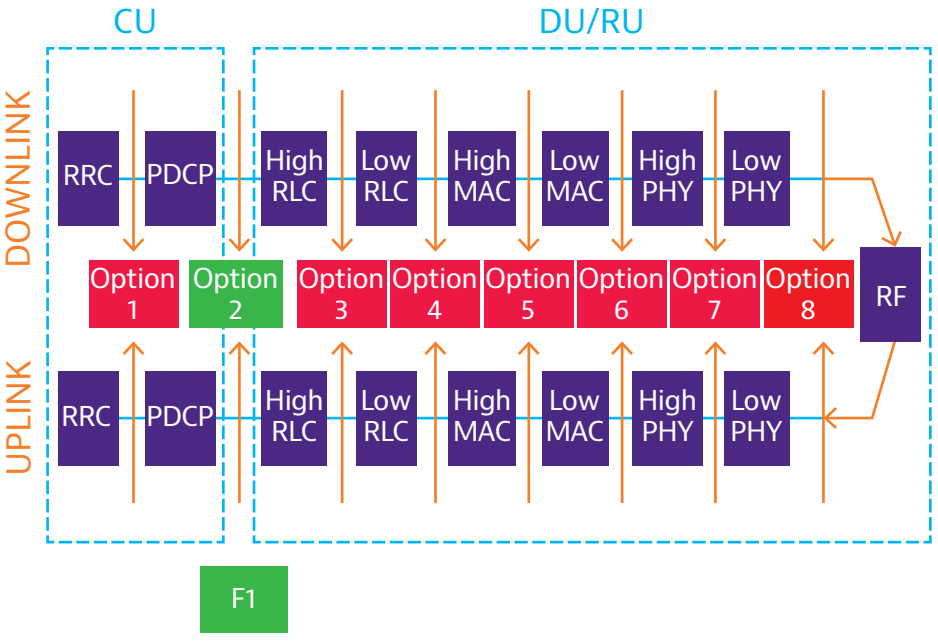
Deployment Case 2

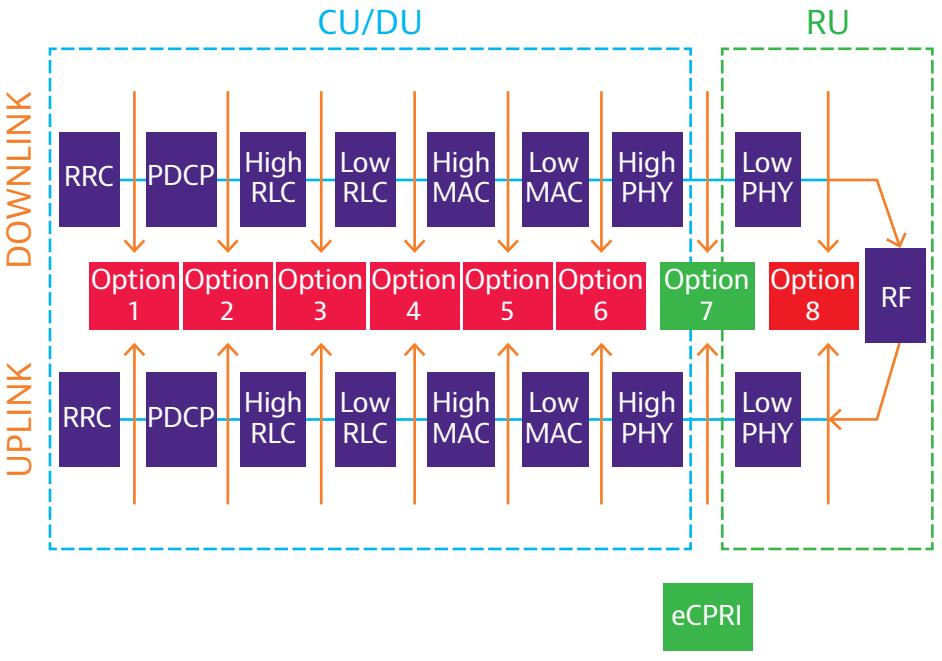


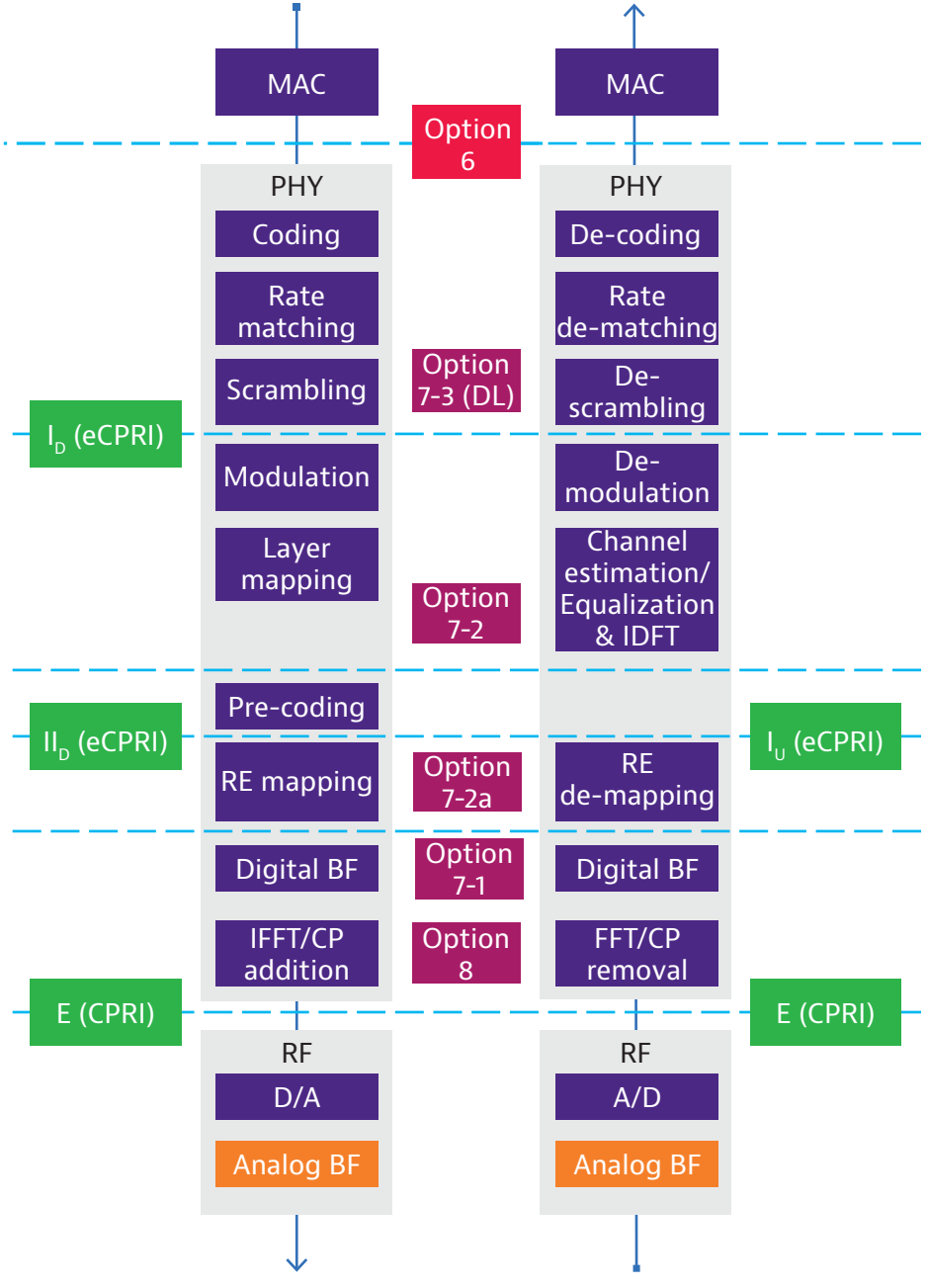

Local Time Ref
(e.g. GNSS)
A'
A
B
C
D
E
PRTC,
PRC
T-GM
Partial Timing
Support Packet
Network
T-BC
T-TSC-A

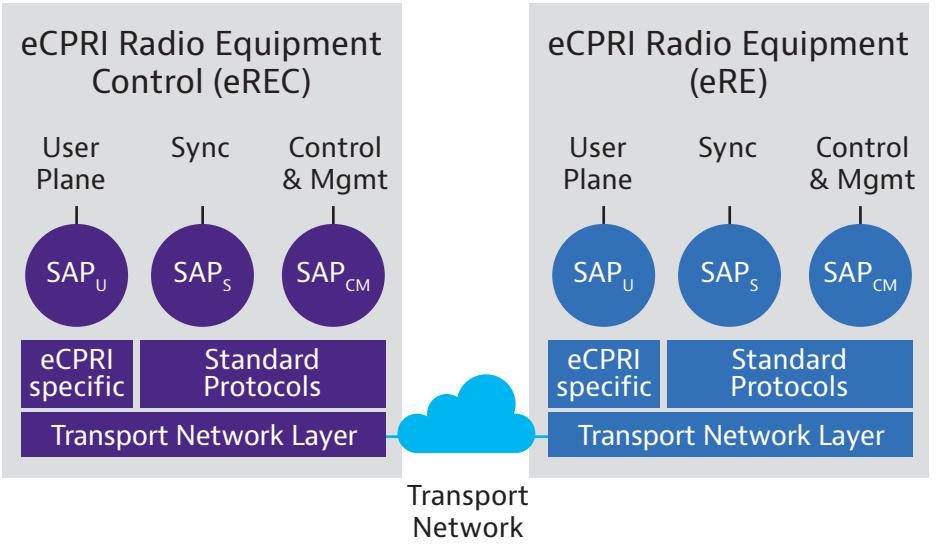

A
B
C
D
E
PRTC, PRC
T-GM
Partial Timing Support Packet Network
T-TSC-P

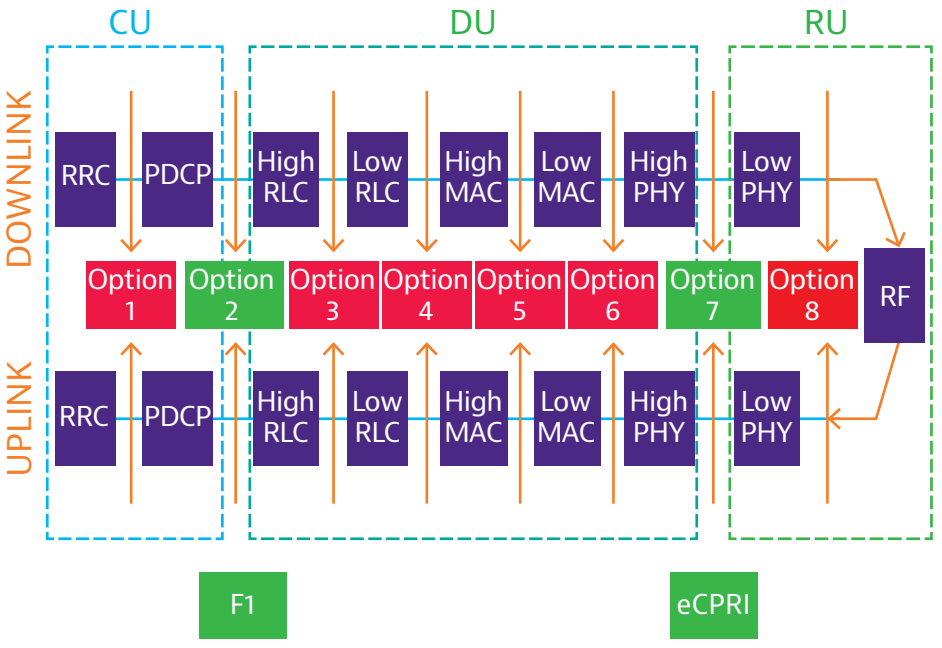

BBU
RRU
DOWNLINK
RRC
PDCP
High RLC
Low RLC
High MAC
Low MAC
High PHY
Low PHY
Option 1
Option 2
Option 3
Option 4
Option 5
Option 6
Option 7
Option 8
RF
UPLINK
RRC
PDCP
High RLC
Low RLC
High MAC
Low MAC
High PHY
Low PHY
CPRI

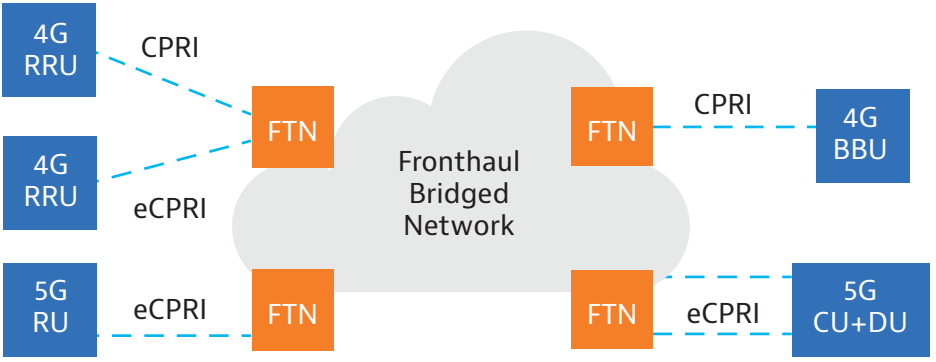

CU
DU/RU
DOWNLINK
UPLINK
RRC
PDCP
High RLC
Low RLC
High MAC
Low MAC
High PHY
Low PHY
Option 1
Option 2
Option 3
Option 4
Option 5
Option 6
Option 7
Option 8
RF
F1

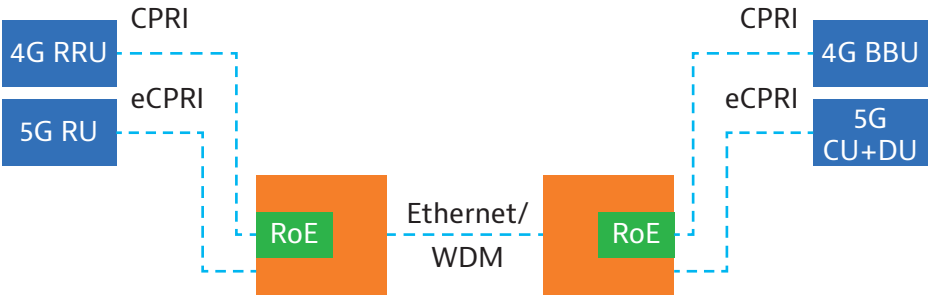

CU/DU
RU
DOWNLINK
RRC
PDCP
High RLC
Low RLC
High MAC
Low MAC
High PHY
Low PHY
Option 1
Option 2
Option 3
Option 4
Option 5
Option 6
Option 7
Option 8
RF
UPLINK
RRC
PDCP
High RLC
Low RLC
High MAC
Low MAC
High PHY
Low PHY
eCPRI

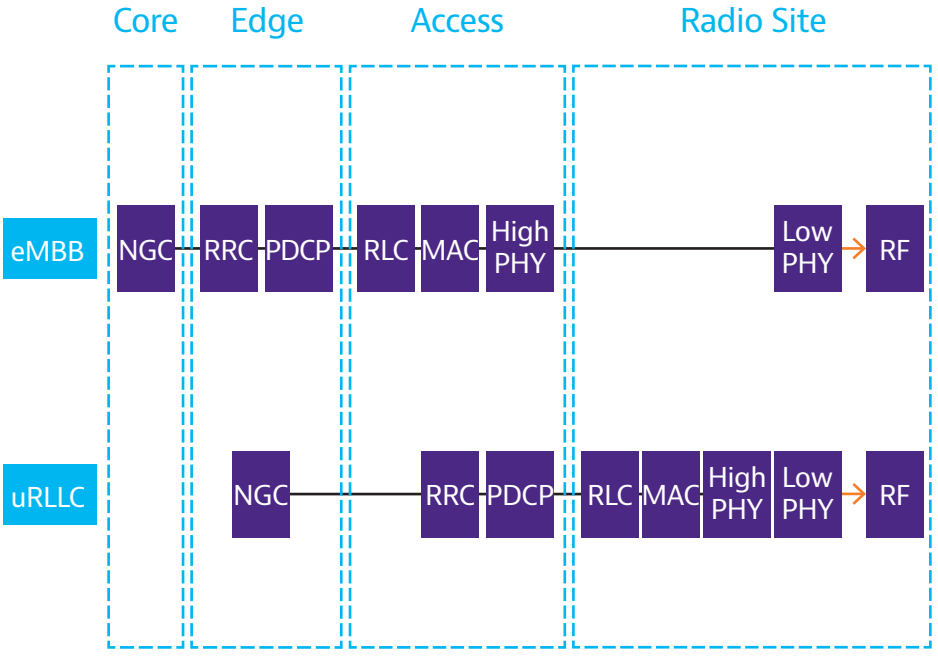

MAC
MAC
Option 6
PHY
PHY
Coding
De-coding
Rate matching
Rate de-matching
Scrambling
Option 7-3 (DL)
De-scrambling
I_D (eCPRI)
Modulation
De-modulation
Layer mapping
Option 7-2
Channel estimation/ Equalization & IDFT
Pre-coding
II_D (eCPRI)
I_U (eCPRI)
RE mapping
Option 7-2a
RE de-mapping
Digital BF
Option 7-1
Digital BF
IFFT/CP addition
Option 8
FFT/CP removal
E (CPRI)
E (CPRI)
RF
RF
D/A
A/D
Analog BF
Analog BF

