Parimala Thulasiraman

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Parimala Thulasiraman is a Professor with the Department of Computer Science at the University of Manitoba. She received her B.Eng. (Honours) and M.A.Sc. degrees in Computer Engineering from Concordia University in Montreal, QC, Canada and obtained her Ph.D. from the University of Delaware in Newark, DE, USA after finishing most of her formalities at McGill University in Montreal, QC, Canada. Parimala's research interests are in the intersection of high performance parallel/distributing computing and graph analytics for real world applications in network science. Her laboratory, Inter-Disciplinary Evolving Algorithmic Sciences (IDEAS), studies innovative, adaptive, self-learning methods for solving modeling, simulation, and optimization problems. She explores novel algorithmic optimization techniques to efficiently map, design, and develop scalable algorithms for distributed and many-core architectures. Parimala has supervised and graduated over 100 students. She has published over 150 papers in notable conferences, such as the IEEE International Parallel and Distributed Symposium, in journals, such as the Journal of Parallel and Distributed Computing, a book and several book chapters. She has received best paper awards in leading high performance computing conferences. She has been invited as a distinguished keynote speaker many major conferences and esteemed universities. Her research is supported through the national grant from the Natural Sciences and Engineering Research Council of Canada as well as other local and industry grants. Parimala has organized many important conferences as local chair, program chair, and tutorial chair. She is the editor and guest editor for major journals and has been serving as a reviewer and program committee member for conferences in high performance computing and computational intelligence. She is also a reviewer for many leading journals. She is a member and senior member of the ACM and IEEE societies, respectively. For more information, please see Parimala's homepage: http://www.cs.umanitoba.ca/~thulasir/.

IARIA InfoWare2020, Online

Panel

Vehicular at Work: Are we Ready?

Chair

Parimala Thulasiraman, Department of Computer Science, University of Manitoba

Panelists

Yuping He, University of Ontario Institute of Technology, Canada
Akimasa Suzuki, Iwate Prefectural University, Japan
Dragana Krstic, Faculty of Electronic Engineering, University of Nis, Serbia
Xiaohong Peng, Aston University, UK
Parimala Thulasiraman, University of Manitoba, Canada

Future of Autonomous vehicles and Intelligent Transportation Systems

University of Manitoba

Challenges & Questions for Discussion

- Starting points for the panelists
  - Benefits of self driving vehicles
  - Safety of the vehicles
  - New algorithms/techniques: Artificial Intelligence and self-driving vehicles
  - Trustworthiness of the vehicles
  - Interaction of other vehicles with autonomous vehicles
  - Changes in transportation industry with respect to intelligent transportation systems
  - Government policies and mandates: vehicle to vehicle communication
  - Implications to infrastructure
  - Implications to Transit: ride sharing

Topics from the panelists

- Yuping He, University of Ontario Institute of Technology, Canada
  - Numerical Simulation and Analysis of Aerodynamic Characteristics of Road Vehicles in Platoon
- Akimasa Suzuki, Iwate Prefectural University, Japan
  - Drivers at work are fired in future?
- Dragana Krstic, University of Nis, Serbia
  - The Future of Inter-Vehicle Wireless Communication Technologies - Issues and Challenges
- Xiaohong Peng, Aston University, UK
  - Connected and Autonomous Vehicles (CAV): Road Safety
- Parimala Thulasiraman, University of Manitoba, Canada
  - Urban Area Traffic Flow Forecasting in Intelligent Transportation Systems

Panel:
Computational Intelligence and Intelligent Transportation Systems
(navigation, machine learning, prediction)

Vehicular 2020

Panellist Position

Urban Area Traffic Flow Forecasting in Intelligent Transportation Systems

Parimala Thulasiraman, University of Manitoba, Canada: thulasir@cs.umanitoba.ca

- Complex Networks
- Vehicular ad hoc Networks
- Computational Intelligence
- Data Analytics

→ Computational intelligence techniques for intelligent transportation systems

→ Vehicle to Vehicle Communication for navigation and prediction

→ AI for Clustering

Panel:
Vehicular at Work: Are we Ready?
(acceptance, electric, wireless communication, high speed processing, self-driving, …)

InfoWare 2020

Panellist Position

Numerical Simulation and Analysis of Aerodynamic Characteristics of Road Vehicles in Platoon

Yuping He, Ontario Tech University Canada: yuping.he@uoit.ca

- Aerodynamic drag reduction
- Platoon driving
- CFD simulation
- Impact factors

→ Road vehicle driving in platoon improves transportation efficiency
→ Road vehicle driving in platoon reduces aerodynamic drags
→ Road vehicle driving in platoon enhances fuel economy

Panel:
Vehicular at Work: Are we Ready?
(acceptance, electric, wireless communication, high speed processing, self-driving, …)

InfoWare 2020

Panellist Position

Drivers at work are fired in future?

Akimasa Suzuki, Iwate Prefectural University, JAPAN suzuki_a@iwate-pu.ac.jp

- Sensors and actuators
- Positioning
- KANSEi search
- UAV, Robotics

→ Private as a hobby and worker cars will be coexistence.

→ As analogies of other vehicular system, monitoring is required.

→ Derivers or operator will be required as a responsible person.

Panellist Position

The Future of Inter-Vehicle Wireless Communications Technologies - Issues and Challenges

Dragana Krstic, *Faculty of Electronic Engineering*, *University of Niš,* Niš, Serbia

dragana.krstic@elfak.ni.ac.rs

- **Smart Transportation**
- **Vehicle To Vehicle Communication**
- **Intelligent Transportation System (ITS)**
- **Integrated Mobility: The Transport Solution For Tomorrow's Cities**

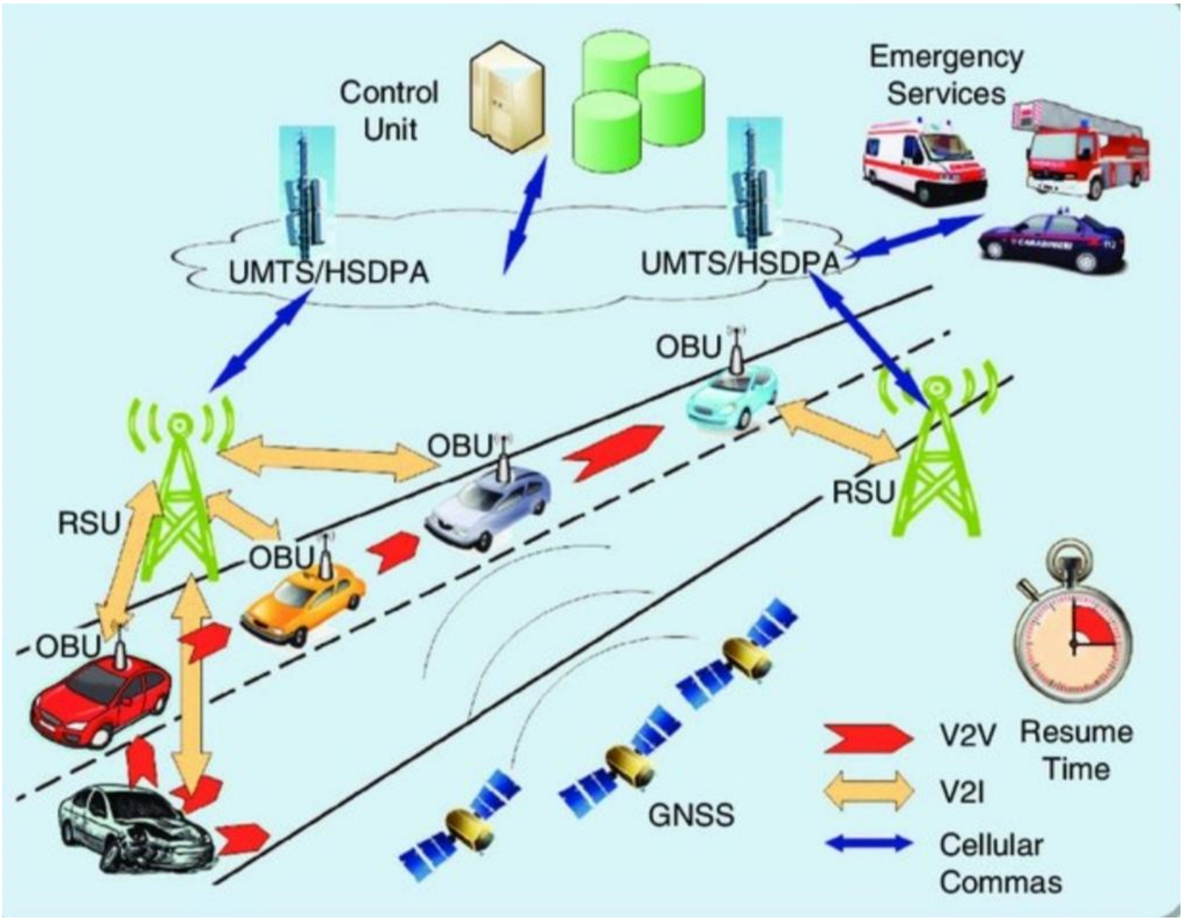
- For the transport sector a few issues are important to analyze: traffic congestion and accidents

- In last years, cooperation between vehicles is developing

- The main goal is to increase road safety and anticipate the circumstances of potential dangers

- Vehicle-to-Vehicle (V2V), Vehicle-to-Infrastructure (V2I) and Vehicle-to-Everything (V2X) technologies try to be communication models used by vehicles in different application contexts

- The resulting infrastructure is an ad-hoc mesh network whose nodes are not only vehicles but also all mobile devices equipped with wireless modules



ITS communication technologies based on the V2V and V2I communications

Panellist Position

Connected and Autonomous Vehicles (CAV): Road Safety

Xiao-Hong Peng, Birmingham City University, UK. xiahong.peng@bcu.ac.uk

- **Critical problems of transportation**
- **Automation levels**
- **Sensing vs. communications**
- **Challenges to CAV**
- **Essential technologies for ensuring safety**

