

# ThinGs In a Fog: System Illustration with Connected Vehicles

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# TGIF Architecture

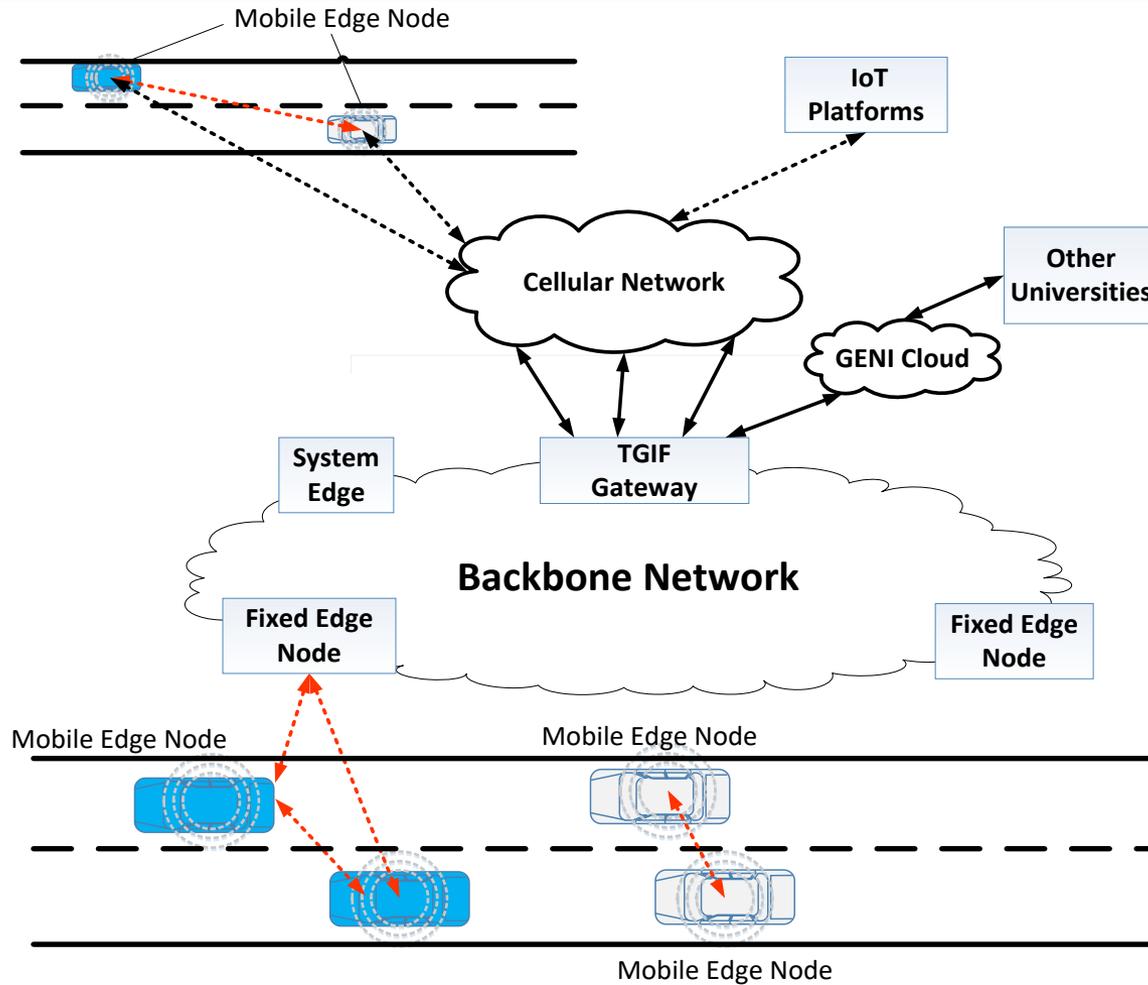
**Machine Node (MN):** An IoT device that does not support the TGIF middleware. TGIF includes gateway services to support a set of Machine Nodes.

**Fixed Edge Node (FEN):** that is logically similar to a MEN but offers greater processing capabilities, support for a wired backhaul (if available at the location), and includes an RSU rather than an OBU and capable of interfacing with different sensors not limited to vehicle data, weather, road hazards etc

