DOCOMO's Views and Activities for LTE/5G Connected Car

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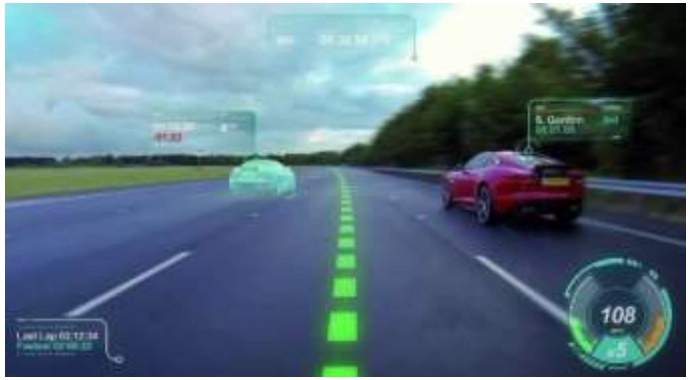
Connected Car
Use case and Requirements

Use cases

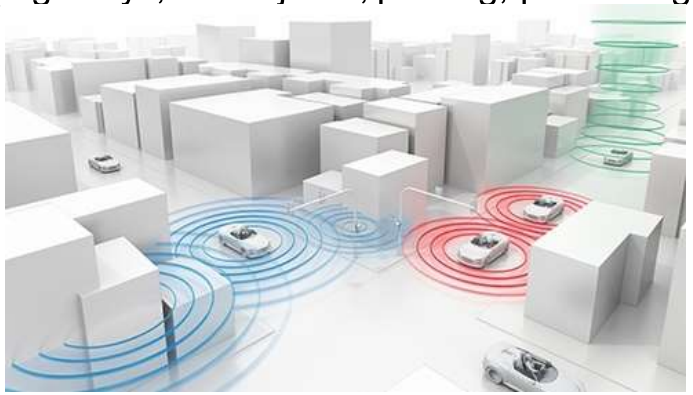
Assisted driving

Navigation, see-through, hazards,
vulnerable road user warning, etc.



Autonomous driving

Partial ~ fully autonomous/ cooperative driving
(highways, traffic jams, parking, platooning,



Tele-operated driving

Remote operations in case of troubles,
remote driving at disaster/ dangerous areas
(mines, construction sites, power plants, etc.)

Info-mediation

Value creation by processing various information
Security (theft tracking, border control), safety
(eCall, bCall), fleet management (car share,
logistics), insurance
g e,

Infotainment

Entertainment (video, VR, AR)
Productivity (video conferencing, in-vehicle

Nomadic nodes

Cellular capacity/ coverage expansion
using moving small cells on vehicles

Reference: http://ngmn.org/uploads/media/160922_NGMN_-_Perspectives_on_Vertical_Industries_and_Implications_for_5G_final.pdf
Image sources (left top to right bottom): Jaguar Land Rover, Volkswagen, Verbundprojekt Vision TUM, erpfm.com, Mercedes Benz, BMW

Use cases

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4. Driving assistance

3. Remote operations

Info-mediation

Value creation by processing various information

Security (theft tracking, border control), safety (eCall, bCall), fleet management (car share, logistics), insurance

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2. Digital maps/ vehicle management

Infotainment

Entertainment (video, VR, AR)

Productivity (video conferencing, in-vehicle

1. Infotainment

Nomadic nodes

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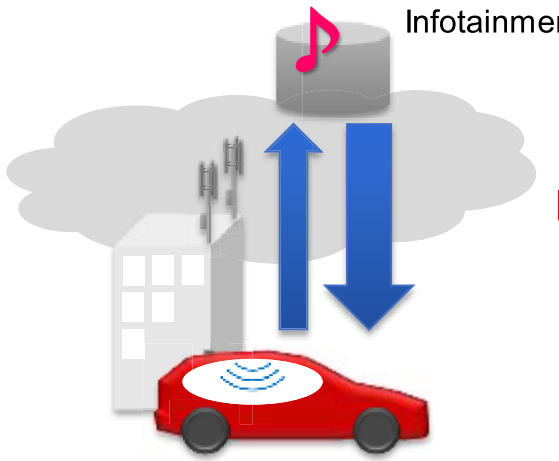
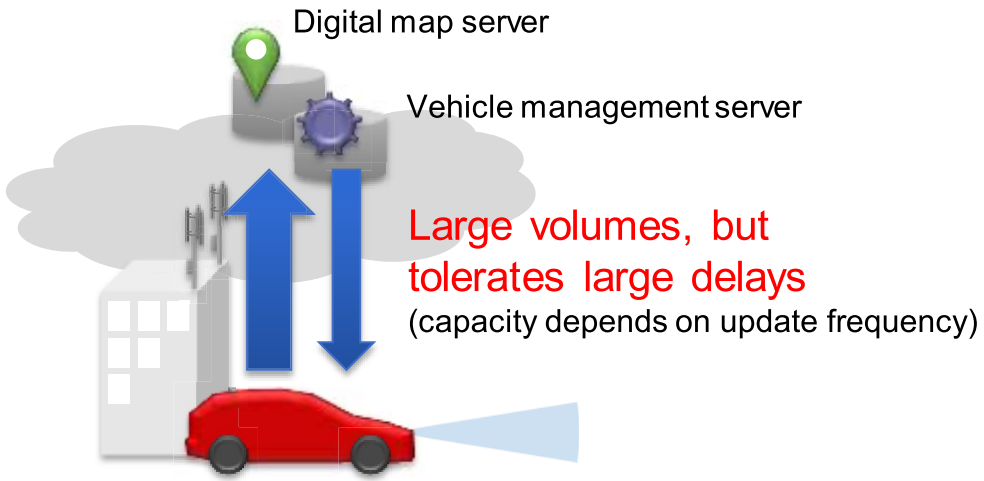
1. Infotainment

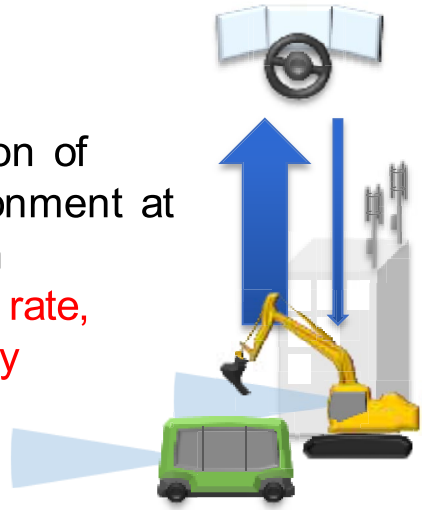
Use case	▪ In-vehicle entertainment (video, VR, AR, etc.) ▪ Productivity (video conferencing, in-vehicle office) • Improved productivity is one of the main motivations for purchasing autonomous driving*
Requirements	 For high speed/ capacity services, Mobile broadband backhaul (5~10 Gb/s) is needed. Coverage is crucial.
Solutions	▪ ~1 Gb/s is possible with LTE/ LTE-A, but 5G can enable higher data rates and capacity. ▪ Massive MIMO can be exploited using larger rooftop antennas. ▪ Use of WiFi can be considered for in-vehicle access, to cater for various passengers.
Key issues	▪ Mobility support in case of using mmWave or small cells. ▪ Attractive value proposition to the customers.

