Towards a WIFI-Bluetooth system for traffic monitoring in different transportation facilities

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Problem Definition

- A growing interest in the development of traffic monitoring systems, to estimate reliable and efficient traffic parameters

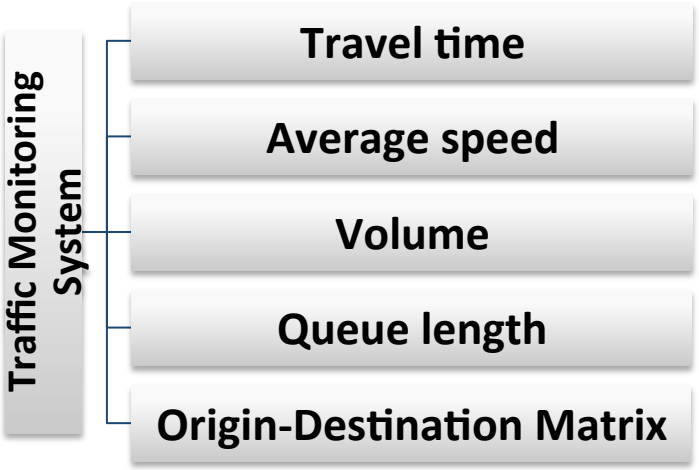
- These parameters can be:
  - Travel time
  - Average speed
  - Queue length
  - Volume

Problem Definition

- With similar purpose, there is also a burgeoning interest in collecting pedestrian traffic flows in specific facilities or locations (downtown areas, terminals, public buildings, etc.)
- Also, biking path and cyclist safety is another interesting subject for research and the parameters that should be measured can be:
  - Average speed
  - Flow
  - Origin-Destination matrices

Main objects

- Design a cost effective and efficient traffic monitoring system to cover all traffic modes including cyclists, pedestrians and vehicles.
- So, the requirement of monitoring system is to cover parameters such as:



Main objects

Public Transit Planning

Source: torontoist.com

Transportation Safety

Source: transportationfortomorrow.com

Intelligent Traffic Light System

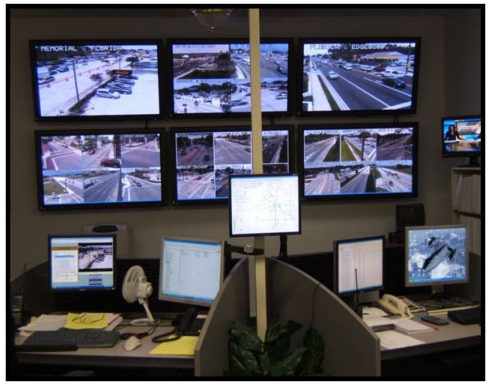
Source: http://www.gadgetking.com

Infrastructure Development

Source: www.solvencyiinews.com

Network users interface

Source: www.wamda.com



Real Time Traffic Monitoring

Source: www.lakelandgov.net

Existing systems

- There are lots of commercial system to monitor traffic network that each one has its own advantages and shortcomings.
- Loop detectors
- Pneumatic tubes
- Radar speed measurement system
- Video Processing
- Bluetooth and WiFi systems
- etc,

