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UAV based 5G Wireless Networks: A Practical Solution for Emergency Communications

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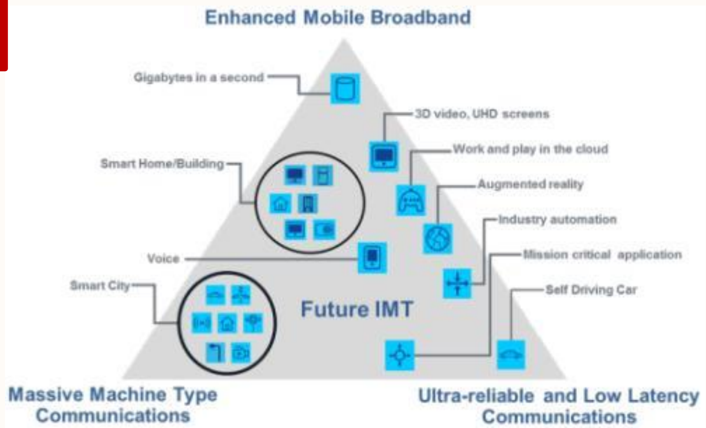
Outline

- Introduction
- System Description
- System Level Simulation
- Field Trial Results
- Conclusion

Scenario & KPI of 5G

3 Typical Scenario

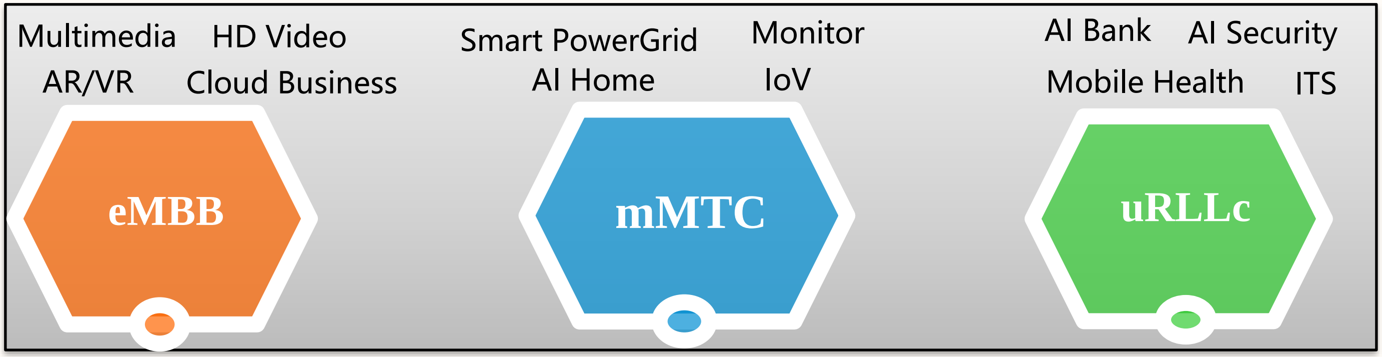


8 KPIs

Network	Traffic density	Connection Density	Delay	Mobility	Energy efficiency	User Speed	Spectrum efficiency	Peak Rate
4G	0.1Mbps/m²	0.1m/km²	Air Interface 10ms	350Km/h	1X	10Mbps	1X	1Gbps
5G	10Mbps/m²	1m/km²	Air Interface 1ms	500Km/h	100X	100M-1Gbps	3-5X	20Gbps

