教育部「5G行動寬頻人才培育跨校教學聯盟計畫」

5G行動網路協定與核網技術聯盟中心

課程:5G垂直應用網路

單元3
eMBB垂直應用網路技術

副教授：吳俊興

助教：胡詠翔、魏宏修

國立高雄大學 資訊工程學系

Outline

- Access Technologies for eMBB
  - Before and After Release 17
  - Scenarios and Attributes
  - Performance Requirements
- Network Technologies for eMBB
  - QoS and Network Slicing
  - Non-Public Networks
  - 5GMS and eMBMS

ITU-R Enhanced Mobile Broadband (eMBB)

- Among the three main 5G application areas (eMBB, URLLC, mMTC), only eMBB is deployed in 2020
- Almost all key capability parameters are related to eMBB

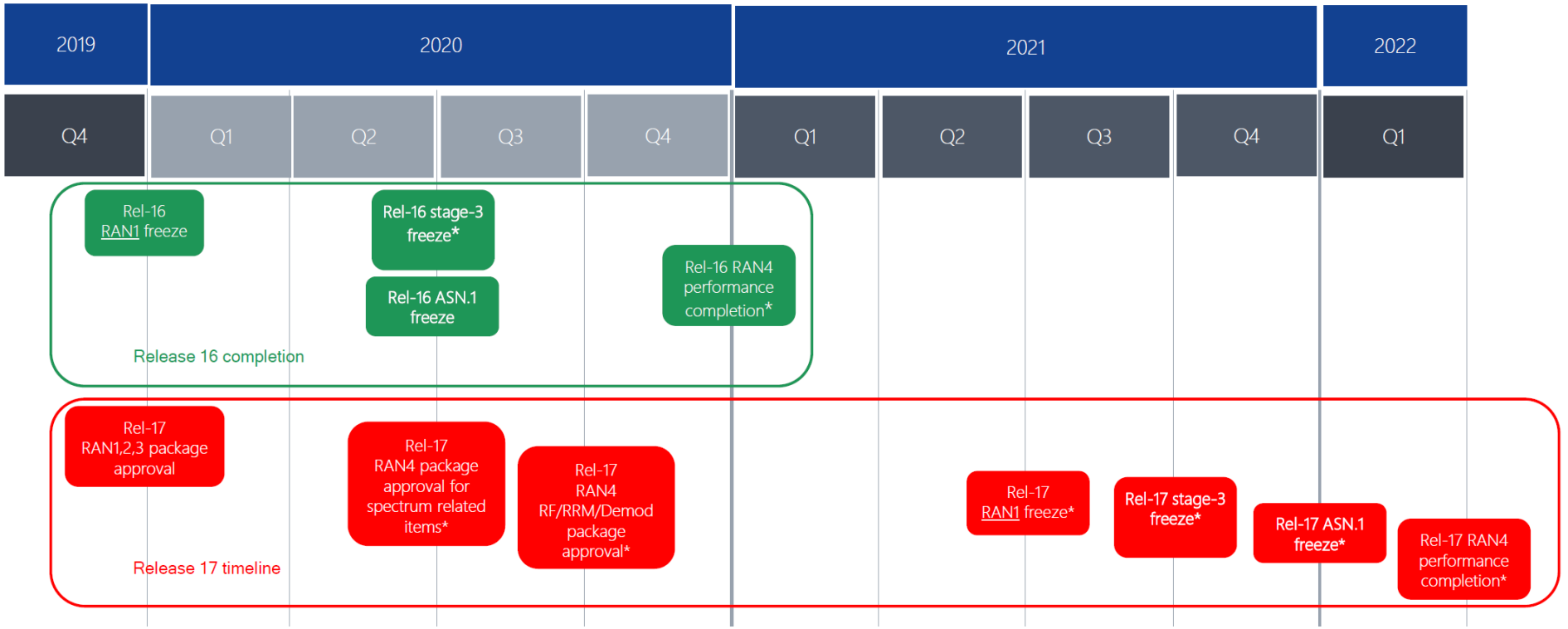
Capability	Description	5G Target	Scenario
Peak data rate	Maximum achievable data rate	20 Gbit/s	eMBB
User experienced data rate	Achievable data rate across the coverage area (hotspot cases)	1 Gbit/s	eMBB
	Achievable data rate across the coverage area	100 Mbit/s	eMBB
Latency	Radio network contribution to packet travel time	1 ms	URLLC
Mobility	Maximum speed for handoff and QoS requirements	500 km/h	eMBB/ URLLC
Connection density	Total number of devices per unit area	10^6 Devices/km^2	MMTC
Energy efficiency	Data sent/received per unit energy consumption (by device or network)	Equal to 4G	eMBB
Area traffic capacity	Total traffic across coverage area	1000 (Mbit/s)/m^2	eMBB
Spectrum efficiency	Throughput per unit wireless bandwidth and per network cell	3–4x 4G	eMBB

3GPP Way Forward on the overall 5G-NR eMBB

- Dec 2017: Stage 3 for Non-Standalone 5G-NR eMBB with Option 3
  - Ensure commonality with Standalone eMBB as well as forward compatibility
    - Complete stage-3 of all L1 and L2-User-Plane for both Non-Standalone and Standalone
    - L1 and L2-User-Plane for both Non-Standalone and Standalone is different
  - Prioritization of NR band definition
- March 2018: intermediate implementable version with frozen ASN.1 for Non-Standalone 5G NR eMBB accordingly
  - Only applies to NSA deployment scenario Options 3
  - A single Rel-15 ASN.1 shall be maintained from September 2018 onwards
- Maintain current schedule for Standalone 5G-NR in Rel-15
  - Stage 3 completion June 2018; ASN.1 freeze September 2018
- Ensure alignment of core network aspects
  - Ensure completion of stage-3 for the so-called “Option 3” family by December 2017 in case modifications to the current specifications are needed
  - Overall 5G Core Network completed

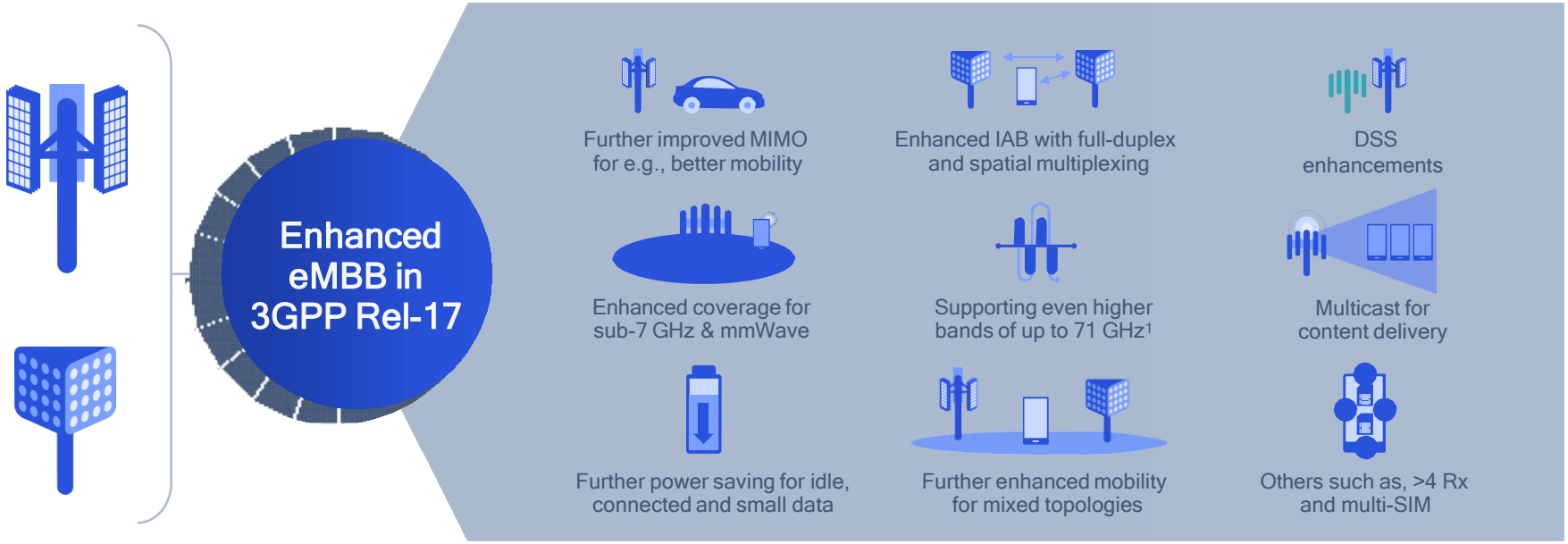
3GPP RP-170741

RAN Work Progressing beyond eMBB



- Release-16 stage-3 freeze moved to June/2020
- Release-16 ASN.1 freeze remains in June/2020
- Release-16 radio performance work completion moved to Dec/2020
- Start of Release-17 work scheduled for May/2020 (physical layer)
- Release-17 RAN1 (physical layer) freeze moved to June/2021
- Release-17 stage-3 freeze moved to September/2021
- Release-17 ASN.1 freeze moved to December/2021
- Release-17 radio performance work completion moved to March/2022

Continue to Enhance eMBB Foundation in R17



Foundational areas
Coverage, capacity, latency, power saving, mobility

Expanded deployments
New spectrum, topologies, integrated backhaul, ….

New services
Latency, reliability, positioning, use cases like XR

Source: RAN work progressing beyond eMBB, *April 24, 2020*
https://www.3gpp.org/ftp/Information/presentations/presentations_2020/3GPP_RAN_Apr2020.pdf

Better Support Industrial IoT in R17

Source: RAN work progressing beyond eMBB, *April 24, 2020*
https://www.3gpp.org/ftp/Information/presentations/presentations_2020/3GPP_RAN_Apr2020.pdf

Scenarios and Requirements for Next Generation Access Technologies

TR 38.913

- Identifies the typical deployment scenarios associated with attributes such as carrier frequency, inter-site distance, user density, maximum mobility speed, etc, and
- Develops requirements for next generation access technologies for the identified deployment scenarios taking into account
  - Not limited to the ITU-R discussion on IMT-2020 requirements
- Contains scenarios and requirements for next generation access technologies used as
  - Guidance to the technical work to be performed in 3GPP RAN WGs
  - Input for ITU-R to take into account when developing IMT-2020 technical performance requirements
  - Not all requirements apply to all deployment scenarios described
  - some of eMBB deployment scenarios may possibly be reused to evaluate mMTC and URLLC, or some specific evaluation tests

Typical Deployment Scenarios (eMBB)

1. Indoor hotspot
2. Dense urban
3. Rural
4. Urban macro
5. High speed (train)
6. Extreme rural (long distance coverage in low density areas)
7. Urban coverage for massive connection
8. Highway
9. Urban Grid for Connected Car
10. Commercial Air to Ground
11. Light aircraft
12. Satellite extension to Terrestrial

Scenario 1. Indoor Hotspot

- Focuses on small coverage per site/TRxP (transmission and reception point) and high user throughput or user density in buildings
- The key characteristics of this deployment scenario are high capacity, high user density and consistent user experience indoor

Attributes for indoor hotspot

Attributes	Values or assumptions
Carrier Frequency	Around 30 GHz or Around 70 GHz or Around 4 GHz
Aggregated system bandwidth	Around 30GHz or Around 70GHz: Up to 1GHz (DL+UL) Around 4GHz: Up to 200MHz (DL+UL)
Layout	Single layer: - Indoor floor (Open office)
ISD (Inter-Site Distance)	20m (Equivalent to 12TRxPs per 120m x 50m)
BS antenna elements	Around 30GHz or Around 70GHz: Up to 256 Tx and Rx antenna elements Around 4GHz: Up to 256 Tx and Rx antenna elements
UE antenna elements	round 30GHz or Around 70GHz: Up to 32 Tx and Rx antenna elements Around 4GHz: Up to 8 Tx and Rx antenna elements
User distribution and UE speed	100% Indoor, 3km/h, 10 users per TRxP
Service profile	Whether to use full buffer traffic or non-full-buffer traffic depends on the evaluation methodology adopted for each KPI. For certain KPIs, full buffer traffic is desirable to enable comparison with IMT-Advanced values.

Scenario 2. Dense Urban

- The dense urban microcellular deployment scenario focuses on
  - Macro TRxPs with or without micro TRxPs and
  - High user densities and traffic loads in city centres and dense urban areas
- The key characteristics of this deployment scenario are high traffic loads, outdoor and outdoor-to-indoor coverage
  - This scenario will be interference-limited, using macro TRxPs with or without micro TRxPs
  - A continuous cellular layout and the associated interference shall be assumed

Attributes for Dense Urban

Attributes	Values or assumptions
Carrier Frequency	Around 4GHz + Around 30GHz (two layers)
Aggregated system bandwidth	Around 30GHz: Up to1GHz (DL+UL) Around 4GHz: Up to 200MHz (DL+UL)
Layout	Two layers: - Macro layer: Hex. Grid - Micro layer: Random drop Step 1 : Around 4GHz in Macro layer Step 2 : Both Around 4GHz & Around 30GHz may be available in Macro & Micro layers (including 1 macro layer, macro cell only)
ISD	Macro layer: 200m Micro layer: 3micro TRxPs per macro TRxP All micro TRxPs are all outdoor
BS antenna elements	Around 30GHz: Up to 256 Tx and Rx antenna elements Around 4GHz: Up to 256 Tx and Rx antenna elements
UE antenna elements	Around 30GHz: Up to 32 Tx and Rx antenna elements Around 4GHz: Up to 8 Tx and Rx antenna elements
User distribution and UE speed	Step1: Uniform/macro TRxP, 10 users per TRxP Step2: Uniform/macro TRxP + Clustered/micro TRxP, 10 users per TRxP, 80% indoor (3km/h), 20% outdoor (30km/h)
Service profile	Whether to use full buffer traffic or non-full-buffer traffic depends on the evaluation methodology adopted for each KPI. For certain KPIs, full buffer traffic is desirable to enable comparison with IMT-Advanced values.

