Private 5G Technology and Implementation Testing

Safe-D VTTI-06-006

Jean Paul Talledo Vilela, M.S.
Senior Technology Implementer, VTTI

Marty Miller
Research Associate, VTTI

Background

Pedestrian and Intersection Fatalities

- Traffic fatalities in the United States rose to approximately 42,915 in 2021 (NHTSA)
  - Pedestrians and cyclists account for ~8,000 or almost 20% of those fatalities
- The most recent data for intersections suggests that upwards of 10,180 fatalities happened at intersections in 2019
- These data show a growing trend in pedestrian fatalities overall and intersection deaths as well
- This project explored how new intersection infrastructure, including 5G and C-V2X technologies, can be leveraged to provide safety alerts to pedestrians and drivers alike.

Fatalities at Signalized Intersections

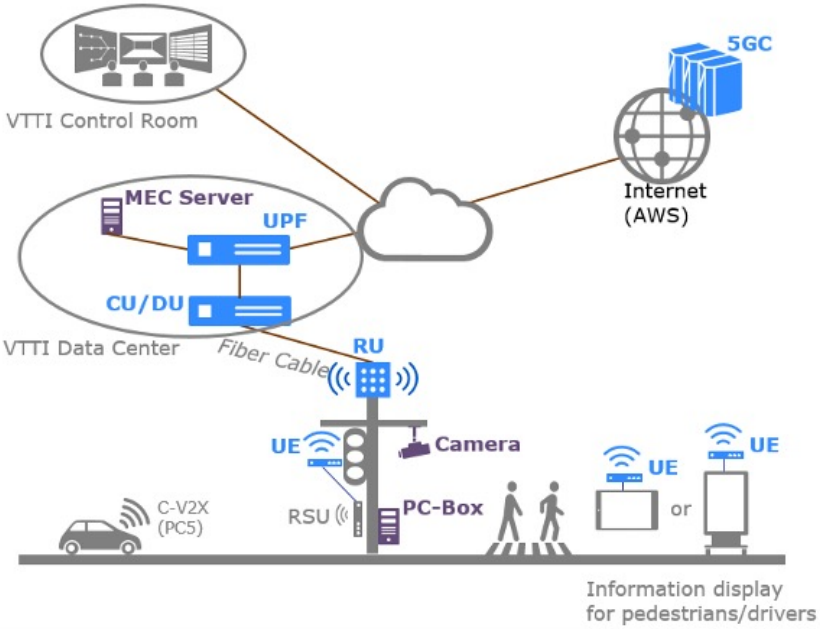
Year	Total Traffic Fatalities	Traffic Fatalities Involving an Intersection	Traffic Fatalities Involving a Signalized Intersection	Traffic Fatalities Involving Red–Light Running at a Signalized Intersection	Pedestrian Fatalities Involving a Signalized Intersection	Bicyclist Fatalities Involving a Signalized Intersection	Pedestrian and Bicyclist Fatalities Involving Red–Light Running at a Signalized Intersection
2015	35,484	9,664	2,923	786	750	119	52
2016	37,806	10,414	3,298	826	795	160	47
2017	37,133	10,301	3,271	890	800	125	46
2018	36,835	10,011	3,274	846	792	135	53
2019	36,096	10,180	TBD	TBD	TBD	TBD	TBD

Methods

1. Install private 5G equipment, camera, and edge computing platform
   - Expecting ultra low latency suitable for safety critical alerts such as for pedestrian collisions
2. Perform system calibration and machine learning model validation
3. Develop HMIs for pedestrians and vehicles to make use of alert capabilities of the private 5G deployment
4. Perform scenario testing to evaluate accuracy and total system latency