Demand for Bearer Network

Capacity	Connection	Delay
10Gbps per User	1000K/km2	AI delay 1ms D2D Delay 5ms



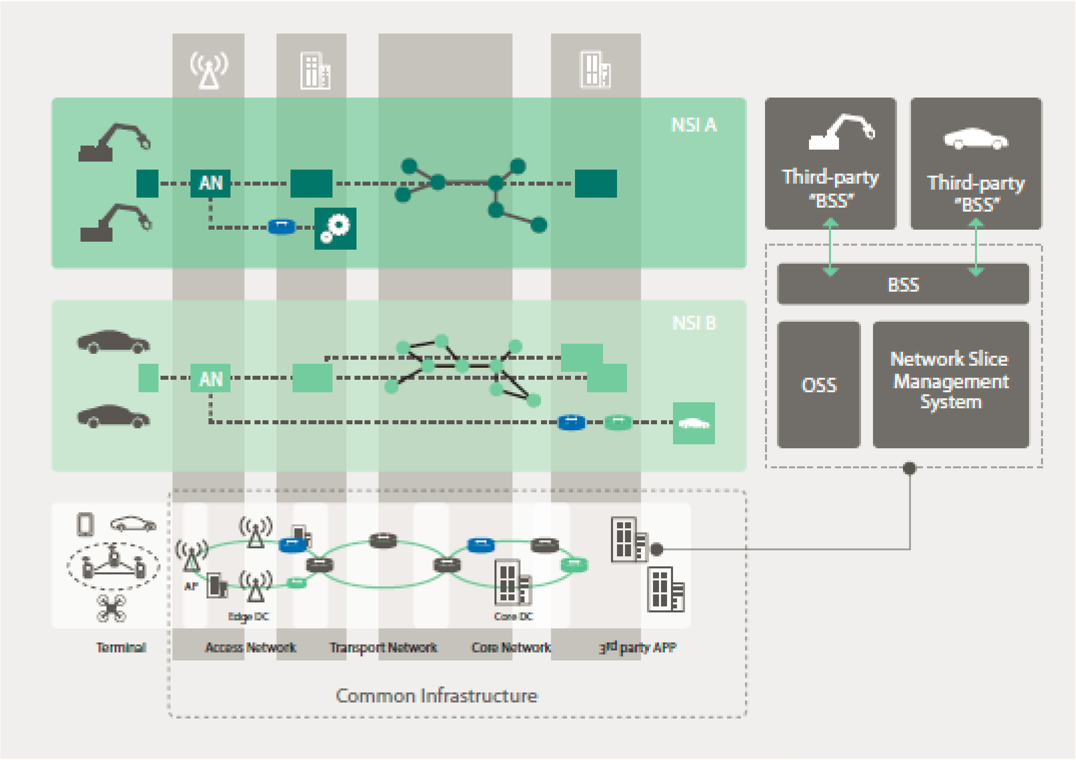
Demand for Bearer Network

- High Speed, Bandwidth
- Precise Timing
- Flattening, Programming, Virtualizing

- Connection
- Delay Tolerance
- Small Bandwidth

- Ultra Low Delay

Network Slicing

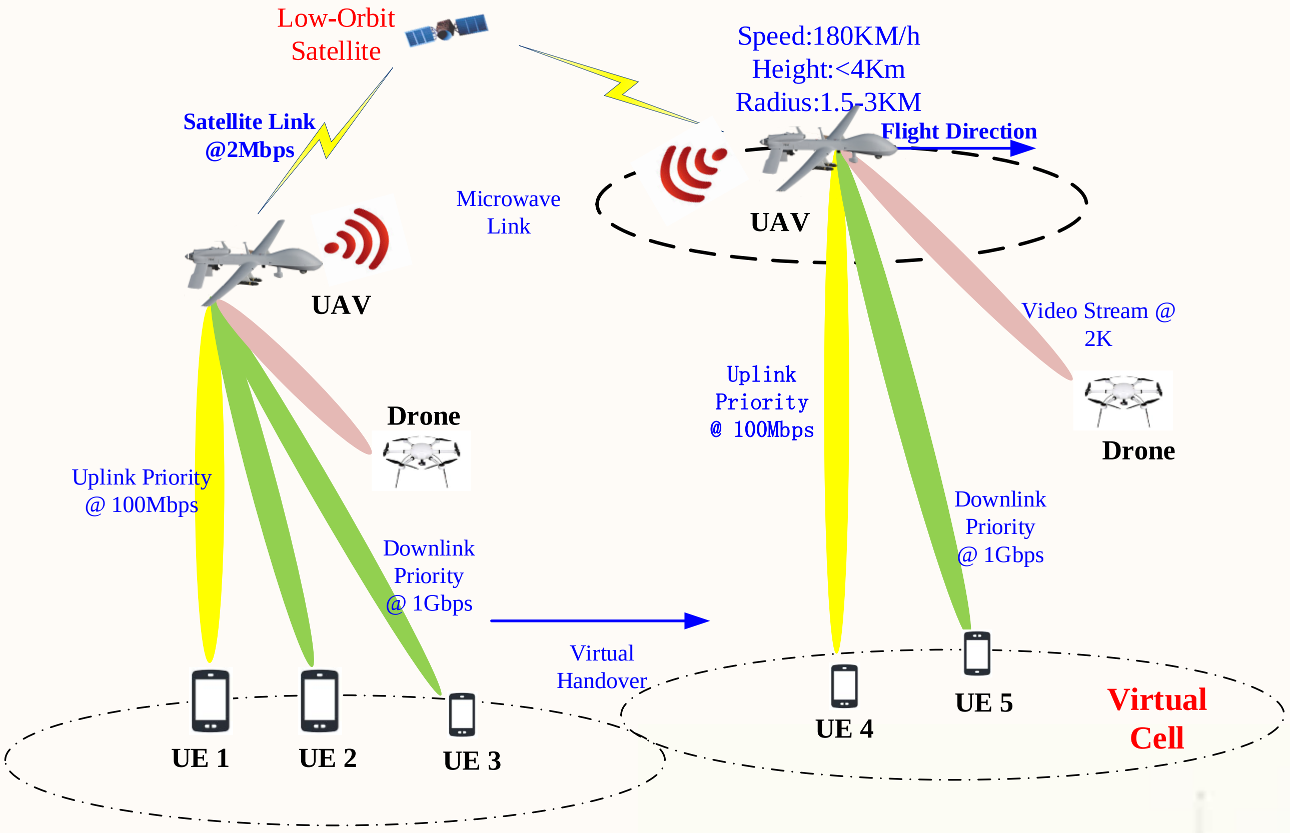


Source：5G-Service-Guaranteed-Network-Slicing-Whitepaper

1. KPI for 5G is quite different from 4G .
2. Ensure the Quality of Every Data Traffic Through Slicing.
3. Valid for Security and Storage Management.

SYSTEM DESCRIPTION

UAV based 5G



Low-Orbit Satellite
Satellite Link @2Mbps
Microwave Link
Speed:180KM/h
Height:<4Km
Radius:1.5-3KM
Flight Direction
UAV
UAV
Drone
