VANET Meets Deep Learning: the Effect of Data Dissemination to the Object Detection Performance

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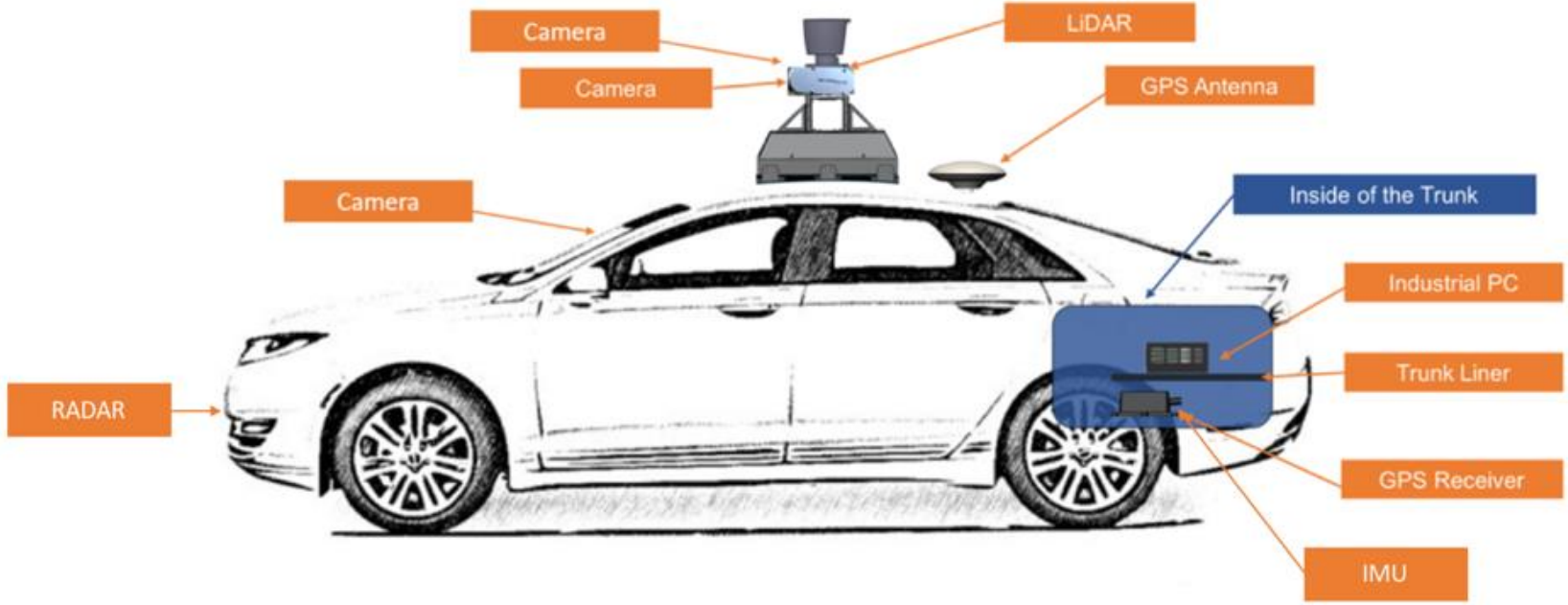
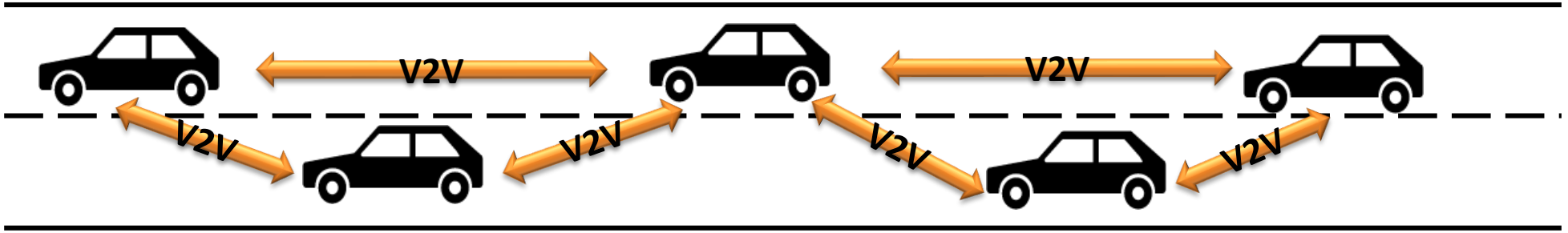
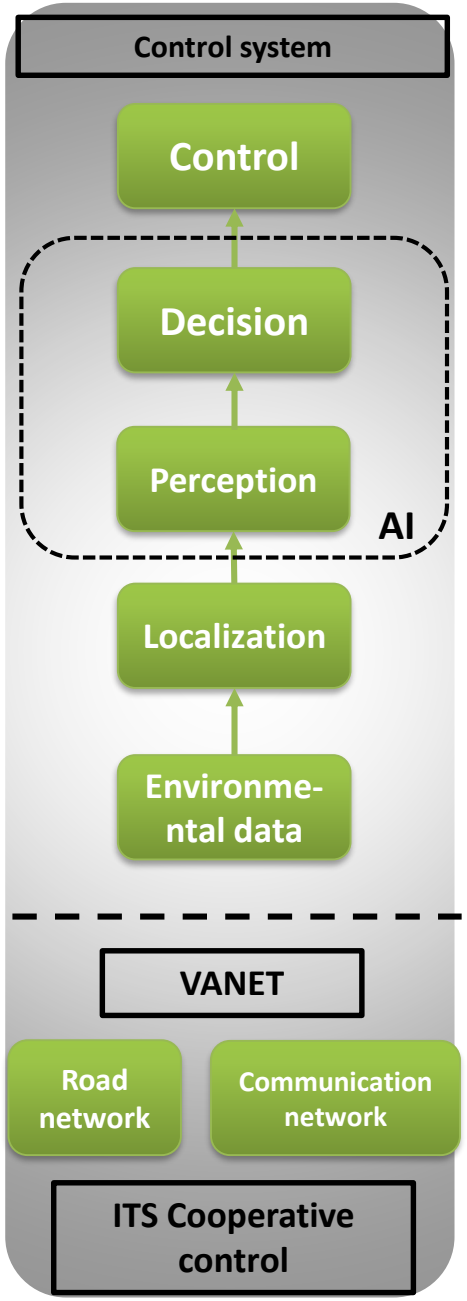
• Research Background

(LiDAR) Sensor Data → AI Decision Making → Vehicular Control



VANET is the core of the Intelligent Transportation System(ITS)