Scenario 3. Rural

- The rural deployment scenario focuses on larger and continuous coverage
- The key characteristics of this scenario are continuous wide area coverage supporting high speed vehicles
  - This scenario will be noise-limited and/or interference-limited, using macro TRxPs

Attributes for rural

Attributes	Values or assumptions
Carrier Frequency	Around 700MHz or Around 4GHz (for ISD 1) Around 700 MHz and Around 2 GHz combined (for ISD 2)
Aggregated system bandwidth	Around 700MHz: Up to 20MHz(DL+UL) Around 4GHz: Up to 200MHz (DL+UL)
Layout	Single layer: - Hex. Grid
ISD	ISD 1: 1732m ISD 2: 5000m
BS antenna elements	Around 4GHz: Up to 256 Tx and Rx antenna elements Around 700MHz: Up to 64 Tx and Rx antenna elements
UE antenna elements	Around 4GHz: Up to 8 Tx and Rx antenna elements Around 700MHz: Up to 4 Tx and Rx antenna elements
User distribution and UE speed	50% outdoor vehicles (120km/h) and 50% indoor (3km/h), 10 users per TRxP
Service profile	Whether to use full buffer traffic or non-full-buffer traffic depends on the evaluation methodology adopted for each KPI. For certain KPIs, full buffer traffic is desirable to enable comparison with IMT-Advanced values.

Scenario 4. Urban Macro

- The rural deployment scenario focuses on larger and continuous coverage
- The key characteristics of this scenario are continuous wide area coverage supporting high speed vehicles
  - This scenario will be noise-limited and/or interference-limited, using macro TRxPs

Attributes for urban macro

Attributes	Values or assumptions
Carrier Frequency	Around 2 GHz or Around 4 GHz or Around 30 GHz
Aggregated system bandwidth	Around 4GHz: Up to 200 MHz (DL+UL) Around 30GHz: Up to 1GHz (DL+UL)
Layout	Single layer: - Hex. Grid
ISD	500m
BS antenna elements	Around 30GHz: Up to 256 Tx and Rx antenna elements Around 4GHz or Around 2GHz: Up to 256 Tx and Rx antenna elements
UE antenna elements	Around 30GHz: Up to 32 Tx and Rx antenna elements Around 4GHz: Up to 8 Tx and Rx antenna elements
User distribution and UE speed	20% Outdoor in cars: 30km/h, 80% Indoor in houses: 3km/h 10 users per TRxP
Service profile	Whether to use full buffer traffic or non-full-buffer traffic depends on the evaluation methodology adopted for each KPI. For certain KPIs, full buffer traffic is desirable to enable comparison with IMT-Advanced values.

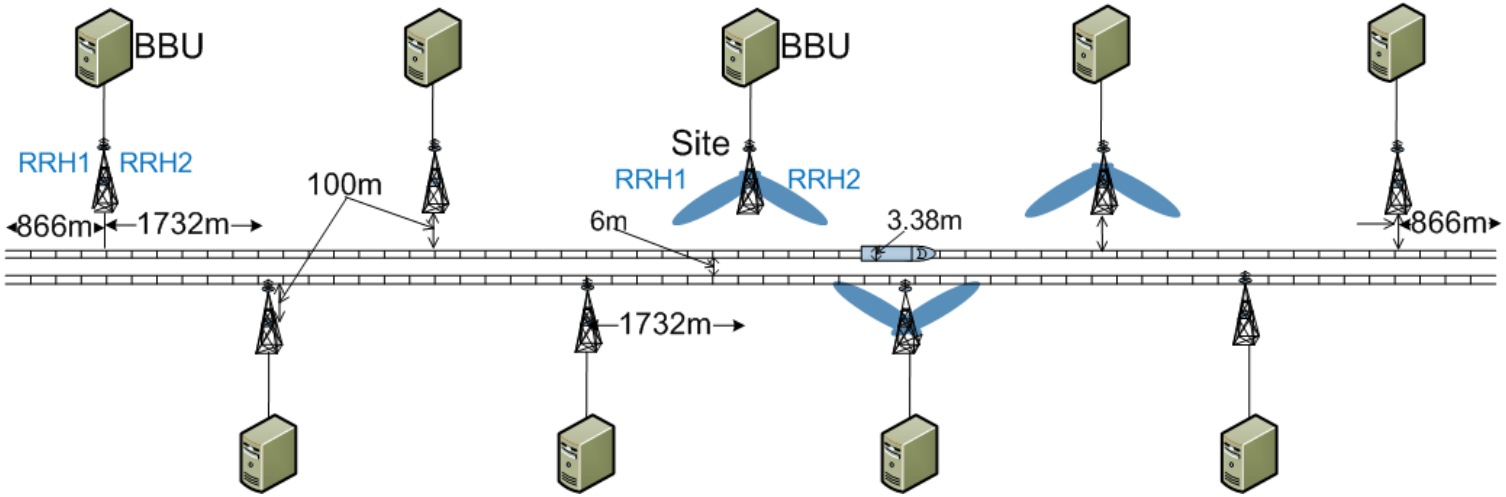
Scenario 5. High Speed

- The high speed deployment scenario focuses on continuous coverage along track in high speed trains
- The key characteristics of this scenario are consistent passenger user experience and critical train communication reliability with very high mobility
- In this deployment scenario, dedicated linear deployment along railway line and the deployments including SFN (Single Frequency Network) scenarios are considered, and passenger UEs are located in train carriages
  - For the passenger UEs, if the antenna of relay node for eNB-to-Relay is located at top of one carriage of the train, the antenna of relay node for Relay-to-UE could be distributed to all carriages

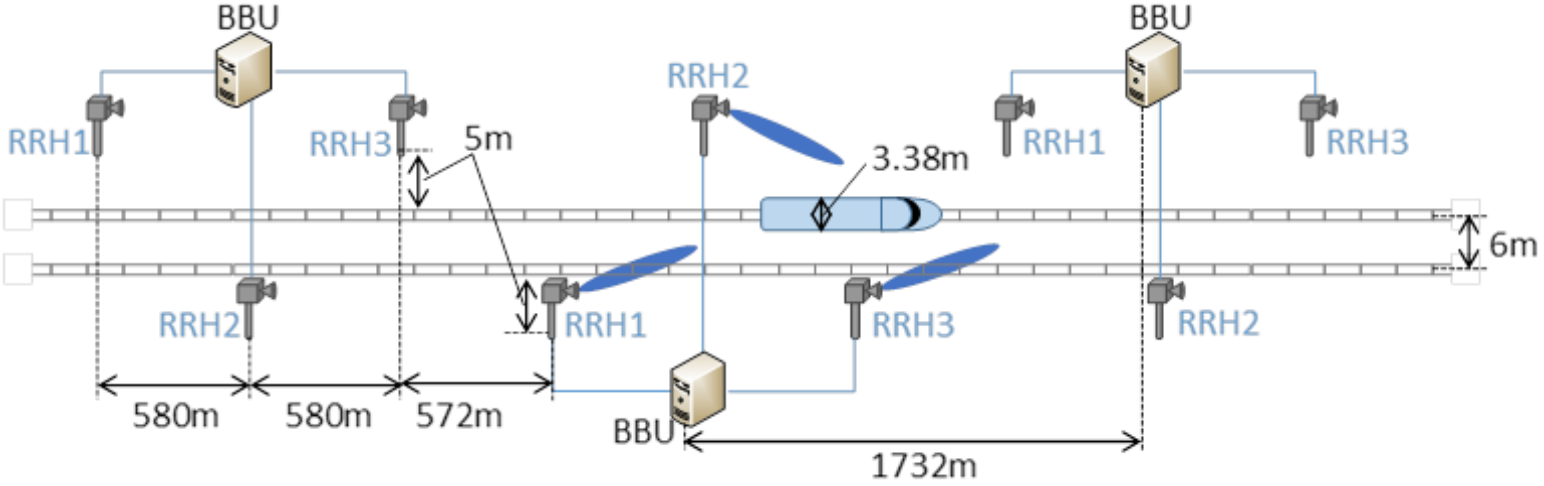
Attributes for High Speed

Attributes	Values or assumptions
Carrier Frequency	Macro only: Around 4GHz Macro + relay nodes: 1) For BS to relay: Around 4 GHz For relay to UE: Around 30 GHz or Around 70 GH or Around 4 GHz 2) For BS to relay: Around 30 GHz For relay to UE: Around 30 GHz or Around 70 GHz or Around 4 GHz
Aggregated system bandwidth	Around 4GHz: Up to 200 MHz (DL+UL) Around 30GHz or Around 70GHz: Up to 1GHz (DL+UL)
Layout	Macro only: - Around 4GHz: RRH site to railway track distance: 100m Macro + relay nodes: - Around 4GHz: RRH site to railway track distance: 100m - Around 30GHz: RRH site to railway track distance: 5m
ISD	- Around 4GHz: ISD 1732m between RRH sites, two TRxPs per RRH site - Around 30GHz: 1732m between BBU sites, 3 RRH sites connected to 1 BBU, one TRxP per RRH site, inter RRH site distance (580m, 580m, 572m) - Small cell within carriages: ISD = 25m
BS antenna elements	Around 30GHz: Up to 256 Tx and Rx antenna elements Around 4GHz: Up to 256 Tx and Rx antenna elements
UE antenna elements	Relay Tx: Up to 256 antenna elements; Relay Rx: Up to 256 antenna elements Around 30GHz: Up to 32 Tx and Rx antenna elements Around 4GHz: Up to 8 Tx and Rx antenna elements
User distribution and UE speed	100% of users in train: For non-full buffer, 300 UEs per macro cell (assuming 1000 passengers per high-speed train and at least 10% activity ratio) Maximum mobility speed: 500km/h
Service profile	Alt 1: Full buffer Alt 2: FTP model 1/2/3 with packet size 0.5 Mbytes, 0.1 Mbytes (other value is not precluded) Other traffic models are not precluded, e.g., for critical train communications

Dedicated Linear Deployment Along the Railway Line



4 GHz deployment



30 GHz deployment

Scenario 6. Extreme Long Distance Coverage in Low Density Areas

- Allow for the Provision of services for very large areas with low density of users whether they are humans and machines
  - e.g. Low ARPU regions, wilderness, areas where only highways are located, etc
- The key characteristics of this scenario are Macro cells with very large area coverage supporting basic data speeds and voice services
  - with low to moderate user throughput and low user density

Attributes for extreme rural

Attributes	Values or assumptions
Carrier Frequency	Below 3 GHz With a priority on bands below 1GHz Around 700 MHz
System Bandwidth	40 MHz (DL+UL)
Layout	Single layer: Isolated Macro cells
Cell range	100 km range (Isolated cell) to be evaluated through system level simulations. Feasibility of Higher Range shall be evaluated through Link level evaluation (for example in some scenarios ranges up to 150-300km may be required).
User density and UE speed	User density: Speed up to 160 km/h
Traffic model	Average data throughput at busy hours/user: 30 kbps User experienced data rate: up to 2 Mbps DL while stationary and 384 kbps DL while moving

Scenario 7. Urban Coverage for Massive Connection

- Focuses on large cells and continuous coverage to provide mMTC
- The key characteristics of this scenario are continuous and ubiquitous coverage in urban areas, with very high connection density of mMTC devices
  - This deployment scenario is for the evaluation of the KPI of connection density

Attributes for urban coverage for massive connection

Attributes	Values or assumptions
Carrier Frequency	700MHz, 2100 MHz as an option
Network deployment including ISD	Macro only, ISD = 1732m, 500m
Device deployment	Indoor, and outdoor in-car devices
Maximum mobility speed	20% of users are outdoor in cars (100km/h) or 20% of users are outdoors (3km/h) 80% of users are indoor (3km/h) Users dropped uniformly in entire cell
Service profile	Non-full buffer with small packets
BS antenna elements	2 and 4 Rx ports (8 Rx ports as optional)
UE antenna elements	1Tx

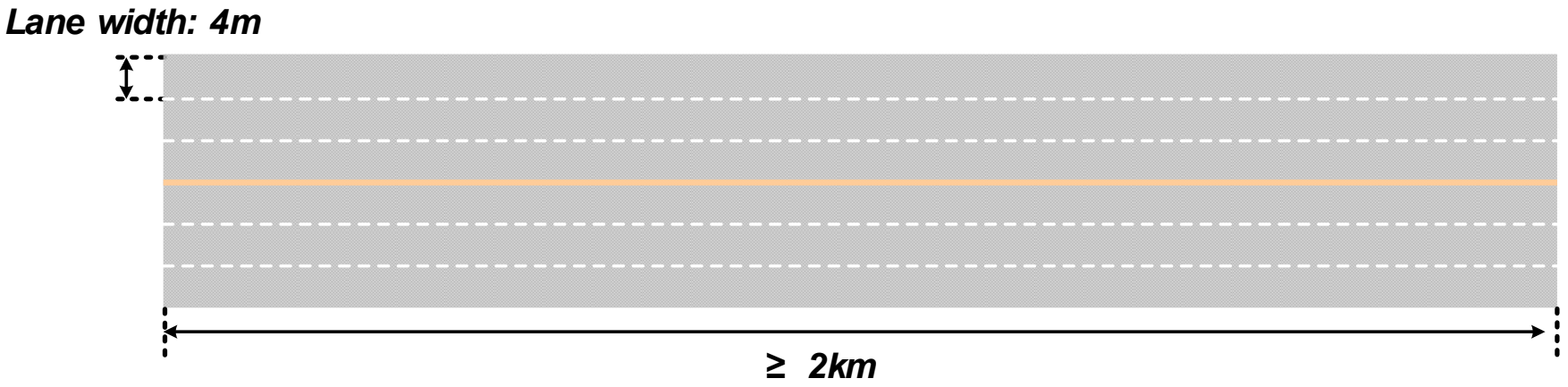
Scenario 8. Highway

- The highway deployment scenario focuses on scenario of vehicles placed in highways with high speeds
- The main KPIs evaluated under this scenario would be reliability/availability under high speeds/mobility (and thus frequent handover operations)