Video Stream @ 2K
Uplink Priority @ 100Mbps
Drone
Uplink Priority @ 100Mbps
Downlink Priority @ 1Gbps
Downlink Priority @ 1Gbps
Virtual Handover
UE 1
UE 2
UE 3
UE 4
UE 5
Virtual Cell

SYSTEM LEVEL SIMULATION

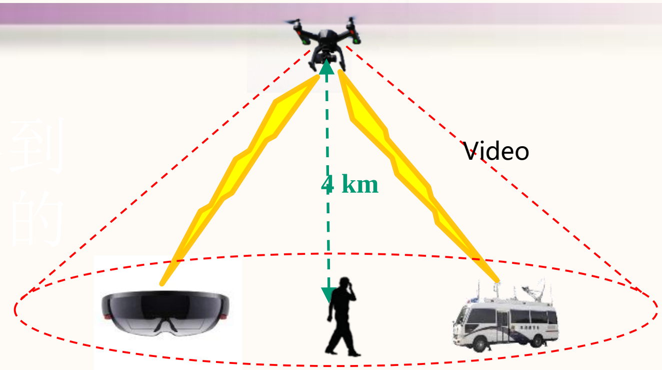
System Description

- The downlink transmission power is set to 126watt and the uplink power is 0.2 watt. The subcarriers in log is set to 35 in both uplink and downlink according to 3GPP Rel 17. Only single antenna is considered in link evaluation to make the simulation simple and clear. If MIMO mode is considered, the influence factors related to system performance will increase, from which we can not decide the accurate influence factors. In the following discussion, unless specified, single antenna system is adopted.