Urban Area Traffic Flow Forecasting in Intelligent Transportation Systems

Ziyue Wang and Parimala Thulasiraman

Dr. Parimala Thulasiraman

Department of Computer Science

University of Manitoba

Canada

UNIVERSITY OF MANITOBA

Outline

INTRODUCTION

MOTIVATION

DYNAMIC TRAFFIC CLUSTERING SYSTEM

LSTM TRAFFIC FLOW CLUSTER PREDICTION

CONCLUSION

Introduction

Traffics are complex

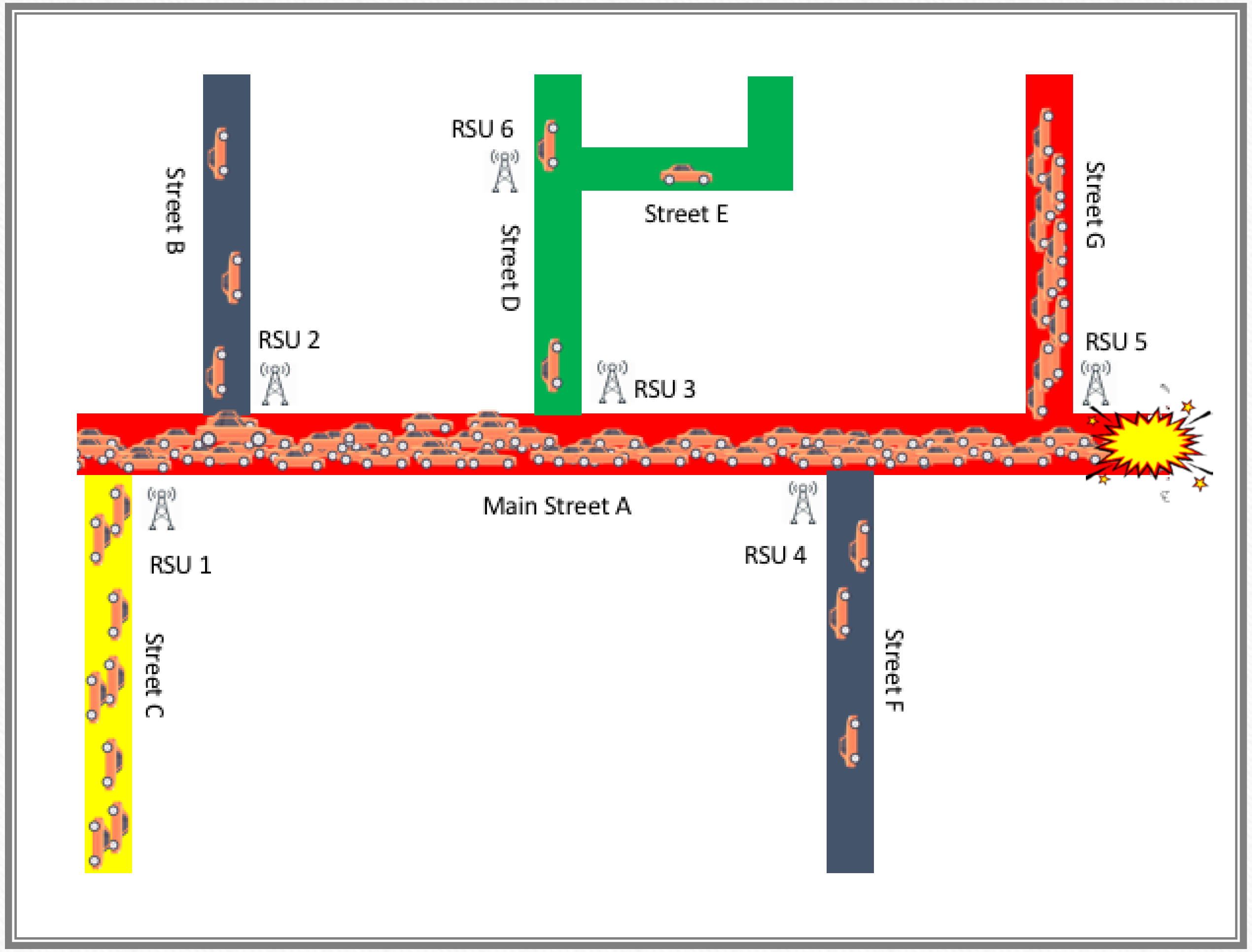
Complex network/peak-hours/accidents

Intelligent transportation system (ITS) studies in this domain

ITS aims to build a smart city

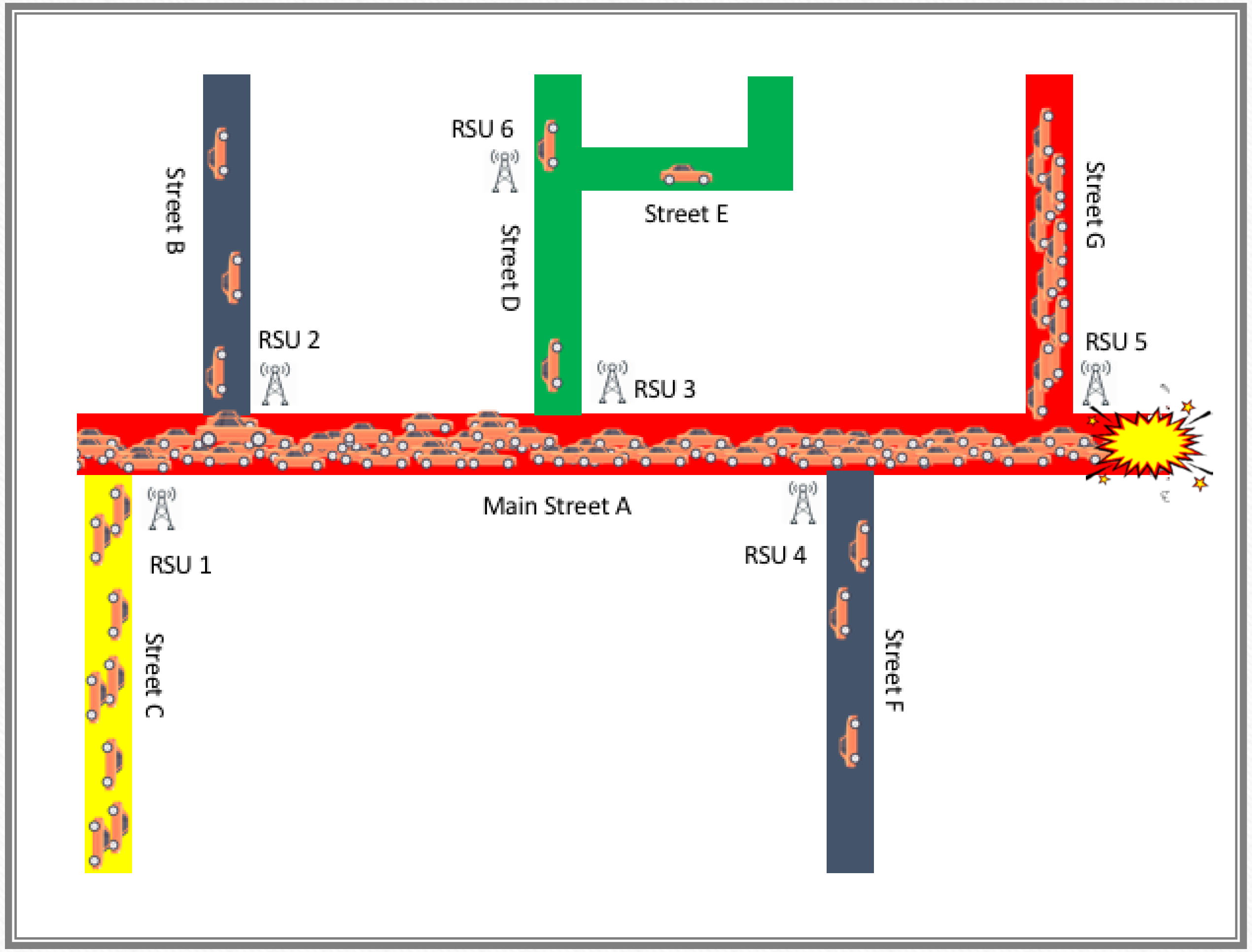
Smart City

Smart City uses many IoT technology to solve the problems related to city



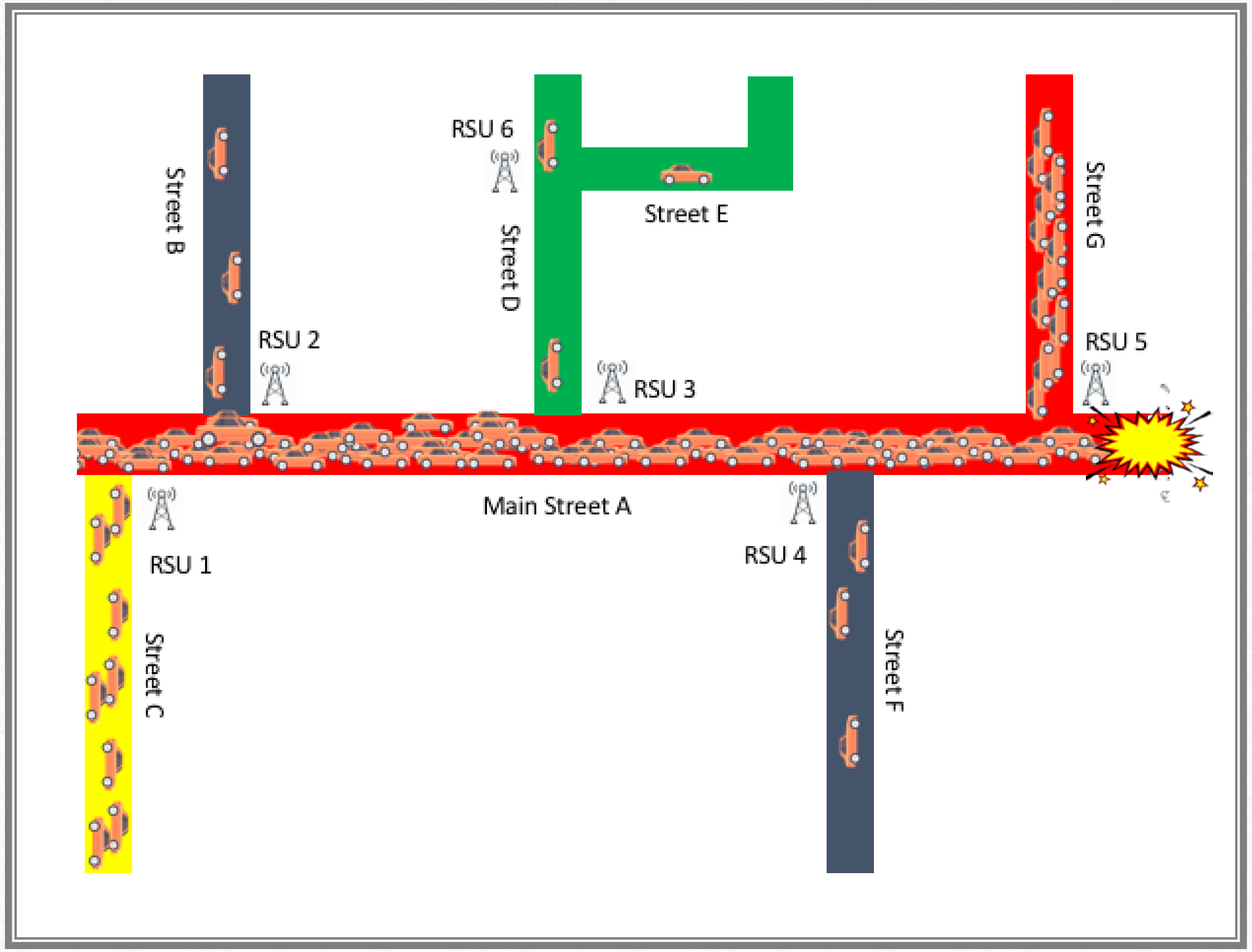
Motivation

- Assume there is an accident somewhere towards the end of main street.
- Then, the speed of the vehicles on main street would decrease.
- This affects other vehicles on main street and creates a traffic jam
- The roads surrounding the congested main street and may also be affected (eg. Street G).



Motivation

- Over period of time, what will happen to Street B and F ?
- Roads are not only spatially correlated but also temporally correlated
- What if I consider all the roads that are influenced by the congested road and cluster them together?



Motivation

- We can train these clusters with artificial neural networks to find the patterns and relationship between the data points, and predict the traffic flow.
- The sensor data (RSU2, RSU3, RSU4, RSU5) available near these road points will be used to train these clusters.

Contributions

Propose a traffic flow based similarity function to clustering the traffic network

Propose a dynamic traffic clustering system

Improve the solution quality of prediction by using neural network with clustered traffic data

Two Parts to My Presentation

Clustering

- Dynamic traffic aware system
- Evaluation

Prediction

- Using long-short term memory
- Evaluation

Outline

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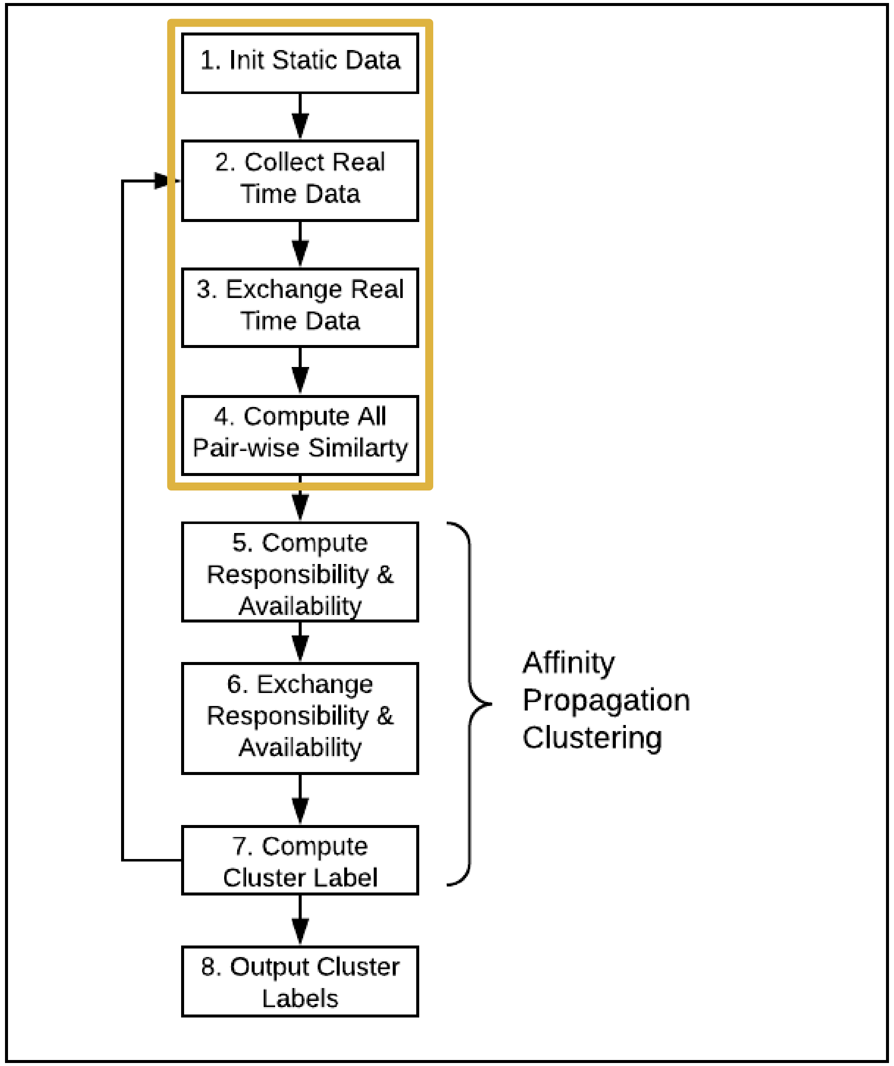
Dynamic Traffic Clustering System

- Step 1: Initial static data
  - Location of the sensors
  - Traffic network
- Step 2: Each (group) of device(s) collect real-time traffic data
  - By IoT devices
- Step 3: Exchange data via wireless network
- Step 4: After received required data, each device starts to compute **pair-wise similarity**



Pari-wise Similarity for Clustering

In order to find the real-time traffic clusters, I need to define the similarity, that is, how an object is similar/dissimilar to another.

Traditional method of define dissimilarity between road points by using Euclidean distance, however, it is static.

Some existing work use real-time traffic speed to cluster the traffic network.

- It does not represent the traffic influence directly
- It is not as easy collect as traffic flow data
- It is not as arcuate as traffic flow data

Thus I propose to use traffic flow data to represent the relationship between road points.

Proposed Pair-wise Traffic Flow Similarity

- If traffic flow from A to B is very high (a lot of vehicles from A to B), point A has high influence on road point B
- We count the flow from A to B, since if drivers want to go to B from A, it is most likely choosing a shortest path
- We normalize the similarity by the from A to B over total flow into B
  - $Similarity\ (A, B) = \frac{Flow\ A\ to\ B}{Total\ flow\ into\ B}$
  - Thus all similarity will be normalized from 0 to 1

Proposed Pair-wise Traffic Flow Similarity

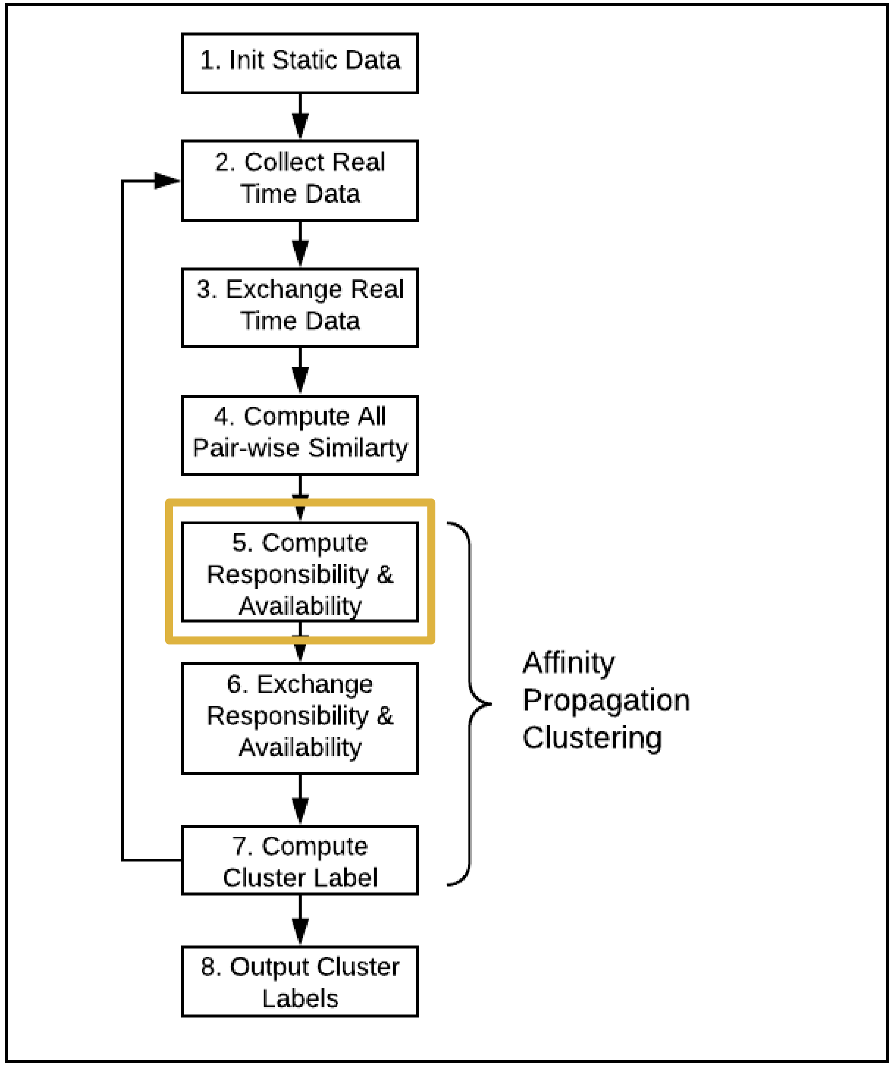
- In order to make the similarity work for most clustering algorithm, it must be symmetric
  - i.e. $Similarity\ (A, B) = Similarity(B, A)$
  - Thus I take the mean of them $s\ (A, B) = \frac{Similarity(A,B) + Similarity(B,A)}{2}$
  - By computing all pairs of similarity, we get a similarity matrix

Clustering Algorithms

- Some algorithms only work for Euclidean distance (requires a real center):
  - K-Means
- Some algorithms does not work for dynamic data:
  - Single-linkage algorithm
- Some algorithms does not well fit in distributed system:
  - k-medoids
- **Affinity Propagation**:
  - Message passing based clustering algorithm
  - Well fit in distributed system
  - Works for dynamic data
  - Accept just similarity matrix (does not need a real center)

Affinity Propagation

- Every phase, compute two local variables: responsibility (*r*), and availability (*a*)
  - *r(i, k)*: how well k is the center of i
  - *a(i, k)*: how well *i* is a member of *k*