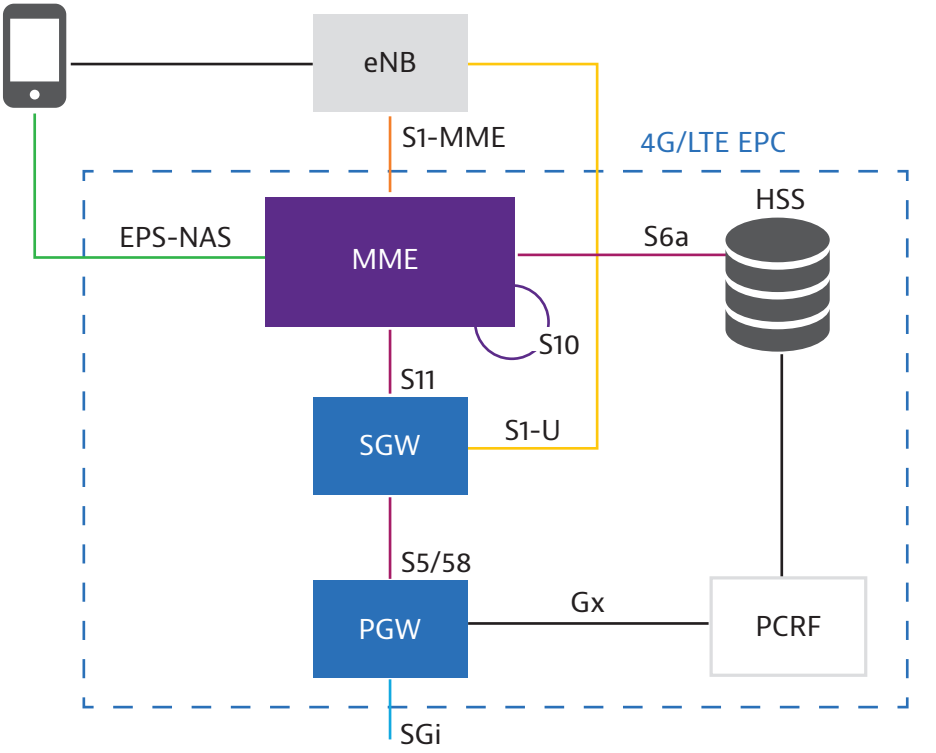

eCPRI Radio Equipment Control (eREC)
User Plane
Sync
Control & Mgmt
SAP U
SAP S
SAP CM
eCPRI specific
Standard Protocols
Transport Network Layer
Transport Network
eCPRI Radio Equipment (eRE)
User Plane
Sync
Control & Mgmt
SAP U
SAP S
SAP CM
eCPRI specific
Standard Protocols
Transport Network Layer

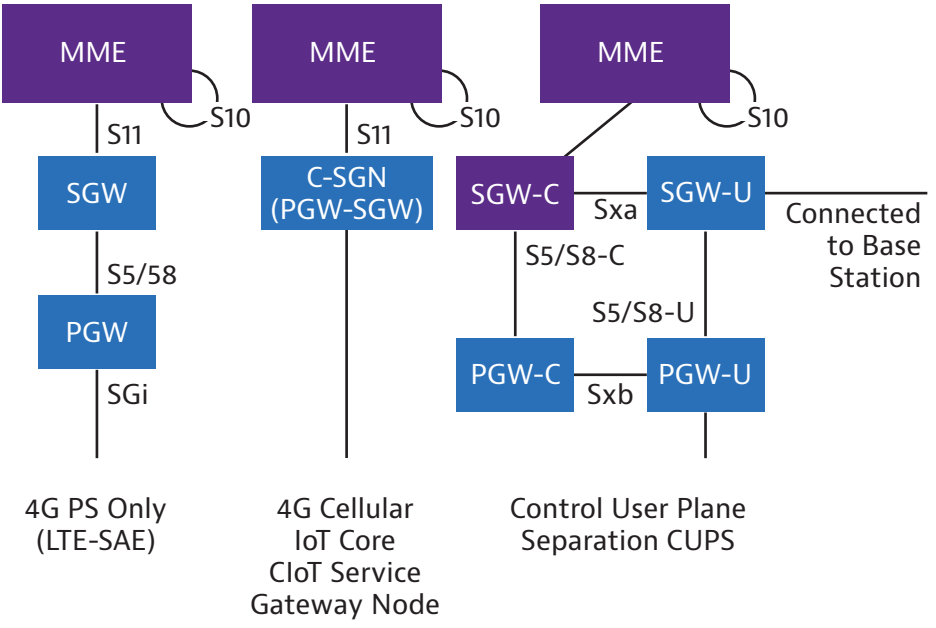

CU
DU
RU
DOWNLINK
UPLINK
RRC
PDCP
High RLC
Low RLC
High MAC
Low MAC
High PHY
Low PHY
Option 1
Option 2
Option 3
Option 4
Option 5
Option 6
Option 7
Option 8
RF
F1
eCPRI

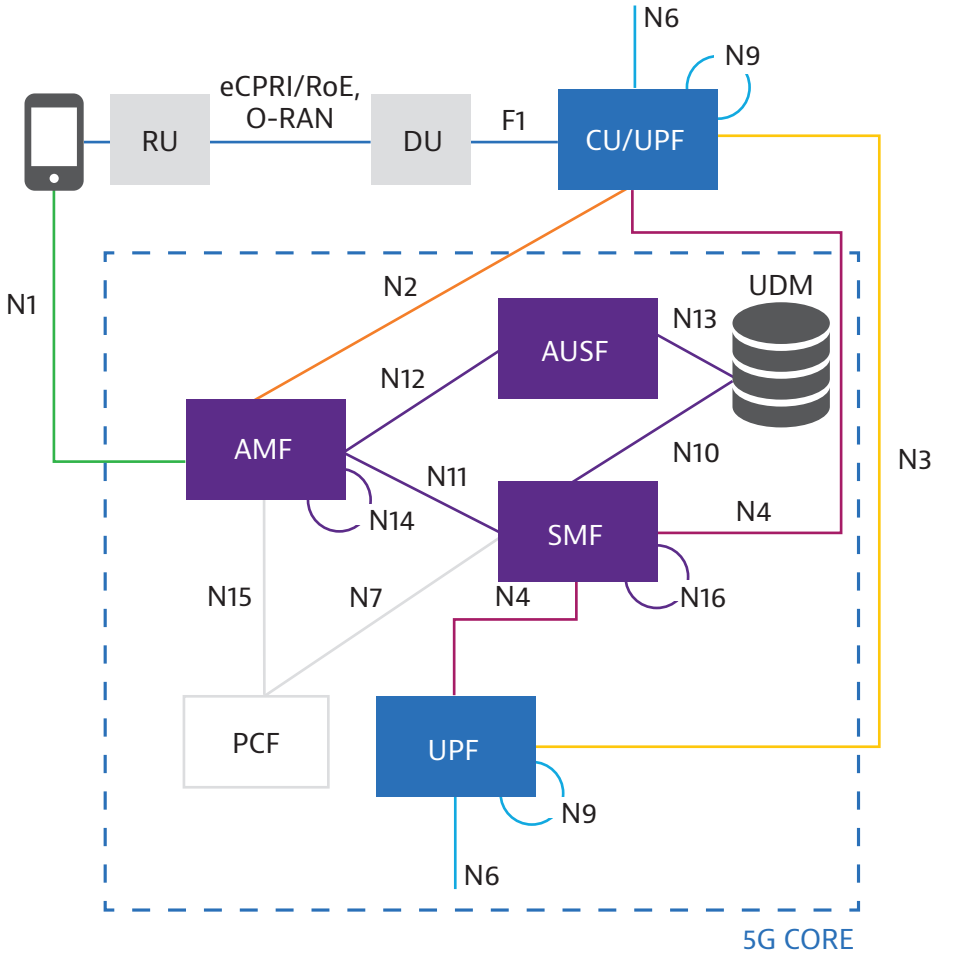

4G
RRU
CPRI
4G
RRU
eCPRI
5G
RU
eCPRI
FTN
FTN
Fronthaul
Bridged
Network
FTN
FTN
CPRI
eCPRI
4G
BBU
5G
CU+DU

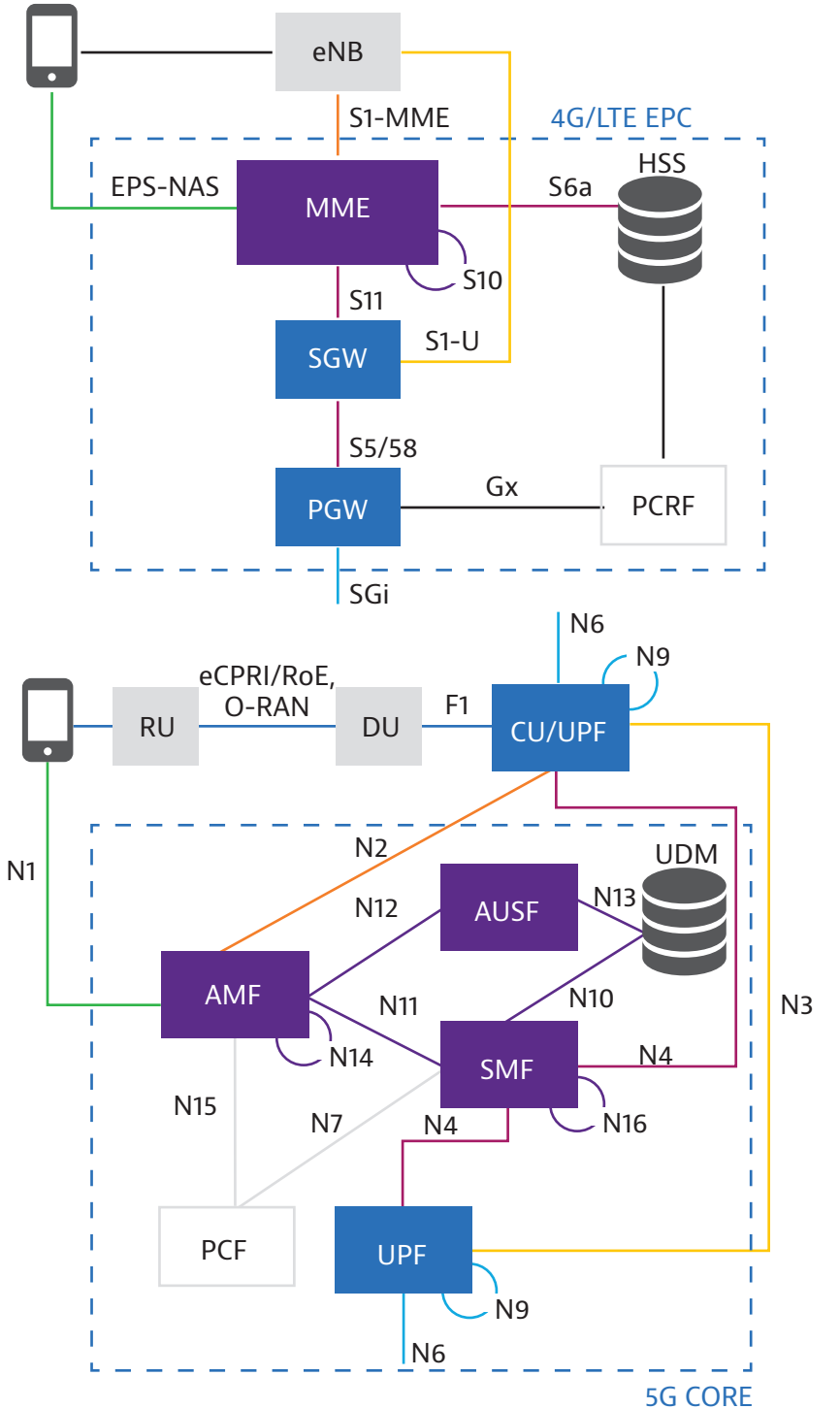

CPRI
4G RRU
eCPRI
5G RU
RoE
Ethernet/
WDM
RoE
CPRI
4G BBU
eCPRI
5G
CU+DU

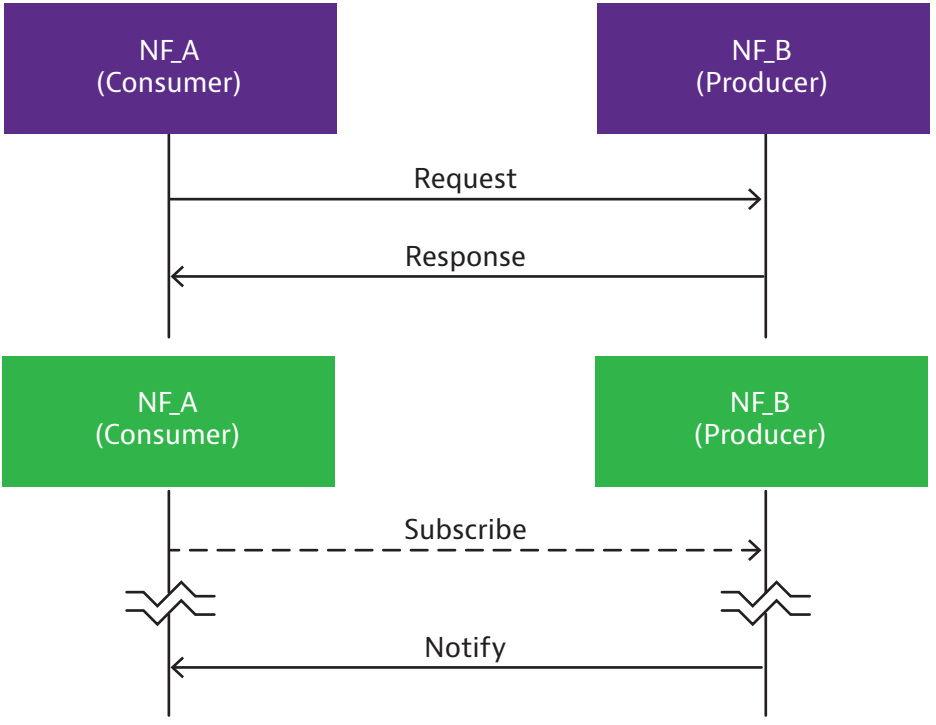

Core
Edge
Access
Radio Site
eMBB
NGC
RRC
PDCP
RLC
MAC
High PHY
Low PHY
RF
uRLLC
NGC
RRC
PDCP
RLC
MAC
High PHY
Low PHY
RF


eNB
S1-MME
4G/LTE EPC
HSS
EPS-NAS
MME
S6a
S10
S11
SGW
S1-U
S5/58
PGW
Gx
PCRF
SGi

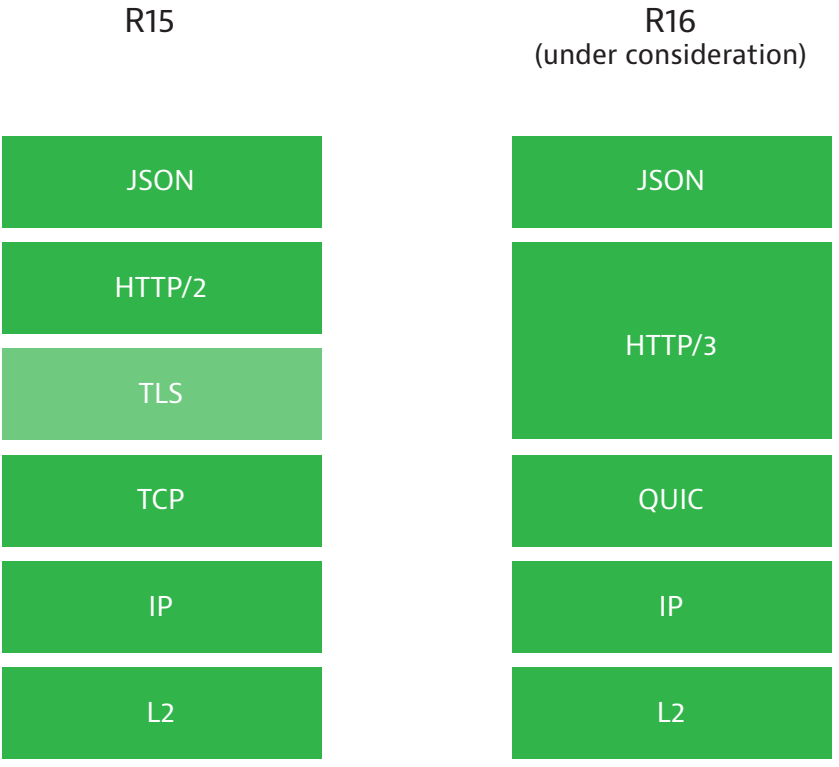

MME
MME
MME
S10
S11
S10
S11
S10
SGW
C-SGN
(PGW-SGW)
SGW-C
Sxa
SGW-U
Connected
to Base
Station
S5/58
S5/S8-C
S5/S8-U
PGW
PGW-C
Sxb
PGW-U
SGi
4G PS Only
(LTE-SAE)
4G Cellular
IoT Core
CIoT Service
Gateway Node
Control User Plane
Separation CUPS


