IoTcloudServe@TEIN 3rd Collaboration Community Meeting
8 September 2020, Thailand-Laos-Korea

Smart-Mobility@Chula: Towards Data-Centric Approach in Traffic Flow Management Enhancement of Rama-4 Road Network

Associate Prof Dr Chaodit Aswakul

Wireless Network and Future Internet Research Unit

Department of Electrical Engineering, Faculty of Engineering

Chulalongkorn University, Bangkok, Thailand

Bangkok (Thailand)

- **Registered vehicles (Feb 2018)**
  4.8M cars + 0.2M buses + 4.7M motorcycles = 9.7M vehicles

- **Bangkok area: 1,569 squared-km (~ 50 EW-km x 30 NS-km)**

- **Estimated Bangkok metropolitan area population 16M (National Statistics Office: 2017)**

- **Tomtom traffic index (March 2016):**
  - **Bangkok is the most congested city in Asia and 2nd most congested city globally**
  - **Extra travel time 64 min. / daily commute**

CHULA ENGINEERING
Foundation toward Innovation

GIST

NECTEC
a member of NSTDA

UNIVERSITY OF MALAYA

Asi@Connect

European Union

TEIN CC
COOPERATION CENTER

IoT
cloudserve
@TEIN

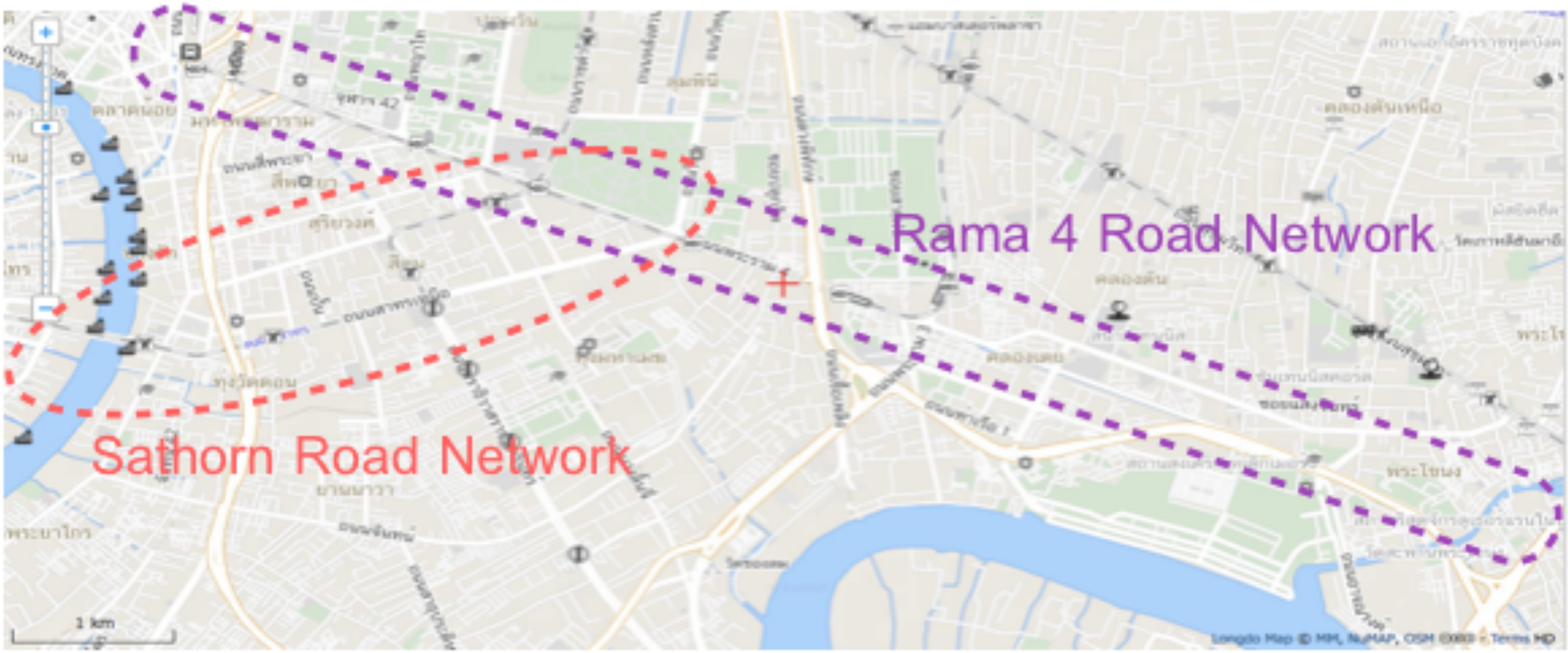
IoTcloudServe@TEIN
Smart-Mobility@Chula (2018-2020)
as connecting enabler

from Sathorn Model Project (2015-2017)
towards Rama-4 Model Project (2020-2021)

Sathorn Model Project (2015-2017)
Rama-4 Model Project (2020-2021)

- ***Main Collaborators:***
  - ***Chulalongkorn University***
  - ***Toyota Thailand, Toyota R&D Lab (Japan)***
  - ***Ministry of Transport***
  - ***Bangkok Metropolitan Administration***
  - ***Metropolitan Police Bureau***
  - ***Private Companies***
- ***Support by Toyota Mobility Foundation in Sustainable Mobility Project 2.0 of the World Business Council for Sustainable Development (WBCSD)***

Area of Interest under MOA for Rama-4 Model Project (TMF, Chula, BMA, MOT, MPB)



Interconnection of Sathorn and Rama 4 road networks

2 Needs

- ***Need for sensors to facilitate informed and better traffic signal operations***
- ***Need for logics to use real-time sensor data in traffic light operations***

Demo-Site Architecture of Smart-Mobility@Chula in IoTcloudServe@TEIN Project

Smart-mobility@Chula Analytics (Road Deadlock Detection)

IoTcloudServe@TEIN

Service Platform

KAFKA

Testbed Infrastructure (Data Lake)

IoT-cloud Storage

Compute Analytics Pool

IoT Access Gateway

Image-stream monitoring in real-time road traffics

SDN control messages

ThaiREN

Client

Local SDN Controller

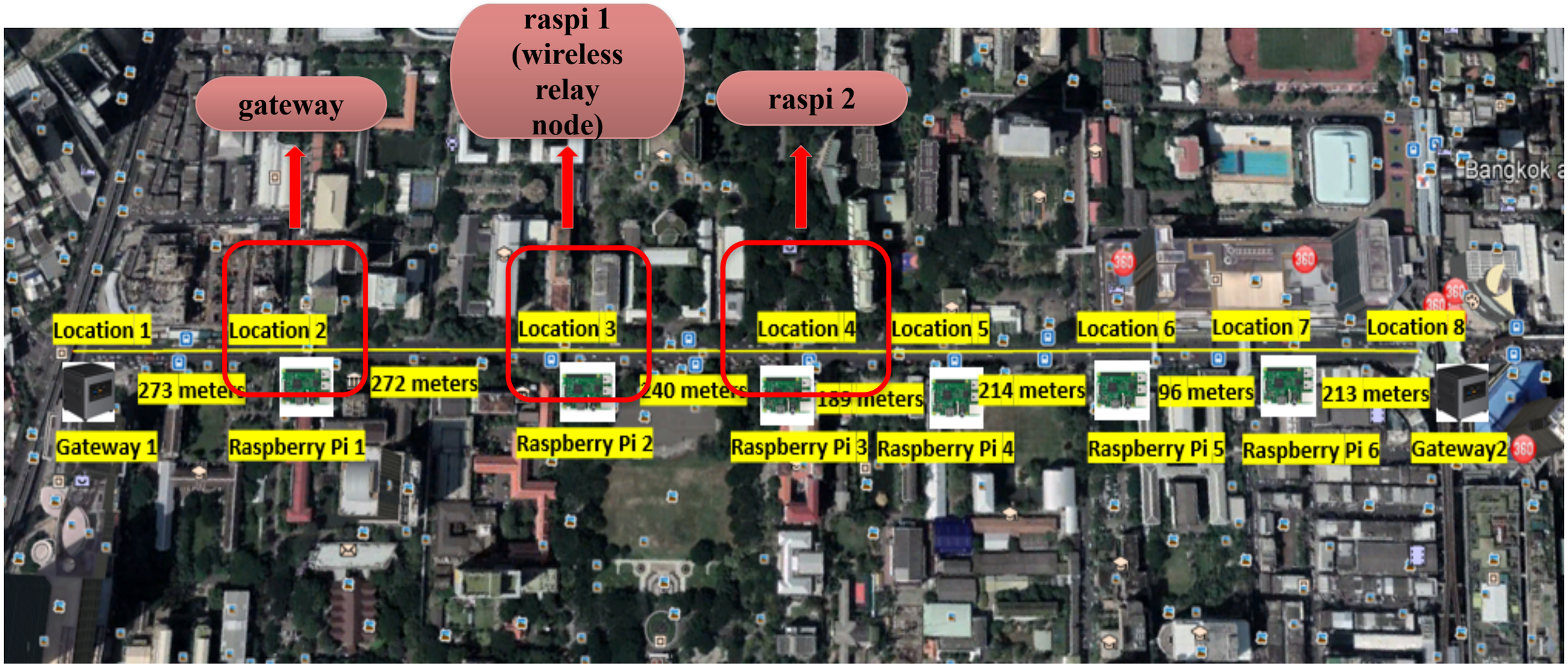
Gateway 1

Gateway 2

Compute box (KAFKA brokers + SDN-controlled OVS + wireless ad hoc link + network interface to central cloud) installed at target intersections with traffic police operating traffic signal controllers

KAFKA producer (PI + Camera) + SDN-controlled OVS + wireless ad hoc interface
Distributively installed along all approaching roads to critical intersections

Outdoor SDWMN Testbed With Multi-Hop Routing



Typical installation scenario of outdoor SDWMN to monitor road network traffic (e.g on Phaya Thai road, Bangkok)

Outdoor SDWMN testbed at PhayaThai road, Bangkok (cont.)