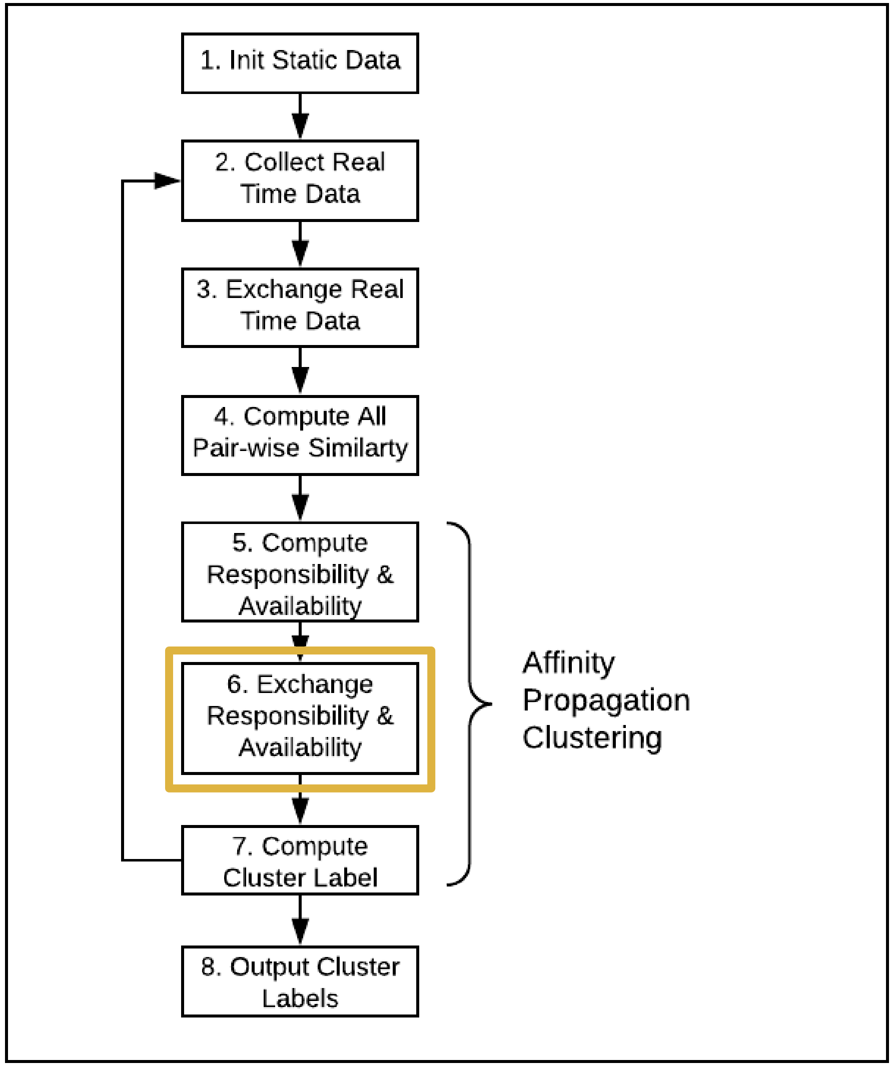
Affinity Propagation

- Initially, every node consider itself as a cluster
- Update and communicate *a* and *r* at each iteration

$$r(i,k) = s(i,k) - \max_{k' s.t. k' \neq k} \{a(i,k') + s(i,k')\}$$

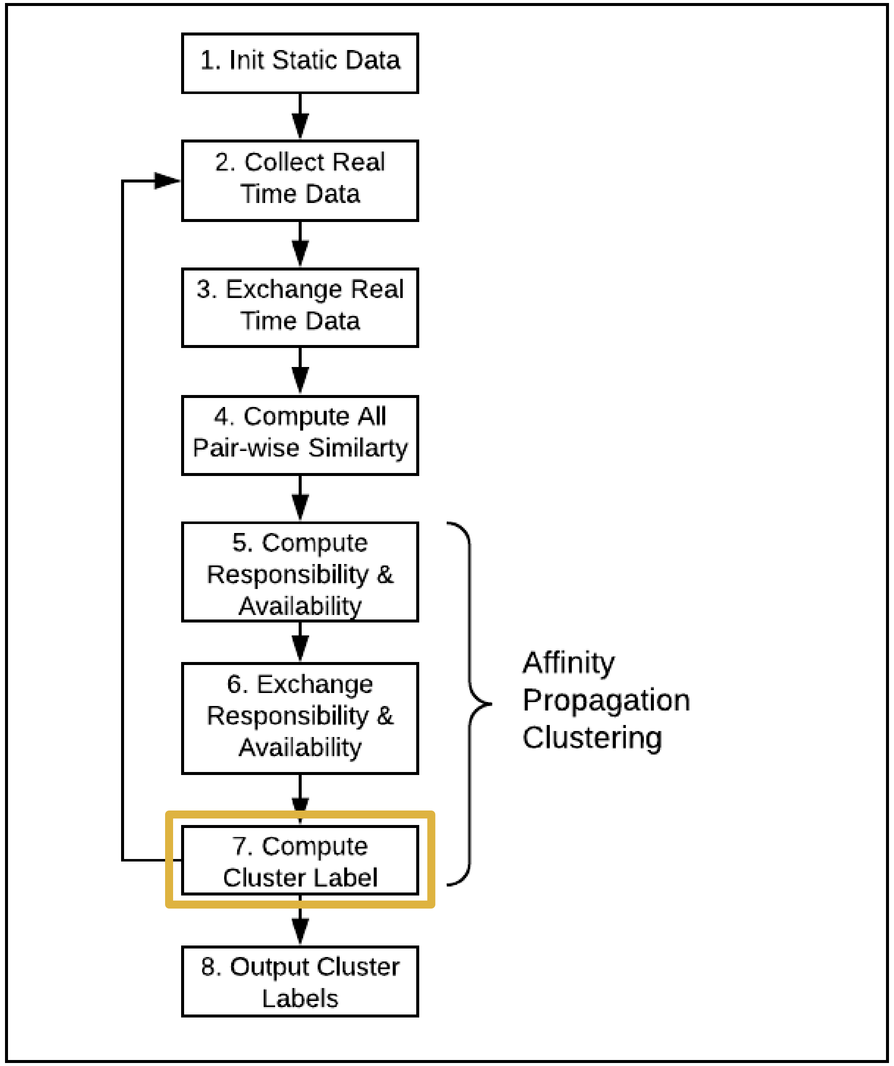
$$a(i,k) = \min\{0, r(k,k) + \sum_{i' s.t. i' \notin \{i,k\}} \max\{0, r(i',k)\}\}$$

$$a(k,k) = \sum_{i' s.t. i' \neq k} \max\{0, r(i',k)\}$$



Affinity Propagation

- Point *i* belongs to the center *k* that gives maximum $a(i, k) + r(i, k)$
- In this system, the algorithm does not terminate since the real-time data is always changing
- I can always take a snapshot when we need the clusters



Evaluation

I measure solution quality and number of clusters

I use data set from Citypulse: Aarhus, Denmark (Open Data Aarhus)

Muhammad Intizar Ali, Feng Gao and Alessandra Mileo, **"CityBench: A Configurable Benchmark to Evaluate RSP Engines Using Smart City Datasets"**, The Semantic Web - ISWC 2015 - 14th International Semantic Web Conference, October 11-15, 2015, Bethlehem, PA, USA

Evaluation

- Compare affinity propagation (AP) with k-medoids (KM), DBSCAN, and average-linkage clustering (AGG)
  - For the algorithm needs the number of clusters to be predefined, I set the number of clusters equals to affinity propagation to show the fairness
  - Since all other algorithms are static clustering algorithms, we only evaluate the algorithms the results in 5-min interval (the previous results does not take into next time interval)

Evaluation Metrics

Silhouette Coefficient:

- How an item is similar to current cluster over other clusters
- The higher the better

Similarity Mean:

- The mean of the inter-cluster similarity
- The higher the better
- For some situation, intra-cluster similarity is not considered

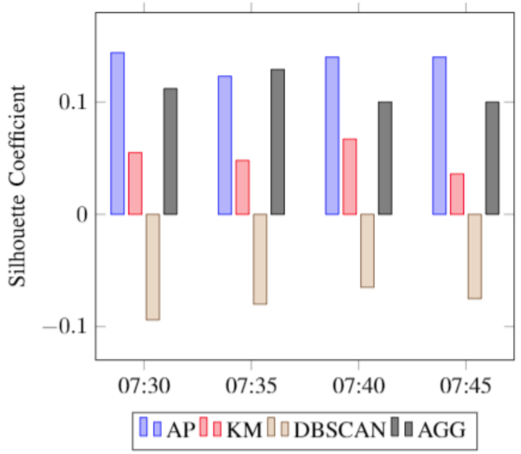


Fig. 2. Peak Hour Silhouette

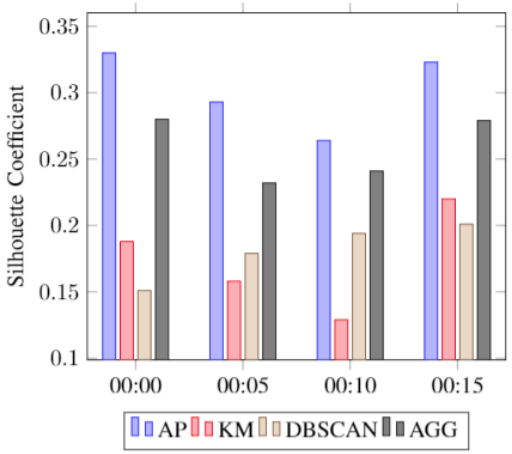


Fig. 4. Non-Peak Hour Silhouette

Silhouette Coefficient

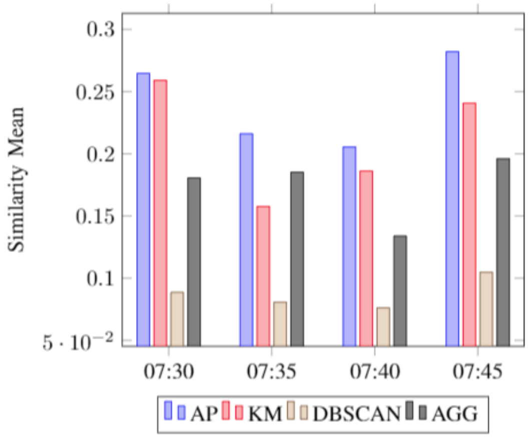


Fig. 3. Peak Hour Similarity Mean

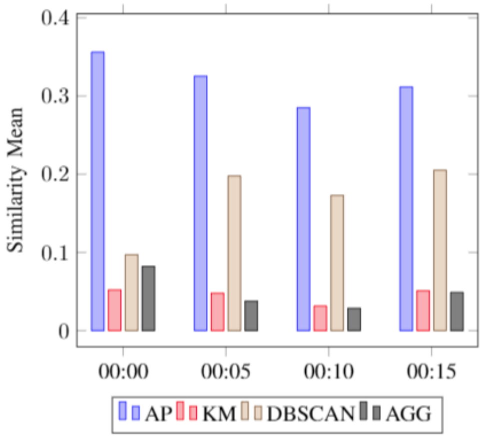
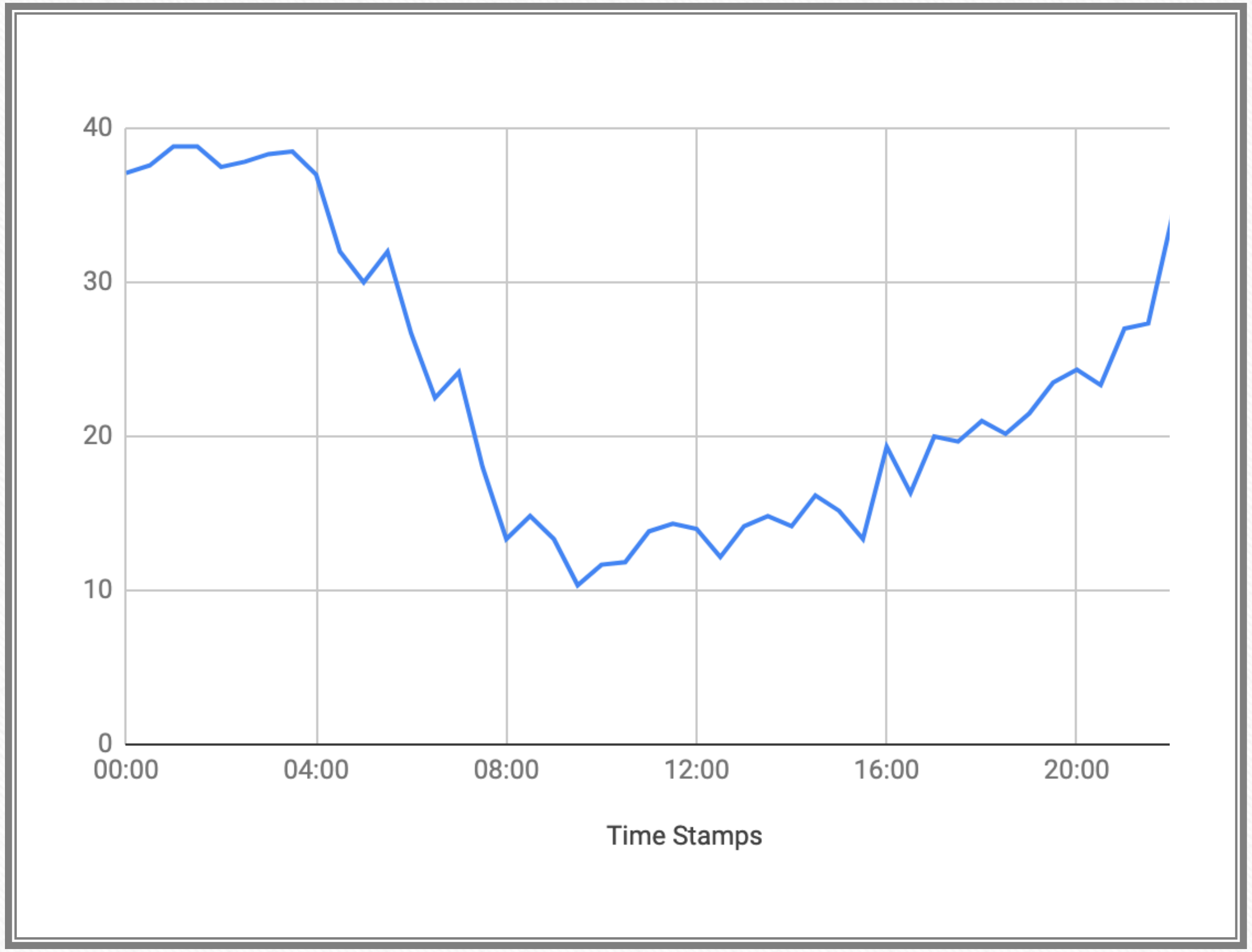


Fig. 5. Non-Peak Hour Similarity Mean

Similarity Mean

Number of Clusters



- A lot of clusters due to low traffic flow
- In peak hours, the number of clusters increases
- 9:00 A.M. is not peak hour but low number of clusters due to smooth and steady traffic flow

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Cluster-based Traffic Prediction

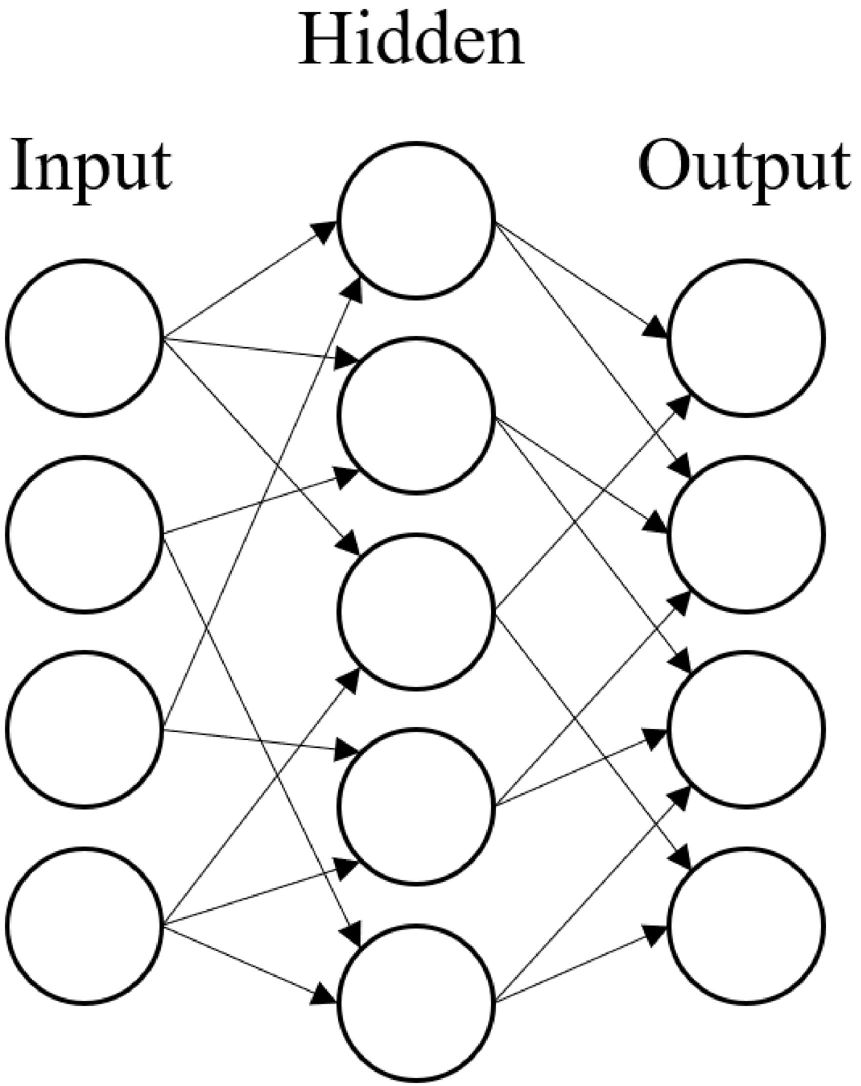
Traffic flow can be predicted by using both nearby traffics and previous data