Private 5G System Development

Private 5G High Level Diagram



Scope

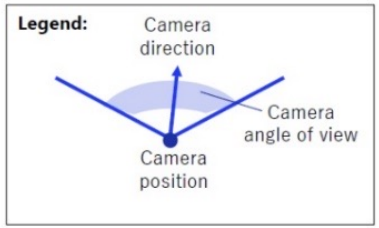
■: NEC
- Private 5G network

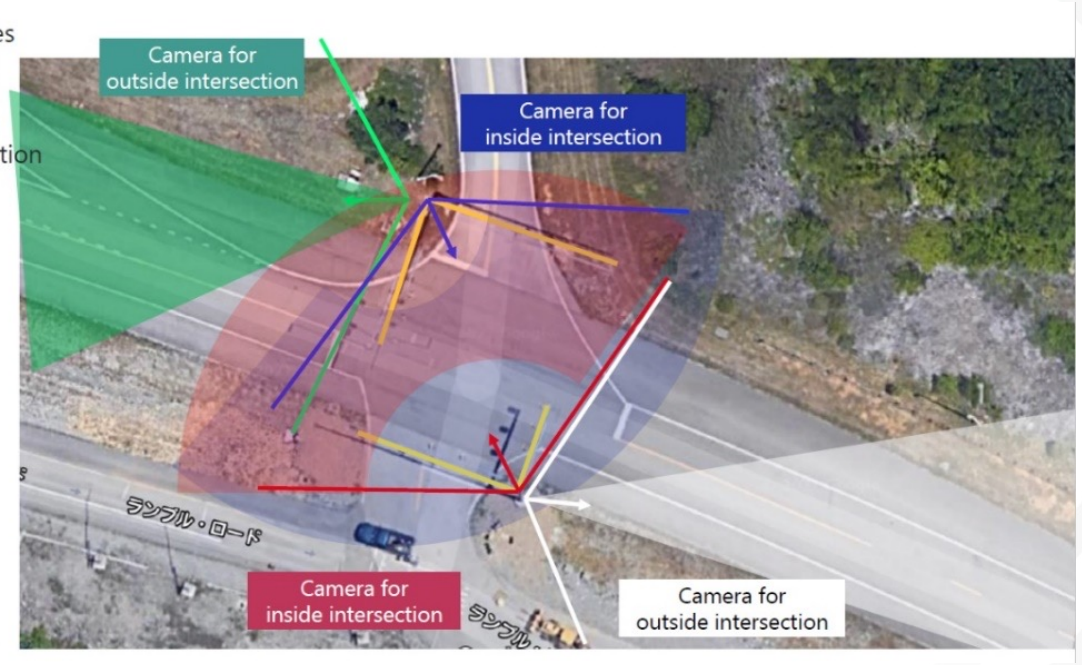
■: NEC
- Video analytics

■: VTTI
- Signal pole
- Test vehicle
- RSU
- Display (tablet, display board)

Private 5G Hardware Setup

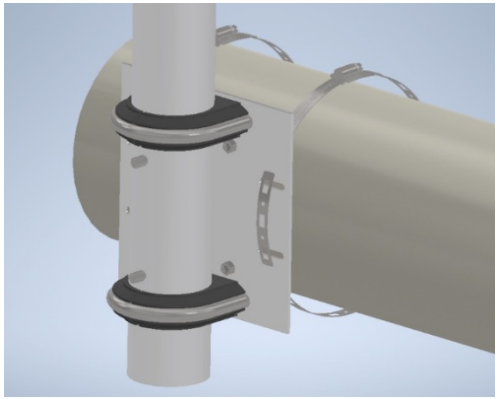
- ✓ Install 4 cameras on 2 traffic poles (2 cameras for each traffic pole)
- ✓ Detect vehicles up to about 60m from camera for outside intersection

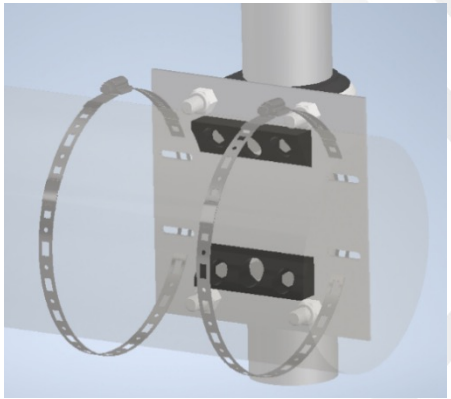




RU Mounting Design

- Pole mount was designed by VTTI team to hold the RU and GPS device on one of the traffic intersection horizontal arms.

