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D2.2. Appendix 8

TRIANGLE Network Scenarios

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List of Abbreviations (Editor:)

1 5G Network Scenarios: General Overview

In this section, some of the widely-discussed scenarios for 5G are presented. In contrast to what is available in the literature (see [6] and references within), the TRIANGLE project aims at the perspective of the end user, rather than an aggregated network-wise vision. Additional specific use cases of interest for App developers and IoT device manufacturers have been then derived.

The 5G usage scenarios have been divided into macro categories per their commonalities in the network deployment and channel conditions. Each usage scenario is then sub-divided into user and traffic present in the surroundings.

1.1 Urban

The urban scenarios are generally characterized by dense urban network deployments. One can think about locations like the London City center, or Manhattan, or Tokyo. Network deployments in urban scenarios are usually characterized by the presence of Macro sites with a reduced or highly reduced inter-site distance, together with the presence of Small Cells as well. Given the need of carrying high amount of traffic, a dense HetNet is required, giving the possibility to the terminal to be connected to Small Cells as Primary Cell as well.

Under this umbrella several 5G usage scenarios characterized by the location and mobility of the users have been identified.

1.1.1 Office

This is the typical indoor office environment where users are static. It is characterized by the presence of indoor wireless network access points (both Wi-Fi and Small Cells). The channel and interference conditions are also dictated by the penetration of signals coming from the outdoor cells, mostly macro sites. The expected traffic scenario is related to typical broadband access with a mixture of applications.

1.1.2 Pedestrian

This is the usual scenario of a user walking down an urban street at 1 to 3 km/h. It is expected that the channel conditions can change due to the presence of moving obstacles e.g. trucks and buses. Even in this case a typical broadband access is the baseline for the traffic-generating applications.

1.1.3 Driving

It is becoming more and more common to have wireless modems inside the car that allow direct connectivity to the onboard computer and entertainment system. Given the urban environment, the expected speed of the vehicle is up to 60 km/h. The traffic conditions are here very dependent on the application, since V2I traffic for vehicular control could also be foreseen.

1.1.3.1 Normal

In normal vehicular traffic conditions, the speed is expected to be on the high end of the urban limits, possibly 40 to 60 km/h. The density of the users on the road is here reasonably low, given the regulatory distance between vehicles.

1.1.3.2 Traffic jam

In a traffic jam it is expected that the vehicles will be more packed, resulting in a higher density, while the speed tends to be from very low to almost static. The users are then expected to do a heavier use of, for example, their own entertainment system creating a heavier load on the network.

1.1.3.3 Emergency Driving

An interesting case for e-health is the path that an ambulance is following when called for an emergency. Despite of the urban settings, the ambulance can drive faster than the limits (60 to 120 km/h). While the ambulance is the most important civilian case, the same type of scenario could be applied to public forces acting on emergency calls for safety and security, from fire fighters to police.

1.1.4 Internet Cafè

While this scenario can be substantially derived from both the office and pedestrian one, we believe it has a value for the App developers, and it is easy to understand for non-experts. The scenario is a typical multi-RAT scenario with users mostly static, with some channel variations due to the street-level nature of the location (moving objects on the street, some indoor penetration).

1.1.4.1 Busy Hours

During for example lunch hours on a weekday the cafè is expected to be full of customer who are trying to access the network for consuming services. This affects the network load and the amount of resources that each customer can get from the network.

1.1.4.2 Off-Peak

During for example a mid-afternoon the number of customers in the cafè decreases, creating easier conditions for network access. At the same time the type of imperfections that affect the channel (interference from other customers, amount of moving shielding objects) is also reduced.

1.2 Sub-Urban

The sub-urban umbrella contains all those scenarios which are generally located outside the city centre, in less densely populated areas. For this reason, most of the access site to the network is macro only, mounted on higher rise towers for coverage, with a larger inter-site distance.

Few sporadic Small Cell hotspots are eventually encountered within the coverage area of the macros, either for localized capacity boosting or for reinforcing the coverage. All the sub-cases of interest in these network and propagation conditions are related to the concentrated and massive presence of users.

1.2.1 Festival

This usage scenario is typically outdoor, with additions of few localized macro sites and Small Cells for increased capacity. The type of expected traffic is mostly consistent with a very dense broadband access, with eventual broadcasting of the concerts in the festival area.