* Ref: Survey by Boston Consulting Group (2015.4), etc.

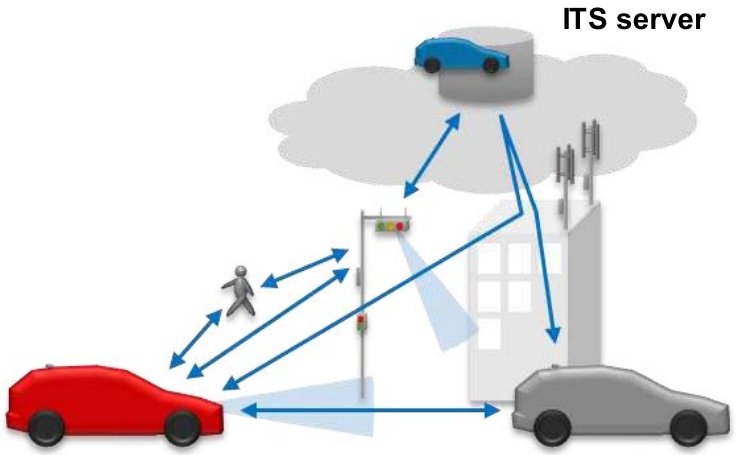
2. Digital map/ vehicle management

Use case	▪ Sensor data collection for 3D digital map update at the server side (UL) ▪ On-board 3D digital map update (DL) ▪ Vehicle diagnostics reporting (UL) ▪ On-board software update (DL)
Requirements	 Large volumes, but tolerates large delays (capacity depends on update frequency) Automobile companies would want to realise applications agnostic to the underlying connectivity layer (avoid specific implementations for each country/ telecom provider)
Solutions	▪ Application control (time triggers, location triggers) ▪ Existing networks can be good, but e.g., split charging, network slicing may be useful.
Key issues	▪ Capacity provisioning, application control vs network control ▪ Realising a global solution

3. Remote operations

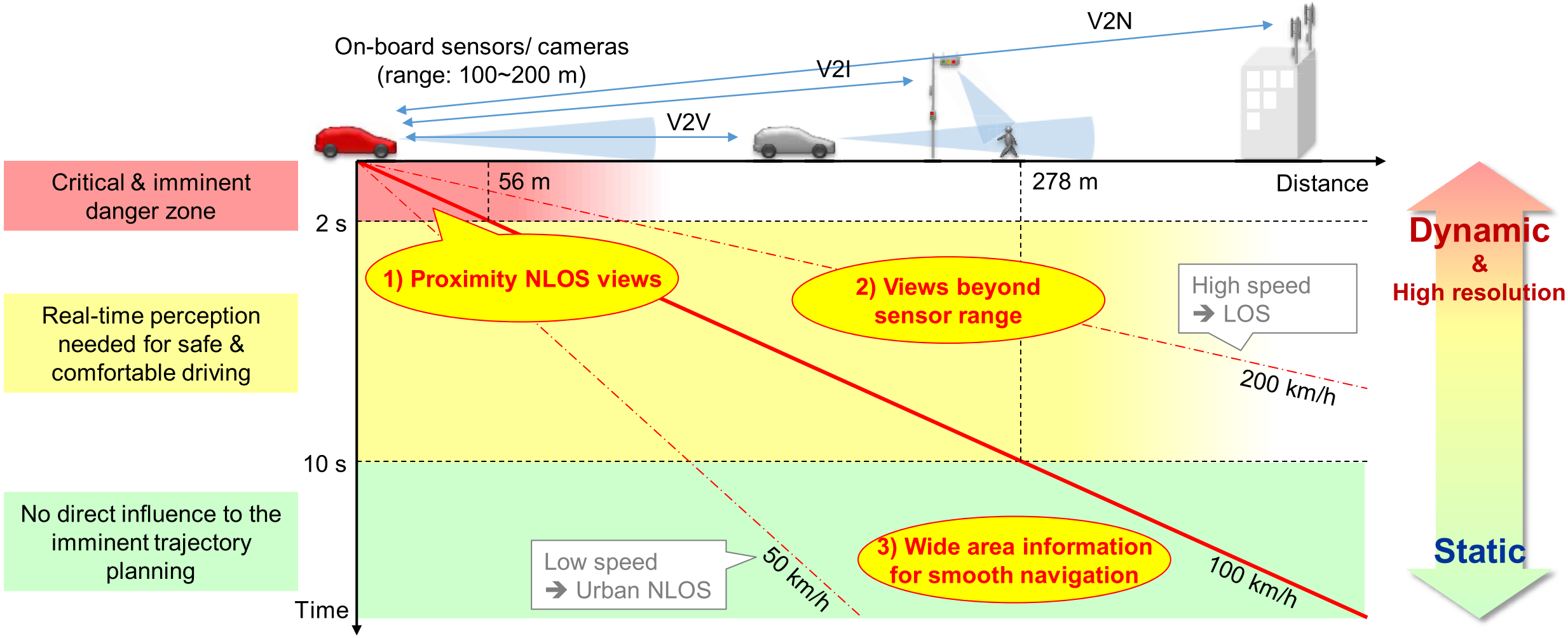
Use case	▪ Remote control of vehicles in case of troubles (safe stopping, system reset) ▪ Remote driving at disaster/ dangerous areas (mine, construction site, power plants, etc.) • Places where autonomous algorithms cannot work effectively and need manual manoeuvre
Requirements	UL: Recreation of driving environment at remote booth ➔ High data rate, low latency  DL: Remote control ➔ Narrow band, low latency, high reliability Example: • 30 km/h ➔ 1 m/ 120 ms • UL: 60 fps video ➔ 16.7 ms • DL: 20 Hz control ➔ 50 ms RTT <50 ms
Solutions	▪ Cellular is good, but need e.g., diversity, QoS control, wider bandwidth, etc. to improve reliability ▪ For safety, operations may need to be limited to low speeds (<30 km/h) or cases without passengers.
Key issues	▪ Certification (remote booth, remote driver, telecom system) ▪ Liability in case of accidents