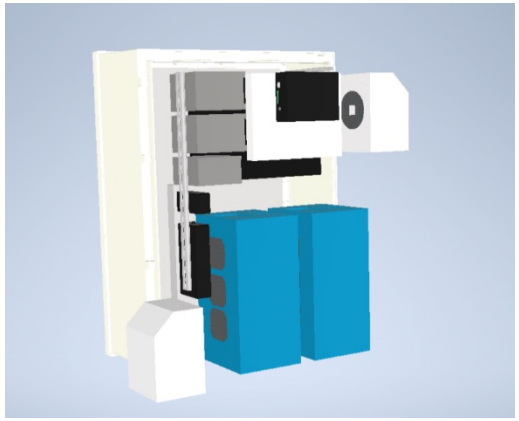


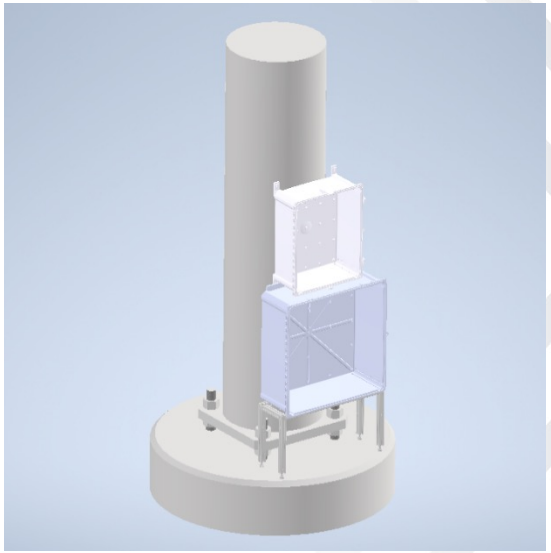


RU Mounting at Smart Road Intersection

EDGE Computing Enclosure Design

- VTTI team had challenges to find one single enclosure to house all the EDGE and Private 5G equipment.
- Enclosure boxes should handle low/high temperatures and be waterproof.
- 3 enclosures were used to house the sub-systems:
  - UE Device for Private 5G connectivity
  - POE for Camera Power and Management Control Link
  - Edge Computing platforms and power supplies.





Installed Equipment

- VTTI team installed successfully the lower MEC sub-systems including:
  - Private 5G UE and RU
  - 4 Cameras (2 per Vertical arm)
  - Power supplies
  - WiFi connectivity for Remote Power Control.

Private 5G Spectrum Usage

- Private 5G deployment uses VT's CBRS spectrum allocation.
- VTTI team get FCC approval to conduct the experiment using 3.4 – 3.5 GHz frequency band.
- No SAS integration was required.

	5G RU (Radio Unit)	5G UE (User Equipment)
Model	RHON-7800	iR730B
Unit Quantity	2	5
Frequency Band	3.4-3.5GHz (3400.195 - 3500.165MHz)	3.4-3.5GHz (3400.195 - 3500.165MHz)
Radiated Power	38dBm, EIRP, Peak	24.5dBm, EIRP, Peak
Station Class	Fixed	Fixed
Emission - Mod. Type	X	X
Signal Nature	7	7
Info. Type	W	W
Modulating Signal	OFDM (QPSK, 16QAM, 64QAM, 256QAM(DL))	OFDM (QPSK, 16QAM, 64QAM, 256QAM)
Necessary Bandwidth	100 MHz	100 MHz