N6
N9
eCPRI/RoE,
O-RAN
RU
DU
F1
CU/UPF
N1
N2
UDM
N13
AUSF
N12
AMF
N10
N3
N11
N14
SMF
N4
N15
N7
N4
N16
PCF
UPF
N9
N6
5G CORE

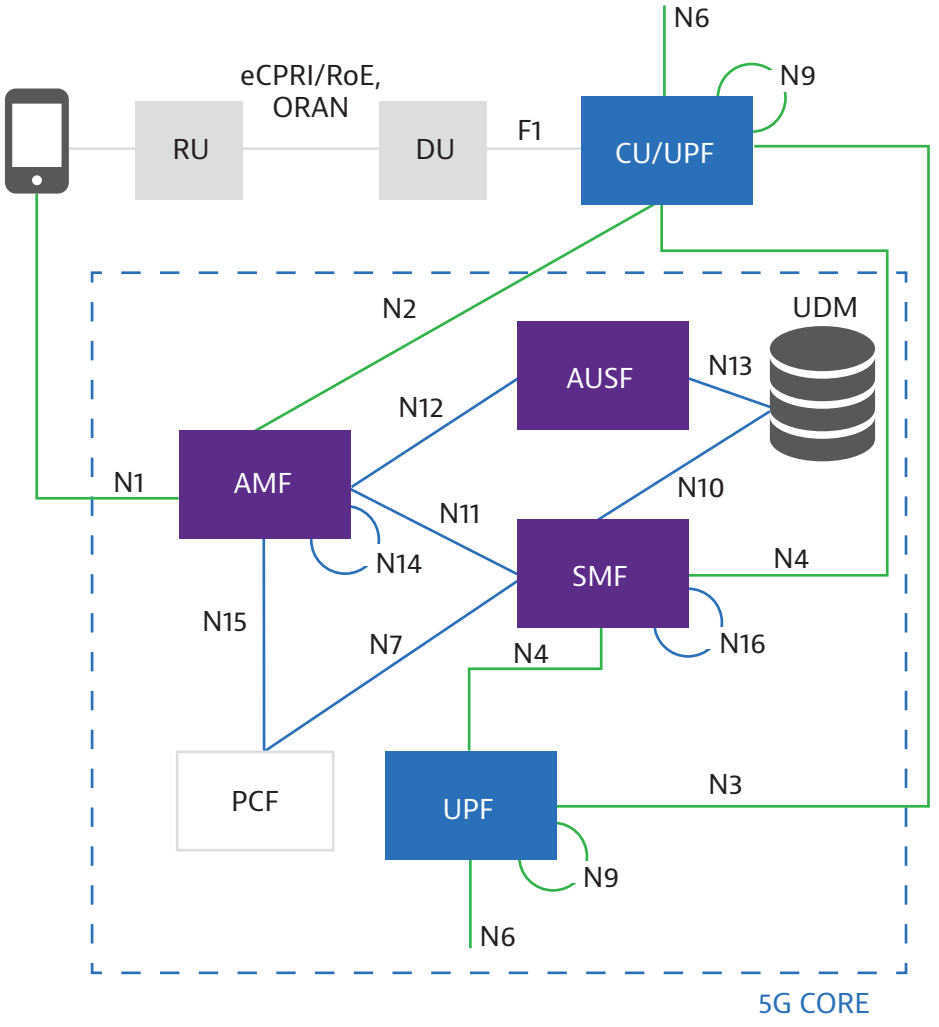

eNB
S1-MME
4G/LTE EPC
EPS-NAS
MME
S6a
HSS
S10
S11
SGW
S1-U
S5/58
PGW
Gx
PCRF
SGi
N6
N9
eCPRI/RoE,
O-RAN
RU
DU
F1
CU/UPF
N1
N2
UDM
N12
AUSF
N13
AMF
N11
N10
N3
N14
SMF
N4
N15
N7
N4
N16
PCF
UPF
N9
N6
5G CORE

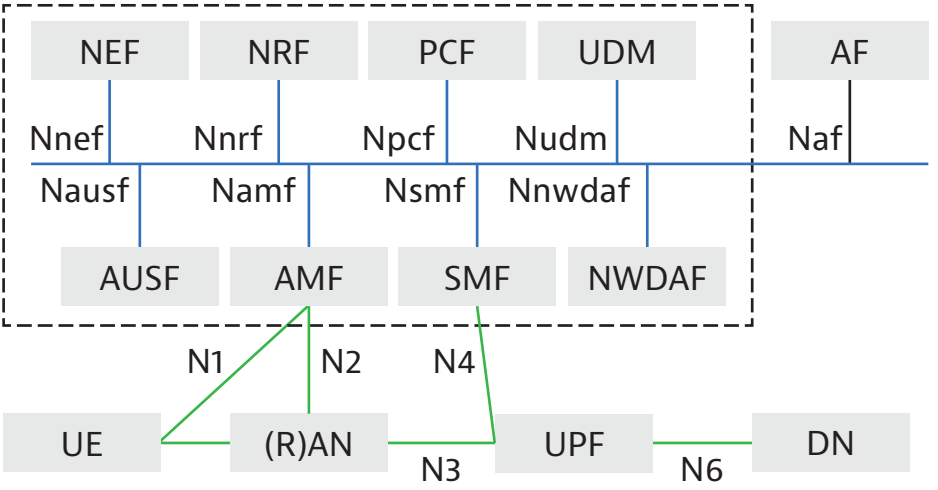


3GPP TS 23.501



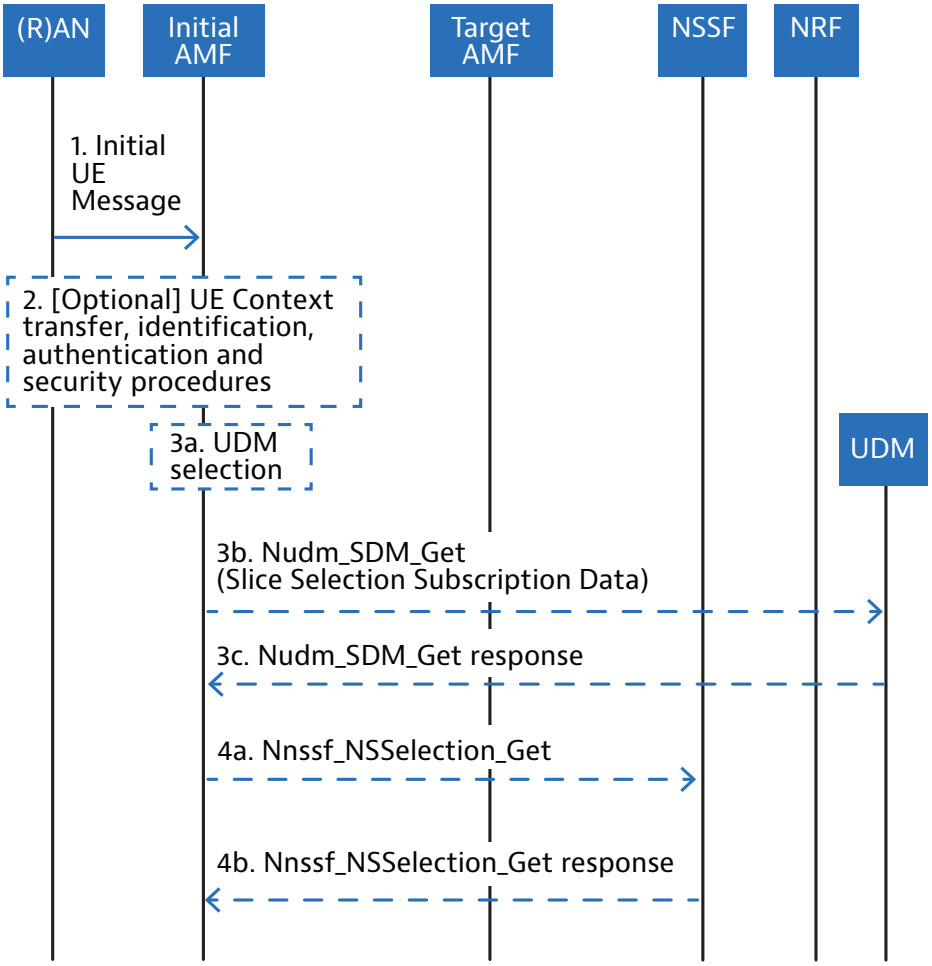
3GPP TR 29.893


N6
N9
eCPRI/RoE,
ORAN
RU
DU
F1
CU/UPF
N2
UDM
AUSF
N13
N12
AMF
N1
N10
N11
N14
SMF
N4
N15
N7
N16
N4
PCF
UPF
N3
N9
N6
5G CORE
Classic
Service Based

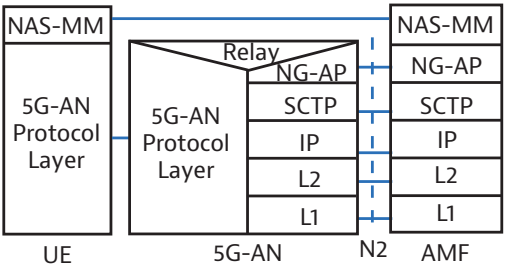


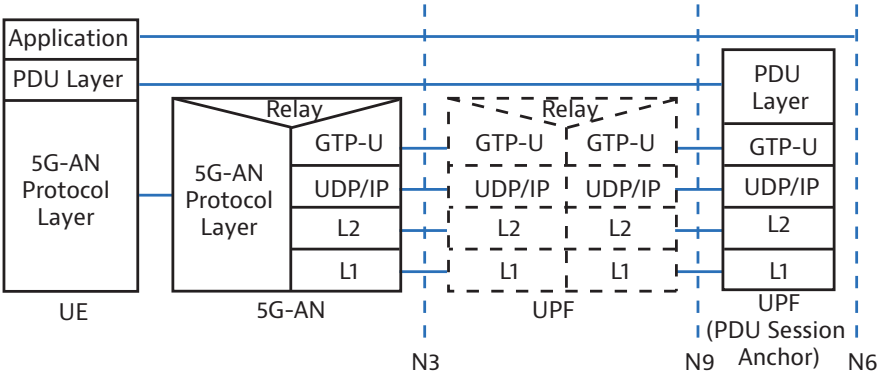
Classic

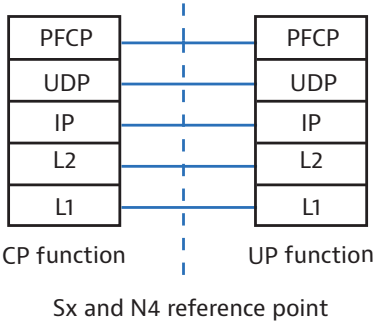
Service Based

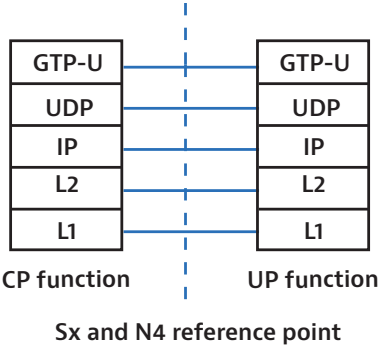


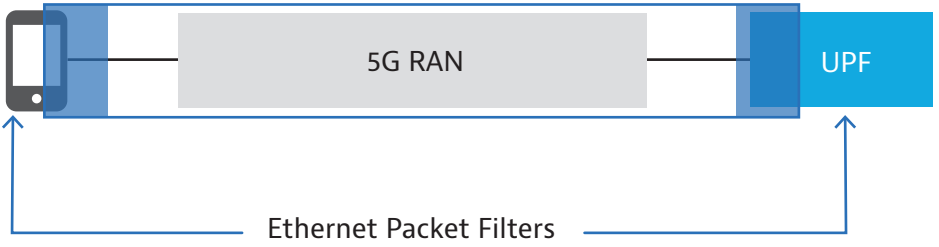
3GPP TS 23.502 Figure 4.2.2.2.3-1

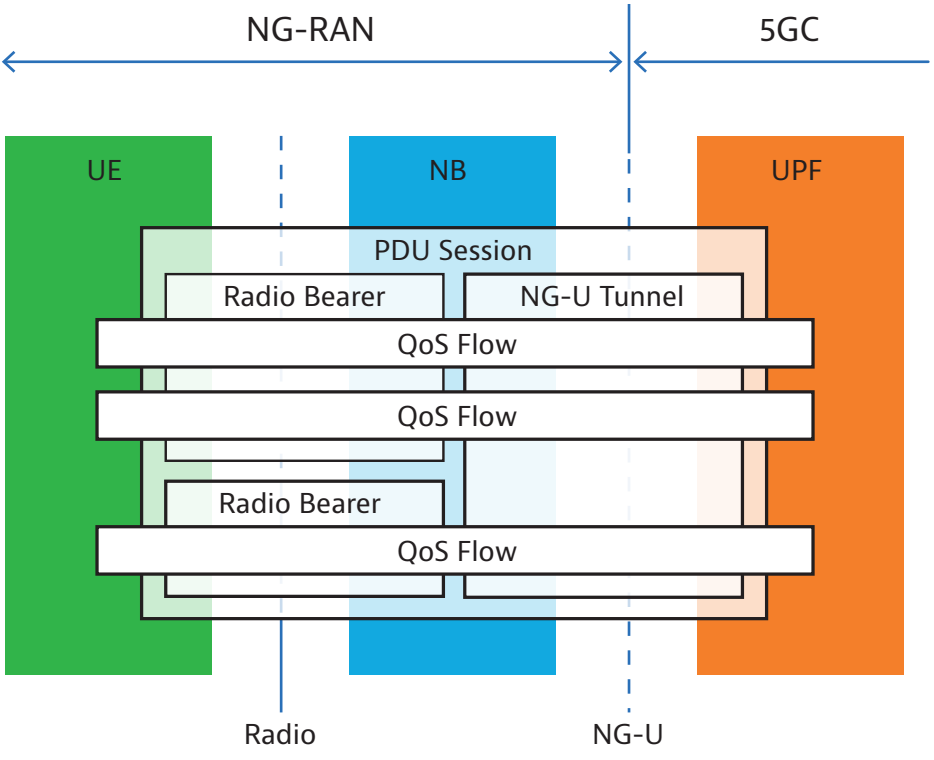

NAS-MM
5G-AN Protocol Layer
Relay
NG-AP
SCTP
IP
L2
L1
5G-AN Protocol Layer
NAS-MM
NG-AP
SCTP
IP
L2
L1
UE
5G-AN
N2
AMF


Application
PDU Layer
5G-AN Protocol Layer
Relay
GTP-U
UDP/IP
L2
L1
5G-AN Protocol Layer
Relay
GTP-U
UDP/IP
L2
L1
GTP-U
UDP/IP
L2
L1
PDU Layer
GTP-U
UDP/IP
L2
L1
UE
5G-AN
UPF
UPF (PDU Session Anchor)
N3
N9
N6


PFCP
UDP
IP
L2
L1
PFCP
UDP
IP
L2
L1
CP function
UP function
Sx and N4 reference point


GTP-U
UDP
IP
L2
L1
GTP-U
UDP
IP
L2
L1
CP function
UP function
Sx and N4 reference point

