Implementation of a Reference State using Bluetooth Technology

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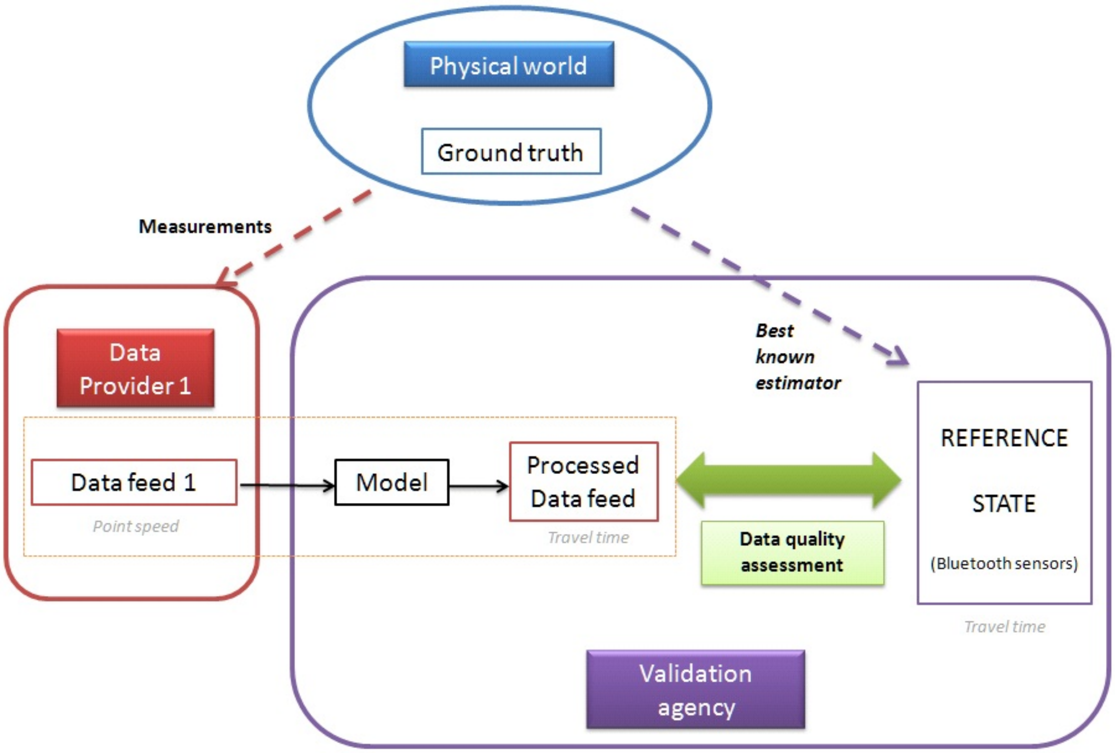


Figure 1: Framework for data validation

1 Introduction

This document presents the preliminary analysis carried out for the implementation of a reference state for the Hybrid Traffic Data Roadmap project. The framework for data validation is shown on Figure 1. Probe data (point speeds) will be received in response to the RFP associated and this data will be used as inputs for the model. The output of the reference state (travel times) will then be compared to the output of the model (travel times). This process will validate the use of probe data by the model.

The technology used for the reference state is bluetooth. Bluetooth sensors will be implemented on three sites: I-880, I-15 in Los Angeles and I-15 in the desert.

2 Site selection

At the location where the reference state will be implemented, traffic should be quite variable so that:

- traffic state is not trivial to predict using historical data
- all the ranges of speeds can be assessed

Figure 2: Potential sites for bluetooth deployment

- the validation can be extended to the whole spatio-temporal domain of interest

Using historical fundamental diagrams available on the PeMS website as well as historical and live data from Google Traffic, we found five segments with quite variable traffic conditions.

Among these sites, the Ontario Segment Southbound from E 4th street to Bellegrave Avenue showed the most variable traffic. In a decreasing order of degree of variability, the other segments were Ontario Northbound, Corona, merger with I-215 and finally Temecula. The following chart shows the plots of speed during November 2010 for the loop detectors available on this segment;

In the desert, very few historical data are available. However, the segment between Los Angeles and Victorville shows favorable characteristics for the implementation of a bluetooth reference state. It has very few off ramps and the flow is high.