4. Driving assistance

Use case	▪ Environment recognition (driving assistance) ▪ Distribution of hazard information, vulnerable road user warning ▪ Sharing of driving intentions and control information
Requirements	 ▪ Environment recognition and driving intention sharing requires stringent latency and reliability. ▪ Broadband for wide area recognition to improve comfort and traffic efficiency.
Solutions	▪ Compound use of V2V, V2I, V2N and V2P depending on the use case and environment/ situation.
Key issues	▪ Clarification on the necessary composition of V2V, V2I, V2N and V2P ▪ Spectrum, business models

Potential areas of connectivity support for environment perception

While on-board sensors/ cameras will play the core role for environment perception, connectivity can support for 1) proximity NLOS, 2) beyond sensor range, and 3) wide area information.



Valid range and expiry time of distributed information

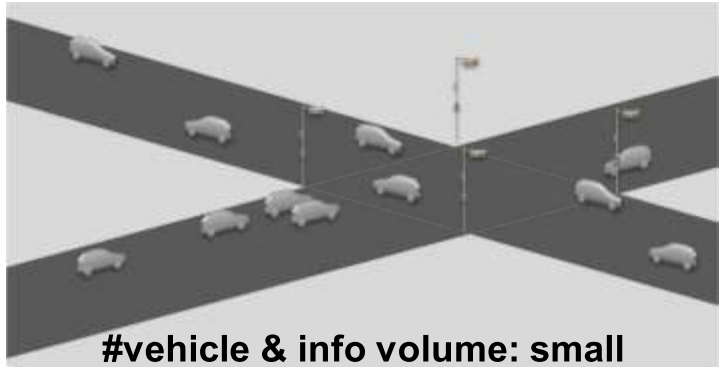
Distributed information has “valid range” and “expiry time” depending on the contents and velocity.

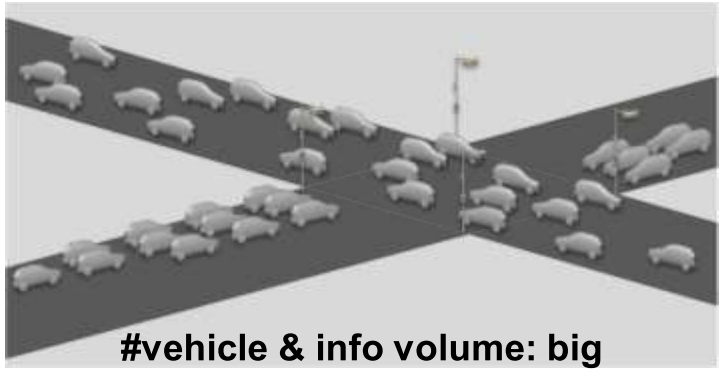
	Distributed information	Data rate	Valid range	Expiry time
Dynamic information	Coordinated control (negotiation)	~2.5 Mb/s x #vehicles	50 m ≀ 500 m	100 ms ≀ 1 s
	Sensor/ video/ object data • Depth, video, 3D grid occupancy, detected object data, etc. • Source: on-board sensors, RSU sensors • Distribution of aggregated data could also be considered	0.5~50 Mb/s x #vehicles (depending on the contents)		
	Planned trajectory	~12.5 Mb/s x #vehicles		
	Simple intention • Lane change, braking, etc.	~50 kb/s x #vehicles		
	Traffic signal information	~1 kb/s x #signals		
Semi-dynamic information	Accidents, traffic jam, parking lots, local proximity weather, etc.		300 m ≀ 100 km	1 s ≀ 1 month
Semi-static information	Construction, road closure, wide area weather, etc.			
Static information	Road surface, lanes, structures, road side facilities, etc. * Some overlap with “2. Map/ vehicle management”			

* Above numbers are indicative. See e.g., 3GPP TR 22.886 for more details.

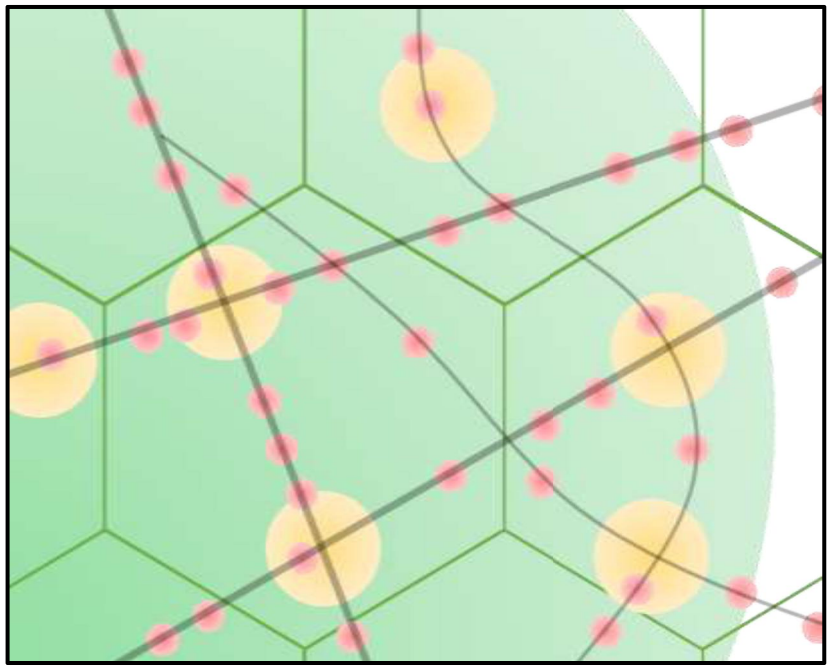
Positioning of technologies for information distribution platform

Platform design needs to consider valid range, expiry time, #vehicles, and data volume of the distributed information





* Need to consider the difference in cell size and the relevant radius for distributing information.