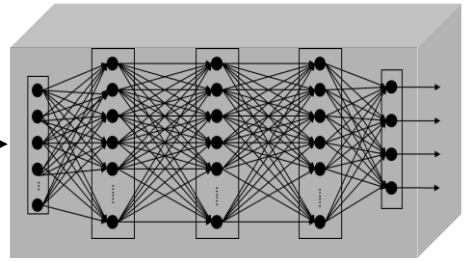


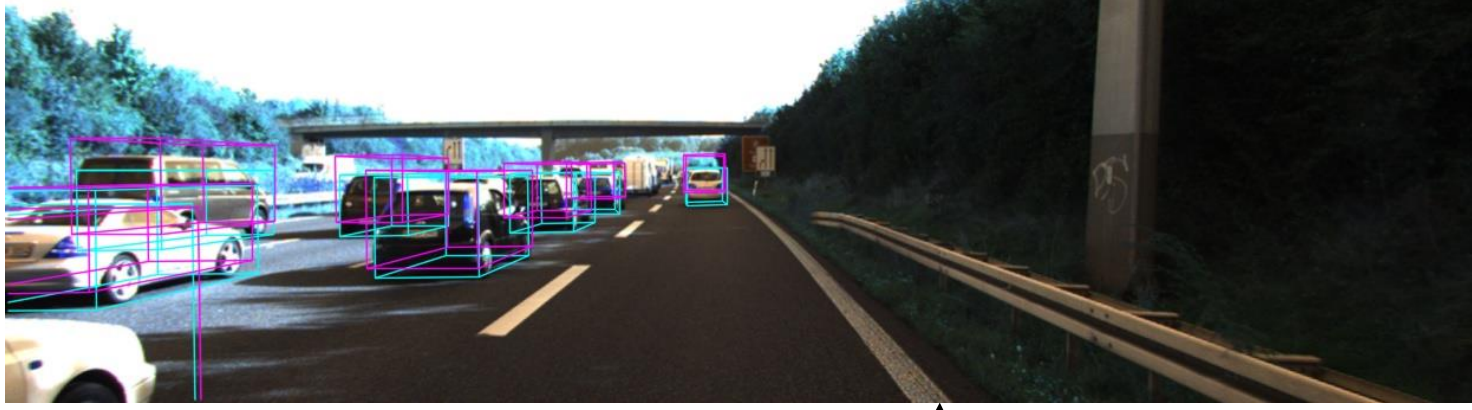


- **Research Background**

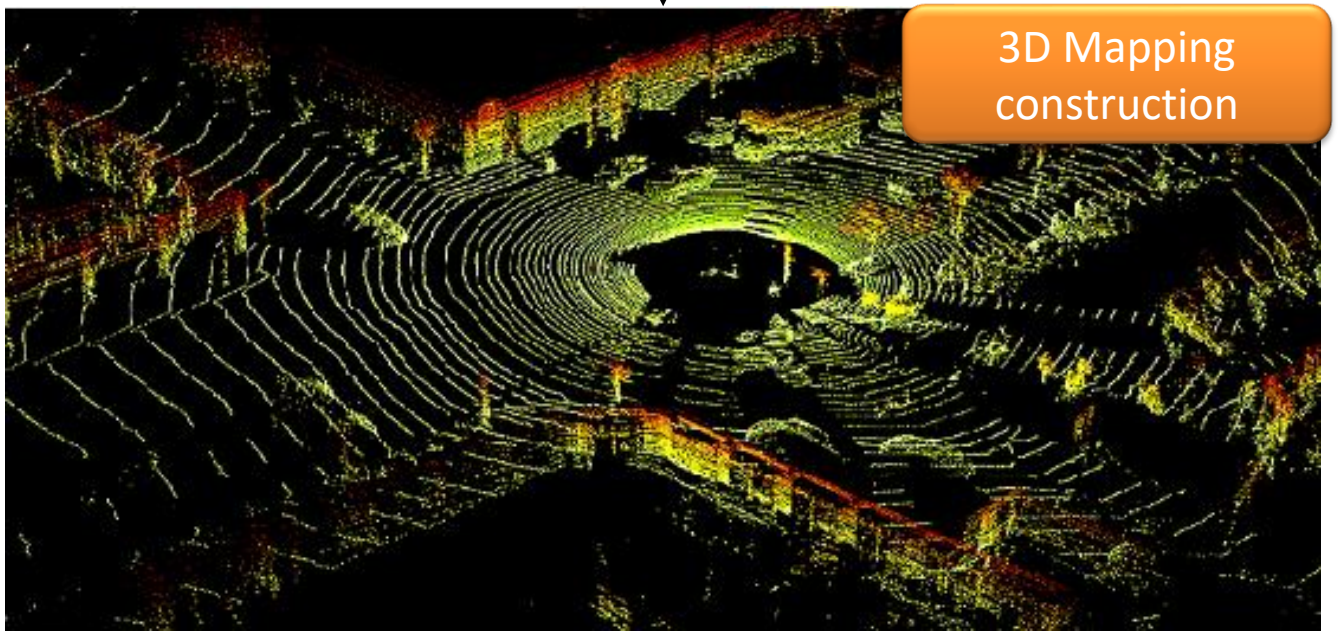
Deep Learning based Intelligent Driving

LiDAR

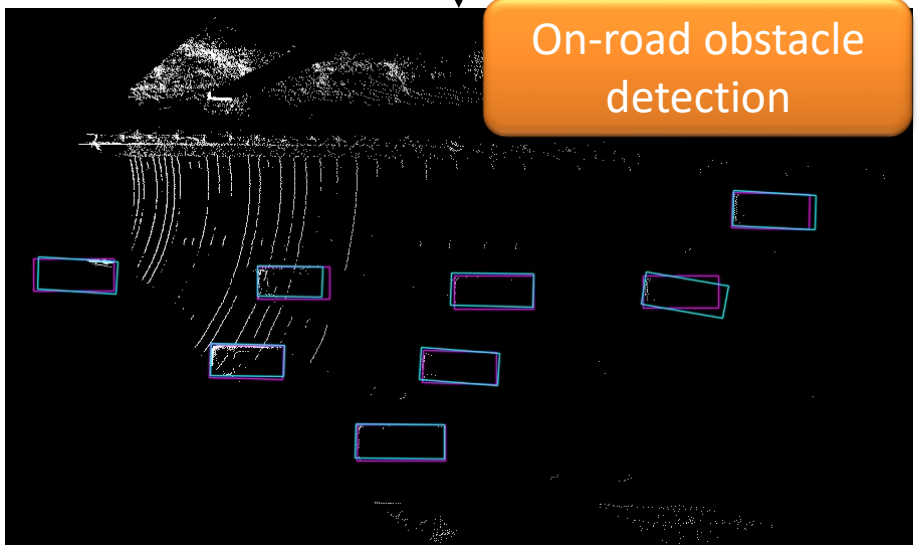




Q: Perception range limitation!