Existing systems

Wireless Technologies

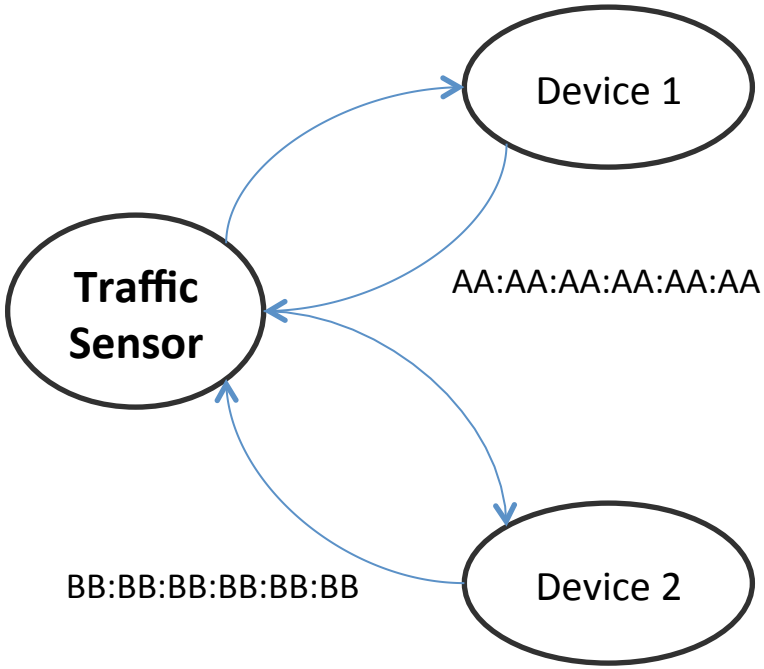
- To overcome the high cost and limitation of traditional data collection methods, simpler approaches have emerged using wireless technologies
- Among the emerging methods, Bluetooth-based sensors have gained popularity because:
  - relatively lower costs (hardware and software is inexpensive)
  - large quantities of data can be collected over time
  - suitable for temporary or permanent installation
  - measure travel times in a highways and arterials *(1, 3, 4, 8)*
  - monitor pedestrian traffic in pedestrian environments [1]

How Wireless Technologies work?

- With Bluetooth and WIFI, a unique media access control (MAC) address for each device is obtained and thus each device can be monitored as it moves through a network
- MAC address: Unique 12 Character hexadecimal ID, for example 90:C1:15:58:CA:70

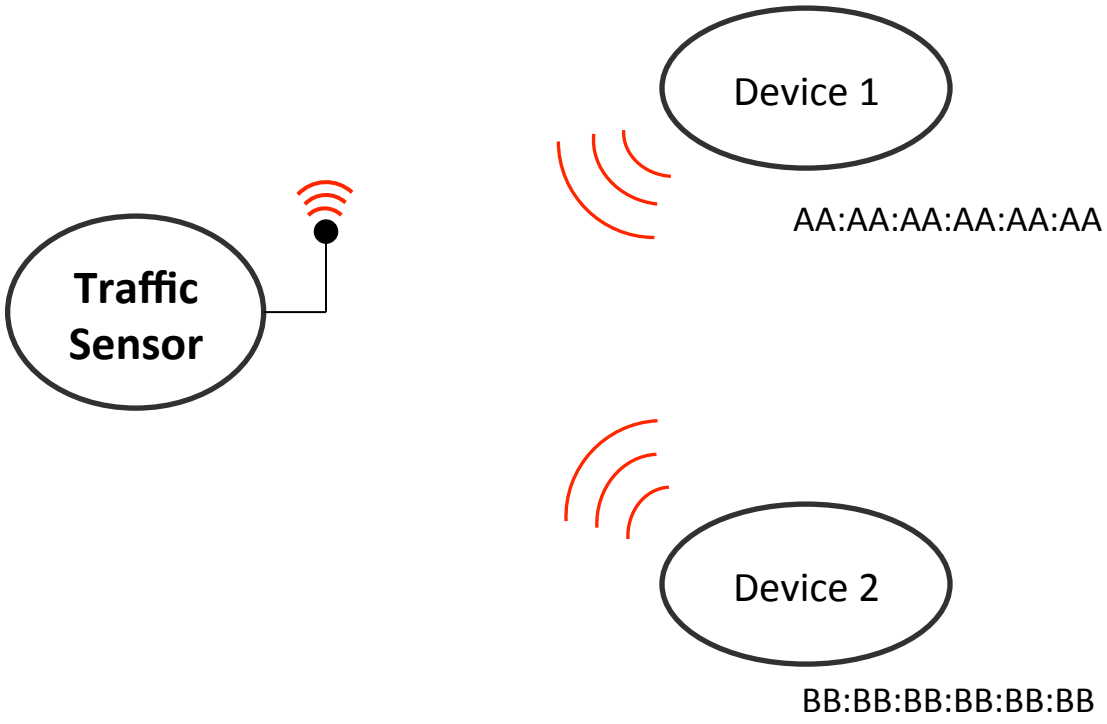
How Wireless Technologies work?

