Recommendations for NGMN KPIs and Requirements for 5G

by NGMN Alliance

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Project:	**P1 WS#3 BBTS**
Editor / Submitter:	
Contributors:	
Approved by / Date:	**03-June-2016**

Commercial Address:
ngmn Ltd.,
Großer Hasenpfad 30 • 60598 Frankfurt • Germany

Phone +49 69/9 07 49 98-04 • Fax +49 69/9 07 49 98-41

Registered Office:
ngmn Ltd.,
Reading Bridge House • George Street • Reading • Berkshire RG1 8LS • UK
Company registered in England and Wales n. 5932387, VAT Number: GB 918713901

Key Performance Indicators

Table 1: General KPIs and their high level evaluation approach

KPI	Definition	Requirement[1]	Evaluation method	Remarks
Bandwidth	The highest aggregated total system bandwidth. It may be supported by single or multiple RF carriers.	Leave to ITU-R to decide	Inspection	
Bandwidth scalability	The ability of the access technology to operate with different bandwidth allocations.	Not worse than IMT-Advanced	Inspection	This bandwidth may be supported by single or multiple RF carriers. Bandwidth scalability's relevance includes providing higher occupancy for the various spectrum block sizes encountered internationally, including those not multiples of 5/10/20 MHz.
Control plane latency	1. Latency from most battery efficient state (e.g., IDLE) to continuous transfer of large data volume The time it takes for a mobile device in its most "battery efficient" state (e.g. RRC Idle) to start transmission of a large volume of Mobile Originated application layer data over the radio interface, from the time when data arrives at its radio protocol layer 2/3 SDU ingress point.	[10 ms]	Analytical	Notes: The states for 5G are not yet defined, but this should typically be a state transition time between the idle state and a connected state that supports efficient transfer of large data volumes.
User plane latency	The time it takes to successfully deliver an application layer packet/message from the radio protocol layer 2/3 SDU ingress point to the radio protocol layer 2/3	General: 4 ms Special case: 0.5 ms (the	Analytical	In the general case the evaluation should include an assessment of the applicable procedural delays when no resource has been already allocated (e.g. request/grant, contention channel access). Furthermore, a

Commercial Address:
ngmn Ltd.,
Großer Hasenpfad 30 • 60598 Frankfurt • Germany

Phone +49 69/9 07 49 98-0 • Fax +49 69/9 07 49 98-41

Registered Office:
ngmn Ltd.,
Reading Bridge House • George Street • Reading •
Berkshire RG1 8LS • UK
Company registered in England and Wales n. 5932387,
VAT Number: GB 918713901

	SDU egress point via the radio interface in both uplink and downlink directions, where neither device nor Base Station reception is restricted by DRX.	feasibility of 0.25 ms should be studied) Note: These values are average values for the uplink and downlink , e.g. 6 ms UL and 2 ms DL would meet the general requirement		fronthauling delay of 250 microseconds should be assumed to allow for a split of processing functions across NG radio access location. The value should be an average latency value, including the averaged HARQ delay. However in special cases for providing a minimum latency (e.g. for URLLC use case or, in case 0.25 ms is feasible, enabling use of NG access for fronthaul), it can be assumed that resources are already allocated, and that no additional transport delay is involved. Furthermore extra robustness can be assumed to reduce the HARQ probability, although the link efficiency impacts of that should then also be evaluated. FFS: How to obtain reasonable assumptions about retransmissions, HARQ probability, etc. in analytical evaluations.
Latency for infrequent small packets	For infrequent application layer small packet/message transfer, the time it takes to successfully deliver an application layer packet/message from the radio protocol layer 2/3 SDU ingress point at the mobile device to the radio protocol layer 2/3 SDU egress point in the RAN, when the mobile device starts from its most "battery efficient" state.	X ms for ≤Y bytes application layer packet size For mMTC extreme coverage and extreme battery life: X = [10000], Y = [TBD] For other use	Analytical	This requirement shall be evaluated for at least when the device is operating in a scenario where extreme battery life and extreme coverage requirements also need to be simultaneously met. FFS: Reasonable assumptions about retransmissions, HARQ probability, etc. in analytical evaluations.