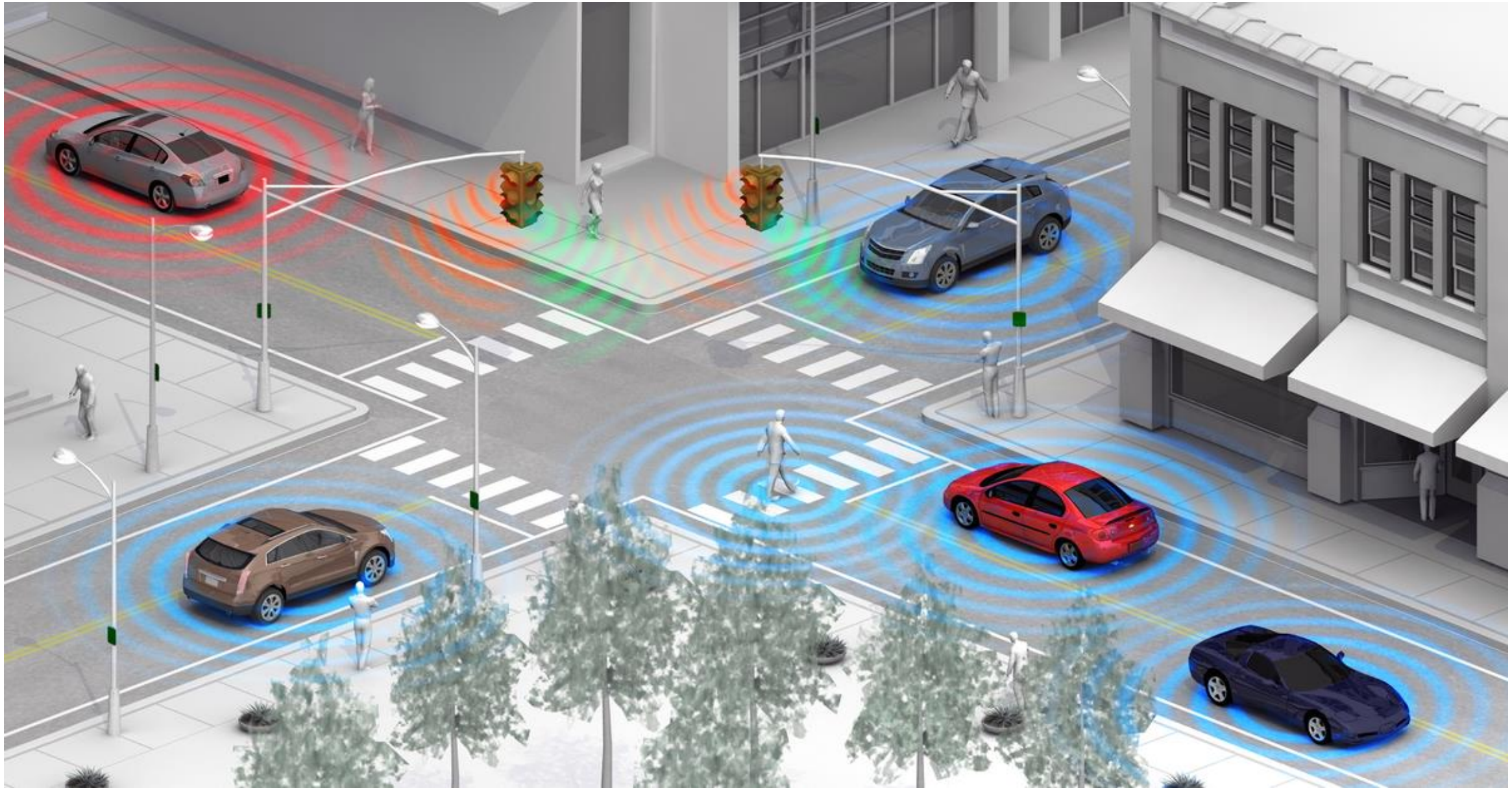


3D Mapping construction

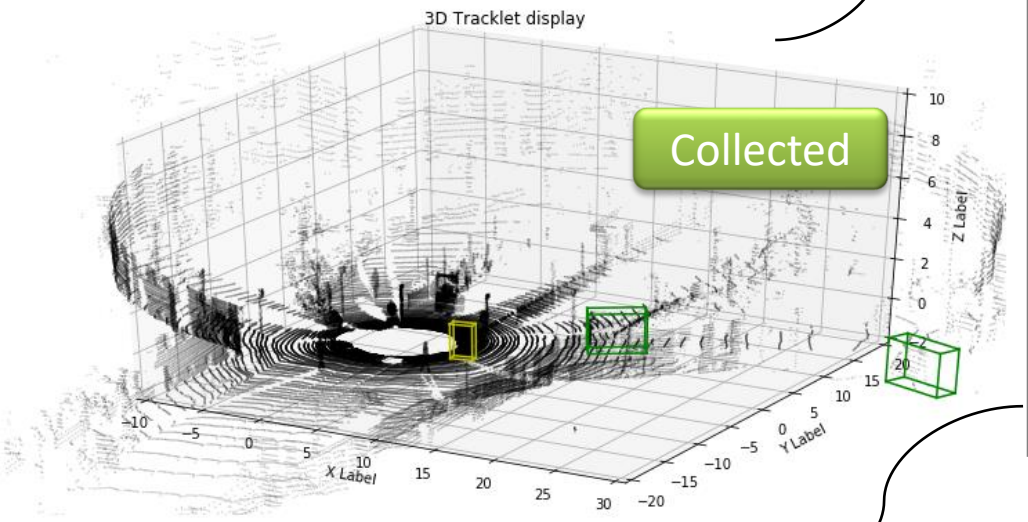


On-road obstacle detection

- **Inter-Vehicle communication** through Vehicular Ad-hoc Network (VANET)
  <Break the 'perception range limitation' through **information sharing mechanism** >