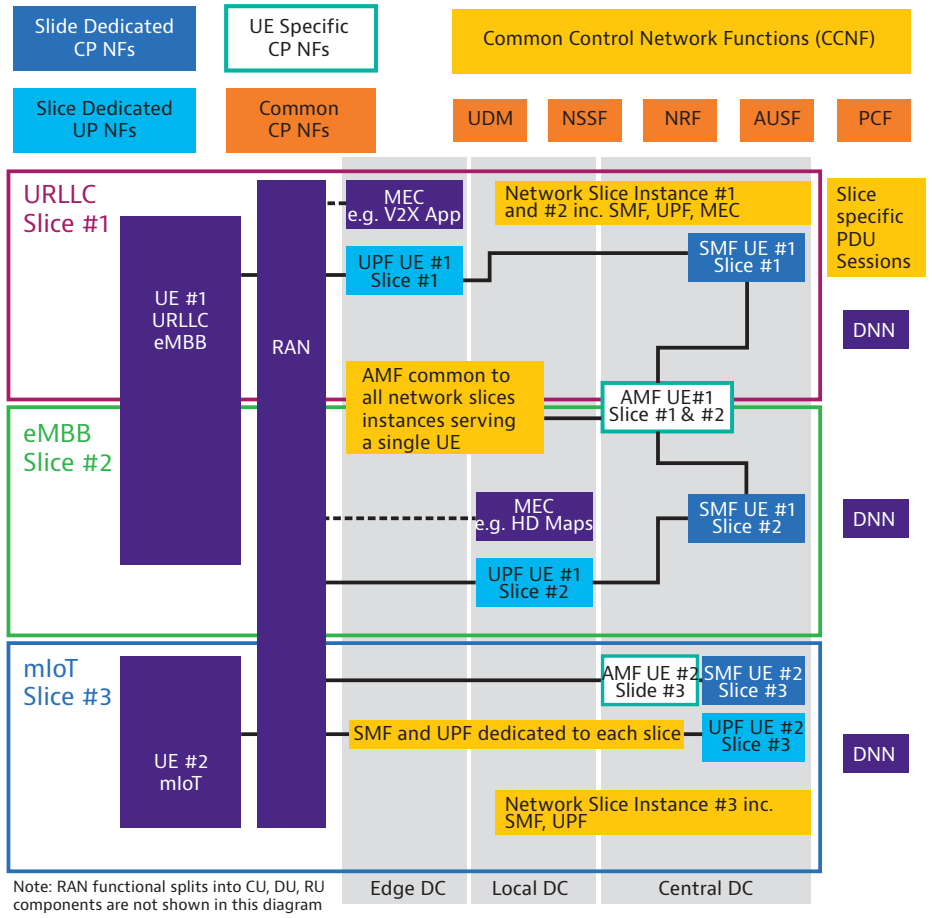

5G RAN
UPF
Ethernet Packet Filters


NG-RAN
5GC
UE
NB
UPF
PDU Session
Radio Bearer
NG-U Tunnel
QoS Flow
QoS Flow
Radio Bearer
QoS Flow
Radio
NG-U

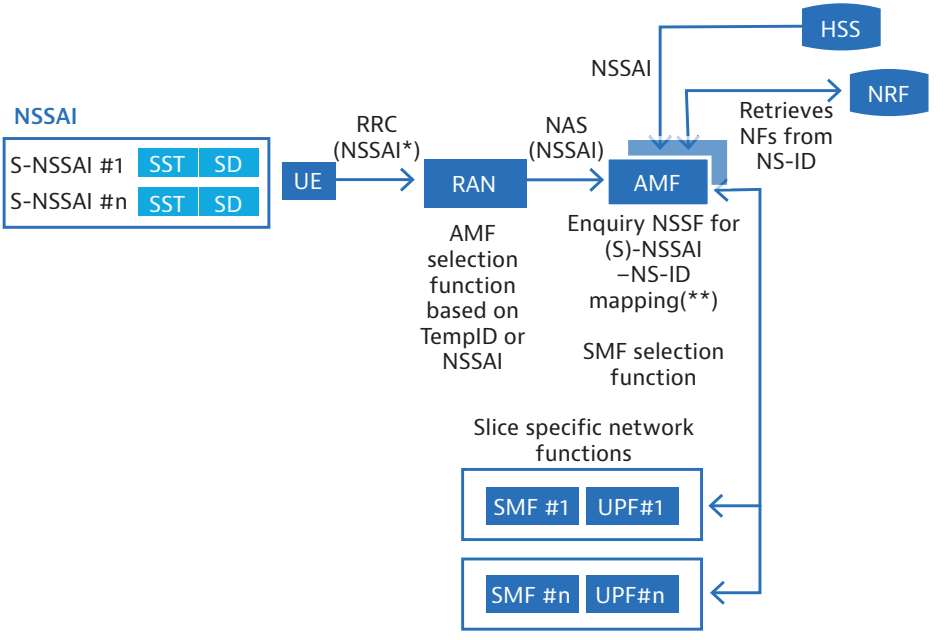
Bits								Number of Octets
7	6	5	4	3	2	1	0	
PDU Type (=0)				Spare				1
PPP	RQI	QoS Flow Identifier						1
PPI				Spare				0 or 1
Padding								0 - 3

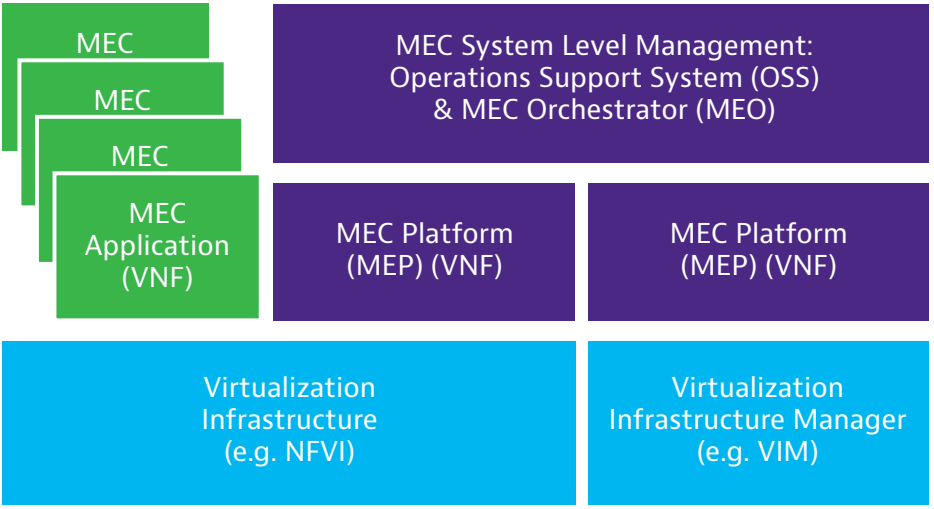
Bits								Number of Octets
7	6	5	4	3	2	1	0	
PDU Type (=1)				Spare				1
Spare	QoS Flow Identifier							1
Padding								0 - 3

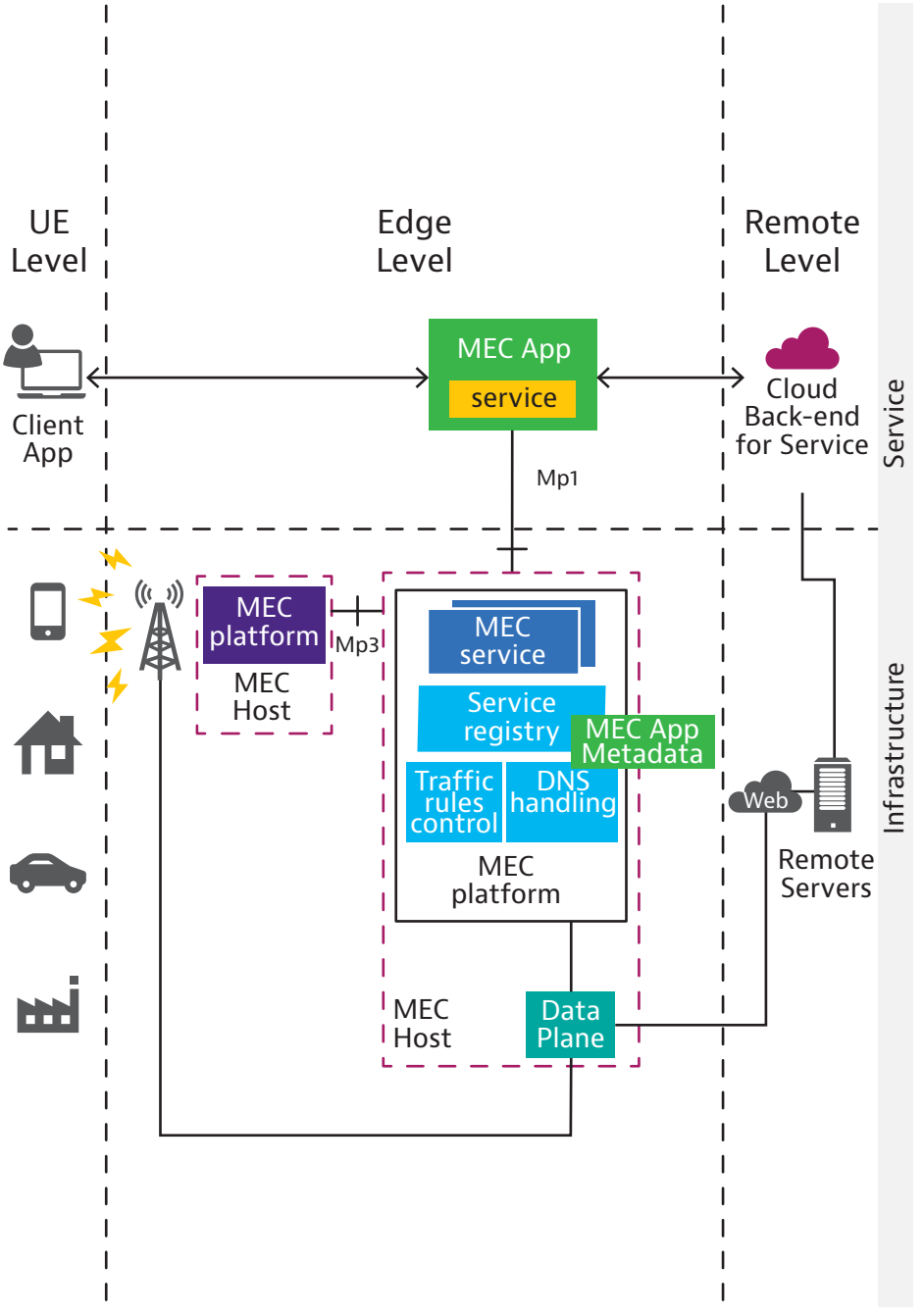
End to End (E2E) Slicing Orchestration and Management System

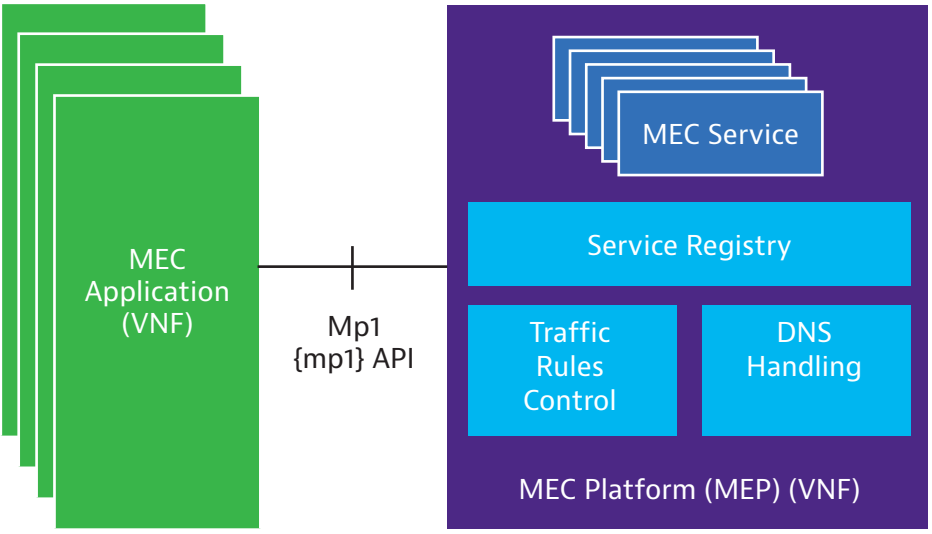


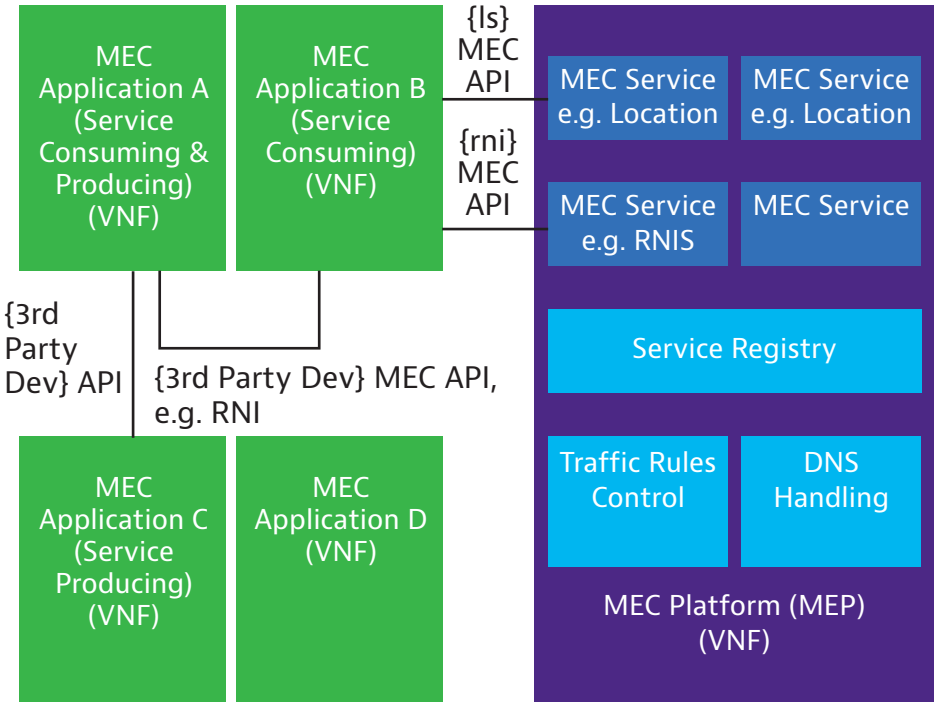
Note: RAN functional splits into CU, DU, RU components are not shown in this diagram

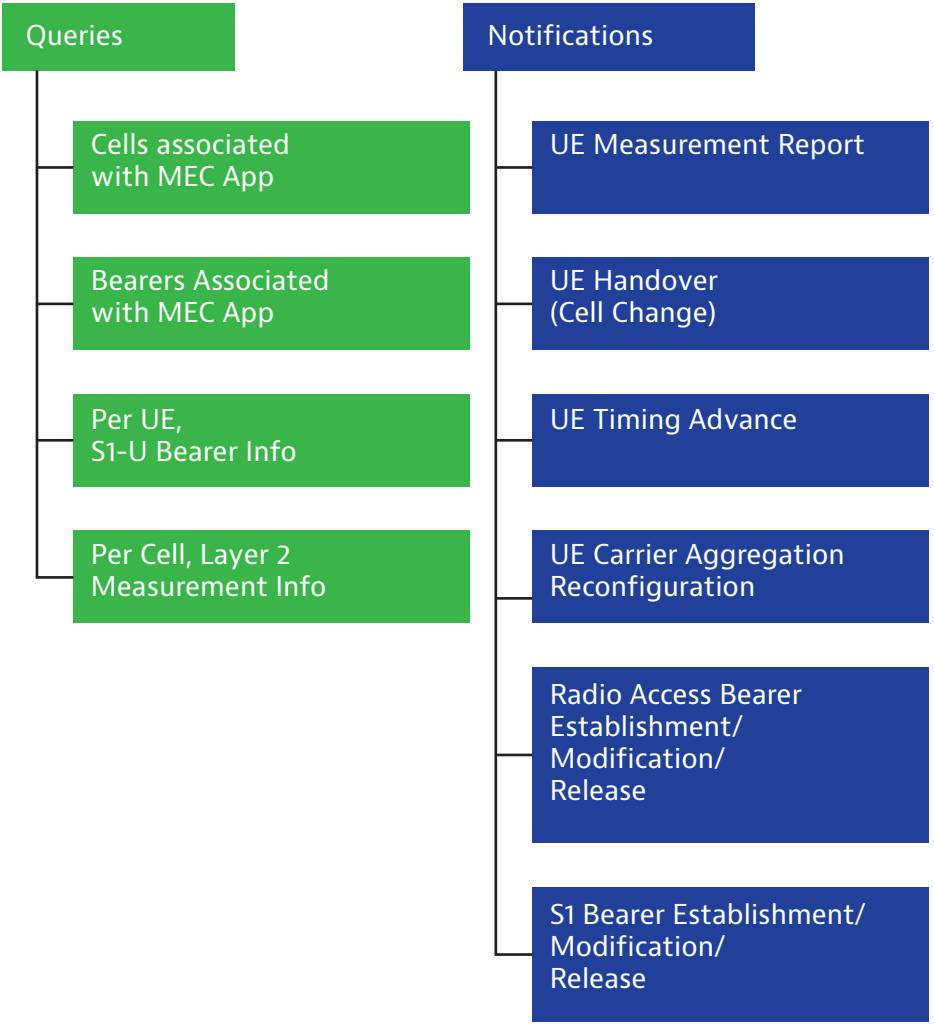

NSSAI
S-NSSAI #1
SST
SD
S-NSSAI #n
SST
SD
UE
RRC
(NSSAI*)
RAN
NAS
(NSSAI)
AMF
HSS
NSSAI
NRF
Retrieves
NFs from
NS-ID
AMF
selection
function
based on
TempID or
NSSAI
Enquiry NSSF for
(S)-NSSAI
–NS-ID
mapping(**)
SMF selection
function
Slice specific network
functions
SMF #1
UPF#1
SMF #n
UPF#n