Attributes for highway

Attributes	Values or assumptions
Carrier Frequency	Macro only: Below 6 GHz (around 6 GHz) Macro + RSUs: 1) For BS to RSU: Below 6 GHz (around 6 GHz) 2) RSU to vehicles or among vehicles: below 6 GHz
Aggregated system bandwidth	Up to 200MHz (DL+UL) Up to 100MHz (SL)
Layout	Option 1: Macro only Option 2: Macro + RSUs
ISD	Macro cell: ISD = 1732m, 500m(Optional) Inter-RSU distance = 50m or 100m
BS antenna elements	Tx: Up to 256 Tx Rx: Up to 256 Rx
UE antenna elements	RSU Tx: Up to 8 Tx RSU Rx: Up to 8 Rx Vehicle Tx: Up to 8 Tx Vehicle Rx: Up to 8 Rx
User distribution and UE speed	100% in vehicles Average inter-vehicle distance (between two vehicles' center) in the same lane is 0.5sec or 1sec * average vehicle speed (average speed: 100-300km/h)
Traffic model	50 messages per 1 second with absolute average speed of either - 100-250 km/h (relative speed: 200 – 500km/h), or 30 km/h

Road Configuration for Highway Scenario



- 3GPP/SA1 defines RSU (Road-Side Unit) as a logical entity that combines V2X application logic with the functionality of an eNB (referred to as eNB-type RSU) or UE (referred to as UE-type RSU)
  - Therefore a RSU can communicate with vehicles via D2D link or cellular DL/UL
- The message size needs further clarification for eMBB and other types of services (e.g. safety)

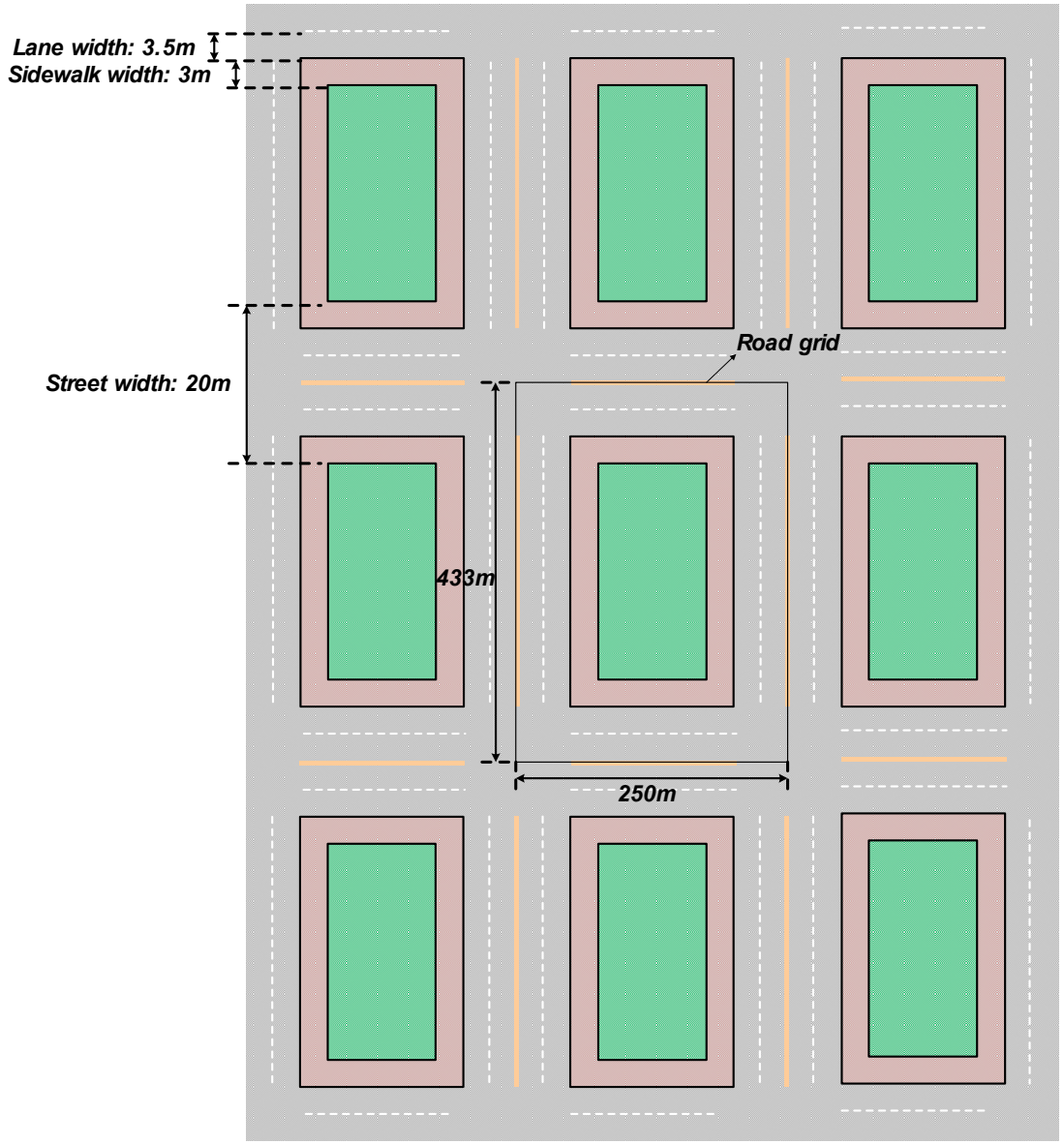
Scenario 9. Urban Grid for Connected Car

- Focuses on scenario of highly densely deployed vehicles placed in urban area. It could cover a scenario where freeways lead through an urban grid
- The main KPI evaluated under this scenario are reliability/availability/latency in high network load and high UE density scenarios

Attributes for urban grid for connected car

Attributes	Values or assumptions
Carrier Frequency	Macro only: Below 6 GHz (around 6 GHz) Macro + RSUs: 1) For BS to RSU: Below 6 GHz (around 6 GHz) 2) RSU to vehicles or among vehicles/pedestrians: below 6 GHz
Aggregated system bandwidth	Up to 200 MHz (DL+UL) Up to 100 MHz (SL)
Layout	Option 1: Macro only Option 2: Macro + RSUs
ISD	Macro cell: ISD = 500m RSU at each intersection for Option 2. Other values (50m and 100m) should also be considered for option 2
BS antenna elements	Tx: Up to 256 Tx Rx: Up to 256 Rx
UE antenna elements	RSU Tx: Up to 8 Tx RSU Rx: Up to 8 Rx Vehicle Tx: Up to 8 Tx Vehicle Rx: Up to 8 Rx Pedestrian/bicycle Tx: Up to 8 Tx Pedestrian/bicycle Rx: Up to 8 Rx
User distribution and UE speed	Urban grid model (lanes and pedestrian/bicycle sidewalks placed around a road block. 2 lanes in each direction, 4 lanes in total, 1 sidewalk, one block size: 433m x 250m) Average inter-vehicle distance (between two vehicles' center) in the same lane is 1sec * average vehicle speed (average speed 15 – 120km/h) Pedestrian/bicycle dropping: average distance between UEs is 20m
Traffic model	50 messages per 1 second with 60km/h, 10 messages per 1 second with 15km/h

Road Configuration for Urban Grid



Details of Vehicle UE Drop and Mobility Model

Parameter	Urban case	Freeway case
Number of lanes	2 in each direction (4 lanes in total in each street)	3 in each direction (6 lanes in total in the freeway)
Lane width	3.5 m	4 m
Road grid size by the distance between intersections	433 m * 250 m	N/A
Simulation area size	Minimum 1299 m * 750 m	Freeway length >= 2000 m. Wrap around should be applied to the simulation area.
Vehicle density	Average inter-vehicle distance in the same lane is 2.5 sec * absolute vehicle speed. Baseline: The same density/speed in all the lanes in one simulation.	
Absolute vehicle speed	15 km/h, 60 km/h, 120 km/h	250 km/h, 140 km/h, 70 km/h

- 3 m is reserved for sidewalk per direction
  (i.e., no vehicle or building in this reserved space)

Scenario 10. Commercial Air to Ground

- Allow for provision of services for commercial aircraft to enable both humans and machines aboard the aircraft to initiate and receive mobile services
  - It is not for the establishment of airborne based base stations
- The key characteristics of this scenario are upward pointed Macro cells with very large area coverage supporting basic data and voice services
  - With moderate user throughput that are optimized for high altitude users that are travelling at very high speeds
  - The commercial airlines aircrafts are likely equipped with an aggregation point

Attributes for Commercial Air to Ground

Attributes	Values or assumptions
Carrier Frequency	Macro + relay: for BS to relay: Below 4 GHz
System Bandwidth	40 MHz (DL+UL)
Layout	Macro + relay nodes
Cell range	Macro cell: 100 km range to be evaluated through system level simulations. Feasibility of Higher Range shall be evaluated through Link level evaluation. Relay: up to 80 m
User density and UE speed	End user density per Macro: UE speed: Up to 1000 km/h Altitude: Up to 15 km
Traffic model	End User experienced data rate: 384kbps DL

Scenario 11. Light Aircraft

- Allow for the provision of services for general aviation aircrafts to enable both humans and machines aboard helicopters and small air plans to initiate and receive mobile services
  - It is not for the establishment of airborne based base stations
- The key characteristics of this scenario are upward pointed Macro cells with very large area coverage supporting basic data and voice services
  - with moderate user throughput and low user density that are optimized for moderate altitude users that might be travelling at high speeds
  - The general regime aviation aircrafts are not equipped with relays

Attributes for light aircraft

Attributes	Values or assumptions
Carrier Frequency	Macro only: Below 4GHz
System Bandwidth	40 MHz (DL+UL)
Layout	Single layer: Macro cell
Cell range	100km range to be evaluated through system level simulations. Feasibility of Higher Range shall be evaluated through Link level evaluation.
User density and UE speed	End user density per aircraft: up to 6users UE speed: Up to 370km/h Altitude: Up to 3km
Traffic model	End user experienced data rate: 384kbps DL

Scenario 12. Satellite extension to Terrestrial

- Allow for the provision of services for those areas where the terrestrial service is not available and also for those services that can be more efficiently supported by the satellite systems such as broadcasting service
- Satellite acts as a fill-in especially on roadways and rural areas where the terrestrial service isn't available
- The supported services via the satellite system are
  - Not limited to just data and voice
  - But also for others such as machine type communications, broadcast and other delay tolerant services

Attributes for satellite extension to terrestrial

Attributes	Deployment-1	Deployment-2	Deployment-3
Carrier Frequency	Around 1.5 or 2 GHz for both DL and UL	Around 20 GHz for DL Around 30 GHz for UL	Around 40 or 50 GHz
Duplexing	FDD	FDD	FDD
Satellite architecture	Bent-pipe	Bent-pipe, On-Board Processing	Bent-pipe, On-Board Processing
Typical satellite system positioning	Access network	Backhaul network	Backhaul network
System Bandwidth (DL + UL)	Up to 2*10 MHz	Up to 2*250 MHz	Up to 2 * 1000 MHz
Satellite Orbit	GEO, LEO	LEO, MEO, GEO	LEO, MEO, GEO
UE Distribution	100% Outdoors	100% Outdoors	100% Outdoors
UE Mobility	Fixed, Portable, Mobile	Fixed, Portable, Mobile	Fixed, Portable, Mobile

Key Performance Indicators – Rate and Latency

Peak data rate	The target for peak data rate should be 20Gbps for downlink and 10Gbps for uplink
User experienced data rate	To this end, 5% user spectrum efficiency gains in the order of three times IMT-Advanced are proposed
Bandwidth	maximal aggregated total system bandwidth not defined here; derived by IMT-2020 requirements
Control plane latency	The target for control plane latency should be 10ms
User plane latency (radio protocol layer 2/3 SDU)	For URLLC, the target for user plane latency should be 0.5ms for UL, and 0.5ms for DL For eMBB, the target for user plane latency should be 4ms for UL, and 4ms for DL When a satellite link is involved in the communication with a user equipment, the target for user plane RTT can be as high as 600ms for GEO satellite systems, up to 180ms for MEO satellite systems, and up to 50ms for LEO satellite systems.
Latency for infrequent small packets	the latency shall be no worse than 10 seconds on the uplink for a 20 byte application packet (with uncompressed IP header corresponding to 105 bytes physical layer) measured at the maximum coupling loss (MaxCL) of 164dB