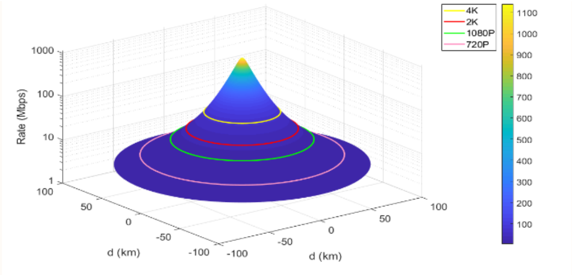
Simulation Parameters	Downlink	Uplink
BS Tx Power in dBm	51	23
$10\log_{10}(N_{subcarrier})$	35	35
TX Gain (dBi)	24	24
Link Margin(dB)	11	7
OTA Loss(dB)	4	4
Thermal Noise(dBm)	-129.23	-129.23
RX Noise Factor(dB)	7	3.5
Decoding Threshold(SINR/dB)	6.4	2.52

System Level Simulation：Static

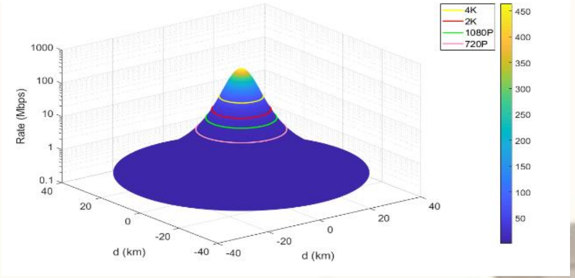
Parameter	Downlink	Uplink
TX power(dBm)	51.00	23.00
10*log10 (No Subcarrier)	35.15	35.15
TX Antenna Gain(dBi)	24.00	24.00
Link Margin(dB)	11.00	7.00
OTA Loss (dB)	4.00	4.00
Thermal Noise(dBm)	-129.23	-129.23
RX Noise Factor(dB)	7.00	3.50
Speed of UAV	0	



Height of UAV @4 km，bandwidth 100 M		
Demand(Mbps)/Video Type	Downlink Radius(km)	Uplink Radius(km)
26.5 / 2K 2560×1440	43.8	9.3
63.7 / 4K 4096×2160	29.9	6.9
6.64 / 720p 1280×720	79.7	14.2
14.93 / 1080p 1920×1080	56	11.1



Downlink



Uplink

UAV and UE Stop，2K Video，Downlink Radius is 43.8Km，Uplink is 9.3Km

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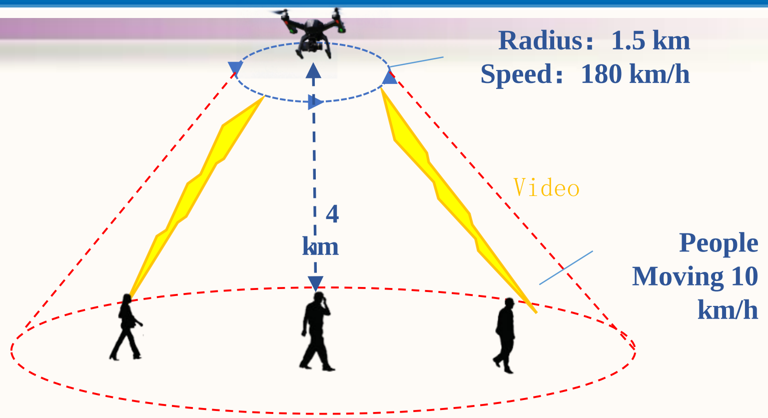
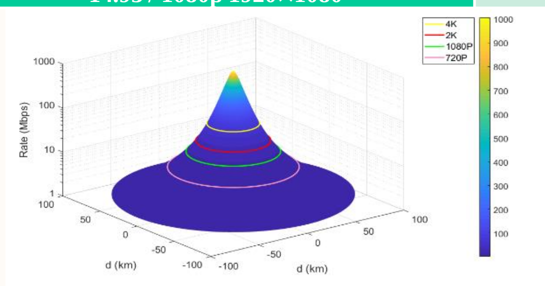
System Level Simulation：UAV and People Moving

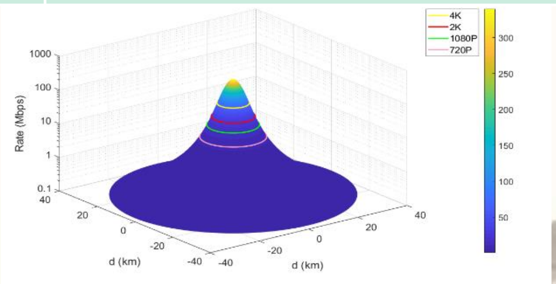
Parameter	Downlink	Uplink
TX power(dBm)	51.00	23.00
10*log10 (No Subcarrier)	35.15	35.15
TX Antenna Gain(dBi)	24.00	24.00
Link Margin(dB)	11.00	7.00
OTA Loss (dB)	4.00	4.00
Thermal Noise(dBm)	-129.23	-129.23
RX Noise Factor(dB)	7.00	3.50
Speed of UAV	180 km/h	
Speed of People	10 km/h	



