3GPP TSG-WG SA2 Meeting #148e
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S2-2108771

Harmonized Communication and Sensing service (HCS)

Huawei, Hisilicon, vivo, CAICT, China Unicom, China Mobile, China Telecom, ZTE, CATT, China Security and Protection Industry Association

Contents

1. HCS use cases and requirements
2. RAN Sensing principle and simulation
3. HCS Network Architecture work
4. Forward compatibility considerations

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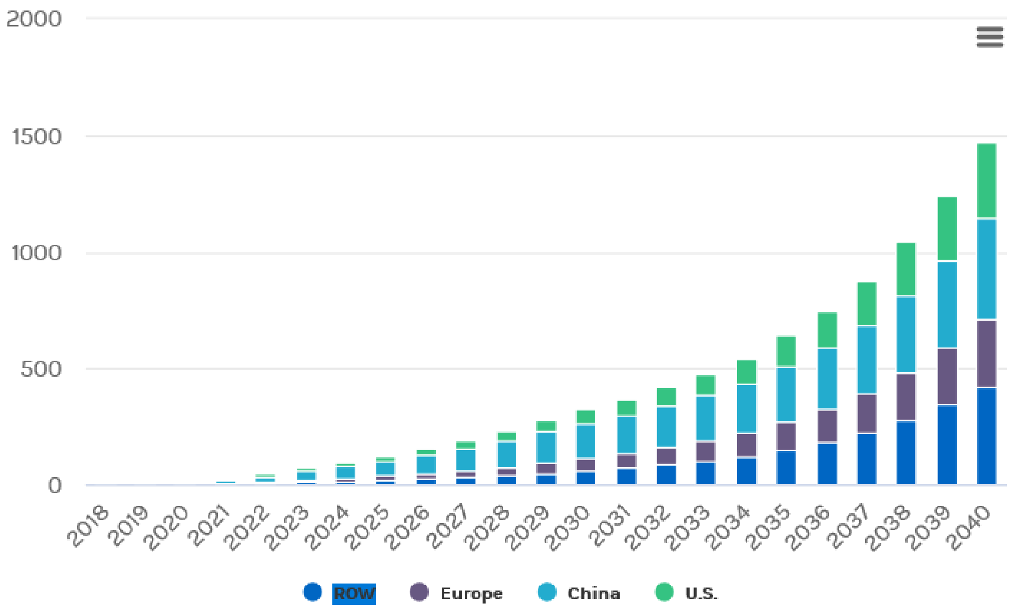
1.1 Low-Altitude traffic management has strong demand on sensing

Large market for UAVs



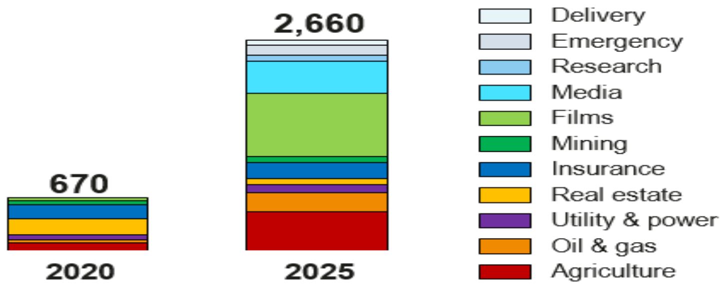
- Urban Air Mobility Global Total Addressable Market

Source: Morgan Stanley Research, 2019.1

Various usages for UAVs

2015~2017	2018~2019	2020~2021	2025~2030
First Flight: SF Express/JD	Trial: Rural → City SF Express (Jiangxi), JD (Shanxi).	13 test base	Large-scale commercial use; 1 million+ in China

- Cargo delivery:
  - Reduced delivery cost by 50%: CNY149/ton → CNY77/ton.
  - Reduced delivery time by 0.5 days: 1.5 days for trucks → 1 day for drones.
  - The last mile in rural areas: rural town-level distribution station → village.



- Industrial Drones forecast [K Units]: More usage on Utility & power/oil & gas/Emergency

Source: Roland Berg, 2020.11

Regulations require sensing capability for UAV supervision and management

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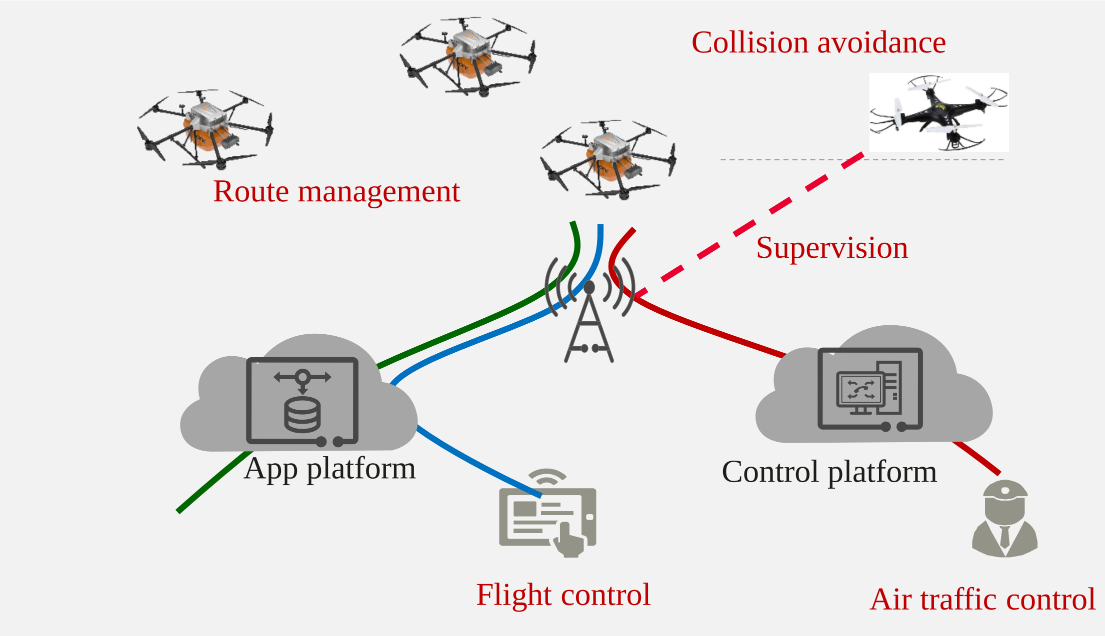
1.1 Communication and Sensing Coexistence for UAV

UAV application, remote control and traffic management require both communication and sensing



Camera live video real time uploading	Remote flight control	• Route management and flight control • supervision
• Uplink 50 Mbit/s (dual-channel 4K)	• Uplink 5Mbps (2K)	• Communication:<1Mbps • Sensing: all-airspace detection

Bottlenecks for current technologies

Radar (Ku/S)

- High cost for only temporary deployment
- Not flexible: Apply the Ku frequency band usage in advance

TDOA networking

- Low positioning accuracy, i.e. 30 meters.
- Can not detect radio-silent drones.