Equipment of gateway

Equipment of wireless mesh node

2 Selected Demos of Smart-Mobility@Chula

Prototyping Small-Scaled Resilient Software-Defined Wireless Mesh Network with Dual-Band Data and Out-of-Band Control Planes (10 minutes)

- Miss Phoo Phoo Thet Lyar Tun
Wireless Network and Future Internet Research Unit
Department of Electrical Engineering, Faculty of Engineering
Chulalongkorn University, Thailand

Simulated Demonstration of WiFi-Based Road Traffic Monitoring Application Using Software Defined Wireless Mesh Network (10 minutes)

- Mr Meechai Homchan
Wireless Network and Future Internet Research Unit
Department of Electrical Engineering, Faculty of Engineering
Chulalongkorn University, Thailand

Analytics Engine

***Traffic-signal-sensor simulator* tool**

allows traffic engineers and traffic police

to experiment and to select

best sensor-based traffic light operation logics

and perform effective incident detection/mitigation

CHULA ENGINEERING
Foundation toward Innovation

GIST

NECTEC
a member of NSTDA

UNIVERSITY OF MALAYA

Asi@Connect

TEIN CC
COOPERATION CENTER

sathorn_w.sumo.cfg - SUMO 0.25.0

File Edit Settings Locate Simulation Windows Help

Time: Delay (ms): 0

custom_1

Partial map of Bangkok

Edit Viewport...

Zoom: 100.0000
X: 6260.2
Y: -6758.64

OK Cancel

0m 1000m

Warning: Vehicle '10.219' ends teleporting on edge 'L40274', time 54084.00.
Warning: Vehicle '39.96' ends teleporting on edge 'L40274', time 54084.00.
Warning: Vehicle '39.96' ends teleporting on edge 'L40274', time 540[illegible]

'C:\Users\SHALINI\Desktop\sathorn model\server\SUMO\sathorn_w.sumo.cfg' loaded. x:15855.59, y:-8817.97 x:16142.35, y:-20682.22

Sathorn Road Network in SUMO

IoT cloudserve @TEIN

CHULA ENGINEERING
Foundation toward Innovation

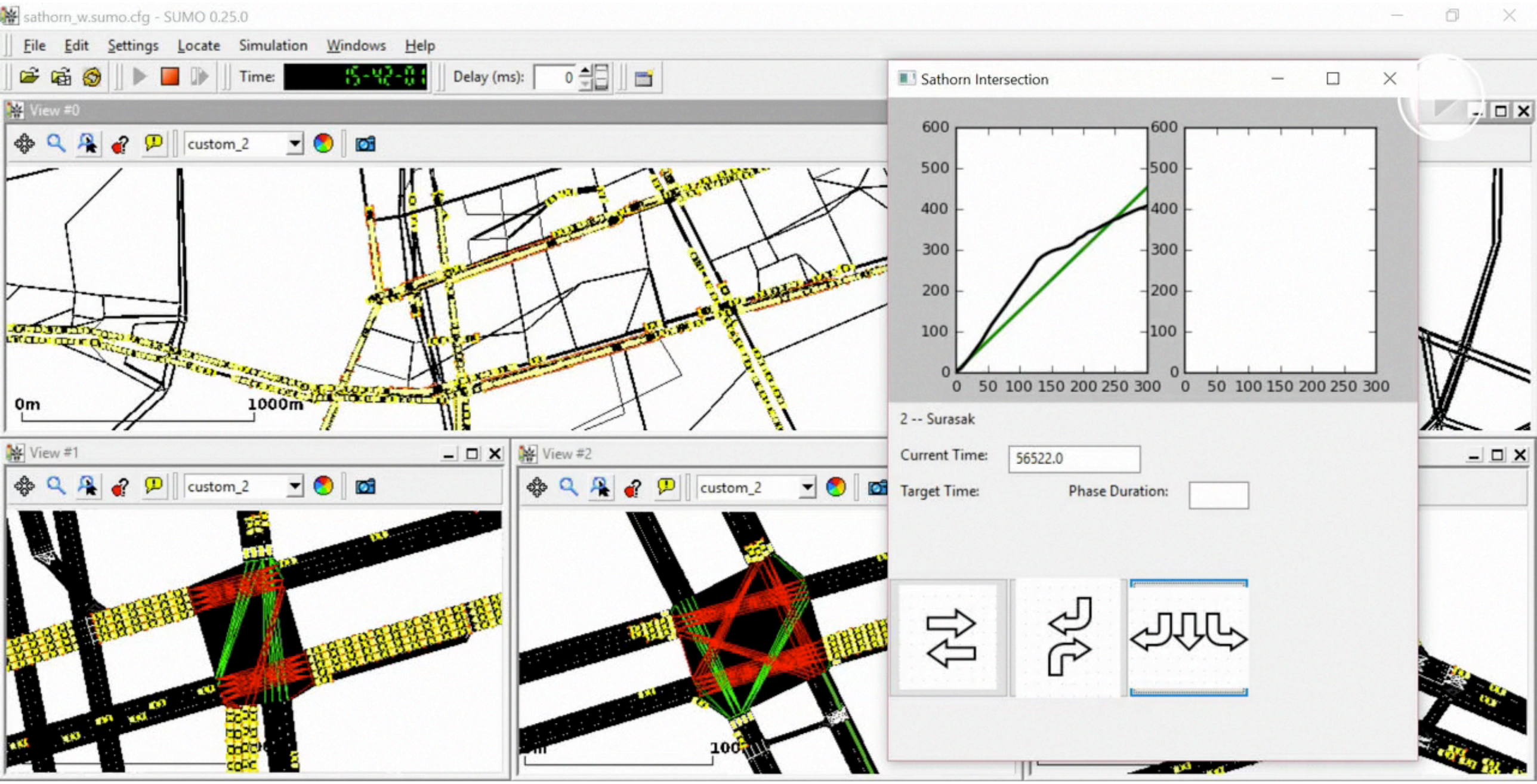
GIST

NECTEC
a member of NSTDA

UNIVERSITY OF MALAYA

Asi@Connect

TEIN CC
COOPERATION CENTER



Chula-SSS Ideation-Phase Demo

IoT cloudserve @TEIN

EPiC Series in Computing, vol. 62, pp. 29-47, 2019

Reinforcement Learning Agent under Partial Observability for **Traffic Light Control** in Presence of **Gridlocks**

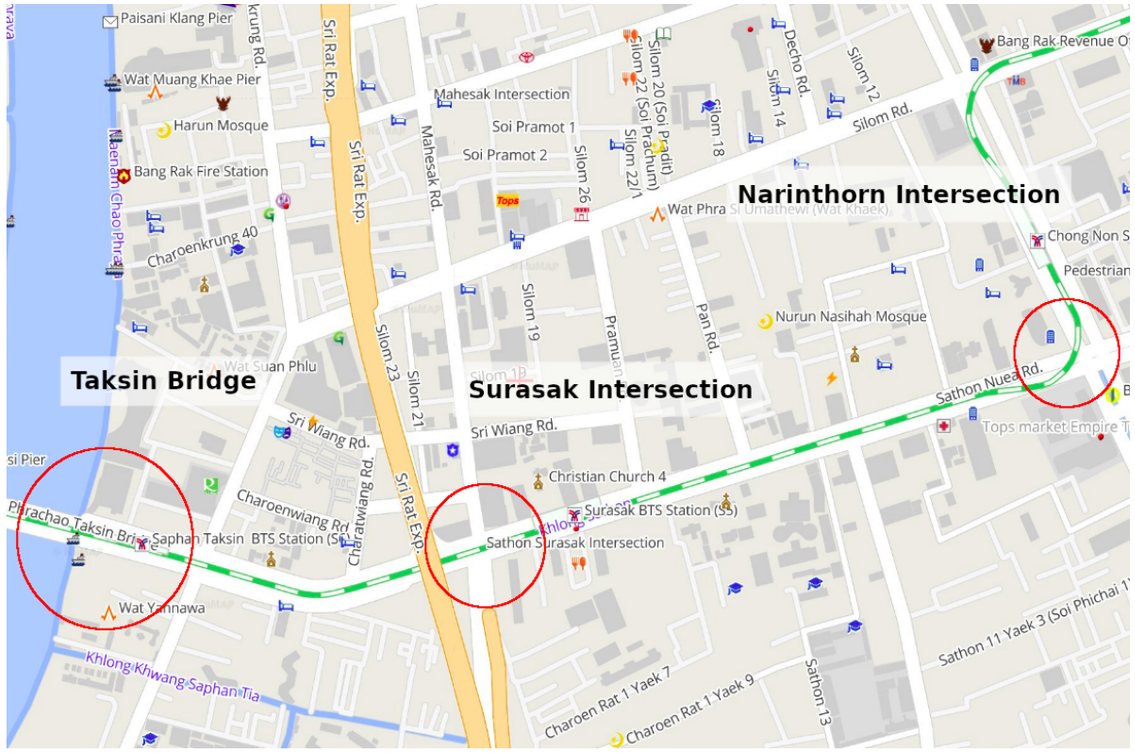
Thanapapas Horsuwan[1], Chaodit Aswakul[2]

[1] International School of Engineering, Faculty of Engineering, Chulalongkorn University
[2] Wireless Network and Future Internet Research Unit, Department of Electrical Engineering, Faculty of Engineering, Chulalongkorn University

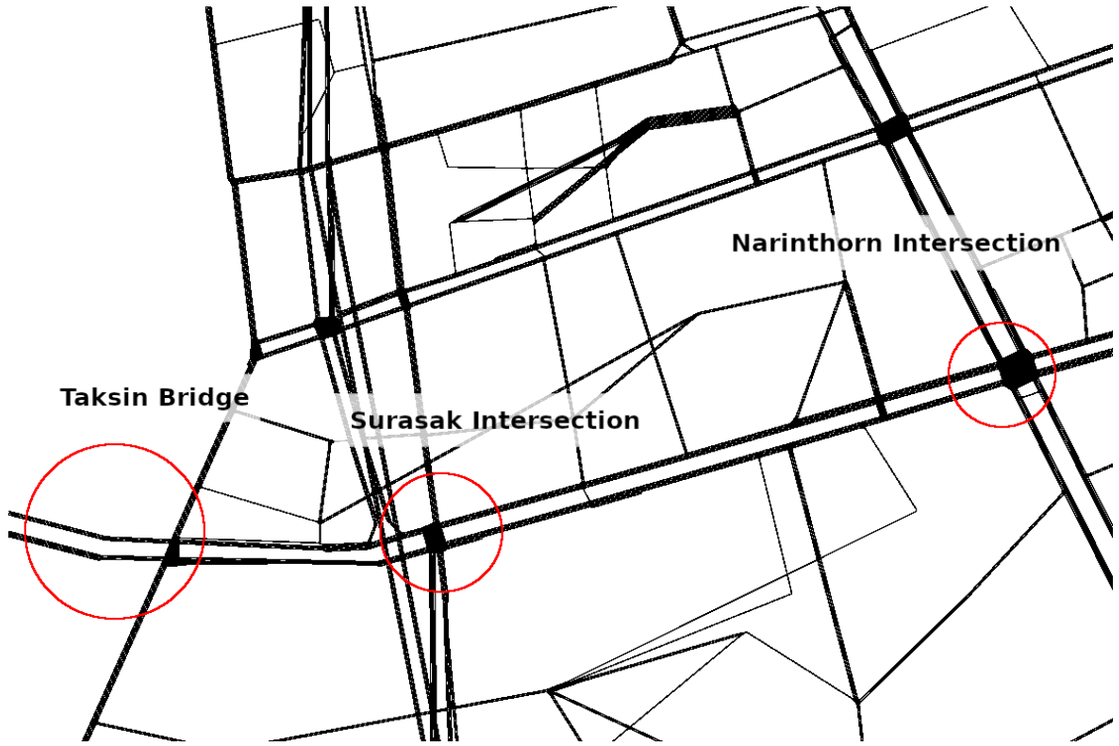
Traffic Gridlocks

queue length spill-back propagates in a closed loop, resulting in a complete standstill