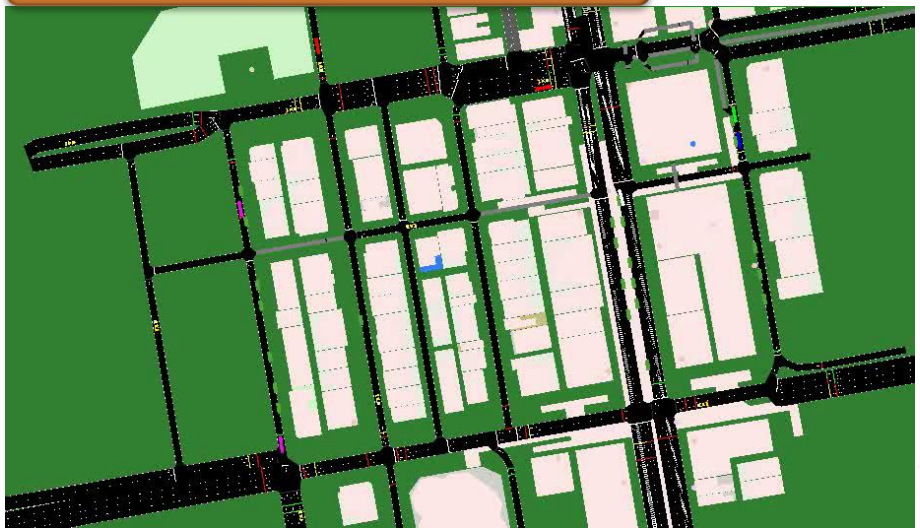


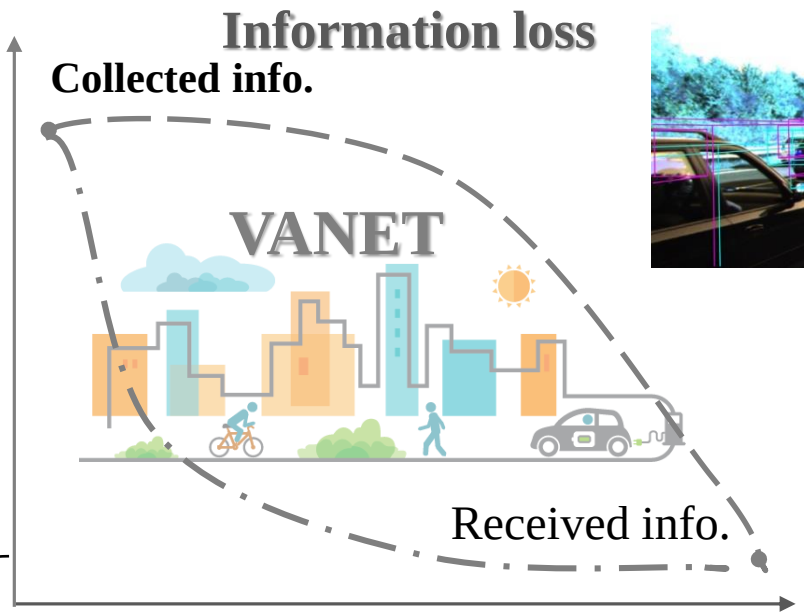
• New problem: Data loss

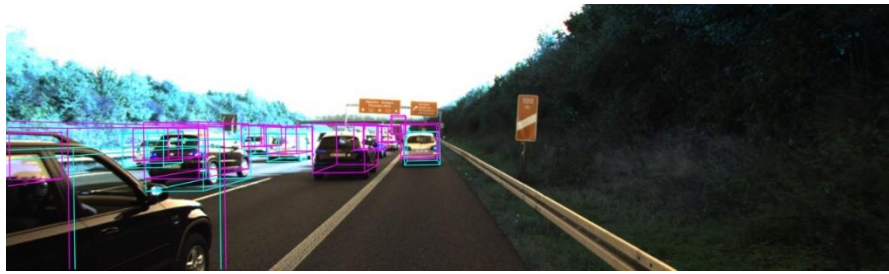


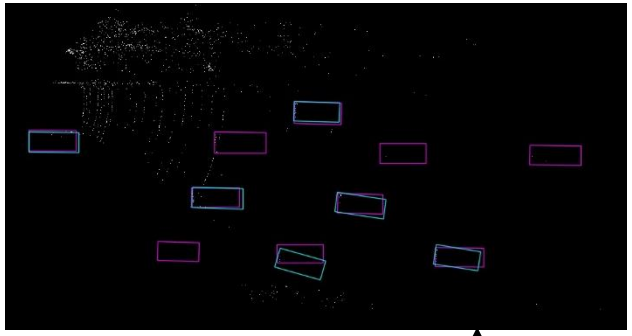
Collected

Dynamic Environment



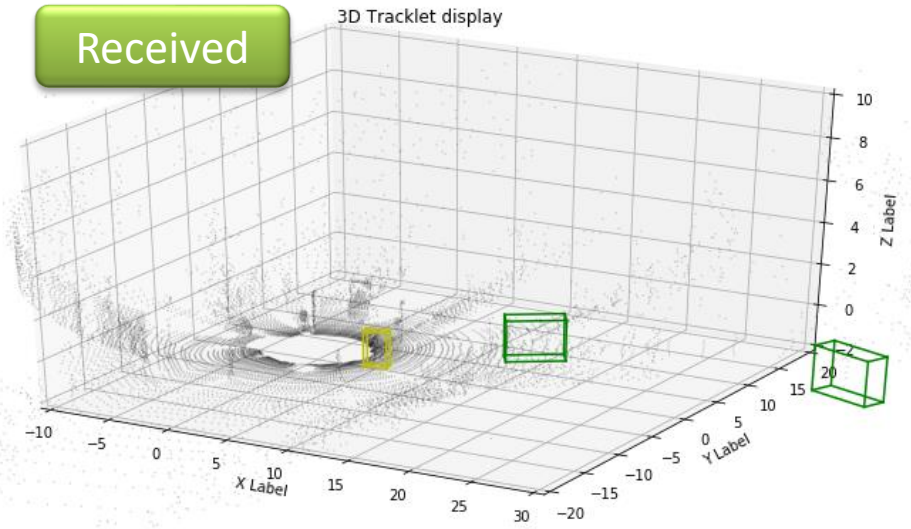


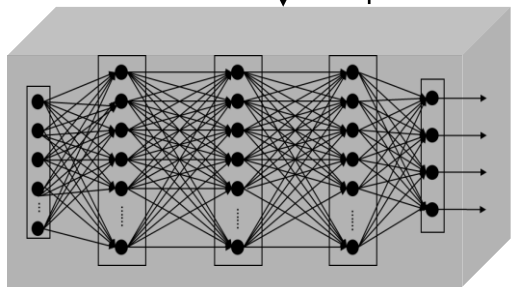




Dynamic Environment

Received





• System framework

(**Baseline**) (V2V commun. topology)

(**Baseline**) (Original Point cloud + Detection results)

Semi-realistic **Traffic Scenario** construction

Inter-vehicle **communication**

Deep-learning based 3D **point cloud object detection**

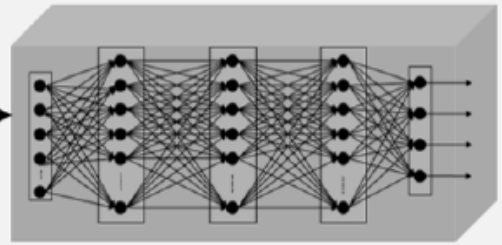
(**Affect**) (V2V packet loss)

(**Affect**) (Deep-learning based object detection accuracy)

Section III A

Section III C

Single perspective vehicular sensor data



Object detection results

Perception range limitation

Original point cloud data

3D mapping construction

Information loss

Collected info.

Cooperative perception

VANET

Received info.

VANET Service Channel (SCH)

Infotainment Service

Inter-vehicle communication

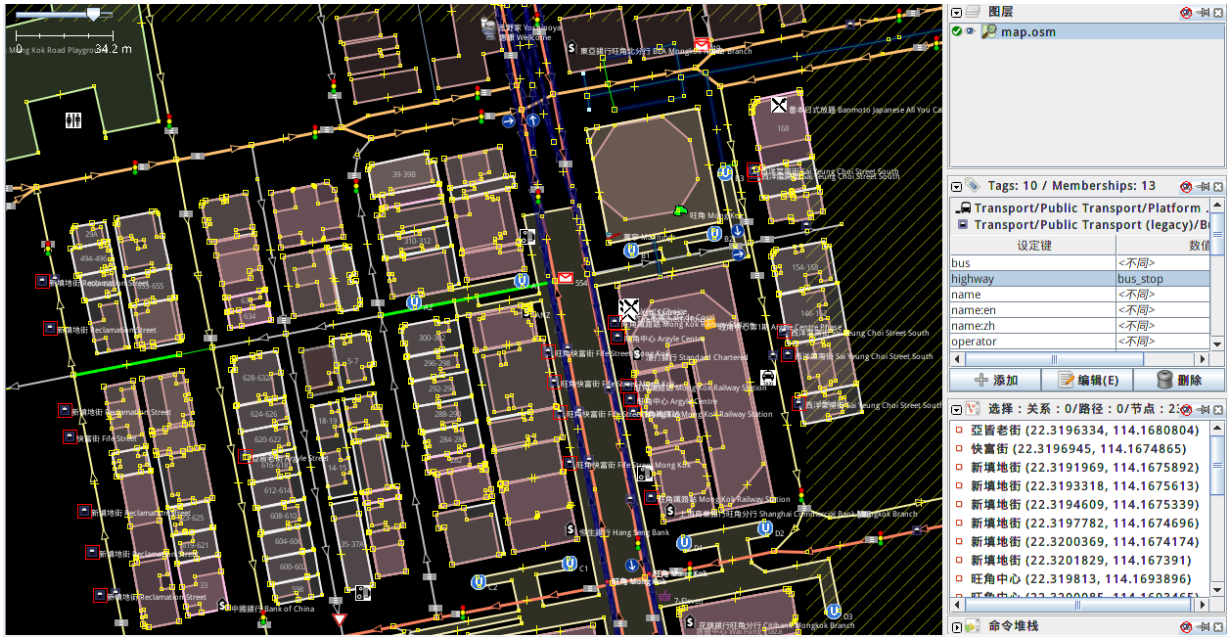
VANET Control Channel (CCH)