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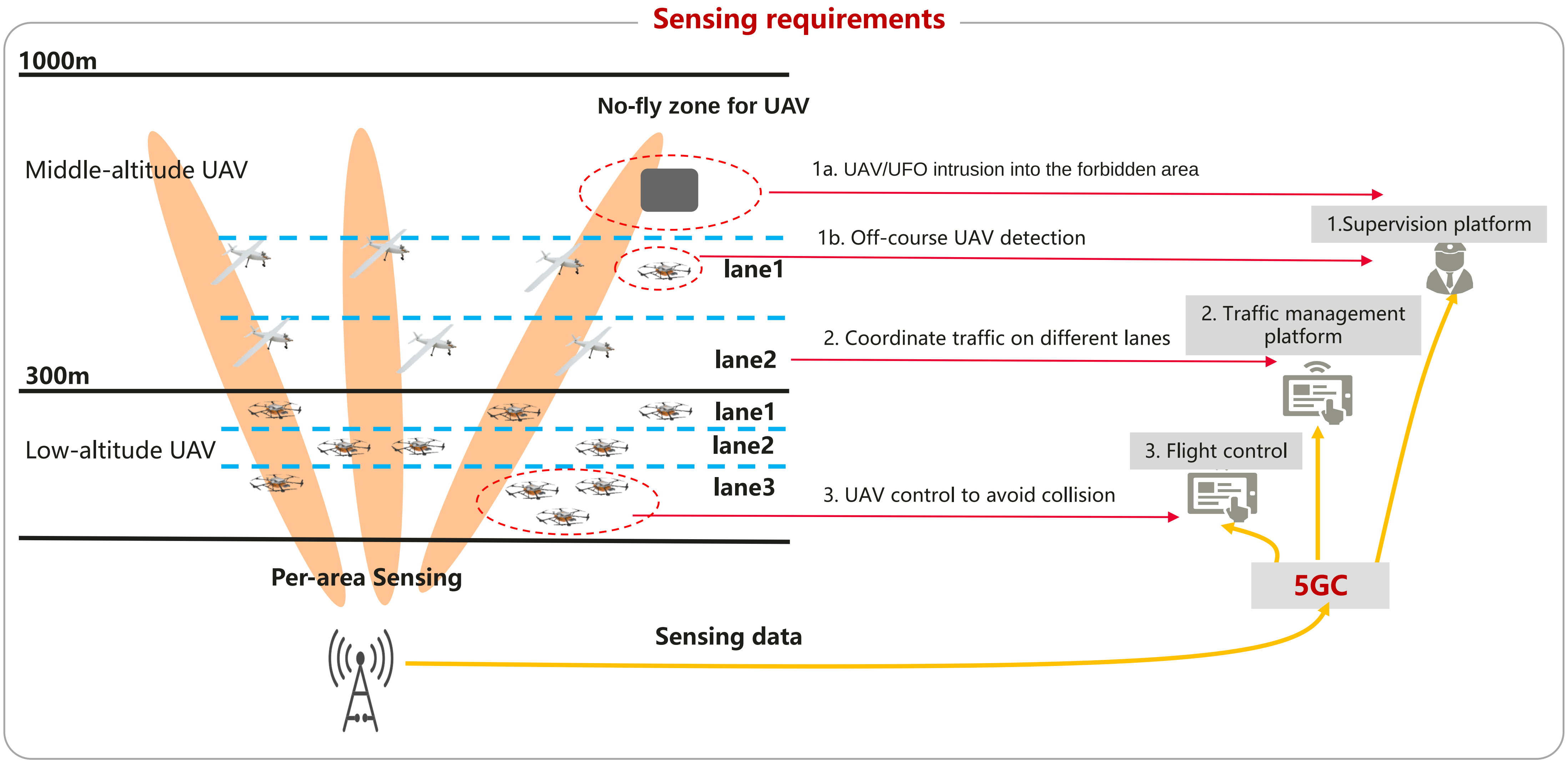
1.1 Sensing requirements for UAV

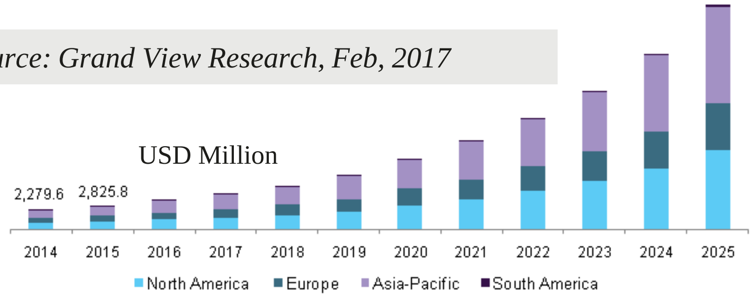


1.2 Intelligent transportation has strong sensing demand

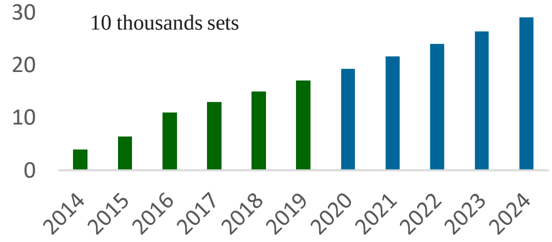
Large market for Intelligent transportation

- Automotive Vehicle-to-Everything (V2X) market by region, 2014-2025

Source: Grand View Research, Feb, 2017

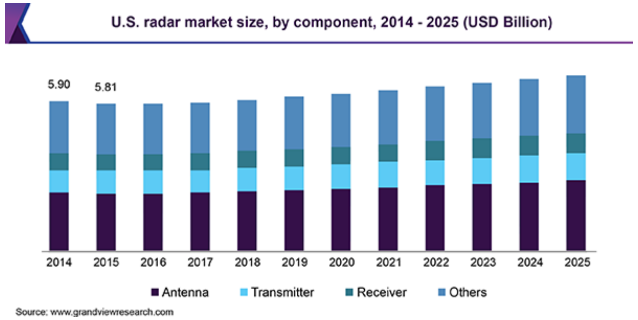


- Radar market in China (200K sets/year)