Chula-Sathorn SUMO Simulator (Chula-SSS)



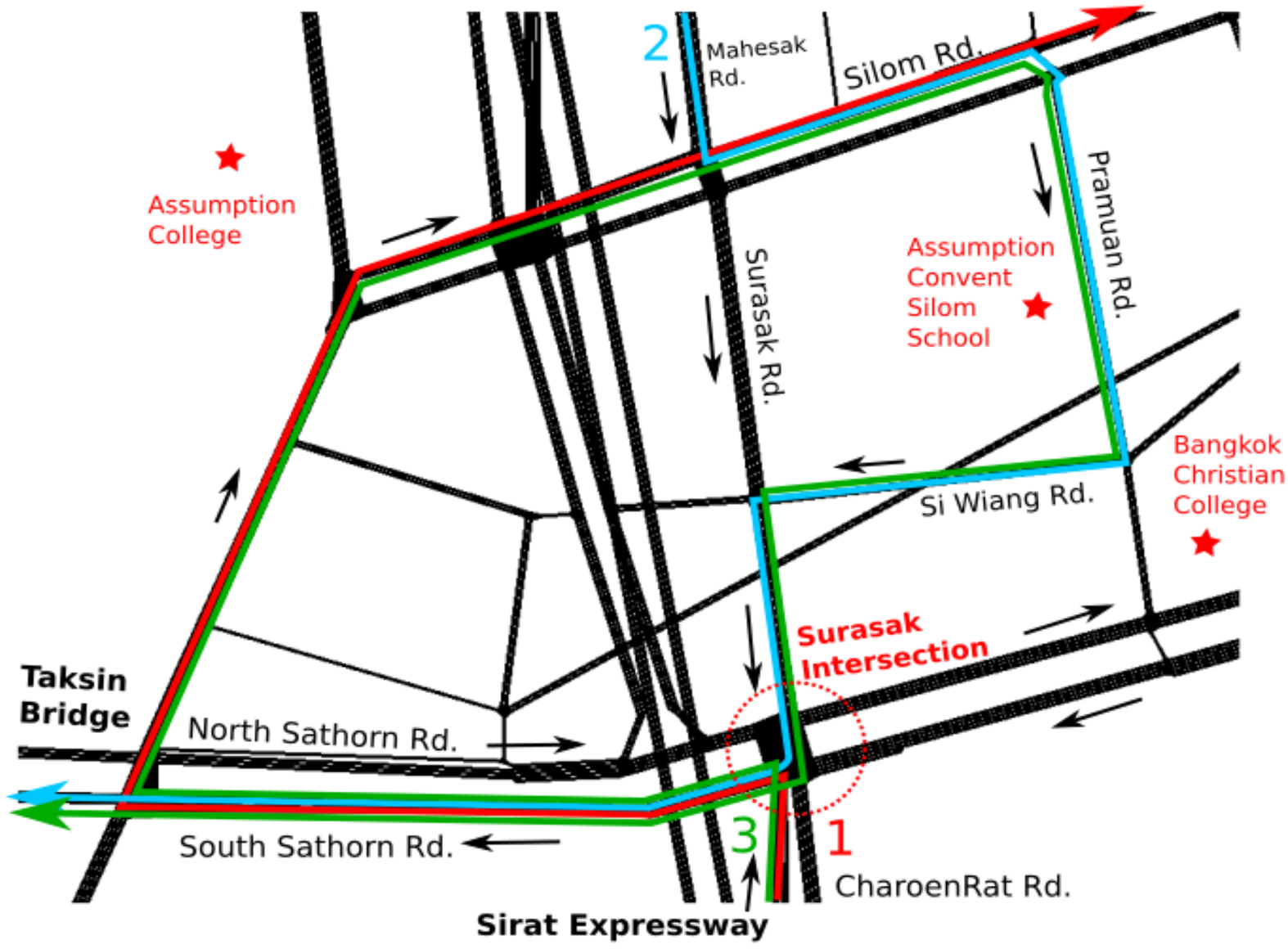
(a) Longdo Map (with granted usage permission from http://map.longdo.com/



(b) Chula-SSS dataset in SUMO

Comparison between actual map and Chula-SSS dataset in the Sathorn Road Area

Chaodit Aswakul, Sorawee Watarakitpaisarn, Patrachart Komolkiti, Chonti Krisanachantara, and Kittiphan Techakittiroj. Chula-SSS: Developmental Framework for Signal Actuated Logics on SUMO Platform in Over-Saturated Sathorn Road Network Scenario. In *SUMO 2018- Simulating Autonomous and Intermodal Transport Systems*, volume 2 of EPiC Series in Engineering, pages 67–81. EasyChair, 2018



Critical Routes in the Sathorn Network

CHULA ENGINEERING
Foundation toward Innovation

GIST

NECTEC
a member of NSTDA

UNIVERSITY OF MALAYA

Asi@Connect

TEIN CC
COOPERATION CENTER

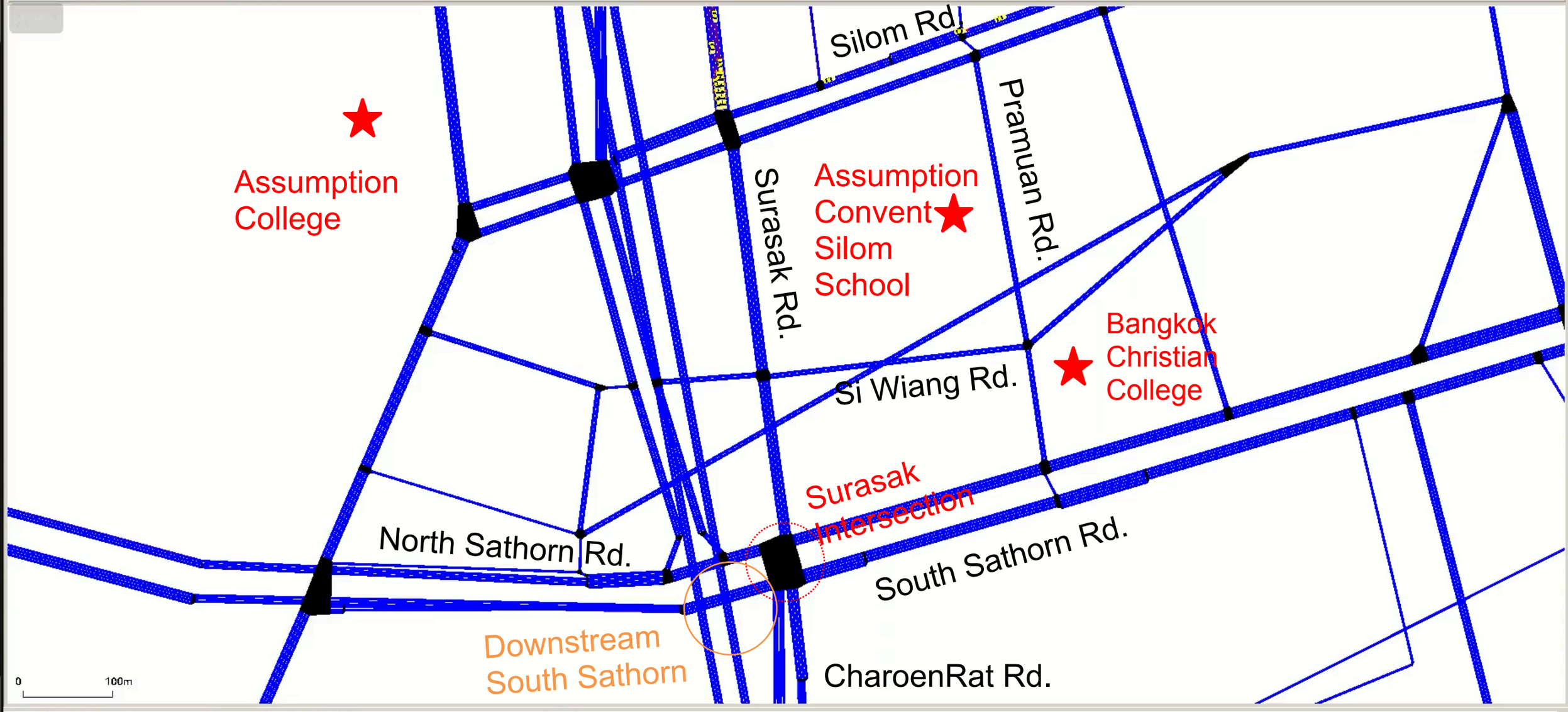
Activities Eclipse Sun May 12 11:12:02 en 49 %

sathorn_w_great_load1.0.sumo.cfg - SUMO 1.0.1

File Edit Settings Locate Simulation Windows Help

Time: Delay (ms): 0 Scale Traffic: 1

custom_3



done (20ms).
Loading done.
Simulation started with time: 21600.00

'/home/sda/Documents/sumo-sathorn-ray/models/sathorn-morning/sathorn_w_great_load1.0.sumo.cfg' loaded. 62 x:5419.43, y:5726.94 x:5706.19, y:5712.03