- Bluetooth sensor transmit signal to all Bluetooth-enabled and discoverable device in its vicinity and listens to their response.



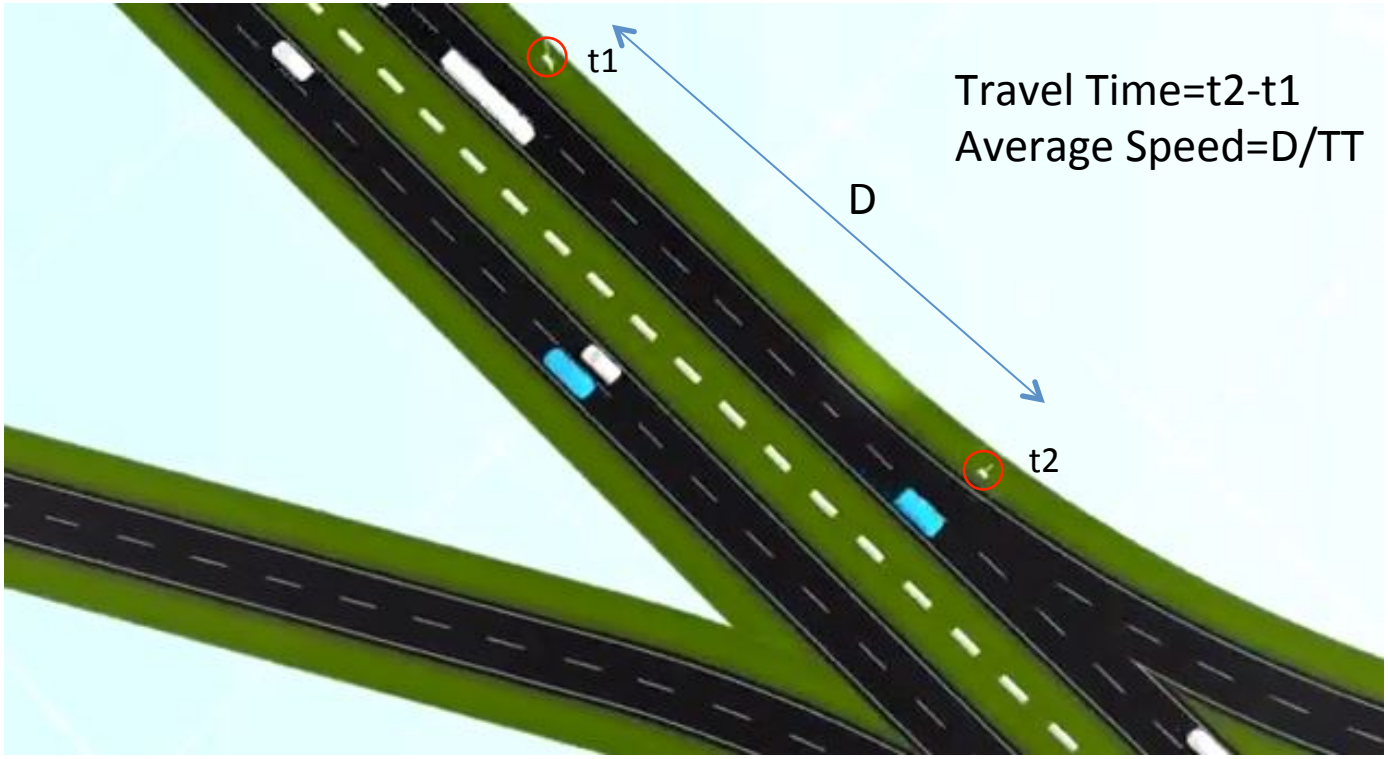
How Wireless Technologies work?