3 Deployment of Bluetooth Readers

3.1 Experimental considerations

Bluetooth readers validation This experiment was designed for 10 bluetooth readers. Bluetooth data validation will be performed using cameras. The implementation of cameras requires the presence of at least two overpasses in order to get travel times.

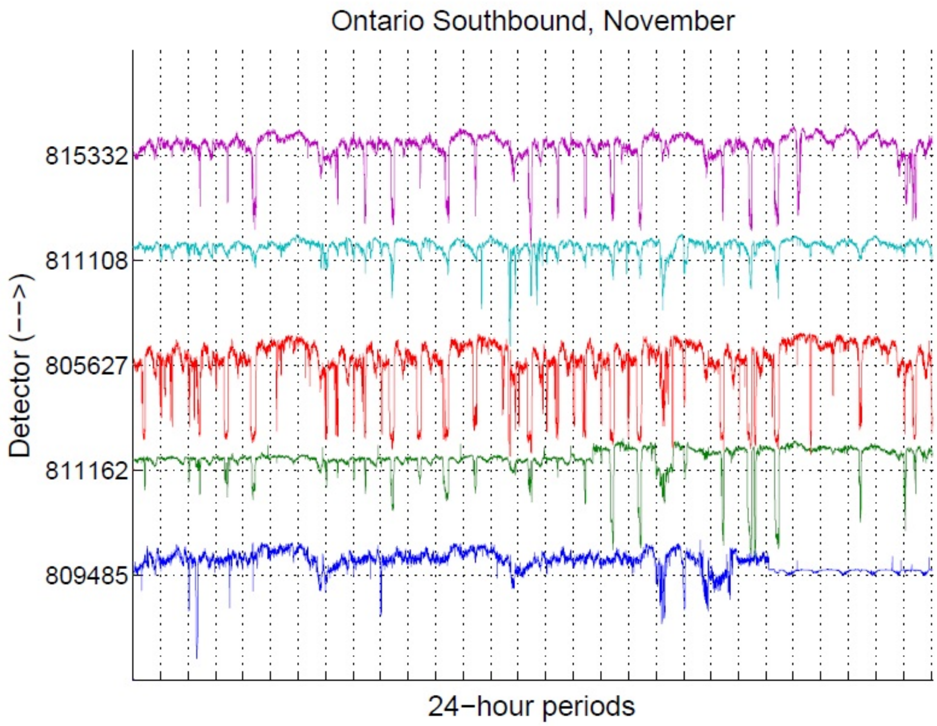


Figure 3: Ontario southbound segment variability

Figure 4: Example of Bluetooth sensor from the Mobile Millenium experiment

Inherent Measurement Error Previous experiments carried out in an urban environment showed that the distance between two consecutive bluetooth readers should be greater than one mile in order to have reasonable measurement errors. Bluetooth sensors indeed detect devices located within a radius of 100m, which results in a high measurement error if the spacing has not been designed carefully.

Penetration rate Bluetooth sensors detect all devices that have their Bluetooth function activated. Thus, penetration rates of 5% to 10% with respect to all traffic can be reached. The bluetooth signal is attenuated when it encounters an obstacle. However, it can go through glass. For this reason, the penetration rate of Bluetooth sensors is better when the device is elevated (10 to 15 feet). Nevertheless, Bluetooth sensors still have reasonable penetration when simply laid on the ground (according to Tom Kuhn and BlueFax).

Roadside and practical implementation A practical consideration that impacts a lot the design of the experiment is that even when laid on the ground, Bluetooth sensors have to be tethered to a fixed object on the road. For safety reasons these objects should be located beyond the guardrail. In order to design the experiment, we used Google Street view to find the potential locations for our devices. Field observation will be needed later to make sure the objects found are still in place.

