GTI
URLLC Evaluation White Paper (Phase1)

URLLC Evaluation WHITE PAPER

Phase1

V1.2

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Contents

1. Introduction

Compared to 4G and the previous generation, 5G is aimed to connect everything and enable verticals. URLLC is an important feature of 5G to accomplish this goal. Starting from 3GPP Release15, lots of standard work has been done to support URLLC communication services. With the global promotion of 5G commercial, the verticals have high interest to fastly adapt 5G networks. They are eager to know what performance 5G network can provide for them and whether the performance can meet their requirements. Considering vertical needs, a performance evaluation has been done in [1].

Among so many vertical industry, Port and Logistics industry have strong demand for 5G and seek cooperation with 5G operators actively. Since 90% of global freight volume comes from sea transportation, RMG in port is an important case and it is new that haven't evaluated yet. TDD mode plays a more important role in 5G and needs further evaluation. In the meanwhile, the operators want to know how to deploy the 5G network efficiently to offer guaranteed service for vertical customers. Base on the above situation, this report will concentrate on these two pre-commercial scenarios and try to take care of operators' needs.

The URLLC Evaluation White Paper will be released in two phases. Phase1 will focus on two pre-commercial vertical scenarios (RMG in port which is a typical outdoor case and AGV in factory which is a typical indoor case) and pre-commercial product realization, frequency band, duplex mode, etc.; the output will be in two dimensions (Network capability is evaluated by given Inter-site Distance and number of station is calculated by given requirements). Phase2 will involve more vertical uses cases which operators and vendors have great interest in, such as AR/VR, gaming, and so on; and more simulation assumptions will be adopted, such as new frequency band, new frame structure, etc.

We are looking forward to enabling verticals by 5G network, and hope this report can help operators create new business more efficiently.

2. Terminology and Abbreviation

Term	Description
3GPP	3rd Generation Partnership Project
URLLC	Ultra-Reliable and Low Latency Communication
RMG	Rail-Mounted Gantry
AGV	Automated Guided Vehicles

3. Use Cases and Requirements

Two pre-commercial use cases will be presented in this chapter: RMG in port and AGV in factory.

RMG case has been involved in NGMN URLLC study. AGV case has been introduced in 3GPP and NGMN URLLC study. This report follows the description of RMG and AGV in [2], and the requirements of these two cases come from vertical customers.

3.1. Remote control of automated Rail-Mounted Gantry (RMG) crane

In a port, the automated Rail-Mounted Gantry (RMG) Crane is used to perform container stacking and lifting operations in container yards. For the safety of RMG Crane operators, there is a desire to operate RMG cranes remotely form the port control center, where the operator controls the RMG loading and unloading operations based on the real-time video backhauled from the terminal field. Remote RMG control provides not only a safe and comfortable working environment for the operator, but also enables one-to-many operations, i.e., remotely support equipment operations in multiple locations.

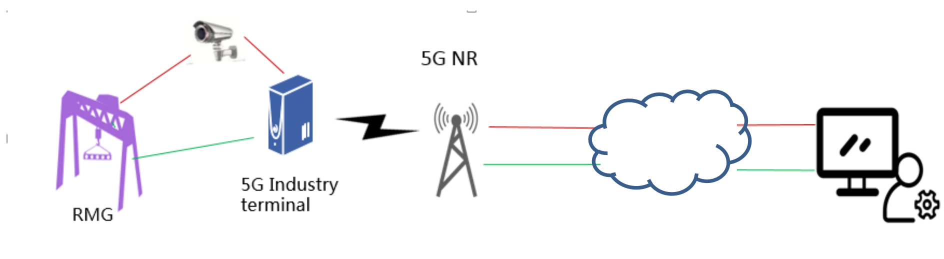


Fig. 1 Remote control of RMG Cranes.

In this case, 5G network is required to provide sufficiently high uplink data throughput and transmission reliability, sufficiently low transmission latency. From the perspective of network deployment, it is a purely outdoor scenario. This case requires video real-time backhaul and remote control applications. Specific considerations in terms of handover delay and cell capacity are needed.

The network architecture requirements:

- Mobility at standard values.
- High-frequency connectivity.
- High UL data-rate per RMG crane.
- Introduction of edge computing would be desirable.

- Special attention to security/privacy of concerned data.

In order to support RMG case, the requirements on communications services are as follows:

Table 3-1: Requirements of RMG

Use case	Reliability (%)	Latency	Data packet size and traffic model	Description
RMG in port	99.999	**E2E latency**: ● UL: 50ms ● DL: 20ms *Note:* air interface latency: UL:18ms; DL:16ms *Note2*: assuming core network is local	**UL:** HD video, 6.25kByte per packet, 600 packets per second **DL:** control, 80Byte, per 6ms;	Motion control

Note: E2E latency is defined as the time that takes to transfer a given piece of information from a source endpoint device to a destination endpoint device, measured at the application service access points, from the moment it is transmitted by the source endpoint device to the moment it is successfully received at the destination endpoint device. See details in [2].

3.2. Control the journey of automated guided vehicles in Factory

Automated Guided Vehicles (AGV) in factory is another typical URLLC use case. The introduction of AGV will allow the transportation of products, pieces of products, tools and raw materials across the factory according to logistic needs between storage areas and production lines. To execute these complex tasks AGVs are to be mobile robots with the capacity to follow information flows on inventory and others, capacity for handling materials, monitoring and control, image processing, recognition, etc.

In the centralized automatic controlled case, AGVs are automatically steered to move materials efficiently in a restricted facility, see Section 5.3.7 of 3GPP TR22.804 [3]. It requires live monitoring and remote control applications.

Fig. 2 AGVs controlled by a centralized automatic controller

From the network deployment point of view it can be a mix of indoor/outdoor or purely indoor, as presented in Fig.3. This will imply specific considerations in terms of frequency band, penetration loses, handover processes and intra-band interference. In this report, we focus on purely indoor case.

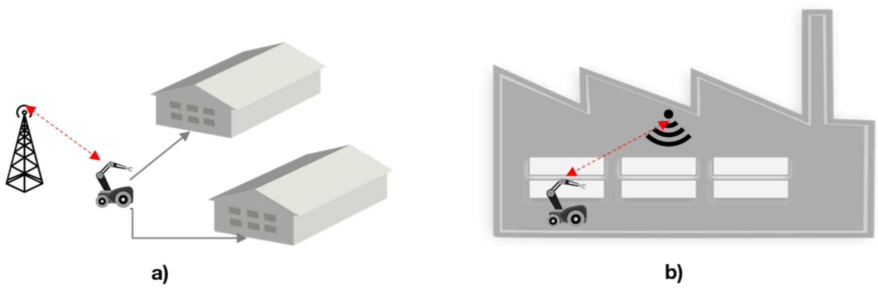


Fig. 3 AGVs network deployment in a) indoor/outdoor or b) indoor environments.

The network architecture in this use case will have the following characteristics:

- No need for dynamic scalability.
- Mobility at standard values.
- Frequent connectivity.
- Moderated number of connected devices per venue.
- Introduction of edge computing would be desirable.
- Special attention to security/privacy of concerned data. Slicing could be a good solution for this.

In order to support AGV case, the requirements on communications services are as follows:

Table 3-2: Requirements of AGV

Use case	Reliability (%)	Latency	Data packet size and traffic model	Description
AGV in factory	99.999	**Network latency:** ● 20ms *Note:* 18ms air interface latency *Note2:* assuming core network is local	**UL/DL:** 300Byte, per 50ms;	Remote driving

4. Performance metric

According to [1], the performance metric for the system level evaluations in this white paper, including evaluation of the baseline performance achievable with Rel-15 NR URLLC and evaluation of the performance achievable with potential enhancement(s) for Rel-16 URLLC, is either option 1 or option 2 as below:

- **Option 1**: Percentage of users satisfying reliability and latency requirements
  - Intend for the case with fixed number of UEs and fixed traffic model per UE
- **Option 2**: URLLC capacity
  - Definition: URLLC system capacity is calculated as follows:
    - C(L, R) is the maximum offered cell load under which Y% of URLLC UEs in a cell operate with target link reliability R under L latency bound
    - X= (100 – Y) % is the percentage of UEs in outage
    - A UE in outage is defined as the UE cannot meet both latency L and link reliability R bound
    - Companies report their assumption on X (either ~5% or 0%)
  - Intend for the case that the number of UEs and/or the data arrival rate is adjustable
    - Adjusting the number of UEs should be applied to periodic deterministic traffic model

5. System level simulation assumptions

Detailed simulation assumptions will be presented in this chapter. Compared to [1], this report focuses on TDD mode, and two carrier frequency (2.6G Hz and 4.9G Hz) will be evaluated. Different frame structure will be adopted in 2.6G and 4.9G as Fig.4 and Fig.5 shows:

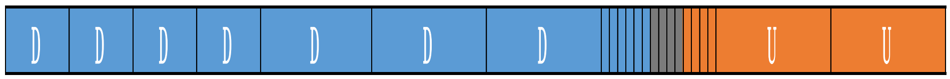


Fig. 4 Frame structure used in 2.6G Hz (5ms switch-point periodicity, 7D:1S:2U, S:6:4:4)

Fig. 5 Frame structure used in 4.9G Hz (2.5ms dual switch-point periodicity, S:10:2:2)

In AGV case, a new type of layout is introduced. Fig.6 shows the typical layout which is used usually in indoor scenario. There are 12 BSs for 120m*50m, and per BS means one cell, as Fig.6 shows. But according to Logistics customers, the actually used layout is that 1 BS (with 12 sets of distributed antennas) for 120*50m and one cell per BS, as Fig.7 shows. In this case, frequently handover is avoided and the AGVs can work more efficiently.