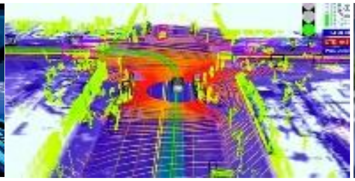


- Radar market in US

Source: Roland Berg, 2019.9



- Various sensing demand on V2X

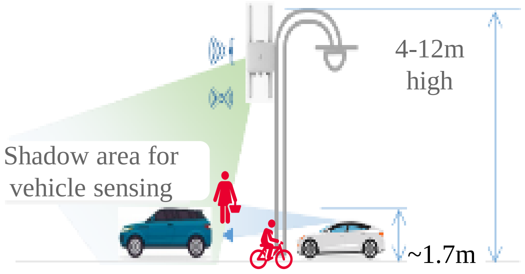


- Automatic driving
- Dynamic 3D map

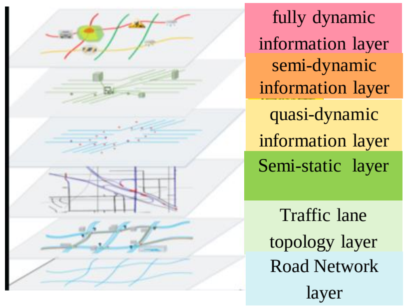
Safety Supervision

Vehicle-Road collaboration accelerates the road side sensing deployment

- Sensing for Corner Case



- Generation of fully dynamic and semi-dynamic layer by sensing



Radar & Camera

- •77 GHz Radar & 400M Camera.
- •The maximum speed measurement distance is 100 meters.

Apollo Air

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1.2 Communication and Sensing Coexistence for V2X

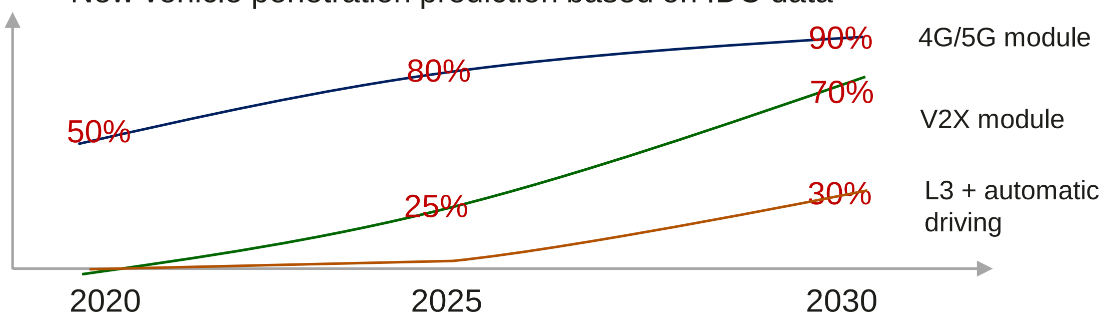
Automatic driving accelerates the usage of 5G

- V2X service requirements

Source: 5GAA

Level	V2N/V2I/V2V	delay (ms)	reliability (%)	Data rate (Mbps)
L4+	Dynamic Intersection management	10	99.9999	1.2
L3+	High-definition dynamic map download	100	99	DL 16
	Facility-Assisted Environment sensing	100	99.9	UL 4~47
	Group start	10	99.999	0.048
	Functional safety	N/A	99.99	UL 26.7

- New vehicle penetration prediction based on IDC data



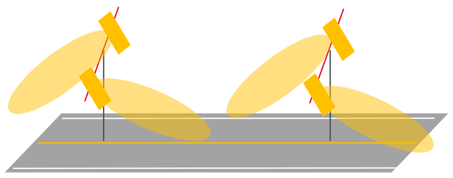
- In-vehicle entertainment: <10GB/month
- Entertainment+V2X: V2N/V2I data rate<1Mbps
- 19 million L3+ automatic driving: ~600GB/month

HCS mode: Better performance and low cost using the base station site

	Bandwidth	EIRP	coverage	Distance resolution	Angle measurement accuracy
gNB	800MHz	70dBm	**2~5 times improvement**	**~5 times improvement**	**~2 times improvement**
Radar	200M@24GHz	13/20dBm	200m	1m	0.5°