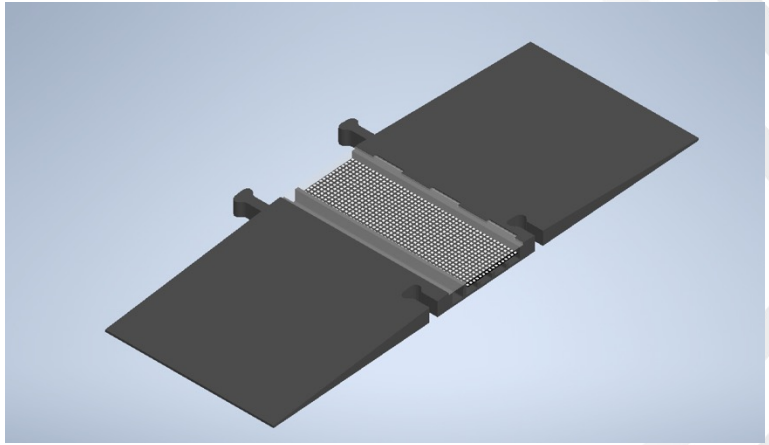
System Calibration

- The full intersection system was calibrated by placing boxes within each camera's FOV and recording video data
  - LiDAR unit was used to provide ground truth positioning relative to the camera view

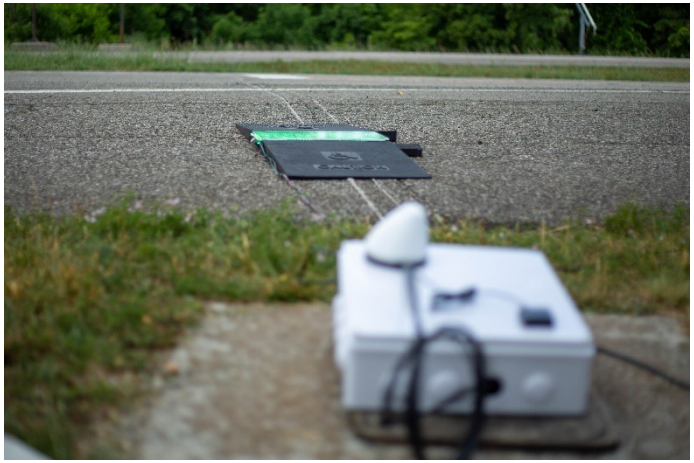
HMI and Safety Alert Development

Pedestrian Lighting Board

- As the system is capable of identifying potential collisions between pedestrians and vehicles, VTTI developed an HMI hardware to alert pedestrians when a threat situation is detected.
- The Pedestrian Lighting Board includes:
  - C-V2X OBU to process SAE J2735 Messages broadcasted by the RSU network
  - Embedded computing platform that generates patterns on the LED panels.
  - Speaker for auditory alerts



Pedestrian Lighting Board



In-Vehicle HMI

- We designed a prototype visual HMI that can provide alerts to drivers
  - C-V2X OBU processes messages from the private 5G deployment

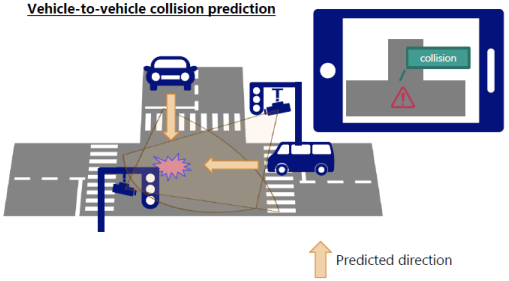
Scenario Testing

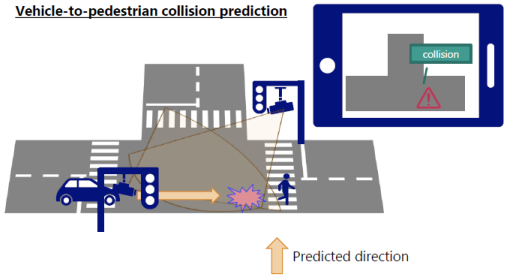
Intersection Scenario Testing

- Six use-cases were provided by NEC to evaluate the private 5G deployment and edge compute capabilities
  - Collision Prediction
  - Street Parking Notification
  - Traffic Accident Detection (post-accident)
  - Pedestrian Crossing Detection
  - Right and Left Turn Detection
  - Overspeeding Detection