IoT cloudserve @TEIN

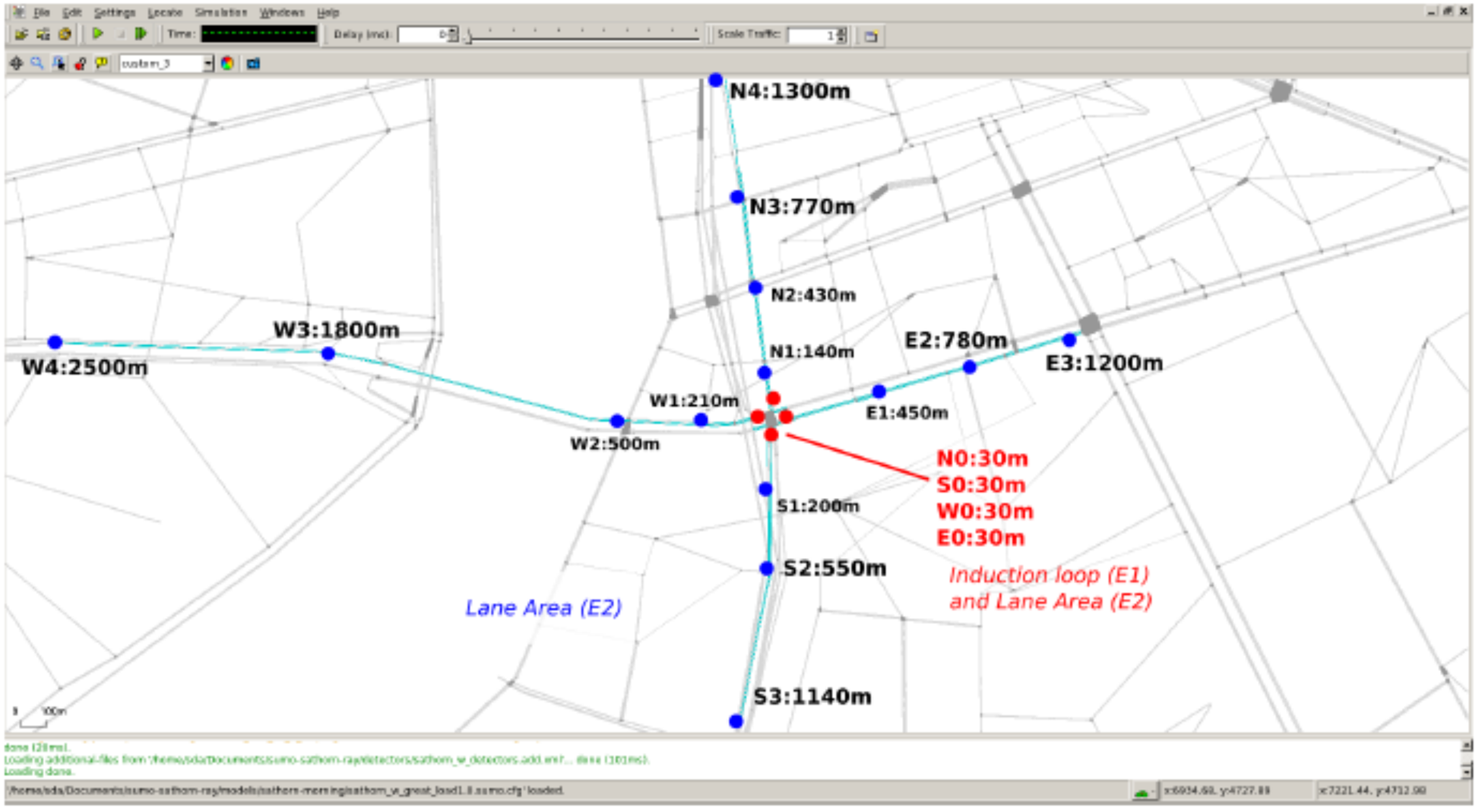
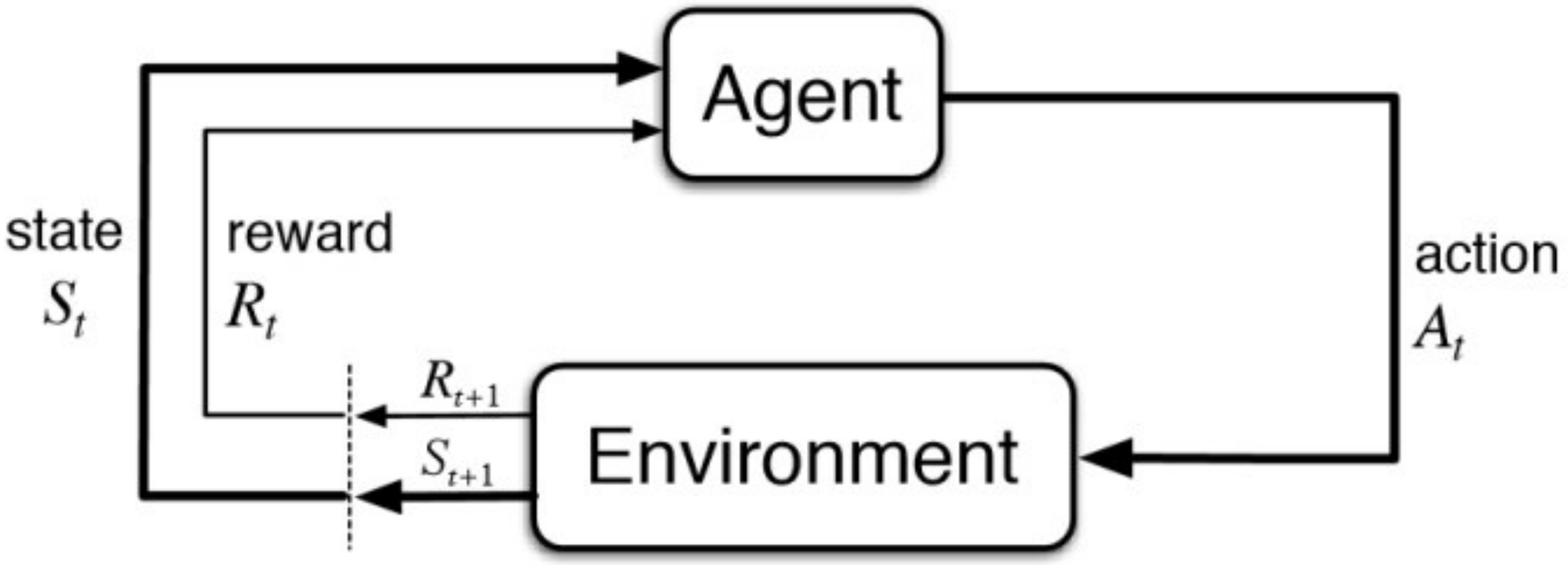


Figure 6: Detector Configuration in SUMO



$$v_\pi(s) = \mathbb{E}_\pi \left[R_{t+1} + \gamma R_{t+2} + \gamma^2 R_{t+3} + \ldots \mid S_t = s \right]$$