1.2.2 Stadium

This is the scenario with the highest density of users. Hotspots cover the stadium area, but its main characteristic is the balancing between the amount of access points and the interference generated.

1.2.3 Shopping Mall

The physical environment is characterized by indoor large spaces, with a certain amount of electromagnetic reflecting materials. Mixed applications are expected to run in the network, for both business internal and external customers' purposes.

1.2.3.1 Busy hours

Considering e.g. a Saturday noon, the Shopping Mall is expected to be flooded with customers, and both the business internal and customers' traffic is expected to overload the network.

1.2.3.2 Off-Peak

Fewer customers present in the premises, partly changing not only the traffic but also the propagation conditions as well.

1.3 High speed train

High speed collective transport, similarly to current scenarios present in Japan, is considered a valuable scenario for 5G where both commercial traffic and critical vehicular control should coexist in the same radio access. The propagation condition is a rural one, with relatively sparse macro sites densified for the railroad coverage purpose. The speed of the train is very high, up to 350 km/h. Two different ways of dealing with the users' affiliation represent the main technical challenges for 5G and how the system should behave.

1.3.1 Relay

One way of dealing with the users' affiliation to the network is by installing a relay (or self-backhauled as sometimes referred to in 5G literature) or an access gateway for Wi-Fi on the train. Since there is only one device affiliated to the fixed wireless network, the C-plane is not the bottleneck, but the aggregated traffic of all the users creates a massive "super-user" which requires great amount of the U-plane resources.

1.3.2 Direct passenger connections

In contrast to the previous scenario, each user is dealt individually by the fixed network. While each user has a limited amount of U-plane resources to be scheduled, the C-plane and the so-called "massive handover" can create difficulties to the networks and impairments to the data flow for the users, impacting their QoE.

1.4 Internet of Things

Given the radically different nature of the devices and the traffic, IoT requires a category on its own. The devices are usually low-power, low performance. The traffic is heavily sporadic and consists of very small packets, roughly around 160 bytes.

1.4.1 Warehouse

This scenario represents IoT devices which are located in typical industrial setting, i.e., a warehouse, where multiple metallic structures often block the signal and introduce harsh environment to the RF signal.

1.4.2 Outdoor sensors

This scenario represents the situation where outdoor sensors are massively deployed in an urban setting [1].The major issue of this scenario is the amount of interference generated by the other devices trying to access the network.

1.4.3 Home sensors (basement)

Another scenario of interest is the deployment of home sensors for, e.g., electricity measurement. While power consumption is not a major issue for such devices since they are connected to the power grid, the coverage conditions can be poor, due to the nature of the installation, possibly in a basement with thick walls, where absorbing and reflecting materials heavily shadow the device.

2 Definition of Scenario Parameters

The wireless cellular networks have a vast number of parameters to be set to ensure a correct functioning of the system. Besides to the parameters of the technology itself, while defining the scenarios, more fine grained details about the environment conditions need to be set in the testbed.

Part of the parameters to be set are dependent on the Device Under Test (DUT) or which reference device is in use. As a matter of fact, different User Equipment (UEs) support different feature from different technology Releases. This factor partially limits the number of common parameters to be set in the scenario description for the testing purposes.

The following table has been selected as containing all the major, relevant parameters for the description of each scenario:

Table 1 - Parameter set for an LTE-based network scenario

Serving cell	RSRP
	Noise/Interference
	Channel model
	Channel model Doppler
	Channel model correlation
LTE scheduling	Frequency domain (DL)
	Time domain (DL)
	Frequency domain (UL)
	Time domain (UL)
Network	Additional each way latency

LTE scheduling parameters must be considered average values that can follow certain time dynamics.

Network latency is also reported as average value follow a certain distribution.

Parameters such as antenna configuration, transmission mode, maximum achievable MCS should be considered device dependent, and they should be set as per achieving maximum performance for the DUT/reference device.

Other parameters that are purely network configurations are normally set as most commonly used, de-facto default values. Example of such parameters can be:

- cyclic prefix length: short

- Max number of HARQ re-transmissions: 4
- BLER Target for first transmission: 30%
- Standard bearer QoS: default bearer

To guarantee the most realistic conditions in each of the scenarios, several sub-scenarios have been defined. Each of the sub-scenarios depict e.g. a different time of the day where different number of users are present in the network, or the environment can suffer from more radical changes.