- But, the WiFi sensors work in passive mode, It just listens to all the packet broadcasted by other WiFi devices



How Wireless Technologies work?

- So, If we consider the traffic network:



Shortcomings of Bluetooth System

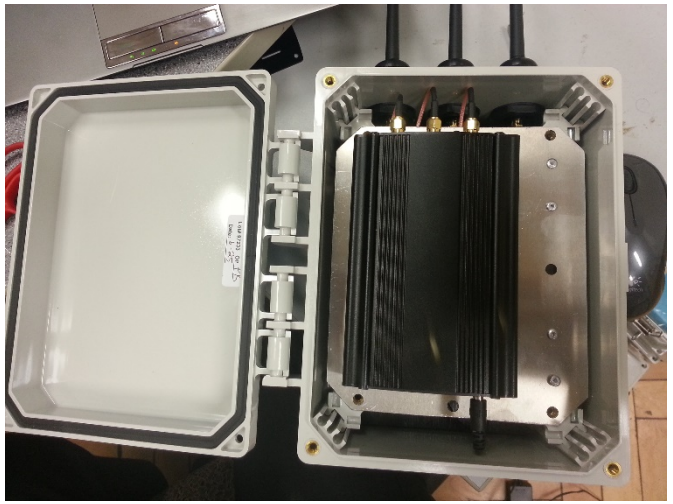
- Low sampling rates varying between 3 to 12 percent in all road types and for all modes [1, 8]
- Other shortcoming is that Bluetooth is often disabled or not "discoverable" on smartphones due to security risks, battery concerns, or lack of use

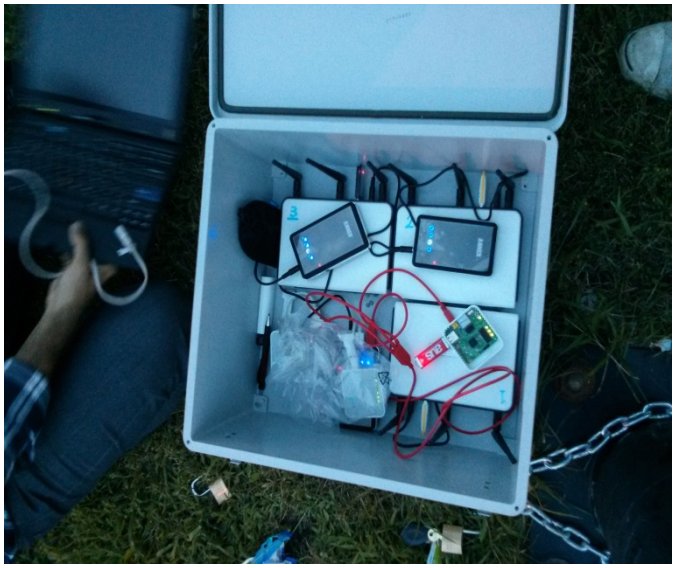
To overcome the issues with Bluetooth and increase the detection rate, some researchers have begun considering Wireless Internet (WIFI) detection as an alternative [9, 10]

Our Proposed System

- So, To solve the problems of the Bluetooth only system we designed an integrated system including both Bluetooth and WiFi system to increase accuracy and detection rate.
- Our system includes:
  - AVR controller as processor of the system
  - GSM modem to send all data in real time to our server through GPRS protocol
  - Micro SD to save all MAC address in case of the GPRS disconnection
  - Bluetooth module
  - WiFi module