Expected

Reward
discounted

Given that state

State Space

$$S^a \in \mathbb{R}^{21} \times P$$

$$P \in \mathbb{B}^{|\mathcal{A}|},$$

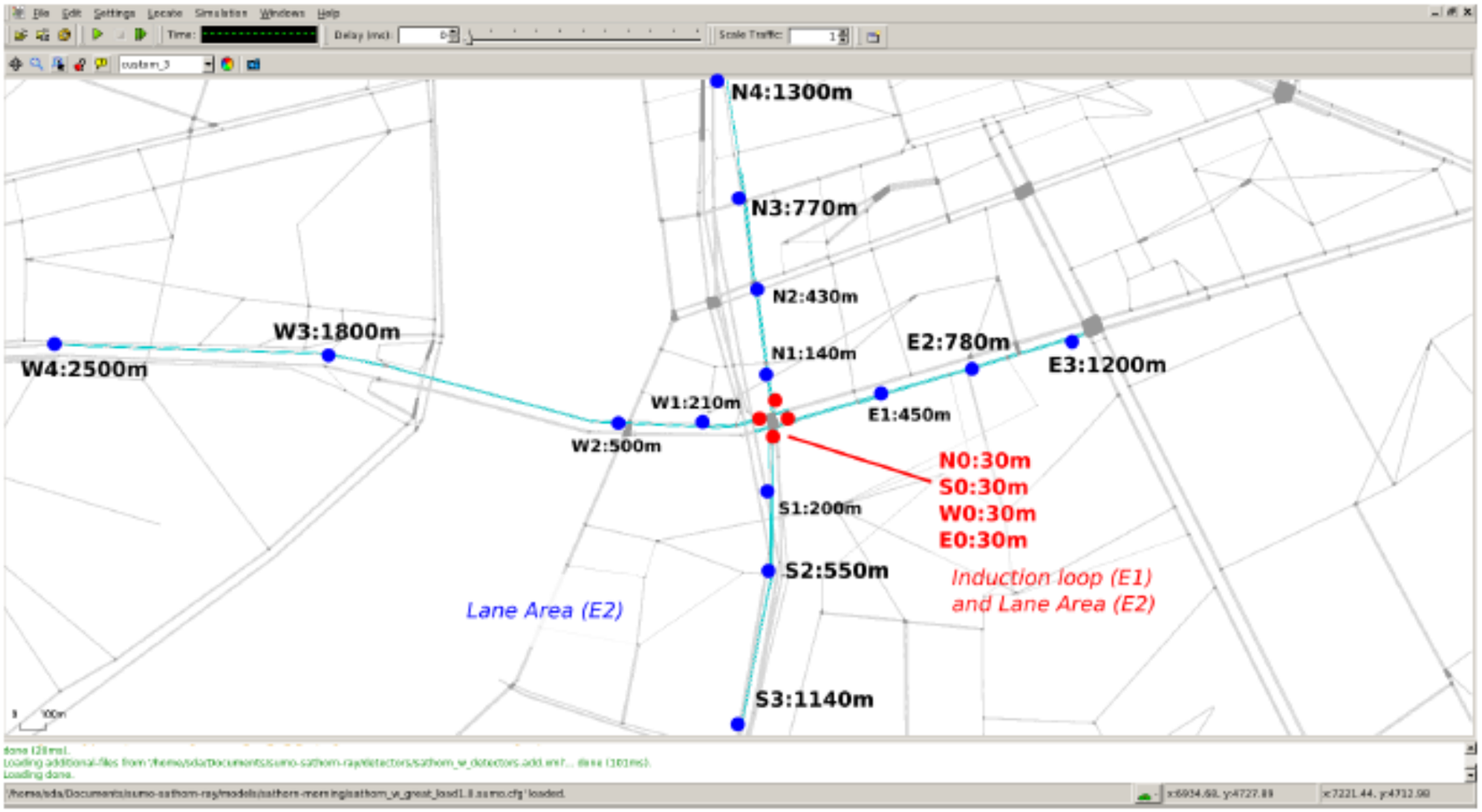
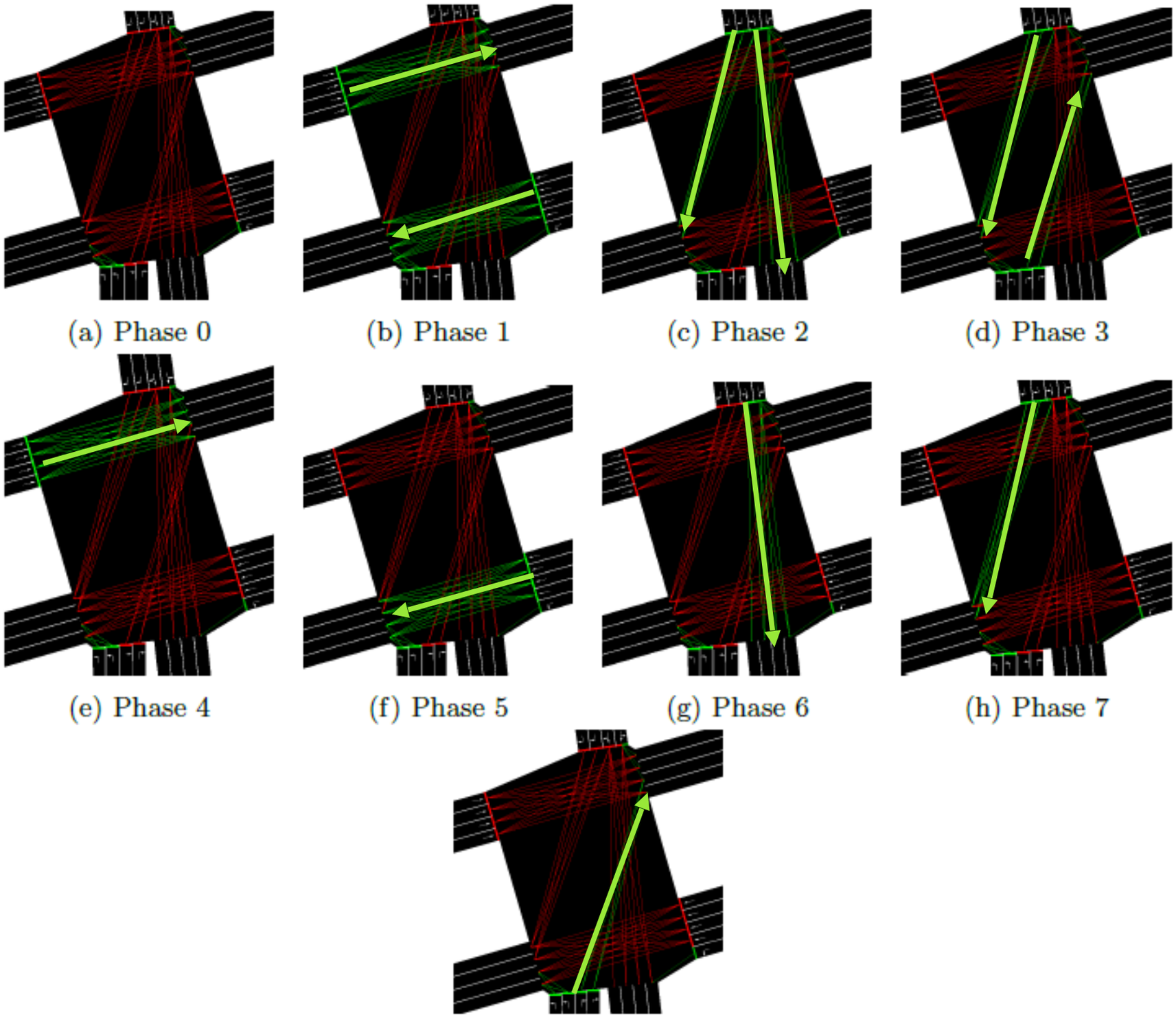


Figure 6: Detector Configuration in SUMO

State is comprised of the **occupancy** value for each E2 detector (cell) and the **traffic phase** vector *P*

Action Space

$$\mathcal{A} = \{0, ..., 8\}$$



(a) Phase 0 (b) Phase 1 (c) Phase 2 (d) Phase 3

(e) Phase 4 (f) Phase 5 (g) Phase 6 (h) Phase 7

(i) Phase 8

Figure 7: Action Space Consisting of 9 Phases

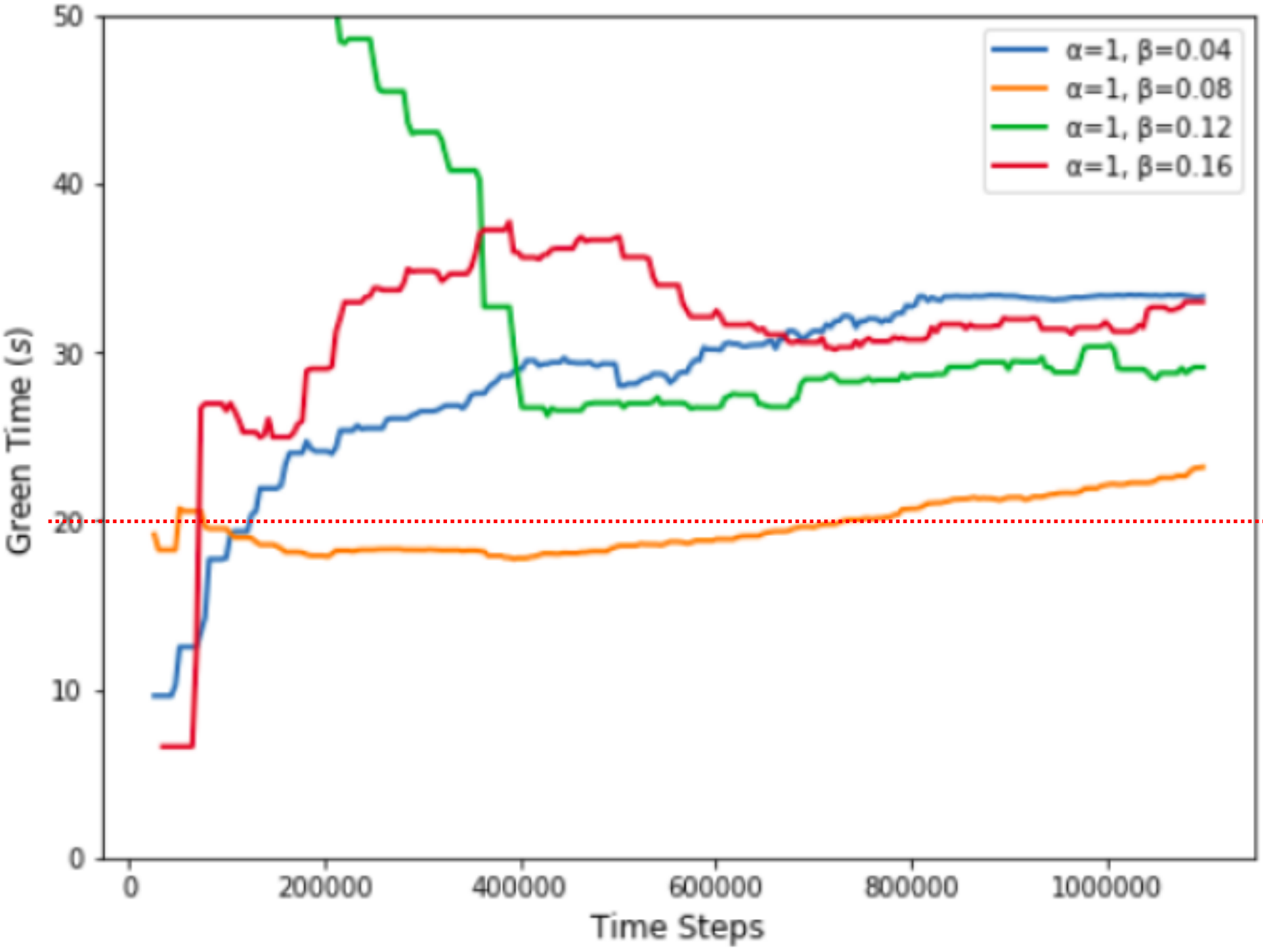
Reward Function

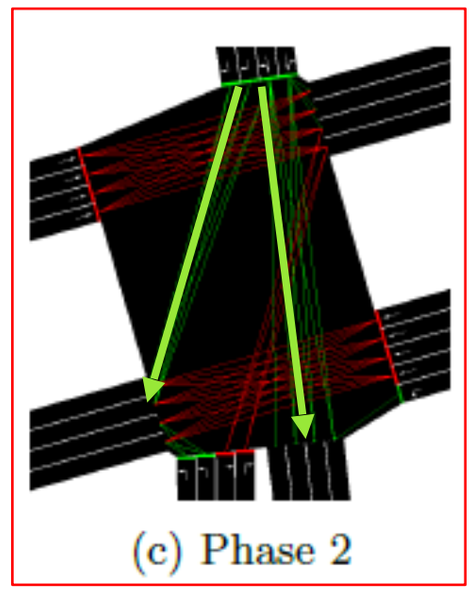
$$r_{t+1} = \alpha\mu_{t+1} - \beta(\mathcal{O}_{t+1} \cdot C)$$

whereby $\alpha \in \mathbb{R}^+$ and $\beta \in \mathbb{R}^+$

μ_{t+1}	Vehicle **throughput** during time step t to t + 1
$\mathcal{O}_{t+1}$	Observed **occupancy** in the next time step
C	Maximum cell capacity