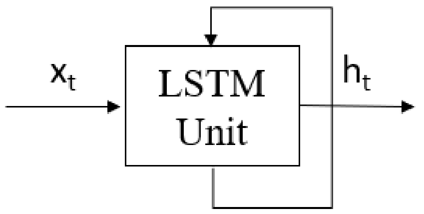
Spatial locality - Clustering

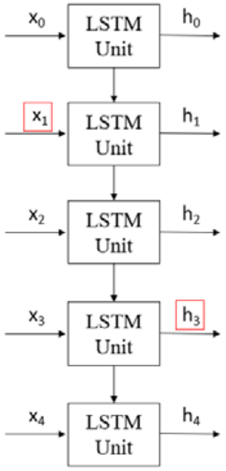
Temporal locality – Time-series prediction: Long-short term memory

Artificial Neural Network

- Inspired by the neurons in the human brain
- Learn the pattern in the data set without any task-specific rules
- Three types of layers: input layer, hidden layer, and output layer
- Each layer has many neurons/unit

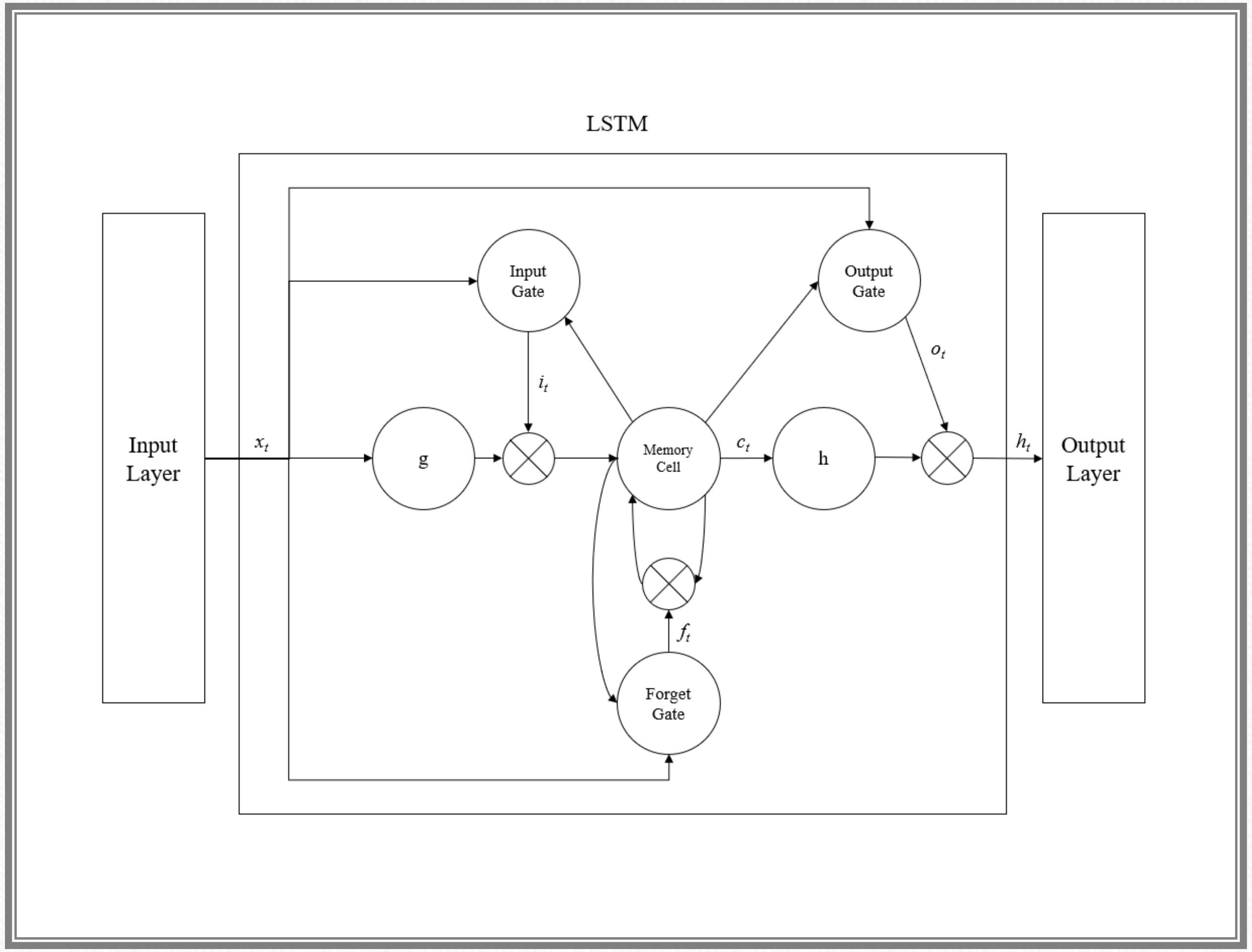






Long-short term memory

- Recurrent neural network is an extension of ANN
- LSTM is an implementation of RNN
- Hidden layer has feedback connections to itself
- Time-stamped input
- Previous data can be take into next iteration



Peephole long-short term memory

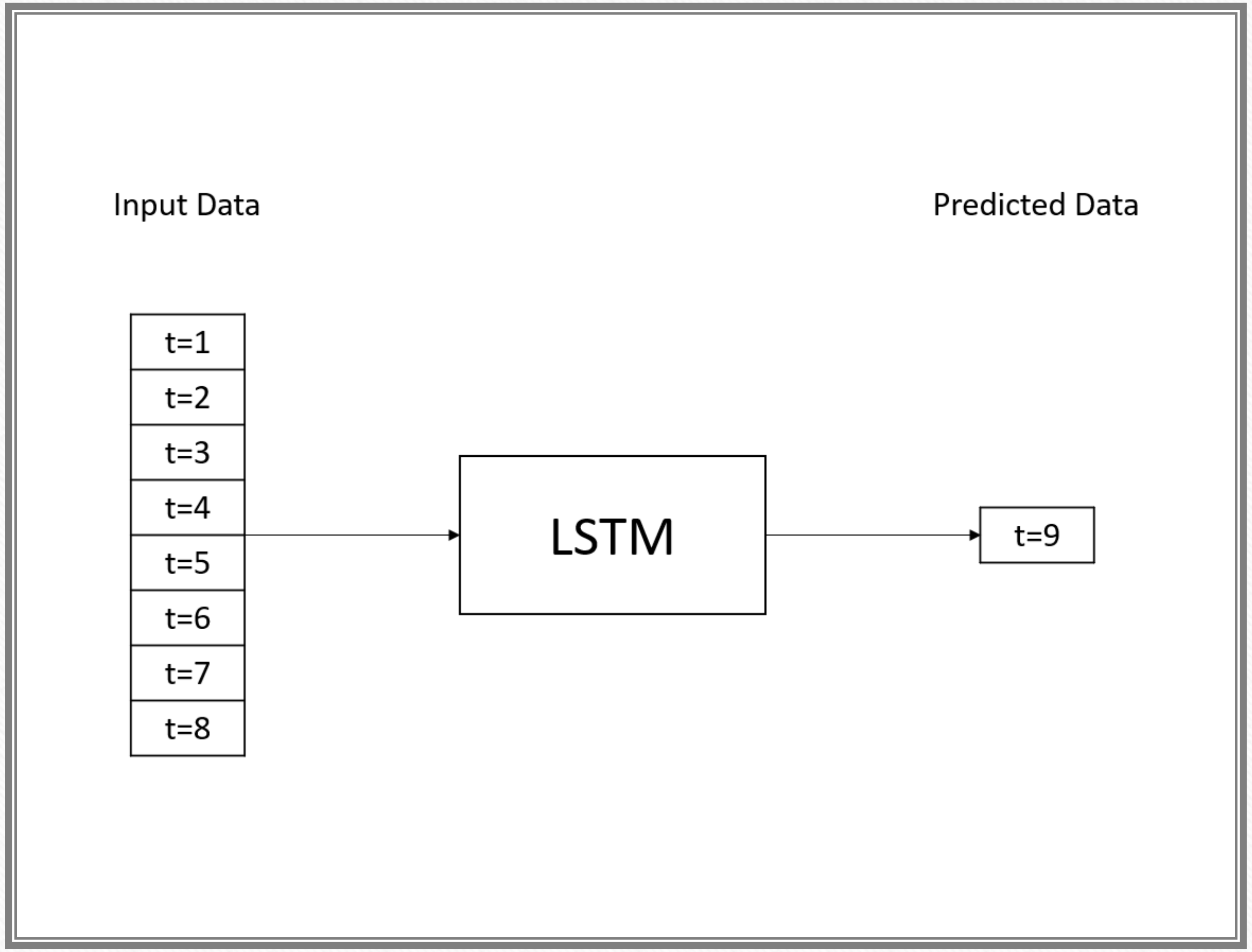
- Weight, Bias, Hidden states
- Sigmoid function
- Loss function
- Back propagation algorithm

Peephole long-short term memory

$$\sigma(x) = \frac{1}{1 + e^{-x}}$$

$$e = \sum_{t=1}^{n} (y_t - p_t)^2$$

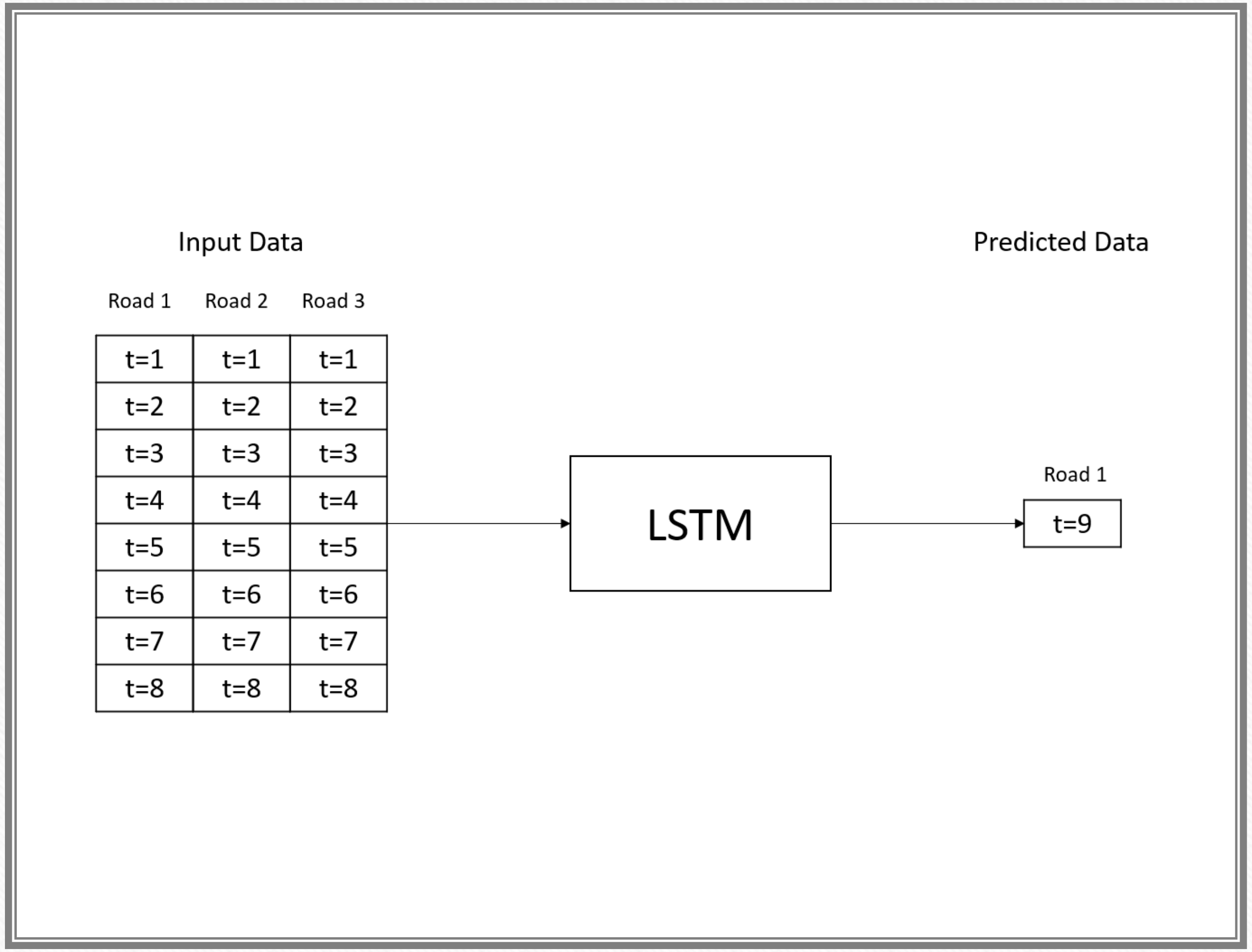
- Sigmoid function
- Square loss function
- Back propagation algorithm: Adam Optimizer



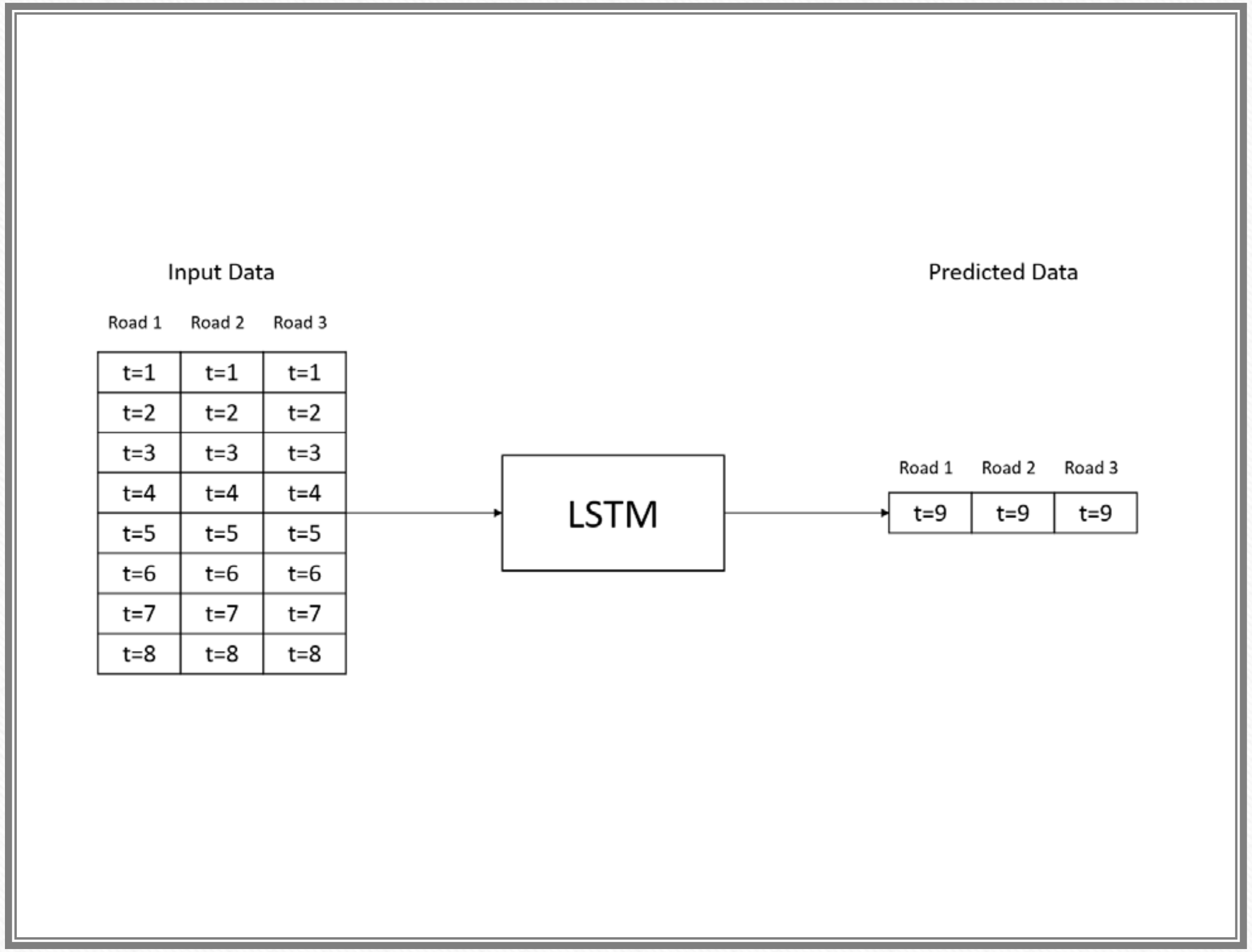
One to One Prediction

- Existing solution
- One time-series data is to predict one result
- Only just the road itself to predict itself

Many to One Prediction



- Use more than one roads to predict
- Use the roads in same cluster
- Potential computation overhead
- Potential higher prediction quality



Many to Many Prediction

- Use cluster data to predict entire cluster
- Potential computation overhead single prediction
- High throughput: more efficient in large predictions

Static Clustering

- In order to make the prediction work, I need static clusters
- That is, the clusters work well for any time-stamp (both peak and non-peak)
- Non-peak hours should have same weight with peak hours
- Proposed cluster merge algorithm

Algorithm 3: Cluster Merge

Data : Clustering Algorithm $A(x)$, Time stamp similarities

$$TS = \{ts_0, ts_1, \dots ts_T\}$$

Result: Cluster labels: $C(i), i \in N$

$s[N, N] = 0;$

for $t \in T$ **do**

    $C_t = A(ts_t);$

    $\forall i, j \in N$: **if** $C_t(i) == C_t(j)$ **then**

        $s[N, N] += 1;$

    end

end

$s[N, N] = \frac{s[N,N] - min(s[N,N])}{max(s[N,N])};$

$C = A(s);$

Return C;

Experiment

- Data set from Citypulse: Aarhus, Denmark (Open Data Aarhus)
- Default Adam optimizer parameters from Keras
- My LSTM design has 4 hidden layers:
  - Layer 1: LSTM layer of 64 units
  - Layer 2: LSTM layer of 64 units
  - Layer 3: Dropout layer of 64 units, dropout rate = 0.2
  - Layer 4: Dense layer of output size units, all apply sigmoid function.