Key Performance Indicators – Mobility/Reliability/Coverage/Capacity/Density

Mobility	The target for mobility target should be 500km/h.
Mobility interruption time (Intra-NR mobility)	The target for mobility interruption time should be 0ms
Inter-system mobility	the ability to support mobility between the IMT-2020 system and at least one IMT system
Reliability	A general URLLC reliability requirement for one transmission of a packet is 1-10-5 for 32 bytes with a user plane latency of 1ms More detailed V2X requirements in TS 22.886
Coverage	The target for coverage should be 164dB. • For a basic MBB service characterized by a downlink datarate of 2Mbps and an uplink datarate of 60kbps for stationary users, the target on maximum coupling loss is 140dB. For mobile users a downlink datarate of 384kbps is acceptable • For a basic MBB service characterized by a downlink datarate of 1Mbps and an uplink datarate of 30kbps for stationary users, the target on maximum coupling loss is 143dB. At this coupling loss relevant downlink and uplink control channels should also perform adequately
Connection density	The target for connection density should be 1 000 000 devices/km2 in urban environment

Key Performance Indicators – Capacity and Efficiency

Area traffic capacity	Total traffic throughput served per geographic area (in Mbit/s/m2) at least 1GHz aggregated bandwidth shall be supported
UE battery life	For mMTC, UE battery life in extreme coverage shall be based on the activity of mobile originated data transfer consisting of 200bytes UL per day followed by 20bytes DL from MaxCL of 164dB, assuming a stored energy capacity of 5Wh. The target for UE battery life for mMTC should be beyond 10 years, 15 years is desirable.
UE energy efficiency	qualitative KPI
Peak Spectral efficiency	The target for peak spectral efficiency should be 30bps/Hz for downlink and 15bps/Hz for uplink.
Cell/Transmission Point/TRxP spectral efficiency 5th percentile user spectrum efficiency	eMBB Target for 3x the cell spectral efficiency of IMT-Advanced targets for Indoor Hotspot, Dense Urban, Rural and Urban Macro for full buffer
Network energy efficiency	Under development

Supplementary-Service Related Requirements

1. Multimedia Broadcast/Multicast Service

- Support existing Multicast/Broadcast services (e.g. download, streaming, group communication, TV, etc.) and new services (e.g. V2X, etc)
- Support Multicast/Broadcast services for fixed, portable and mobile UEs. Mobility up to 250 km/h shall be supported
- Support Multicast/Broadcast services for mMTC devices

2. Location/Positioning Service

- The NR should enable, and improve if suitable, state-of-art positioning techniques, such as RAN-embedded (Cell-ID, E-Cell ID, OTDOA, UTDOA, etc.) and RAN-external (GNSS, Bluetooth, WLAN, Terrestrial Beacon Systems (TBS), sensors, etc.
- Support for range of accuracy levels, latency levels and device categories
- Support accuracy and latency as defined in TR 22.862

Supplementary-Service Related Requirements (Cont.)

3. Critical Communications services

- Public safety communications
  - Support D2D (ProSe in TS 23.303)
  - Support Mission Critical Communications for diverse types of services (e.g. MCPTT, MCVideo, MCData in TS 22.179, TS 22.280, TS 22.281 and TS 22.282)
  - Support efficient group communications (GCSE_LTE, SC-PTM in TS 22.468 and TR 36.890)
  - Support isolated communications (e.g. IOPS in TS 22.346)
- Emergency communications
  - Enable emergency calls including positioning/location for emergency calls (TS 22.101 section 10 for emergency calls and TS 22.071 for position/location)
  - Enable Multimedia Priority Services (TS 22.153)
- Public warning/emergency alert systems
  - Enable public warning services that provides warning/notifications to users meeting regional regulatory requirements (TS 22.268)

4. V2X communication

- NR V2X shall provide communication via infrastructure, including MBMS support, for V2X services (TS 22.185) and advanced V2X services (TS 22.886)
- NR V2X shall provide communication via sidelink for V2X services (TS 22.185) and advanced V2X services (TS 22.886)

Performance Requirements for High Data Rate and Traffic Density Scenarios

	Scenario	Experienced data rate (DL)	Experienced data rate (UL)	Area traffic capacity (DL)	Area traffic capacity (UL)	Overall user density	Activity factor	UE speed	Coverage
1	Urban macro	50 Mbit/s	25 Mbit/s	100 Gbit/s/km^2	50 Gbit/s/km^2	10 000 /km^2	20%	Pedestrians and users in vehicles (up to 120 km/h)	Full network
2	Rural macro	50 Mbit/s	25 Mbit/s	1 Gbit/s/km^2	500 Mbit/s/km^2	100 /km^2	20%	Pedestrians and users in vehicles (up to 120 km/h)	Full network
3	Indoor hotspot	1 Gbit/s	500 Mbit/s	15 Tbit/s/km^2	2 Tbit/s/km^2	250 000 /km^2		Pedestrians	Office and residential
4	Broadband access in a crowd	25 Mbit/s	50 Mbit/s	[3,75] Tbit/s/km^2	[7,5] Tbit/s/km^2	[500 000] /km^2	30%	Pedestrians	Confined area
5	Dense urban	300 Mbit/s	50 Mbit/s	750 Gbit/s/km^2	125 Gbit/s/km^2	25 000 /km^2	10%	Pedestrians and users in vehicles (up to 60 km/h)	Downtown

Performance Requirements for High Data Rate and Traffic Density Scenarios (Cont.)

	Scenario	Experienced data rate (DL)	Experienced data rate (UL)	Area traffic capacity (DL)	Area traffic capacity (UL)	Overall user density	Activity factor	UE speed	Coverage
6	Broadcast-like services	Maximum 200 Mbit/s (per TV channel)	N/A or modest (e.g. 500 kbit/s per user)	N/A	N/A	[15] TV channels of [20 Mbit/s] on one carrier	N/A	Stationary users, pedestrians and users in vehicles (up to 500 km/h)	Full network
7	High-speed train	50 Mbit/s	25 Mbit/s	15 Gbit/s/train	7,5 Gbit/s /train	1 000 /train	30%	Users in trains (up to 500 km/h)	Along railways
8	High-speed vehicle	50 Mbit/s	25 Mbit/s	[100] Gbit/s/km^2	[50] Gbit/s /km^2	4 000 /km^2	50%	Users in vehicles (up to 250 km/h)	Along roads
9	Airplanes connectivity	15 Mbit/s	7,5 Mbit/s	1,2 Gbit/s/plane	600 Mbit/s /plane	400 /plane	20%	Users in airplanes (up to 1 000 km/h)	

Performance Requirements for High Data Rate and Traffic Density Scenarios (cont.)

6	Broadcast-like services	Maximum 200 Mbit/s (per TV channel)	N/A or modest (e.g. 500 kbit/s per user)	N/A	N/A	[15] TV channels of [20 Mbit/s] on one carrier	N/A	Stationary users, pedestrians and users in vehicles (up to 500 km/h)	Full network (note 1)
7	High-speed train	50 Mbit/s	25 Mbit/s	15 Gbit/s/train	7,5 Gbit/s/train	1 000/train	30%	Users in trains (up to 500 km/h)	Along railways (note 1)
8	High-speed vehicle	50 Mbit/s	25 Mbit/s	[100] Gbit/s/km^2	[50] Gbit/s/km^2	4 000/km^2	50%	Users in vehicles (up to 250 km/h)	Along roads (note 1)
9	Airplanes connectivity	15 Mbit/s	7,5 Mbit/s	1,2 Gbit/s/plane	600 Mbit/s/plane	400/plane	20%	Users in airplanes (up to 1 000 km/h)	(note 1)

NOTE 1: For users in vehicles, the UE can be connected to the network directly, or via an on-board moving base station.

NOTE 2: A certain traffic mix is assumed; only some users use services that require the highest data rates [2].

NOTE 3: For interactive audio and video services, for example, virtual meetings, the required two-way end-to-end latency (UL and DL) is 2-4 ms while the corresponding experienced data rate needs to be up to 8K 3D video [300 Mbit/s] in uplink and downlink.

NOTE 4: These values are derived based on overall user density. Detailed information can be found in [10].

NOTE 5: All the values in this table are targeted values and not strict requirements.

Outline

- Access Technologies for eMBB
  - Before and After Release 17
  - Scenarios and Attributes
  - Performance Requirements
- Network Technologies for eMBB
  - QoS and Network Slicing
  - Non-Public Networks
  - 5GMS and eMBMS

QoS Model (TS 23.501 Clause 5.7)

- The 5G QoS model is based on QoS flows
  - A QoS Flow is associated with QoS requirements as specified by QoS parameters and QoS characteristics
- The 5G QoS model supports the following QoS flows
  - **GBR QoS** flows: require *Guaranteed* flow *Bit Rate*
  - **Non-GBR QoS** flows: do not require guaranteed flow bit rate
  - **Reflective QoS** (TS 23.501 clause 5.7.5)
    - Enables the UE to map UL User Plane traffic to QoS flows without SMF provided QoS rules and
    - It applies for IP PDU session and Ethernet PDU session

QoS Flow

- The QoS Flow is the finest granularity of QoS differentiation in the PDU Session
- Within the 5GS, a QoS Flow is controlled by the SMF and may be preconfigured, or established via
  - the PDU Session Establishment procedure (TS 23.502 clause 4.3.2), or
  - the PDU Session Modification procedure (TS 23.502 clause 4.3.3)

QoS Flow ID (QFI)

- A QoS Flow ID (QFI) is used to identify a QoS Flow in the 5G System
  - User Plane traffic with the same QFI within a PDU Session receives the same traffic forwarding treatment (e.g. scheduling, admission threshold)
  - The QFI is carried in an encapsulation header on N3 (and N9) i.e. without any changes to the e2e packet header
  - QFI shall be used for all PDU Session Types
  - The QFI shall be unique within a PDU Session
  - The QFI may be dynamically assigned or may be equal to the 5QI (clause 5.7.2.1)

QoS Flow Characteristics

Any QoS Flow is characterized by

- A QoS profile provided by the SMF to the AN
  - via the AMF over the N2 reference point or preconfigured in the AN
- One or more QoS rule(s) and optionally QoS Flow level QoS parameters (TS 24.501) associated with these QoS rule(s)
  - Provided by the SMF to the UE via the AMF over the N1 reference point and/or
  - Derived by the UE by applying Reflective QoS control
- One or more UL and DL Packet Detection Rules (PDRs) provided by the SMF to the UPF

Default QoS Flow

- Within the 5GS, a QoS Flow associated with the default QoS rule is required to be established for a PDU Session
  - Remains established throughout the lifetime of the PDU Session
  - This QoS Flow should be a Non-GBR QoS Flow (clause 5.7.2.7)
- The above QoS Flow provides the UE with connectivity throughout the lifetime of the PDU Session
  - Possible interworking with EPS motivates the recommendation for this QoS Flow to be of type Non-GBR

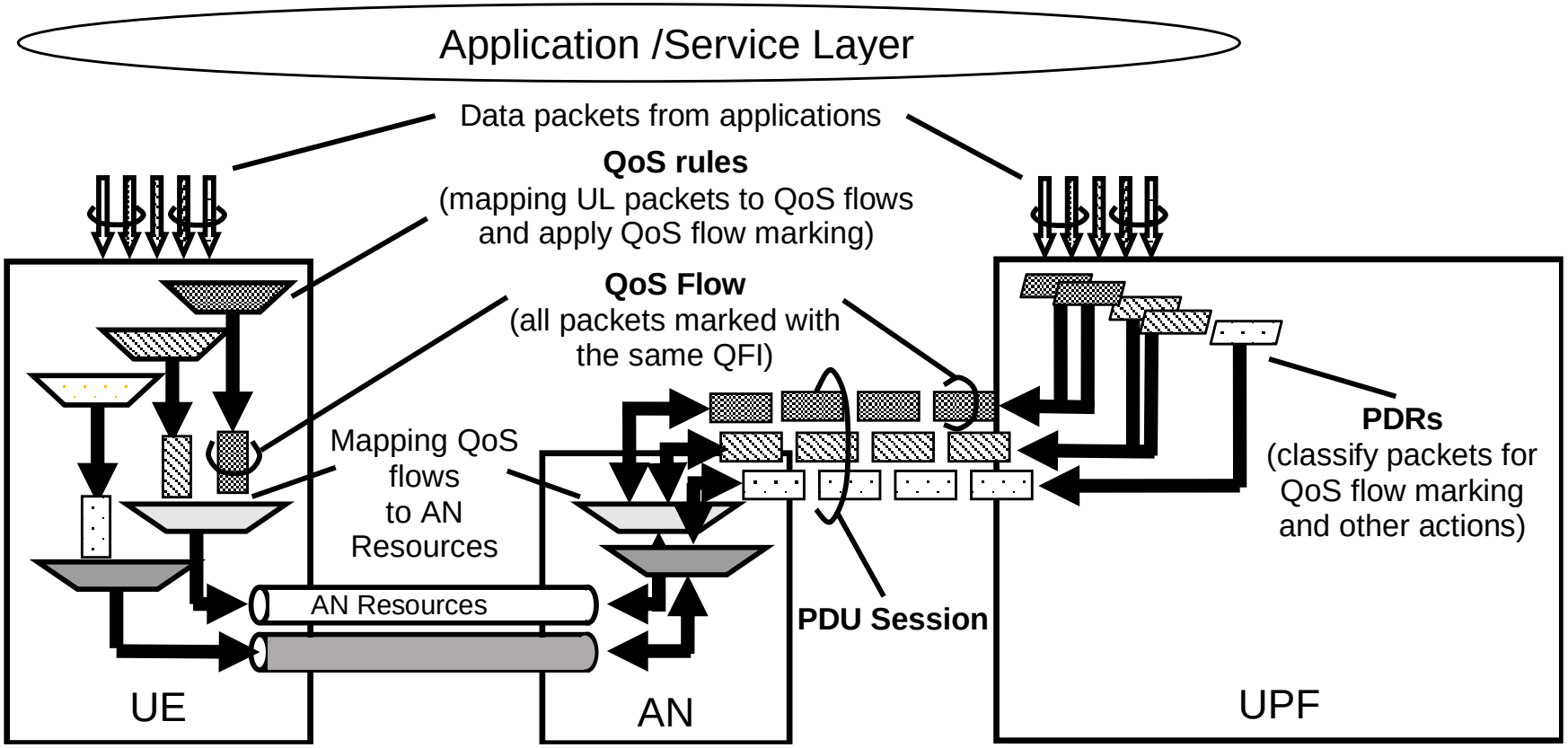
QoS Profile

- A QoS Flow may either be 'GBR' or 'Non-GBR' depending on its QoS profile
- The QoS profile of a QoS Flow is sent to the (R)AN and it contains QoS parameters as described below (clause 5.7.2)
  - For each QoS Flow, the QoS profile shall include the QoS parameters
    - 5G QoS Identifier (5QI); and
    - Allocation and Retention Priority (ARP)
  - For each Non-GBR QoS Flow only, the QoS profile may also include the QoS parameter
    - Reflective QoS Attribute (RQA)
  - For each GBR QoS Flow only, the QoS profile
    - shall also include the QoS parameters
      - Guaranteed Flow Bit Rate (GFBR) - UL and DL; and
      - Maximum Flow Bit Rate (MFBR) - UL and DL
    - may also include one or more of the QoS parameters
      - Notification control
      - Maximum Packet Loss Rate - UL and DL