α kept constant at 1; β linear sequence from 0.04 to 0.16 in intervals of 0.04

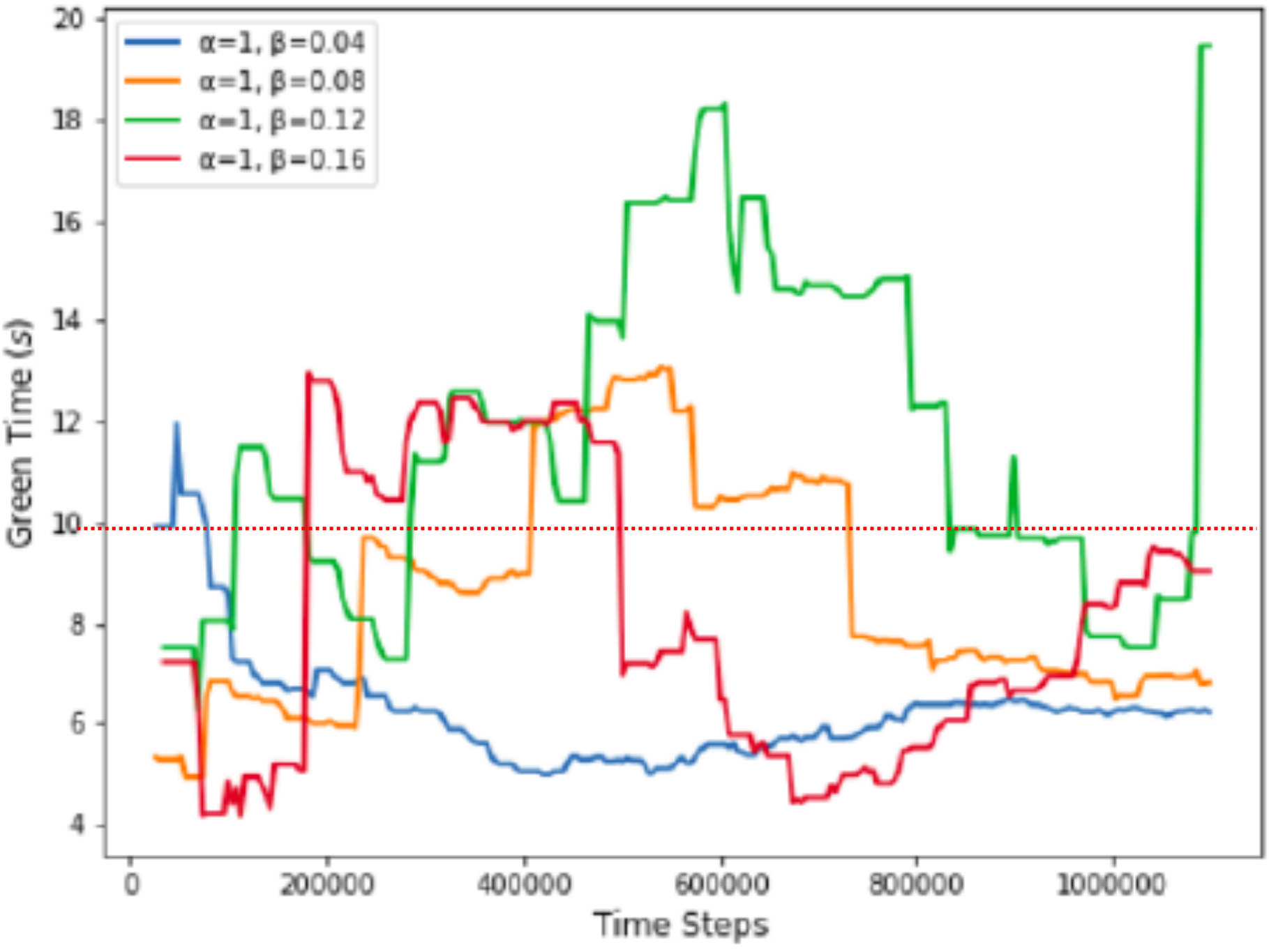


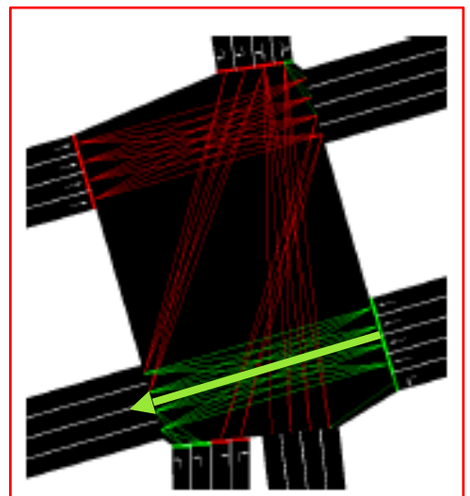


(c) Phase 2

All Agents give high importance

Figure: Average Green Time of Phase 2





(f) Phase 5

All Agents are undecided but does not give high average green time

Figure: Average Green Time of Phase 5

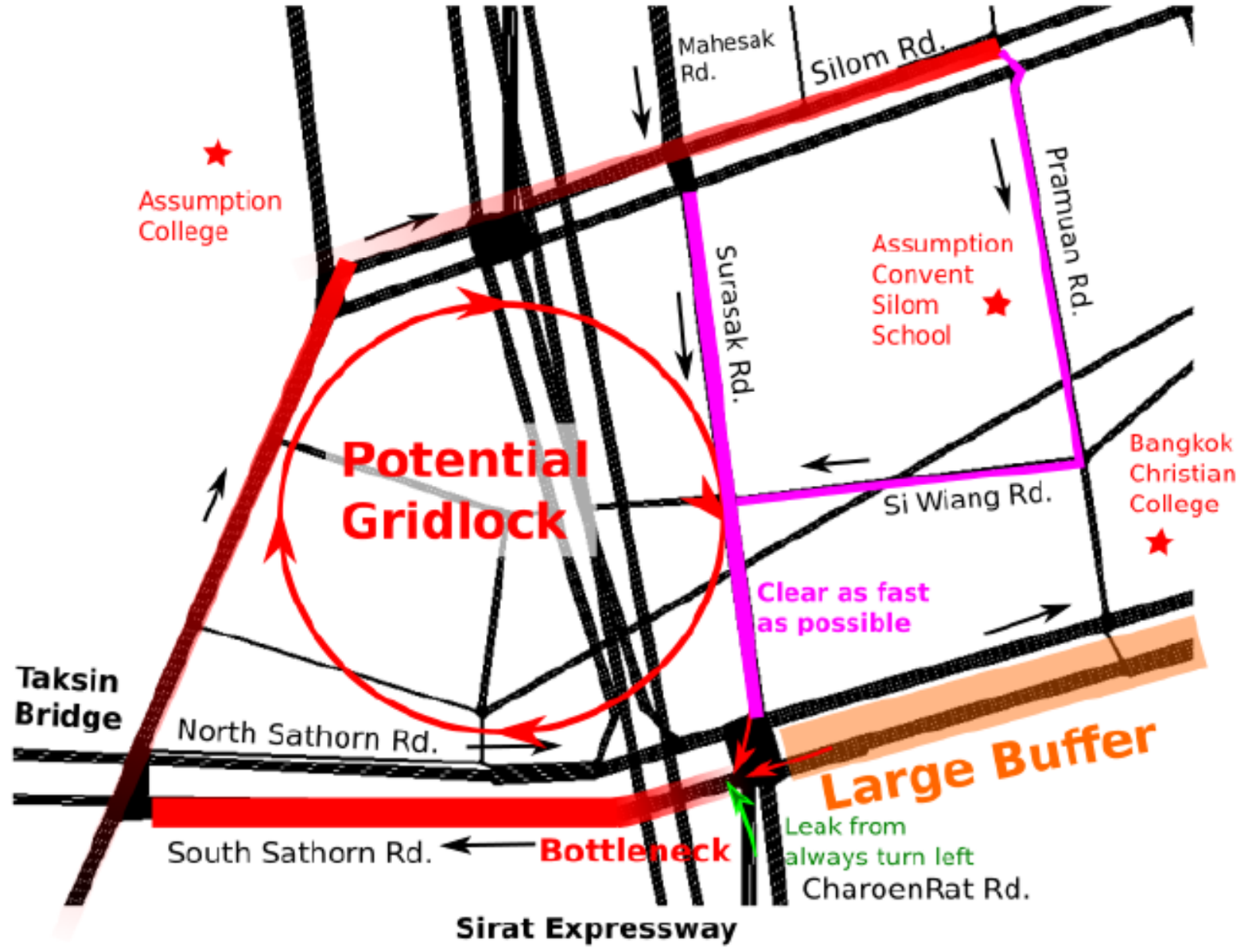
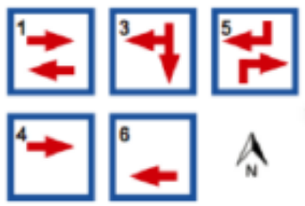


Figure 10: Potential Visual Policy of the Sathorn Road Network



Standard Phase 1-3-1-5

Changing Phase from 1 to 3:

- When the queue of downstream North Sathorn reaches the Sathorn Intersection
- When the queue of downstream South Sathorn reaches the Sathorn Intersection
- Queue of Si Wiang Road reaches Pramuan Road on Bangkok Christian College and Assumption Convent School
- Vehicles on Taksin Bridge 300 meters from Sathorn Intersection is starting to move
- Phase 1 duration more than 120-150 seconds

Changing Phase from 3 to 1:

- Reduced jam length of Si Wiang Road or vehicles are moving on Pramuan Road continuously for 20-30 seconds
- Minimum gap between vehicles that crosses the intersection is too high
- Velocity of the vehicles that crosses the intersection is too low
- Phase 3 duration more than 30-80 seconds

Changing Phase from 1 to 5:

- Queue of Si Wiang Road reaches Pramuan Road on Bangkok Christian College and Assumption Convent School
- Queue of CharoenRat is too long
- Phase 1 duration more than 120-150 seconds

Changing Phase from 5 to 1:

- Reduced jam length of CharoenRat Road
- Phase 5 duration more than 40-50 seconds

Note: Use Phase 1-3-1-3-5 if want to get cars out from Surasak and Pramuan Road. Use Phase 4 (instead of Phase 1) when the head of queue from Sathorn South reaches Sathorn Intersection. Use Phase 6 (instead of Phase 1) when the head of queue from Sathorn North reaches Sathorn Intersection.