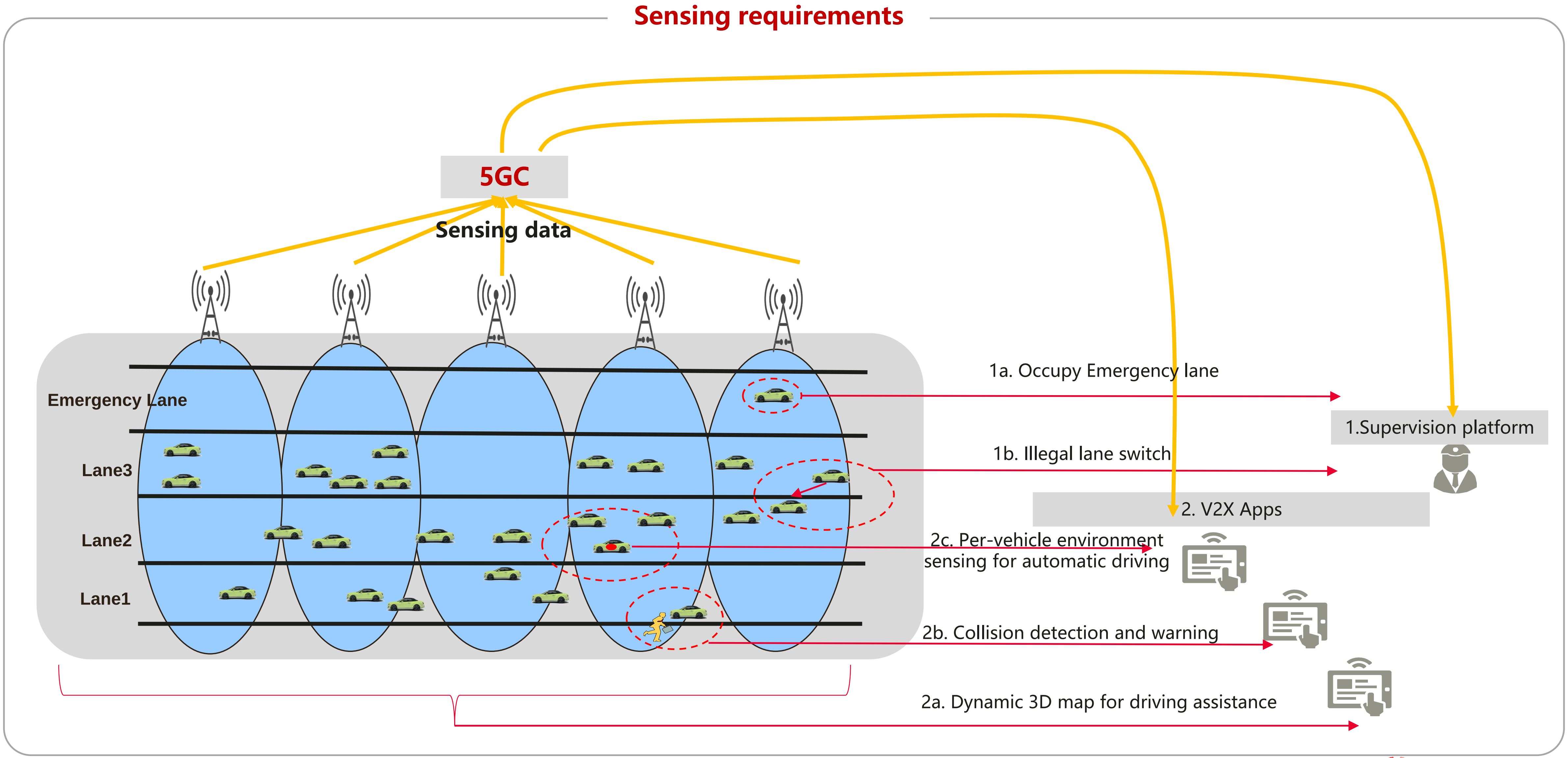
Highway case

Communication : sensing=1:1



- Better Coverage
- Reduce the extra radar sites.
- Low cost: Co-site deployment of communication & sensing.

1.2 Sensing requirements for V2X



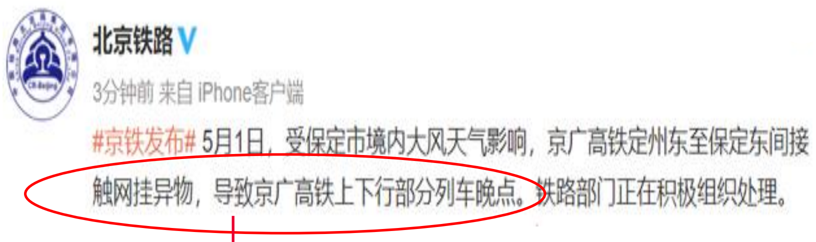
1.3 Railway Intrusion Detection

Combination of Communication & Sensing improve efficiency and Safety

Accident Event

- Engineering vehicles invade the track without in time detection and report.

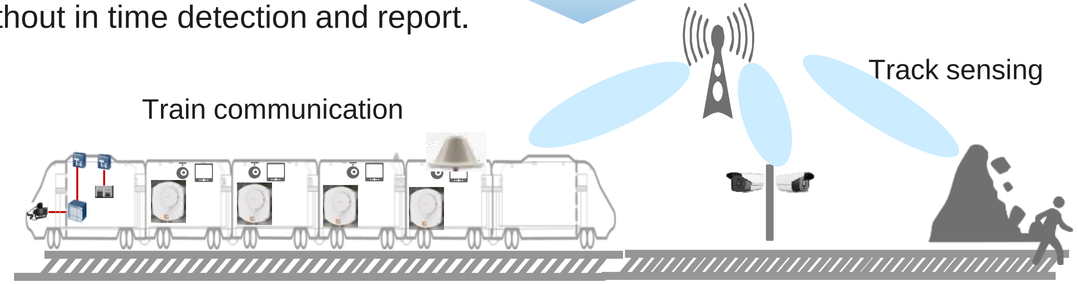
Unexpected delay for Beijing-Shanghai high-speed train


北京铁路

3分钟前 来自 iPhone客户端

#京铁发布# 5月1日，受保定市境内大风天气影响，京广高铁定州东至保定东间接触网挂异物，导致京广高铁上下行部分列车晚点。铁路部门正在积极组织处理。

- 80% train delay caused due to abnormal objects intrusion.



Communication		Sensing
CCTV	Passenger on Train communication	Intelligent Safety management
40~60 channel monitor video	Passenger on Train communication	Natural disaster detection Intrusion detection
~	~	Intrusion sensing

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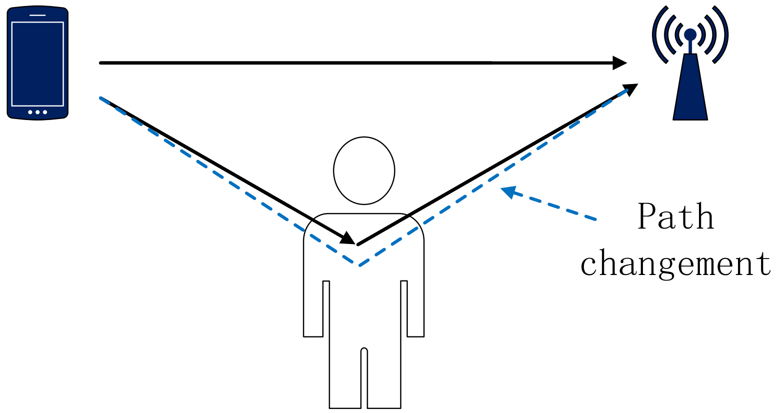
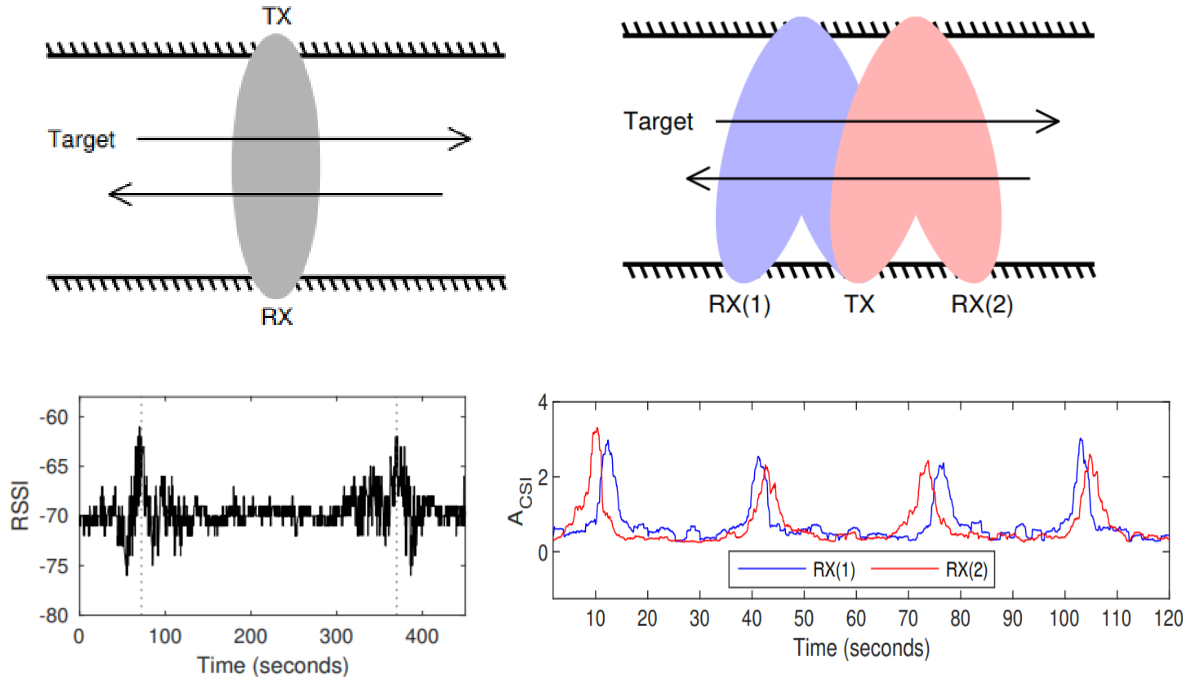
1.4 Indoor Health Care and Intrusion Detection