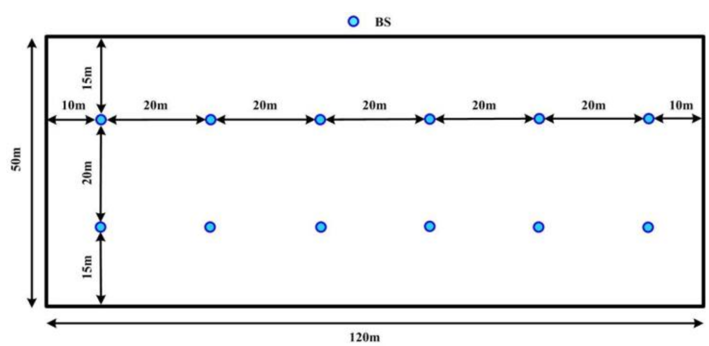


Fig. 6 Indoor layout in TR38.824[1]

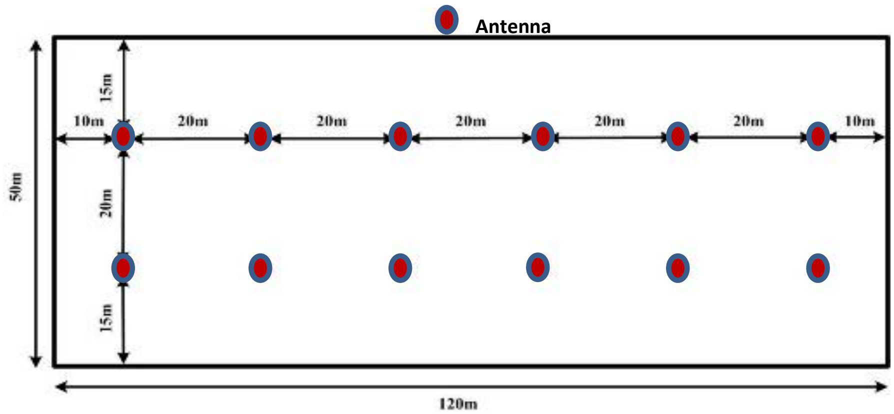
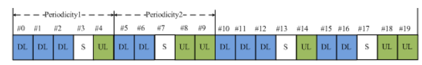


Fig. 7 New indoor layout

5.1. Simulation assumptions for RMG in port

Table 5-1 shows the detailed simulation assumptions for RMG case.

Table 5-1: System-level simulation assumptions for RMG in port

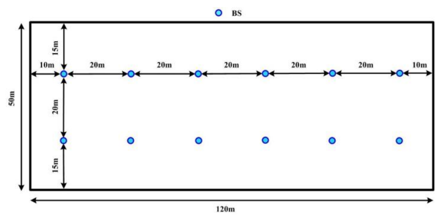
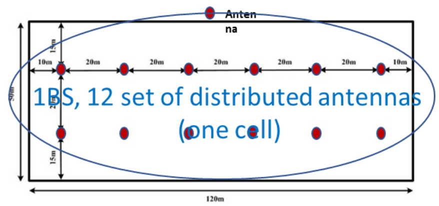
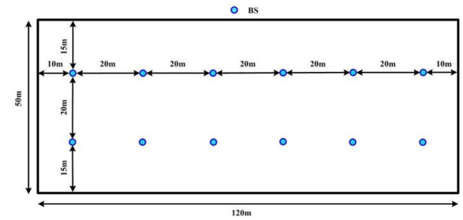
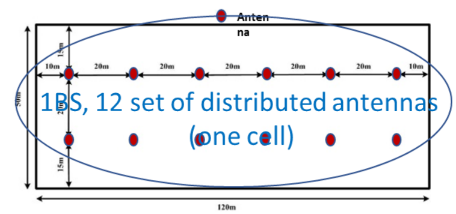
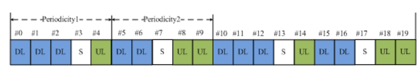
Parameters	Value	Value
Layout	Single layer - Macro layer: Hex. Grid 7 sites, 21cells	Single layer - Macro layer: Hex. Grid 7 sites, 21cells
Inter-BS distance	350m, 250m, 150m	350m, 250m, 150m
Carrier frequency	2.6GHz	4.9 GHz,
Duplex mode	TDD	TDD
Frame structure	5ms, 7D:1S:2U， S:6:4:4 	2.5ms dual TDD-UL-DL-Pattern，S:10:2:2 
Channel model	UMa in TR 38.901	UMa in TR 38.901
UE Tx power	26dBm	26dBm
BS antenna configurations	64 Tx/64 Rx antenna ports (M, N, P, Mg, Ng; Mp, Np) = (12, 8, 2, 1, 1; 4, 8) for 64 Tx/64 Rx antenna ports; dH = 0.5λ, dV = 0.7λ; Companies report the antenna tilt	64 Tx/64 Rx antenna ports (M, N, P, Mg, Ng; Mp, Np) = (12, 8, 2, 1, 1; 4, 8) for 64 Tx/64 Rx antenna ports dH = 0.5λ, dV = 0.7λ; Companies report the antenna tilt
BS antenna height	25m	25m
BS antenna element gain + connector loss	6 dBi	5.5 dBi
BS receiver noise figure	4dB	5dB
OTA	4dB	4dB
UE antenna configuration	2 Tx/4 Rx antenna ports Panel model 1: Mg=1, Ng=1, P=2, d_H=0.5 (M, N, P, Mg, Ng; Mp, Np) = (1, 2, 2, 1, 1; 1, 2) for 4 Rx; (M, N, P, Mg, Ng; Mp, Np) = (1, 1, 2, 1, 1; 1, 1) for 2 Tx;	2 Tx/4 Rx antenna ports Panel model 1: Mg=1, Ng=1, P=2, d_H=0.5 (M, N, P, Mg, Ng; Mp, Np) = (1, 2, 2, 1, 1; 1, 2) for 4 Rx; (M, N, P, Mg, Ng; Mp, Np) = (1, 1, 2, 1, 1; 1, 1) for 2 Tx;
UE antenna height	20m	20m
UE antenna gain	0dBi as starting point	0dBi as starting point
UE receiver noise figure	7 dB	7 dB
Total transmit power per TRxP	53 dBm (100M)	53 dBm (100M)

BS receiver	MMSE-IRC as the baseline receiver Note: Advanced receiver is not precluded.	MMSE-IRC as the baseline receiver Note: Advanced receiver is not precluded.
Number of UEs per cell	Up to 4 (ISD350m) Up to 3 (ISD250m) Up to 2 (ISD150m) Note: The number of users per cell in this table is the number of pure URLLC UEs.	Up to 4 (ISD350m) Up to 3 (ISD250m) Up to 2 (ISD150m) Note: The number of users per cell in this table is the number of pure URLLC UEs.
Simulation bandwidth	100 MHz Note: For TDD, 100 MHz for DL/UL.	100 MHz Note: For TDD, 100 MHz for DL/UL.
SCS	30 kHz Note: Other values for evaluation are not precluded.	30 kHz Note: Other values for evaluation are not precluded.
UE distribution	100% of users are outdoors Use 3 km/h for modeling fading channel	100% of users are outdoors Use 3 km/h for modeling fading channel
UE power control	Companies report the PC mechanisms used for URLLC.	Companies report the PC mechanisms used for URLLC.
HARQ/repetition	Companies report (including HARQ mechanisms).	Companies report (including HARQ mechanisms).
Channel estimation	Realistic	Realistic
SRS/CSI configuration	Realistic, Companies report	Realistic, Companies report
Guard band ratio	1.72% for 100M	1.72% for 100M
Handover margin	3dB	3dB

5.2. Simulation assumptions for AGV in factory

Table 5-2 shows the detailed simulation assumptions for AGV case.