Figure 4: Heuristic Signal Actuated Logics at the Morning Rush Hour of Surasak Intersection [3] Version 23/11/2016 Yannawa Police District

AI vs Human Traffic Police in Heuristic Signal Actuated Logics

Phase 1→3, Phase 1→5

Triggering Event:
Si Wiang Queue Length

Phase 3→1, Phase 5→1

Triggering Event:
Never about South Sathorn Queue Length

[3] Chaodit Aswakul, Sorawee Watarakitpaisarn, Patrachart Komolkiti, Chonti Krisanachantara, and Kittiphan Techakittiroj. Chula-SSS: Developmental Framework for Signal Actuated Logics on SUMO Platform in Over-Saturated Sathorn Road Network Scenario. In *SUMO 2018- Simulating Autonomous and Intermodal Transport Systems*, volume 2 of EPiC Series in Engineering, pages 67–81. EasyChair, 2018

ICFCC 2019 Conference
27th February – 1st March, 2019

ICFCC 2019

Traffic Anomaly Classification by Support Vector Machine with Radial Basis Function on Chula-SSS Urban Road Network

Ei Ei Mon[1], Hideya Ochiai[2], Chaiyachet Saivichit[2], Chaodit Aswakul[1]

[1]*Wireless Network and Future Internet Research Unit, Department of Electrical Engineering, Faculty of Engineering, Chulalongkorn University, Bangkok, Thailand.*

[2]*Information and Communication Engineering, Graduate School of Information Science and Technology, The University of Tokyo, Japan*

Paper Session XIV: Modern Electronic Technology and Application
Chair – Dr. Yasunori Kawai (National Institute of Technology, Ishikawa College, Japan)
Place – Inle Meeting Room, Novotel Hotel, Yangon, Myanmar
Date and time – 28th February, 2019 (15:20– 16:40)

WiFUN RESEARCH GROUP

EPiC Series in Computing, vol. 62, pp. 158-171, 2019

Recurrent and Non-recurrent Congestion Based Gridlock Detection on Chula-SSS Urban Road Network

Ei Ei Mon, Hideya Ochiai,
Chaiyachet Saivichit and Chaodit Aswakul

Electronics 2020, 9, 1412; doi:10.3390/electronics9091412, pp. 1-20

Bottleneck Based Gridlock Prediction in an Urban Road Network Using Long Short-Term Memory

Ei Ei Mon, Hideya Ochiai,
Chaiyachet Saivichit and Chaodit Aswakul

Smart-Mobility@Chula

From Sathorn Model

Towards Rama-4 Model

Data-Integration Platform Ideation For Enhancing Traffic Flow Management: Rama 4 Model

POTENTIAL PPP DATA SOURCES

- Vehicle Probed Data e.g. Taxis
- Bluetooth-Scanning Based Traffic Sensors
- CCTV Video Streams / Signal Control Data From e.g. BMA/Police
- Portable WiFi-Scanning Based Traffic Sensors & Wireless Networked Cameras Using SDWMN
- Public Traffic Data Provider e.g. ITIC

OPEN & SECURED TRAFFIC DATA AND COMPUTING CLOUD

IoT Data Integration & Computing Container Orchestration Engine

Internet-Based Applications For Interactive Traffic Data Visualisation

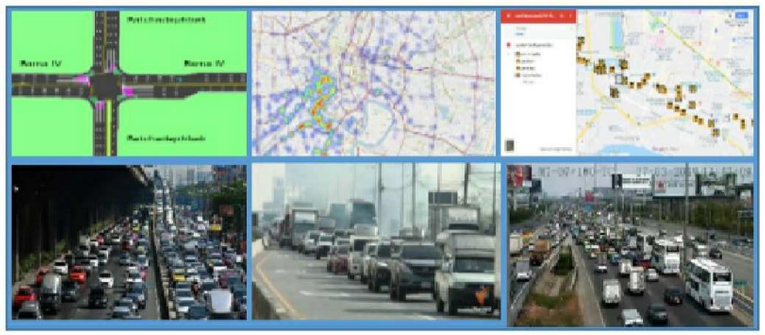
Participatory End Users e.g. Commuters, Traffic Police, BMA, MOT, Companies

SCALABLE, FAULT-TOLERANT CONTAINERISED FUNCTIONS ENABLED BY COMPUTE CLOUD

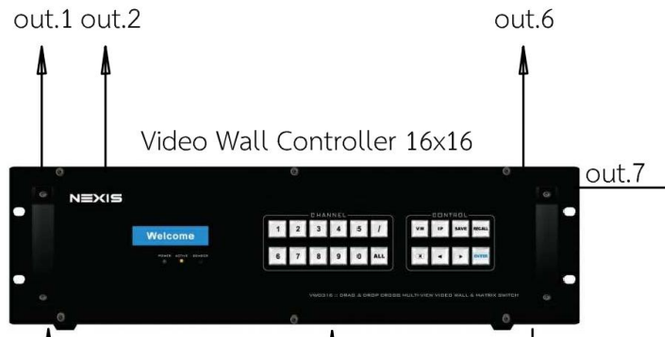
- Real-Time Congestion and Travel Time Estimation
- Incidence/Deadlock Detection Analytics
- Development of Rama-4 Road Computer Simulation Extensible From Sathorn Model SUMO Datasets
- Knowledge Management For Traffic Signal Standardisation Based on Sathorn Model's Chula-SSS Framework

IoT cloudserve @TEIN

Central Command
Traffic War Room
At Traffic Police Division



VDO wall & matrix mode



HDMI INPUT 12 Input (Up to 16)