Basic Safety Message

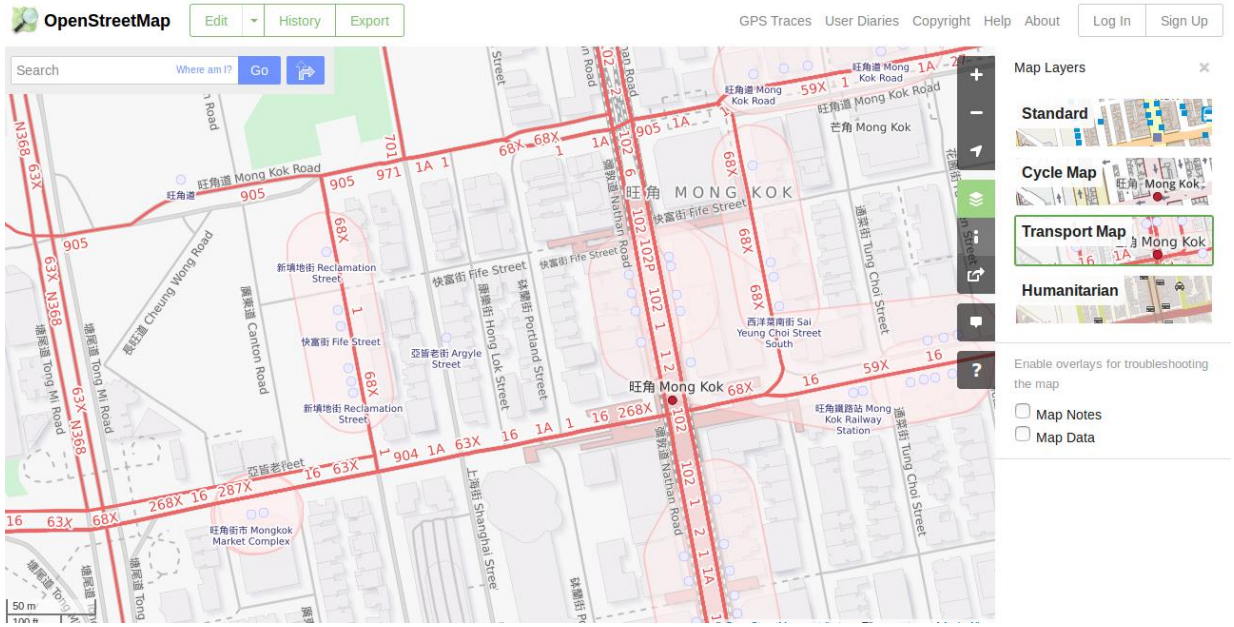
Section III B

Dynamic Environment

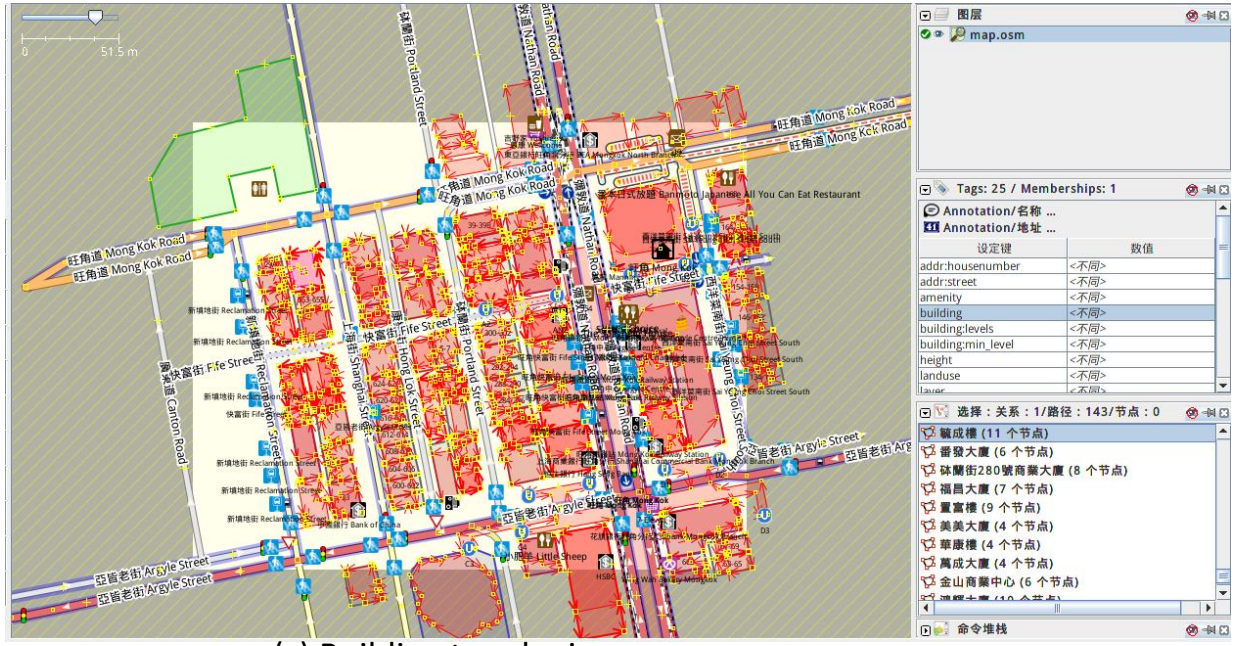
- **Scenario construction**



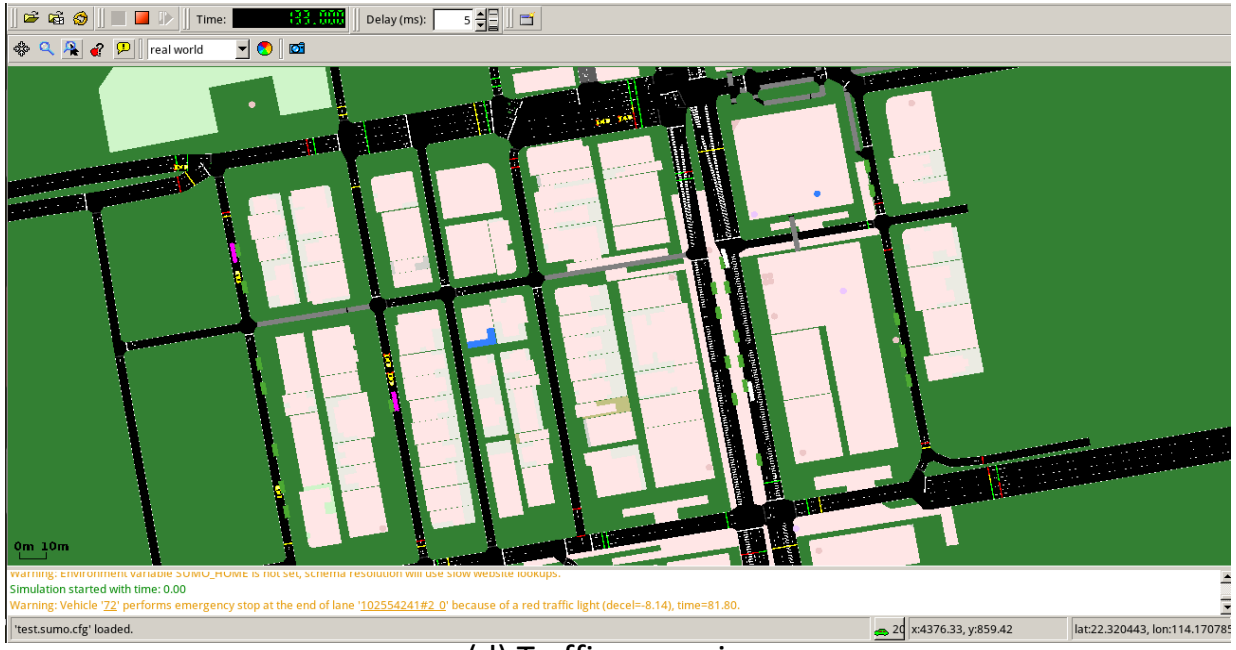
(a) Traffic infrastructure



(b) Bus routes



(c) Building topologies

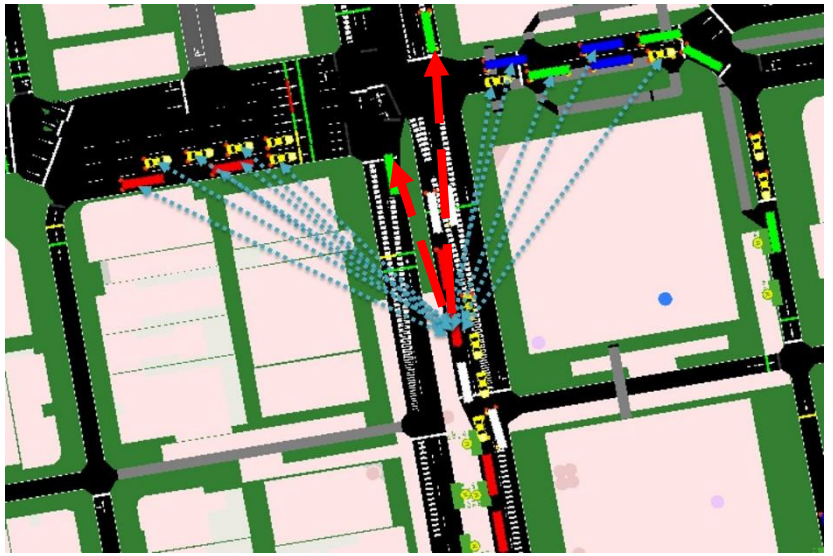


(d) Traffic scenario

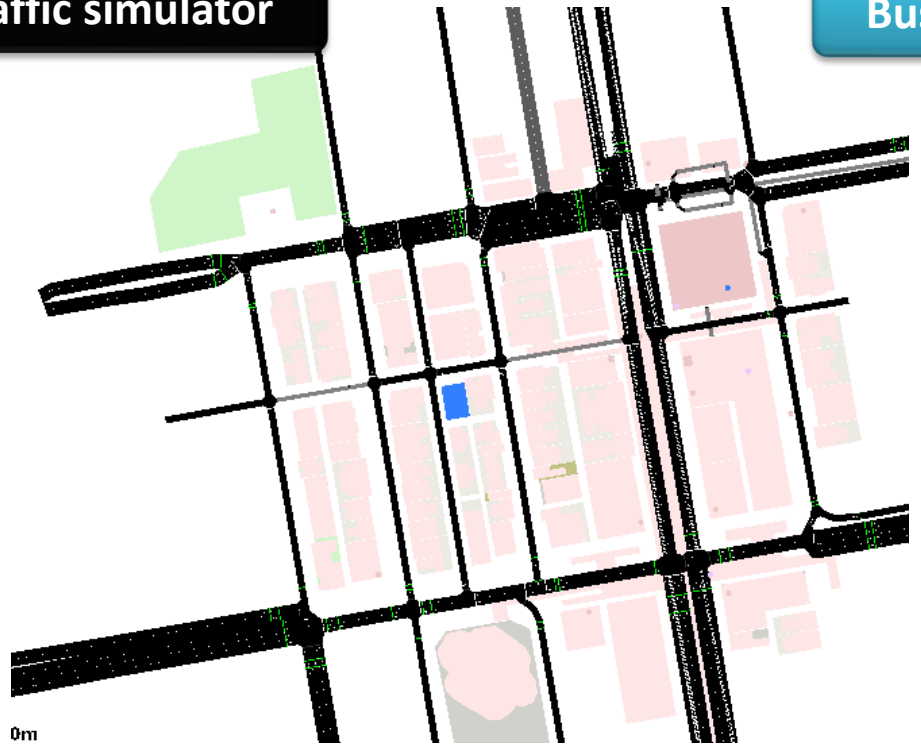
What is VANET