QoS Flow Mapping

- The SMF performs the binding of PCC rules to QoS Flows based on the QoS and service requirements (as defined in TS 23.503)
- The SMF assigns the QFI for a new QoS Flow and derives its QoS profile, corresponding UPF instructions and QoS Rule(s) from the PCC rule(s) bound to the QoS Flow and other information provided by the PCF
  - QFI
  - QoS profile
  - optionally, Alternative QoS Profile(s)

Classification and User Plane Marking for QoS Flows and Mapping to AN Resources



Downlink (DL) Classification

- Incoming DL data packets are classified by the UPF based on the Packet Filter Sets of the DL PDRs in the order of their precedence (without initiating additional N4 signalling)
  - The UPF conveys the classification of the User Plane traffic belonging to a QoS Flow through an N3 (and N9) User Plane marking using a QFI
  - If no matching DL PDR is found, the UPF shall discard the DL data packet
- The AN binds QoS Flows to AN resources (i.e. Data Radio Bearers of in the case of 3GPP RAN)
  - There is no strict 1:1 relation between QoS Flows and AN resources
  - It is up to the AN to establish the necessary AN resources that QoS Flows can be mapped to, and to release them
  - The AN shall indicate to the SMF when the AN resources onto which a QoS Flow is mapped are released

Uplink (UL) Classification

- For a PDU Session of Type IP or Ethernet
  - The UE evaluates UL packets against the UL Packet Filters in the Packet Filter Set in the QoS rules
    - Based on the precedence value of QoS rules in increasing order
    - Until a matching QoS rule (i.e. whose Packet Filter matches the UL packet) is found
  - If no matching QoS rule is found, the UE shall discard the UL data packet
- For a PDU Session of Type Unstructured, the default QoS rule does not contain a Packet Filter Set and allows all UL packets

- The UE uses the QFI in the corresponding matching QoS rule to bind the UL packet to a QoS Flow
  - The UE then binds QoS Flows to AN resources

5G QoS Parameters

- 5QI – 5G QoS Indicator
  - A specific QoS forwarding behaviour for a 5G QoS Flow (similar to the QCI value used for LTE)
- ARP - Allocation and Retention Priority
- RQA - Reflective QoS Attribute
- TS23.203 Policy and Charging Control Architecture (PCC)

5QI to QoS Characteristics Mapping – **GBR** Resource Types

TS23.501 Table 5.7.4-1

5QI Value	Default Priority Level	Packet Delay Budget	Packet Error Rate	Default Averaging Window	Example Services
1	20	100 ms	10^{-2}	2000 ms	Conversational Voice
2	40	150 ms	10^{-3}	2000 ms	Conversational Video (Live Streaming)
3	30	50 ms	10^{-3}	2000 ms	Real Time Gaming, V2X messages (TS 23.287). Electricity distribution – medium voltage, Process automation monitoring
4	50	300 ms	10^{-6}	2000 ms	Non-Conversational Video (Buffered Streaming)
65	7	75 ms	10^{-2}	2000 ms	Mission Critical user plane Push To Talk voice (e.g., MCPTT)
66	20	100 ms	10^{-2}	2000 ms	Non-Mission-Critical user plane Push To Talk voice
67	15	100 ms	10^{-3}	2000 ms	Mission Critical Video user plane
71	56	150 ms	10^{-6}	2000 ms	"Live" Uplink Streaming (e.g. TS 26.238)
72	56	300 ms	10^{-4}	2000 ms	"Live" Uplink Streaming (e.g. TS 26.238)
73	56	300 ms	10^{-8}	2000 ms	"Live" Uplink Streaming (e.g. TS 26.238)
74	56	500 ms	10^{-8}	2000 ms	"Live" Uplink Streaming (e.g. TS 26.238)
76	56	500 ms	10^{-4}	2000 ms	"Live" Uplink Streaming (e.g. TS 26.238)

5QI to QoS Characteristics Mapping – **Delay Critical GBR** Resource Types

5QI Value	Default Priority Level	Packet Delay Budget	Packet Error Rate	Default Max Data Burst Volume	Default Averaging Window	Example Services
82	19	10 ms	10^{-4}	255 bytes	2000 ms	Discrete Automation (TS 22.261)
83	22	10 ms	10^{-4}	1354 bytes	2000 ms	Discrete Automation (TS 22.261); V2X messages (UE - RSU Platooning, Advanced Driving: Cooperative Lane Change with low LoA. TS 22.186, TS 23.287)
84	24	30 ms	10^{-5}	1354 bytes	2000 ms	Intelligent transport systems (TS 22.261)
85	21	5 ms	10^{-5}	255 bytes	2000 ms	Electricity Distribution- high voltage (TS 22.261) V2X messages (Remote Driving. TS 22.186, TS 23.287)
86	18	5 ms	10^{-4}	1354 bytes	2000 ms	V2X messages (Advanced Driving: Collision Avoidance, Platooning with high LoA. TS 22.186, TS 23.287)

5QI to QoS Characteristics Mapping – **Non-GBR** Resource Types

5QI Value	Default Priority Level	Packet Delay Budget	Packet Error Rate	Example Services
5	10	100 ms	10^{-6}	IMS Signalling
6	60	300 ms	10^{-6}	Video (Buffered Streaming), TCP-based (e.g., www, e-mail, chat, ftp, p2p file sharing, progressive video, etc.)
7	70	100 ms	10^{-3}	Voice, Video (Live Streaming), Interactive Gaming
8 9	80 90	300 ms	10^{-6}	Video (Buffered Streaming), TCP-based (e.g., www, e-mail, chat, ftp, p2p file sharing, progressive video, etc.)
69	5	60 ms	10^{-6}	Mission Critical delay sensitive signalling (e.g., MC-PTT signalling)
70	55	200 ms	10^{-6}	Mission Critical Data (e.g. example services are the same as 5QI 6/8/9)
79	65	50 ms	10^{-2}	V2X messages (TS 23.287)
80	68	10 ms	10^{-6}	Low Latency eMBB applications Augmented Reality

Network Slicing for eMBB

- Network slicing allows the operator to provide customised networks
  - For example, there can be different requirements on functionality
    - e.g. priority, charging, policy control, security, and mobility
  - Differences in performance requirements
    - e.g. latency, mobility, availability, reliability and data rates, or
  - They can serve only specific users
    - e.g. MPS users, Public Safety users, corporate customers, roamers, or hosting an MVNO

- A network slice can provide the functionality of a complete network
  - including radio access network functions, core network functions and IMS functions
    - e.g. potentially from different vendors

- One network can support one or several network slices

Network Slicing Requirements

- The serving 5G network shall support providing connectivity to home and roaming users in the same network slice

- The 5G system shall be able to support IMS
  - As part of a network slice
  - Independent of network slices

- The 5G system shall support
  - A mechanism for the VPLMN to assign a UE to a network slice with the needed services or to a default network slice
    - As authorized by the HPLMN
  - Scaling of a network slice, i.e. adaptation of its capacity
  - Means by which the operator can differentiate policy control, functionality and performance provided in different network slices

Network Slicing Management (Cont.)

- In shared 5G network configuration, each operator shall be able to apply all the requirements from this clause to their allocated network resources

- The 5G system shall allow the operator
  - to create, modify, and delete a network slice
  - to define and update the set of services and capabilities supported in a network slice
  - to configure the information which associates a UE to a network slice
  - to configure the information which associates a service to a network slice
  - to assign a UE to a network slice, to move a UE from one network slice to another, and to remove a UE from a network slice
    - based on subscription, UE capabilities, the access technology being used by the UE, operator's policies and services provided by the network slice

Network Slicing Management (Cont.)

- Traffic and services in one network slice shall have no impact on traffic and services in other network slices in the same network

- Creation, modification, and deletion of a network slice shall have no or minimal impact on traffic and services in other network slices in the same network

- The 5G system shall
  - Enable the network operator to define a minimum available capacity for a network slice
    - Scaling of other network slices on the same network shall have no impact on the availability of the minimum capacity for that network slice
  - Enable the network operator to define a maximum capacity for a network slice
  - Enable the network operator to define a priority order between different network slices in case multiple network slices compete for resources on the same network
  - Enable a UE to be simultaneously assigned to and access services from more than one network slice of one operator

Network Slice Constraints

- The 5G system shall support a mechanism to prevent an unauthorized UE from trying to access a radio resource dedicated to a specific private slice for any purpose other than that authorized by the associated third-party

- The 5G system shall support a mechanism to configure a specific geographic area in which a network slice is accessible
  - i.e. a UE shall be within the geographical area in order to access the network slice

- The 5G system shall support a mechanism to limit a UE to only receiving service from an authorized slice

Cross-network Slice Coordination

- The 5G system shall support a mechanism to provide time stamps with a common time base at the monitoring API, for services that cross multiple network slices and 5G networks

- The 5G system shall provide suitable APIs to coordinate network slices in multiple 5G networks so that the selected communication services of a non-public network can be extended through a PLMN
  - e.g. the service is supported by a slice in the non-public network and a slice in the PLMN

- The 5G system shall provide a mechanism to enable an MNO to operate a hosted non-public network and private slice(s) of its PLMN associated with the hosted non-public network in a combined manner

Outline

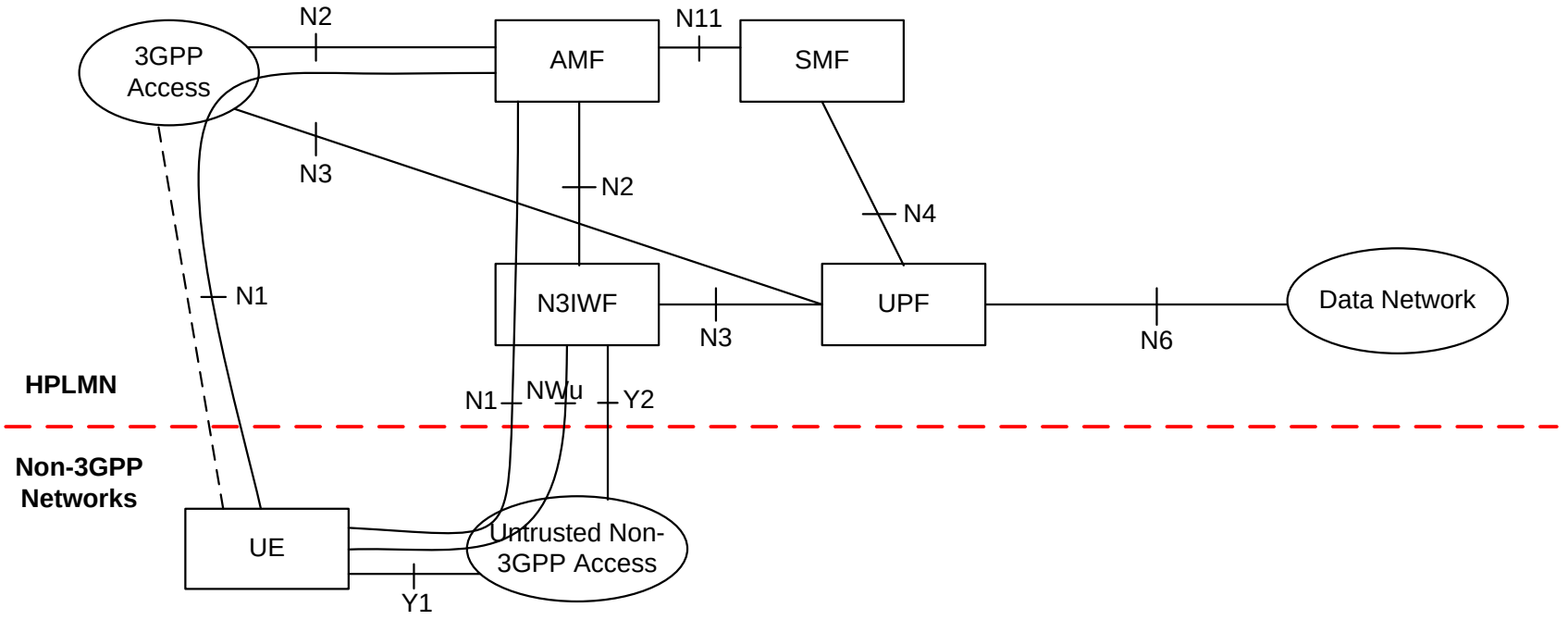
- Access Technologies for eMBB
  - Before and After Release 17
  - Scenarios and Attributes
  - Performance Requirements
- Network Technologies for eMBB
  - QoS and Network Slicing
  - Non-Public Networks
  - 5GMS and eMBMS