Commercial Address:
ngmn Ltd.,
Großer Hasenpfad 30 • 60598 Frankfurt • Germany

Phone +49 69/9 07 49 98-0 • Fax +49 69/9 07 49 98-41

Registered Office:
ngmn Ltd.,
Reading Bridge House • George Street • Reading •
Berkshire RG1 8LS • UK
Company registered in England and Wales n. 5932387,
VAT Number: GB 918713901

		cases X = [10], Y = [TBD]		
Mobility interruption time	The shortest time duration supported by the system during which a user terminal cannot exchange user plane packets with any base station during transitions.	0 ms	Analytical	Possibly different requirements for intra-frequency and inter-frequency mobility interruption and for different services. In case multi-connectivity is supported, there could be no mobility interruption time.
Inter-system handover interruption time	The shortest time duration supported by the system during which a user terminal cannot exchange user plane packets with any base station during transitions between 5G new radio and another radio access technology (RAT). Other RATs include at least LTE evolution. Additional other RATs, including non-3GPP RATs, are FFS.	TBD	Analytical	Possibly different requirements for handovers between new 5G RAT and different RATs.
Support for wide range of services	The ability of the access technology to meet the connectivity requirements of a range of existing and future (as yet unknown) services to be operable on a single continuous block of spectrum in an efficient manner.	Yes	Inspection	The components to inspect are for FFS.
Duplexing flexibility	The ability of the access technology to adapt its allocation of resources flexibly for uplink and downlink for both paired and unpaired frequency bands.	Yes	Inspection	Applicable for frequency bands in at least existing and future IMT-bands. This flexibility may be used for a wide range of requirements such as uplink/downlink traffic patterns, latency, load, etc.
Network energy efficiency	The capability of a radio access network (RAN) to minimize the RAN energy consumption while providing a much better area traffic capacity.	FFS	Inspection and system-level simulation (FTP traffic)	Note: Definition of better area traffic capacity is to be captured as part of the evaluation. 3GPP is encouraged to study models to help clarify how energy efficiency can be evaluated. Evaluation shall allow to benchmark technology proposals on their

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ngmn Ltd.,
Großer Hasenpfad 30 • 60598 Frankfurt • Germany

Phone +49 69/9 07 49 98-0 • Fax +49 69/9 07 49 98-41

Registered Office:
ngmn Ltd.,
Reading Bridge House • George Street • Reading •
Berkshire RG1 8LS • UK
Company registered in England and Wales n. 5932387,
VAT Number: GB 918713901

				energy efficiency potential. Inspection: Introduce design principles taking into account energy consumption, e.g., (if no/limited transmission when there is no data, etc.) System-level simulation: This KPI should be evaluated in terms of Mbit/s/W at the global RAN level. Specifically, this KPI has to be defined for different load levels and for different deployment scenarios. 3GPP is encouraged to evaluate energy efficiency not for peak hour but based on a 24 hour daily traffic profile. The related evaluation methodology needs to be developed within 3GPP relevant studies [5G Technology Study] (ex. ETSI 203 228). For example, base station load levels could be recorded during simulations to be translated into energy consumption by means of a base station power model (e.g., Greentouch) assuming the following energy efficiency (EE) formulation: • a_l=weight for load level l • b_K=weight for deployment scenario K • V_l=aggregated throughput served in the simulated area for load level l (in Mbps), or equivalently served traffic volume divided by the simulation period

Commercial Address:
ngmn Ltd.,
Großer Hasenpfad 30 • 60598 Frankfurt • Germany

Phone +49 69/9 07 49 98-0 • Fax +49 69/9 07 49 98-41

Registered Office:
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VAT Number: GB 918713901

				• EC_l=sum of the average power consumption of all RAN nodes in the simulated area during load level l (in Watt) $$EE_{scenario} = \sum_{load\ level\ l} a_l \frac{V_l}{EC_l}$$ $$EE_{global} = \sum_{scenario\ K} b_K EE_{scenario}$$ Other methodology could also be studied. Proposals for the 24 hour daily traffic profiles could be provided by operators. At least, energy efficiency should be evaluated in coverage limited environments (e.g., rural) and capacity limited environments (e.g., urban). Every effort should be made to obtain the energy gain without degrading the performance, but the technology should allow native flexibility for the operator to configure trade-off between energy efficiency versus performance where justified.
Peak data rate	The highest theoretical data rate which is the received data bits assuming error-free conditions assignable to a single mobile station, when all available radio resources for the corresponding link direction are utilised (i.e., excluding radio resources that are used for physical layer synchronisation, reference signals or pilots, guard bands and guard times).	N/A	Analytical	NGMN will not define requirements for peak data rate and peak spectral efficiency. Consistent user experience is of a higher priority for NGMN than peak data rate.