Table 5-2: System-level simulation assumptions for AGV in factory

Parameters	Value	Value
Layout	Single layer as defined in 38.802 Indoor floor: 120 m x 50 m Case 1: 12BSs (one cell per BS) Case 2: 1BS (with 12 sets of distributed antennas, one cell per BS)   	Single layer as defined in 38.802 Indoor floor: 120 m x 50 m Case 1: 12BSs (one cell per BS) Case 2: 1BS (with 12 sets of distributed antennas, one cell per BS)  
Inter-BS distance	20m	20m
Carrier frequency	2.6GHz	4.9 GHz,
Duplex mode	TDD	TDD
Frame structure	5ms, 7D:1S:2U，S:6:4:4  	2.5ms dual TDD-UL-DL-Pattern，S:10:2:2 
Channel model	ITU InH for 2.6 GHz Companies report the modification of the channel model	ITU InH for 4.9 GHz Companies report the modification of the channel model
UE Tx power	26dBm	26dBm
BS antenna configurations	4 Tx/4 Rx antenna ports Omnidirectional antenna	4 Tx/4 Rx antenna ports Omnidirectional antenna
BS antenna height	10 m Note: Other value (e.g. 3 m) is not precluded for evaluation	10 m Note: Other value (e.g. 3 m) is not precluded for evaluation
BS antenna element gain + connector loss	2 dBi	2.5 dBi
BS receiver noise figure	5dB	5dB
OTA	4dB	4dB

UE antenna configuration	2 Tx/4 Rx antenna ports Panel model 1: Mg=1, Ng=1, P=2, d_H=0.5 (M, N, P, Mg, Ng; Mp, Np) = (1, 2, 2, 1, 1; 1, 2) for 4 Rx; (M, N, P, Mg, Ng; Mp, Np) = (1, 1, 2, 1, 1; 1, 1) for 2 Tx;	2 Tx/4 Rx antenna ports Panel model 1: Mg = 1, Ng = 1, P = 2, dH = 0.5 (M, N, P, Mg, Ng; Mp, Np) = (1, 2, 2, 1, 1; 1, 2) for 4 Rx; (M, N, P, Mg, Ng; Mp, Np) = (1, 1, 2, 1, 1; 1, 1) for 2 Tx;
UE antenna height	Follow the modelling of TR 38.901 (e.g. 0.5m)	Follow the modelling of TR 38.901 (e.g. 0.5m)
UE antenna gain	0dBi as starting point	0dBi as starting point
UE receiver noise figure	9 dB	9 dB
Total transmit power per TRxP	30 dBm (100 MHz)	30 dBm (100 MHz)
BS receiver	MMSE-IRC as the baseline receiver Note: Advanced receiver is not precluded.	MMSE-IRC as the baseline receiver Note: Advanced receiver is not precluded.
Number of UEs per 120m*50m	For both case1 & case2: Up to 250 the number of users for evaluation can be 50, 100, 150, 200, 250. Note: The number of users per cell in this table is the number of pure URLLC UEs	For both case1 & case2: Up to 250 the number of users for evaluation can be 50, 100, 150, 200, 250. Note: The number of users per cell in this table is the number of pure URLLC UEs
Simulation bandwidth	100 MHz Note: For TDD, 100 MHz for DL/UL.	100 MHz Note: For TDD, 100 MHz for DL/UL.
SCS	30 kHz Note: Other values for evaluation are not precluded.	30 kHz Note: Other values for evaluation are not precluded.
UE distribution	100% of users are indoor: 30 km/h UE-speed	100% of users are indoor: 30 km/h UE-speed
UE power control	Companies report the PC mechanisms used for URLLC.	Companies report the PC mechanisms used for URLLC.
HARQ/repetition	Companies report (including HARQ mechanisms).	Companies report (including HARQ mechanisms).
Channel estimation	Realistic	Realistic
SRS/CSI	Realistic, Companies report	Realistic, Companies report

configuration		
Guard band ratio	1.72% for 100M	1.72% for 100M
Handover margin	3dB	3dB

6. Evaluation Results

6.1. Evaluation on RMG in port

Four sources evaluate the performance achievable with Rel-15 NR for RMG, with the evaluation results as shown in Table 6-1 (ISD350m), Table 6-2 (ISD250m), and Table 6-3 (ISD150m).

- Four sources show that the percentage of UEs satisfying the latency (i.e. 16 ms for control) and reliability (i.e. 99.999%) requirements by Rel-15 NR is higher than 95% for downlink transmission for RMG assuming up to 4 URLLC users without any eMBB users per cell, 2.6 GHz/4.9 GHz and TDD.

1) ISD350m

As Table 6-1 shows,

- Two sources show that the percentage of UEs satisfying the latency (i.e. 18 ms for HD video) and reliability (i.e. 99.999%) requirements by Rel-15 NR is higher than 95% for uplink transmission for RMG assuming 1 users per cell, 2.6GHz using 5ms switch-point periodicity frame structure (7D:1S:2U, S:6:4:4).
- Two sources show that the percentage of UEs satisfying the latency (i.e. 18 ms for HD video) and reliability (i.e. 99.999%) requirements by Rel-15 NR is higher than 95% for uplink transmission for RMG assuming up to 3 users per cell, 4.9GHz using 2.5ms dual switch-point periodicity (S:10:2:2).

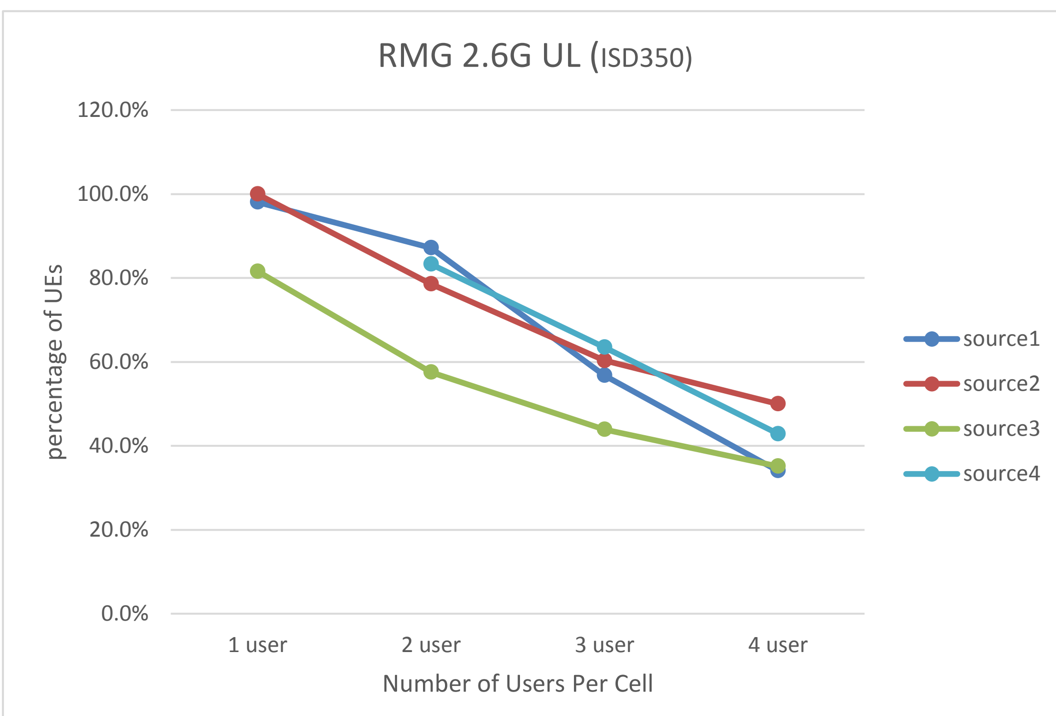


Fig. 8 UL Performance of RMG 2.6G (ISD350)