Reuse existing communication link (e.g., uplink) to support sensing use cases with no impact on communication



Use cases	Requirements
• Remote patient monitoring • Daily sleeping monitoring • Elders vital sign monitoring	• Respiration rate estimation • Breathing depth estimation • Apnea detection • Sleeping positions detection • Can be realized with no impact on communication

Fitness monitoring application based on existing communication system and measurements



Use cases[1]	Requirements
• Surveillance systems • Smart homes and apartments	• Indoor intrusion detection • Location and distance estimation • Recognize targets according to the RSS or CSI variation

Occupancy monitoring application based on existing communication system and measurements

Source[1]: S. M. Hernandez and E. Bulut, "Adversarial occupancy monitoring using One-Sided Through-Wall WiFi sensing,

1.5 Unified sensing requirements

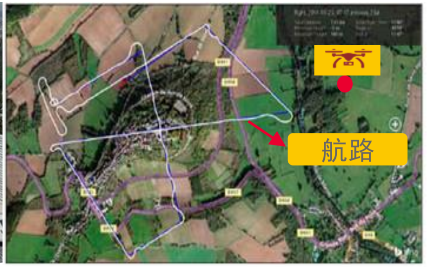
Automatic Driving

Case1(V2X & UAV):
Real time road traffic information sensing.
Requirement 1:
per-area sensing to generate dynamic 3D map.

Case2 (V2X & UAV):
Emergency event detection.
Requirement 2:
per-area sensing to detect the danger event, and notify the related vehicles.

Case3(V2X & UAV):
Automatic driving assistance.
Requirement 3:
High granularity sensing to assist automatic driving.

Safety Supervision

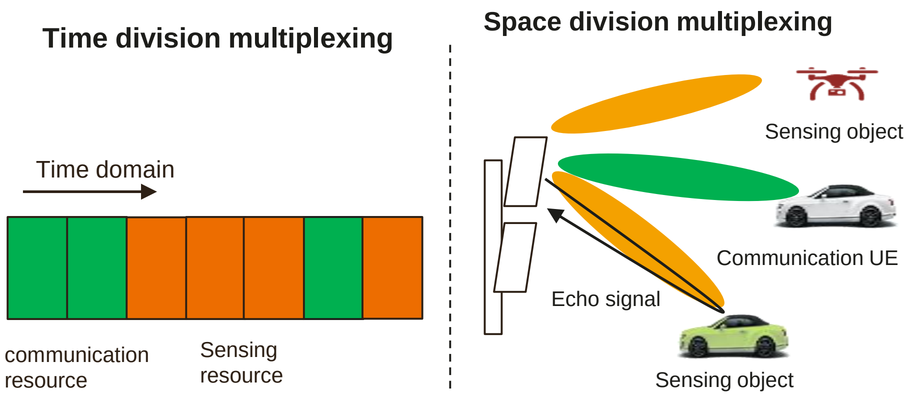


Case1(V2X & UAV):
Driving violation, e.g. vehicle occupies emergency lane, UAV flies away from the planned route.
Requirement 1：
Per-area sensing to detect driving and flying violation

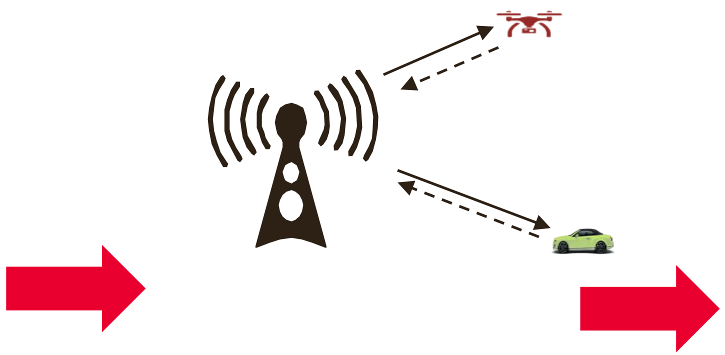
Case2 (Railway & UAV) :
UAV/object intrusion into the forbidden area.
Requirement2：
per-area sensing to detect illegal UAV/object intrusion

2.1 Sensing Principle(no RAN1/RAN2 work expected for R18)

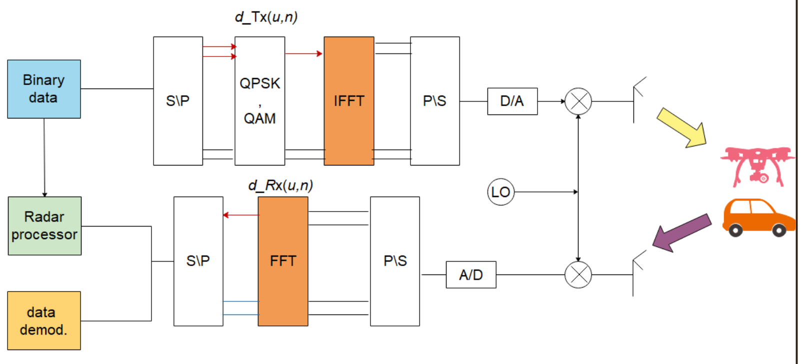
HCS: RAN sensing by resource multiplexing