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Großer Hasenpfad 30 • 60598 Frankfurt • Germany

Phone +49 69/9 07 49 98-0 • Fax +49 69/9 07 49 98-41

Registered Office:
ngmn Ltd.,
Reading Bridge House • George Street • Reading •
Berkshire RG1 8LS • UK
Company registered in England and Wales n. 5932387,
VAT Number: GB 918713901

Peak spectral efficiency	The peak data rate normalized by bandwidth.	N/A	Analytical	See remark for peak data rate (above).

Note: The different content from the previous LS to RAN AH is marked in red.

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ngmn Ltd.,
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Phone +49 69/9 07 49 98-0 • Fax +49 69/9 07 49 98-41

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Table 2: Deployment-scenario specific KPIs and requirements

KPI	Definition	Requirement	Evaluation method	Remarks
Transmission/ Reception Point (TRP) average spectrum efficiency	The aggregate throughput of all users (the number of correctly received bits, i.e. the number of bits contained in the service data units (SDUs) delivered to Layer 3, over a certain period of time) divided by the channel bandwidth divided by the number of TRPs. The channel bandwidth for this purpose is defined as the effective bandwidth times the frequency reuse factor, where the effective bandwidth is the operating bandwidth normalised appropriately considering the uplink/downlink ratio. The TRP spectral efficiency is measured in bit/s/Hz/TRP. A 3 sector site consists of 3 TRPs.	TBD	System-level simulation (full-buffer)	Assessment for multi-layer and multi-band is FFS. How to evaluate outdoor and indoor users independently needs to be considered. NGMN white paper targets significant improvements in spectrum efficiency.

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ngmn Ltd.,
Großer Hasenpfad 30 • 60598 Frankfurt • Germany

Phone +49 69/9 07 49 98-0 • Fax +49 69/9 07 49 98-41

Registered Office:
ngmn Ltd.,
Reading Bridge House • George Street • Reading • Berkshire RG1 8LS • UK
Company registered in England and Wales n. 5932387, VAT Number: GB 918713901

User experienced data rate	The 5%-percentile of the user throughput. User throughput (during active time) of an individual burst is defined as the size of a burst divided by the time between the arrival of the first packet of a burst and the reception of the last packet of the burst.	Indoor DL: 1 Gbit/s UL: 500 Mbit/s Dense urban DL: 300 Mbit/s UL: 50 Mbit/s Urban DL: 50 Mbit/s UL: 25 Mbit/s Rural DL: 50 Mbit/s UL: 25 Mbit/s High speed DL: 50 Mbit/s UL: 25 Mbit/s	System-level simulation (FTP traffic)	This KPI needs to be achieved at the target area traffic capacity for each relevant deployment scenario. The definition of a burst depends on the traffic model and is FFS. The requirements derived from the NGMN white paper may be revised after a careful review of assumptions on connection density and available bandwidth.
5th percentile user spectrum efficiency	The cell edge user spectral efficiency is defined as 5% point of the cumulative distribution function (CDF) of the normalized user throughput. The (normalized) user throughput is defined as the average user throughput (the number of correctly received bits by users, i.e., the number of bits contained in the SDU delivered to Layer 3, over a certain period of time, divided by the channel bandwidth and is measured in bit/s/Hz. The channel bandwidth for this purpose is defined as the effective bandwidth times the frequency reuse factor, where the	TBD	System-level simulation (full buffer)	This KPI was previously called user experienced spectrum efficiency in (reference LS to RAN #70). Assessment for multi-layer and multi-band is FFS. How to evaluate outdoor and indoor users independently needs to be considered. NGMN white paper targets significant