3 Scenario Parameters Setting

Table 2 - Urban-Office Scenario Parameters

		Urban-Office				
		UR-OF				
High level scenario description		Business building area - stationary user, good coverage, high number of users				
Sub-scenario description		**Default working conditions** (average NW & cell load)	**Daily servers back-up/git clone/OS updates deployment** (high NW latency due to multiple small packets)	**After lunch break** (many users light browsing, spurious traffic)	**Videoconference calls over 5G** (Many users, heavy combined load, scattered free bandwidth)	**Late night/weekend crunch** (light NW & cell load)
Serving cell	RSRP	fixed at -90dBm	fixed at -90dBm	fixed at -90dBm	fixed at -90dBm	fixed at -90dBm
	AWGN	Constant AWGN level for average SNR = 25dB	Constant AWGN level for average SNR = 25dB	Constant AWGN level for average SNR = 25dB	Constant AWGN level for average SNR = 25dB	Constant AWGN level for average SNR = 25dB
	Channel model	EPA	EPA	EPA	EPA	EPA
	Channel model Doppler	5 Hz	5 Hz	5 Hz	5 Hz	5 Hz
	Channel model correlation	Medium	Medium	Medium	Medium	Medium
LTE scheduling	Frequency domain (DL)	50% of PRBs	30% of PRBs	40% of PRBs	20%	50%
	Time domain (DL)	30% of subframes	30% of subframes	30% of subframes	20%	100%
	Frequency domain (UL)	50% of PRBs	30% of PRBs	40% of PRBs	20%	50%
	Time domain (UL)	30% of subframes	30% of subframes	30% of subframes	20%	100%
Network	Additional each way latency	0ms	150ms	0ms to 50ms	100ms	0ms
Comments		Medium correlation due to offices being in skyscrapers/tall buildings				Cell shared between at max 2 users
	Modules	A	B	C	D	E
	Typical flow:	8am-9am, 10am-12pm, 4pm-5pm	9am-10am	1pm-2pm	2pm-4pm	5pm-6pm
	Full scenario flow:	A, B, A, A, C, D, D, A, E, E				
		30 seconds each, 5 minutes total				

Table 3 - Urban-Pedestrian Scenario Parameters

		Urban-Pedestrian			
		UR-PE			
High level scenario description		Slowly moving user, good to average coverage, occasional high number of users, no handovers			
Sub-scenario description		**Center to park walk** Walking from near cell to mid cell coverage	**Busy green area - park** Walking around in mid cell, high number of users	**Park to center walk** Return to near cell conditions	**City main square** (good conditions, many users)
Serving cell	RSRP	from -90dBm down to -105dBm, linear decrease with 4 seconds per 1dB step, total scenario length of 64 seconds	-105dBm	from -105 back to -90dBm 4 seconds per 1 dB step	-90dBm
	AWGN	AWGN injected to drop from 25dB to 10dB, fixed compared to RSRP, identically 1dB drop every 4 seconds	10dB	from 10dB to 25dB 4 seconds per 1 dB step	25dB
	Channel model	EPA	EPA	EPA	EPA
	Channel model Doppler	5 Hz	5 Hz	5 Hz	5 Hz
	Channel model correlation	Low (at RSRP > -98dBm) Medium (at RSRP < -98dBm)	Medium	Low (at RSRP > -98dBm) Medium (at RSRP < -98dBm)	Low
LTE scheduling	Frequency domain (DL)	50% of PRBs	40% of PRBs	50% of PRBs	30% of PRBs
	Time domain (DL)	30% of subframes	30% of subframes	30% of subframes	30% of subframes
	Frequency domain (UL)	50% of PRBs	40% of PRBs	50% of PRBs	30% of PRBs
	Time domain (UL)	30% of subframes	30% of subframes	30% of subframes	30% of subframes
Network	Additional each way latency	0 to 50 ms (at each RSRP step, increase by 3ms)	50 ms	50 to 0 ms (at each RSRP step, decrease by 3ms)	0ms
Comments		potentially add handovers here		and here	
	Modules	A	B	C	D
	Typical flow:				
	Full scenario flow:	A, B, C, D			