1. sensing resource configuration



2. sensing detection



3. Sensing data retrieval

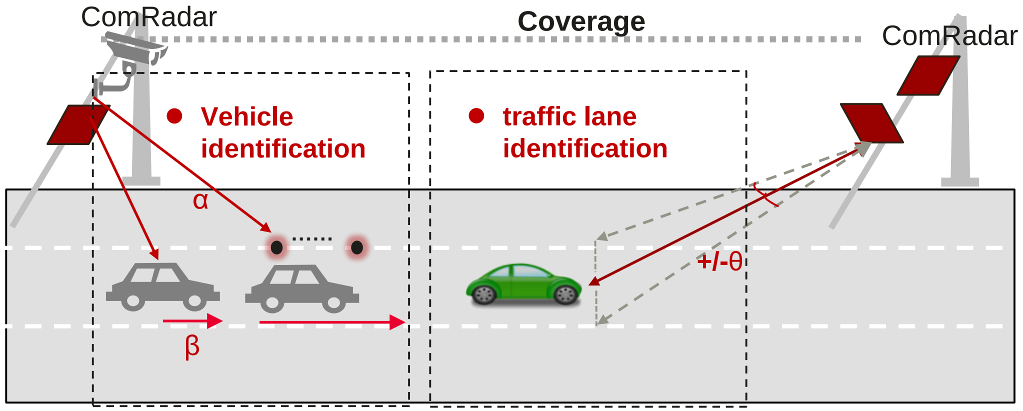
Key performances for sensing (e.g. V2X)

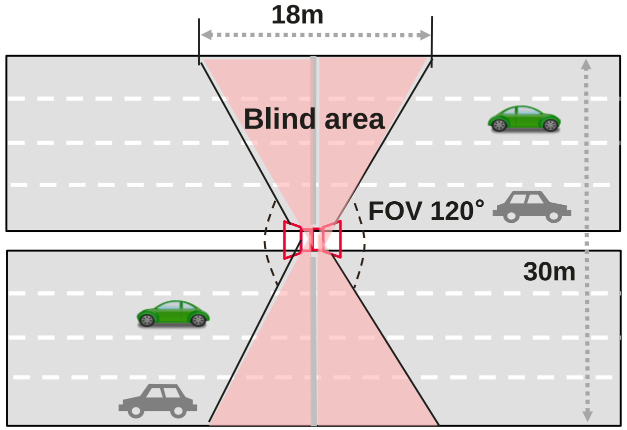
① **Distance Resolution α:** The ability to distinguish adjacent targets over distance. It can be used to identify different vehicles.

② **Velocity resolution β:** The ability to distinguish targets on the radial velocity. It can be used to identify different vehicles.

③ **Angle measurement accuracy θ:** The ability to distinguish between adjacent targets in angular terms,. It can be used to identify different traffic lanes.

④ **Horizontal FOV:** 120°. If the road is 30m wide, the bidirectional blind area is less than 18m.





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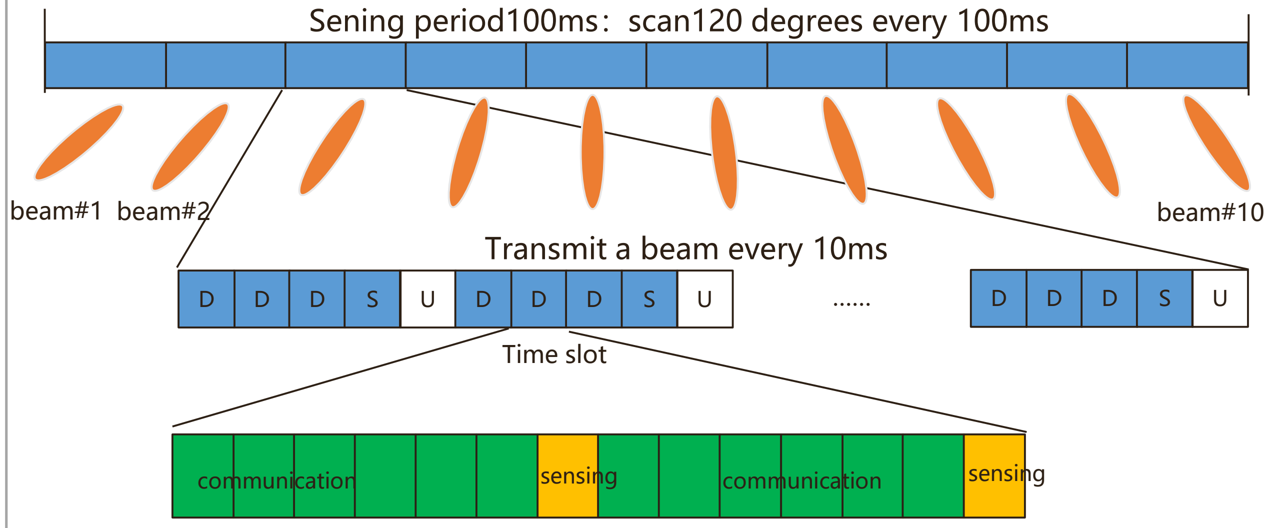
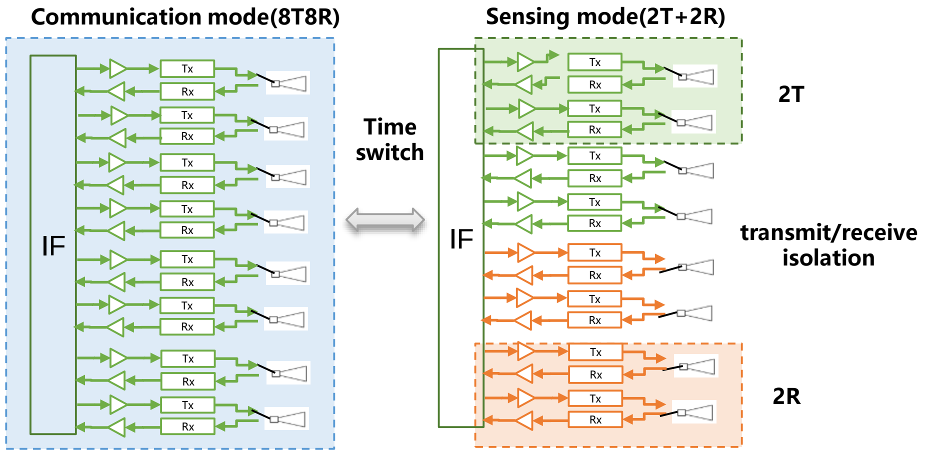
2.2 RAN sensing capability： existing RAN1 technology supports sensing