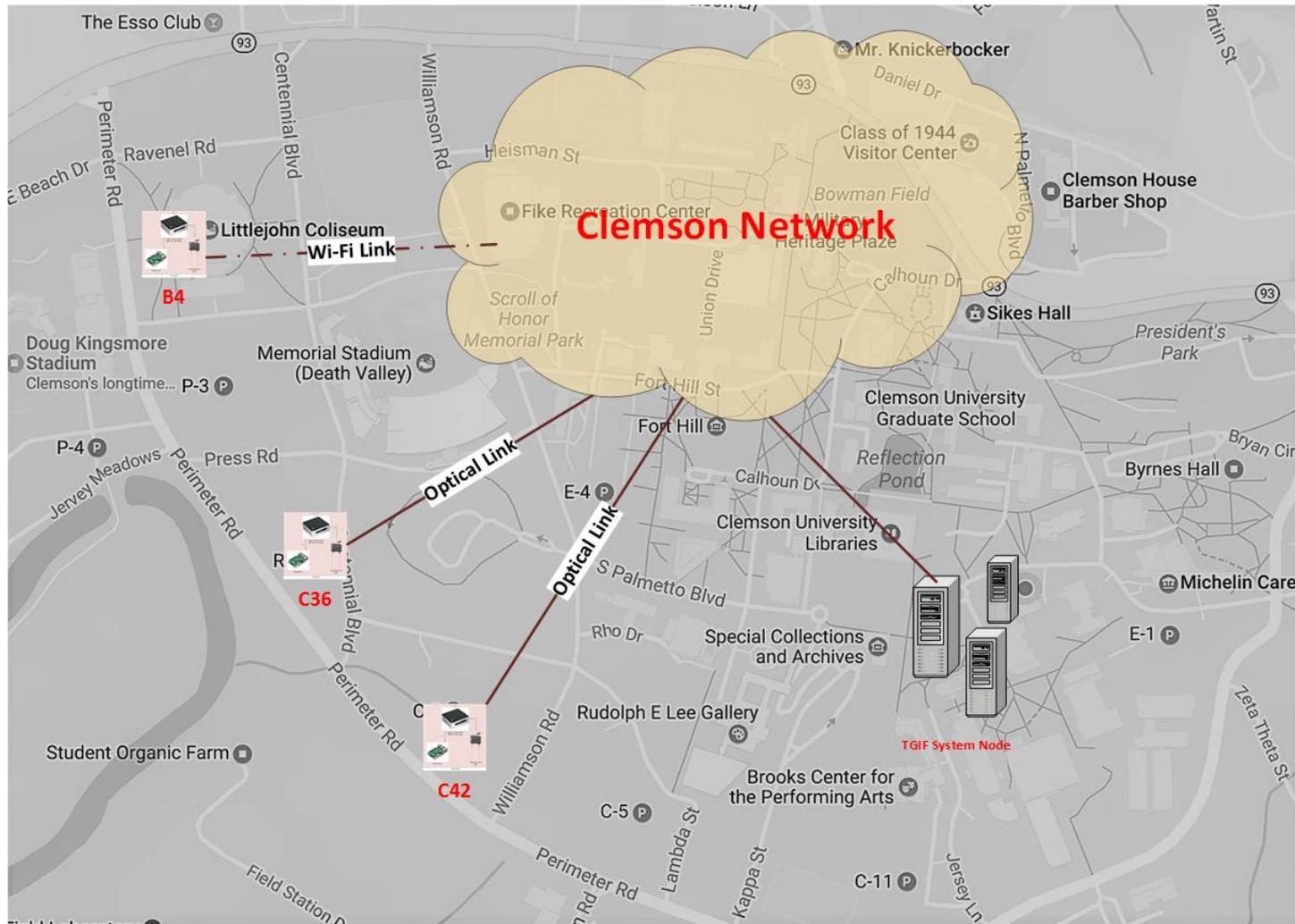
**Mobile Edge Node (MEN):** Edge computing capability added to mobile units such as vehicle or low flying drones. These are capable of supporting Heterogeneous Networks and can leverage Wi-Fi, LTE or DSRC through other nodes.

**System Node Node (SEN):** An end point for data generated and computed locally within the realm of TGIF, also supports third party application interfaces such as DOT, user applications etc. Provide services for global networking, data collection etc