Commercial Address:
ngmn Ltd.,
Großer Hasenpfad 30 • 60598 Frankfurt • Germany

Phone +49 69/9 07 49 98-0 • Fax +49 69/9 07 49 98-41

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Berkshire RG1 8LS • UK
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VAT Number: GB 918713901

	effective bandwidth is the operating bandwidth normalised appropriately considering the uplink/downlink ratio.			improvements in spectrum efficiency.
Connection density	Total number of devices fulfilling specific QoS per unit area (per km^2).	1e6 devices/km^2 for mMTC for urban environment	Option 1: Analytical Option 2: Simulation	Foreseen as most relevant for mMTC. QoS definition should take into account the amount of data generated within a time t_gen that can be sent or received within a given time, t_sendrx, with x% probability. Note 1: Evaluation environment is FFS Note 2: Report bandwidth used in evaluation.
Area traffic capacity	Full buffer: Total traffic throughput served per geographic area (in Mbit/s/m^2). The computation of this metric is based on full buffer traffic.		Analytical	
	Non full buffer: Total traffic throughput served per geographic area (in Mbit/s/m^2). Both the user experienced data rate and the area traffic capacity need to be evaluated at the same time using the same traffic model.		System level simulations (FTP traffic)	This KPI is used to derive the burst arrival rate for the FTP simulations
Mobility	Maximum user speed at which a defined QoS can be achieved (in km/h).	500 km/h	Simulation (link and system level)	Mobility classes and QoS will be defined for each scenario.
Reliability	The success probability of transmitting a layer 2/3 packet of [x bytes] within a maximum time of [t ms], which is the time it takes to deliver a small data packet from the radio protocol layer 2/3 SDU ingress point to the radio protocol layer 2/3 SDU egress point of the radio interface at a certain channel quality.	TBD	Link-level simulation	Foreseen as most relevant for URLLC. If channel access is not granted, the reliability and delay of that should be taken into account. The channel quality target and its variation characteristics need to be defined, including the relevant channel model. Mobility aspects

Commercial Address:
ngmn Ltd.,
Großer Hasenpfad 30 • 60598 Frankfurt • Germany

Phone +49 69/9 07 49 98-0 • Fax +49 69/9 07 49 98-41

Registered Office:
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Berkshire RG1 8LS • UK
Company registered in England and Wales n. 5932387,
VAT Number: GB 918713901

				can be treated as part of the channel quality to be targeted.
Device battery life	The battery life of the device without recharge. For at least mMTC, device battery life in extreme coverage shall be based on the activity of mobile originated data transfer consisting of [200 bytes] UL per day followed by [20 bytes] DL from maximum coupling loss of [164 dB], assuming a stored energy capacity of [5Wh].	[15 years]	Link-level simulation (Reuse TR 45.820)	Battery life KPI definition of other terminal types than mMTC is FFS. The battery life extension should not be achieved by a relaxation of any of the key parameters - and their corresponding values - indicated in the definition. NGMN white paper targets device battery life of up to 15 years. 3GPP should investigate the feasible operating boundaries (data activity, coupling loss, etc.) under which such a device battery life target could be reached.
Extreme Coverage	“Maximum coupling loss” in uplink and downlink between device and Base Station site (antenna connector(s)) for a data rate of [160bps], where the data rate is observed at the egress/ingress point of the radio protocol stack in uplink and downlink.	[164 dB]	Link-level simulation (Reuse TR 45.820)	Foreseen as most relevant for mMTC.
UE energy efficiency	The capability of a UE to reduce UE modem energy consumption while sustaining better performance (e.g., mobile broadband data rate).	Significant enhancement compared to LTE	Inspection	Foreseen as most relevant for eMBB.