Minimum number of probe data points and spacing between sensors The model imposes some constraints when the traffic flow is low. Indeed, for the model to work, a minimum number of probe data points is needed within each segment considered. Consequently, in areas such as the desert between Las Vegas and Los Angeles, longer segments and longer spacings between the travel times considered for data validation.

3.2 I-880: Fremont to Castro Valley (Northbound)

For this segment, we designed a plan with 10 sensors separated by an average distance of 1.3 mile. Thus, the travel times we get between most devices can be exploited. The travel times we get every other devices can be exploited as well. Two overpasses were found so the validation of bluetooth readers can take place on this segment.

Caltrans District 4 was reluctant to placing the bluetooth sensors on signs or overhead signs. However, it seems that they would agree to place the devices on lamp posts along the roads. The following images show the screenshots of I-880 we took in order to choose the locations for the Bluetooth devices. The actual existence of these locations were verified by filming while driving along this segment. Some crucial differences were found around BT9 between Google Maps and the current situation. To save time in the process, verification should thus take place prior to presenting the plan to Caltrans.

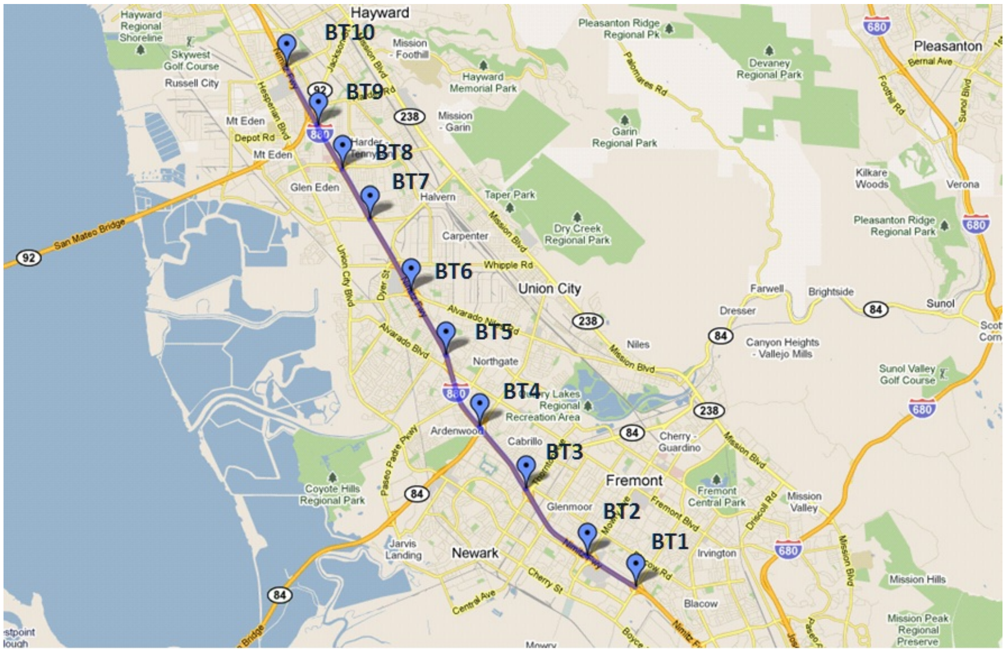
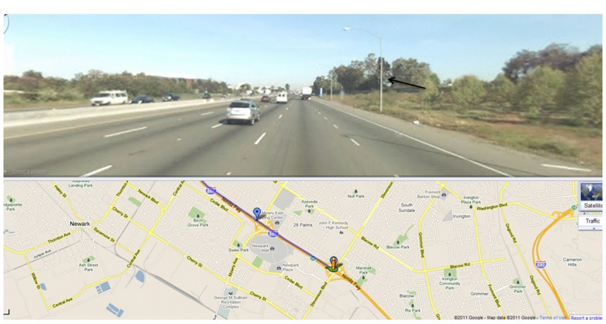
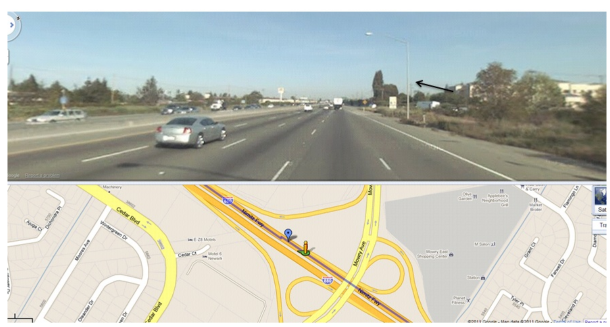