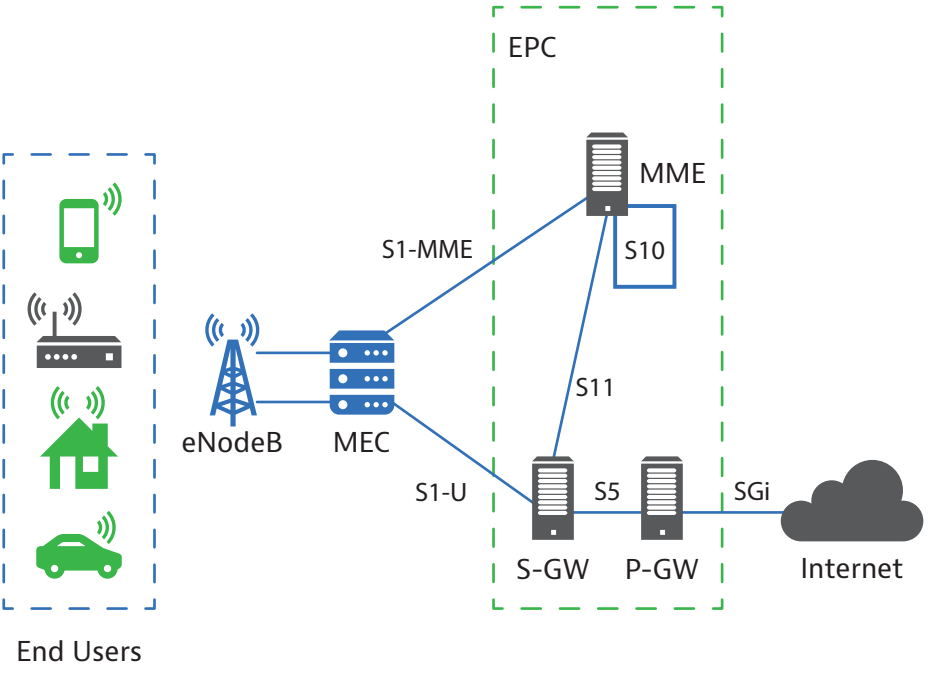

MEC
MEC
MEC
MEC Application (VNF)
MEC System Level Management: Operations Support System (OSS) & MEC Orchestrator (MEO)
MEC Platform (MEP) (VNF)
MEC Platform (MEP) (VNF)
Virtualization Infrastructure (e.g. NFVI)
Virtualization Infrastructure Manager (e.g. VIM)

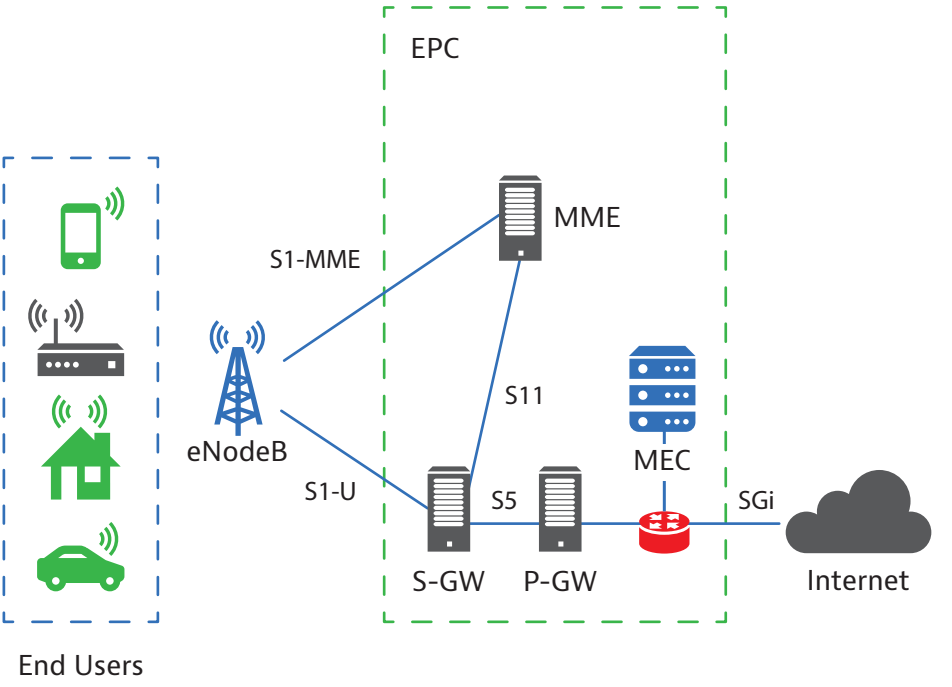

UE Level
Edge Level
Remote Level
Client App
MEC App
service
Cloud Back-end for Service
Service
Mp1
MEC platform
MEC Host
Mp3
MEC service
Service registry
MEC App Metadata
Traffic rules control
DNS handling
MEC platform
MEC Host
Data Plane
Web
Remote Servers
Infrastructure

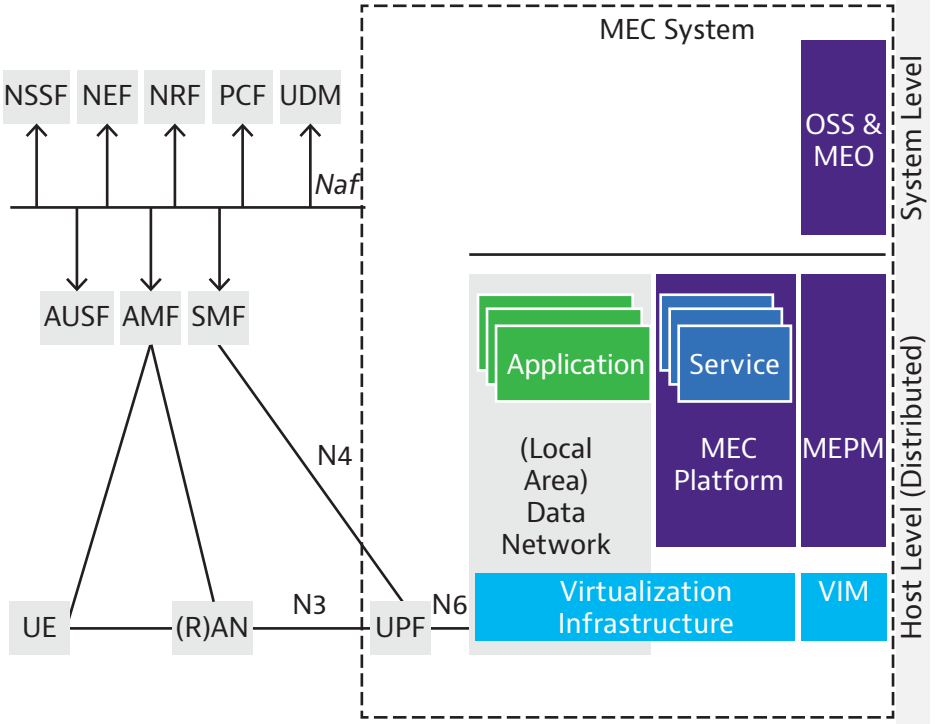

MEC Application (VNF)
Mp1 {mp1} API
MEC Service
Service Registry
Traffic Rules Control
DNS Handling
MEC Platform (MEP) (VNF)

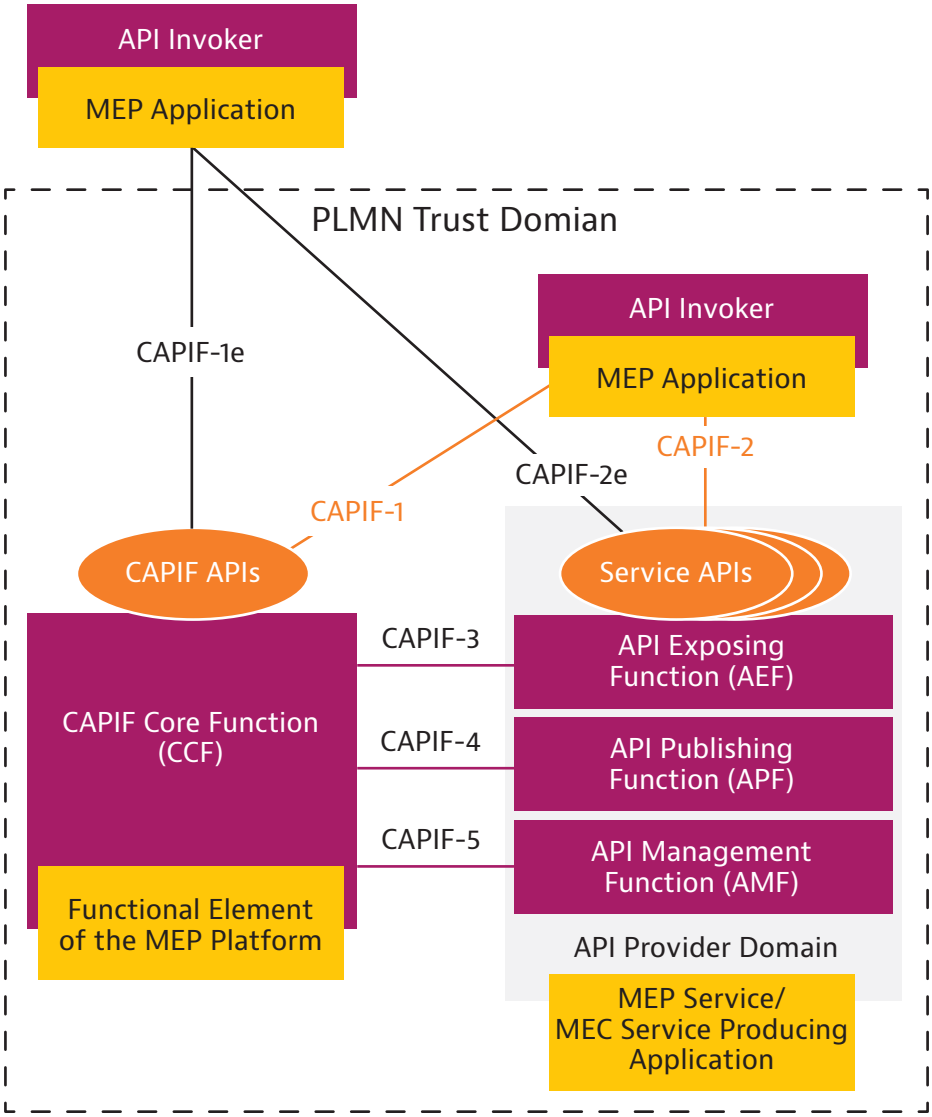

MEC Application A (Service Consuming & Producing) (VNF)
MEC Application B (Service Consuming) (VNF)
{ls} MEC API
{rni} MEC API
MEC Service e.g. Location
MEC Service e.g. Location
MEC Service e.g. RNIS
MEC Service
Service Registry
Traffic Rules Control
DNS Handling
MEC Platform (MEP) (VNF)
{3rd Party Dev} API
{3rd Party Dev} MEC API, e.g. RNI
MEC Application C (Service Producing) (VNF)
MEC Application D (VNF)

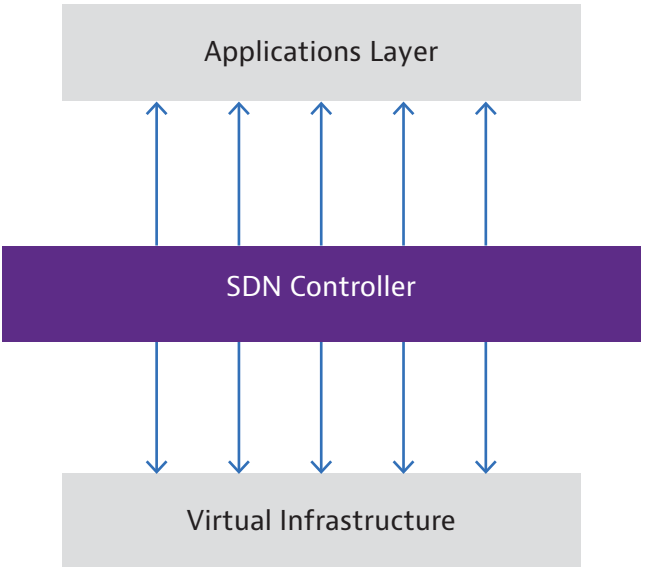

Queries
Cells associated with MEC App
Bearers Associated with MEC App
Per UE, S1-U Bearer Info
Per Cell, Layer 2 Measurement Info
Notifications
UE Measurement Report
UE Handover (Cell Change)
UE Timing Advance
UE Carrier Aggregation Reconfiguration
Radio Access Bearer Establishment/ Modification/ Release
S1 Bearer Establishment/ Modification/ Release

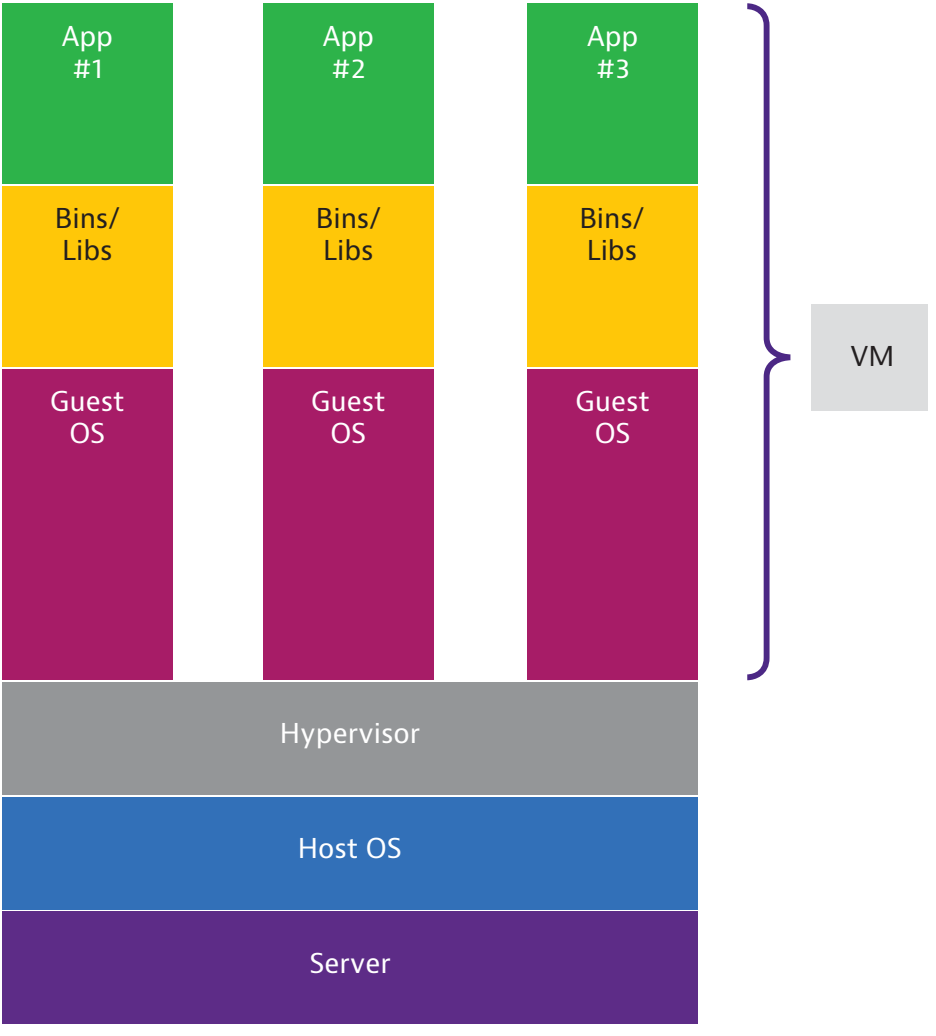

EPC
MME
S1-MME
S10
S11
eNodeB
MEC
S1-U
S5
SGi
S-GW
P-GW
Internet
End Users

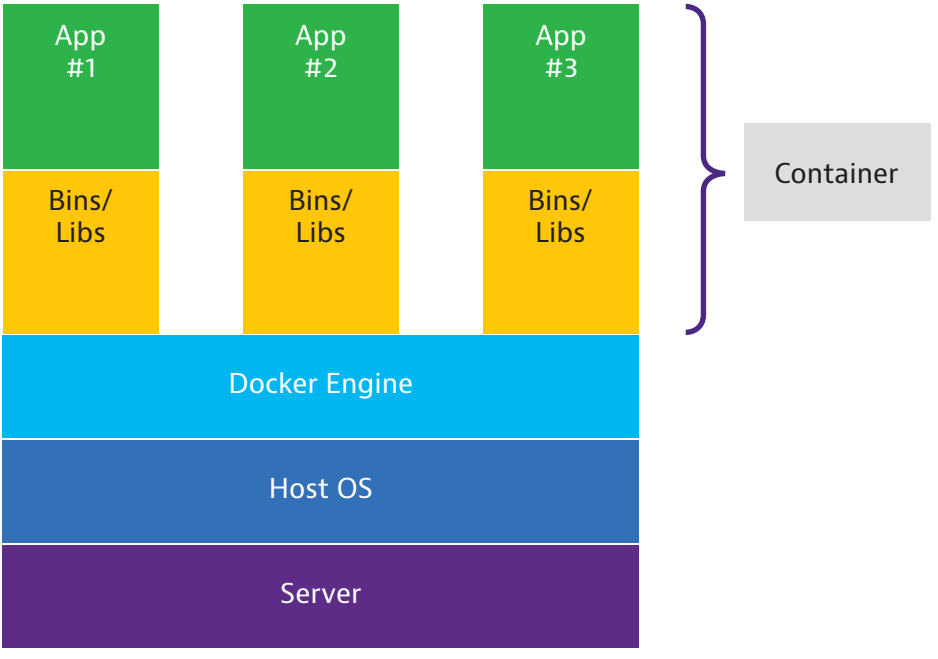

EPC
MME
S1-MME
S11
eNodeB
MEC
S1-U
S5
SGi
S-GW
P-GW
Internet
End Users


MEC System
NSSF
NEF
NRF
PCF
UDM
Naf
OSS &
MEO
System Level
AUSF
AMF
SMF
Application
Service
(Local
Area)
Data
Network
MEC
Platform
MEPM
N4
Host Level (Distributed)
UE
(R)AN
N3
UPF
N6
Virtualization
Infrastructure
VIM