• (Vehicular Ad hoc Network) packets are exchanged between mobile nodes (Vehicles) traveling on constrained paths;

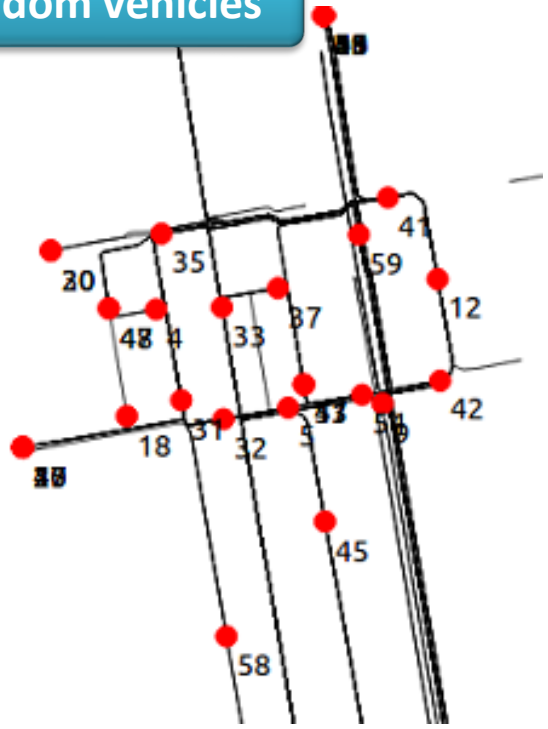
Scenario size	$274.441m \times 433.396m$
Simulation duration	1200s
Transmission power	16dBm - 28dBm
Routing protocol	OLSR
Physical mode	OFDMRate6MbpsBW10MHz
80211mode	MAC:802.11p / 5.9GHz
Packet size	200 bytes (Basic Safety Message) & 4,000,000 bytes (3D point cloud data)
Transmission range	50m - 400m
Porpagation loss model	ITUR1411LosPropagationLossModel