LAN

Official

Desktop PC

CLOUD CHULA

Desktop PC

Desktop PC

Desktop PC

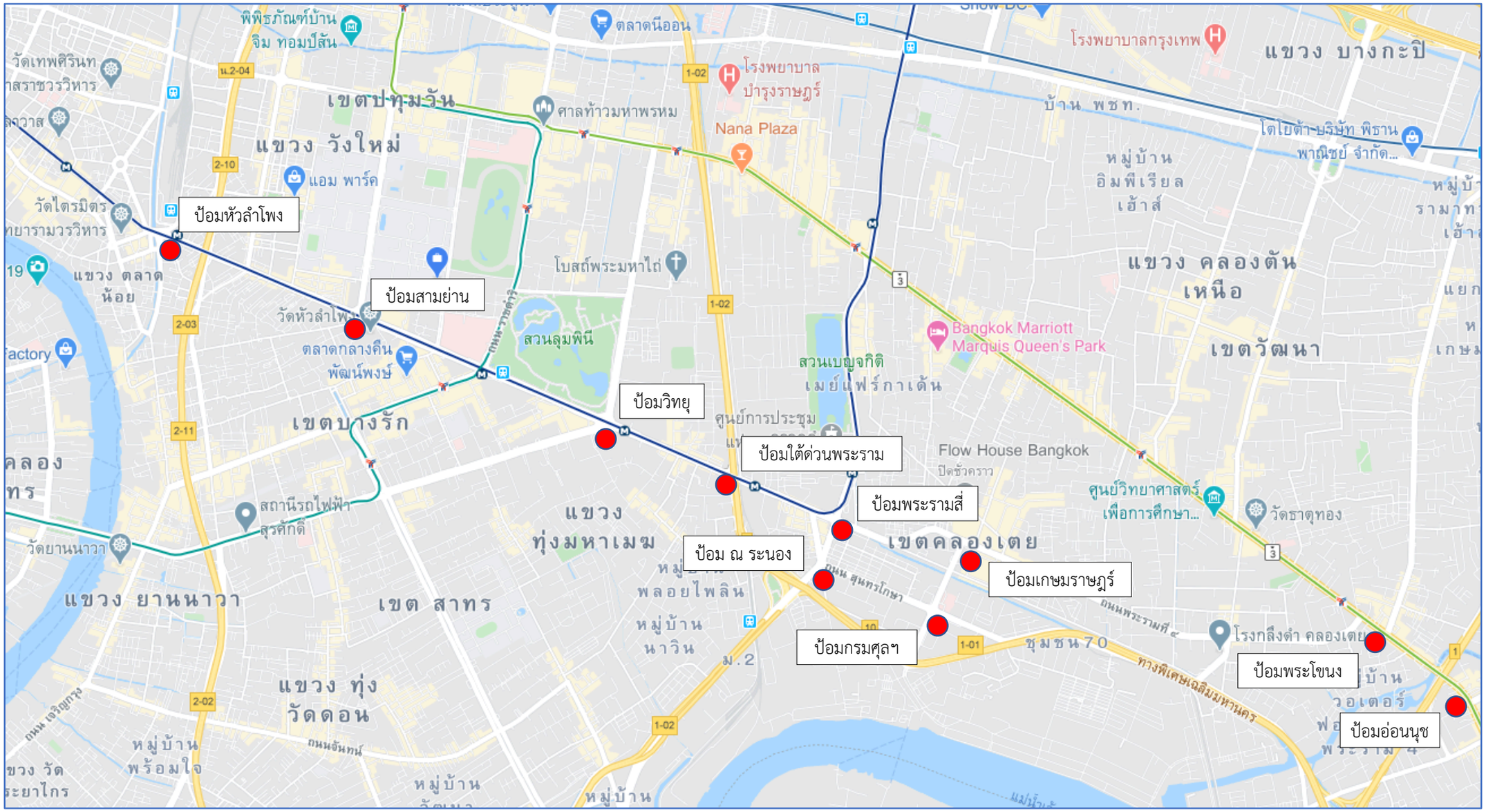
Desktop PC

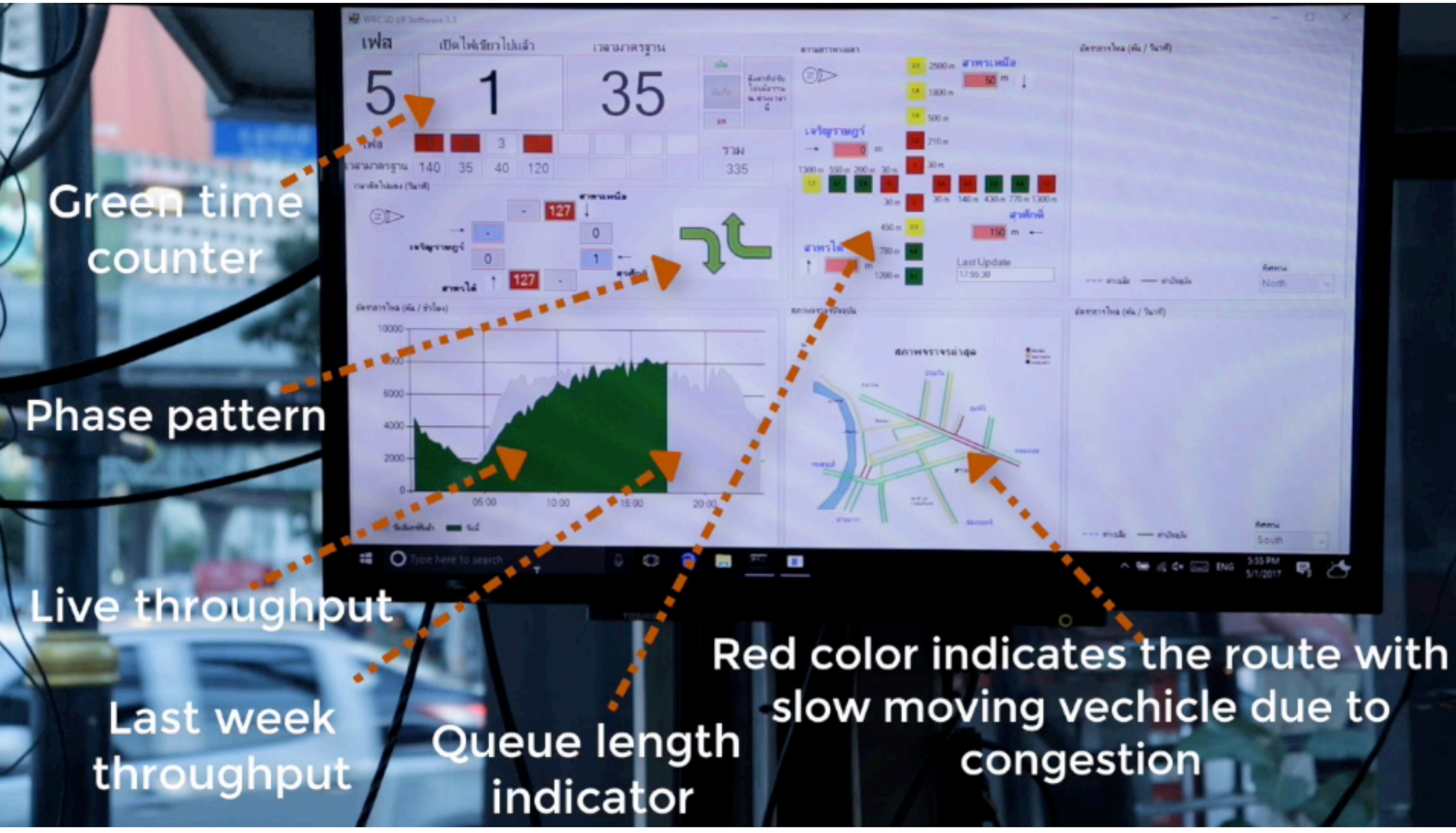
Desktop PC

LED TV 32"

บล็อคไดอะแกรม ระบบ Videowall 2x3

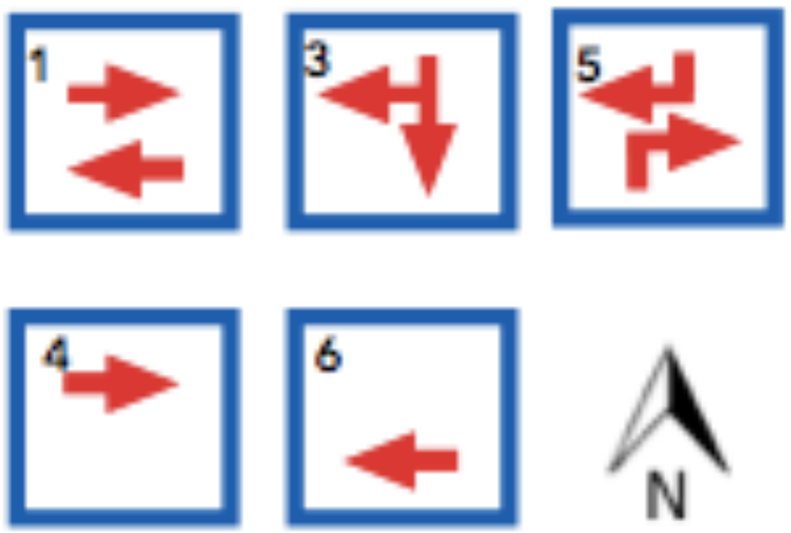
Proposed Rama4-Model Distributed Traffic War Room Locations (10 locations, 12 junctions, 6 police districts)





Local traffic control display at Sathorn Intersection
(as a baseline example for further Rama 4 enhancement using richer data visualisation)

วิธีควบคุมสัญญาณไฟจราจร แยกสาทร (เร่งด่วนเช้า)



รูปแบบเฟสมาตรฐาน 1-3-1-5

เปลี่ยนเฟส 1 ไป 3

- ทางเลี้ยวของสิ่งสาธารณะเหนือสิ่งนอกสาธร
- ทางเลี้ยวของสิ่งสาธารใต้สิ่งนอกสาธร
- ทางเลี้ยวของศรีเวียงสิ่งประดู่ฝั่งถนนประมวลของโรงเรียนกรุงเทพคริสเตียนและยังสิ่นชัญ
- ทางเลี้ยวของสุรศักดิ์สิ่งนอกสุรศักดิ์ (มหศักดิ์?)
- รถยนต์บนสะพานลากสิน 400 เมตรจากนอกสาธร (สังเกตจาก CCTV) เริ่มเคลื่อนตัว
- ระยะเวลาเปิดไฟเขียวในเฟส 1 เป็นเวลา ?? - ?? วินาที

เปลี่ยนเฟส 3 ไป 1

- ทางเลี้ยวของศรีเวียงลดน้อยลงมากพอหรือรถยนต์ทางฝั่งประมวลสามารถเคลื่อนตัวได้อย่างต่อเนื่องเป็นเวลา 20 – 30 วินาที
- ระยะห่างของรถยนต์ที่ผ่านนอกสาธรที่มาจากสุรศักดิ์ทิ้งช่วงกันเกินไป
- การเคลื่อนตัวของรถยนต์ผ่านนอกสาธรที่มาจากสุรศักดิ์ช้าเกินไป
- ระยะเวลาเปิดไฟเขียวในรูปแบบที่ 3 เป็นเวลา ?? - ?? วินาที

เปลี่ยนเฟส 1 ไป 5

- ทางเลี้ยวของศรีเวียงสิ่งประดู่ฝั่งถนนประมวลของโรงเรียนกรุงเทพคริสเตียนและยังสิ่นชัญ
- ทางเลี้ยวของจริญราษฎร์ยาวเกินไป (สื่อสารกับตำรวจด้วยวิทยุสื่อสารที่นอกได้ส่วนจันทน์)
- ระยะเวลาเปิดไฟเขียวในเฟส 1 เป็นเวลา ?? - ?? วินาที

เปลี่ยนเฟส 5 ไป 1

- ระยะเวลาเปิดไฟเขียวในรูปแบบที่ 5 เป็นเวลา 40 – 50 วินาที
- ทางเลี้ยวของจริญราษฎร์ตลอดเวลาเพอ (สื่อสารกับตำรวจด้วยวิทยุสื่อสารที่นอกได้ส่วนจันทน์)

หมายเหตุ เลือกใช้รูปแบบเฟส1-3-1-3-5 เมื่อต้องการที่จะระบายรถจากทางสุรศักดิ์ / ถนนประมวล เพื่อป้องกันการหยุดนิ่ง
ใช้เฟส 4 (แทนเฟส 1) เมื่อหัวแถวของสาธรได้มาถึงนอกสาธร
ใช้เฟส 6 (แทนเฟส 1) เมื่อหัวแถวของสาธรเหนือมาถึงนอกสาธร

SOCIAL EXPERIMENT ON REAL ROAD NETWORK

Rama-4 Model Proposed Data-Centric Traffic Flow Management Strategies

April - June 2021

List of Publications from Smart-Mobility@Chula Demonstration Site of IoTcloudServe@TEIN Project

Ei Ei Mon, Hideya Ochiai, Chaiyachet Saivichit and Chaodit Aswakul, "Bottleneck Based Gridlock Prediction in an Urban Road Network Using Long Short-Term Memory," Electronics 2020, 9, 1412; doi:10.3390/electronics9091412, pp. 1-20.
C. Eosanurak, N. Wongtrakoon, E. Mon and C. Aswakul, "Computer simulation study of vehicle type classification using machine learning techniques with mobile phone location data," accepted for SUMO User Conference 2020, 2020.
Soe Ye Htet and Choadit Aswakul, "Design and Implementation of Outdoor Fault-Tolerant In-Band Software-Defined Wireless Mesh Network with Observable Node Reachability," submitted for journal, 2020.
Phoo Phoo Thet Lyar Tun and Chaodit Aswakul, "Design and Preliminary Functionality Test of Road Network Traffic Monitoring System Based on Indoor SDWMN In-Band Architecture", submitted for conference, 2020.
Phoo Phoo Thet Lyar Tun, Chaodit Aswakul and JongWon Kim, "Prototyping a Small-Scaled Resilient Software-Defined Wireless Mesh Network with Dual-band Data and Out-of-band Control Planes," presented at APAN50: Asia Pacific Advanced Network Conference Meeting 50, Hong Kong, 3-7 August 2020.
Ei Ei Mon, Hideya Ochiai, Chaiyachet Saivichit and Chaodit Aswakul, "Recurrent and Non-recurrent Congestion Based Gridlock Detection on Chula-SSS Urban Road Network," EPiC Series in Computing, vol. 62, pp. 158-171, 2019, url = https://easychair.org/publications/paper/vxbj, doi = 10.29007/cxkb.
Thanapapas Horsuwan and Chaodit Aswakul, "Reinforcement Learning Agent under Partial Observability for Traffic Light Control in Presence of Gridlocks," EPiC Series in Computing, vol. 62, pp. 29-47, 2019, url = https://easychair.org/publications/paper/nsT5, doi = 10.29007/bdgn.
|Ei Ei Mon, Hideya Ochiai, Chaiyachet Saivichit and Chaodit Aswakul, "Traffic Anomaly Classification by Support Vector Machine with Radial Basis Function on Chula-SSS Urban Road Network," Proceedings of ICFCC 2019 Conference, 27th February – 1st March, 2019, 2019, Yangon, Myanmar.Radial Basis Function on Chula-SSS Urban Road Network|
A. M. Htut, S. Y. Htet, K. Leevangtou, K. Kawila and C. Aswakul, "Testbed design of near real-time wireless image streaming with Apache Kafka for road traffic monitoring," 33rd International Technical Conference on Circuits/Systems, Computers and Communications (ITC-CSCC), pp. 188-191, 2018.

CHULA ENGINEERING
Foundation toward Innovation

GIST

NECTEC
a member of NSTDA

UNIVERSITY OF MALAYA

Asi@Connect

European Union

TEIN CC
COOPERATION CENTER

IoT cloudserve @TEIN

Facebook Page

https://www.facebook.com/iotcloudserve/

Github

https://github.com/IoTcloudServe

Chula (Electrical Engineering)

https://www.elec.eng.chula.ac.th/grad

THANK YOU

Associate Prof Dr Chaodit Aswakul
Email: chaodit.a@chula.ac.th
Wireless Network & Future Internet Research Unit
Chulalongkorn University, Bangkok, Thailand