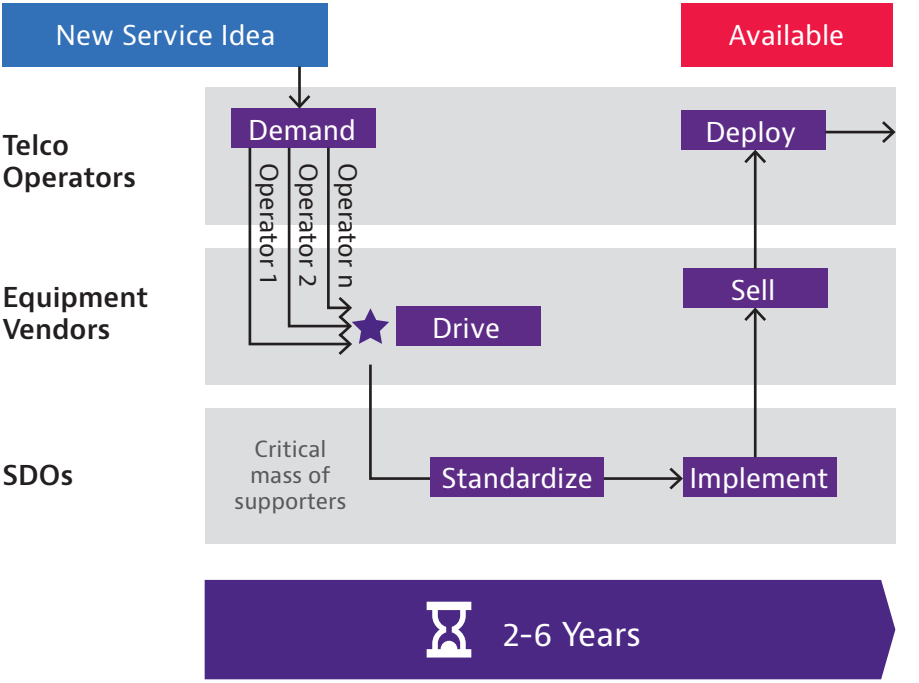

API Invoker
MEP Application
PLMN Trust Domian
CAPIF-1e
API Invoker
MEP Application
CAPIF-2
CAPIF-2e
CAPIF-1
CAPIF APIs
Service APIs
CAPIF-3
CAPIF Core Function (CCF)
API Exposing Function (AEF)
CAPIF-4
API Publishing Function (APF)
CAPIF-5
API Management Function (AMF)
Functional Element of the MEP Platform
API Provider Domain
MEP Service/ MEC Service Producing Application


Applications Layer
SDN Controller
Virtual Infrastructure

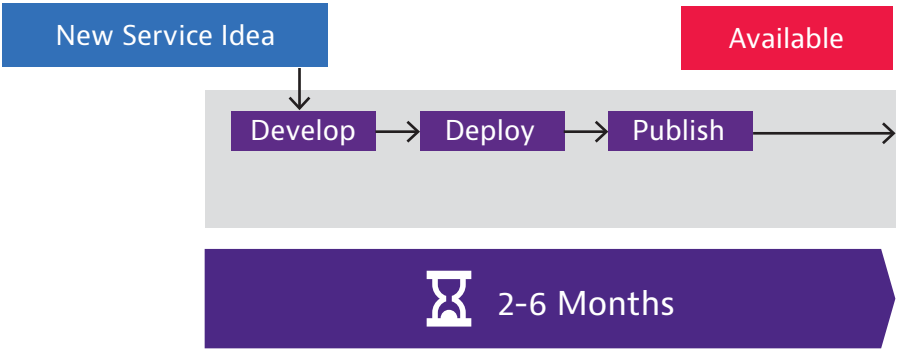

App #1
App #2
App #3
Bins/ Libs
Bins/ Libs
Bins/ Libs
Guest OS
Guest OS
Guest OS
VM
Hypervisor
Host OS
Server

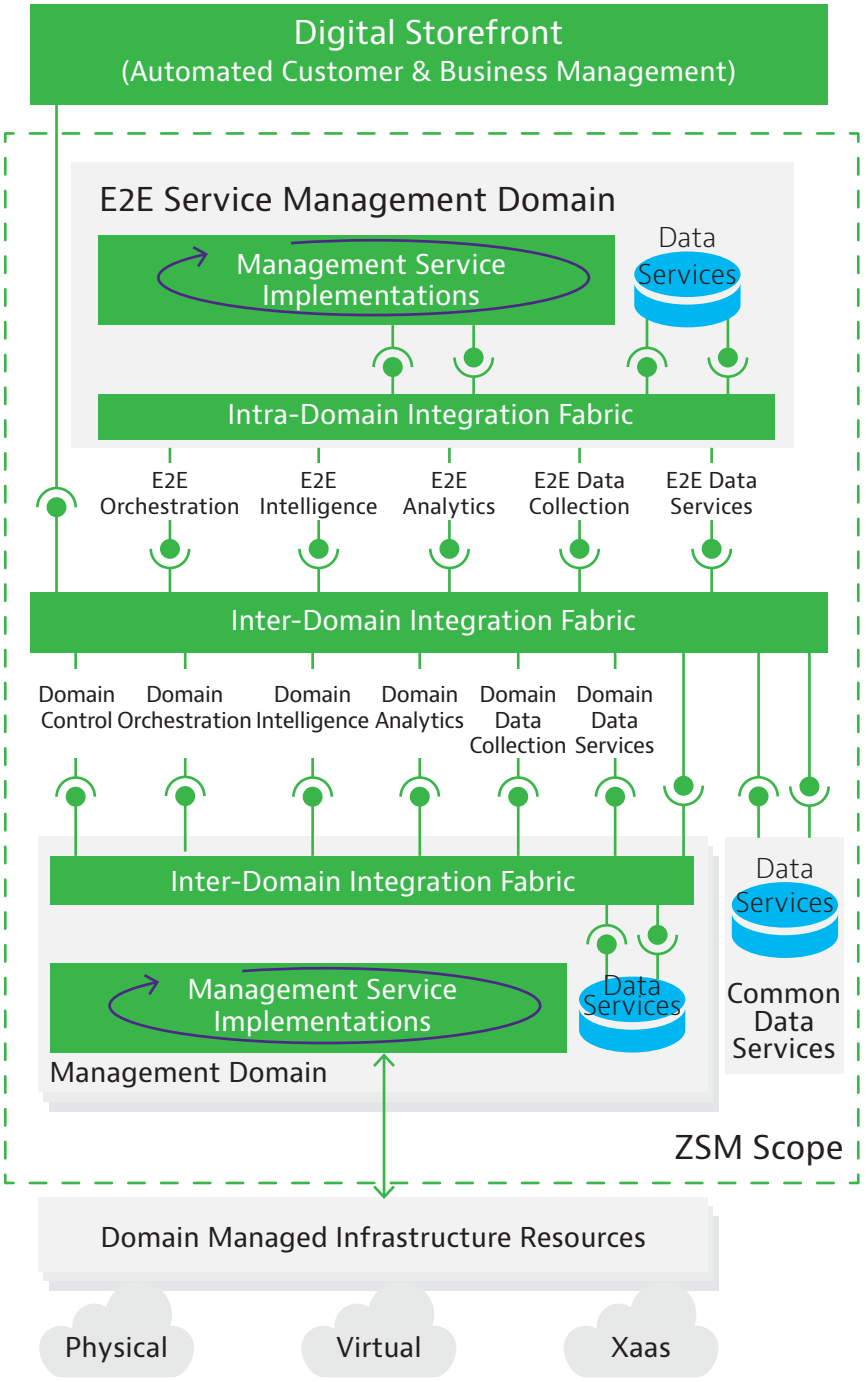

App
#1
App
#2
App
#3
Bins/
Libs
Bins/
Libs
Bins/
Libs
Container
Docker Engine
Host OS
Server