Dynamic (local)

Static (wide area)

(on-board sensors)

DSRC / ITS

Direct V2X
latency <20 ms,
range & capacity expansion

5G
further low latency,
high reliability & capacity

Densification (RSU, sectorization)

Content optimization by location/ direction

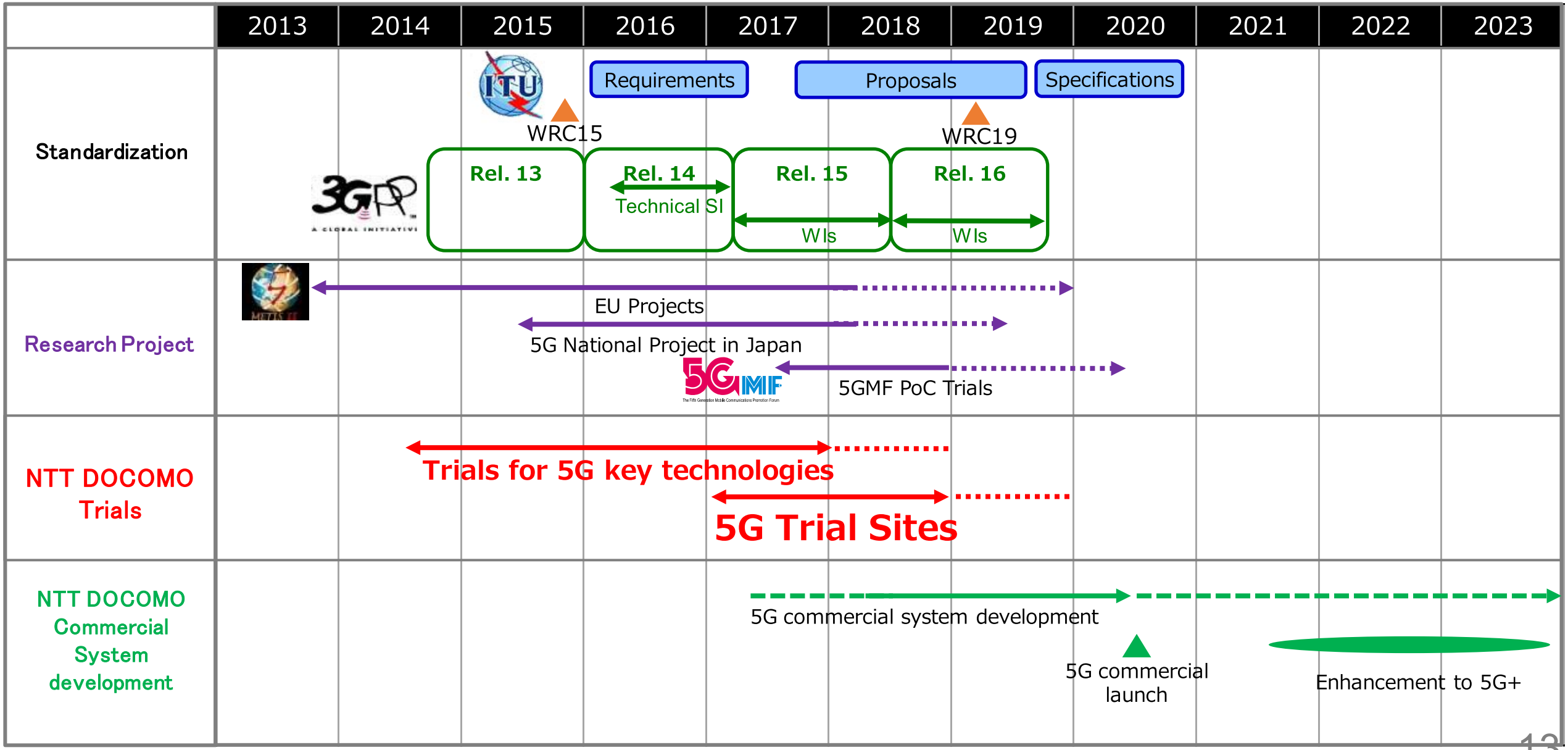
Existing cellular (unicast)
avg latency ~50 ms

Multicast
larger #devices & capacity

Time shifting
traffic normalization

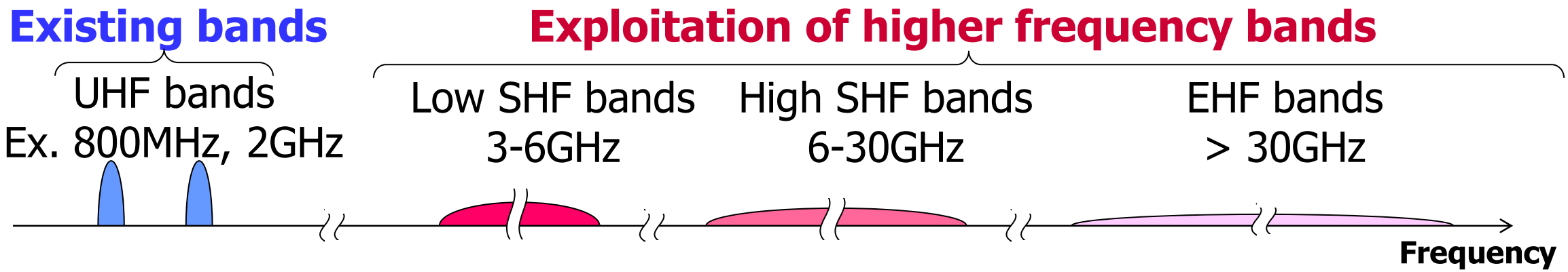
DOCOMO's Activities for LTE/5G Connected Car