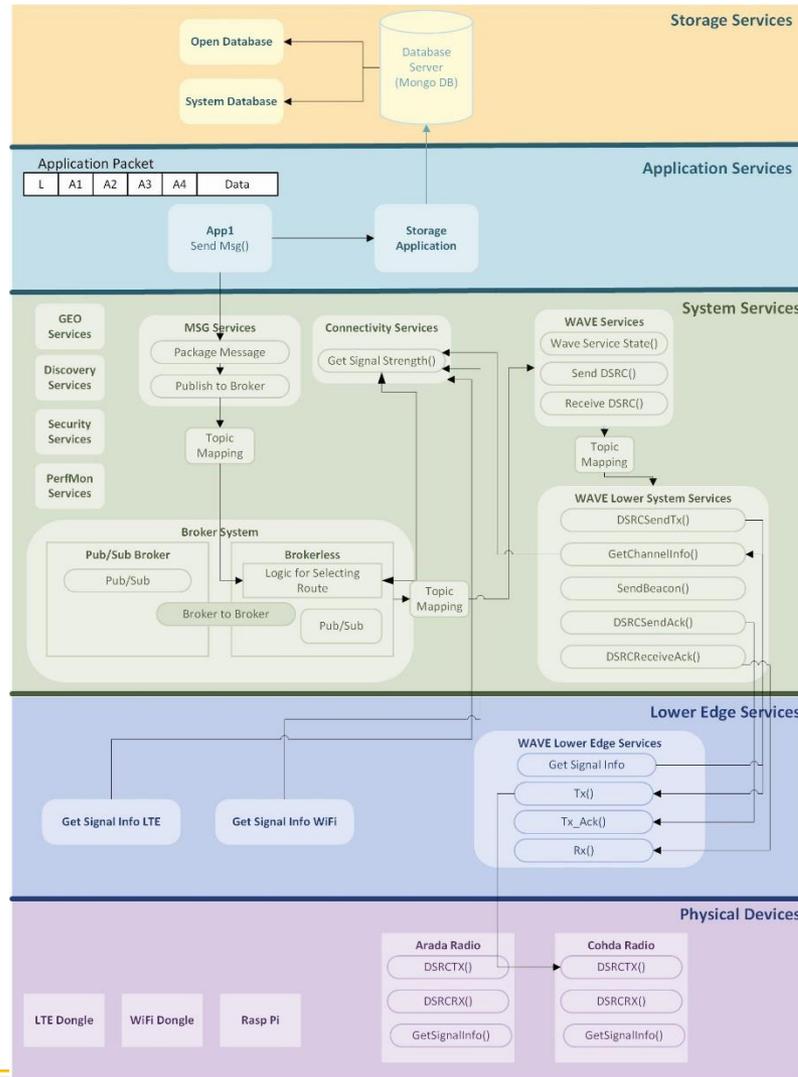
# TGIF Architecture



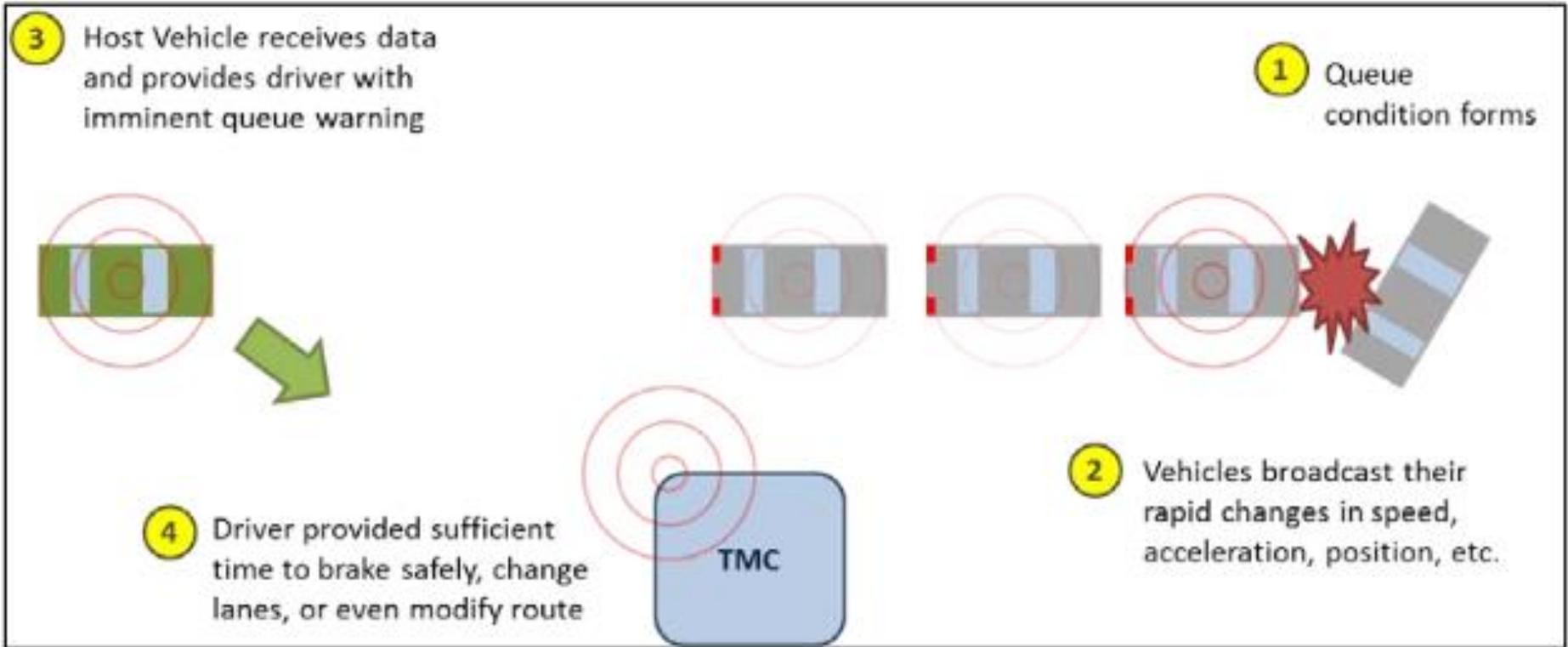
# TGIF Connected Vehicle Testbed



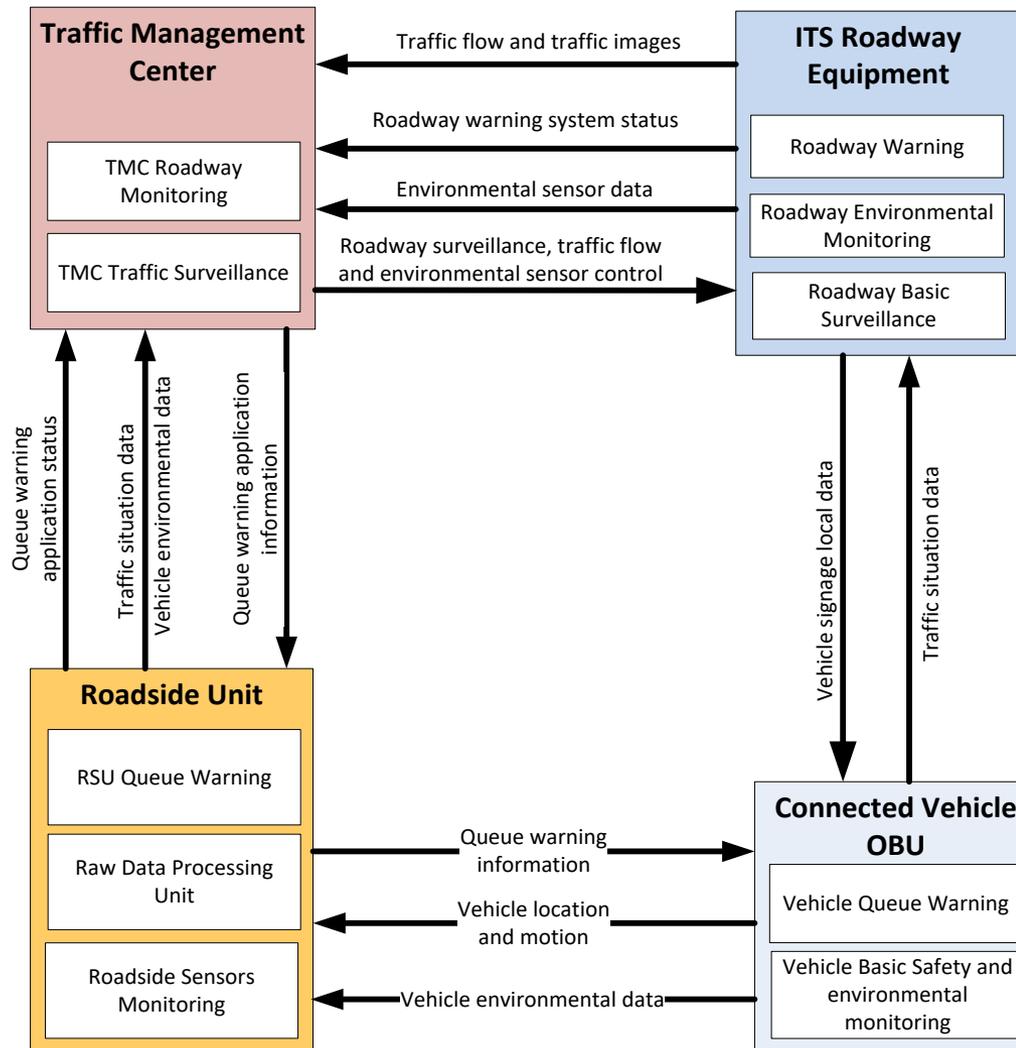
# TGIF Software System Diagram



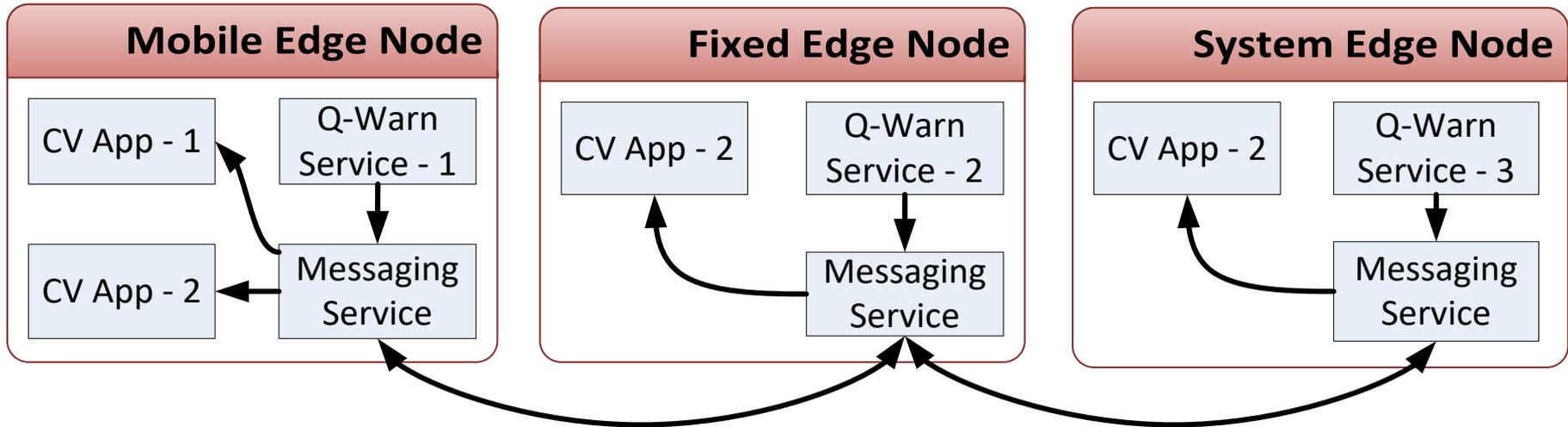