Evaluation Metrics

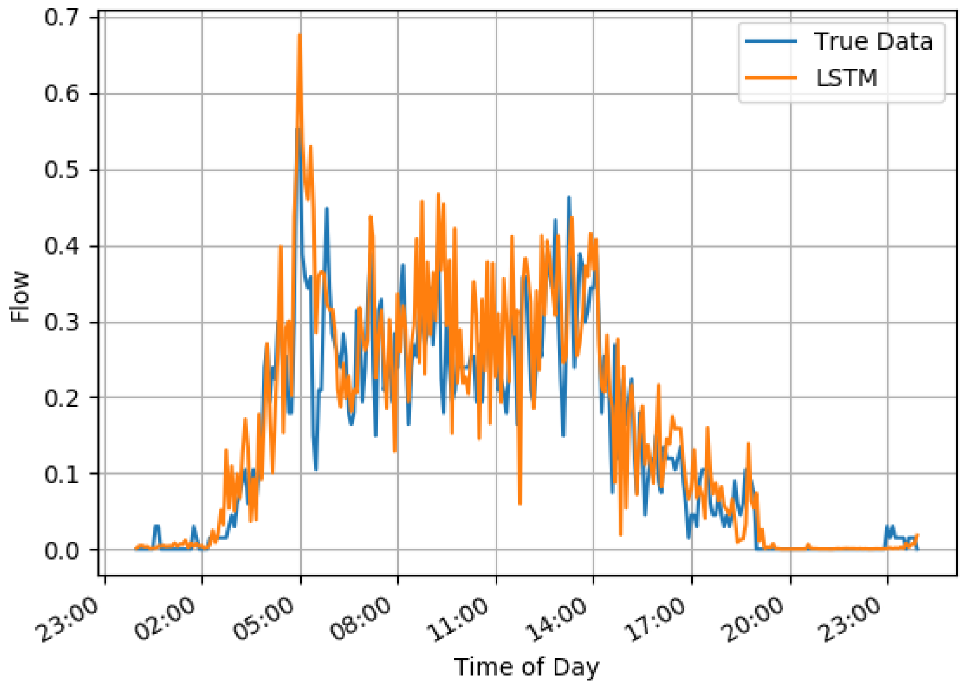
$$MSE = \frac{1}{n}\sum_{i=1}^{n}(y_i - p_i)^2$$

$$MAE = \frac{1}{n}\sum_{i=1}^{n}|y_i - p_i|$$

$$EV = 1 - \frac{Var(y-p)}{y}$$

$$R^2 = 1 - \frac{\sum_{i=1}^{n}(y_i - p_i)^2}{\sum_{i=1}^{n}(y_i - \bar{y})^2}$$

- mean square error (MSE)
- mean absolute error (MAE)
- explained variance (EV)
- R^2 (R2)



Many to One Prediction

- 52 roads are in the cluster, 52 time-series data is used to predict one of them
- The prediction is very close to the real traffic flow value and the floating pattern
- One to one, many to one, many to many have no difference in performance

Evaluation

- MSE is reduced by 30%, MAE is reduced by 21%, the errors are clearly decreased
- EV and R2 has increased by about 7%
- 52 times higher throughput in many to many prediction

Models	MSE	MAE	EV	R2
One to One	0.006501	0.051743	0.779400	0.779377
Many to One	0.004556	0.042653	0.810834	0.810533
Many to Many	**0.004004**	**0.039840**	**0.836513**	**0.833502**

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Conclusion

- To predict the traffic flow effectively, both spatial locality and temporal locality are important
- Spatial locality is captured by Clustering
    - Designed a dynamic traffic clustering system
    - Affinity propagation is well designed for distributed system, and can work with real-time data
    - The results show a good solution quality of affinity propagation
    - The number of clusters found by affinity propagation shows it works well on both peak hours and non-peak hours
- Temporal locality is captured by LSTM
    - Proposed a cluster merge algorithm to merge time-series clusters that will produce a cluster work for any time stamp
    - Based on clustered traffic data, I proposed many to one prediction model and many to many prediction model
    - Many to one and many to many model outperforms existing one to one model

Future Work

01

Experiment on larger and many datasets

02

Improve the similarity measurement

03

Find multiple paths (say k) using bio-inspired techniques such an ant colony optimization

04

Implement the affinity propagation on real IoT devices

05

Implement on domain specific architectures such as TPU


Questions?

Numerical Simulation and Analysis of Aerodynamic Characteristics of Road Vehicles in Platoon

Wei Gao, Zhaowen Deng, Ying Feng, Yuping He

Dr. Yuping He

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Faculty of Engineering and Applied Science,

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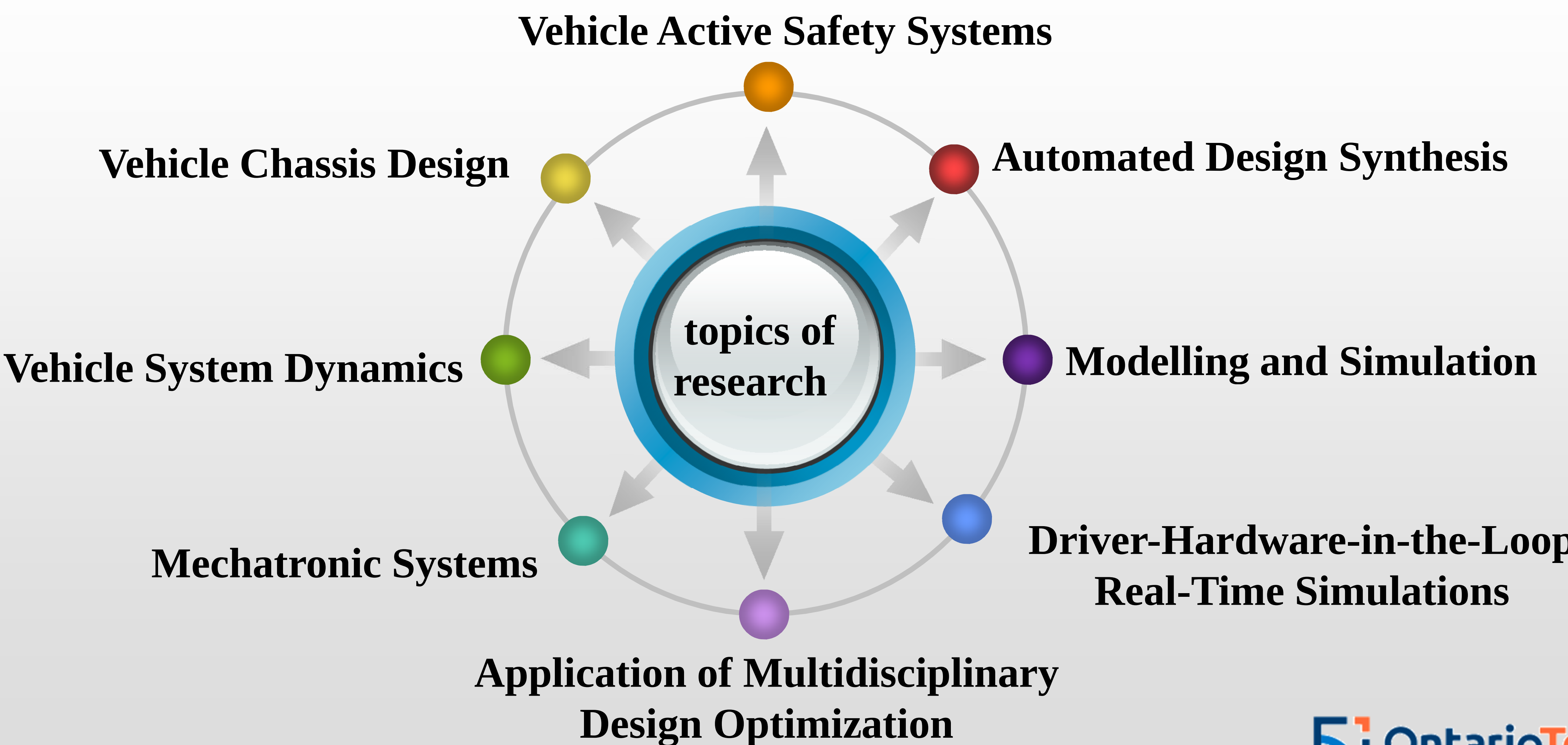
Background of the Presenter

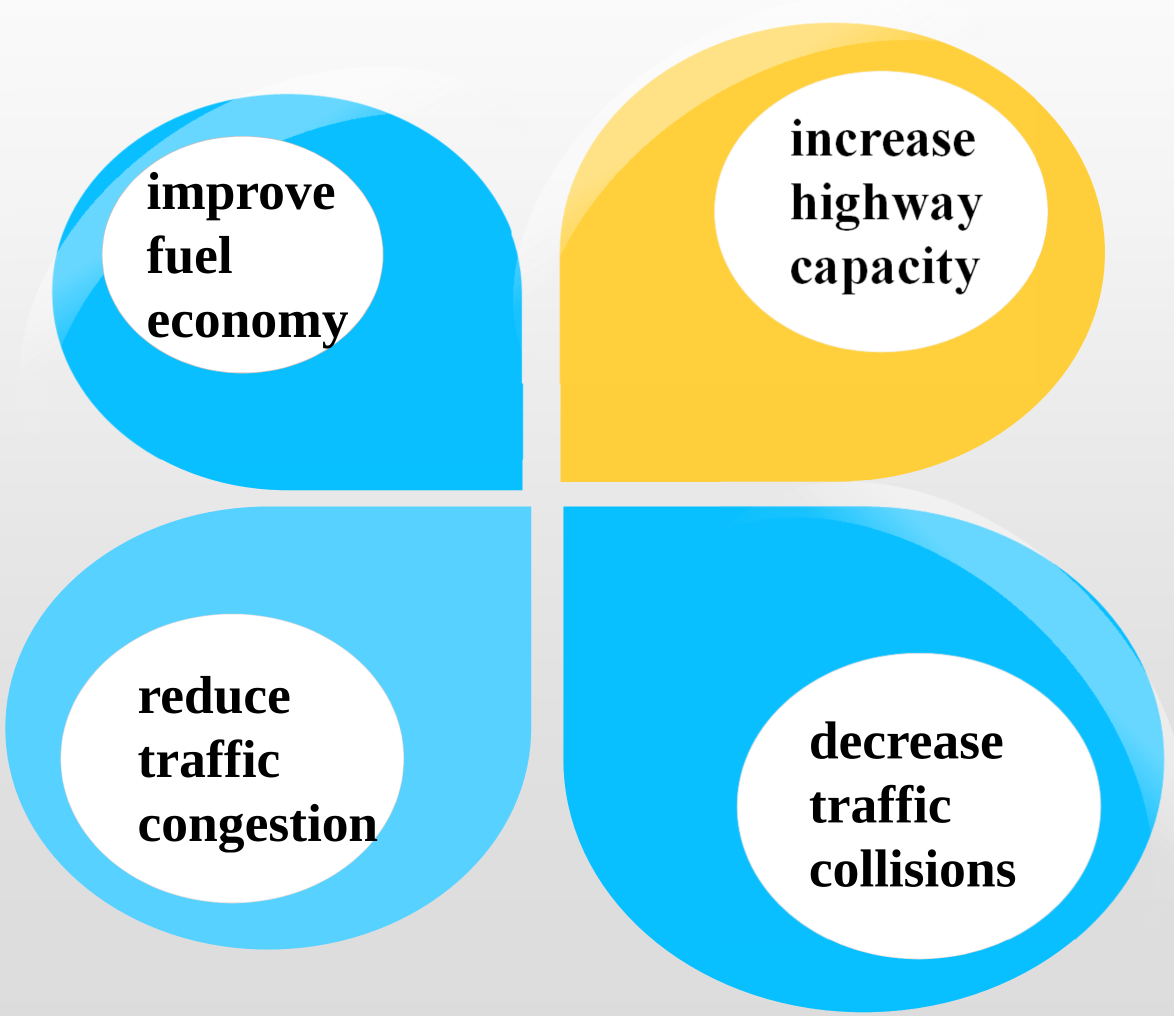
- Yuping He, PhD, PEng, CSME Fellow
- Professor, Ontario Tech University
  Email: yuping.he@uoit.ca
- Chair, Transportation Systems Technical Committee, Canadian Society for Mechanical Engineering
- Associate Editor of Transactions of the Canadian Society for Mechanical Engineering
- Associate Editor of International Journal of Vehicle Performance

Research Topics



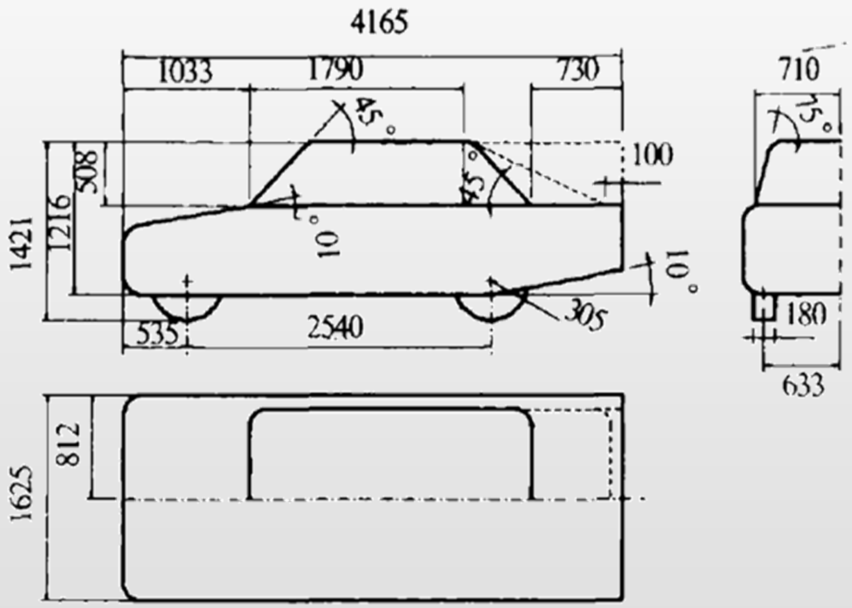
Introduction

The development of autonomous driving technology makes it possible for vehicles to travel in the form of a platoon.