Height of UAV @4 km，bandwidth 100 M		
Demand(Mbps)/Video Type	Downlink Radius(km)	Uplink Radius(km)
26.5 / 2K 2560×1440	30.9	7.1
63.7 / 4K 4096×2160	21.7	5.2
6.64 / 720p 1280×720	54.2	10.8
14.93 / 1080p 1920×1080	38.9	8.5



Downlink



Uplink

UAV and UE Stop，2K Video，Downlink Radius is 30.9Km，Uplink is 7.1Km

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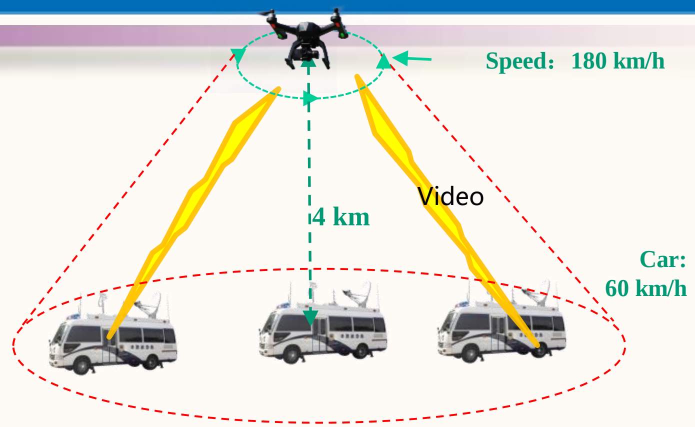
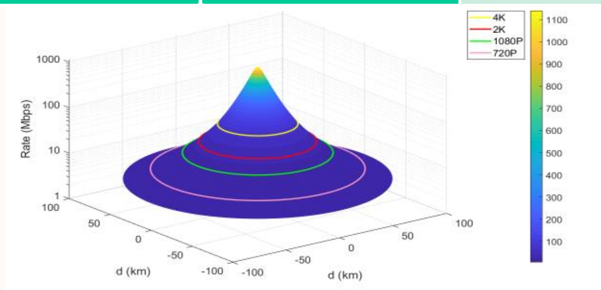
System Level Simulation：UAV and CAR Moving

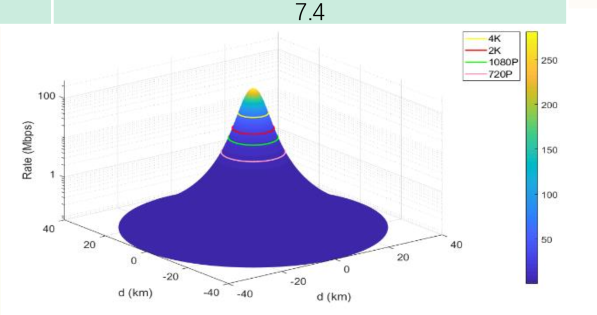
Parameter	下行	上行
TX power(dBm)	51.00	23.00
10*log10 (No Subcarrier)	35.15	35.15
TX Antenna Gain(dBi)	24.00	24.00
Link Margin(dB)	11.00	7.00
OTA Loss (dB)	4.00	4.00
Thermal Noise(dBm)	-129.23	-129.23
RX Noise Factor(dB)	7.00	3.50
Speed of UAV	180 km/h	
Speed of Car	60 km/h	



Height of UAV @4 km，bandwidth 100 M		
Demand(Mbps)/Video Type	Downlink Radius(km)	Uplink Radius(km)
26.5 / 2K 2560×1440	24.2	6.2
63.7 / 4K 4096×2160	16.9	4.5
6.64 / 720p 1280×720	42.6	9.5
14.93 / 1080p 1920×1080	30.5	7.4