Time division multiplexing for sensing symbol and communication symbol

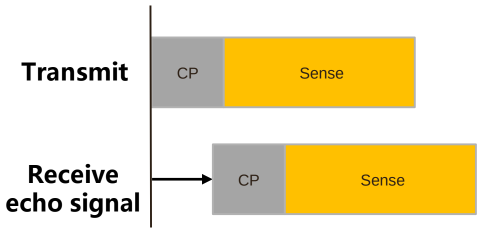


- **Existing RAN1 technology supports time division multiplexing for sensing symbol and communication symbol**
- NR Rel-15 support Type B PDSCH dispatch， and the number of symbols occupied by the PDSCH and the positions in timeslots can be flexibly configured.
- NR Rel-15 supports the configuration of reserved resources. The symbols occupied by sensing signals can be configured as reserved resources to implement time division multiplexing for communication and sensing.

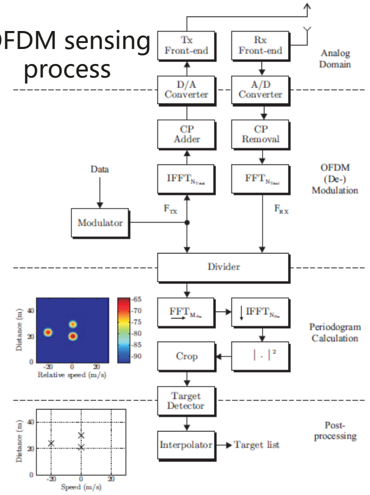
The base station hardware can implement self-transmit/receiving



OFDM wave has sensing capability



OFDM sensing process



The farthest echo signal can be correctly detected within the CP rang.

- Source：” OFDM Radar Algorithms in Mobile Communication Networks” Martin Braun

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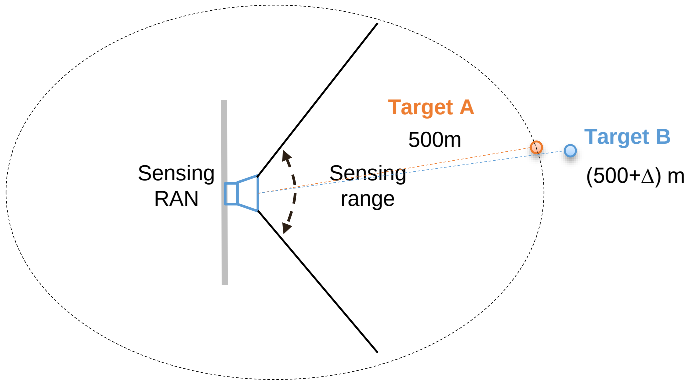
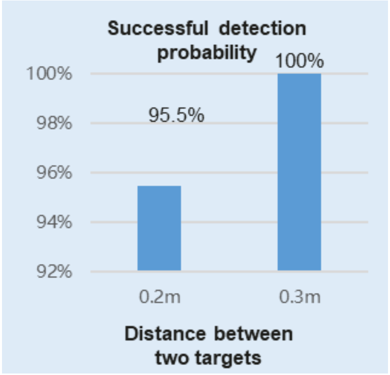
2.3 Simulation result for sensing capability

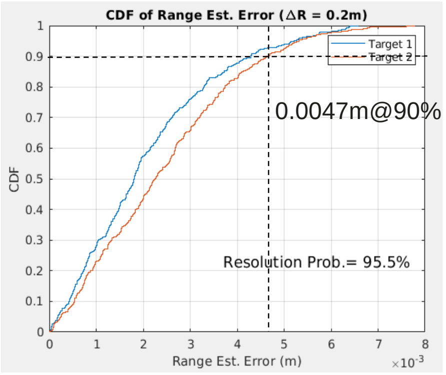
Simulation Scenarios

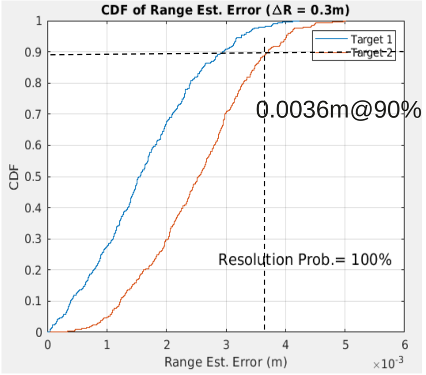
- **Distance resolution:** When the distance between two targets is Δ, two targets can be successfully identified (dual-target resolution).
- **Simulation configuration:** The radial distance between points A and B is 0.2 meters, and the LOS free space channel model is used.



Single RAN node with 800MHz Bandwidth @26GHz by using current OFDM RS

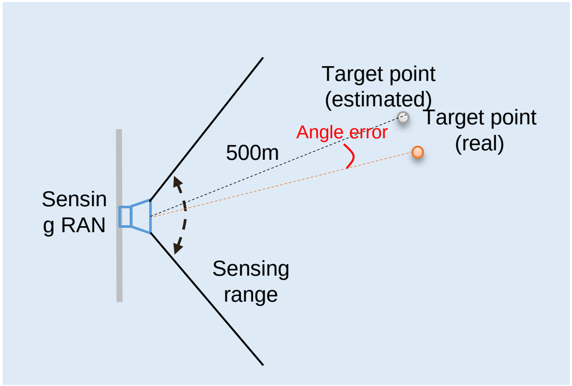


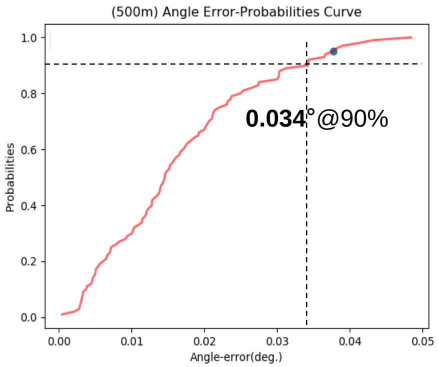




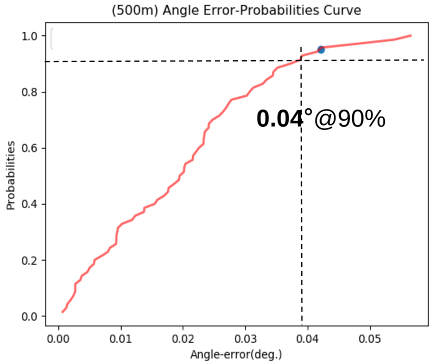
- The distance resolution is much smaller than current 1m capability of 24GHz commercial radar, while the detection probability is larger than 90%.