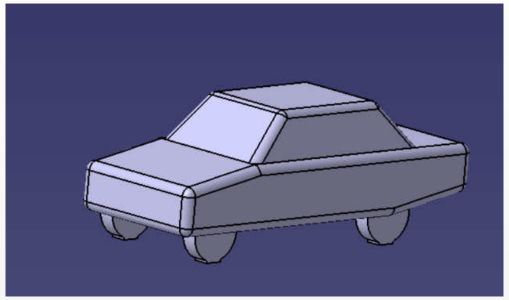


Simulation and Validation of External Flow Field of Single-Vehicle

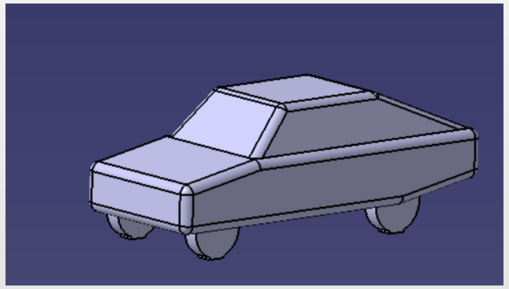
➢ Modelling



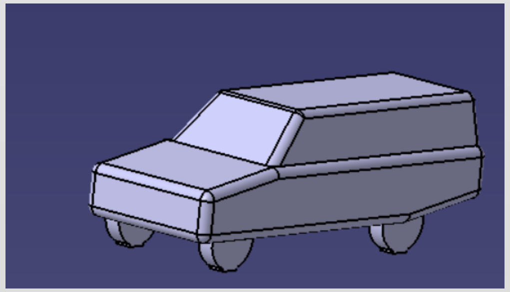
Dimensions of the MIRA model group



Notchback Model



Hatchback Model



Squareback Model

Simulation and Validation of External Flow Field of Single-Vehicle

➢ Validation of Numerical Simulation

Comparison of simulation and test of drag coefficient

Vehicle Type	Simulation	Wind Tunnel Test	Error
Notchback	0.3156	0.3237	2.5%
Hatchback	0.2911	0.2749	5.8%
Squareback	0.3661	0.3870	5.4%

Numerical Analysis of Influencing Factors on the Aerodynamic Performance of Vehicles Platoon

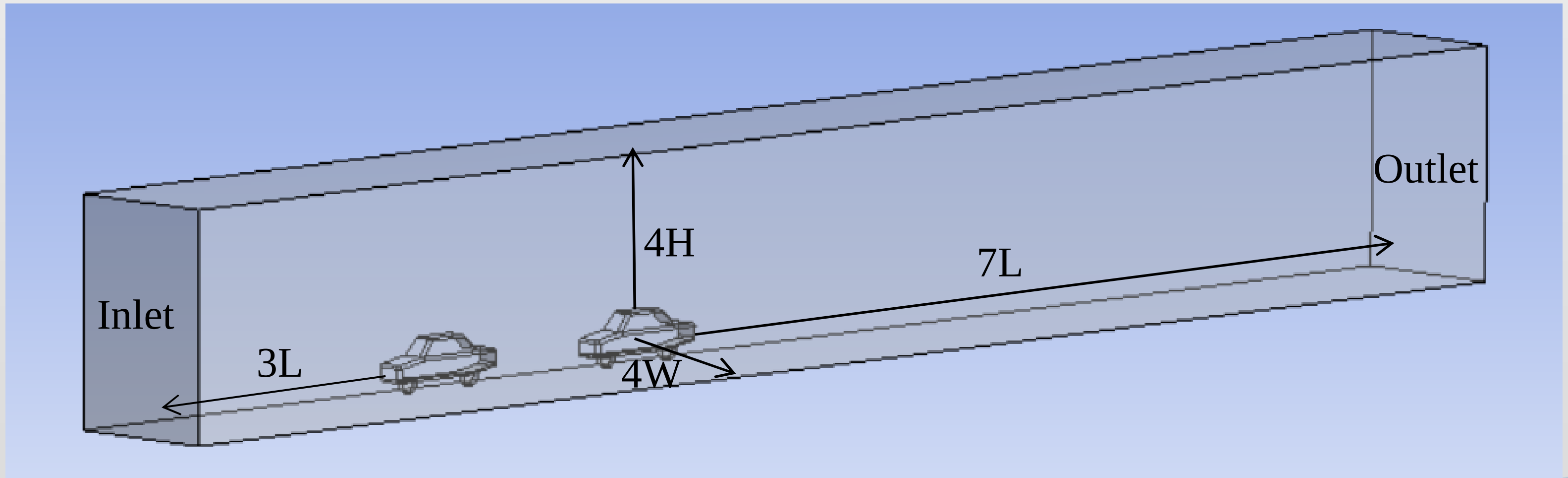
➢Effect of Longitudinal Spacing

- **Calculation Scheme**

Calculation scheme

Number of Vehicle	Longitudinal Spacing
2	0.5L, L, 1.5L, 2L, 2.5L, 3L

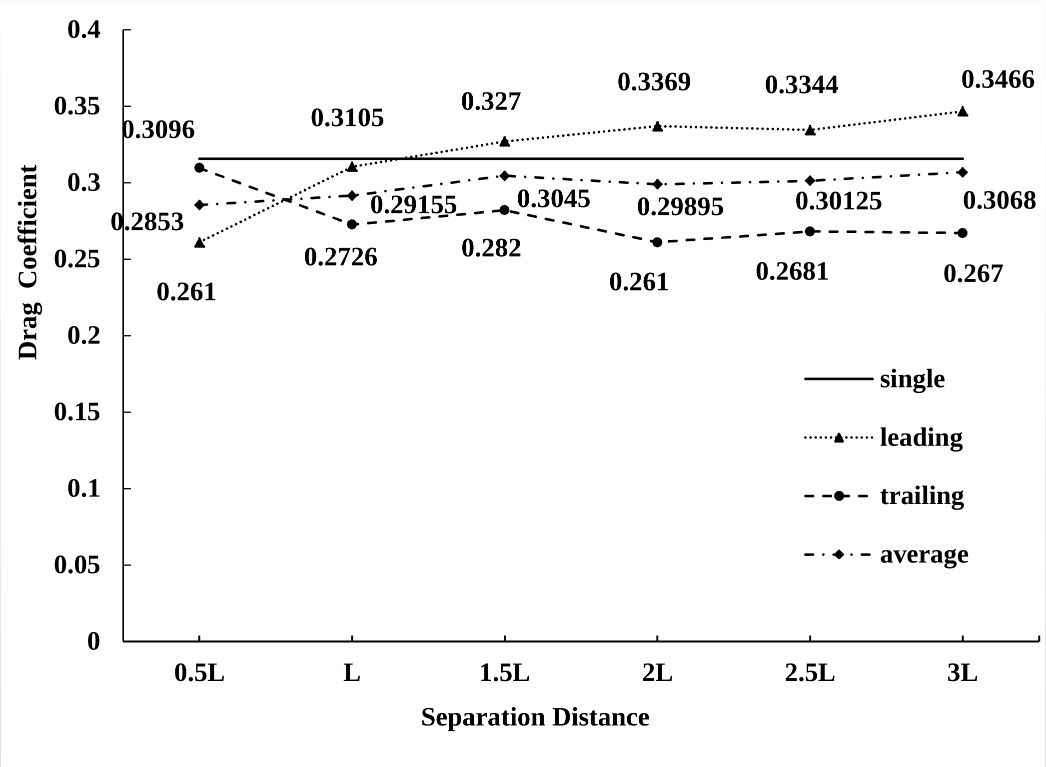
- **Computational Domain**



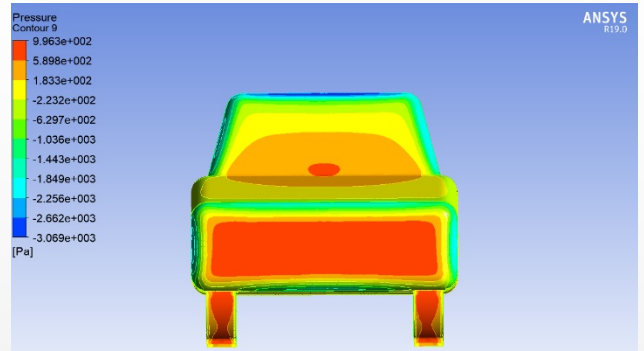
Schematic diagram of computational domain

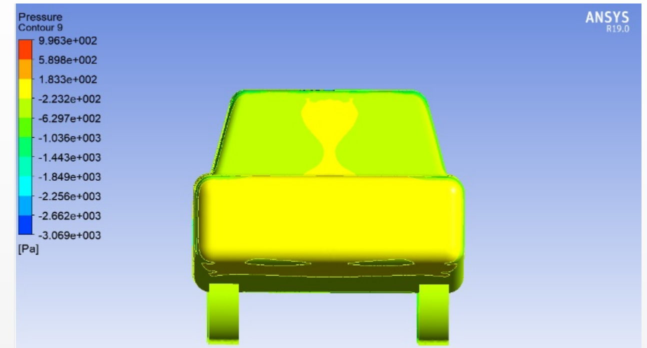
Numerical Analysis of Influencing Factors on the Aerodynamic Performance of Vehicles Platoon

Results of Simulation

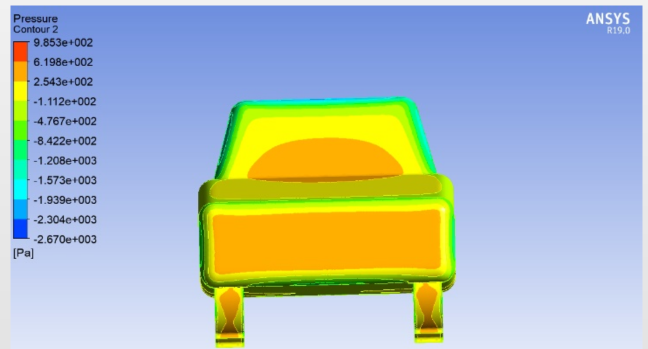


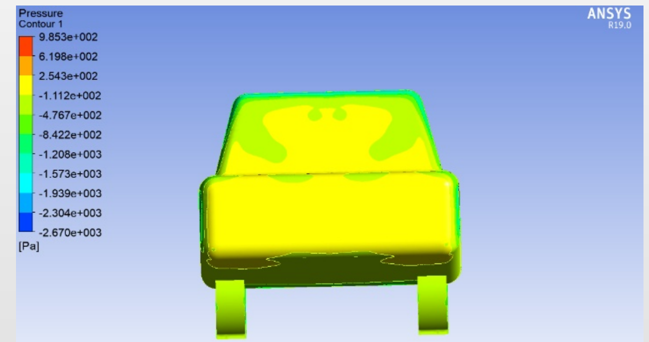
The drag coefficient of vehicle platoon for various separation distances





single-vehicle





trailing vehicle at the separation distance of 1L

leading vehicle at the separation distance of 1L

Distribution of pressure at the front of the vehicle

Distribution of pressure at the rear of the vehicle

OntarioTech UNIVERSITY

Numerical Analysis of Influencing Factors on the Aerodynamic Performance of Vehicles Platoon

➢ Effect of the Numbers of Vehicles

- **Calculation Scheme**

Calculation scheme

Longitudinal Spacing	Number of Vehicles
L	2, 3, 4, 5, 6, 7

- **Results of Simulation**

Drag coefficient of vehicles in the platoon

Number	First	Second	Third	Fourth	Fifth	Sixth	Seventh	$C_{Daverage}$
two	0.3105	0.2726						0.2916
three	0.3148	0.2489	0.2425					0.2687
four	0.3214	0.2621	0.2451	0.2808				0.2774
five	0.3097	0.2508	0.2259	0.251	0.272			0.2619
six	0.3207	0.2573	0.2403	0.2588	0.2693	0.2931		0.2733
seven	0.3037	0.2473	0.2352	0.2617	0.2701	0.2779	0.3021	0.2711

Conclusions

- when the separation distance of two vehicle platoon is 0.5L, the maximum of the average drag reduction rate is 9.6%. The average drag coefficient of two vehicle platoon is lower than that of the single-vehicle within the range of 0.5-3L;

- The average drag coefficient is minimum for five vehicles platoon. The average drag coefficients of other cases are less than that of the single-vehicle;

- Two MIRA notchback model platoon has the highest average drag reduction rate and its maximum value is up to 8.093%, followed by the squareback, hatchback is minimum;

- When the velocity is in the range of 10m/s-40m/s, the drag coefficient of both the leading and trailing vehicle for various velocities are lower than that of the single-vehicle. The average drag coefficient of two vehicles platoon is minimum at the velocity of 20m/s;

- When the vehicles are driving in the platoon, the flow field of the trailing vehicle is affected by that of the leading vehicle, and vice versa. The aerodynamic properties of both leading and trailing vehicle are influenced by the change of the wake region of the leading vehicle.

Drivers at work are fired in future?

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Vehicular 2020

Environment in Public Roads

- At closed area → All vehicles can be controlled automatically.
  → We can realize car control without drivers.
  → Monitoring is even required.
- Public roads
  - Private as a hobby and worker cars will be coexistence.
  - It seems herder to realize than closed area.
    → who has responsibility?

Ube Kosan separates public / private road by crossing
https://mapio.net/pic/p-76491314/

Conventional Cases

- Airplane
  - Auto pilot but course is set by pilots and registrars
  - Manufactures share the philosophy that the pilots are ultimately responsible for the safe operation of the aircraft,
    - Airbus has stated that “Automation should allow the operator to use the safe flight envelope to its full extent…” (Spitzer, Ferrell 2015: 224) (Airbus 2017: 6).
    - Boeing has stated in its design philosophy tha “The pilot is the final authority for the operatio of the aeroplane” (Spitzer, Ferrell 2015: 224).
- However, pilot is required.

Auto pilot system
https://weekendcaptainflight.com/pmdg737-auto-pilot-roll-mode/

Conventional Cases

- Railroad
  - In some systems, crew ride a vehicle.
  - Monitoring is required.

https://jidounten-lab.com/u_train-autonomous-matome

Monitoring

- Most of autonomous transportation system have centralized control and monitoring system
- Person, who has responsibility, has to check the control.

Control tower
https://www.mlit.go.jp/common/001067906.jpg

As analogies of other vehicular system, monitoring is required.

Conclusions

- Drivers at work may be fired, but worker for monitoring will be continuously required.
- In public road, automatic control is hard to realize because of not technique but responsibility.
- Derivers or operator will be required as a responsible person.
  - However, they have certainly less physically stress than conventional systems.