Figure 5: I-880: Fremont to Castro Valley Northbound

BT1

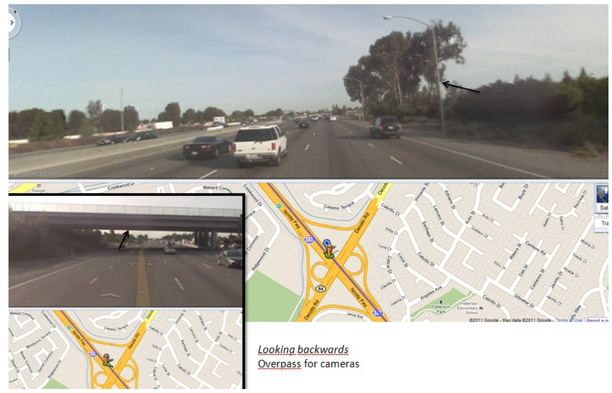


BT2

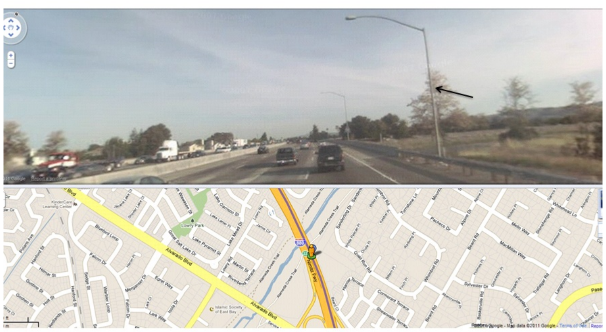


BT3

BT4



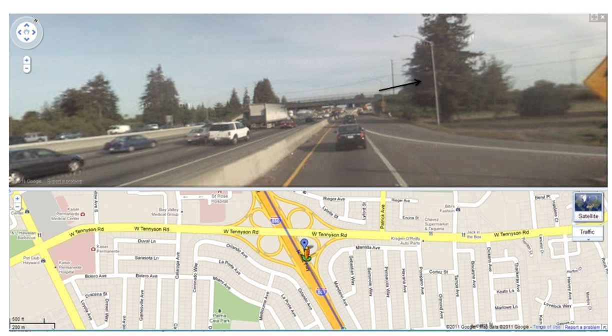
BT5



BT6

BT7

BT8



BT9

BT10

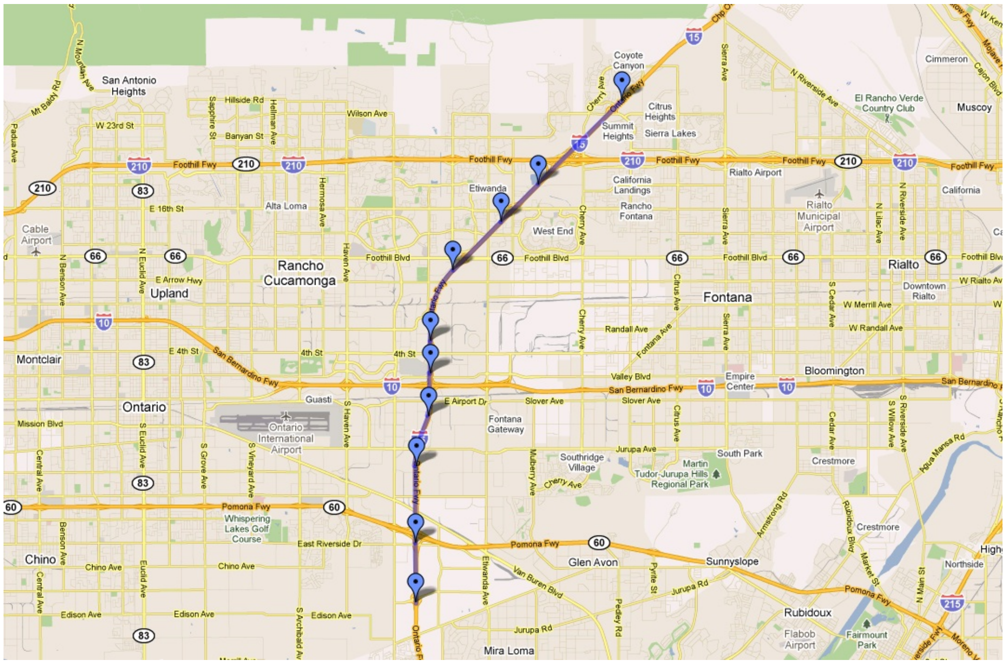


Figure 6: I-15: Ontario Southbound segment

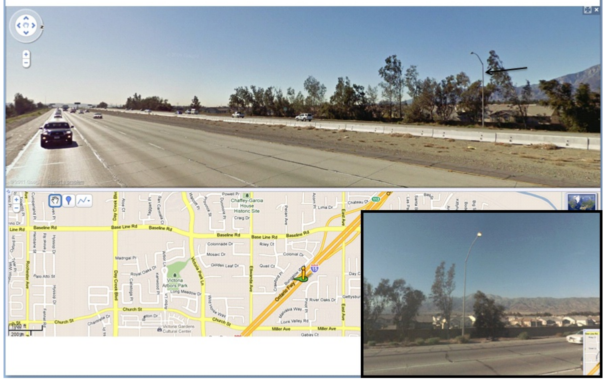
3.3 I-15: Ontario segment in Los Angeles (Sounthbound)

For this segment, we designed a plan with 10 sensors separated by an average distance of 1.4 miles. There is not enough overpasses on this segment to deploy cameras. All the possible lampposts found are located on the same side of the highway. On the following design, some lampposts were not visible on Google Street View because of the sun or because of a vehicle. Consequently, for BT3, BT4 and BT6 for instance, we show various viewpoints of the same lamppost. In the design, for BT3 for example, the big picture is taken from the other side of the highway.