- **Angle measurement accuracy:** the difference between the estimated value of the target point and the true value.

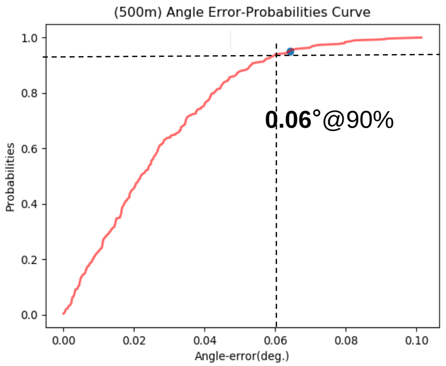




$A_{init} \in [88^{\circ}, 92^{\circ}]$



$A_{init} \in [65^{\circ}, 70^{\circ}]$

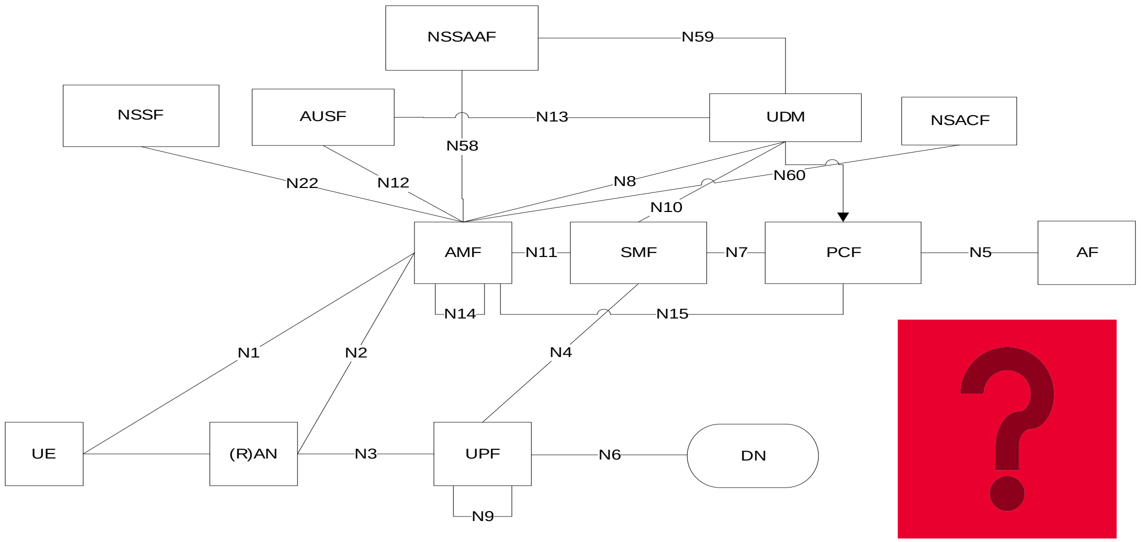


$A_{init} \in [45^{\circ}, 50^{\circ}]$

- The angle measurement accuracy is much smaller than current 0.5 degree capability of 24GHz commercial radar, in the cases of different angle offsets.

3.1 Network Architecture enhancement is required to enable the business

Challenges on the new sensing capabilities



- Legacy UE level control (e.g. communication and positioning) => Area level control and management of sensing capabilities in specific areas.
- Lightweight network architecture to support the flexible and secure deployment to expose the new sensing capability.
- New business model.

Network architecture design principles for sensing capabilities

- ☐ Network architecture enables new capabilities
  - The network architecture requires end-to-end management and control of the new capability: trigger and manage sensing events; calculate and report sensing results.
- ☐ Network architecture enables new business models
- ☐ RAN and CN function split to support the end-to-end sensing service (RAN base station + CN sensing control)
  - RAN + centralized CN sensing control function;
  - RAN reports sensing information to the CN sensing control function;
  - The CN sensing control function calculates the sensing result and exposes the sensing result.

3.2 SA2 R18 5G architecture enhancements for Harmonized Communication and Sensing service(5G_HCS) SID proposal

This study aims at studying the 5G end-to-end Harmonized Communication and Sensing (HCS) architecture to enable the sensing services (focusing on network based sensing for R18). The following aspects are the objectives of the study:

WT#1: Overall architecture to support new sensing service including:

- WT#1.1: Study and define the possible architecture and function enhancement to support new sensing service, e.g. whether new network function is needed. Gap analysis of the existing 5GS architecture and functionalities for the support of sensing capability
- WT#1.2: Study the RAN and CN function split to support the sensing service.

WT#2: E2E signalling to support new sensing service including:

- WT#2.1: define the E2E signaling interactions to support sensing service including the sensing control and sensing data report
- WT#2.2: study and define the sensing service authorization and exposure.

Note: the study will not have RAN1/2 standard impact. RAN and CN coordination is expected focusing on the sensing signalling and data transmission between RAN and CN (RAN3 work). Other coordination with RAN is on a need basis.

Work Task ID	TU Estimate (Study)	TU Estimate (Normative)	RAN Dependency (Yes/No/Maybe)	Inter Work Tasks Dependency
WT#1:Overall architecture	6	3	Yes	WT#1 is self-contained
WT#1.1:	3	2	Maybe	
WT#1.2:	3	1	Yes	
WT#2: E2E signalling	5	3	Yes	WT#2 depends on WT#1
WT#2.1	3	2	Yes	
WT#2.2:	2	1	No	

- **Total TU estimates: 17**
- **Total TU estimates for the study phase: 11**
- **Total TU estimates for the normative phase: 6**

4 Forward compatibility considerations

- R18 Standard work focus on the basic architecture aspects to enable the new business:
  - Target the network centric based sensing, collect the sensing data from the NR base station
  - Calculate and open the sensing result to the third party
  - No new work/enhancement expected in RAN1 and RAN2
- Take the existing 5GS architecture as the baseline
  - Align with the existing 5GS design principle, no new architecture is expected
  - Analyze and decide whether new NF is needed for the new sensing capability
  - Define the control signaling for the sensing and sensing data reporting from the RAN to CN
- Pave the way for future enhancement
  - Do not put any limitation for the future enhancement
  - Flexible Architecture design following the SBA, forward compatible with potential new sensing related features, e.g. air interface sensing efficiency enhancement, more UE role involvement…..

Thank you.