Collision Prediction

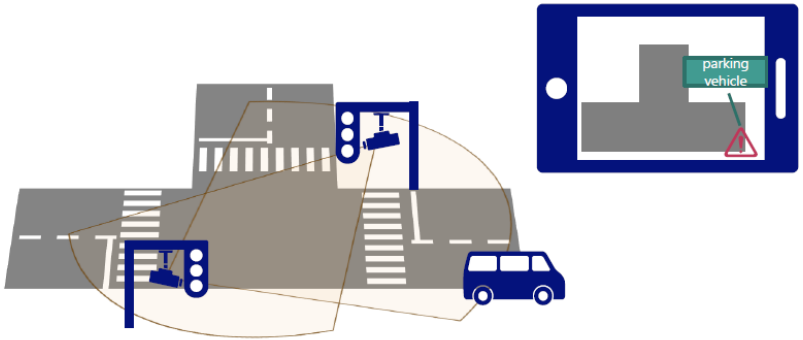
- Key performance indicators
  - Time from predicting a collision to displaying on a tablet: less than 1 second (6m at 15mph)
  - Detection rate: 80%





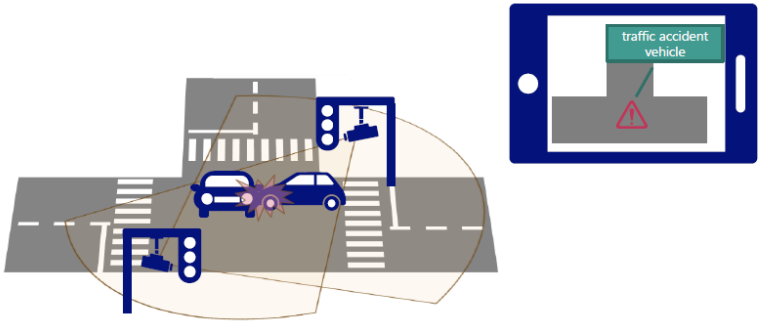
Street Parking Notification

- Key performance indicators
  - Time to display the position on the research vehicle's HMI: 1 second after occurrence
  - Detectable distance: within 40m of the camera.
  - Detection rate: 80%



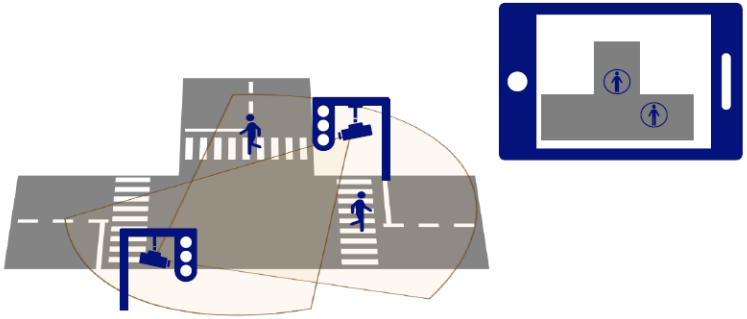
Traffic Accident Detection

- Key performance indicators
  - Time to display the position on the research vehicle's HMI: 1 second after occurrence
  - Detection rate: 80%