Time schedule for 5G deployment in 2020



5G Experimental Trials 【w/ 13 vendors】

5G experimental trials are being started since Q4 of 2014



HUAWEI FUJITSU NEC ERICSSON SAMSUNG MITSUBISHI ELECTRIC NOKIA

Key devices/Chip sets vendors

intel QUALCOMM® MEDIATEK

System solution vendors

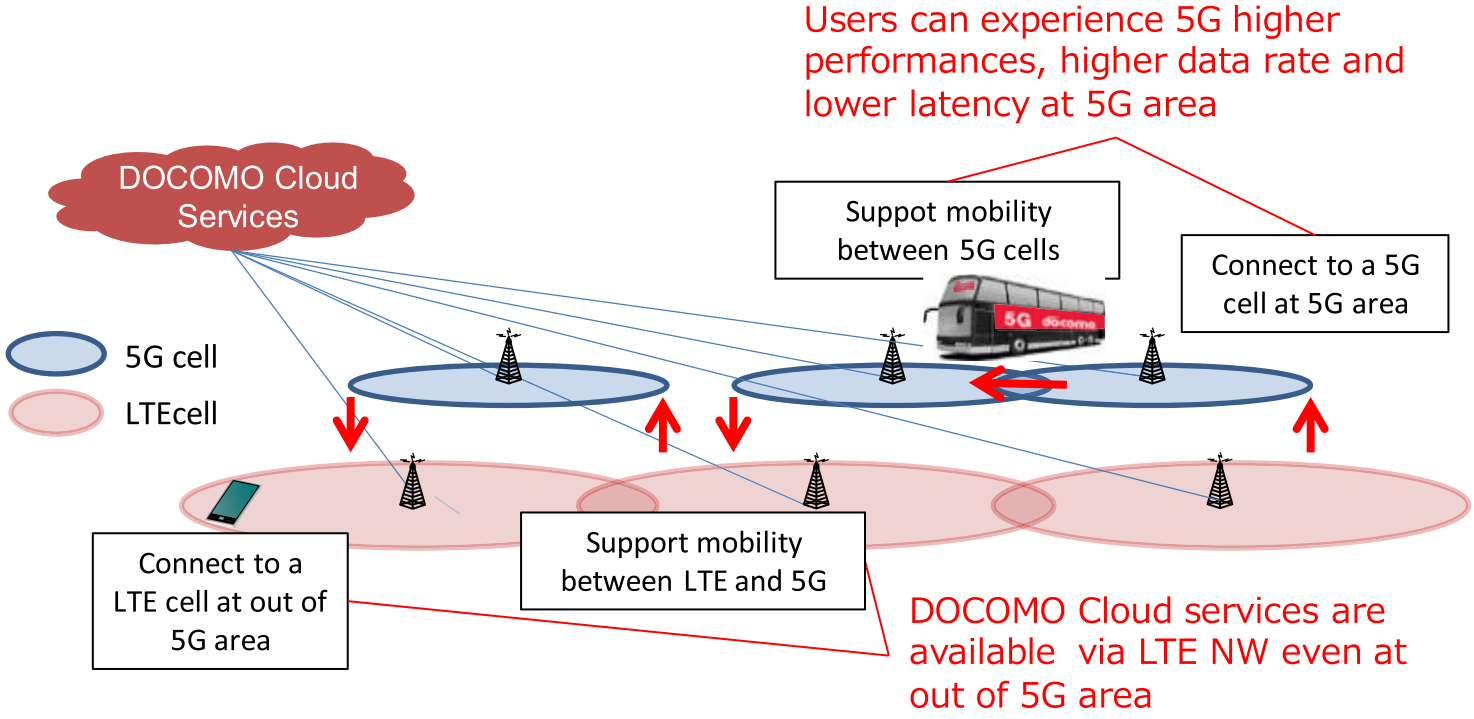
Panasonic

Measuring instruments vendors

KEYSIGHT TECHNOLOGIES ROHDE&SCHWARZ

NTT DOCOMO 5G Trial Sites

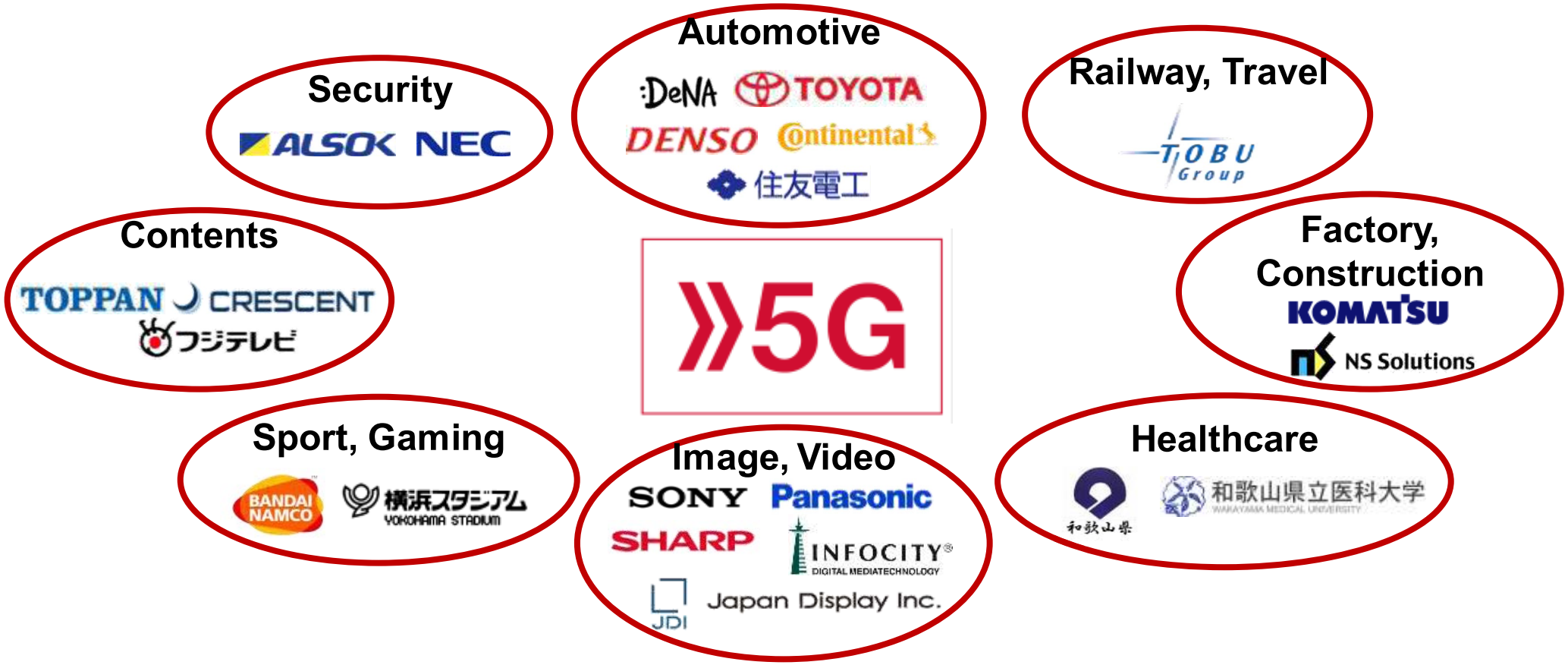
The 5G Trial Sites are offered in two distinct of Tokyo, the Odaiba waterfront and Tokyo SKYTREE TOWN from May, 2017