Dwonlink



Uplink

UAV and UE Stop，2K Video，Downlink Radius is 24.2Km，Uplink is 6.2Km

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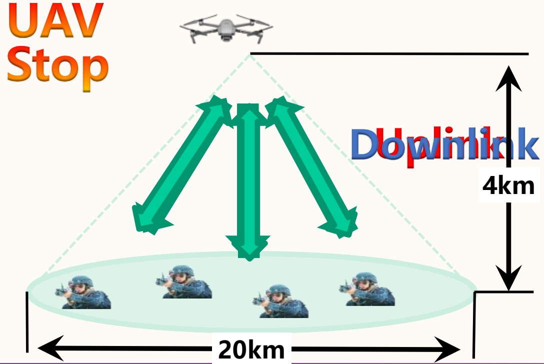
Conditional Supported for Uplink

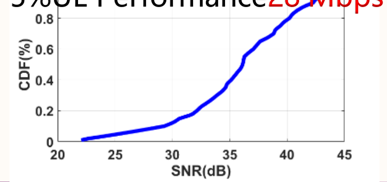
UAV Stop



Assumption	
Scenario	4 sector、40 UE
Carrier	2.6 GHz
bandwidth	100 MHz/Sector
TX Power	DL：51 dBm UL：23 dBm
Antenna	BS：4， UE：1
Channel	Free Space

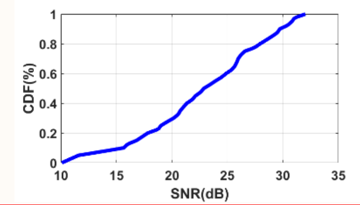
Downlink:

Sector Sum Rate388 Mbps
UE Average Speed38 Mbps
5%UE Performance28 Mbps



Uplink:

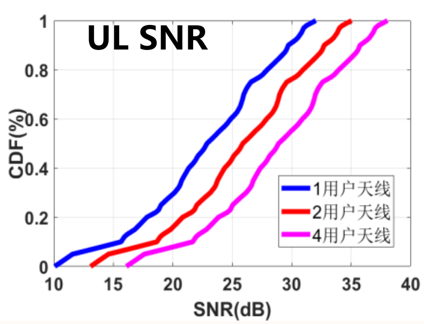
Sector Sum Rate326 Mbps
UE Average Speed 31 Mbps



Different UE Antenna

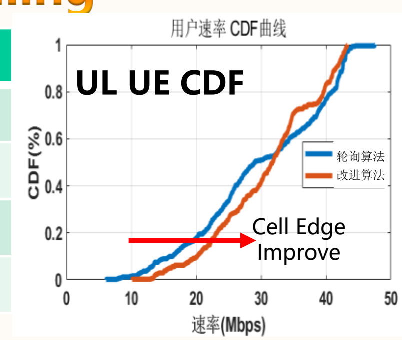
Antennas		1	2	4
DL Speed (Mbps)	Sector	388	390	391
	5%UE	28	31	31
UL 速率 (Mbps)	扇区	326	356	379
	5%UE	15	19	23

2K Ready



Different Scheduling

Scheduling		RR	IRR
DL Speed (Mbps)	Sector	388	360 ↓
	5%UE	28	30 ↑
UL Speed (Mbps)	Sector	326	313 ↓
	5%UE	15.9	17.5 ↑