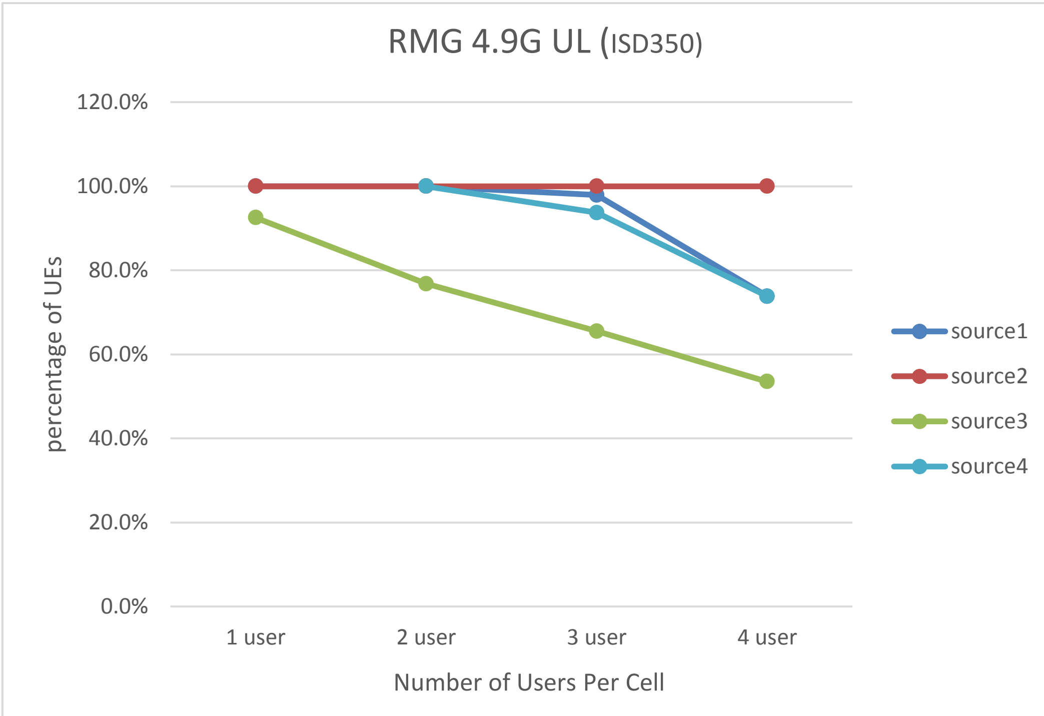


Fig. 9 UL Performance of RMG 4.9G (ISD350)

Table 6-1: The percentage of UEs satisfying requirements for RMG (ISD350m)

Source 1 : RMG in port (2.6GHz) Reliability of 99.999%, 16 ms (DL)/18 ms (UL) air interface, 2.6GHz, TDD, 64Tx/64Rx at gNB and 2Tx/4Rx at UE, realistic channel estimation, ISD350m, Uma, P0=-86 dBm, alpha=-0.9			
		Percentage of UEs	Resource utilization
1 users per cell	DL:	100%	0.31%
	UL:	98.1%	19.2%
2 users per cell	DL:	100%	0.62%
	UL:	87.2%	34.8%
3 users per cell	DL:	100%	0.96%
	UL:	56.8%	57.4%
4 users per cell	DL:	100%	1.24%
	UL:	34.1%	73.0%
Source 1 : RMG in port (4.9GHz) Reliability of 99.999%, 16 ms (DL)/18 ms (UL) air interface, 4.9GHz, TDD, 64Tx/64Rx at gNB and 2Tx/4Rx at UE, realistic channel estimation, ISD350m, Uma, P0=-86 dBm, alpha=-0.9			
		Percentage of UEs	Resource utilization
1 users per cell	DL:	100%	0.35%
	UL:	100%	14.1%
2 users per cell	DL:	100%	0.70%
	UL:	100%	28.3%
3 users per cell	DL:	100%	1.05%
	UL:	97.9%	42.0%
4 users per cell	DL:	100%	1.40%
	UL:	73.8%	58.2%
Source 2 : RMG in port (2.6GHz) Reliability of 99.999%, 16 ms (DL)/18 ms (UL) air interface, 2.6GHz, TDD, 64Tx/64Rx at gNB and 2Tx/4Rx at UE, realistic channel estimation, ISD350m, Uma, P0=-90 dBm, alpha=1			
		Percentage of UEs	Resource utilization
1 users per cell	DL:	100%	0.33%
	UL:	100%	21.32%
2 users per cell	DL:	100%	0.66%
	UL:	78.57%	39.65%
3 users per cell	DL:	100%	0.99%
	UL:	60.32%	55.71%
4 users per cell	DL:	100%	1.32%
	UL:	50%	71.67%
Source 2 : RMG in port (4.9GHz)			

Reliability of 99.999%, 16 ms (DL)/18 ms (UL) air interface, 4.9GHz, TDD, 64Tx/64Rx at gNB and 2Tx/4Rx at UE, realistic channel estimation, ISD350m, Uma, P0=-90 dBm, alpha=1			
		Percentage of UEs	Resource utilization
1 users per cell	DL:	100%	0.36%
	UL:	100%	17.55%
2 users per cell	DL:	100%	0.73%
	UL:	100%	33.92%
3 users per cell	DL:	100%	1.10%
	UL:	100%	50.19%
4 users per cell	DL:	100%	1.46%
	UL:	100%	65.2%
Source 3 : RMG in port (2.6GHz) Reliability of 99.999%, 16 ms (DL)/18 ms (UL) air interface, 2.6GHz, TDD, 64Tx/64Rx at gNB and 2Tx/4Rx at UE, realistic channel estimation, ISD350m, Uma, P0=-86 dBm, alpha=-1			
		Percentage of UEs	Resource utilization
1 users per cell	DL:	100%	4.91%
	UL:	81.60%	54.31%
2 users per cell	DL:	100%	8.37%
	UL:	57.57%	64.78%
3 users per cell	DL:	100%	11.20%
	UL:	43.92%	68.86%
4 users per cell	DL:	100%	13.36%
	UL:	35.16%	70.55%
Source 3 : RMG in port (4.9GHz) Reliability of 99.999%, 16 ms (DL)/18 ms (UL) air interface, 4.9GHz, TDD, 64Tx/64Rx at gNB and 2Tx/4Rx at UE, realistic channel estimation, ISD350m, Uma, P0=-86 dBm, alpha=-1			
		Percentage of UEs	Resource utilization
1 users per cell	DL:	100%	5.90%
	UL:	92.52%	43.96%
2 users per cell	DL:	100%	8.94%
	UL:	76.80%	59.97%
3 users per cell	DL:	100%	11.98%
	UL:	64.52%	68.42%
4 users per cell	DL:	100%	14.68%
	UL:	53.52%	71.44%
Source 4 : RMG in port (2.6GHz) Reliability of 99.999%, 16 ms (DL)/18 ms (UL) air interface, 2.6GHz, TDD, 64Tx/64Rx at			

gNB and 2Tx/4Rx at UE, realistic channel estimation, ISD350m, Uma, P0=-86 dBm, alpha=-0.9			
		Percentage of UEs	Resource utilization
1 users per cell	DL:	-	-
	UL:	-	-
2 users per cell	DL:	100%	3.8%
	UL:	83.3%	37.6%
3 users per cell	DL:	100%	5.6%
	UL:	63.5%	60.6%
4 users per cell	DL:	100%	7.5%
	UL:	42.9%	78.5%
Source 4 : RMG in port (4.9GHz) Reliability of 99.999%, 16 ms (DL)/18 ms (UL) air interface, 4.9GHz, TDD, 64Tx/64Rx at gNB and 2Tx/4Rx at UE, realistic channel estimation, ISD350m, Uma, P0=-86 dBm, alpha=-0.9			
		Percentage of UEs	Resource utilization
1 users per cell	DL:	-	-
	UL:	-	-
2 users per cell	DL:	100%	5.1%
	UL:	100%	30.2%
3 users per cell	DL:	100%	7.7%
	UL:	93.7%	46.4%
4 users per cell	DL:	100%	10.2%
	UL:	73.8%	59.7%

2) ISD250m

As Table 6-2 shows,

- Two sources show that the percentage of UEs satisfying the latency (i.e. 18 ms for HD video) and reliability (i.e. 99.999%) requirements by Rel-15 NR is higher than 95% for uplink transmission for RMG assuming 1 users per cell, 2.6GHz using 5ms switch-point periodicity frame structure (7D:1S:2U, S:6:4:4).
- Three sources show that the percentage of UEs satisfying the latency (i.e. 18 ms for HD video) and reliability (i.e. 99.999%) requirements by Rel-15 NR is higher than 95% for uplink transmission for RMG assuming up to 2 users per cell, 4.9GHz using 2.5ms dual switch-point periodicity (S:10:2:2).