Support mobility between 5G and commercial LTE NW
Utilize 28 GHz and 4.5 GHz frequency bands

Collaboration with Vertical Industries for 5G Service Creation

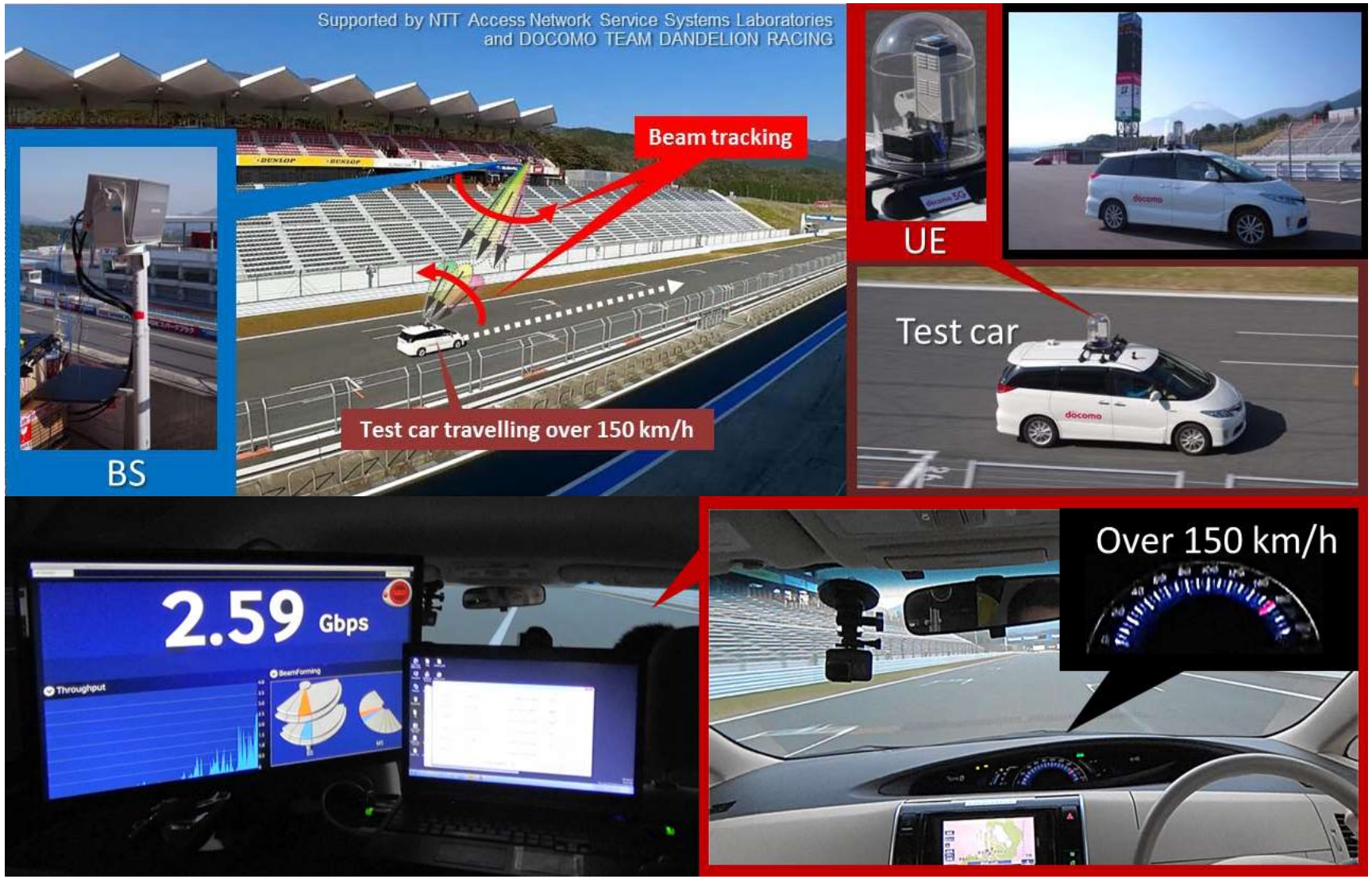
- To create excellent 5G services, DOCOMO is collaborating with many partners of variety of vertical industries
- DOCOMO intend to expand collaborations for 5G service co-creation



NTT docomo 5G NW technologies, AI platform, Web API, etc

Samsung @ 28 GHz　5G High Mobility Test in Fuji Speedway

We have successfully achieved a data speed of more than 2.5 Gbps on a vehicle travelling at a speed over 150 km/h



Major specifications

Freq. band	28 GHz band (800 MHz bandwidth)
BS	•96 antenna elements •support up to 2 stream MIMO transmission with 2 beams
UE	•8 antenna elements •2 beams reception

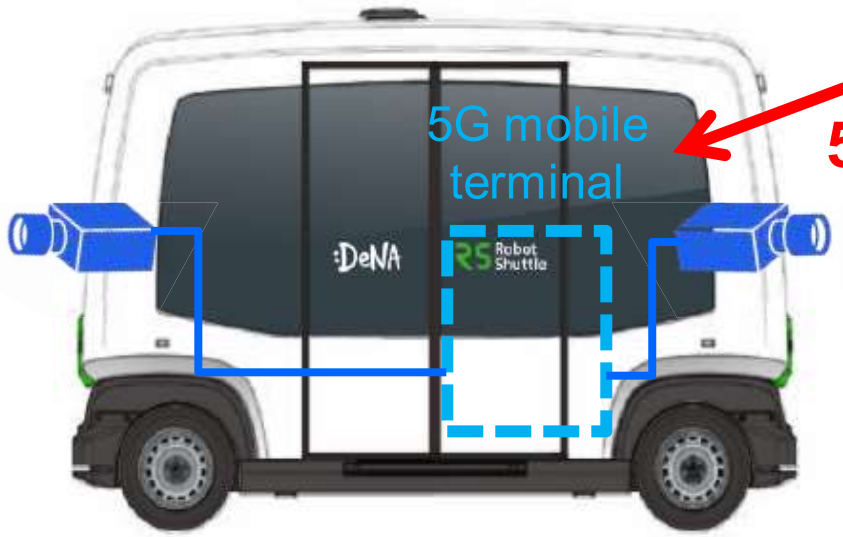
Remote monitoring of autonomous vehicles using 5G

Joint project with DeNA

- Remote monitoring system trial jointly with DeNA
- Transmission of realtime videos to the remote operation centre using 5G
- Transmission of multiple high resolution video streams by 5G enables quick responses upon emergency events

Demo at NTT DOCOMO R&D Open House (Nov 2016)

Autonomous driving bus
"Robot Shuttle"



5G base station

5G

4K video
2 streams

2K videos
4 streams

Remote booth

Video chat service using 5G

Joint project with Continental Automotive

- Joint trials with Continental Automotive on connected car infotainment services.
- Exhibited a video chat system at 5G Tokyo Bay Summit in May 2017, using 5G connections between the exhibition sites and the moving vehicle at a remote area (at DOCOMO's R&D Center).