# Queue Warning Application



# USDOT Reference for Queue Warning Application

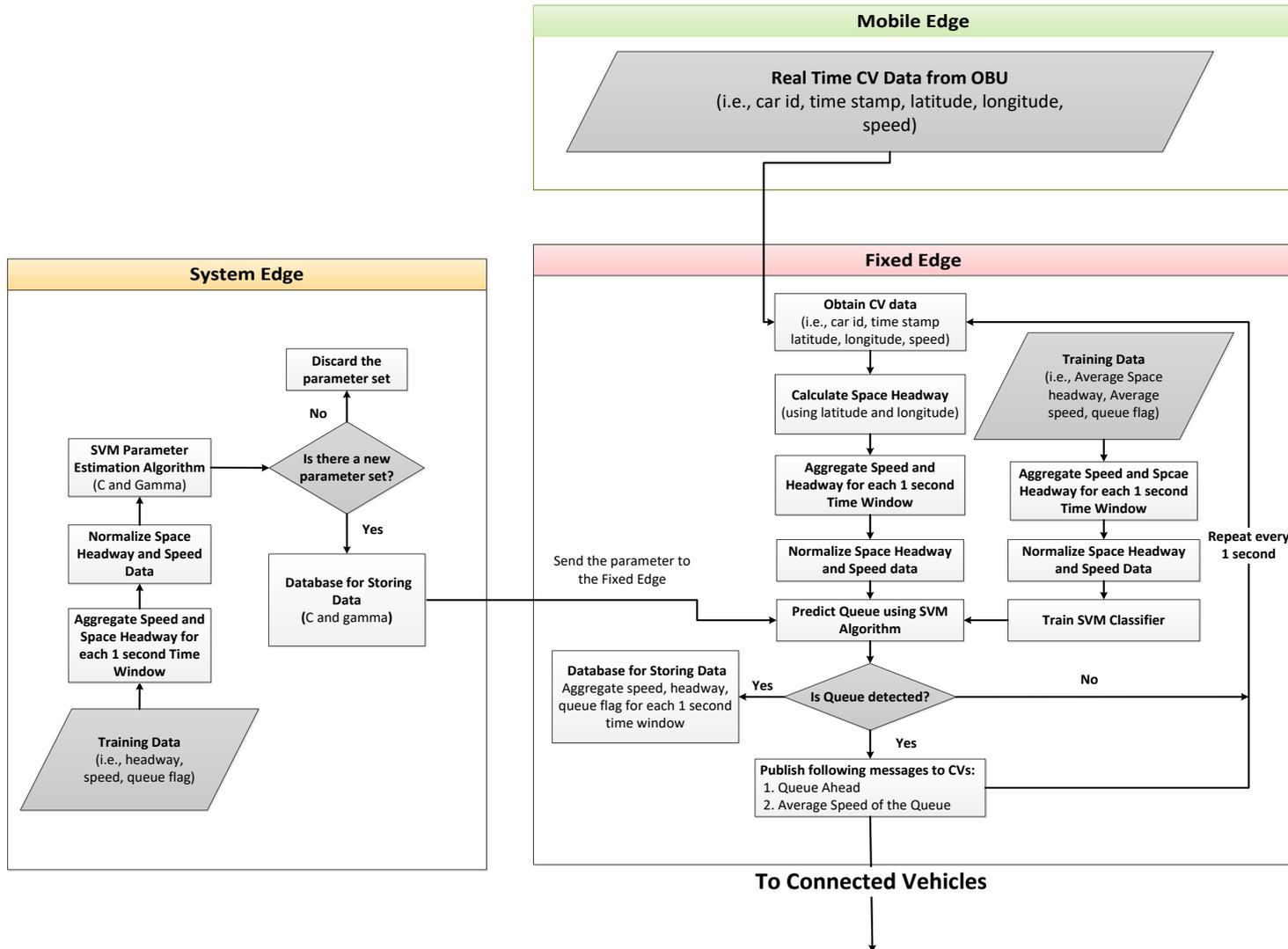


# High Level Design of Queue Warning Services

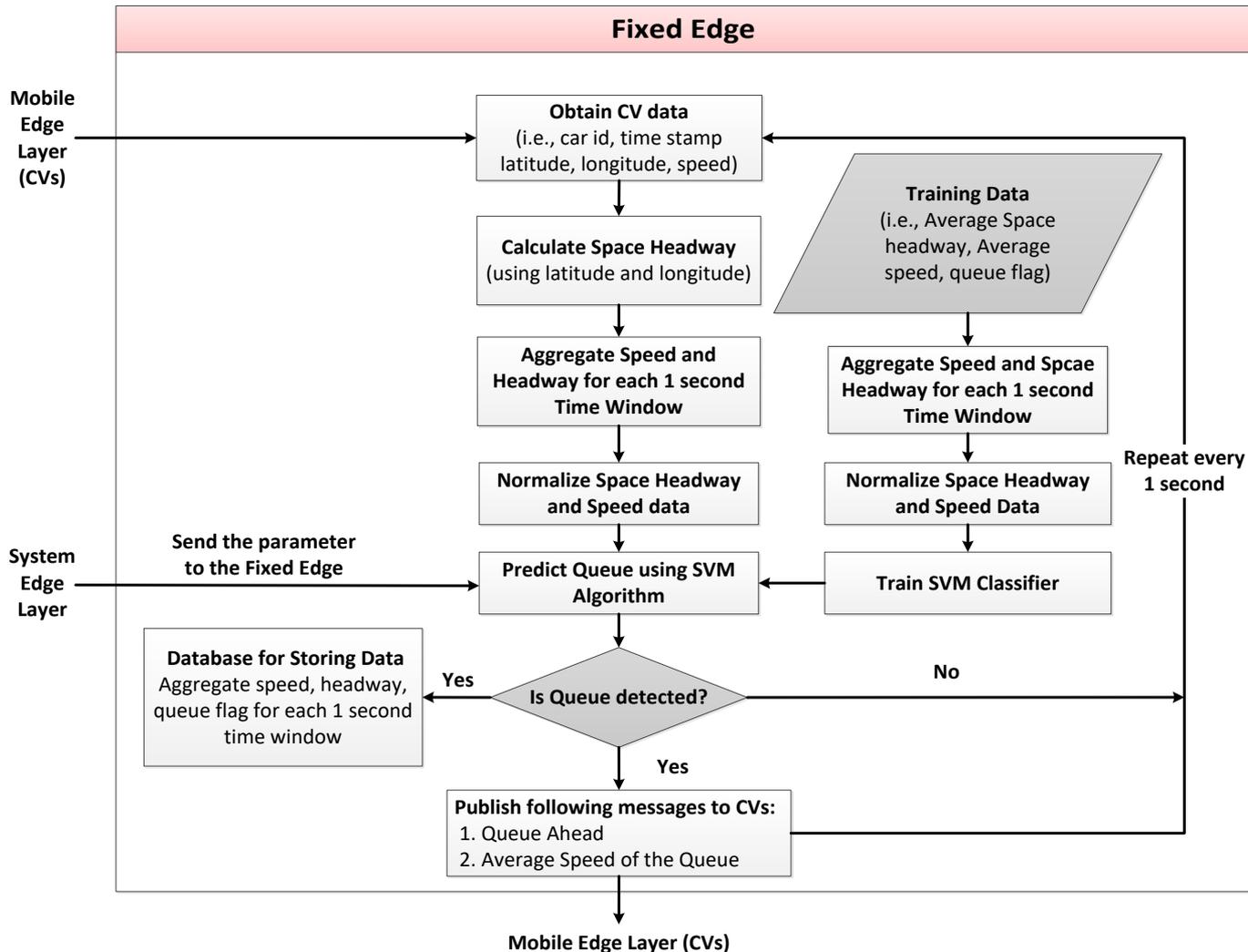


**In our system, we have three different perspectives for queue warning service: 1) Q-Warn service at vehicle level (CV OBU), 2) Q-Warn Service at Fixed Edge node (i.e., roadside unit), and 3) Q-Warn service at System Edge node (i.e., TMC).**