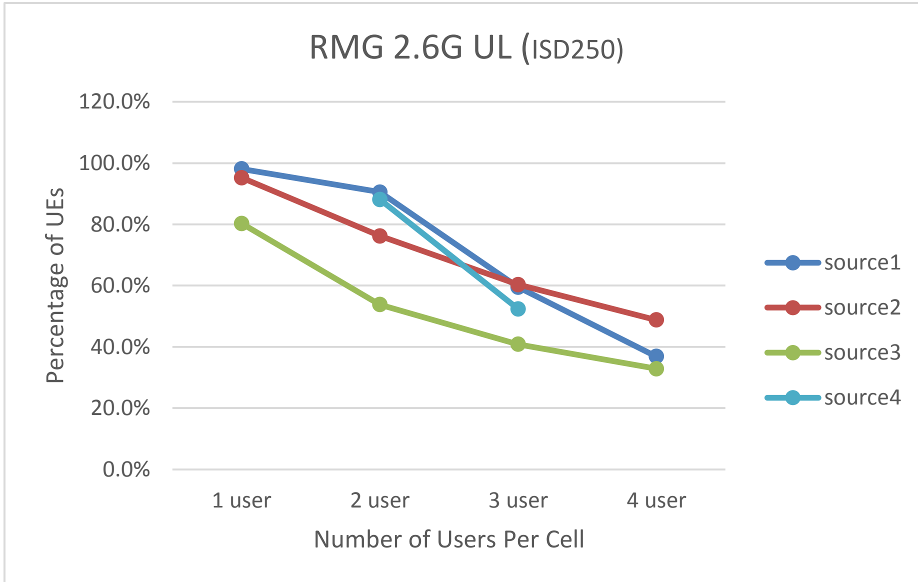


Fig. 10 UL Performance of RMG 2.6G (ISD250)

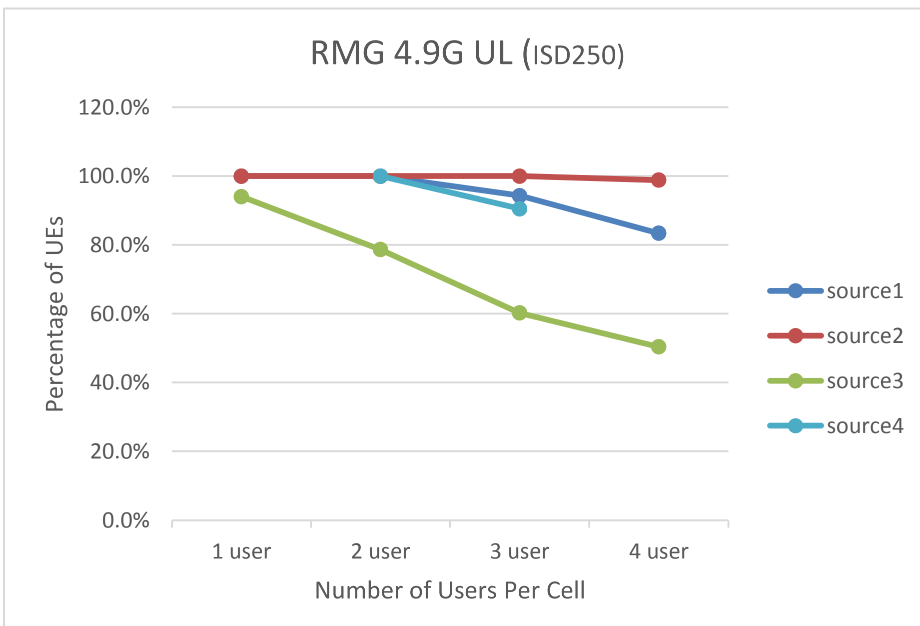


Fig. 11 UL Performance of RMG 4.9G (ISD250)

Table 6-1: The percentage of UEs satisfying requirements for RMG (ISD250m)

Source 1 : RMG in port (2.6GHz) Reliability of 99.999%, 16 ms (DL)/18 ms (UL) air interface, 2.6GHz, TDD, 64Tx/64Rx at gNB and 2Tx/4Rx at UE, realistic channel estimation, ISD250m, Uma, P0=-86 dBm, alpha=-0.9			
		Percentage of UEs	Resource utilization
1 users per cell	DL:	100%	0.31%
	UL:	98.1%	16.0%
2 users per cell	DL:	100%	0.62%
	UL:	90.5%	36.1%
3 users per cell	DL:	100%	0.93%
	UL:	59.5%	55.0%
4 users per cell	DL:	100%	1.24%
	UL:	36.9%	74.1%
Source 1 : RMG in port (4.9GHz) Reliability of 99.999%, 16 ms (DL)/18 ms (UL) air interface, 4.9GHz, TDD, 64Tx/64Rx at gNB and 2Tx/4Rx at UE, realistic channel estimation, ISD250m, Uma, P0=-86 dBm, alpha=-0.9			
		Percentage of UEs	Resource utilization
1 users per cell	DL:	100%	0.35%
	UL:	100%	14.5%
2 users per cell	DL:	100%	0.70%
	UL:	100%	28.3%
3 users per cell	DL:	100%	1.05%
	UL:	94.3%	41.2%
4 users per cell	DL:	100%	1.40%
	UL:	83.4%	57.4%
Source 2 : RMG in port (2.6GHz) Reliability of 99.999%, 16 ms (DL)/18 ms (UL) air interface, 2.6GHz, TDD, 64Tx/64Rx at gNB and 2Tx/4Rx at UE, realistic channel estimation, ISD250m, Uma, P0=-90 dBm, alpha=1			
		Percentage of UEs	Resource utilization
1 users per cell	DL:	100%	0.33%
	UL:	95.24%	20.96%
2 users per cell	DL:	100%	0.66%
	UL:	76.19%	39.15%
3 users per cell	DL:	100%	0.99%
	UL:	60.32%	55.5%
4 users per cell	DL:	100%	1.32%
	UL:	48.81%	70.83%
Source 2 : RMG in port (4.9GHz)			

Reliability of 99.999%, 16 ms (DL)/18 ms (UL) air interface, 4.9GHz, TDD, 64Tx/64Rx at gNB and 2Tx/4Rx at UE, realistic channel estimation, ISD250m, Uma, P0=-90 dBm, alpha=1			
		Percentage of UEs	Resource utilization
1 users per cell	DL:	100%	0.36%
	UL:	100%	17.33%
2 users per cell	DL:	100%	0.73%
	UL:	100%	33.98%
3 users per cell	DL:	100%	1.10%
	UL:	100%	50.22%
4 users per cell	DL:	100%	1.46%
	UL:	98.81%	65.48%
Source 3 : RMG in port (2.6GHz) Reliability of 99.999%, 16 ms (DL)/18 ms (UL) air interface, 2.6GHz, TDD, 64Tx/64Rx at gNB and 2Tx/4Rx at UE, realistic channel estimation, ISD250m, Uma, P0=-86 dBm, alpha=1			
		Percentage of UEs	Resource utilization
1 users per cell	DL:	100%	5.53%
	UL:	80.30%	55.12%
2 users per cell	DL:	100%	8.02%
	UL:	53.79%	65.65%
3 users per cell	DL:	100%	11.53%
	UL:	40.88%	69.88%
4 users per cell	DL:	100%	13.54%
	UL:	32.87%	71.21%
Source 3 : RMG in port (4.9GHz) Reliability of 99.999%, 16 ms (DL)/18 ms (UL) air interface, 4.9GHz, TDD, 64Tx/64Rx at gNB and 2Tx/4Rx at UE, realistic channel estimation, ISD250m, Uma, P0=-86 dBm, alpha=1			
		Percentage of UEs	Resource utilization
1 users per cell	DL:	100%	5.88%
	UL:	94.03%	44.72%
2 users per cell	DL:	100%	9.28%
	UL:	78.66%	60.44%
3 users per cell	DL:	100%	11.76%
	UL:	60.24%	69.30%
4 users per cell	DL:	100%	14.84%
	UL:	50.38%	73.88%
Source 4 : RMG in port (2.6GHz) Reliability of 99.999%, 16 ms (DL)/18 ms (UL) air interface, 2.6GHz, TDD, 64Tx/64Rx at			

gNB and 2Tx/4Rx at UE, realistic channel estimation, ISD250m, Uma, P0=-86 dBm, alpha=-0.9			
		Percentage of UEs	Resource utilization
1 users per cell	DL:	-	-
	UL:	-	-
2 users per cell	DL:	100%	2.9%
	UL:	88.1%	37.1%
3 users per cell	DL:	100%	4.3%
	UL:	52.4%	61.6%
4 users per cell	DL:	-	-
	UL:	-	-
Source 4 : RMG in port (4.9GHz) Reliability of 99.999%, 16 ms (DL)/18 ms (UL) air interface, 4.9GHz, TDD, 64Tx/64Rx at gNB and 2Tx/4Rx at UE, realistic channel estimation, ISD250m, Uma, P0=-86 dBm, alpha=-0.9			
		Percentage of UEs	Resource utilization
1 users per cell	DL:	-	-
	UL:	-	-
2 users per cell	DL:	100%	4.8%
	UL:	100%	30.8%
3 users per cell	DL:	100%	7.1%
	UL:	90.5%	47.1%
4 users per cell	DL:	-	-
	UL:	-	-

3) ISD150m

As Table 6-3 shows,

- Two sources show that the percentage of UEs satisfying the latency (i.e. 18 ms for HD video) and reliability (i.e. 99.999%) requirements by Rel-15 NR is higher than 95% for uplink transmission for RMG assuming 1 users per cell, 2.6GHz using 5ms switch-point periodicity frame structure (7D:1S:2U, S:6:4:4).
- Two sources show that the percentage of UEs satisfying the latency (i.e. 18 ms for HD video) and reliability (i.e. 99.999%) requirements by Rel-15 NR is higher than 95% for uplink transmission for RMG assuming up to 3 users per cell, 4.9GHz using 2.5ms dual switch-point periodicity (S:10:2:2).