Designed System: Hardware

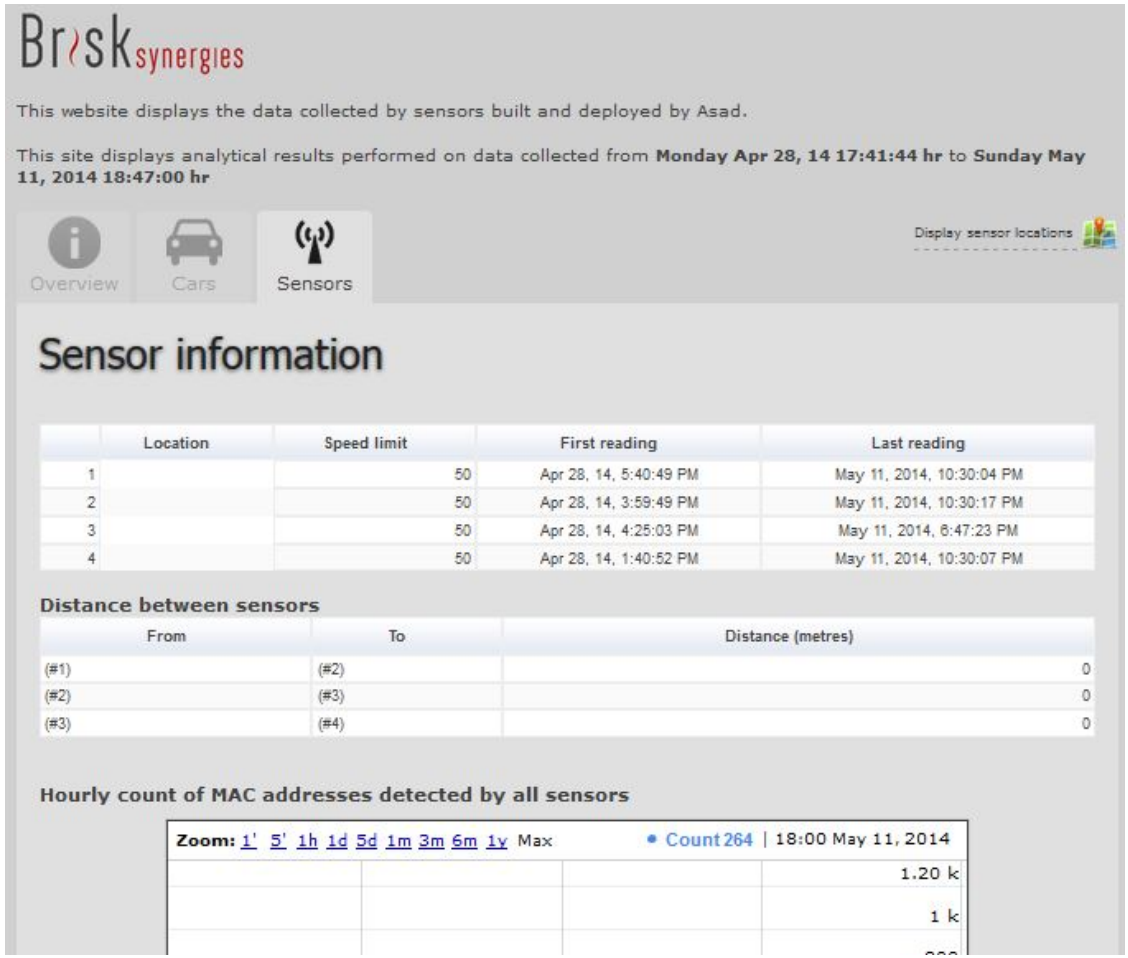




Designed System: Software

- The pre-processing of the data in each sensor is done using AVR based micro controller.
- Also, our WiFi modules has been flashed with OpenWRT, a linux based operation system
- All the detected MAC addresses will be sent to the server through HTTP protocol, and a cloud computing process, analyze the data in real time

Designed System: Server



Case Study

- In this project we have tested our designed WiFi system
- We have three case studies:
  - Arterial Test, Avenue Du Parc, multi modal network
  - Pedestrian network, McGill Campus
  - Travel time and average speed validation

- In two first case studies, Video data has been used to validate result of the system, and for last case, floating car technic has been used to find average travel time and average speed