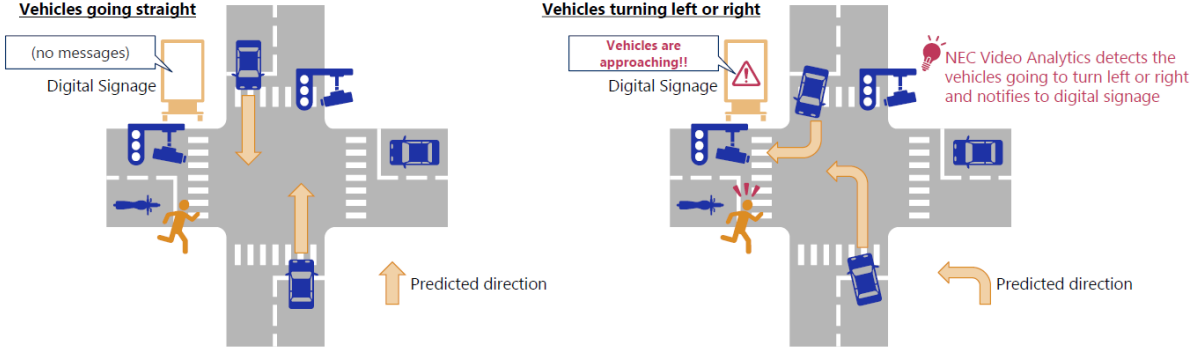
Pedestrian Crossing Detection

- Key performance indicators
  - Time from detecting a target pedestrian to displaying the position on the research vehicle's HMI: less than 1 sec
  - Detectable distance within 20m from the camera.
  - Detection rate: 80%



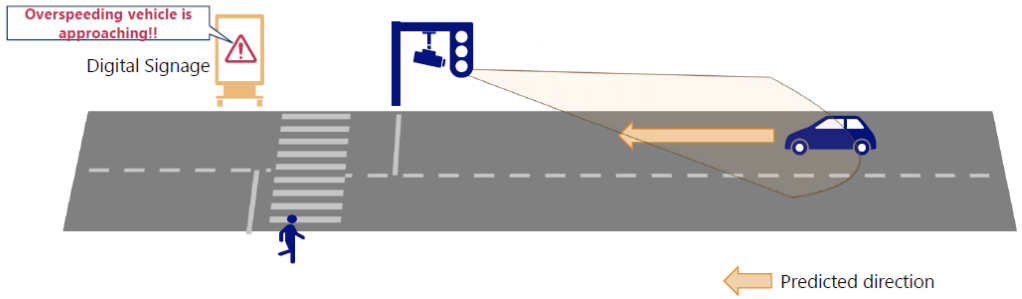
Right and Left Turn Detection

- Key performance indicators
  - Time from detecting a target vehicle to displaying the position on the research vehicle's HMI: less than 1 sec
  - Detection rate: 80%



Overspeeding Detection

- Key performance indicators
  - Time from detecting a target vehicle to displaying the position on the research vehicle's HMI: less than 1 sec
  - Detection rate: 80% (target: more than 90%)



Scenario Testing

- We performed many variations of each scenario with pedestrians or vehicles crossing or approaching from different areas to ensure accuracy across all intersection entrances
  - In total 138 unique scenarios were performed, often with multiple repetitions
  - Scenarios involving collisions with pedestrians were ran with an AB Dynamics articulated pedestrian target