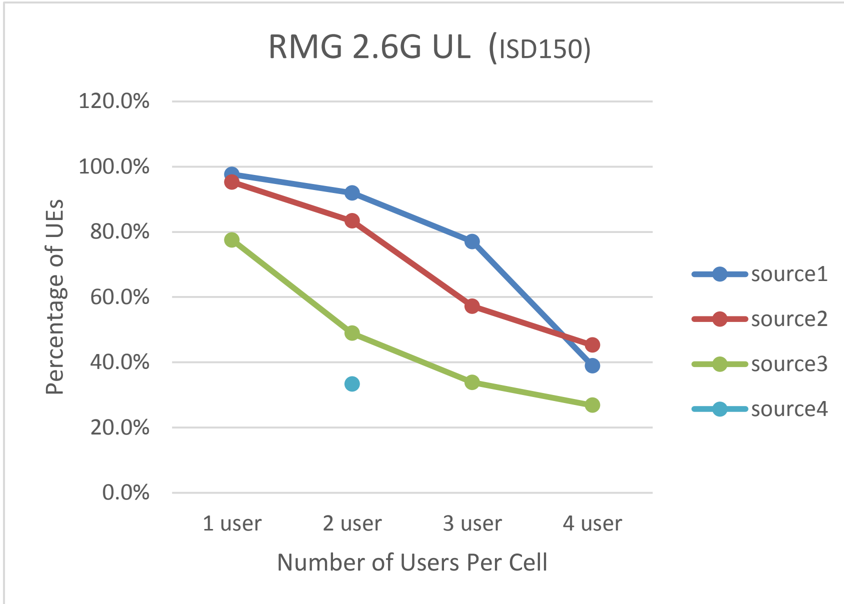


Fig. 12 UL Performance of RMG 2.6G (ISD150)

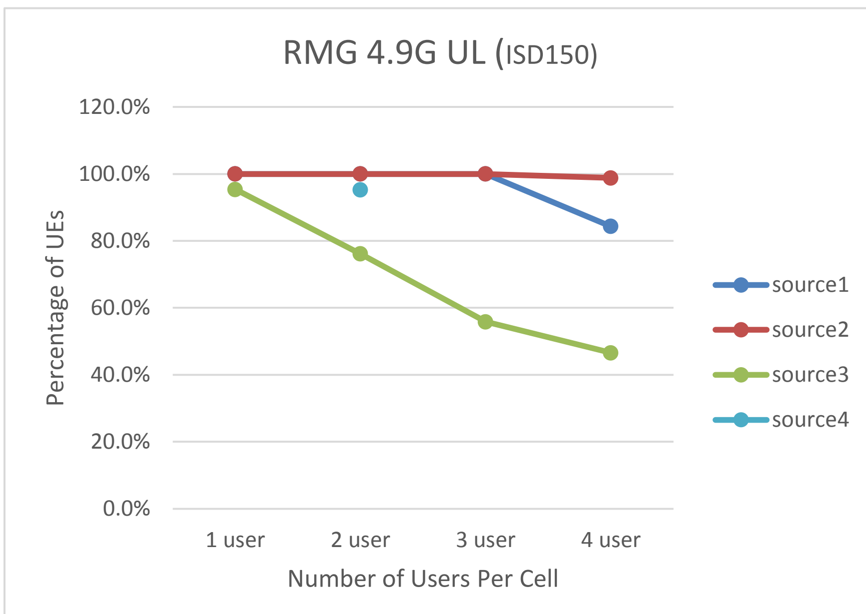


Fig. 13 UL Performance of RMG 4.9G (ISD150)

Table 6-3: The percentage of UEs satisfying requirements for RMG (ISD150m)

Source 1 : RMG in port (2.6GHz) Reliability of 99.999%, 16 ms (DL)/18 ms (UL) air interface, 2.6GHz, TDD, 64Tx/64Rx at gNB and 2Tx/4Rx at UE, realistic channel estimation, ISD150m, Uma, P0=-86 dBm, alpha=-0.9			
		Percentage of UEs	Resource utilization
1 users per cell	DL:	100%	0.31%
	UL:	97.6%	16.2%
2 users per cell	DL:	100%	0.62%
	UL:	91.9%	38.0%
3 users per cell	DL:	100%	0.96%
	UL:	77.0%	58.3%
4 users per cell	DL:	100%	1.24%
	UL:	38.9%	70.9%
Source 1 : RMG in port (4.9GHz) Reliability of 99.999%, 16 ms (DL)/18 ms (UL) air interface, 4.9GHz, TDD, 64Tx/64Rx at gNB and 2Tx/4Rx at UE, realistic channel estimation, ISD150m, Uma, P0=-86 dBm, alpha=-0.9			
		Percentage of UEs	Resource utilization
1 users per cell	DL:	100%	0.35%
	UL:	100%	14.1%
2 users per cell	DL:	100%	0.70%
	UL:	100%	27.8%
3 users per cell	DL:	100%	1.05%
	UL:	100%	42.5%
4 users per cell	DL:	100%	1.40%
	UL:	84.3%	54.9%
Source 2 : RMG in port (2.6GHz) Reliability of 99.999%, 16 ms (DL)/18 ms (UL) air interface, 2.6GHz, TDD, 64Tx/64Rx at gNB and 2Tx/4Rx at UE, realistic channel estimation, ISD150m, Uma, P0=-90 dBm, alpha=1			
		Percentage of UEs	Resource utilization
1 users per cell	DL:	100%	0.33%
	UL:	95.24%	20.96%
2 users per cell	DL:	100%	0.66%
	UL:	83.33%	40.25%
3 users per cell	DL:	100%	0.99%
	UL:	57.14%	55.02%
4 users per cell	DL:	100%	1.32%
	UL:	45.24%	68.19%
Source 2 : RMG in port (4.9GHz)			

Reliability of 99.999%, 16 ms (DL)/18 ms (UL) air interface, 4.9GHz, TDD, 64Tx/64Rx at gNB and 2Tx/4Rx at UE, realistic channel estimation, ISD150m, Uma, P0=-90 dBm, alpha=1			
		Percentage of UEs	Resource utilization
1 users per cell	DL:	100%	0.36%
	UL:	100%	17.55%
2 users per cell	DL:	100%	0.73%
	UL:	100%	33.78%
3 users per cell	DL:	100%	1.10%
	UL:	100%	49.2%
4 users per cell	DL:	100%	1.46%
	UL:	98.81%	65.1%
Source 3 : RMG in port (2.6GHz) Reliability of 99.999%, 16 ms (DL)/18 ms (UL) air interface, 2.6GHz, TDD, 64Tx/64Rx at gNB and 2Tx/4Rx at UE, realistic channel estimation, ISD150m, Uma, P0=-86 dBm, alpha=1			
		Percentage of UEs	Resource utilization
1 users per cell	DL:	100%	5.53%
	UL:	77.46%	58.31%
2 users per cell	DL:	100%	8.12%
	UL:	48.85%	67.75%
3 users per cell	DL:	100%	11.63%
	UL:	33.80%	70.09%
4 users per cell	DL:	100%	14.20%
	UL:	26.77%	71.30%
Source 3 : RMG in port (4.9GHz) Reliability of 99.999%, 16 ms (DL)/18 ms (UL) air interface, 4.9GHz, TDD, 64Tx/64Rx at gNB and 2Tx/4Rx at UE, realistic channel estimation, ISD150m, Uma, P0=-86 dBm, alpha=1			
		Percentage of UEs	Resource utilization
1 users per cell	DL:	100%	5.70%
	UL:	95.34%	47.44%
2 users per cell	DL:	100%	9.05%
	UL:	76.09%	64.57%
3 users per cell	DL:	100%	11.71%
	UL:	55.83%	68.25%
4 users per cell	DL:	100%	15.29%
	UL:	46.57%	73.66%
Source 4 : RMG in port (2.6GHz) Reliability of 99.999%, 16 ms (DL)/18 ms (UL) air interface, 2.6GHz, TDD, 64Tx/64Rx at			

gNB and 2Tx/4Rx at UE, realistic channel estimation, ISD150m, Uma, P0=-86 dBm, alpha=-0.9			
		Percentage of UEs	Resource utilization
1 users per cell	DL:	-	-
	UL:	-	-
2 users per cell	DL:	100%	2.9%
	UL:	33.3%	40.8%
3 users per cell	DL:	-	-
	UL:	-	-
4 users per cell	DL:	-	-
	UL:	-	-
Source 4 : RMG in port (4.9GHz) Reliability of 99.999%, 16 ms (DL)/18 ms (UL) air interface, 4.9GHz, TDD, 64Tx/64Rx at gNB and 2Tx/4Rx at UE, realistic channel estimation, ISD150m, Uma, P0=-86 dBm, alpha=-0.9			
		Percentage of UEs	Resource utilization
1 users per cell	DL:	-	-
	UL:	-	-
2 users per cell	DL:	100%	4.8%
	UL:	95.2%	31.8%
3 users per cell	DL:	-	-
	UL:	-	-
4 users per cell	DL:	-	-
	UL:	-	-

6.2. Evaluation on AGV in factory

Five sources evaluate the performance achievable with Rel-15 NR for AGV layout case1, with the evaluation results as shown in Table 6-4. Four sources evaluate the performance achievable with Rel-15 NR for AGV layout case2, with the evaluation results as shown in Table 6-5.