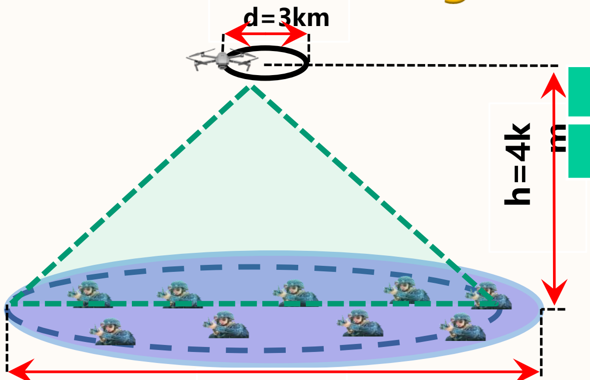


Antenna ↑, Performance↑

Scheduling Affect Cell Edge Performance

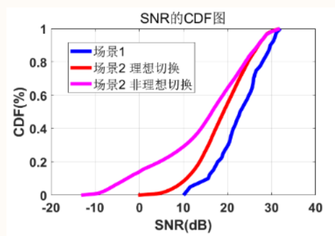
When UAV Moving……

S2: UAV Moving



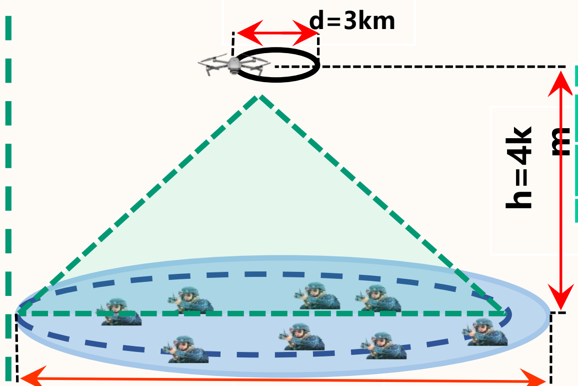
UAV Speed	180km/h
UAV Radius	1.5Km

scenario		static	ideal	Non-ideal
DL speed（Mbps）	sector	388	301	244.8
	5%UE	28	23	16.7
UL speed（Mbps）	sector	326	261	201
	5%UE	15	14	10



The Movement of UAV will cause the loss of cell edge performance and the handover performance.

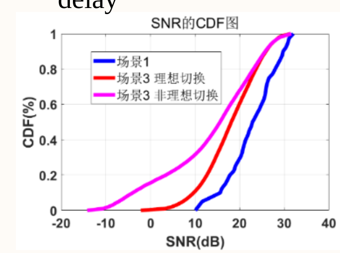
S3: UE and UAV Moving



UAV Speed	180km/h
UAV Radius	1.5Km
UE mobility	50%10km/h+50%60km/h
UE Method	Random

Ideal: RSRP Based handover
Non-ideal: considering handover delay

scenario		static	ideal	Non-ideal
DL speed（Mbps）	sector	388	285	224
	5%UE	28	21	15
UL speed（Mbps）	sector	326	246	188
	5%UE	15	13	9



When adding the movement of UE, the cell edge performance is reducing significantly

Multi-UAV must be introduced to reduce the loss of performance.

FIELD TRIAL RESULTS

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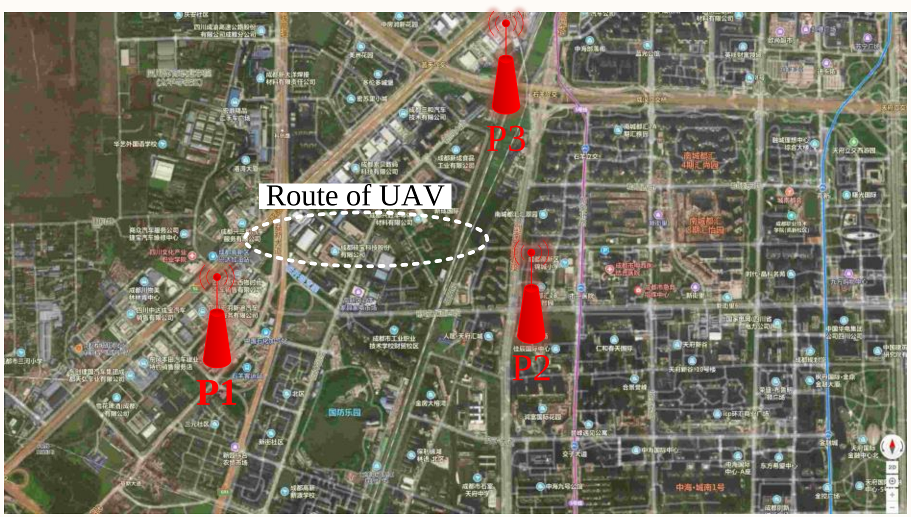
Link Prediction

In order to meet the requirements of the private network for 2K video transmission, we use the uplink rate of 20M and the downlink rate of 100M for the link budget, and derive the maximum allowable coverage distance of 13KM. Under the premise of a horizontal coverage radius of 5KM and a flight height of 4KM, the base station The distance to the terminal is 6.4KM, which is lower than the link budget of 7.8KM (uplink 10M-20M, downlink 100M), which can meet this coverage requirement.