Table 4 - Urban Driving Scenarios Parameters (Normal, Traffic Jam, Emergency)

		Urban-Driving-Normal		Urban-Driving-Traffic jam		Urban-Driving-Emergency driving	
		UR-DN		UR-DT		UR-DE	
High level scenario description		driving user, average coverage, low number of users		slowly moving user, high number of users,		high speed driving, identical coverage as	
Sub-scenario description		**Light traffic** (faster driving, fewer users)	**Heavy traffic** (slower driving, more users)	**Ordinary traffic jam conditions**	**Multiple emergency response vehicles drive fast in next lane**	**Default emergency driving** (in light traffic)	**Default emergency driving** (in heavy traffic)
Serving cell	RSRP	from -90dBm to -119dBm, 1.5dB drop per second, resulting in mean time between handovers of 20 seconds	from -90dBm to -119dBm, 1dB drop per second, 30 seconds in average between handovers	around -100dBm, fixed	around -100dBm, fixed	from -90dBm to -119dBm, with 3dB drop per second, with average time of 10s between handovers	from -90dBm to -119dBm, with 3dB drop per second, with average time of 10s between handovers
	AWGN	between 25dB to 10dB , 1.5dB drop/increase per second	between 25dB to 10dB, 1dB drop/increase per second	around 10dB	around 10dB	between 25dB to 10dB 3dB drop/increase per second	between 25dB to 10dB 3dB drop/increase per second
	Channel model	EVA	EVA	EVA	EVA	EVA	EVA
	Channel model Doppler	75Hz	50Hz	25Hz	150 Hz	150Hz	150Hz
	Channel model correlation	Medium	Medium	Medium	Medium	Medium	Medium
LTE scheduling	Frequency domain (DL)	100% of PRBs	50% of PRBs	20% of PRBs	20% of PRBs	100% of PRBs	50% of PRBs
	Time domain (DL)	50% of subframes	30% of subframes	20% of subframes	20% of subframes	50% of subframes	30% of subframes
	Frequency domain (UL)	100% of PRBs	50% of PRBs	20% of PRBs	20% of PRBs	100% of PRBs	50% of PRBs
	Time domain (UL)	50% of subframes	30% of subframes	20% of subframes	20% of subframes	50% of subframes	30% of subframes
Network	Additional each way latency	0 to 50 ms (at each RSRP step, increase by 3ms)	50ms to 100ms (at each RSRP step, increase by 3ms)	75ms	75ms	0ms to 50ms (at each RSRP step, increase by 5ms)	50ms to 100ms (at each RSRP step, increase by 5ms)
Comments							
	Modules	A	B	A	B	A	B
	Typical flow:						
	Full scenario flow:	A, B		A, A, A, B, A, A, A			

Table 5 - Urban Internet Café Scenarios Parameters (Busy Hours, Off-Peak)

		Urban-Internet Cafè, Busy Hours			Urban-Internet Cafè, Off-Peak		
		UR-IB			UR-IO		
High level scenario description		good coverage, but many users instagramming their coffee mugs			good coverage, same number of users as pedestrian, stationary		
Sub-scenario description		**Average coffee shop**	**Heavy car traffic in front** (worse radio channel - higher AWGN, lower power)	**User spills coffee on device** (user rubbing phone on clothes - changing correlation)	**Average coffee shop**	Heavy car traffic in front (worse radio channel - higher AWGN, lower power)	User spills coffee on device (user rubbing phone on clothes - changing correlation)
Serving cell	RSRP	fixed at -95dBm (worse than business area)	drops to -105dBm	fixed at -95dBm (worse than business area)	fixed at -95dBm (worse than business area)	drops to -105dBm	fixed at -95dBm (worse than business area)
	AWGN	fixed at 20dB	drops to 10dB	fixed at 20dB	fixed at 20dB	drops to 10dB	fixed at 20dB
	Channel model	EPA	EPA	EPA	EPA	EPA	EPA
	Channel model Doppler	5 Hz	20 Hz	5 Hz	5 Hz	20 Hz	5 Hz
	Channel model correlation	Low	Low	Medium	Low	Low	Medium
LTE scheduling	Frequency domain (DL)	20 % of PRBs	20 % of PRBs	20 % of PRBs	100% of PRBs	100% of PRBs	100% of PRBs
	Time domain (DL)	20% of subframes	20% of subframes	20% of subframes	20% of subframes	20% of subframes	20% of subframes
	Frequency domain (UL)	20 % of PRBs	20 % of PRBs	20 % of PRBs	100% of PRBs	100% of PRBs	100% of PRBs
	Time domain (UL)	20% of subframes	20% of subframes	20% of subframes	20% of subframes	20% of subframes	20% of subframes
Network	Additional each way latency	0ms to 50ms	0ms to 50ms	0ms to 50ms	0ms	0ms to 50ms	0ms to 50ms
Comments							
	Modules	**A**	**B**	**C**	**A**	**B**	**C**
	Typical flow:	50%	40%	10%	50%	40%	10%
	Full scenario flow:	A, A, B, A, B, A, A, B, C, B			A, A, B, A, B, A, A, B, C, B		
		30 seconds each, 5 minutes total			30 seconds each, 5 minutes total		