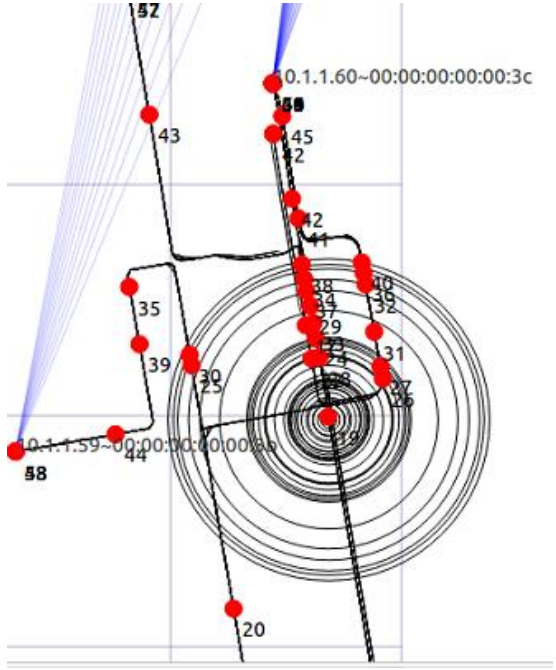
Traffic simulator



Bus and random vehicles

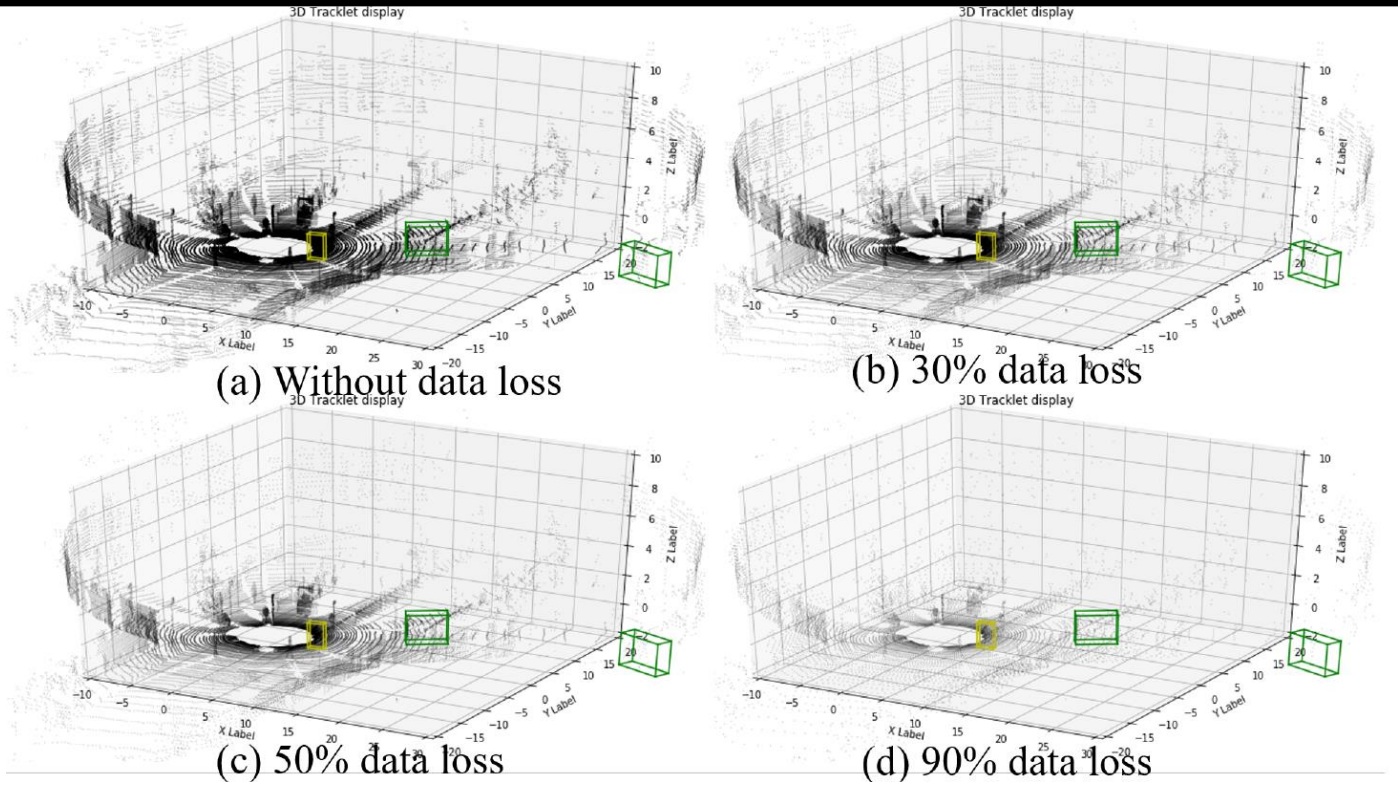


Bus only



• Inter-vehicle communication --- Packet Loss Ratio

- The dissemination of both **original point cloud data** (4,000,000 Bytes) as the **infotainment service** through VANET **Service Channel** (SCH);
- and the deep learning-based **object detection results** as the **Basic Safety Message** (BSM) (200 Bytes) through VANET **Control Channel** (CCH)



(a) Without data loss (b) 30% data loss

(c) 50% data loss (d) 90% data loss

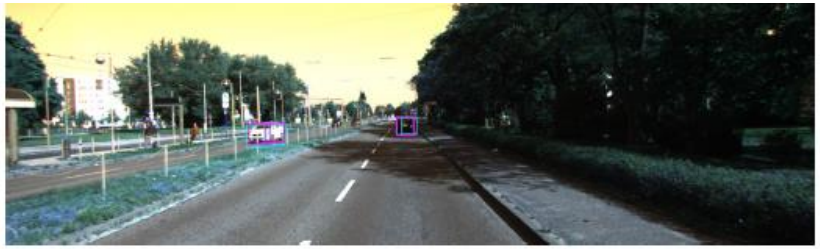
TABLE V: Packet Loss Ratio to the 3D point cloud data dissemination

Transmission power	16dBm	24dBm	28dBm
Transmission distance	100m	150m	200m
Packet Loss Ratio	90.03%	89.68%	89.63%

TABLE IV: Packet Loss Ratio to the 3D point cloud data dissemination

Packet Loss Ratio under vaiours transmission Power, different vehicle density and various transmission range																				
Txp	16dBm			18dBm			20dBm			22dBm			24dBm			26dBm			28dBm		
density / distance	S	M	C	S	M	C	S	M	C	S	M	C	S	M	C	S	M	C	S	M	C
50m	22.20	28.11	54.53	20.71	25.88	51.46	27.67	23.97	48.46	18.29	21.95	45.74	16.56	19.00	41.62	14.71	16.55	37.96	13.05	13.93	33.69
100m	46.27	58.08	80.57	45.24	56.78	79.26	50.05	55.67	77.98	43.58	54.59	76.74	42.38	52.28	75.05	41.10	51.34	73.46	39.96	49.81	71.60
150m	56.32	71.25	88.24	55.49	70.35	87.44	59.40	69.59	86.64	54.13	68.79	85.59	53.16	67.61	85.93	53.16	66.62	83.93	51.19	65.58	82.80
200m	63.48	78.86	91.96	62.79	78.19	91.41	60.06	77.64	90.88	61.65	77.05	90.37	60.84	76.18	89.67	60.84	75.46	89.01	59.19	74.68	88.24
250m	68.46	82.03	92.64	67.86	81.47	92.64	70.68	80.99	92.18	66.89	80.49	91.74	66.18	79.76	91.15	65.43	79.15	90.58	64.76	78.49	89.92
300m	70.64	83.45	93.62	70.08	82.93	93.19	72.70	82.49	92.77	69.16	82.03	92.36	68.51	81.35	92.39	67.81	80.79	91.28	67.19	80.18	90.67
350m	78.22	86.31	94.07	77.80	85.88	93.67	79.75	85.52	93.28	77.13	85.14	92.93	76.64	84.58	92.90	76.13	84.11	91.90	75.66	83.61	91.33
400m	78.22	86.31	94.07	77.80	85.88	93.67	79.75	85.52	93.28	77.13	85.14	92.93	76.64	84.58	92.90	76.13	84.11	91.90	75.66	83.61	91.33

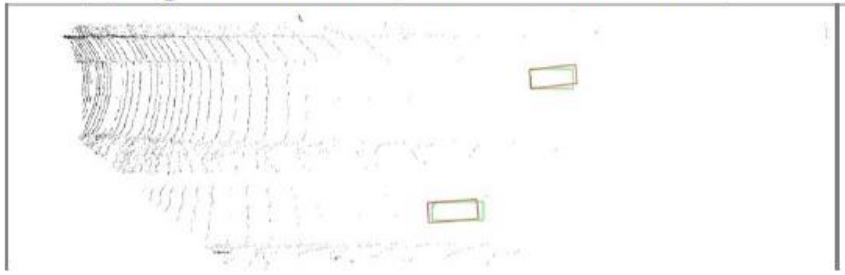
Feature Learning Network → Convolutional Middle Layers → Region Proposal Network



(a) Sparse traffic (Without data loss)

(b) Dense traffic (Without data loss)

(c) Urban scenario (Without data loss)