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Großer Hasenpfad 30 • 60598 Frankfurt • Germany

Phone +49 69/9 07 49 98-0 • Fax +49 69/9 07 49 98-41

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Reading Bridge House • George Street • Reading •
Berkshire RG1 8LS • UK
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VAT Number: GB 918713901

Deployment scenarios – key challenges and evaluation goals

Table 3: Deployment scenarios with associated key challenges and evaluation goals

Usage scenario	Deployment scenario	Key challenges	Most relevant KPIs	Evaluation goals	Remarks
eMBB	Indoor hotspot (eMBB-InH)	- high capacity - high density - consistent user experience - poor cell isolation	- TRP spectrum efficiency - 5th percentile user spectrum efficiency - user experienced data rate	- Show that high frequency bands can be used indoor.	Candidate scenario for system level evaluations.
	Dense urban (eMBB-UMx)	- high capacity - high density - consistent user experience - poor cell isolation - users distributed in height	- TRP spectrum efficiency - 5th percentile user spectrum efficiency - user experienced data rate - [network energy efficiency]	- Clarify the feasibility of different outdoor deployment options for serving both outdoor and indoor users: macro only or macro and outdoor small cells; considering different spectrum options: low frequency bands only , high frequency bands only or a combination of both high and low frequency bands.	Candidate scenario for system-level evaluations.
	Urban macro (eMBB-UMa)	- capacity - consistent user experience	- TRP spectrum efficiency - 5th percentile user spectrum efficiency - user experienced data rate - [network energy efficiency]	- Clarify the feasibility of a macro outdoor deployment considering different spectrum options: low frequency bands only, high frequency bands only or a combination of both high and low frequency bands to serve both outdoor and indoor users.	Candidate scenario for system-level evaluations.
	Rural macro (eMBB-RMa)	- consistent user experience over wide area - capacity - high user mobility	- TRP spectrum efficiency - 5th percentile user spectrum efficiency - user experienced data rate - mobility - [network energy efficiency]	- Show that low frequency bands can provide wide area coverage. - Clarify the feasibility of meeting the user experience requirement and the capacity requirement with a reasonable site density.	Candidate scenario for system-level evaluations.
	High speed train (eMBB-HS)	- very high speed - high capacity - high connection density	- user experienced data rate - mobility	- Show that link performance can be maintained at very high speeds. - Show the capacity requirement can be met	Special test (link level) could be employed, e.g., under a rural macro setting.

Commercial Address:
ngmn Ltd.,
Großer Hasenpfad 30 • 60598 Frankfurt • Germany

Phone +49 69/9 07 49 98-0 • Fax +49 69/9 07 49 98-41

Registered Office:
ngmn Ltd.,
Reading Bridge House • George Street • Reading •
Berkshire RG1 8LS • UK
Company registered in England and Wales n. 5932387,
VAT Number: GB 918713901

		- consistent user experience		with a reasonable site density.	
mMTC		- massive number of devices - coverage - energy constraints	- connection density - extreme coverage - device battery life	- Clarify the coverage and capacity impact of offering mMTC service (e.g., by evaluation of link-level performance).	Some relevant KPIs may be evaluated without system level simulations. For KPIs that need system level simulations, eMBB deployment scenarios could be reused, possibly with some parameter changes. The need for additional non-eMBB specific deployment scenarios is FFS.
URLLC		- high reliability - very low latency - capacity - coverage - mobility	- latency - reliability	- Clarify the coverage and capacity impact of offering URLLC service (e.g., by evaluation of link-level performance).	

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ngmn Ltd.,
Großer Hasenpfad 30 • 60598 Frankfurt • Germany

Phone +49 69/9 07 49 98-0 • Fax +49 69/9 07 49 98-41

Registered Office:
ngmn Ltd.,
Reading Bridge House • George Street • Reading •
Berkshire RG1 8LS • UK
Company registered in England and Wales n. 5932387,
VAT Number: GB 918713901

Table 4: Deployment scenarios and spectrum options

Deployment scenario	KPI	KPI value	Deployment options[1]	Spectrum options[2]	Bandwidth[3]	Comments
Indoor hotspot (eMBB-InH)	User experienced data rate[4]	DL: 1 Gbps UL: 500 Mbps	Indoor floor, ISD 20m	Above 6 GHz (around 30 GHz [5]or around 70 GHz[6])	Up to 1000 MHz	
	Area traffic capacity (non-	DL: 15 Tbps/km^2	100% indoors	Above 6 GHz (around 30 GHz or around 70 GHz) and	Up to 1000 MHz and	Evaluation only required if >6GHz cannot meet requirement.