Results

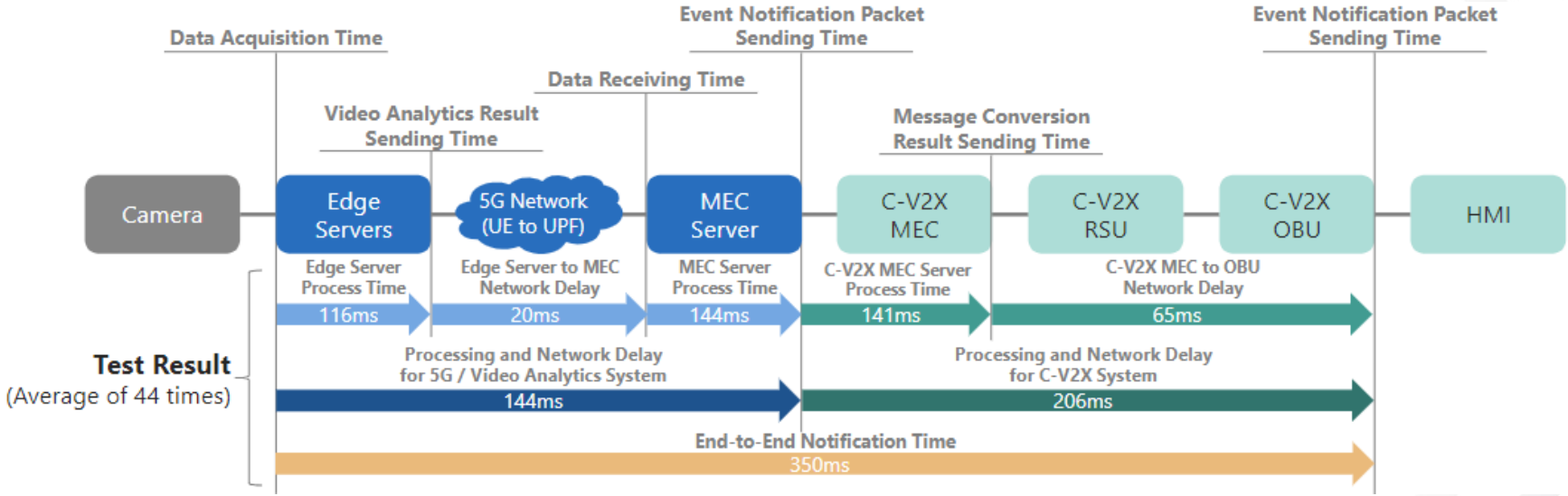
5G Deployment Data Speeds

Test UEs	Items	Test Results
5G UE#1 (RSRP: -93dBm)	TCP Uplink	**123.6 Mbps**
	TCP Downlink	**72.3 Mbps**
	ping RTT (Round-Trip-Time)	**49.1 msec** (min: 25.4 msec, Max: 247.7 msec)
5G UE#2 (RSRP: -106dBm)	TCP Uplink	**127.5 Mbps**
	TCP Downlink	**91.8 Mbps**
	ping RTT (Round-Trip-Time)	**50.4 msec** (min: 22.1 msec, Max: 86.8 msec)

Latency and Detection Rates

No	Use Cases	KPI	Applicable Scenarios *	Result of 5G/Video System
1	Collision Prediction	• The system notify Tablet within 1 sec • Detection rate : 80% or more	Priority-1: 65, 75, 82, 105 Priority-2: 18, 28, 34, 36, 77, 78, 79, 80	**Passed** Avg. Notification Time: 125ms Detection Rate: 100%
2	Street Parking Notification	• The system notify Tablet within 1 sec • Detectable distance: 40m from camera • Detection rate : 80% or more	Priority-1: 113, 115, 118, 120 Priority-2: 114, 116, 117, 119	**Passed** Avg. Notification Time: 142ms Test Distance: 45m Detection Rate: 88%
3	Traffic Accident Detection	• The system notify Tablet within 1 sec • Detection rate : 80% or more	Priority-1: 126, 127, 129, 131 Priority-2: 125, 128, 130	**Passed** Avg. Notification Time: 159ms Detection Rate: 89%
4	Pedestrian Crossing Detection	• The system notify Tablet within 1 sec • Detectable distance: 20m from camera • Detection rate : 80% or more	Priority-1: 1, 7, 9, 15 Priority-2: 3, 5, 11, 13	**Passed** Avg. Notification Time: 137ms Test Distance: 40m Detection Rate: 100%
5	Vehicle Detection for Right & Left Turns	• The system notify Tablet within 1 sec • Detection rate : 80% or more	Priority-1: 138 Priority-2: 132, 133, 134, 135, 136, 137	**Passed** Avg. Notification Time: 162ms Detection Rate: 100%
6	Overspeed Detection	• The system notify Tablet within 1 sec • Detection rate : 80% or more	Priority-1: 121, 122, 123, 124	**Passed** Avg. Notification Time: 121ms Detection Rate: 100%
			Total	**Avg. Notification Time: 144ms** **Detection Rate: 96%**

Total System Latency



Conclusions

- The private 5G network implementation was able to provide low-latency alerts for all target scenarios
- Total system latency was approximately 350ms, from when the event started to when the HMIs would receive the alert
  - Improved latency is always beneficial for safety critical applications
  - Current work is ongoing to improve latency
- Work still to do to assess HMI appropriateness and effectiveness

Thank You!

Q & A