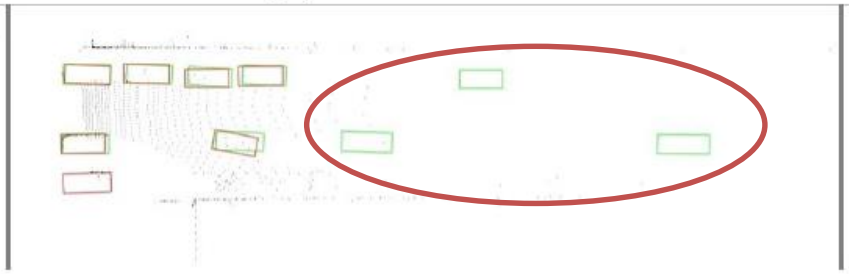


(d) 50% data loss

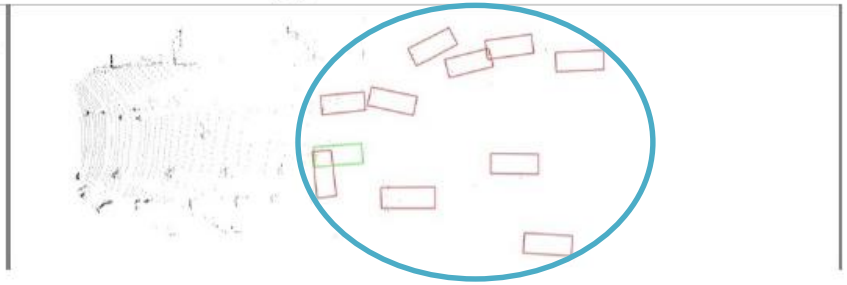
(e) 50% data loss

(f) 50% data loss

(g) 90% data loss



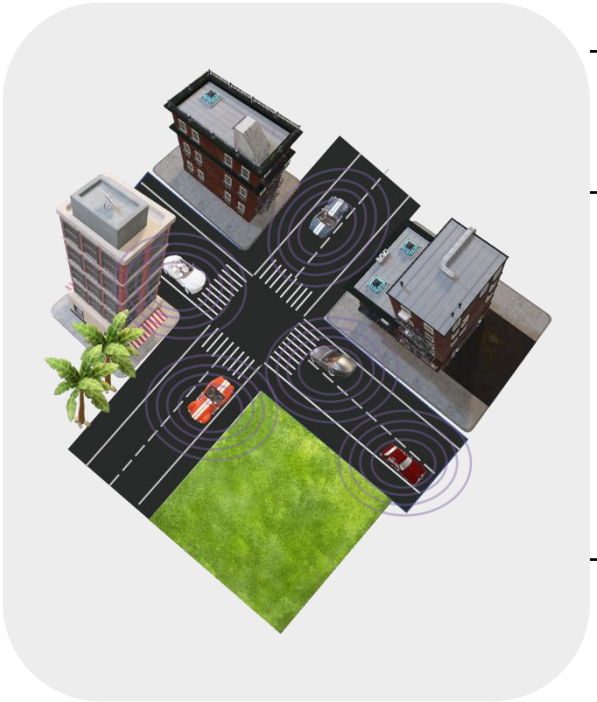
(h) 90% data loss

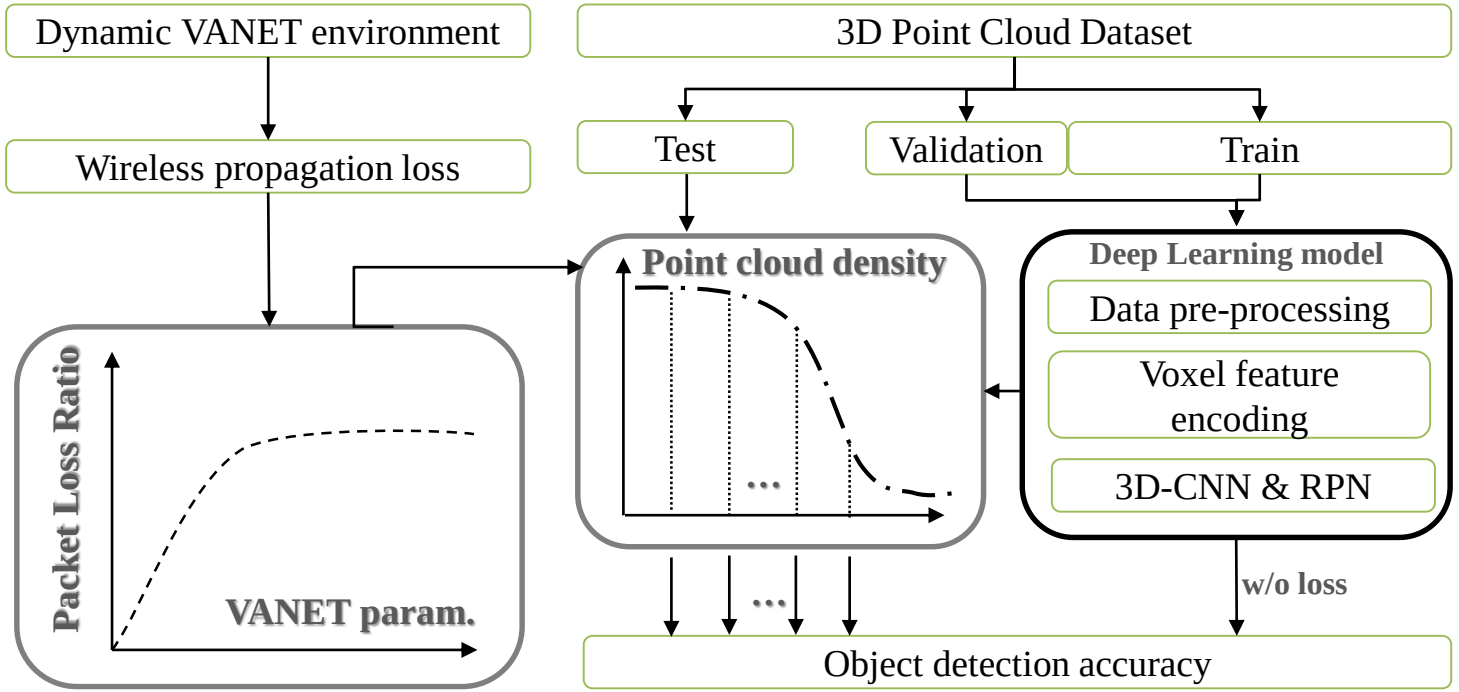


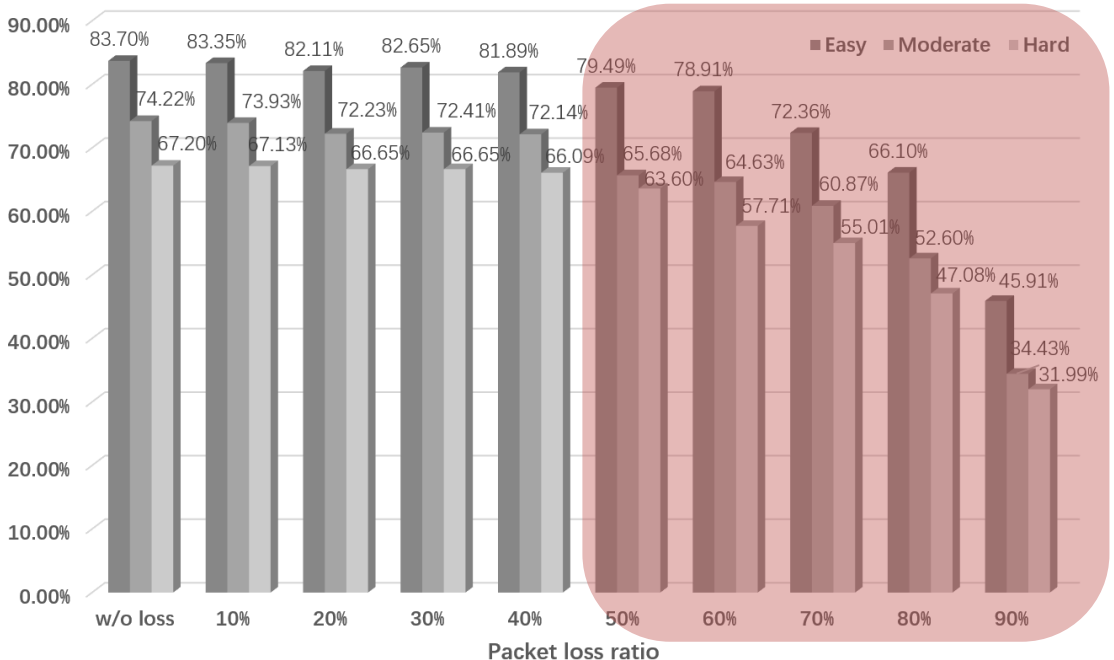
(i) 90% data loss

Fig. 3: Deep-learning-based object detection results with various packet loss degree. ((a, b, c) are qualitative results. We projected the point cloud detection results on RGB-images for better explanation.)

• Experiment Results (the effect of data loss to the deep learning-based object detection accuracy)







- The effect of **various Packet Loss Ratio** to the **deep learning-based** object detection **accuracy;**
- And we found that when **data loss beyond 50%** can lead to the **rapid decline** of the object detection **accuracy;**
- Based on our simulation, **more than 50% data loss** is a **common** scenario;

Major contributions:

- We propose **a system architecture** that integrates vehicular communications and deep-learning-based object detection for analyzing the impact of communication loss on 3D object detection;

- We build a **semi-realistic traffic scenario** to evaluate the amount of packet loss due to fading and signal attenuation in dense city like downtown Hong Kong.

- The **potential issue under this framework**: the VANET packet loss to the deep learning-based object detection accuracy and vehicular perception range.

Future work:

- Reducing the packet loss ratio through the global adjustment of inter-vehicle communications could be a straightforward way.

- Meanwhile, the interpretability of the deep neural network is also important to avoid the opacity of the decision-making process.

Thank you!