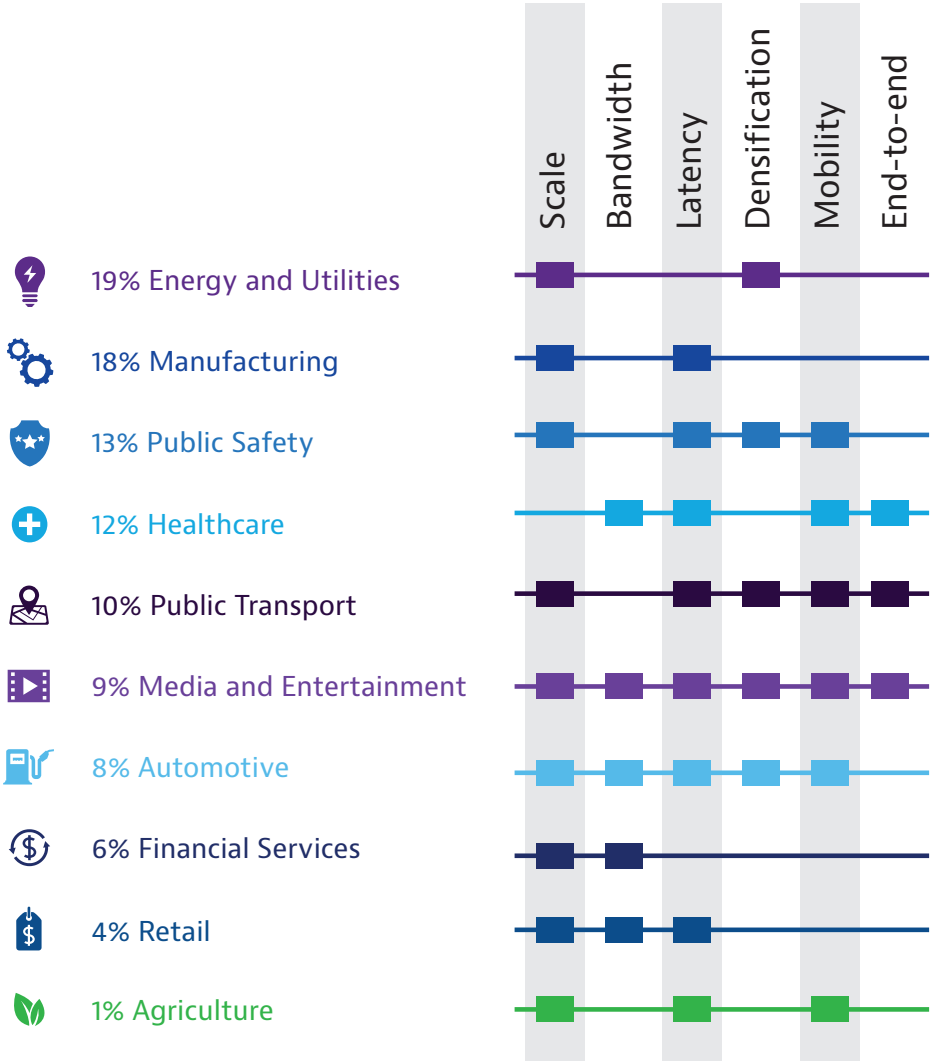
Telco Cycle

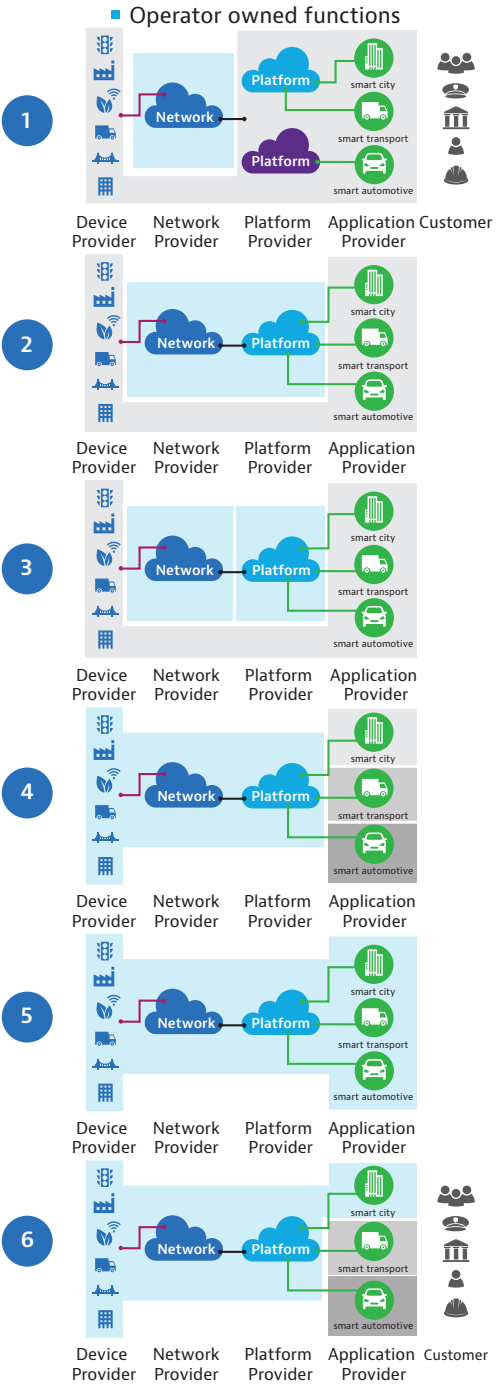


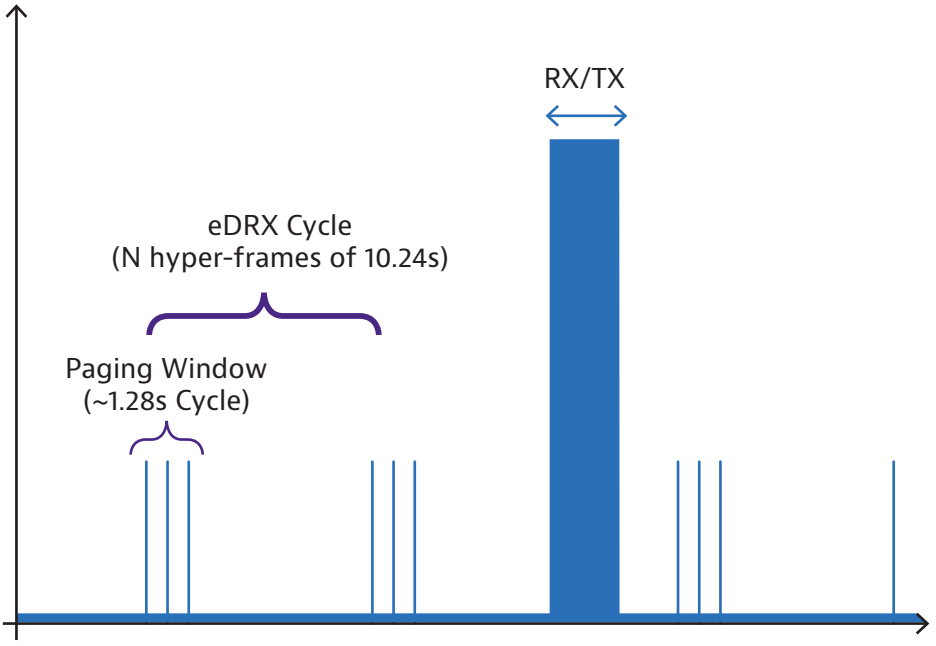
OTT Provider Cycle

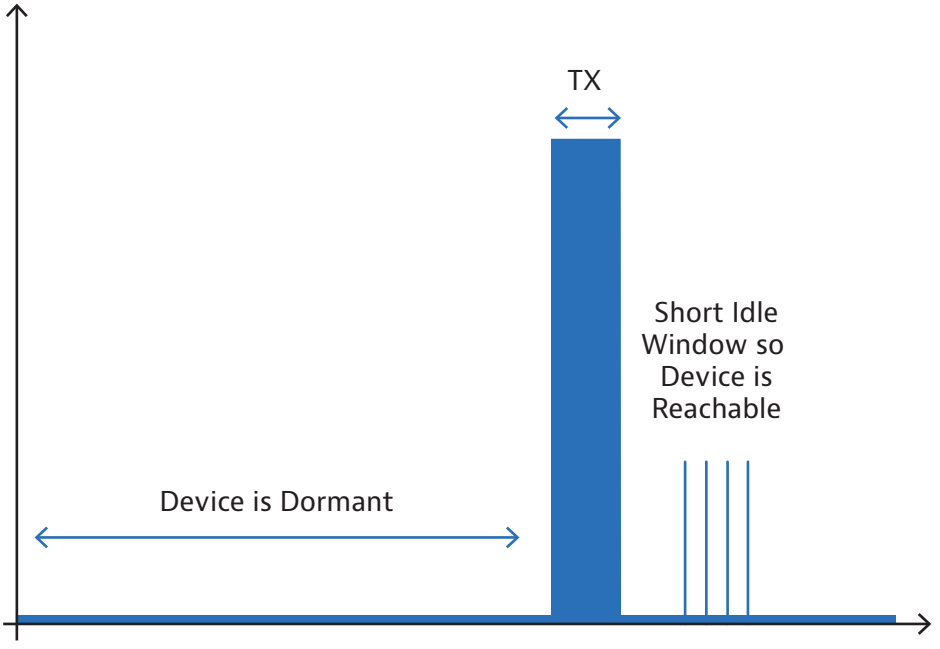



Digital Storefront
(Automated Customer & Business Management)
E2E Service Management Domain
Management Service Implementations
Data Services
Intra-Domain Integration Fabric
E2E Orchestration
E2E Intelligence
E2E Analytics
E2E Data Collection
E2E Data Services
Inter-Domain Integration Fabric
Domain Control
Domain Orchestration
Domain Intelligence
Domain Analytics
Domain Data Collection
Domain Data Services
Inter-Domain Integration Fabric
Data Services
Management Service Implementations
Data Services
Common Data Services
Management Domain
ZSM Scope
Domain Managed Infrastructure Resources
Physical
Virtual
Xaas

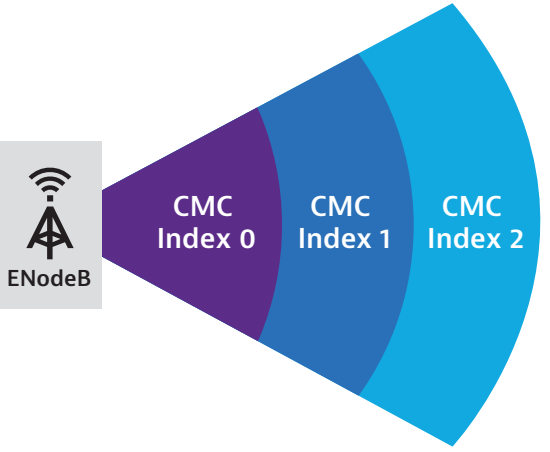

Scale
Bandwidth
Latency
Densification
Mobility
End-to-end
19% Energy and Utilities
18% Manufacturing
13% Public Safety
12% Healthcare
10% Public Transport
9% Media and Entertainment
8% Automotive
6% Financial Services
4% Retail
1% Agriculture


Operator owned functions
1
Network
Platform
Platform
smart city
smart transport
smart automotive
Device Provider
Network Provider
Platform Provider
Application Provider
Customer
2
Network
Platform
smart city
smart transport
smart automotive
Device Provider
Network Provider
Platform Provider
Application Provider
3
Network
Platform
smart city
smart transport
smart automotive
Device Provider
Network Provider
Platform Provider
Application Provider
4
Network
Platform
smart city
smart transport
smart automotive
Device Provider
Network Provider
Platform Provider
Application Provider
5
Network
Platform
smart city
smart transport
smart automotive
Device Provider
Network Provider
Platform Provider
Application Provider
6
Network
Platform
smart city
smart transport
smart automotive
Device Provider
Network Provider
Platform Provider
Application Provider
Customer

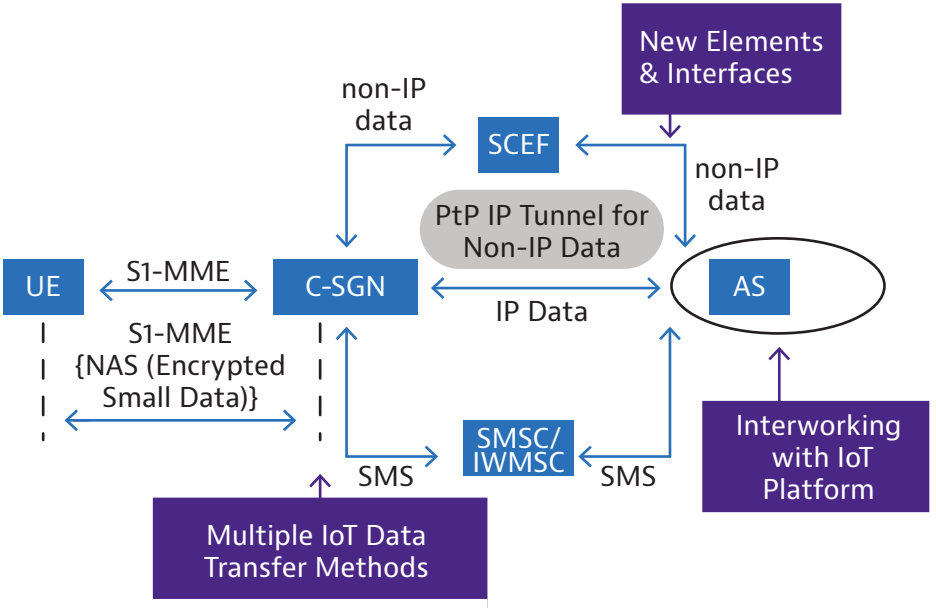

RX/TX
eDRX Cycle
(N hyper-frames of 10.24s)
Paging Window
(~1.28s Cycle)

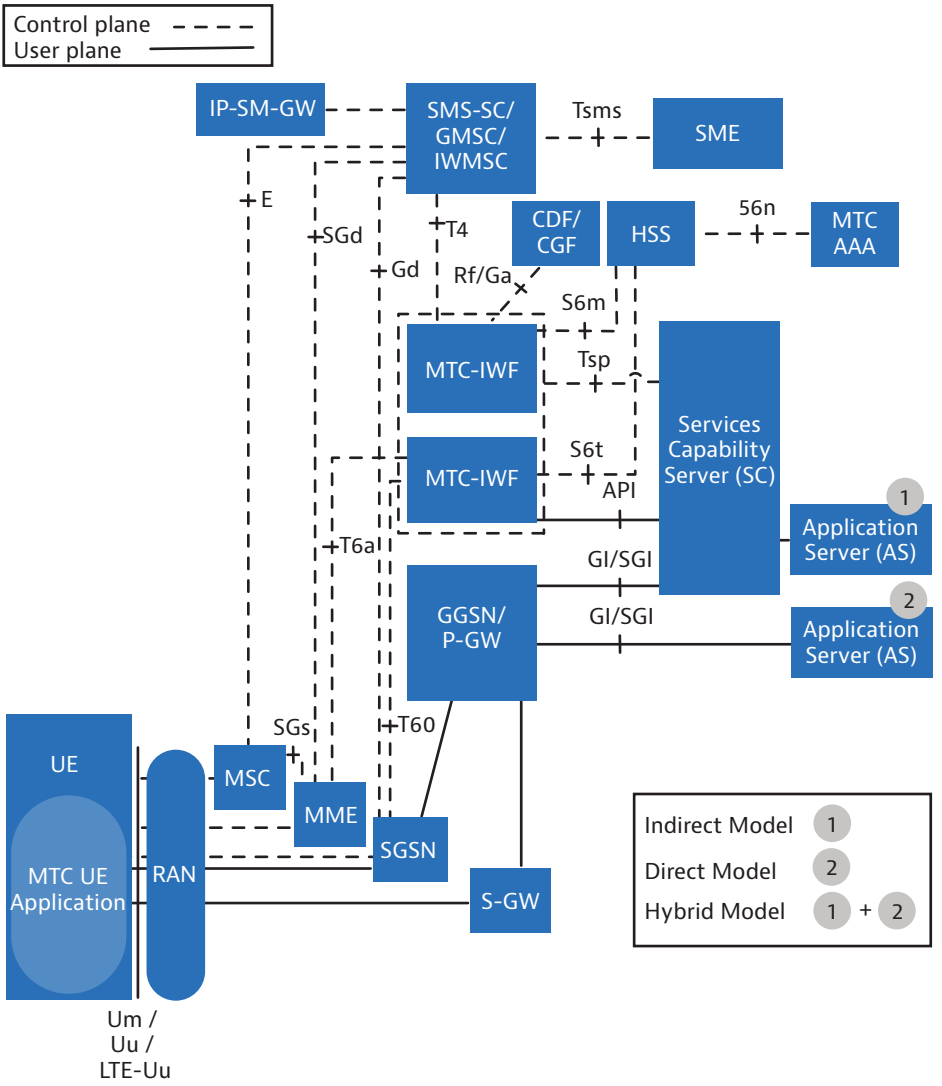

TX
Short Idle
Window so
Device is
Reachable
Device is Dormant

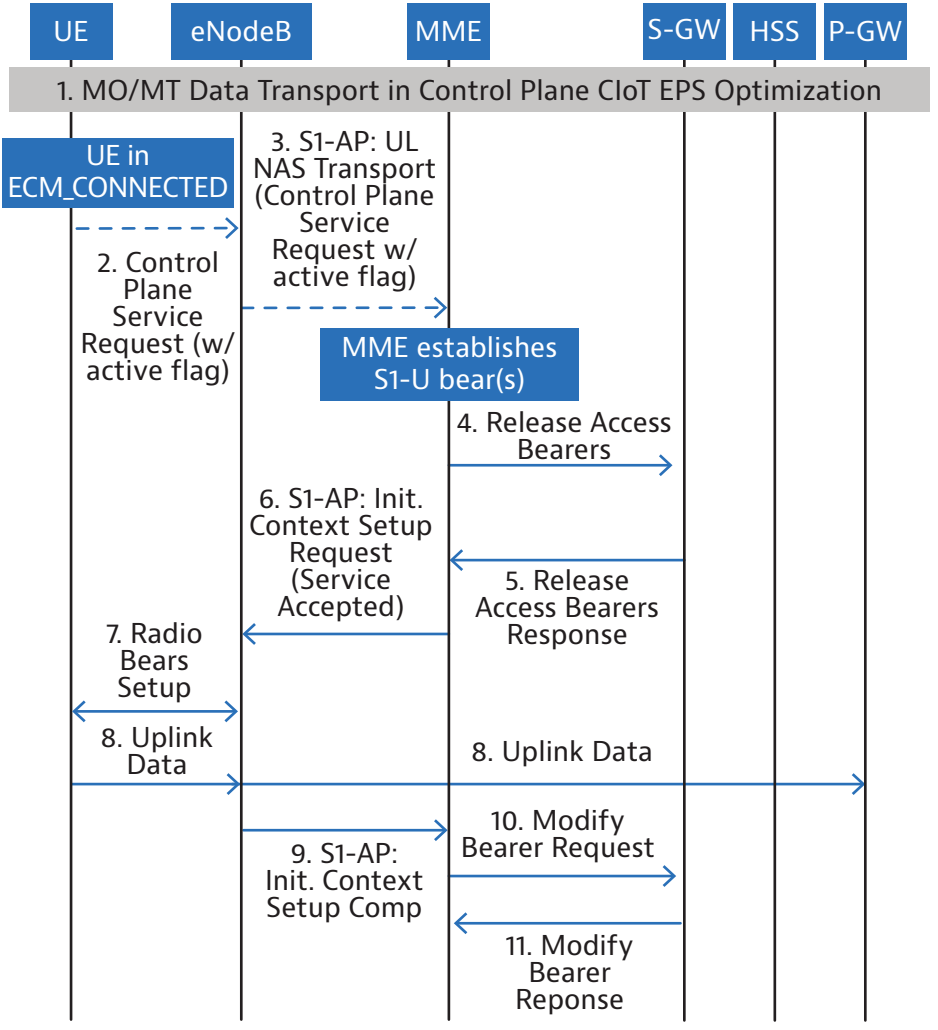
ManagedElement
+-ENodeBFunction
+-NblotCell
ceLevelNumber = 1 {1,2,3}
1 = CE_level1
2 = CE_level2
3 = CE_level3
cmcIndex = 0 {0,1,2}
0 = CMC Index 0
1 = CMC Index 1
2 = CMC Index 2