[1] Indicates deployment options that can be studied to identify the option(s) that can meet the requirements. Not all options need to be necessarily evaluated.
[2] The options noted here are for evaluation purpose, and do not mandate the deployment of these options or preclude the study of other spectrum options.
[3] This is not the simulation bandwidth. Simulation bandwidth may be much smaller. This bandwidth denotes an aspirational background to the capacity/user experienced data rate/area traffic capacity requirements and not necessarily what will be available to an operator in a single block. The bandwidth value given is per operator.
[4] The user experienced data rate (non full buffer) and area traffic capacity values are target values and not strict requirements. The user experienced data rate is the target for 5th percentile user data rate at a loading determined by the area traffic capacity (non-full buffer) target for that deployment scenario.
In case the user experienced data rate target is not achieved at the target loading for a particular deployment scenario, the 5th percentile user data rate shall be calculated at a reasonably well utilized loading (e.g. consistent with 50% harmonic mean normalized cell throughput (HM-NCT, see TR 36.814)).
Providing results for different loading levels is useful, but it is not strictly necessary to check that the user experience data rate is met. It is up to 3GPP to decide how many loading levels are simulated. The assumptions for deriving area traffic capacity (non-full buffer) for a single operator are provided in the appendix
[5] A range of bands from 24 GHz – 40 GHz identified for WRC-19 are currently being considered and around 30 GHz is chosen as a proxy for this range.
[6] A range of bands from 66 GHz – 86 GHz identified for WRC-19 are currently being considered and around 70 GHz is chosen as a proxy for this range.

Commercial Address:
ngmn Ltd.,
Großer Hasenpfad 30 • 60598 Frankfurt • Germany

Phone +49 69/9 07 49 98-0 • Fax +49 69/9 07 49 98-41

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VAT Number: GB 918713901

	full buffer) for a single operator[4]	UL: 2 Tbps/km[2]		Below 6 GHz (around 4 GHz)	Up to 200 MHz	
Dense urban (eMBB-UMx)	User experienced data rate Area traffic capacity (non-full buffer)	DL: 300 Mbps UL: 50 Mbps DL: 250 Gbps/sq km UL: 42 Gbps/sq km	Macrocell only, ISD 200m 20% outdoor (3 km/h) and 80% indoor (3 km/h)	Below 6 GHz (around 4 GHz)	Up to 200 MHz	
				Above 6 GHz (around 30 GHz)	Up to 1000 MHz	
				Below 6 GHz (around 4 GHz) and above 6 GHz (around 30 GHz) combined	Up to 200 MHz and Up to 1000 MHz	
			Macro cells with outdoor small cells Macro ISD: 200m Small cell ISD: [3][7] small cell per macro sector. Users: 20% outdoor (3 km/h) and 80% indoor (3 km/h)	Below 6GHz (around 4 GHz) for both macro and small cells	Up to 200 MHz	
				Above 6 GHz (around 30 GHz) for both macro and small cells	Up to 1000MHz	
				Below 6 GHz (around 4 GHz) and above 6 GHz (around 30 GHz) combined for macro and small cells	Up to 200 MHz and Up to 1000 MHz	
				Below 6 GHz (around 4 GHz) for macro and above 6 GHz (around 30 GHz or around 70 GHz) for small cells	Up to 200 MHz and Up to 1000 MHz	
Urban macro	User	DL: 50 Mbps	Macro only, hex grid	Below 6 GHz (around 2 GHz or around 4	Up to:	

[7] This does not preclude the study of other options (e.g., 4 or 10 small cells).

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ngmn Ltd.,
Großer Hasenpfad 30 • 60598 Frankfurt • Germany