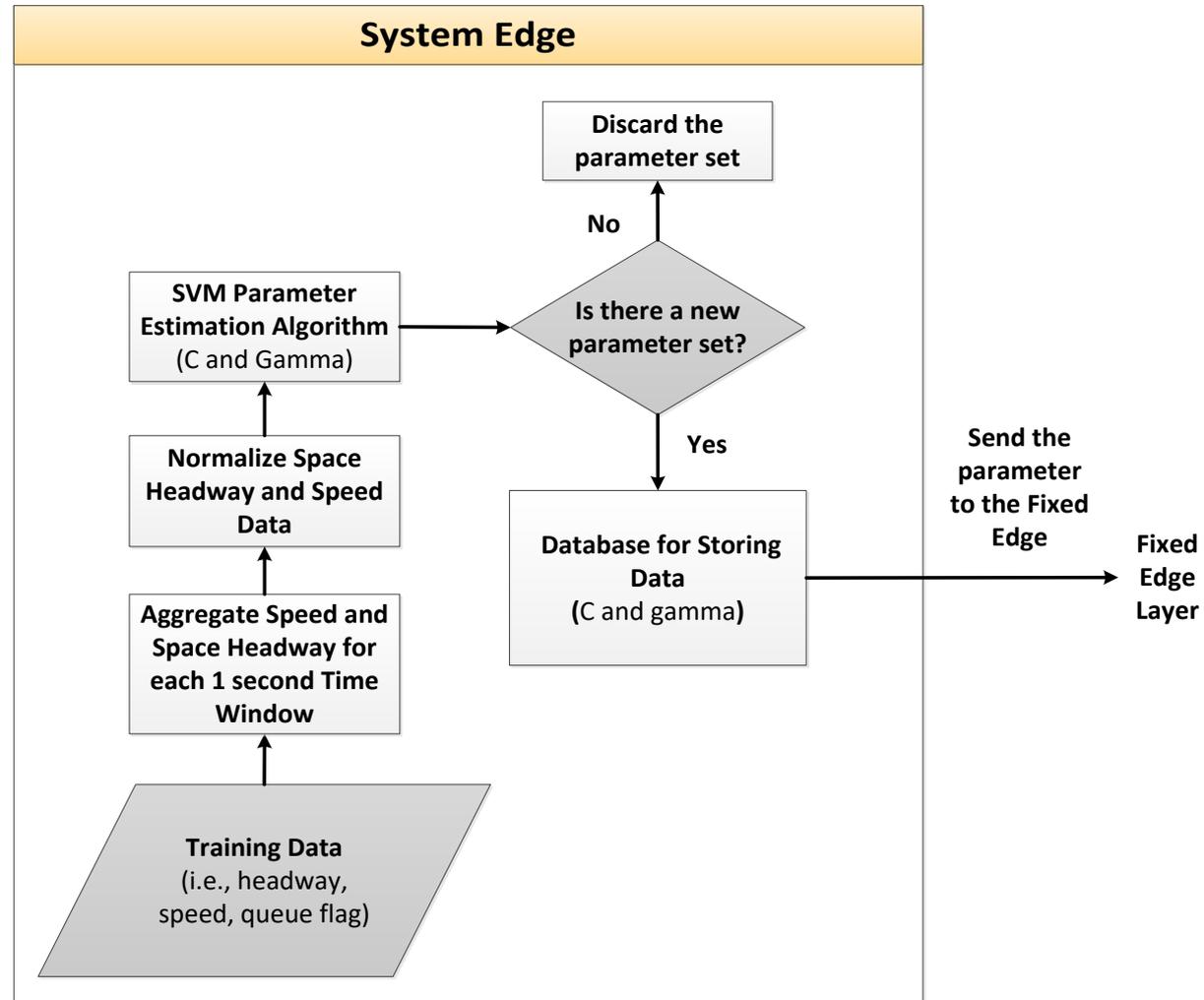
# Queue Warning Algorithm



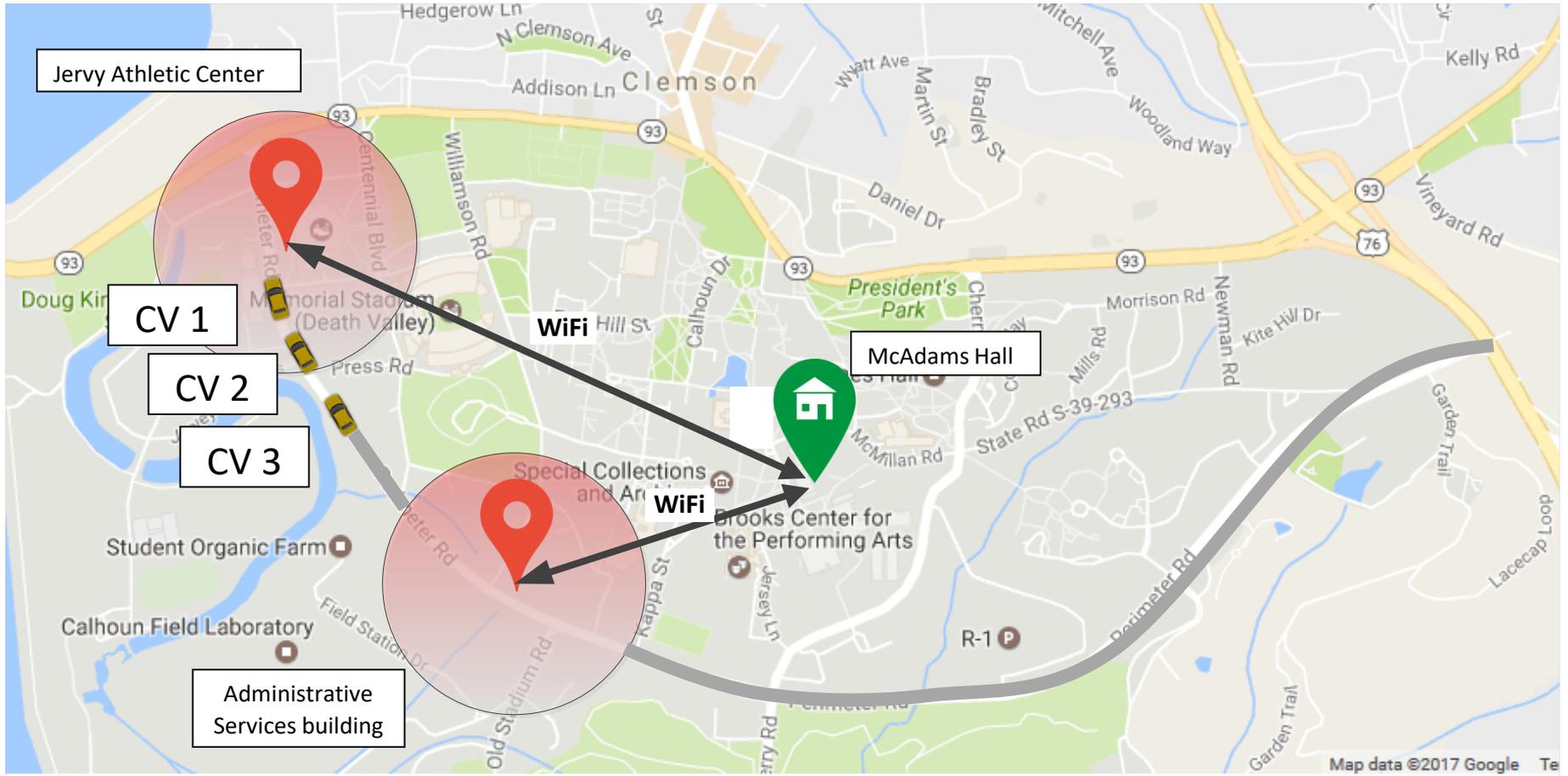
# Research Method: CPS based Queue Warning Algorithm