Non-Public Networks (TS 23.501 Clause 5.30)

- A Non-Public Network (NPN) is a 5GS deployed for non-public use
- An NPN is either
  - A Stand-alone Non-Public Network (SNPN), or
    - i.e. operated by an NPN operator and

      not relying on network functions provided by a PLMN
    - An SNPN and a PLMN can share NG-RAN
  - A Public Network Integrated NPN (PNI-NPN)
    - i.e. a non-public network deployed with the support of a PLMN

SNPN 5GS Deployment Architecture



Non-roaming architecture for 5G Core Network with untrusted non-3GPP access (As in 23.501 V16.5, 2020-07)

Stand-alone Non-Public Networks: Identifiers

- The combination of a PLMN ID and Network identifier (NID) identifies an SNPN
- The NID shall support two assignment models
  - Self-assignment: NIDs are chosen individually by SNPNs at deployment time (and may therefore not be unique)
    - But use a different numbering space than the coordinated assignment NIDs as defined in TS 23.003
  - Coordinated assignment: NIDs are assigned using one of the following two options:
    1. The NID is assigned such that it is globally unique independent of the PLMN ID used; or
    2. The NID is assigned such that the combination of the NID and the PLMN ID is globally unique

Stand-alone NPN: Broadcast System Information

NG-RAN nodes which provide access to SNPNs broadcast the following information

- One or multiple PLMN IDs
- List of NIDs per PLMN ID identifying the non-public networks NG-RAN provides access to
  - It is assumed that an NG-RAN node supports broadcasting a total of twelve NIDs (TS 38.331)
  - The presence of a list of NIDs for a PLMN ID indicates that the related PLMN ID and NIDs identify SNPNs
- Optionally a human-readable network name per NID
  - The human-readable network name per NID is only used for manual SNPN selection
  - The mechanism how human-readable network name is provided
    - i.e. whether it is broadcasted or unicasted) to the UE is specified in TS 38.331
- Optionally information to prevent UEs not supporting SNPNs from accessing the cell
  - e.g. if the cell only provides access to non-public networks
  - TS 38.300, TS 38.331 and TS 38.304

Stand-alone NPN: UE Configuration and Subscription Aspects

- An SNPN-enabled UE is configured with subscriber identifier (SUPI) and credentials for each subscribed SNPN identified by the combination of PLMN ID and NID
- A subscriber of an SNPN is either
  - Identified by a SUPI containing a network-specific identifier that takes the form of a Network Access Identifier (NAI), or
    - using the NAI RFC 7542 [20] based user identification (TS 23.003 clause 28.7.2)
    - The realm part of the NAI may include the NID of the SNPN
  - Identified by a SUPI containing an IMSI
- An SNPN-enabled UE supports the SNPN access mode
  - When the UE is set to operate in SNPN access mode the UE only selects and registers with SNPNs over Uu

Public Network Integrated NPN (PNI-NPN)

- Public Network Integrated NPNs are NPNs made available via PLMNs
  - e.g. by means of dedicated DNNs, or by one (or more) Network Slice instances allocated for the NPN
  - When a PNI-NPN is made available via a PLMN, then the UE shall have a subscription for the PLMN in order to access PNI-NPN
- Closed Access Groups (CAG) may optionally be used to apply access control
  - A Closed Access Group identifies a group of subscribers who are permitted to access one or more CAG cells associated to the CAG
  - CAG is used for the PNI-NPNs to prevent UE(s), which are not allowed to access the NPN via the associated cell(s), from automatically selecting and accessing the associated CAG cell(s)
  - As network slicing does not enable the possibility to prevent UEs from trying to access the network in areas where the UE is not allowed to use the Network Slice allocated for the NPN

PNI-NPN: Identifiers

The following is required for identification

- A CAG is identified by a CAG Identifier which is unique within the scope of a PLMN ID
- A CAG cell broadcasts one or multiple CAG Identifiers per PLMN
  - It is assumed that a cell supports broadcasting a total of twelve CAG Identifiers (TS 38.331)
- A CAG cell may in addition broadcast a human-readable network name per CAG Identifier
  - The human-readable network name per CAG Identifier is only used for presentation to user when user requests a manual CAG selection

PNI-NPN:
UE Configuration and Subscription Aspects

- The UE may be pre-configured or (re)configured with the following CAG information, included in the subscription as part of the Mobility Restrictions
  - An Allowed CAG list i.e. a list of CAG Identifiers the UE is allowed to access; and optionally
  - A CAG-only indication whether the UE is only allowed to access 5GS via CAG cells
- The HPLMN may configure or re-configure a UE with the above CAG information using the UE Configuration Update procedure for access and mobility management related parameters
  - The above CAG information is provided by the HPLMN on a per PLMN basis
- When the subscribed CAG information changes
  - UDM sets a CAG information Subscription Change Indication and sends it to the AMF
  - The AMF shall provide the UE with the CAG information when the UDM indicates that the CAG information within the Access and Mobility Subscription data has been changed
- The AMF may update the UE using
  - either the UE Configuration Update procedure after registration procedure is completed
  - or by including the new CAG information in the Registration Accept or in Registration Reject

Non-Public Networks (TS22.261 Clause 6.25)

- Non-public networks are intended for the sole use of a private entity
  - such as an enterprise, and may be deployed in a variety of configurations, utilising both virtual and physical elements
  - Specifically, they may be deployed as completely standalone networks, they may be hosted by a PLMN, or they may be offered as a slice of a PLMN
- It is expected that unauthorized UEs, those that are not associated with the enterprise, will not attempt to access the non-public network
  - Which could result in resources being used to reject that UE and thereby not be available for the UEs of the enterprise
- It is also expected that UEs of the enterprise will not attempt to access a network they are not authorized to access
  - For example, some enterprise UEs may be restricted to only access the non-public network of the enterprise, even if PLMN coverage is available in the same geographic area
  - Other enterprise UEs may be able to access both a non-public network and a PLMN where specifically allowed

Non-public Networks Requirements

- The 5G system shall support non-public networks
  - The 5G system shall support non-public networks that provide coverage within a specific geographic area
  - The 5G system shall support both physical and virtual non-public networks
  - The 5G system shall support standalone operation of a non-public network, i.e. a non-public network may be able to operate without dependency on a PLMN
- Subject to an agreement between the operators and service providers, operator policies and the regional or national regulatory requirements, the 5G system shall support for non-public network subscribers
  - Access to subscribed PLMN services via the non-public network
  - Seamless service continuity for subscribed PLMN services between a non-public network and a PLMN
  - Access to selected non-public network services via a PLMN
  - Seamless service continuity for non-public network services between a non-public network and a PLMN
- Subject to regional or national regulatory requirements for emergency services, 5G system shall be able to support IMS emergency services for non-public networks
- A non-public network subscriber to access a PLMN service shall have a service subscription using 3GPP identifiers and credentials provided or accepted by a PLMN

Non-public Networks Requirements (Cont.)

- The 5G system shall support a mechanism for a UE to identify and select a non-public network.
- The 5G system shall support identifiers for a large number of non-public networks to minimize collision likelihood between assigned identifiers
- The 5G system shall support a mechanism to prevent a UE with a subscription to a non-public network from automatically selecting and attaching to a PLMN or non-public network it is not authorized to select
- The 5G system shall support a mechanism to prevent a UE with a subscription to a PLMN from automatically selecting and attaching to a non-public network it is not authorized to select
- The 5G system shall support a mechanism for a PLMN to control whether a user of a UE can manually select a non-public network hosted by this PLMN that the UE is not authorized to select automatically
- The 5G system shall support a change of host of a non-public network from one PLMN to another PLMN without changing the network selection information stored in the UEs of the non-public network
- The 5G system shall enable an NPN to support multiple third-party service providers

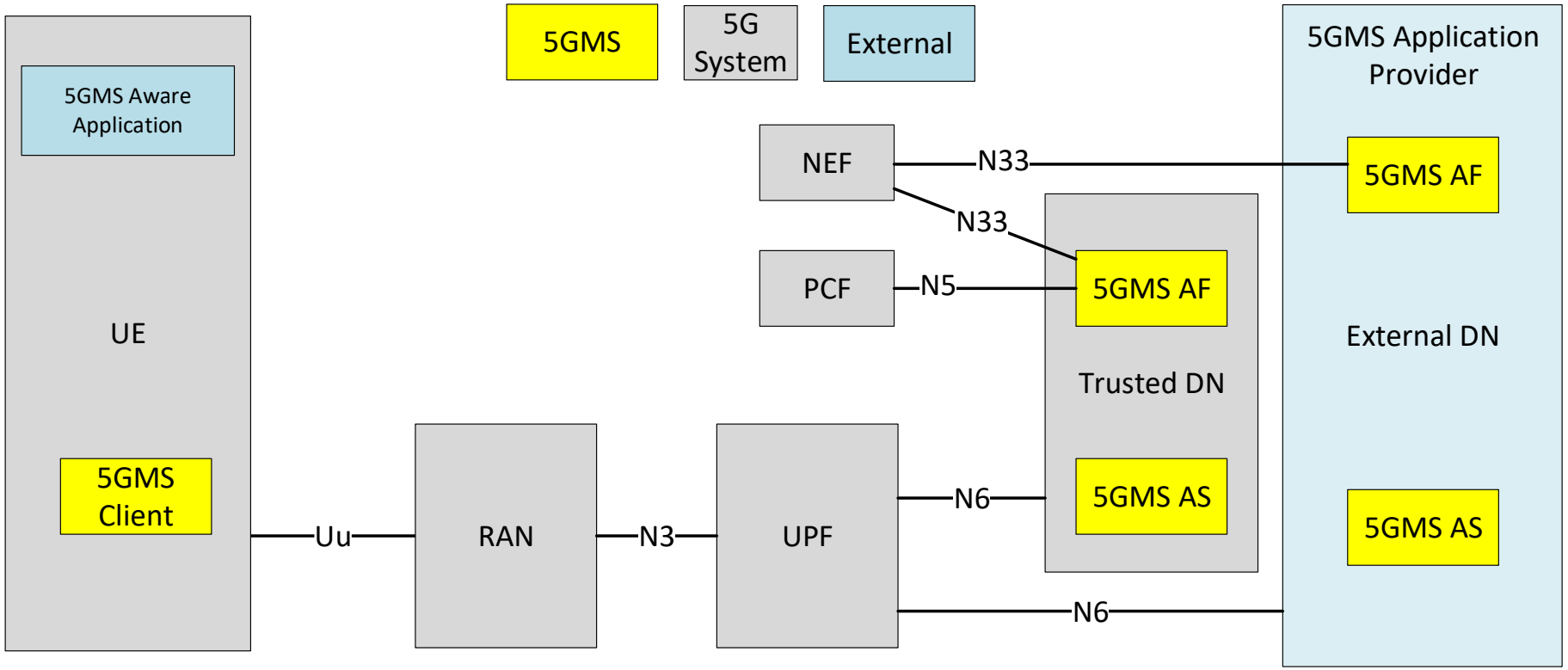
Outline

- Access Technologies for eMBB
  - Before and After Release 17
  - Scenarios and Attributes
  - Performance Requirements
- Network Technologies for eMBB
  - QoS and Network Slicing
  - Non-Public Networks
  - 5GMS and eMBMS

5G Media Streaming (5GMS)

- 5GMS supports
  - MNO and third-party Downlink Media Streaming Services, and
  - MNO and third-party Uplink Media Streaming Services
- The 5GMS architecture supports
  - Related network and UE functions and APIs,
  - backwards compatible functions for EUTRAN deployments
    - (with and without MBMS)
  - 5G specific features
- The 5GMS architecture is functionally divided into independent components enabling different deployments with various degrees of integration between 5G MNOs and Content Providers