Table 6 - Suburban Scenarios Parameters (Festival, Stadium)

		Suburban-Festival		Suburban-Stadium	
		SU-FE		SU-ST	
High level scenario description		good coverage (outdoor festival) - away from		average coverage (inside a metal building),	
Sub-scenario description		**Entrance tickets check** (attendees downloading e-tickets - DL starved)	**Popular band playing** (heavy live streaming - UL starved)	**Entrance tickets check** (attendees downloading e-tickets - DL starved)	**Sports game ongoing**
Serving cell	RSRP	fixed at -80dBm	fixed at -80dBm	fixed at -95dBm	fixed at -95dBm
	AWGN	fixed at 30dB	fixed at 30dB	fixed at 15dB	fixed at 15dB
	Channel model	ETU	ETU	ETU	ETU
	Channel model Doppler	5 Hz	5 Hz	5 Hz	5 Hz
	Channel model correlation	Medium	Medium	Medium	Medium
LTE scheduling	Frequency domain (DL)	10 % of PRBs	20 % of PRBs	10 % of PRBs	30% of PRBs
	Time domain (DL)	10% of subframes	20% of subframes	10% of subframes	30% of subframes
	Frequency domain (UL)	20% of PRBs	10% of PRBs	20 % of PRBs	30% of PRBs
	Time domain (UL)	20% of subframes	10% of subframes	20% of subframes	30% of subframes
Network	Additional each way latency	150ms	150ms	100ms	0ms
Comments					same as city good conditions - many users but not much traffic

Table 7 - Suburban Shopping Mall Scenarios Parameters (Busy Hours, Off-Peak)

		Suburban-Shopping Mall, Busy Hours		Suburban-Shopping Mall, Off-Peak	
		SU-SB		SU-SO	
High level scenario description		poor coverage (multi-stories mall)		poor coverage (multi-stories mall)	
Sub-scenario description		**Ordinary busy mall**	**Online wallet payment** (users pay with apps on phone, no cards/cash)	**Ordinary empty mall**	**Multiple delivering trucs around the mall**
Serving cell	RSRP	fixed at -100dBm	fixed at -100dBm	fixed at -100dBm	fixed at -100dBm
	AWGN	fixed at 5dB	fixed at 5dB	fixed at 5dB	fixed at 5dB
	Channel model	ETU	ETU	ETU	ETU
	Channel model Doppler	5 Hz	5 Hz	5 Hz	70 Hz
	Channel model correlation	High	High	High	High
LTE scheduling	Frequency domain (DL)	20 % of PRBs	10 % of PRBs	100% of PRBs	50% of PRBs
	Time domain (DL)	20% of subframes	10% of subframes	20% of subframes	20% of subframes
	Frequency domain (UL)	20 % of PRBs	10 % of PRBs	100% of PRBs	50% of PRBs
	Time domain (UL)	20% of subframes	10% of subframes	20% of subframes	20% of subframes
Network	Additional each way latency	100ms	100ms	0ms	0ms
Comments		same allocation as busy internet café, but different channel	heavily both DL and UL starved	same allocation as empty internet café, but different channel	higher doppler, smaller allocation