# TGIF based Queue Warning Algorithm



# Field Deployment of Queue Warning in TGIF System



System Edge



Fixed Edge

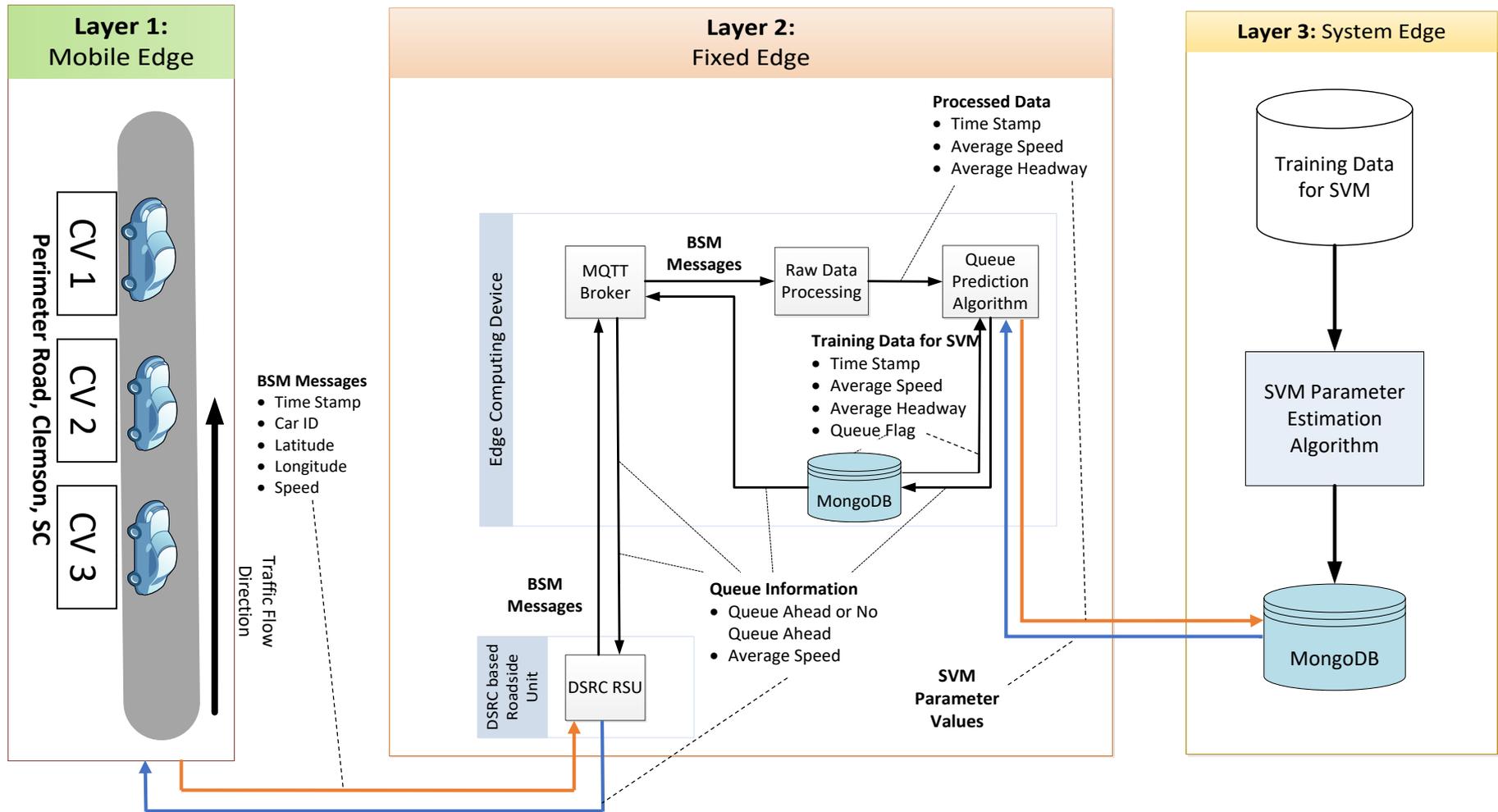


Mobile Edge

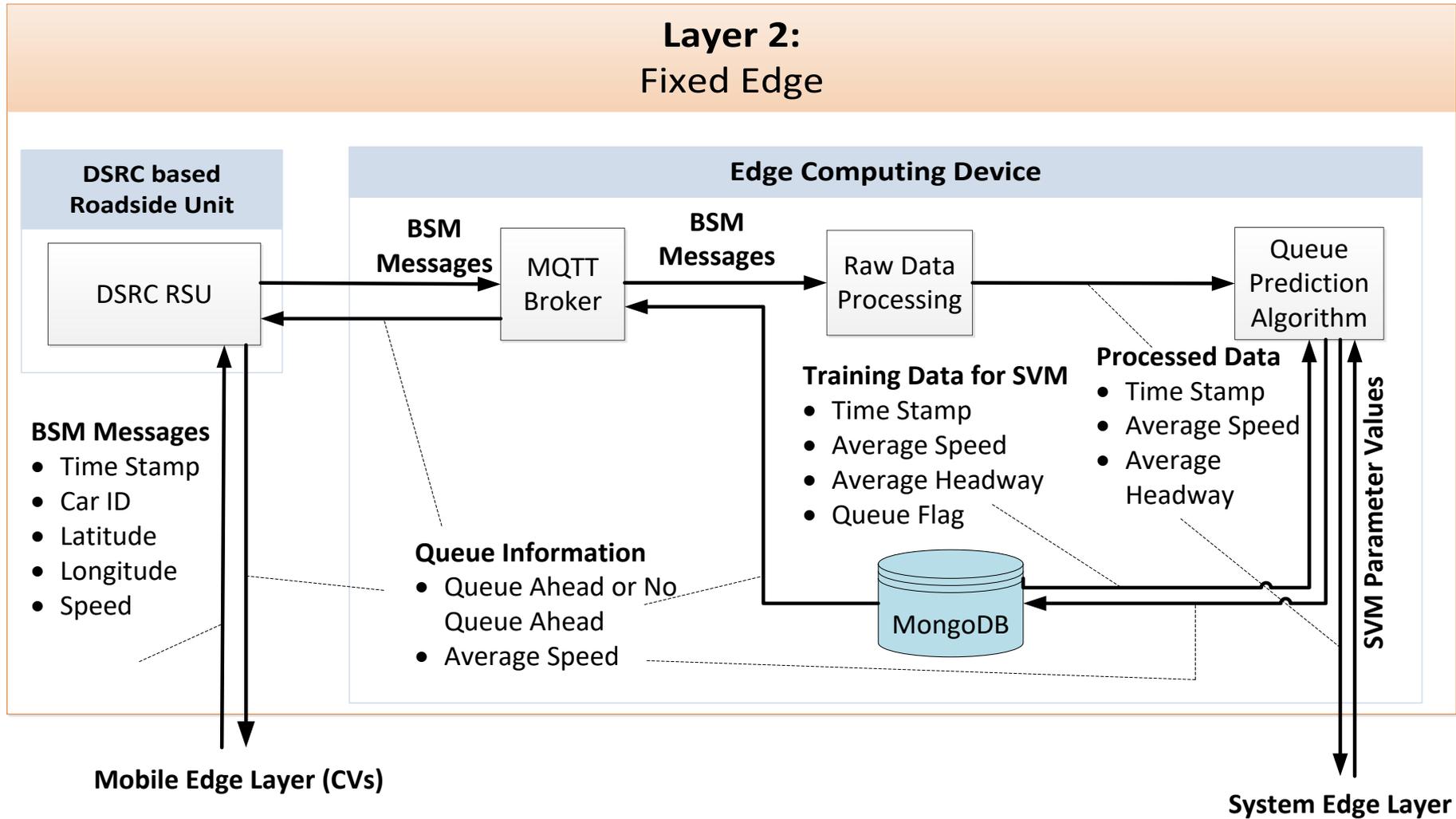


DSRC Coverage

# Experimental Set-up: Queue Warning Application Algorithm



# Experimental Set-up: Queue Warning Application Algorithm



# Preliminary Results: Sample Basic Safety Messages (BSMs)

Car ID	Time Stamp	Latitude	Longitude	Speed (mph)
3	1483118940394	34.680788	-82.847857	28
2	1483118940796	34.680788	-82.847755	30
1	1483118940949	34.679973	-82.847697	24
3	1483118941440	34.680673	-82.847839	30
2	1483118941873	34.680014	-82.847732	31
1	1483118941985	34.679676	-82.847681	25
3	1483118942517	34.680522	-82.847816	32
2	1483118942910	34.679888	-82.847711	32
1	1483118943022	34.679572	-82.847665	27

**Connected vehicle data are collected from each vehicle (Mobile Edge) one tenth of a second.**

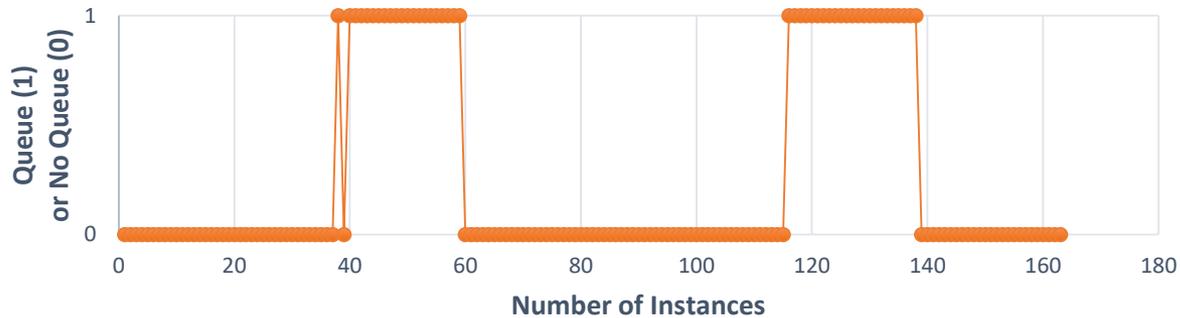
# Preliminary Results: A Sample Queue Prediction Results

Average Speed (mph)	Average Space Headway (ft)	Average Gap between two immediate CV vehicles (ft)	Cyber-physical system based Algorithm	Field Data (using video Camera)