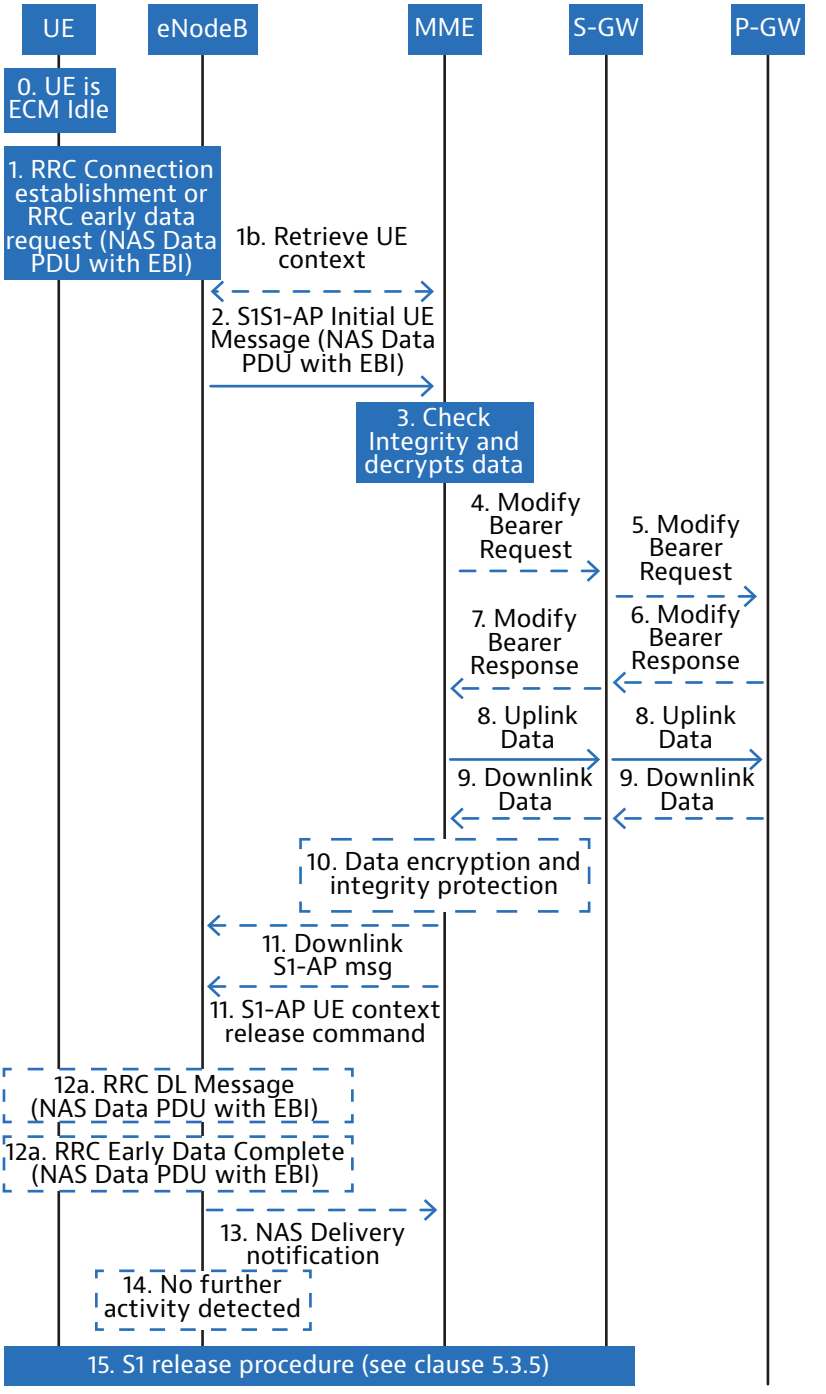


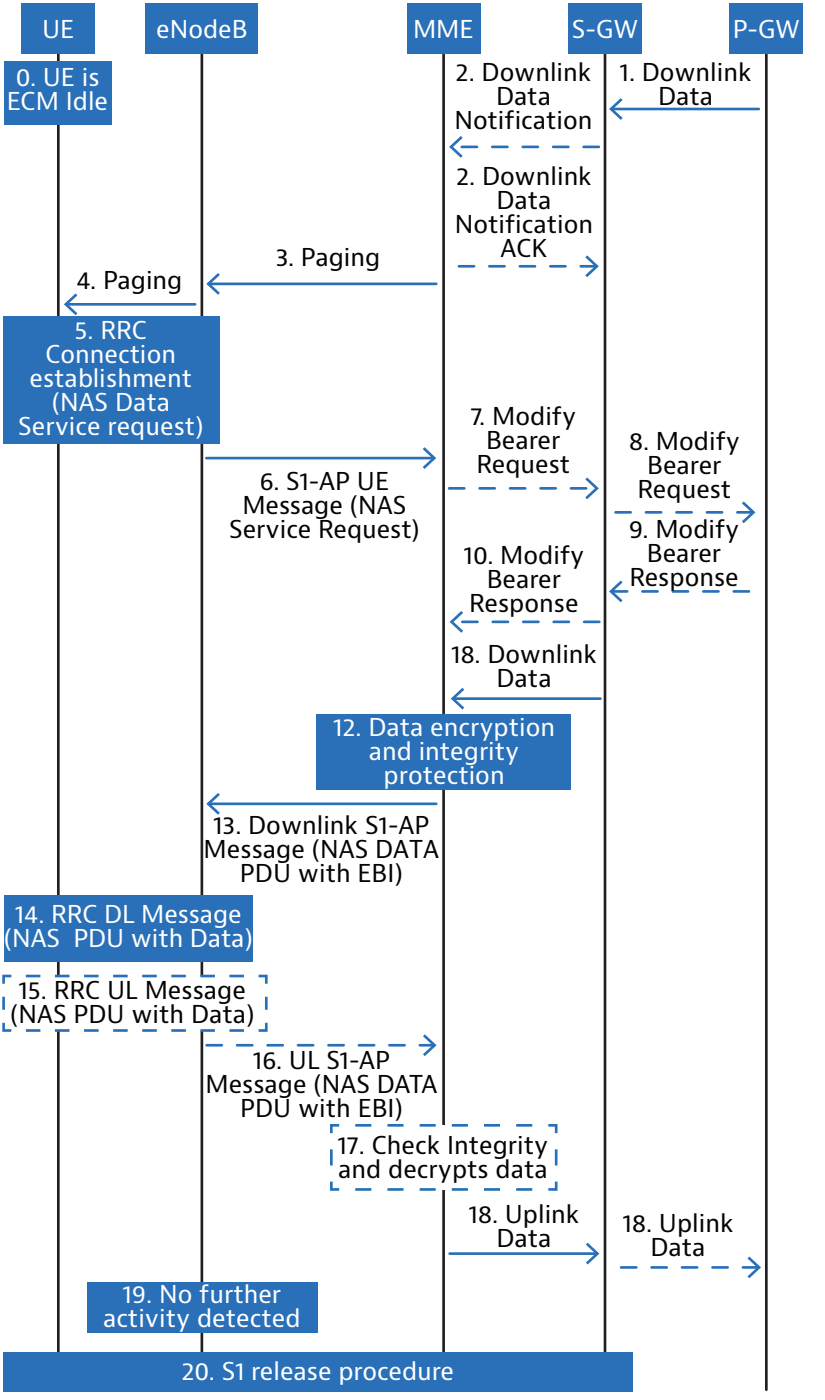
Channel (carrying)	Maximum Number of Repetitions		
	CMC Index 0	CMC Index 1	CMC Index 2
NPDSCH (NB-SIB1)	4	8	16
NPDCCH	2	16	64
NPUSCH (ACK/NACK)	2	16	64
NPRACH (preamble)	2	8	16

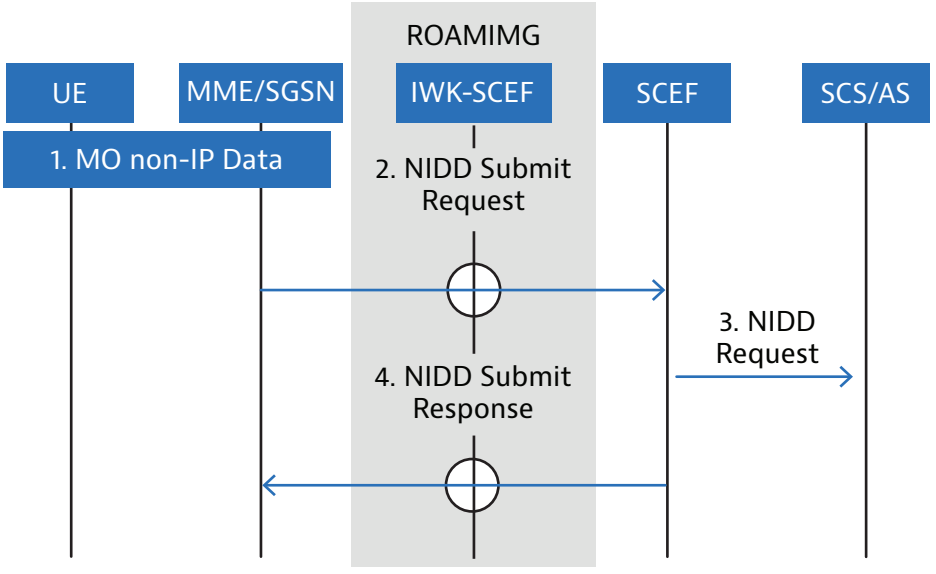

New Elements & Interfaces
non-IP data
SCEF
non-IP data
PtP IP Tunnel for Non-IP Data
UE
S1-MME
C-SGN
IP Data
AS
S1-MME {NAS (Encrypted Small Data)}
SMSC/ IWMSC
SMS
SMS
Interworking with IoT Platform
Multiple IoT Data Transfer Methods

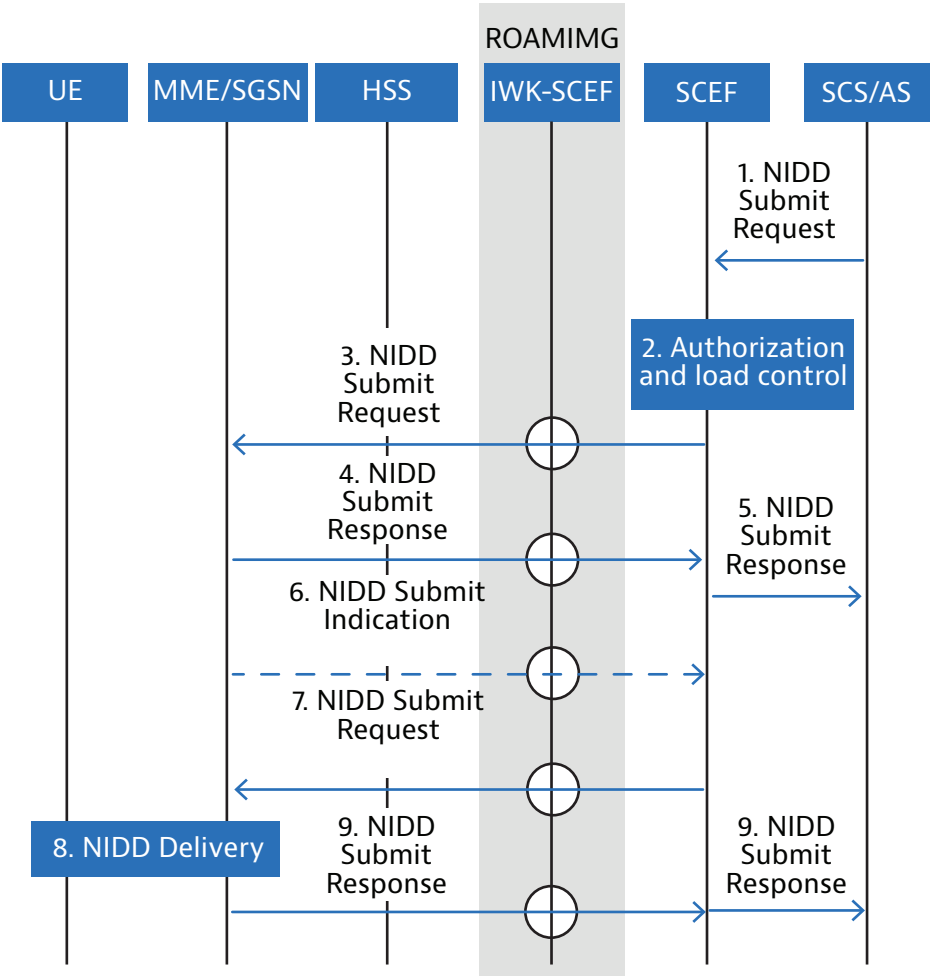

Control plane
User plane
IP-SM-GW
SMS-SC/
GMSC/
IWMSC
Tsms
SME
E
SGd
T4
CDF/
CGF
HSS
56n
MTC
AAA
Gd
Rf/Ga
S6m
MTC-IWF
Tsp
Services
Capability
Server (SC)
MTC-IWF
S6t
API
1
Application
Server (AS)
T6a
GI/SGI
GGSN/
P-GW
GI/SGI
2
Application
Server (AS)
SGs
T60
UE
MTC UE
Application
MSC
MME
SGSN
RAN
S-GW
Um /
Uu /
LTE-Uu
Indirect Model 1
Direct Model 2
Hybrid Model 1 + 2


UE
eNodeB
MME
S-GW
HSS
P-GW
1. MO/MT Data Transport in Control Plane CIoT EPS Optimization
UE in ECM_CONNECTED
2. Control Plane Service Request (w/ active flag)
3. S1-AP: UL NAS Transport (Control Plane Service Request w/ active flag)
MME establishes S1-U bear(s)
4. Release Access Bearers
5. Release Access Bearers Response
6. S1-AP: Init. Context Setup Request (Service Accepted)
7. Radio Bears Setup
8. Uplink Data
8. Uplink Data
9. S1-AP: Init. Context Setup Comp
10. Modify Bearer Request
11. Modify Bearer Reponse

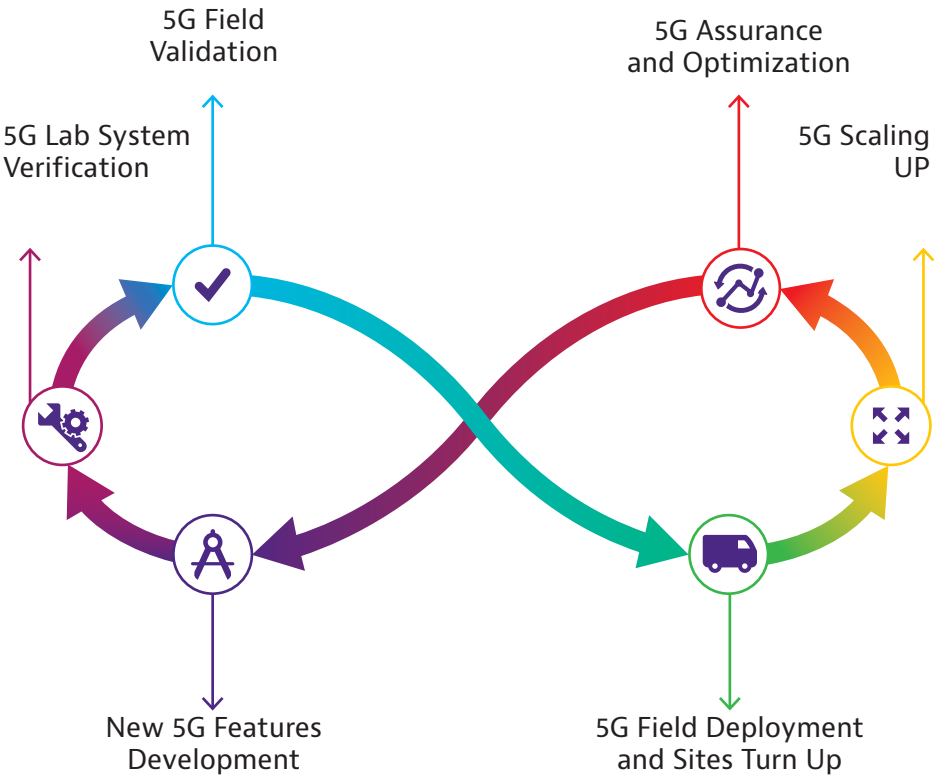

UE
eNodeB
MME
S-GW
P-GW
0. UE is ECM Idle
1. RRC Connection establishment or RRC early data request (NAS Data PDU with EBI)
1b. Retrieve UE context
2. S1S1-AP Initial UE Message (NAS Data PDU with EBI)
3. Check Integrity and decrypts data
4. Modify Bearer Request
5. Modify Bearer Request
6. Modify Bearer Response
7. Modify Bearer Response
8. Uplink Data
8. Uplink Data
9. Downlink Data
9. Downlink Data
10. Data encryption and integrity protection
11. Downlink S1-AP msg
11. S1-AP UE context release command
12a. RRC DL Message (NAS Data PDU with EBI)
12a. RRC Early Data Complete (NAS Data PDU with EBI)
13. NAS Delivery notification
14. No further activity detected
15. S1 release procedure (see clause 5.3.5)


UE
eNodeB
MME
S-GW
P-GW
0. UE is ECM Idle
2. Downlink Data Notification
1. Downlink Data
2. Downlink Data Notification ACK
3. Paging
4. Paging
5. RRC Connection establishment (NAS Data Service request)
7. Modify Bearer Request
8. Modify Bearer Request
6. S1-AP UE Message (NAS Service Request)
9. Modify Bearer Response
10. Modify Bearer Response
18. Downlink Data
12. Data encryption and integrity protection
13. Downlink S1-AP Message (NAS DATA PDU with EBI)
14. RRC DL Message (NAS PDU with Data)
15. RRC UL Message (NAS PDU with Data)
16. UL S1-AP Message (NAS DATA PDU with EBI)
17. Check Integrity and decrypts data
18. Uplink Data
18. Uplink Data
19. No further activity detected
20. S1 release procedure


ROAMIMG
UE
MME/SGSN
IWK-SCEF
SCEF
SCS/AS
1. MO non-IP Data
2. NIDD Submit Request
3. NIDD Request
4. NIDD Submit Response


ROAMIMG
UE
MME/SGSN
HSS
IWK-SCEF
SCEF
SCS/AS
1. NIDD Submit Request
2. Authorization and load control
3. NIDD Submit Request
4. NIDD Submit Response
5. NIDD Submit Response
6. NIDD Submit Indication
7. NIDD Submit Request
8. NIDD Delivery
9. NIDD Submit Response
9. NIDD Submit Response

Category	Application Example	Availability	UL Bandwidth & Data Size	DL Data Size	Frequency	Power	Delay Sensitivity	Coverage
Automotive	Connected Car	HIGH 99.9%	HIGH 10Mbps 200bytes	HIGH 200bytes	HIGH Continuous	LOW	HIGH 1ms	NORMAL
Industrial Control	Switch on/off, device triggered to send	HIGH 99.999%	HIGH 50Mbps 0-20bytes 50% of cases require UL response	HIGH 20bytes	MED 1 day (40%) 2hrs (40%) 1 hour (15%) 30mins (5%)	LOW	HIGH 1ms	DEEP
Utilities/ Meters	Smart Water Meter	LOW 99%	LOW 50kbps 20bytes with cut off of 200 bytes	LOW 50% of UL data size	MED 1 day (40%) 2hrs (40%) 1 hour (15%) 30mins (5%)	HIGH 10yrs & 4800mAH	LOW 5sec	DEEP
Security	Smoke alarm detectors, power failure otification, tamper notifications	HIGH 99.9%	LOW 50kbps 20bytes	LOW 0 ACK payload size is assumed to be 0bytes	LOW Every few months, Every Year	LOW	MED 1sec	DEEP


5G Field
Validation
5G Assurance
and Optimization
5G Lab System
Verification
5G Scaling
UP
New 5G Features
Development
5G Field Deployment
and Sites Turn Up