- Five sources show that the percentage of UEs satisfying the latency (i.e. 18 ms for control) and reliability (i.e. 99.999%) requirements by Rel-15 NR is higher than 95% for downlink transmission for AGV layout case1 assuming up to 250 URLLC users without any eMBB users per 120m*50m, 2.6 GHz/4.9 GHz and TDD.
- Four sources show that the percentage of UEs satisfying the latency (i.e. 18 ms for control) and reliability (i.e. 99.999%) requirements by Rel-15 NR is higher than 95% for downlink transmission for AGV layout case2 assuming up to 250 URLLC users without any eMBB users per 120m*50m, 2.6 GHz/4.9 GHz and TDD.

- Four sources show that the percentage of UEs satisfying the latency (i.e. 18 ms for control) and reliability (i.e. 99.999%) requirements by Rel-15 NR is higher than 95% for uplink transmission for AGV layout case1 assuming up to 250 URLLC users without any eMBB users per 120m*50m, 2.6 GHz/4.9 GHz and TDD.
- Four sources show that the percentage of UEs satisfying the latency (i.e. 18 ms for control) and reliability (i.e. 99.999%) requirements by Rel-15 NR is higher than 95% for uplink transmission for AGV layout case2 assuming up to 250 URLLC users without any eMBB users per 120m*50m, 2.6 GHz/4.9 GHz and TDD.

1) Case1

Table 6-4: The percentage of UEs satisfying requirements for AGV (layout case1)

Source 1 : AGV in factory (2.6GHz) Reliability of 99.999%, 18 ms air interface, 2.6GHz, TDD, 4Tx/4Rx at gNB and 2Tx/4Rx at UE, realistic channel estimation, ISD20m, case1, ITU channel model, P0 = -60 dBm, alpha=0.6			
		Percentage of UEs	Resource utilization
50 users per 120m*50m	DL:	100%	0.15%
	UL:	100%	0.61%
100 users per 120m*50m	DL:	100%	0.31%
	UL:	100%	1.23%
150 users per 120m*50m	DL:	100%	0.46%
	UL:	100%	1.84%
200 users per 120m*50m	DL:	100%	0.61%
	UL:	100%	2.45%
250 users per 120m*50m	DL:	100%	0.77%
	UL:	100%	3.06%
Source 1 : AGV in factory (4.9GHz) Reliability of 99.999%, 18 ms air interface, 4.9GHz, TDD, 4Tx/4Rx at gNB and 2Tx/4Rx at UE, realistic channel estimation, ISD20m, case1, ITU channel model, P0 = -60 dBm, alpha=0.6			
		Percentage of UEs	Resource utilization
50 users per 120m*50m	DL:	100%	0.18%
	UL:	100%	0.41%
100 users per 120m*50m	DL:	100%	0.35%
	UL:	100%	0.82%
150 users per 120m*50m	DL:	100%	0.53%
	UL:	100%	1.23%
200 users per 120m*50m	DL:	100%	0.70%
	UL:	100%	1.63%
250 users per 120m*50m	DL:	100%	0.88%
	UL:	100%	2.04%
Source 2 : AGV in factory (2.6GHz) Reliability of 99.999%, 18 ms air interface, 2.6GHz, TDD, 4Tx/4Rx at gNB and 2Tx/4Rx at UE, realistic channel estimation, ISD20m, case1, ITU channel model, P0 = -90 dBm, alpha=1			
		Percentage of UEs	Resource utilization
50 users per 120m*50m	DL:	100%	0.16%
	UL:	100%	0.31%
100 users per 120m*50m	DL:	100%	0.33%
	UL:	100%	0.67%
150 users per	DL:	100%	0.50%

120m*50m	UL:	100%	1.02%
200 users per 120m*50m	DL:	100%	0.66%
	UL:	100%	1.37%
250 users per 120m*50m	DL:	100%	0.82%
	UL:	100%	1.81%
Source 2: AGV in factory (4.9GHz) Reliability of 99.999%, 18 ms air interface, 4.9GHz, TDD, 4Tx/4Rx at gNB and 2Tx/4Rx at UE, realistic channel estimation, ISD20m, case1, ITU channel model, P0 = -90 dBm, alpha=1			
		Percentage of UEs	Resource utilization
50 users per 120m*50m	DL:	100%	0.18%
	UL:	100%	0.1%
100 users per 120m*50m	DL:	100%	0.37%
	UL:	100%	0.21%
150 users per 120m*50m	DL:	100%	0.55%
	UL:	100%	0.34%
200 users per 120m*50m	DL:	100%	0.74%
	UL:	100%	0.44%
250 users per 120m*50m	DL:	100%	0.92%
	UL:	100%	0.5%
Source 3 : AGV in factory (2.6GHz) Reliability of 99.999%, 18 ms air interface, 2.6GHz, TDD, 4Tx/4Rx at gNB and 2Tx/4Rx at UE, realistic channel estimation, ISD20m, case1, ITU channel model, P0 = -60 dBm, alpha=1			
		Percentage of UEs	Resource utilization
50 users per 120m*50m	DL:	100%	2.17%
	UL:	100%	3.13%
100 users per 120m*50m	DL:	100%	4.16%
	UL:	100%	6.16%
150 users per 120m*50m	DL:	100%	6.16%
	UL:	100%	9.22%
200 users per 120m*50m	DL:	100%	8.18%
	UL:	100%	13.24%
250 users per 120m*50m	DL:	100%	10.18%
	UL:	100%	15.28%
Source 3 : AGV in factory (4.9GHz) Reliability of 99.999%, 18 ms air interface, 4.9GHz, TDD, 4Tx/4Rx at gNB and 2Tx/4Rx at UE, realistic channel estimation, ISD20m, case2, ITU channel model, P0 = -60 dBm, alpha=1			
		Percentage of UEs	Resource utilization

50 users per 120m*50m	DL:	100%	2.50%
	UL:	100%	2.15%
100 users per 120m*50m	DL:	100%	4.78%
	UL:	100%	4.25%
150 users per 120m*50m	DL:	100%	7.05%
	UL:	100%	6.37%
200 users per 120m*50m	DL:	100%	9.35%
	UL:	100%	8.47%
250 users per 120m*50m	DL:	100%	11.63%
	UL:	100%	10.60%
Source 4 : AGV in factory (2.6GHz) Reliability of 99.999%, 18 ms air interface, 2.6GHz, TDD, 4Tx/4Rx at gNB and 2Tx/4Rx at UE, realistic channel estimation, ISD20m, case1, ITU channel model, P0 = -60 dBm, alpha=0.6			
		Percentage of UEs	Resource utilization
50 users per 120m*50m	DL:	100%	1.0%
	UL:	100%	4.7%
100 users per 120m*50m	DL:	100%	2.1%
	UL:	100%	10.5%
150 users per 120m*50m	DL:	100%	3.1%
	UL:	100%	17.0%
200 users per 120m*50m	DL:	100%	4.6%
	UL:	100%	25.3%
250 users per 120m*50m	DL:	100%	6.1%
	UL:	77.2%	22.9%
Source 4 : AGV in factory (4.9GHz) Reliability of 99.999%, 18 ms air interface, 4.9GHz, TDD, 4Tx/4Rx at gNB and 2Tx/4Rx at UE, realistic channel estimation, ISD20m, case1, ITU channel model, P0 = -60 dBm, alpha=0.6			
		Percentage of UEs	Resource utilization
50 users per 120m*50m	DL:	100%	1.3%
	UL:	100%	2.8%
100 users per 120m*50m	DL:	100%	3.1%
	UL:	100%	5.8%
150 users per 120m*50m	DL:	100%	4.5%
	UL:	100%	9.9%
200 users per 120m*50m	DL:	100%	7.1%
	UL:	100%	13.1%
250 users per	DL:	100%	7.7%