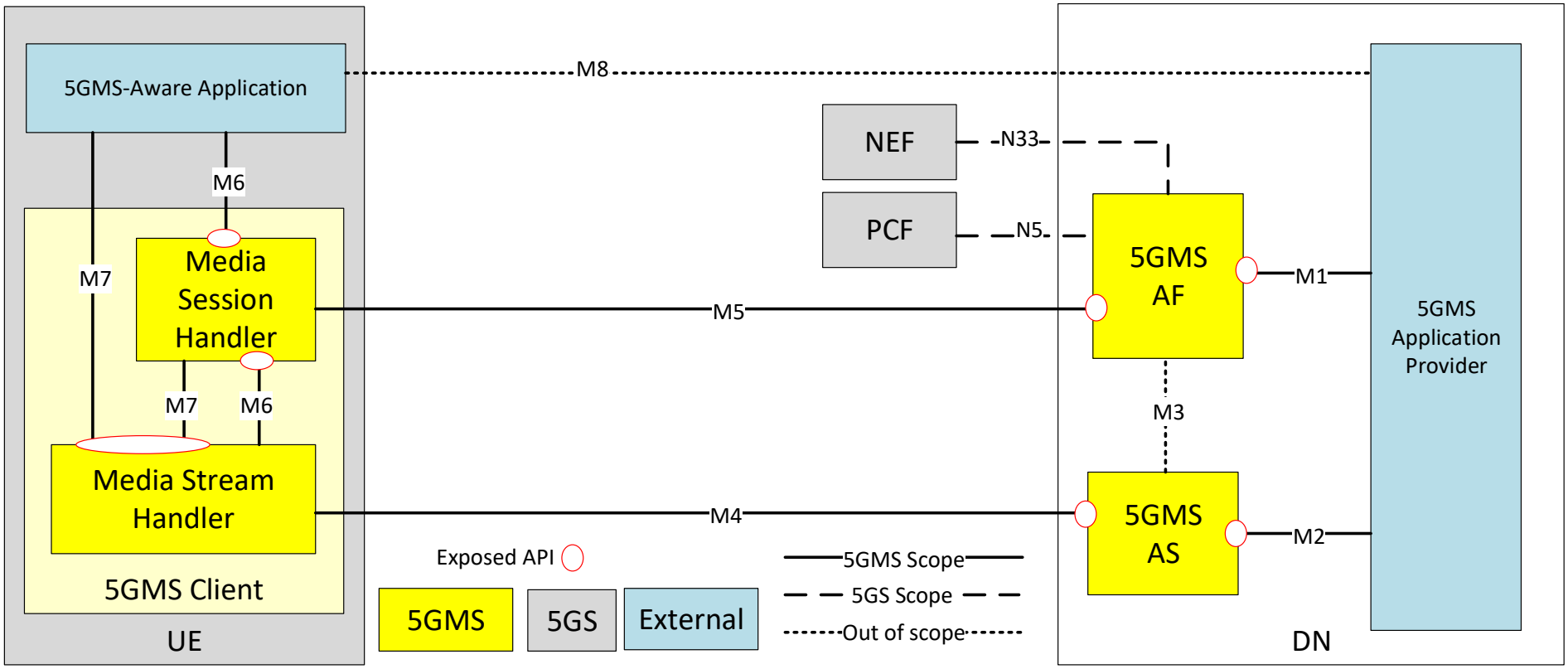
5G Media Streaming within the 5G System



5GMS AF and AS are Data Network (DN) functions and communicate with UE via N6

- The functions indicated by the yellow filled boxes are in scope of stage 3 specifications for 5GMS
- The functions indicated by the grey boxes are defined in 5G System specifications
- The functions indicated by the blue boxes are neither in scope of 5G Media Streaming nor 5G System specifications

5GMS General Architecture Example

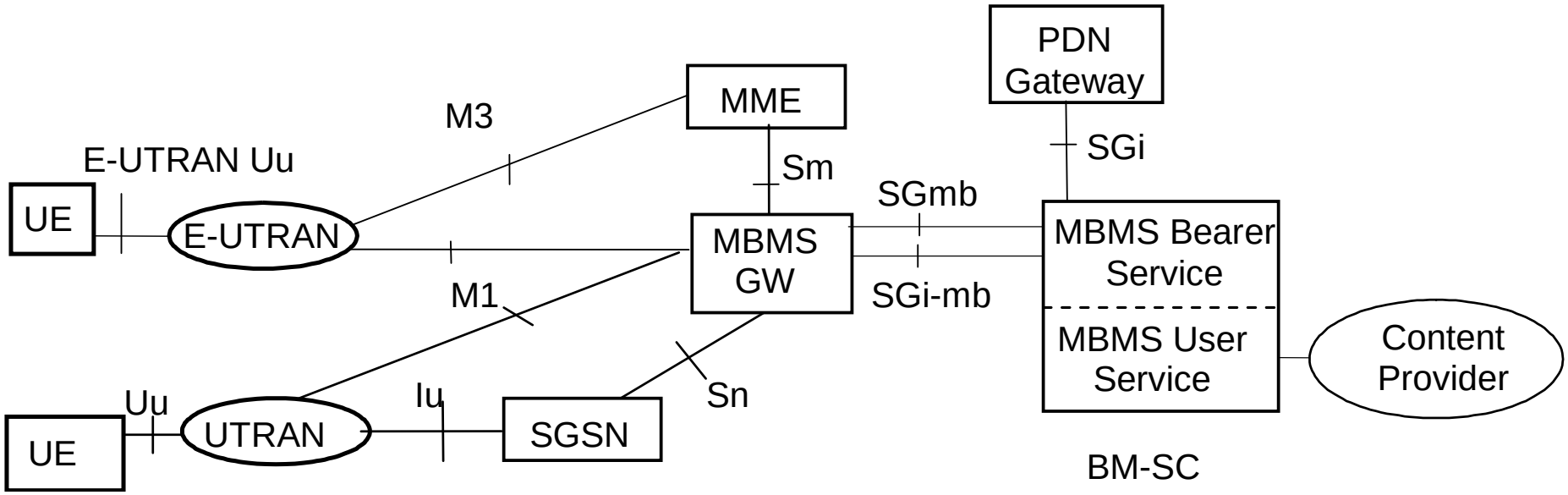


- This UE architecture is not applicable generally
  - It is just as valid to implement a 5GMS Client that does not expose interfaces M6 ad M7 within the 5GMS Client
  - It is also valid for a 5GMS Client inside a UE to be completely self-contained, such that all functionality typically implemented in the 5GMS-aware application is embedded in the UE and thus interfaces M6 and M7 are not exposed at all

MBMS Architecture and Functional Description

- Control Plane
  - providing control of session initiation/modification/termination by the MBMS User Service and managing bearer resources for the distribution of MBMS data
  - Transmit Session control messages towards multiple E-UTRAN nodes
  - Provision of the list of MBMS Service Areas served by the MCE to the MME
  - Transmit Session Control messages towards the necessary E-UTRAN nodes to ensure the distribution of content from ongoing MBMS sessions
- Bearer Plane
  - Broadcast mode or multicast mode
    - EPS only support broadcast mode.
  - A particular instance of the MBMS Bearer Service is identified by an IP Multicast Address and an APN Network Identifier
    - A TMGI also can be used to identify one MBMS Bearer Service inside one PLMN

MBMS Reference Architecture Model



Single-Cell Transmission

- MBMS is transmitted in the coverage of a single cell
- Scheduling is done by the eNB
- Transport channel: SC-MCCH and SC-MTCH
- One SC-MCCH and one or more SC-MTCH(s) are mapped on DL-SCH
  - SC-MCCH and SC-MTCH transmissions are each indicated by a logical channel specific RNTI on PDCCH (there is a one-to-one mapping between TMGI and G-RNTI used for the reception of the DL-SCH to which a SC-MTCH is mapped)
  - A single transmission is used for DL-SCH (i.e. neither blind HARQ repetitions nor RLC quick repeat) on which SC-MCCH or SC-MTCH is mapped
- SC-MCCH and SC-MTCH use the RLC-UM mode

Multi-Cell Transmission

- Synchronous transmission of MBMS within its MBSFN Area
  - Combining of MBMS transmission from multiple cells is supported
- Transport channel: MCCH and MTCH
  - MTCH and MCCH can be multiplexed on the same MCH and are mapped on MCH for p-t-m transmission
  - MTCH and MCCH use the RLC-UM mode
  - The MAC subheader indicates the LCID for MTCH and MCCH
- Scheduling of each MCH is done by the MCE
  - A single transmission is used for MCH (i.e. neither blind HARQ repetitions nor RLC quick repeat)
  - A single Transport Block is used per TTI for MCH transmission, that TB uses all the MBSFN resources in that subframe
- The MBSFN Synchronization Area, the MBSFN Area, and the MBSFN cells are semi-statically configured e.g. by O&M
- MBSFN areas are static, unless changed by O&M (i.e. no dynamic change of areas)

MBMS Specific Reference Points

- M1: The reference point between MBMS GW and E-UTRAN/UTRAN for MBMS data delivery. IP Multicast is used on this interface to forward data
- M3: The reference point for the control plane between MME and E-UTRAN
- Sm: The reference point for the control plane between MME and MBMS GW
- Sn: The reference point between MBMS GW and SGSN (S4 based) for the control plane and for MBMS data delivery. Point-to-point mode is used on this interface to forward data
- SGi-mb: The reference point between BM-SC and MBMS GW function for MBMS data delivery
- SGmb: The reference point for the control plane between BM-SC and MBMS GW
- Protocol assumption:
  - The Sm reference point is based on GTPv2-C
  - The Sn reference point is based on GTPv2-C and GTPv1-U
  - The M1 reference point is based on GTPv1-U

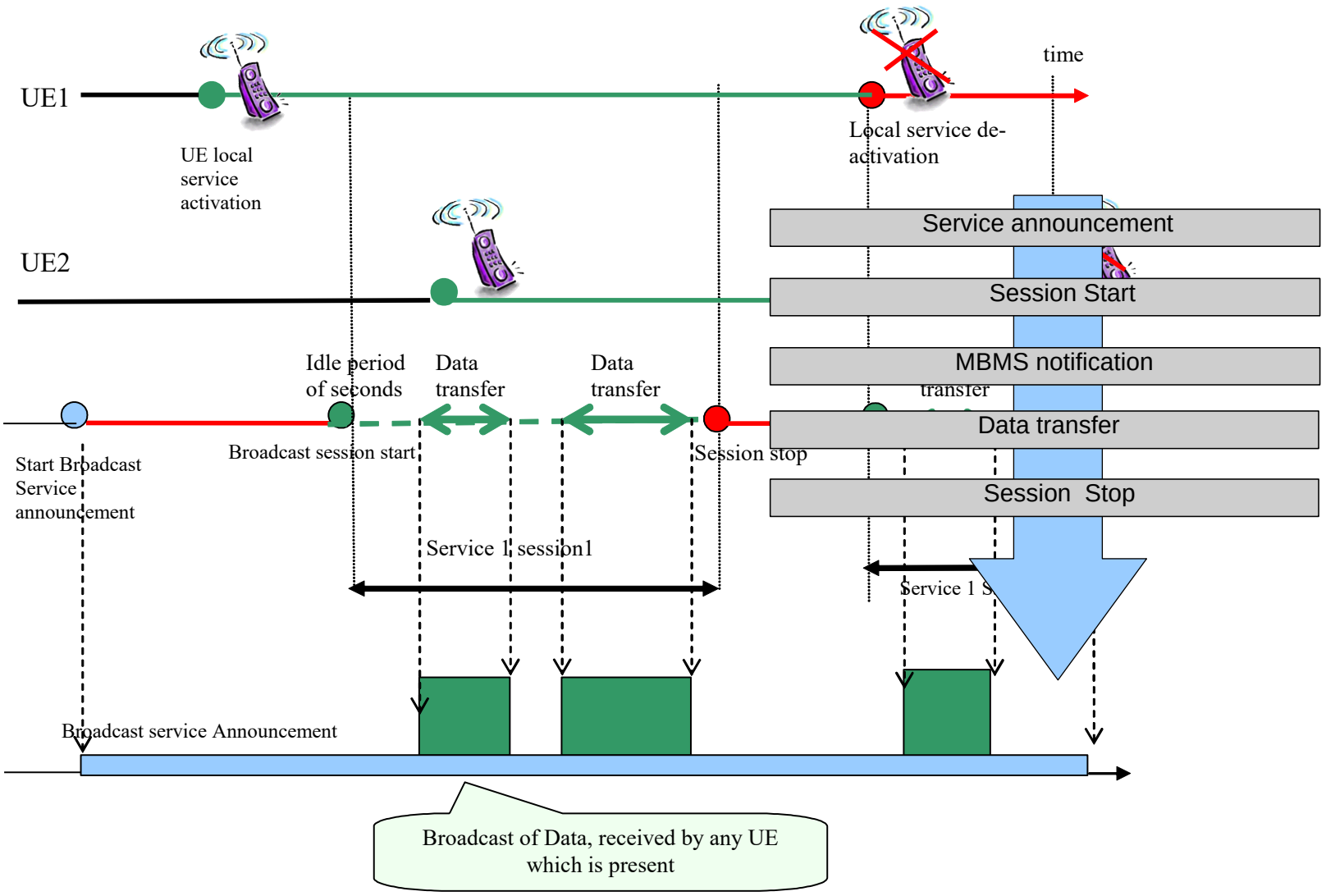
MBMS Functional Entity - BM-SC

- Broadcast-Multicast Service Centre (BM-SC)
- A functional entity, the Broadcast Multicast Service Centre (BM-SC) provides a set of functions for MBMS User Services. BM-SC functions for different MBMS User Services may be supported from the same or different physical network elements
- Consist of the following sub-functions
  - Membership function
  - Session and Transmission function
  - Proxy and Transport function
  - Service Announcement function
  - Security function
  - Content synchronization for MBMS in UTRAN
  - Content synchronization for MBMS in E-UTRAN for broadcast mode
  - Header compression for MBSFN MBMS data in UTRAN
  - Header compression for Mission Critical services using MBMS in E-UTRAN