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Panel:
Vehicular at Work: Are we Ready?
(acceptance, electric, wireless communication, high speed processing, self-driving, …)

InfoWare 2020

Panellist Position

The Future of Inter-Vehicle Wireless Communications Technologies - Issues and Challenges

Dragana Krstic, *Faculty of Electronic Engineering, University of Niš,* Niš, Serbia

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- **Smart Transportation**
- **Vehicle To Vehicle Communication**
- **Intelligent Transportation System (ITS)**
- **Integrated Mobility: The Transport Solution For Tomorrow's Cities**

- For the transport sector a few issues are important to analyze: traffic congestion and accidents
- In last years, cooperation between vehicles is developing
- The main goal is to increase road safety and anticipate the circumstances of potential dangers
- Vehicle-to-Vehicle (V2V), Vehicle-to-Infrastructure (V2I) and Vehicle-to-Everything (V2X) technologies try to be communication models used by vehicles in different application contexts
- The resulting infrastructure is an ad-hoc mesh network whose nodes are not only vehicles but also all mobile devices equipped with wireless modules

Smart Transportation

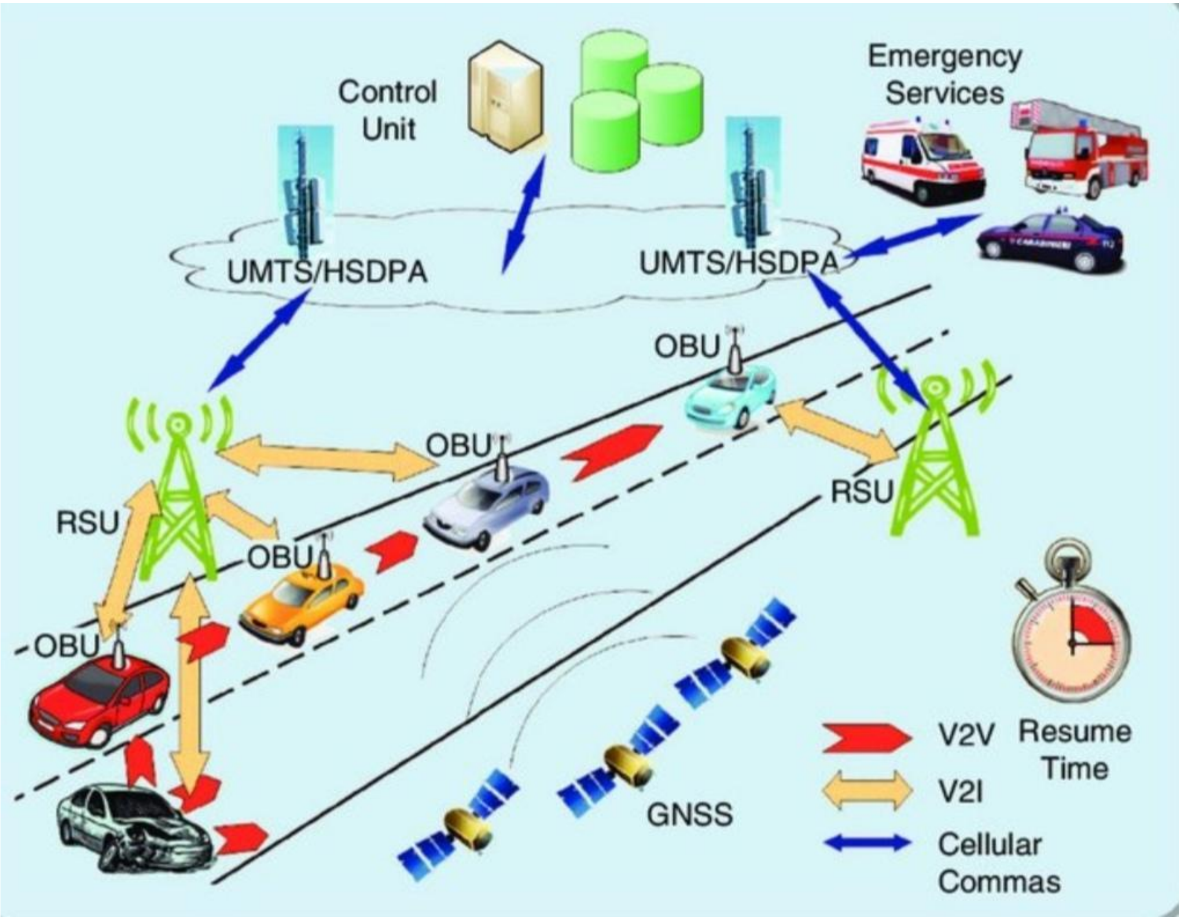
- The smart transport revolution is spreading in the world
- Users have more transport options than ever before and entirely new ways to consume transport services
- City governments have new opportunities to incentivize green, efficient modes of transport, to reduce congestion and improve the quality of life

Intelligent Transportation System (ITS)

- An Intelligent Transportation Systems (ITS) is an effective transportation and mobility system used in smart cities
- It takes advantage of technologies such as the Internet of Things (IoT) and big data analytics to manage traffic and mobility, enhance transport infrastructure, and provide improved interfaces for transport services

- Benefits of an ITS include:

- Creating interconnected transport systems with open communication between devices and vehicles.
- Actively managing traffic, helping public transport to keep the schedules
- Ensuring citizens have access to real-time information about traffic and public transportation conditions.



ITS communication technologies based on the V2V and V2I communications

Integrated Mobility: The Transport Solution For Tomorrow's Cities

- By 2030, roughly 60% of the global population will live in cities
- An increase in the number of "megacities" (with a population of over ten million) is causing new transportation challenges
- With growing access to connectivity, mobile applications, and transport automation, methods people use to travel around cities will change
- Integrated mobility is helping cities make the most of new transportation options, and leverage them to solve problems like congestion, pollution, and access to economic opportunity.
- The basis of integrated mobility is public transport

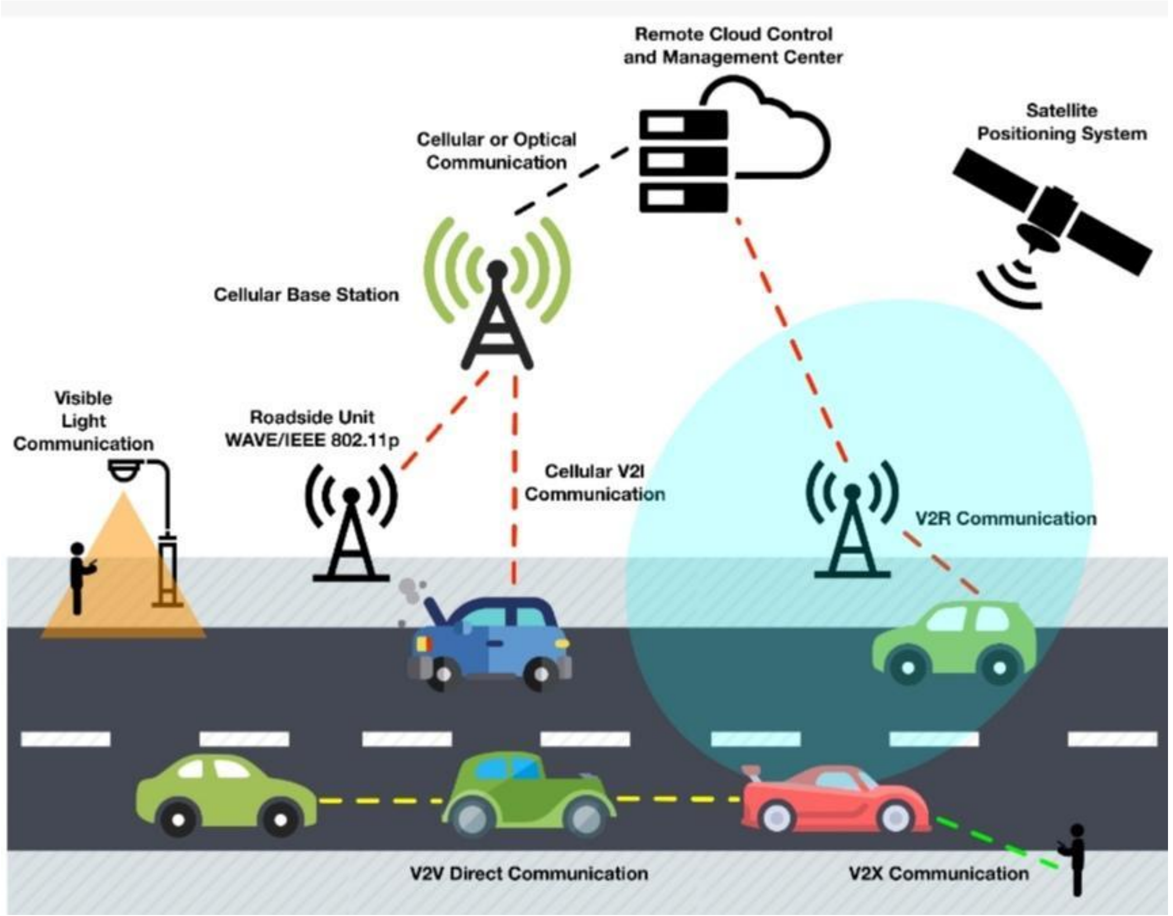
- Challenges In Today’s Transport Systems
- Cities experience pressing transport challenges when transport systems cannot meet the demands of urban mobility.
- Land consumption: Today’s cities are expending. The result is often complex transit and long commutes. In North America, 30-60% of the area of an urban region may be set aside for roads and parking lots, caused by over-dependence on certain types of transportation, particularly the automobile.
- Congestion and parking problems: Transportation infrastructures are under strain due to the spread and motorization of the automobile. Vehicles spend most of their time parked, creating a need for parking spaces
- Aging infrastructure: maintenance costs are growing
- Movement of freight: Globalization, materialization, and online shopping demand the movement of growing quantities of freight and congestion are bigger when freight traffic shares infrastructure with passenger traffic

- Benefits Of Integrated Mobility For Cities
- Social inclusion: An aim of mobility is to provide citizens with access to city services (low-floor trams, barrier-free public transport, smart cards, etc.
- Economic benefits: Better mobility solutions provide people with better access to their activities
- Green cities: Increasing of road safety, reduced noise pollution, efficient utilization of public space, better air quality,...
- Save time and money: Time wasted sitting in traffic, billion gallons of wasted fuel. Mobility solutions such as ridesharing save time for citizens and reduces expenses.
- Solve urban density problems: The goal is the interoperability of public transportation working together with the private sector.
- The flexibility of city commuting: Users can use cloud platforms and apps dedicated to mobility to organize their journeys, book trips, vehicles in real time, use electronic payment services,...

Vehicle To Vehicle Communication

- The transport sector is tied with several problems, such as traffic congestion and accidents
- Because of that, in recent years, the cooperation between vehicles is developing
- The main goal of this trend is to increase road safety, attempting to anticipate the circumstances of potential danger
- Vehicle to Vehicle Communication (V2V) is an upcoming technology under development by automotive giants, as well as numerous small companies
- Vehicle to vehicle communication helps vehicles form spontaneous wireless networks on the go and transfer data over an ad-hoc mesh network
- Each vehicle sends reports about traffic and road conditions, vehicle position and speed, route direction, and loss of stability and brakes if these occur
- The information is added to the network and serves as a safety warning for the other vehicles, similar as traffic radio stations provide information for people

- Individual cars use the information from the network to create a dynamic view of their surroundings
- A complete overview enables the car can send danger alerts and encourage actions that prevent accidents and reduce traffic congestion
- It promises to make human driving safer and become an enabler for autonomous driving by connecting vehicles and road infrastructure via ad hoc networks
- V2V systems, once fully deployed, could reduce accidents caused by human error by up to 70-80%, and can have a massive impact on congestion and carbon emissions, but there are still many restrictions: technical, security and regulatory concerns


Remote Cloud Control and Management Center
Satellite Positioning System
Cellular or Optical Communication
Cellular Base Station
Visible Light Communication
Roadside Unit WAVE/IEEE 802.11p
Cellular V2I Communication
V2R Communication
V2V Direct Communication
V2X Communication

How V2V Communication Works?

- Vehicle-to-Vehicle (V2V), Vehicle-to-Infrastructure (V2I) and Vehicle-to-Everything (V2X) technologies tend to define communication models that can be employed by vehicles in different application contexts; together, the systems form an interactive routing map
- Vehicle to vehicle communication is made possible due to

  -the Internet of Things (IoT) devices like GPS receivers, which let vehicles communicate their location through the V2V system, and

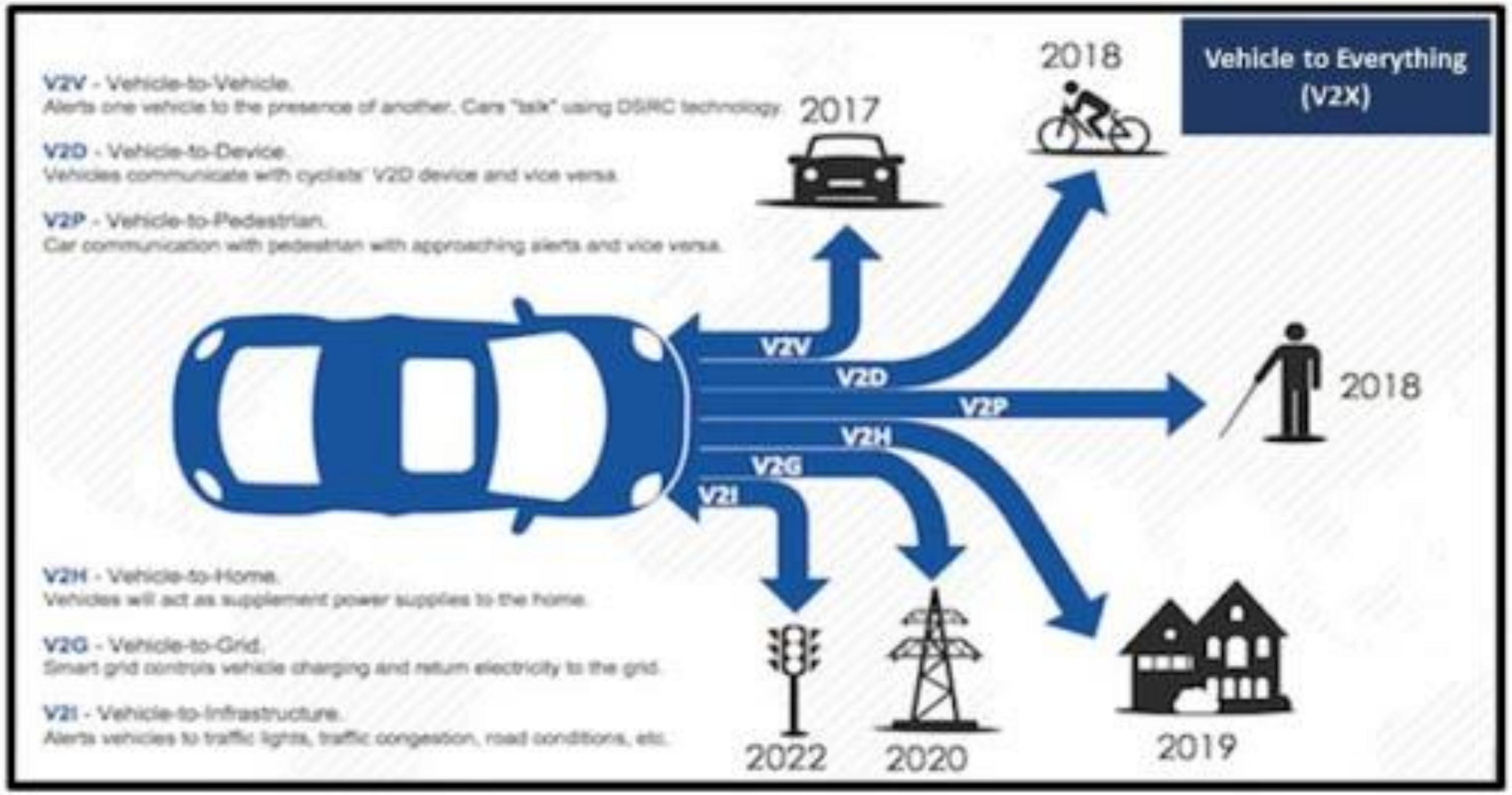
  - road sensors, which send data about road conditions through the V2I system
- DSRC (Dedicated Short Range Communications) connect the two systems and ensure each vehicle receives all the information it needs for safe navigation
- The multiple connected units consists of information exchange through the adoption of suitable communication protocols


V2V
Vehicle-to-vehicle
e.g., collision avoidance safety systems
V2I
Vehicle-to-infrastructure
e.g., traffic signal timing/priority
V2P
Vehicle-to-pedestrian
e.g., safety alerts to pedestrians, bicyclists
V2N
Vehicle-to-network
e.g., real-time traffic/routing, cloud services

What Is Vehicle-to-Everything (V2X)?