BT1

BT2

BT3

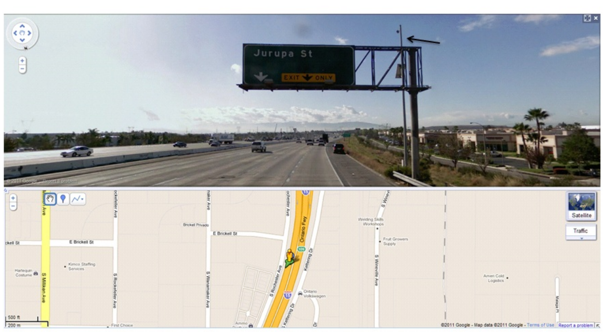


BT4

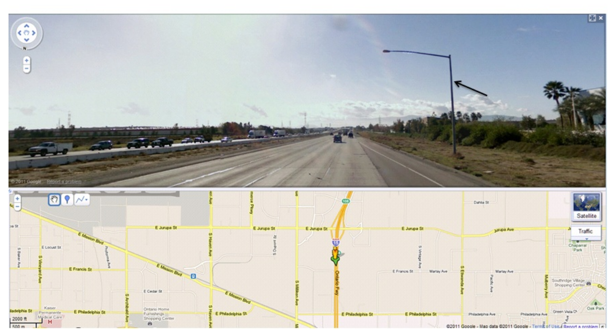
BT5

BT6

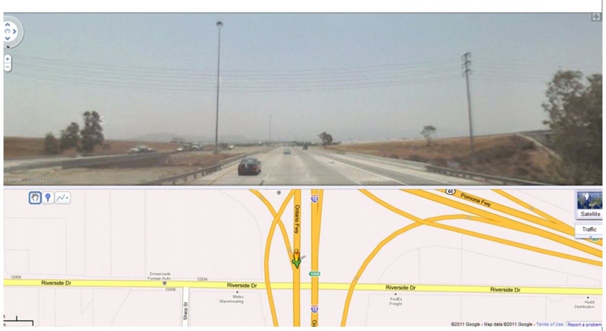
BT7



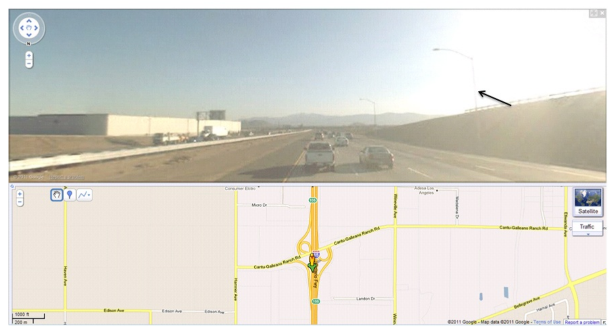
BT8



BT9


Riverside Dr
Pomona Fwy
Satellite
Traffic

BT10


Satellite
Traffic

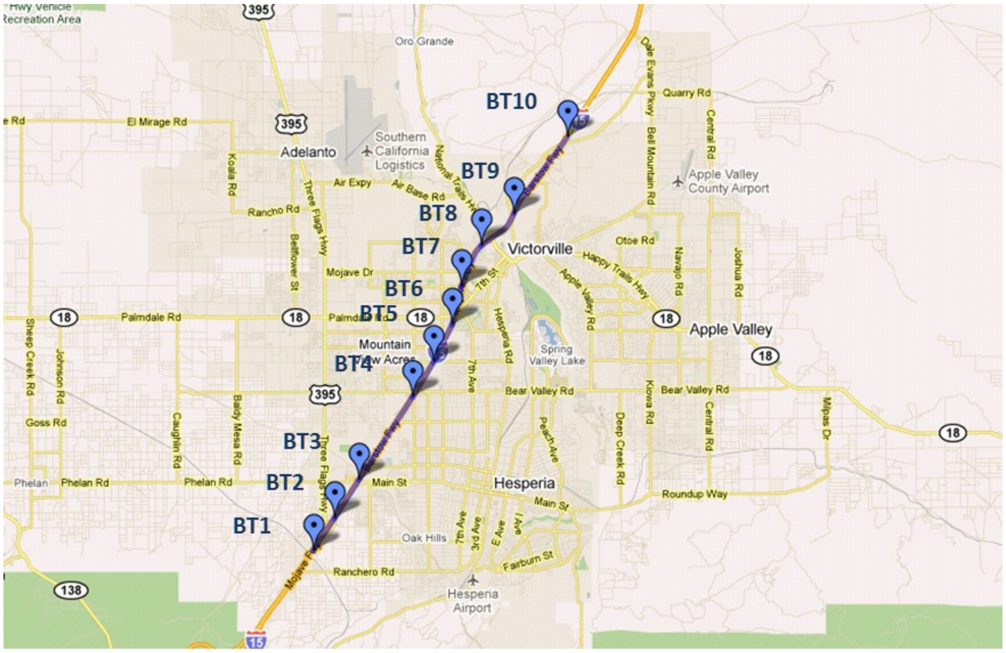
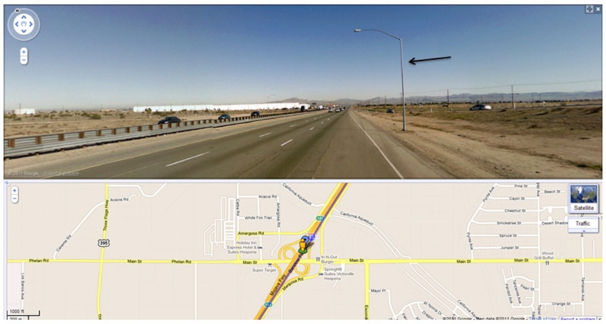