Demo at 5G Tokyo Bay Summit (May 2017)

NTT DOCOMO R&D Center (YRP)

Using 5G connection to the vehicle

5G base station

5G

5G mobile terminal

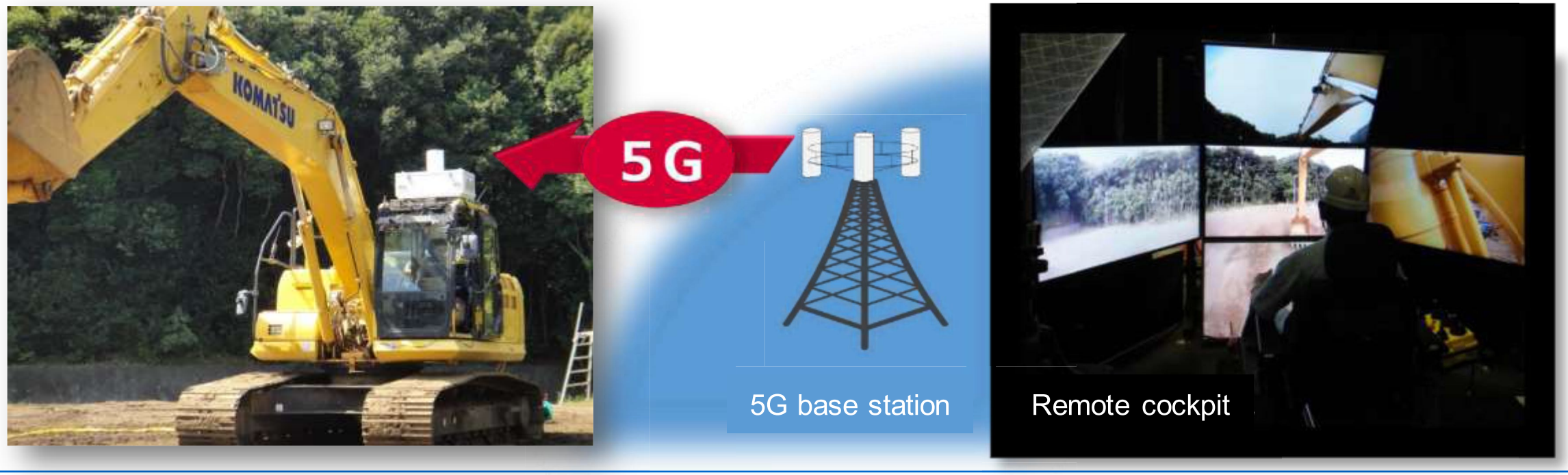
Future construction sites realized by 5G

- To realize future ICT construction -

To realize a remote operating system for construction/mining machines leveraging the high-speed and low-latency characteristics of the 5G radio technology

≫Features

- Remote in-depth monitoring of the construction site by five high-definition video streams transmitted via the high-speed broadband capability of 5G
- High-precision operation by leveraging the low-latency capability of 5G
- By setting up 5G base stations at dangerous disaster aftermath, remote operation of heavy machinery can be rapidly provisioned



Demonstration of 5G connected cars

Real-time video streaming demonstrations of 5G connected cars, by collaboration with Intel, Ericsson, Denso and Toyota

≫Features

- Transmission of rich contents (i.e., diagnostics, 4K videos, etc.) by 5G with TOYOTA ALPHARD driving in the Odaiba area.
- Demonstration of 5G performance dynamics and beam tracking capability through the original visualization system.

5G Trial Site: Odaiba area

Base station Antenna

TOYOTA ALPHARD mounted with 5G mobile equipment

Providing new moving experience of the 5G era

New concept cart

Being inspired by the fact that mobile phones have evolved into smartphones by adopting various sensors and interfaces, we have evolved smartphones and realized a new concept vehicle by employing SONY's technologies and designs

≫Features

- Displaying on a 4K-drive display, 360°-view videos taken by a camera sensor with ultra-high sensitivity beyond that of human eyes
- Communications employing 4K Digital Signage & communication display

Main function

- 4K ultra high sensitive camera sensor & drive display
- 360-degree view system
- Digital Signage x 6
- Olivine-type lithium-ion rechargeable battery
- Ultrasonic sensor
- Control with game controller

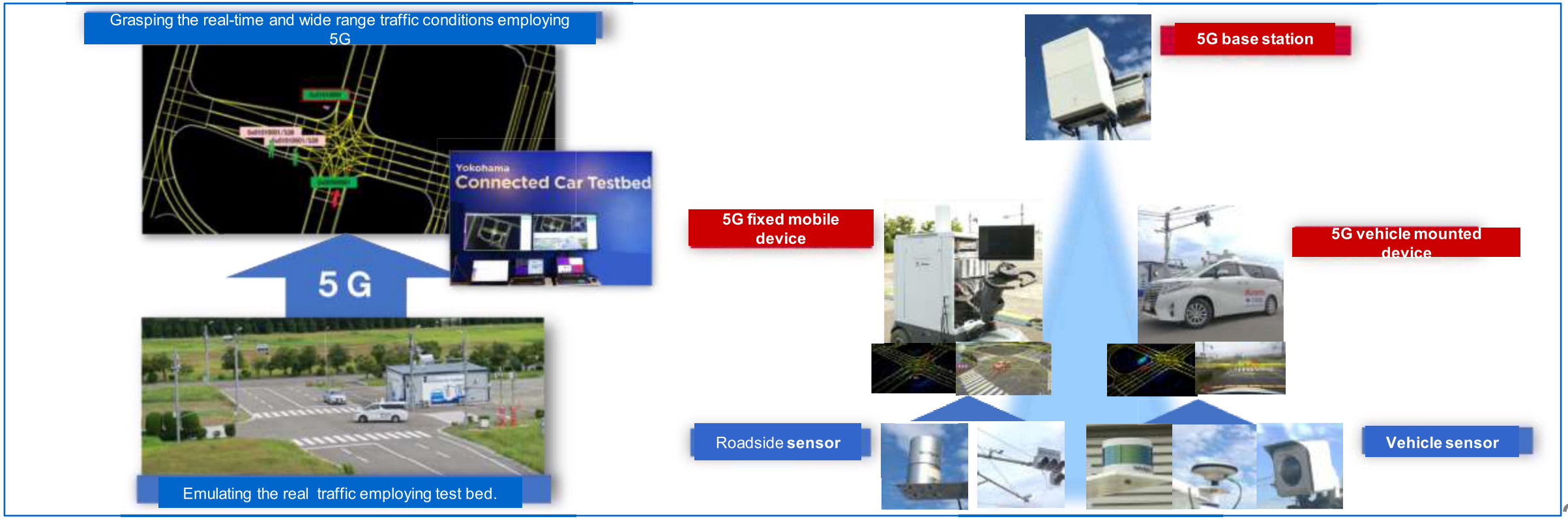
Demonstration targeting use of road traffic condition data employing 5G