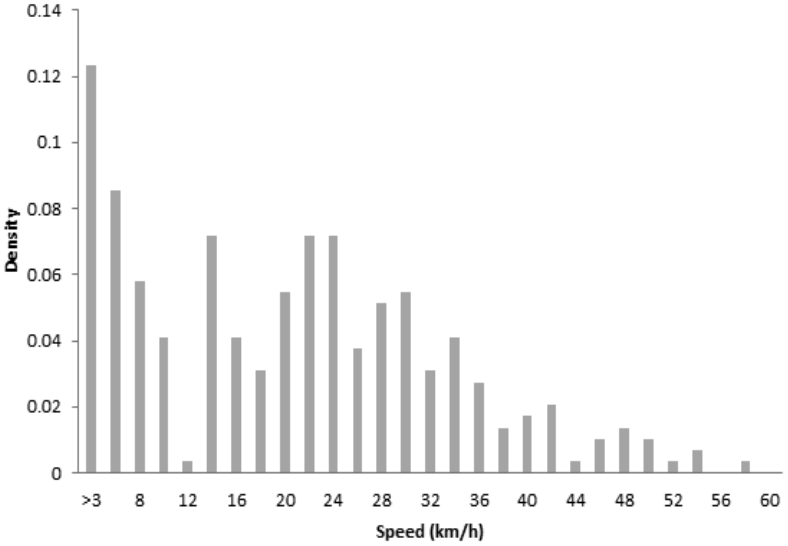
Case Study: Arterial Test

- In this case study detection rate of 6 installed WiFi sensors in network has been considered.
- Avenue Du Parc is selected arterial with:
  - The length of the section that was used (between the first and last device) for this test is of 1360m
  - bi-directional sections with three

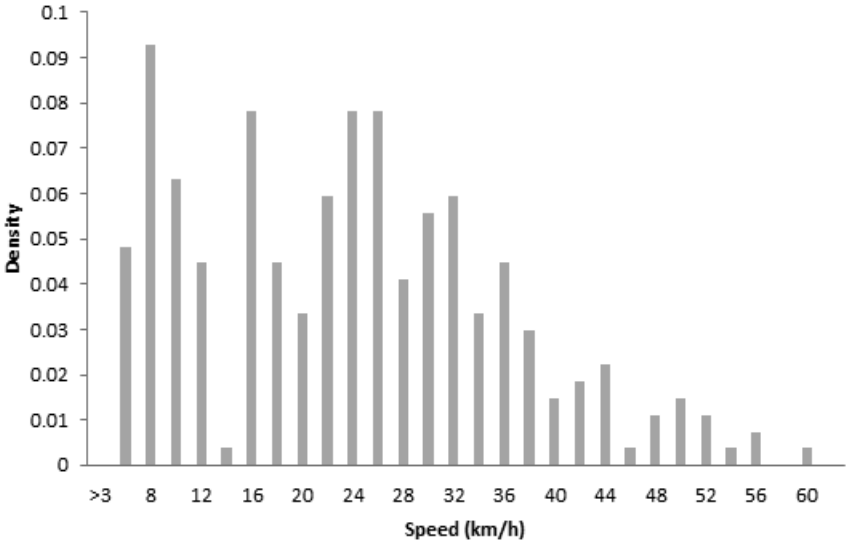
Measure	15:30-16:30 Hours	
	Southbound	**Northbou**
Number of detection	160	70
Total vehicular traffic	924	336
Detection rate (%)	**17.3**	**20.8**

Case Study: Arterial Test

- Also, histograms of the average speed of detected devices in each direction are:



Southbound direction



Northbound direction

Using a simple (naïve) classification, non-motorized and motorized modes are classified using thresholds on different modes speed

Case Study: Pedestrian Network

- In this study 4 sensors has been deployed on McGill campus to track and count pedestrian in campus

Case Study: Pedestrian Network

- To validate the output of the system, manual counting using recorded video was used