Simulation Parameters	Downlink	Uplink
Target Throughput	100Mbps	20Mbps
$10\log_{10}(N_{subcarrier})$	35.15	35.15
TX Power (dBm)	51.96	23
TX Gain(dBi)	24	0
RX Gain(dBi)	0	24
OTA Loss(dB)	4	4
Thermal Noise(dBm)	-129.23	-129.23
RX Noise Factor(dB)	7	3.5
Demodulation Threshold SINR(dB)	9.5	8
Maximum Pathloss(dBm)	138.54	118.58

Test Results

No.	Address	Power	Macro Power	gNodeB Tag	PCI	Time	Lat	Lon	Download	Upload	SS-RSRP	SS-SINR
1	奥迪世界-H5H	32.7dBm	120W	9429788	336	2019/12/17 11:39	30.48129270	104.11283493	131.6	2.5	-102	3.2
2	奥迪世界-H5H	32.7dBm	120W	9429788	45	2019/12/17 11:42	30.48154240	104.11140992	139.5	3.2	-101.59	9.7
3	奥迪世界-H5H	32.7dBm	120W	9429788	336	2019/12/17 11:53	30.48054805	104.11474063	59.5	1.9	-106	6.4
4	天府新区红星路南延线补点1-H5H	33.9dBm	160W	9430055	166	2019/12/17 14:29	30.4412573	104.0964529	517.4	25.1	-95.98	10.1
5	天府新区红星路南延线补点1-H5H	33.9dBm	160W	9430055	166	2019/12/17 14:31	30.4412573	104.0964529	699.4	47.3	-92.28	9.6
6	天府新区红星路南延线补点1-H5H	33.9dBm	160W	9430055	166	2019/12/17 14:32	30.4412573	104.0964529	290.8	17.3	-94.72	7.7
7	天府新区红星路南延线补点1-H5H	33.9dBm	160W	9430055	315	2019/12/17 14:33	30.4412573	104.0964529	294.2	22.2	-99.64	6.3
8	天府新区永安供电所楼顶-H5H	33.9dBm	160W	9430348	84	2019/12/17 15:12	30.40623753	103.9732787	62.4	4.9	-106.3	7.5
9	天府新区永安供电所楼顶-H5H	33.9dBm	160W	9430348	84	2019/12/17 15:14	30.40623753	103.9732787	208.5	5.9	-105.5	10.5
10	天府新区永安供电所楼顶-H5H	33.9dBm	160W	9430348	84	2019/12/17 16:12	30.40542347	103.9725537	131.2	0.0	-109.7	8.5
11	天府新区永安供电所楼顶-H5H	33.9dBm	160W	9430348	84	2019/12/17 16:15	30.40542347	103.9725537	71.2	6.5	-110	7.6
12	天府新区永安供电所楼顶-H5H	33.9dBm	160W	9430348	84	2019/12/17 16:16	30.40542347	103.9725537	62.0	2.5	-116.1	3.5
13	天府新区永安供电所楼顶-H5H	33.9dBm	160W	9430348	84	2019/12/17 16:18	30.40542347	103.9725537	17.2	10.2	-120	0

On December 17, 2019, according to the test results, when the downlink SINR value is about 8dBm, the downlink rate can reach about 200M. Due to ground occlusion and reflection, the rate fluctuates greatly. If it is a ground-air channel, the channel conditions will be better. When the downlink rate reaches near the sensitivity, the uplink rate is probably below 10M.

Conclusion

- The UAV based 5G provides a flexible and intelligent way for emergency communication, especially when some unexpected events occurs, the UAV based 5G could provide timely and satisfied service to critical users, even when the optimization of such scenario is still blank. Current UAV platform can provide enough space and power supply for UAV embedded systems. In the ideal situation, the downlink coverage and the QoS is acceptable for emergency use, but limited by the terminal power, the uplink system performance is not satisfied, especially when the movement of UAV is considered. So, traditional commercial 5G terminals may not suitable for UAV based 5G scenario, some hardware configurations must be adopted to accommodate the demand of uplink transmission. Also, the 5G UAV platform needs some solid work on antenna design, resource allocation, scheduling, mobility control, access control and more dedicated signal processing methods for mobility enhancement and MIMO optimized transmission. Furthermore, the multi-UAV networking will be discussed when cooperation between UAVs is enabled, compression and fusion to ensure the full use of wireless resources.