120m*50m	UL:	100%	15.6%
Source 5 : AGV in factory (2.6GHz) Reliability of 99.999%, 18 ms air interface, 2.6GHz, TDD, 4Tx/4Rx at gNB and 2Tx/4Rx at UE, realistic channel estimation, ISD20m, case1, ITU channel model, P0 = -60 dBm, alpha=0.6			
		Percentage of UEs	Resource utilization
50 users per 120m*50m	DL:	100%	0.22%
	UL:	100%	1.84%
100 users per 120m*50m	DL:	100%	0.43%
	UL:	100%	3.68%
150 users per 120m*50m	DL:	100%	0.64%
	UL:	100%	5.52%
200 users per 120m*50m	DL:	100%	0.86%
	UL:	100%	7.36%
250 users per 120m*50m	DL:	100%	1.08%
	UL:	100%	9.20%
Source 5 : AGV in factory (4.9GHz) Reliability of 99.999%, 18 ms air interface, 4.9GHz, TDD, 4Tx/4Rx at gNB and 2Tx/4Rx at UE, realistic channel estimation, ISD20m, case1, ITU channel model, P0 = -60 dBm, alpha=0.6			
		Percentage of UEs	Resource utilization
50 users per 120m*50m	DL:	100%	0.24%
	UL:	100%	1.30%
100 users per 120m*50m	DL:	100%	0.48%
	UL:	100%	2.60%
150 users per 120m*50m	DL:	100%	0.73%
	UL:	100%	3.90%
200 users per 120m*50m	DL:	100%	0.97%
	UL:	100%	5.20%
250 users per 120m*50m	DL:	100%	1.22%
	UL:	100%	6.50%

2) Case2

Table 6-5: The percentage of UEs satisfying requirements for AGV (layout case2)

Source 1 : AGV in factory (2.6GHz) Reliability of 99.999%, 18 ms air interface, 2.6GHz, TDD, 4Tx/4Rx at gNB and 2Tx/4Rx at UE, realistic channel estimation, ISD20m, case2, ITU channel model, P0 = -50 dBm, alpha=0.9			
		Percentage of UEs	Resource utilization
50 users per 120m*50m	DL:	100%	1.8%
	UL:	100%	7.3%
100 users per 120m*50m	DL:	100%	3.7%
	UL:	100%	14.7%
150 users per 120m*50m	DL:	100%	5.5%
	UL:	100%	22.1%
200 users per 120m*50m	DL:	100%	7.4%
	UL:	100%	29.4%
250 users per 120m*50m	DL:	100%	9.2%
	UL:	100%	37.8%
Source 1 : AGV in factory (4.9GHz) Reliability of 99.999%, 18 ms air interface, 4.9GHz, TDD, 4Tx/4Rx at gNB and 2Tx/4Rx at UE, realistic channel estimation, ISD20m, case2, ITU channel model, P0 = -50 dBm, alpha=0.9			
		Percentage of UEs	Resource utilization
50 users per 120m*50m	DL:	100%	2.1%
	UL:	100%	4.9%
100 users per 120m*50m	DL:	100%	4.2%
	UL:	100%	9.8%
150 users per 120m*50m	DL:	100%	6.3%
	UL:	100%	14.7%
200 users per 120m*50m	DL:	100%	8.4%
	UL:	100%	19.6%
250 users per 120m*50m	DL:	100%	10.5%
	UL:	100%	24.5%
Source 2 : AGV in factory (2.6GHz) Reliability of 99.999%, 18 ms air interface, 2.6GHz, TDD, 4Tx/4Rx at gNB and 2Tx/4Rx at UE, realistic channel estimation, ISD20m, case2, ITU channel model, P0 = -50 dBm, alpha=0.9			
		Percentage of UEs	Resource utilization
50 users per 120m*50m	DL:	100%	1.97%
	UL:	100%	3.72%
100 users per 120m*50m	DL:	100%	3.98%
	UL:	100%	8.04%
150 users per	DL:	100%	5.92%

120m*50m	UL:	100%	12.12%
200 users per 120m*50m	DL:	100%	7.92%
	UL:	100%	20.76%
250 users per 120m*50m	DL:	100%	9.83%
	UL:	100%	33.48%
Source 2 : AGV in factory (4.9GHz) Reliability of 99.999%, 18 ms air interface, 4.9GHz, TDD, 4Tx/4Rx at gNB and 2Tx/4Rx at UE, realistic channel estimation, ISD20m, case2, ITU channel model, P0 = -50 dBm, alpha=0.9			
		Percentage of UEs	Resource utilization
50 users per 120m*50m	DL:	100%	2.21%
	UL:	100%	1.32%
100 users per 120m*50m	DL:	100%	4.46%
	UL:	100%	2.52%
150 users per 120m*50m	DL:	100%	6.60%
	UL:	100%	3.96%
200 users per 120m*50m	DL:	100%	8.81%
	UL:	100%	5.16%
250 users per 120m*50m	DL:	100%	10.95%
	UL:	100%	6.72%
Source 3 : AGV in factory (2.6GHz) Reliability of 99.999%, 18 ms air interface, 2.6GHz, TDD, 4Tx/4Rx at gNB and 2Tx/4Rx at UE, realistic channel estimation, ISD20m, case2, ITU channel model, P0 = -50 dBm, alpha=1			
		Percentage of UEs	Resource utilization
50 users per 120m*50m	DL:	100%	3.19%
	UL:	100%	5.51%
100 users per 120m*50m	DL:	100%	6.09%
	UL:	100%	10.80%
150 users per 120m*50m	DL:	100%	8.99%
	UL:	100%	15.79%
200 users per 120m*50m	DL:	100%	11.94%
	UL:	100%	21.06%
250 users per 120m*50m	DL:	100%	14.85%
	UL:	100%	26.61%
Source 3 : AGV in factory (4.9GHz) Reliability of 99.999%, 18 ms air interface, 4.9GHz, TDD, 4Tx/4Rx at gNB and 2Tx/4Rx at UE, realistic channel estimation, ISD20m, case2, ITU channel model, P0 = -50 dBm, alpha=1			
		Percentage of UEs	Resource utilization

50 users per 120m*50m	DL:	100%	3.69%
	UL:	100%	5.41%
100 users per 120m*50m	DL:	100%	6.60%
	UL:	100%	10.67%
150 users per 120m*50m	DL:	100%	9.56%
	UL:	100%	15.93%
200 users per 120m*50m	DL:	100%	13.20%
	UL:	100%	21.18%
250 users per 120m*50m	DL:	100%	16.12%
	UL:	100%	26.01%
Source 4 : AGV in factory (2.6GHz) Reliability of 99.999%, 18 ms air interface, 2.6GHz, TDD, 4Tx/4Rx at gNB and 2Tx/4Rx at UE, realistic channel estimation, ISD20m, case2, ITU channel model, P0 = -50 dBm, alpha=1			
		Percentage of UEs	Resource utilization
50 users per 120m*50m	DL:	100%	2.19%
	UL:	100%	16.24%
100 users per 120m*50m	DL:	100%	4.37%
	UL:	100%	32.48%
150 users per 120m*50m	DL:	100%	6.56%
	UL:	100%	48.72%
200 users per 120m*50m	DL:	100%	8.74%
	UL:	100%	64.96%
250 users per 120m*50m	DL:	100%	10.93%
	UL:	100%	81.20%
Source 4 : AGV in factory (4.9GHz) Reliability of 99.999%, 18 ms air interface, 4.9GHz, TDD, 4Tx/4Rx at gNB and 2Tx/4Rx at UE, realistic channel estimation, ISD20m, case2, ITU channel model, P0 = -50 dBm, alpha=1			
		Percentage of UEs	Resource utilization
50 users per 120m*50m	DL:	100%	2.52%
	UL:	100%	12.46%
100 users per 120m*50m	DL:	100%	5.04%
	UL:	100%	24.92%
150 users per 120m*50m	DL:	100%	7.55%
	UL:	100%	37.38%
200 users per 120m*50m	DL:	100%	10.70%
	UL:	100%	49.84%

250 users per 120m*50m	DL:	100%	12.59%
	UL:	100%	62.30%

7. Conclusion and recommendation

For UL heavy and ultra reliability (under certain delay requirements) traffic, e.g. RMG, 5ms switch-point periodicity frame structure (7D:1S:2U, S:6:4:4) seems could not meet the vertical requirements which needs up to 3 URLLC users per cell. With 5ms switch-point periodicity frame structure, only 1 URLLC user's performance can be guaranteed while up to 3 URLLC user's performance can be guaranteed using 2.5ms dual switch-point periodicity. Therefore, frame structure with short switch-point periodicity and more UL resources should be used in this type of URLLC cases.

For AGV cases, sufficient performance can be achieved both in layout case1 and case2. Vertical customers could take layout case2 into account due to the less handover and lower cost.

Reference

[1]. 3GPP, TR 38.824, “Study on physical layer enhancements for NR ultra-reliable and low latency case (URLLC)”

[2]. NGMN, ”Verticals URLLC Use Cases and Requirements”

[3]. 3GPP TR 22.804, “Study on Communication for Automation in Vertical Domains”.