Case Study: Pedestrian Network

Direction: going towards the intersection in center of campus (Other sensors)				
Time	**Number of detected MAC addresses**	**Number of pedestrian**	**Detection percentage**	**Average speed**
11:00-11:30	49	94	52.1	5.44
11:30-12:00	59	180	32.8	5.19
12:00-12:30	60	223	26.9	5.17
12:30-13:00	73	264	27.7	4.90
12:00-13:30	49	185	26.5	5.65
13:30-14:00	45	171	26.3	5.00
Direction: direction going towards the Roddick Gates (Sherbrooke - Sensor 1)				
Time	**Number of detected MAC addresses**	**Number of pedestrian**	**Detection percentage**	**Average speed**
11:00-11:30	20	89	22.5	5.54
11:30-12:00	28	145	19.3	5.24
12:00-12:30	31	186	16.7	5.01
12:30-13:00	27	258	10.5	5.23
12:00-13:30	21	186	11.3	5.01
13:30-14:00	22	174	12.6	4.85
Total Detection on both directions				
Time	**Number of detected MAC addresses**	**Number of pedestrian**	**Detection percentage**	**Average speed**
11:00-11:30	69	183	37.7	5.48
11:30-12:00	87	325	26.8	5.21
12:00-12:30	91	409	22.2	5.10
12:30-13:00	100	522	19.2	5.02
12:00-13:30	70	371	18.9	5.32
13:30-14:00	67	345	19.4	4.94

Case Study: Travel time Validation

- In this case 6 sensors were deployed on Parc Avenue due to validate accuracy of the system in travel time estimation.
- The output of the system was validated using floating car technic.
- A vehicle equipped with a high-quality GPS logger performed 12 to 13 trips between [illegible] with the

	Southbound		Northbound	
(Speeds in km/h)	Avg. speed (floating car method)	Avg. seed (sensors)	Avg. speed (floating car method)	Avg. speed (sensors)
8:00 to 9:00	24.27	25.68	27.14	26.05
9:00 to 10:00	24.11	25.76	26.17	24.85
10:00 to 11:00	28.31	30.83	26.98	26.32
11:00 to 12:00	27.34	28.33	25.84	24.68

Conclusion

- This work proposes a system to detect anonymous MAC addresses of devices at short distances at fixed locations.
- The output of the system is not just limited to travel time and speed, it can be used to:
  - Origin-Destination study in whole network through tracking the detected MAC addresses in the network
  - Public transit planning using the estimated number of people in each bus stop
  - Smart traffic networks on mobile apps (showing congestion on map, arrival time of buses, etc.)
  - Accident detection and safety issue using analyzing queue length and speed

Conclusion

- The advantages of our designed system:
  - Using the advantages of Bluetooth only system
  - Cost effective in term of the hardware and software
  - Easy to be deployed in traffic network
  - Low maintenance cost
  - Real time working
  - Getting many of traffic parameters by just using one system

Conclusion

- The shortcoming of our designed system:
  - The systems need WiFi-enabled or Bluetooth-enabled and discoverable devices
  - The Study is limited just to people with WiFi or Bluetooth devices
  - It is difficult to find if the detected Bluetooth and WiFi MAC addresses at the same time belong to same vehicle (over counting issue)
  - We don’t get socio-economy information

Future Works

- Remaining researches on this system can be divided in three groups
- 1-Testing the sensors
  - Test the integrated system including both Bluetooth and WiFi system on different traffic conditions and networks
  - Test the effect of antenna selection on detection rate
  - Minimize the power consumption of the system to work on battery for more days

Future Works

- Remaining researches on this system can be divided in three groups
- 2-Flow Management and prediction
  - How to use available travel time and speed to forecast travel time of a link
  - Forecast queue length based on the available data of the sensors
  - Intelligent traffic light control in arterials using sensors data

Future Works

- Remaining researches on this system can be divided in three groups
- 3-Planning and safety
  - Activity based modeling for both pedestrian and vehicles in different networks like urban area, airports, university campus and public transportation hubs
  - Accident occurrence prediction to analyze safety issues
  - Public transit planning

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Thank you for your attention

Any Questions?