29	95	80	0	0
31	97	82	0	0
27	82	67	0	0
25	87	72	0	0
18	89	74	0	0
11	66	51	0	0
18	69	54	0	0
11	73	58	0	0
9	67	52	0	0
9	46	31	0	0
4	43	28	1	1
4	41	26	0	1
2	36	21	1	1
2	35	20	1	1
0	33	18	1	1
0	30	15	1	1
0	29	14	1	1

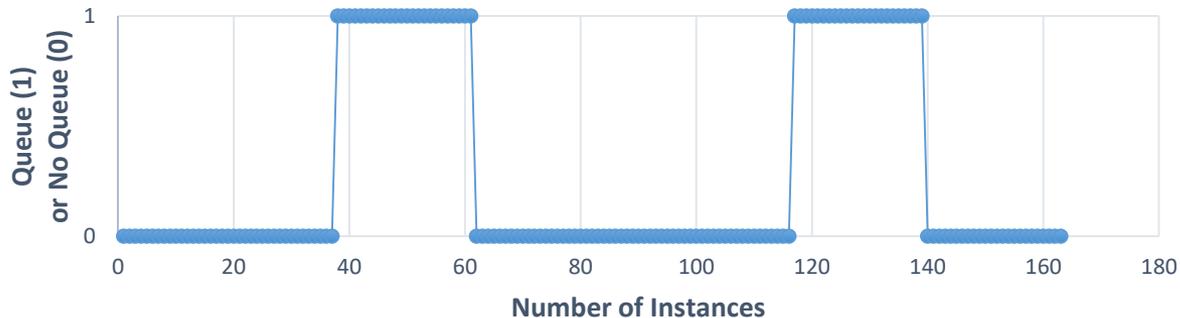
No queue =0

Queue =1

# Preliminary Results: Queue Prediction Results



—●— TGIF based Queue Warning Algorithm



—●— Field Data (using video Camera)

**The accuracy of TGIF based queue warning algorithm is 94%.**

# Conclusions

- We introduced the TGIF system framework, and illustrated the concept in more detail by summarizing work-to-date on the design and implementation of the Queue Warning application.
- TGIF was developed by necessity to support our research.
- The novelty of our work is more likely our illustrative example of how an emerging CV systems might coexist and integrate with an IoT system based on an Edge Computing model.
- We will provide a thorough description and evaluation of TGIF with several illustrate applications from multiple application domains. We also plan to make TGIF available to the community as an open source project.



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