Phone +49 69/9 07 49 98-0 • Fax +49 69/9 07 49 98-41

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VAT Number: GB 918713901

(eMBB-UMa)	experienced data rate Area traffic capacity (non-full buffer)	UL: 25 Mbps DL: 33 Gbps/sq km UL: 17 Gbps/sq km	ISD: 500 m Users: 1)20% outdoor (3 km/h) and 80% indoor (3 km/h) 2)100% in cars (30 km/h)	GHz)	160 Mhz (2GHz) 200 MHz (4GHz)	
				Above 6 GHz (around 30 GHz)	Up to 1000 MHz	
				Below 6 GHz (around 2 GHz or around 4 GHz) and above 6 GHz (around 30 GHz) combined.	Up to 160 Mhz (2GHz) or200 MHz (4GHz) and Up to 1000 MHz (30 Ghz)	
Rural macro (eMBB-RMa)	User experienced data rate Area traffic capacity (non-full buffer)	DL: 50 Mbps UL: 25 Mbps DL: 0.33 Gbps/sq km UL: 0.17 Gbps/sq km	Macro only ISD: 1732 m Users: 1)20% outdoor (3 km/h) and 80% indoor (3 km/h) 2)100% in cars (120 km/h)	Below 6 GHz (around 800 MHz or around 4 GHz).	Up to 200 MHz	Note: Bands above 6 GHz if needed.
			Macro only ISD: 5 km Users: 1)20% outdoor (3 km/h) and 80% indoor (3 km/h) 2)100% in cars (120 km/h)	Below 6 GHz (around 800 MHz and around 2 GHz combined)	Up to 100 MHz (e.g., 60 MHz @ around 800 MHz 40 MHz @ around 2 GHz)	

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High speed (eMBB-HS) **Train**	User experienced data rate Users/train Traffic/train	DL: 50 Mbps UL: 25 Mbps 1000 /train DL: 15 Gbps/ train UL: 7.5 Gbps/ train	Outdoor base stations to users in trains @ 500 Km/h Use of link level or system level simulation is TBD	Below 6 GHz (Tbc)		
			Outdoor BS to relay on trains, and then from relay to users in trains @ 500 Km/h Use of link level or system level simulation is TBD	For BS to relay: Below 6 GHz (around 4 GHz) For relay to UE: Above 6 GHz (around 30 GHz or around 70 GHz) and below 6 GHz (around 4 G Hz)	Up to 200 MHz Up to 1000 MHz and Up to 200 MHz	Evaluations will focus on the BS to relay link.
				For BS to relay: Above 6 GHz (around 30 GHz) For relay to UE: Above 6 GHz (around 30 GHz or around 70 GHz) and below 6 GHz (around 4 GHz)	Up to 1000 MHz Up to 1000 MHz and Up to 200 MHz	Evaluations will focus on the BS to relay link.

Appendix: Assumptions for deriving Area traffic capacity (non-full buffer) for a single operator

(1) Downlink:

Commercial Address:
ngmn Ltd.,
Großer Hasenpfad 30 • 60598 Frankfurt • Germany

Phone +49 69/9 07 49 98-0 • Fax +49 69/9 07 49 98-41

Registered Office:
ngmn Ltd.,
Reading Bridge House • George Street • Reading • Berkshire RG1 8LS • UK
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VAT Number: GB 918713901

	Overall User density	User density (1 out of 3 operators)	Active user average data rate	Activity factor	Average user busy hour usage rate	Area traffic capacity (non-full buffer)
	per sq km	per sq km	Mbps	%	Mbps	Gbps/sq km
Indoor	250,000	250,000	200	30%	60	**15000**
Dense Urban	25,000	8333	300	10%	30	**250**
Urban	10,000	3333	50	20%	10	**33**
Rural	100	33	50	20%	10	**0.33**
High speed	1000/train	1000/train	50	30%	15	**15 bps/train**

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(2) Uplink:

	Overall User density	User density (1 out of 3 operators)	Active user average data rate	Activity factor	Average user busy hour usage rate	Area traffic capacity (non-full buffer)
	per sq km	per sq km	Mbps	%	Mbps	Gbps/sq km
Indoor	250,000	250000	26.67	30%	8.0	**2000**
Dense Urban	25,000	8333	50	10%	5	**42**
Urban	10,000	3333	25	20%	5	**17**
Rural	100	33	25	20%	5	**0.17**
High speed	1000/train	1000/train	25	30%	7.5	**7.5 Gbps/train**

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ngmn Ltd.,
Großer Hasenpfad 30 • 60598 Frankfurt • Germany

Phone +49 69/9 07 49 98-0 • Fax +49 69/9 07 49 98-41

Registered Office:
ngmn Ltd.,
Reading Bridge House • George Street • Reading •
Berkshire RG1 8LS • UK
Company registered in England and Wales n. 5932387,
VAT Number: GB 918713901