Table 8 - High Speed Train Scenarios Parameters (Direct Connection)

		High Speed-Direct Passenger Connection		High Speed-Relay	
		HS-DP		HS-RE	
High level scenario description		Each passenger is directly connected to the fixed		All passengers are connected to a mobile "hotspot" (relay)	
Sub-scenario description		**High speed train in suburban area**	**Max speed train in empty fields**	**High speed train in suburban area**	**Max speed train in empty fields**
Serving cell	RSRP	from -90dBm to -119dBm, with 3dB drop per second, with average time of 10s between handovers	from -90dBm to -119dBm, with 5dB drop per second, with average time of 6s between handovers	fixed at -90dBm	fixed at -90dBm
	AWGN	between 25dB to 10dB 3dB drop/increase per second	between 25dB to 10dB, 5dB drop/increase per second	Constant AWGN level for average SNR = 25dB	Constant AWGN level for average SNR = 25dB
	Channel model	HST	HST	Static	Static
	Channel model Doppler	150 Hz	250 Hz	n/a	n/a
	Channel model correlation	n/a	n/a	n/a	n/a
LTE scheduling	Frequency domain (DL)	20 % of PRBs	20 % of PRBs	20 % of PRBs	20 % of PRBs
	Time domain (DL)	20% of subframes	20% of subframes	20% of subframes	20% of subframes
	Frequency domain (UL)	20 % of PRBs	20 % of PRBs	20 % of PRBs	20 % of PRBs
	Time domain (UL)	20% of subframes	20% of subframes	20% of subframes	20% of subframes
Network	Additional each way latency	Latency average: 50ms	Latency average: 75ms	Latency average: 100ms Latency random variation: ± 50ms Packet loss: 1%	Latency average: 150ms Latency random variation: ± 50ms Packet loss: 3%
Comments		Poor channel conditions, very fast handovers, Doppler going back and forth, many simultaneous users. Cells should be configured with a lower max number of retransmissions (maxHARQ-Tx = 2 rather than 4)		Here the channel conditions are great, as they represent the channel between the relay (on top of the train) to the users. The real poor reception will be represented by brutal network settings (latency, jitter, packet loss).	

Table 9 - Internet of Things Scenarios Parameters (Warehouse, Outdoor Sensors, Home Sensors)

		Internet of Things-Warehouse		Internet of Things-Outdoor Sensors		Internet of Things-Home Sensors	
		IT-WA		IT-OS		IT-HS	
High level scenario description		Very densely sensored area (factory, amazon		Average sparsely sensored area		Very sparsely sensored area	
Sub-scenario description		**Factory scenario** (a lot of moving parts)	**Warehouse scenario** (stationary conditions)	**Daytime** (busy with car traffic, data traffic)	**Nighttime** (no car traffic, little data traffic)	**Sensor in the habitable area**	**Sensor in the basement**
Serving cell	RSRP	-100dBm	-100dBm	-90dBm	-90dBm	-95dBm	-110dBm
	AWGN	10dB	10dB	10dB	10dB	5dB	-5dB
	Channel model	ETU	ETU	ETU	ETU	EPA	EPA
	Channel model Doppler	50 Hz	5 Hz	70 Hz	5 Hz	5Hz	5Hz
	Channel model correlation	Medium	Medium	Medium	Medium	Medium	High
LTE scheduling	Frequency domain (DL)	100% of PRBs	100% of PRBs	20 % of PRBs	100% of PRBs	100% of PRBs	100% of PRBs
	Time domain (DL)	20% of subframes	20% of subframes	20% of subframes	20% of subframes	20% of subframes	20% of subframes
	Frequency domain (UL)	100% of PRBs	100% of PRBs	20 % of PRBs	100% of PRBs	100% of PRBs	100% of PRBs
	Time domain (UL)	20% of subframes	20% of subframes	20% of subframes	20% of subframes	20% of subframes	20% of subframes
Network	Additional each way latency	0ms	0ms	100ms	0ms	0ms	0ms
Comments		control of robots	thermostat, package tracker		lamppost, floor sensor, wind detector	thermostat, electric plug meter	bad coverage scenario (basement, electric closet, bathroom cabinet)

4 References

[1] Telefónica I+D. Santander on FIRE. [Online]. http://www.smartsantander.eu/