Figure 7: I-15: Victorville Segment

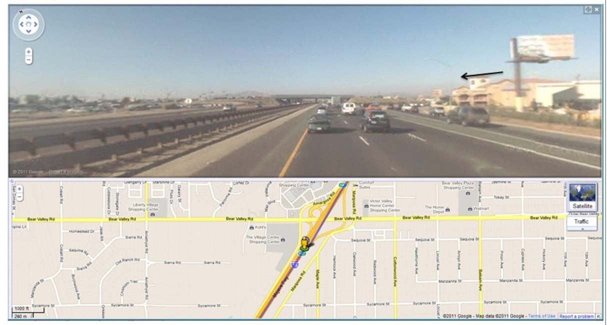
3.4 I-15: between Los Angeles and Victorville (Northbound)

For this segment, we designed a plan with 10 sensors separated by an average distance of 2.5 miles. 8 overpasses can be used to implement cameras.

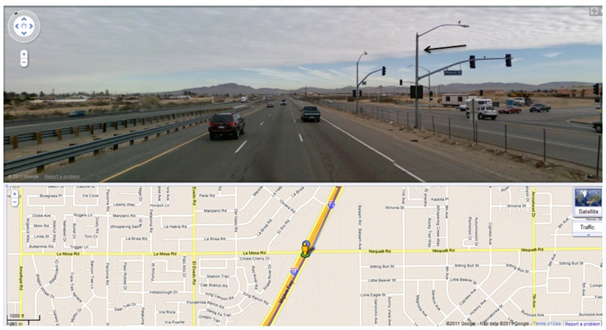
BT3



BT4



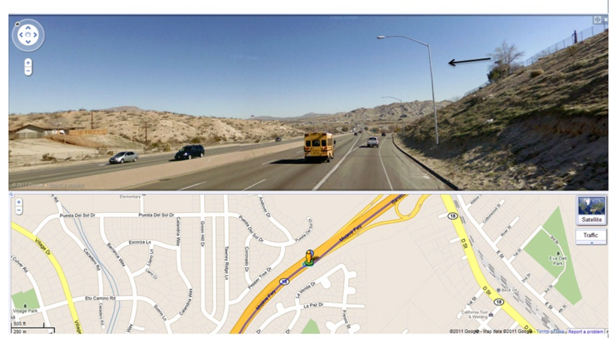
BT5



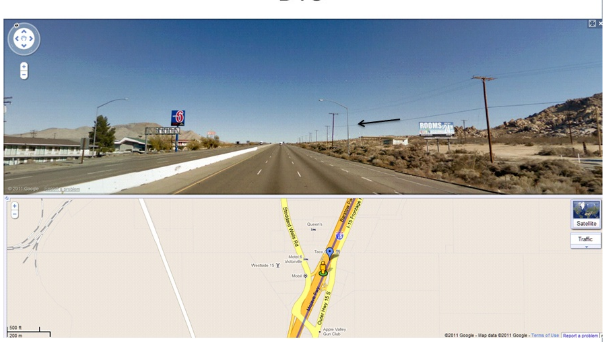
BT6

BT7

BT8



BT9



BT10

Figure 8: Camcorder CANON HV20

4 Bluetooth validation using cameras

4.1 Locations of camera

In order to operate well, cameras need to be located on overpasses. For a scientifically sound validation, a bluetooth reader should be placed close to the overpass where the cameras will be located.

A camera can work on 2 lanes. The freeways studied have 3 to 4 lanes. Consequently, 2 cameras are needed for each location.

4.2 Camcorders and softwares

The brand and model of the camcorders used are CANON HV20. These camcorders work with tapes and are able to register films in High Definition quality.

During the experiment, several settings can be considered.

- The camcorders can work independently with tapes. However, the autonomy of the tape is only 1 hour. Consequently, people would have to replace the tapes every hour. Later, the tapes can be processed using computers. In this case, it is very simple to record in the HDV format and then transfer it to computers (PC or Mac) using Firewire cables and softwares such as Windows Live Movie Maker.