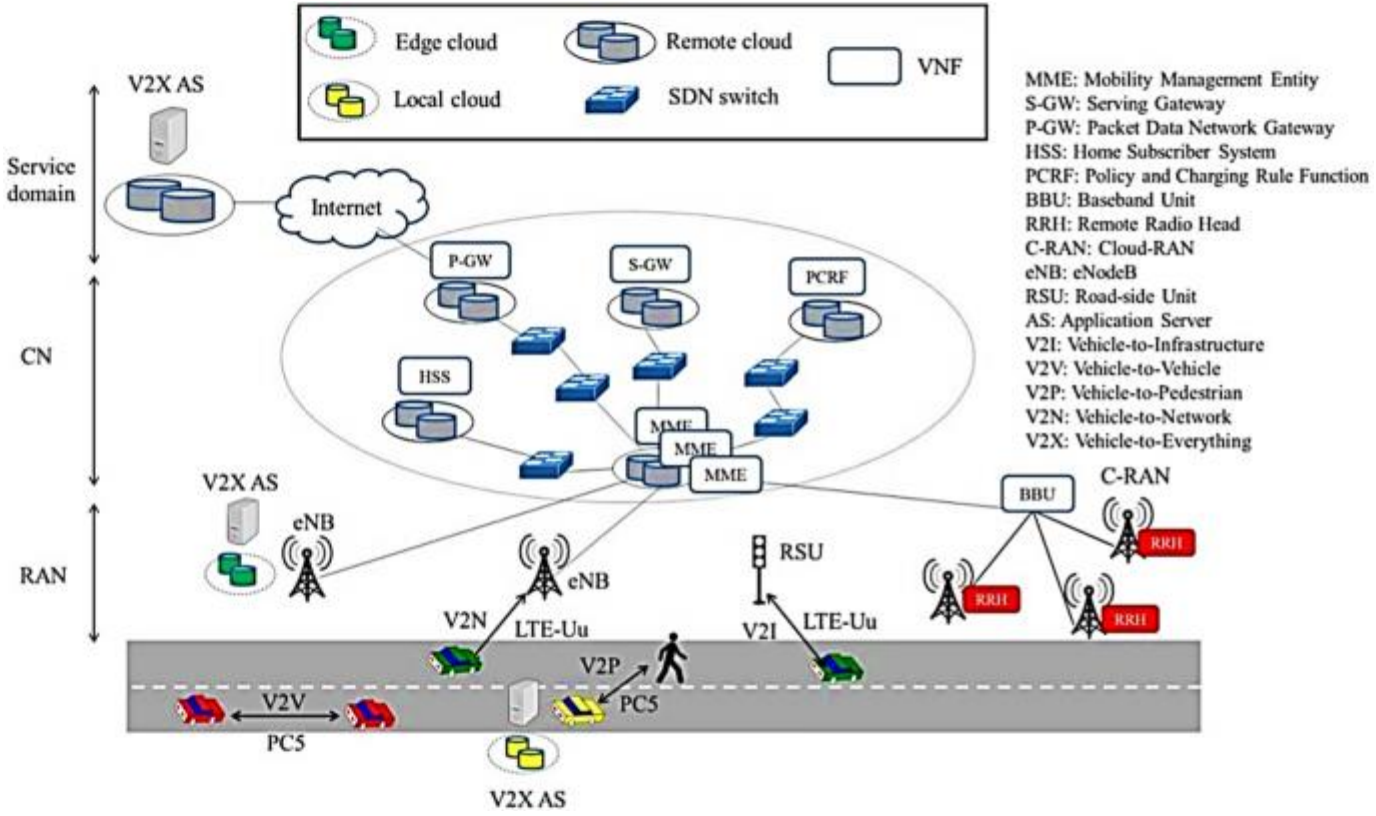
- Vehicle-to-everything (V2X) is a technology that allows vehicles to communicate with moving parts of the traffic system around them, known as connected-vehicle-to-everything communication
- V2X communications systems are mainly used for the purpose of increasing safety and preventing collisions
- In a traditional vehicle, V2X systems can convey important information to the driver regarding inclement weather, nearby accidents, road conditions, and the dangerous activities of nearby vehicles
- In autonomous vehicles, V2X provides extra information to vehicle's existing navigation system

- V2X consists of several components, including:
  - -vehicle-to-vehicle (V2V) which allows vehicles to communicate with one another.
  - -vehicle to infrastructure (V2I) which allows vehicles to communicate with external systems such as street lights, buildings, and even cyclists or pedestrians
  - - Intra-Vehicle (InV),
  - - vehicle-to-pedestrian (V2P)
  - - vehicle-to-network (V2N)
- Vehicles exchange information about their state, view of current road, navigation information and other general information about weather report and digital map update
- V2X also offers other benefits like enabling automatic payment of toll fees, parking, and similar fees



Vehicle to Everything (V2X)
V2V - Vehicle-to-Vehicle.
Alerts one vehicle to the presence of another. Cars "talk" using DSRC technology.
V2D - Vehicle-to-Device.
Vehicles communicate with cyclists' V2D device and vice versa.
V2P - Vehicle-to-Pedestrian.
Car communication with pedestrian with approaching alerts and vice versa.
V2H - Vehicle-to-Home.
Vehicles will act as supplement power supplies to the home.
V2G - Vehicle-to-Grid.
Smart grid controls vehicle charging and return electricity to the grid.
V2I - Vehicle-to-Infrastructure.
Alerts vehicles to traffic lights, traffic congestion, road conditions, etc.
V2V
V2D
V2P
V2H
V2G
V2I
2017
2018
2018
2019
2020
2022

- A key for exchanging information in timely manner is an opportunity to access the medium for longer life with low power consumption in various ranges
- They provide high reliability without experiencing long and uncertain delay
- V2X uses a short-range wireless signal to communicate with compatible systems, and this signal is resistant to interference and inclement weather
- Thus, widespread adoption of vehicular networks is fast becoming a reality, where additional functions will be provide by the car electronics and the passengers will be able to access the Internet and other core network resources


Edge cloud
Remote cloud
VNF
Local cloud
SDN switch
V2X AS
Service domain
Internet
CN
P-GW
S-GW
PCRF
HSS
MME
MME
MME
V2X AS
eNB
RAN
eNB
V2N
LTE-Uu
RSU
V2I
LTE-Uu
BBU
C-RAN
RRH
RRH
RRH
V2P
V2V
PC5
PC5
V2X AS
MME: Mobility Management Entity
S-GW: Serving Gateway
P-GW: Packet Data Network Gateway
HSS: Home Subscriber System
PCRF: Policy and Charging Rule Function
BBU: Baseband Unit
RRH: Remote Radio Head
C-RAN: Cloud-RAN
eNB: eNodeB
RSU: Road-side Unit
AS: Application Server
V2I: Vehicle-to-Infrastructure
V2V: Vehicle-to-Vehicle
V2P: Vehicle-to-Pedestrian
V2N: Vehicle-to-Network
V2X: Vehicle-to-Everything

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Connected and Autonomous Vehicles (CAV): Road Safety

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IARIA

InfoWare 2020

Critical Problems of Transportation

- **Safety:** More than1.35M people die each year on roads worldwide due to accident. (WHO)
- **Energy:** In the USA, congestion wasted 3.1B gallons of fuels. (DoE)
- **Climate:** Road transportation CO2 contributes 21.6% of green house emissions. (EU Parliament)

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Major Causes of Accidents

Study by National Highway Transportation and Safety Administration (UK) shows:

- 93% accidents due to human error.
- 80% crashes due to driver inattention in 3 seconds before event.
- 60% road accident fatalities due to unintentional lane departure.

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Five Automation Levels

Eyes on Hands on	Eyes on Hands on	Temporary Hands off	Temporary Eyes/Hands off	Eyes off Hands off	Eyes off Hands off

0	1	2	3	4	5
No Automation	**Driver Assistance**	**Partial Automation**	**Conditional Automation**	**High Automation**	**Full Automation**
Zero autonomy; the driver performs all driving tasks.	Vehicle is controlled by the driver, but some driving assist features may be included in the vehicle design.	Vehicle has combined automated functions, like acceleration and steering, but the driver must remain engaged with the driving task and monitor the environment at all times.	Driver is a necessity, but is not required to monitor the environment. The driver must be ready to take control of the vehicle at all times with notice.	The vehicle is capable of performing all driving functions under certain conditions. The driver may have the option to control the vehicle.	The vehicle is capable of performing all driving functions under all conditions. The driver may have the option to control the vehicle.

Source: SAE (Society of Automotive Engineers)

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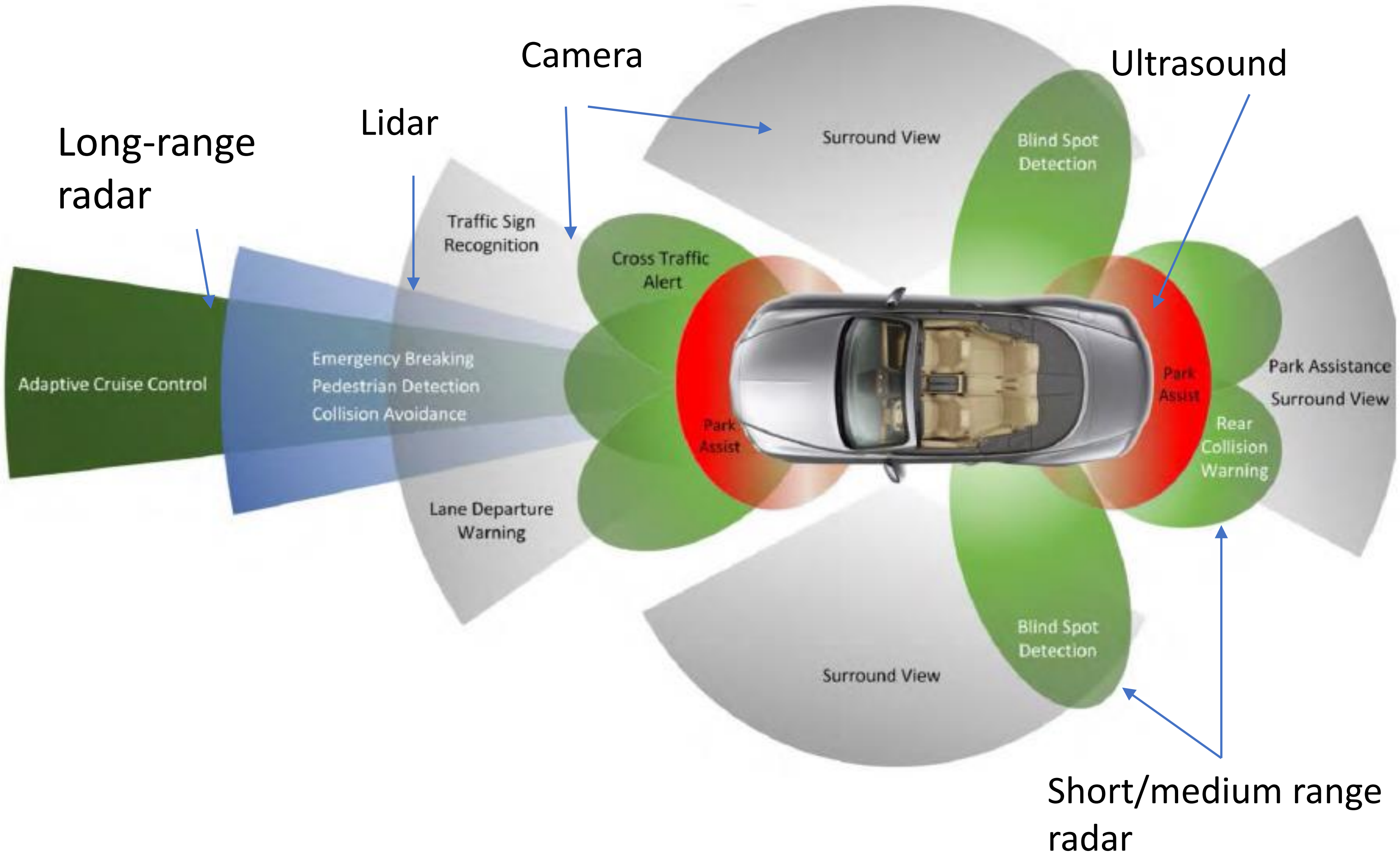
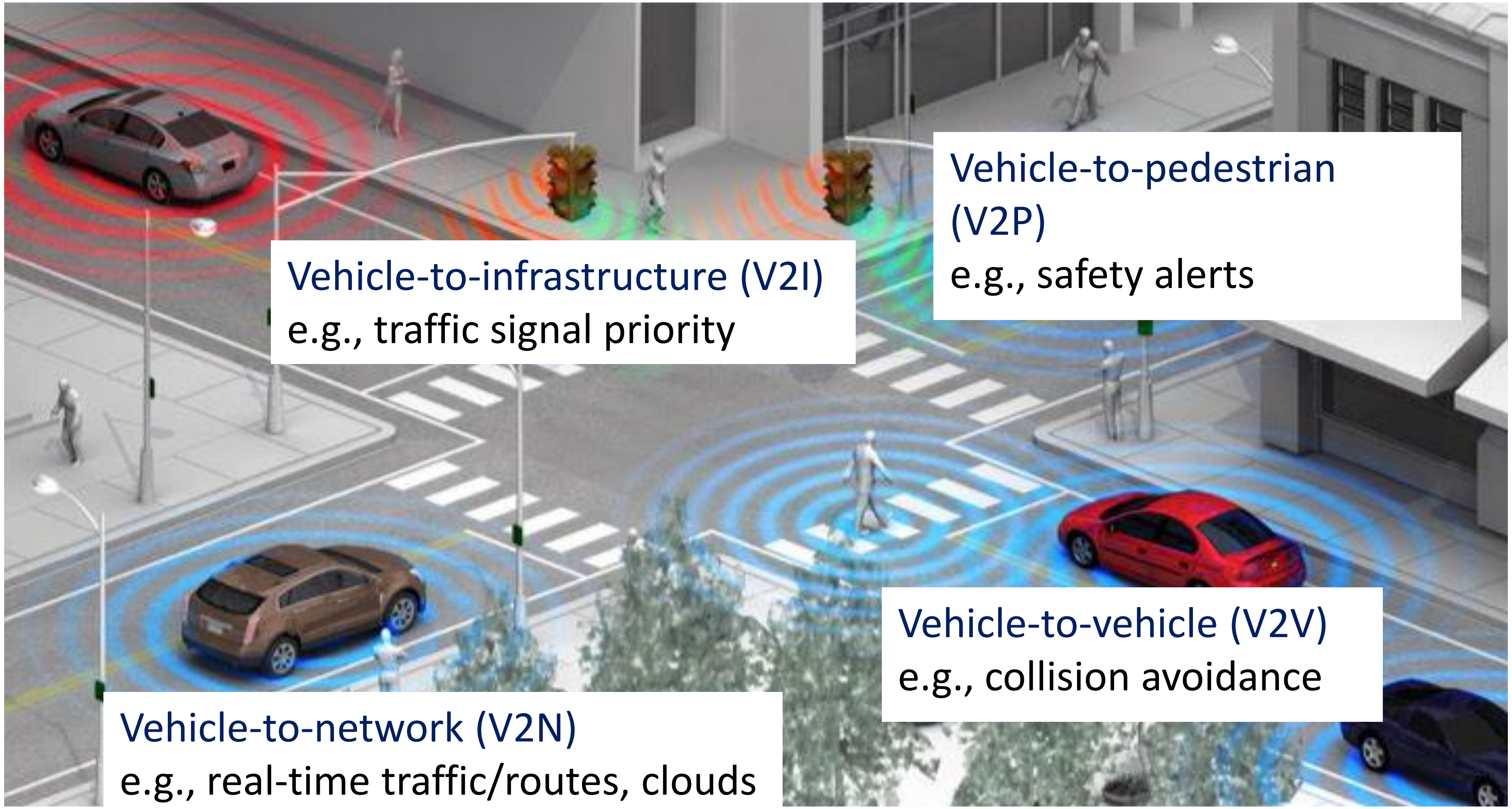
Vehicle Sensing Equipment



Communications for Connected Vehicles



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Sensing vs. Communications

Safety can be ensured by applying both sensing and communications technologies.

- ❖ Sensing is mainly used to detect instantaneous distance and its change rate between neighboring vehicles.
- ❖ Communications can provide prompt road and traffic conditions between vehicles within a long range.
- ❖ Both technologies should be used collectively to maximize the level of driving safety required.

Challenges to CAV

- **Safer**: towards zero road accidents.
- **Greener**: reduce air pollution & emissions.
- **More predictable**: foresee risks to operation reliability and public safety.
- **Productive travel**: preplanning, timely update, and uneventful journey.

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Promising Technologies for CAV

Heterogeneous connectivity

Service:
Cooperative safety
Always-on telematics
Connected infor-tainment
Wireless EV charging
Real-time navigation

Vehicle-to-everything (V2X):
WiFi/HotSpot, DSRC
Cellular 3G/4G/5G
Bluetooth
CAN/ Ethernet /Powerline

On-device intelligence

Applications:
Always-on sensing
Augmented reality
Immersive multimedia
Intuitive instrumentation

Tools:
AI
Computer vision
Machine learning
Integrated cybersecurity architecture
Distributed cooperation

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Thanks