Real-time data collection and analysis of road traffic conditions

Real-time data collection and analysis of road traffic conditions employing 5G; the next generation radio system, and sensors embedded in the traffic infrastructures such as vehicles, roads and buildings

≫Features

- Employing 5G, featuring high-speed, broadband and low-latency
- Collection and analysis of traffic condition data of the surrounding environment such as driving vehicles, pedestrians, and road traffic conditions
- Grasping real-time and wide-range traffic conditions and providing advanced support for vehicles and pedestrians



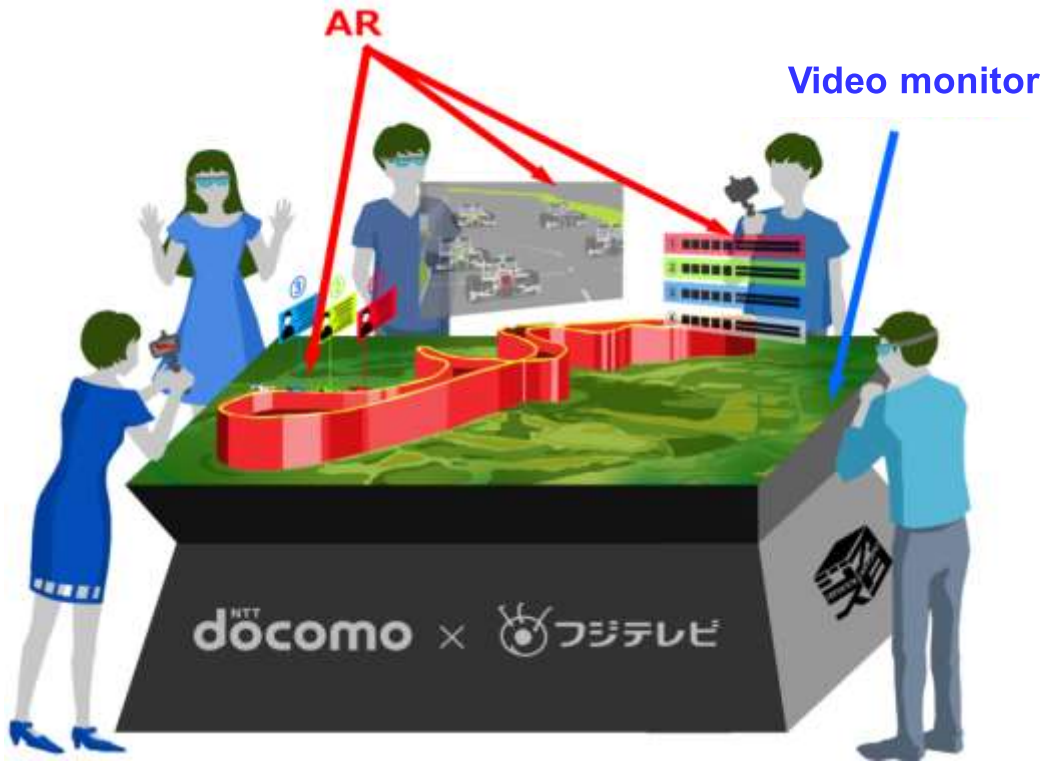
Synchronized TV broadcasting & real-time AR

“Dio-stadium” introduces new viewing experience by AR!
A new form of watching sports broadcast is proposed

≫Features

- New user experience by real-time AR; enables arbitrary viewpoints to watch sports games
- AR indication of information linked to TV broadcasting

By projecting videos taken in Suzuka Circuit on the 55-inch 4-screen monitor, users can enjoy formula car racing on their devices in 3D



Celluler V2X Trial Collaboration

docomo

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▸ Internet ▸ Con

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Press Releases

January 12, 2018

Leading Automotive, Telecom and ITS Companies Unveil First Announced Cellular V2X Trials in Japan

— Continental, Ericsson, Nissan, NTT DOCOMO, OKI and Qualcomm Technologies join forces to host C-V2X trials in Japan in 2018 to validate and demonstrate C-V2X benefits —

Print Like Tweet

TOKYO, JAPAN, January 12, 2018 --- Continental, Ericsson, Nissan, NTT DOCOMO, INC., OKI and Qualcomm Technologies, Inc., a subsidiary of Qualcomm Incorporated (NASDAQ: QCOM), announced today plans to carry out their first Cellular Vehicle-to-Everything (C-V2X) trials in Japan. The objective is to validate and demonstrate the benefits of C-V2X using direct communication technology defined by the 3rd Generation Partnership Project (3GPP) in their Release 14 specifications. The trials are designed to show the enhanced range, reliability and latency benefits of C-V2X direct communications operated in 5 GHz band. Additionally, the C-V2X Trials are designed to demonstrate the complementary benefits of network-based communications utilizing LTE-Advanced (LTE-A). The trial results will help develop the ecosystem by providing inputs to the relevant stakeholders, including ITS-related organizations and government agencies, as we prepare for the connected car of the future and the industry's evolutionary transition towards 5G New Radio (NR), the new global cellular standard being defined in 3GPP.

While complementing other Advanced Driver Assistance System (ADAS) sensors, such as radar, lidar, and camera systems, C-V2X provides non-line-of-sight (NLOS) low latency awareness with longer range and cloud capabilities, and is designed to extend a vehicle's ability to see, hear and communicate further down the road, even at blind intersections.

Thank you for your attention!