MBMS Functional Entity - MBMS-GW

- One or more MBMS GW function entities may be used in a PLMN
- MBMS GW functions
  - Provides an interface for entities using MBMS bearers through the SGi-mb (user plane) reference point
  - Provides an interface for entities using MBMS bearers through the SGmb (control plane) reference point
  - IP multicast distribution of MBMS user plane data to E-UTRAN (M1 reference point)
    - If the MBMS GW has allocated both an IPv4 and an IPv6 IP Multicast address, IP multicast distribution of MBMS user plane data is performed towards both IP Multicast addresses, using the same C-TEID
  - An eNodeB should join to IP Multicast distribution using one IP Multicast address (either IPv4 or IPv6) to receive the MBMS data
    - When a single IP Multicast address is allocated by the MBMS-GW, this IP Multicast address together with the IP address of the multicast source (SSM) and a C-TEID is provided to the eNodeB via MME

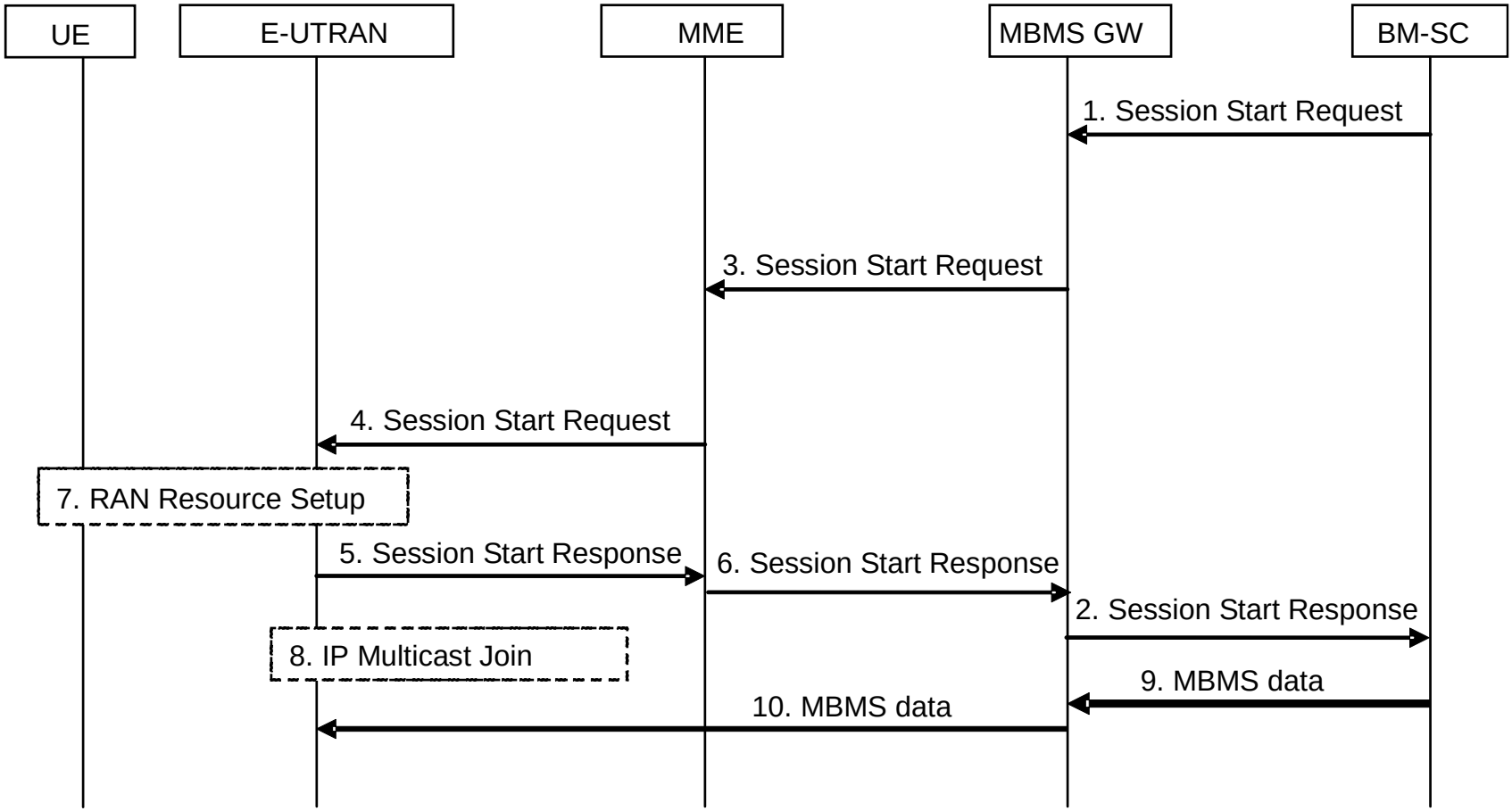
Phase of Broadcast Service



Phase of Broadcast Service (cont.)

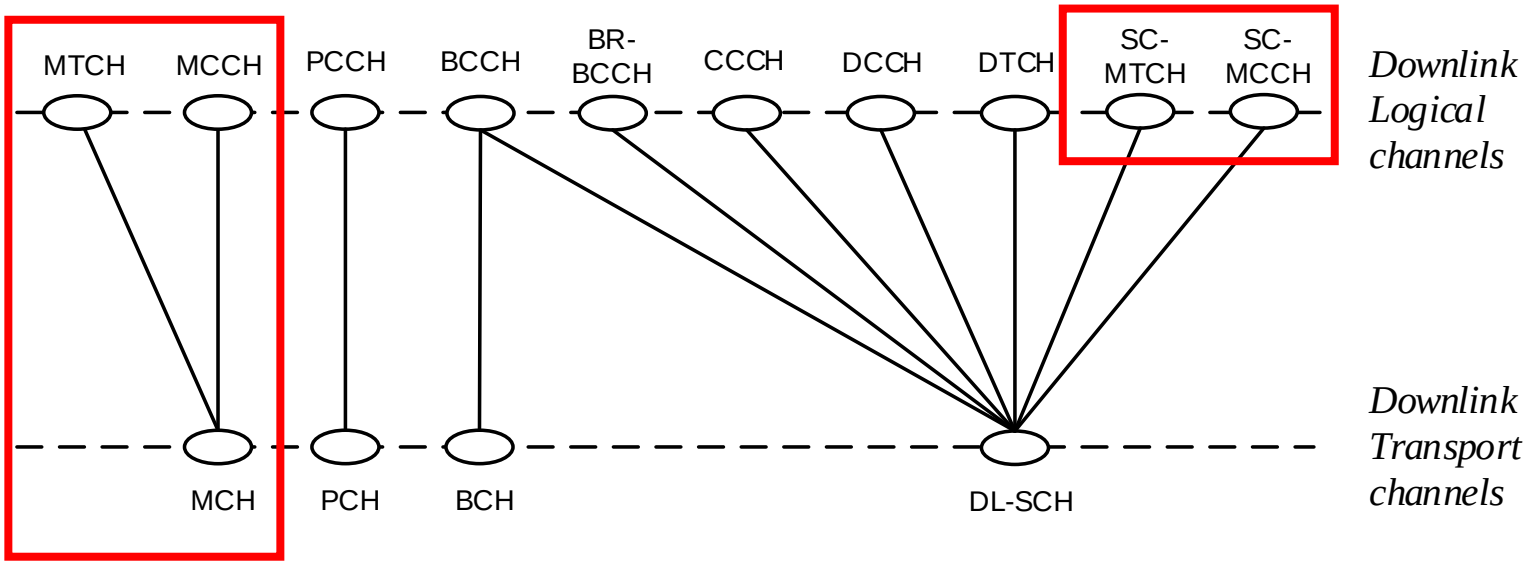
- Service announcement
  - Service announcement is used to distribute to users information about the service, parameters required for service activation (e.g. IP multicast address(es)) and possibly other service related parameters (e.g. service start time)
  - The MBMS user service part in the UE initiates reception of the MBMS bearer service to receive an MBMS user service
- Session Start
  - Session Start is the point at which the BM-SC is ready to send data
  - Start occurs independently of activation of the service by the user
- MBMS notification
  - Informs the UEs about forthcoming (and potentially about ongoing) MBMS multicast data transfer
- Data transfer
  - It is the phase when MBMS data are transferred to the UEs
- Session Stop
  - It is the point at which the BM-SC determines that there will be no more data to send for some period of time – this period being long enough to justify removal of bearer resources associated with the session. At Session Stop, the bearer resources are released
- Session Update
  - Session Update is used to update specific parameters of an ongoing MBMS Broadcast session

Session Start Procedure



MBMS Channels

- Transport Channel: Multicast Channel(MCH)
  - Multiplexed by MCCH and MTCH
  - A new LCID is assigned to MCH
- Logical Channel: Multicast Control Channel(MCCH) or SC-MCCH
  - Transfer RRC information
  - MCCH is transmitted by RRC every MCCH repetition period
- Logical Channel: Multicast Transport Channel(MTCH) or SC-MTCH
  - Transfer GTP encapsulated data from BM-SC
  - The scheduling information is carried by MCCH or SC-MCCH



Multicast Control Channel (MCCH)

- One MBSFN Area is associated with one MCCH and one MCCH corresponds to one MBSFN Area
- MCCH consists of a single MBSFN Area configuration RRC message
  - All the MBMS services with ongoing sessions
  - An optional MBMS counting request message which, when present, comes after the former message in the repetition period
- MCCH is transmitted by all cells within an MBSFN Area, except the MBSFN Area Reserved Cells
  - The MCCH is sent on MCH
  - MCCH is transmitted by RRC every MCCH repetition period
  - MCCH uses a modification period
  - A notification mechanism is used to announce changes of MCCH due to either Session Start or the presence of an MBMS counting request message
  - The UE detects changes to MCCH which are not announced by the notification mechanism by MCCH monitoring at the modification period

SC-MCCH

- There is one SC-MCCH per cell
- The SC-MCCH provides the list of all MBMS services with ongoing sessions transmitted on SC-MTCH(s)
  - TMGI of each MBMS service
  - Optional session ID
  - Associated G-RNTI
  - Scheduling information
- SC-MCCH is transmitted by RRC every SC-MCCH repetition period
  - The SC-MCCH is sent on DL-SCH
  - SC-MCCH uses a modification period
- Except for NB-IoT UEs, BL UEs or UEs in enhanced coverage a notification mechanism is used to announce changes of SC-MCCH due to Session Start:
  - The notification is sent in the first subframe in a repetition period where the SC-MCCH can be scheduled. The notification is sent using the DCI format 1C with SC-N-RNTI and one bit within the 8-bit bitmap
  - When the UE receives a notification, it acquires the SC-MCCH in the same subframe
- The UE detects changes to SC-MCCH which are not announced by the notification mechanism by SC-MCCH monitoring at the modification period.

SC-MCCH (Cont.)

- For each SC-MTCH, the following scheduling information is provided on SC-MCCH:
  - SC-MTCH scheduling cycle
  - SC-MTCH on-duration: duration in downlink subframes that the UE waits for, after waking up from DRX, to receive PDCCHs. If the UE successfully decodes a PDCCH indicating the DL-SCH to which this SC-MTCH is mapped, the UE stays awake and starts the inactivity timer
  - SC-MTCH inactivity-timer: duration in downlink subframes that the UE waits to successfully decode a PDCCH, from the last successful decoding of a PDCCH indicating the DL-SCH to which this SC-MTCH is mapped, failing which it re-enters DRX. The UE shall restart the inactivity timer following a single successful decoding of a PDCCH

MBMS Signaling

- MBMS is signaling on BCCH(SIB2 and SIB13)
- BCCH points to the resources where the MCCH(s)/SC-MCCH can be found
- BCCH does not indicate the availability of the services
- For each MCCH, BCCH indicates independently:
  - The scheduling of the MCCH for multi-cell transmission on MCH
  - The MCCH modification period, repetition period radio frame offset and subframe allocation
  - An MCS which applies to the subframes indicated for MCCH scheduling and for the first subframe of all MSPs in that MBSFN Area
- For the notification commonly used for all MCCH, BCCH:
  - Configures the position of the MCCH change notification subframe and the number of occasions monitored by the UE
  - Indicates the mapping between the PDCCH bit(s) carried in the notification and the MCCH(s)
  - BCCH indicates the SC-MCCH modification period, SC-MCCH repetition period and SC-MCCH subframe offset

Summary

- 5G-NR and SA/NSA 5GC support eMBB that covers most key performance indicators
  - There are specific attributes and requirements for individual eMBB use cases
- 5GS supports differentiated eMBB services with QoS and networking slicing
- Two kinds of non-public networks for vertical domains
  - Stand-alone Non-Public Network (SNPN)
  - Public Network Integrated NPN (PNI-NPN)
- Two 3GPP systems for multimedia services
  - 5G Media Streaming (5GMS)
  - Enhanced Multimedia Broadcast/Multicast Service (eMBMS)

References

- TR 38.913 - Study on scenarios and requirements for next generation access technologies (16.0.0)
  - TS 22.261 Clause 6.1 Network Slicing and 6.25 Non-Public Networks (17.3.0)
  - TS 23.501 Clause 5.30 Support for NPN (16.5.0)
  - TS 24.501 Clause 4.14 Non-Public Networks (16.5.0)
- TS 26.501 - 5GMS General description and architecture (16.4.0)
  - TS 26.511 - 5GMS Profiles, codecs and formats (16.0.0)
  - TS 26.512 - 5GMS Protocols (1.2.0)
- TS 22.146 - MBMS Stage 1 (16.0.0)
  - TS 22.246 - MBMS user services; Stage 1 (16.0.0)
  - TS 23.246 - MBMS Architecture and functional description (16.1.0)
  - TS 25.346 - MBMS in the RAN; Stage 2 (16.0.0)
  - TS 26.346 - MBMS Protocols and codecs (16.5.0)