- The camcorders can be linked to computers during the whole experiment. In this case, tapes are not needed. High definition quality videos can indeed be directly recorded on the computer's hard drive. In order to do this, two softwares are needed: ffdshow and HDV Split. ffdshow video decoder is required if the MPEG2 decoder is not setup on the computer. You can dowload it on the following link: `http://sourceforge.net/projects/ffdshow`

  – Setting ffdshow video decoder:

1. In start menu open "ffdshow" -> "Video decoder configuration"
2. Choose "Codec" tab
3. Find in the table, under "Format" column, "MPEG2" row.
4. In "Decoder" column choose "libavcodec" for "MPEG2".
5. Choose "Apply" and "OK"

Setting ffdshow audio decoder:

1. In start menu open "ffdshow" -> "Audio decoder configuration"
2. Choose "Codec" tab
3. Find in the table, under "Format" column, "MP1,MP2" row.
4. In "Decoder" column choose "mp3lib" for "MP1,MP2"
5. Choose "Apply" and "OK"

– Setting HDV Split: Download the software on the following link: `http://strony.aster.pl/paviko/hdvsplit.htm`.

A Preliminary study of variability on I-15

5 segments were studied. This section reports the results we got from the analysis of the variability of traffic using the PeMS data available. Prior to this study, Google Traffic, Yahoo Map Traffic and PeMS data were used to preselect these segments. The graphs show the evolution of speed overtime for the loop detectors located on the segment of interest. For Ontario Southbound for instance, the direction of traffic goes from sensor ID 809485 to 815332 as shown by the arrow on the left of the graph. Each vertical line separates the days in the period studied. To give an order of magnitude of the scale of the graph, the average speed plotted is around 64 mph.

- Ontario Southbound
- Ontraio Northbound
- Coronna Southbound
- Junction with I-215 Northbound
- Temecula Southbound

B Distances between sensors

In this section, we are reporting the distance matrices that show how far from each other sensors are in the deployment plans.

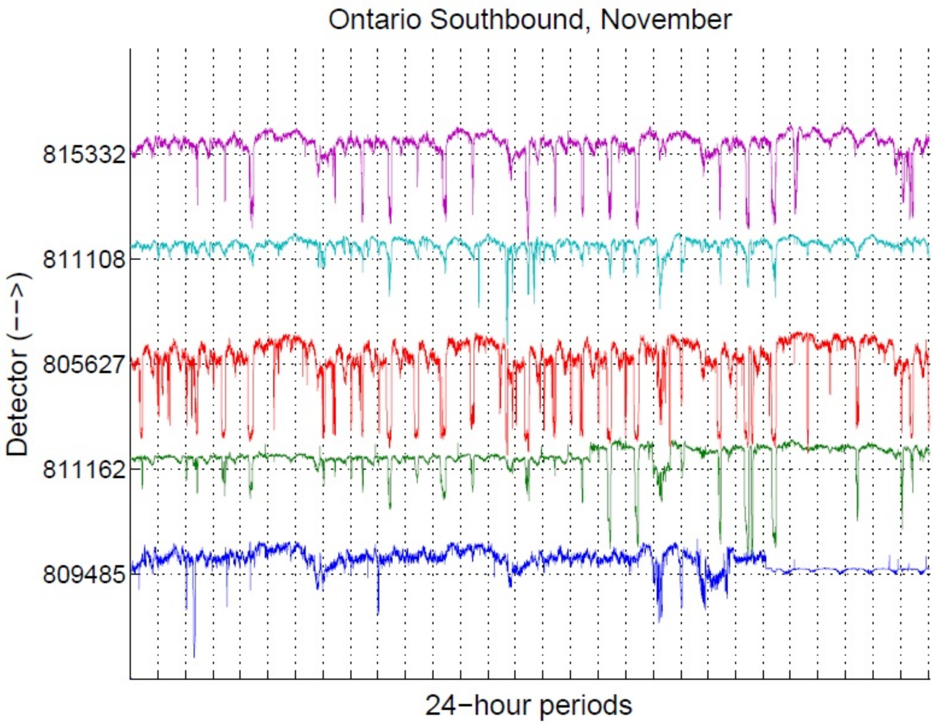


Figure 9: Ontario Southbound Variability

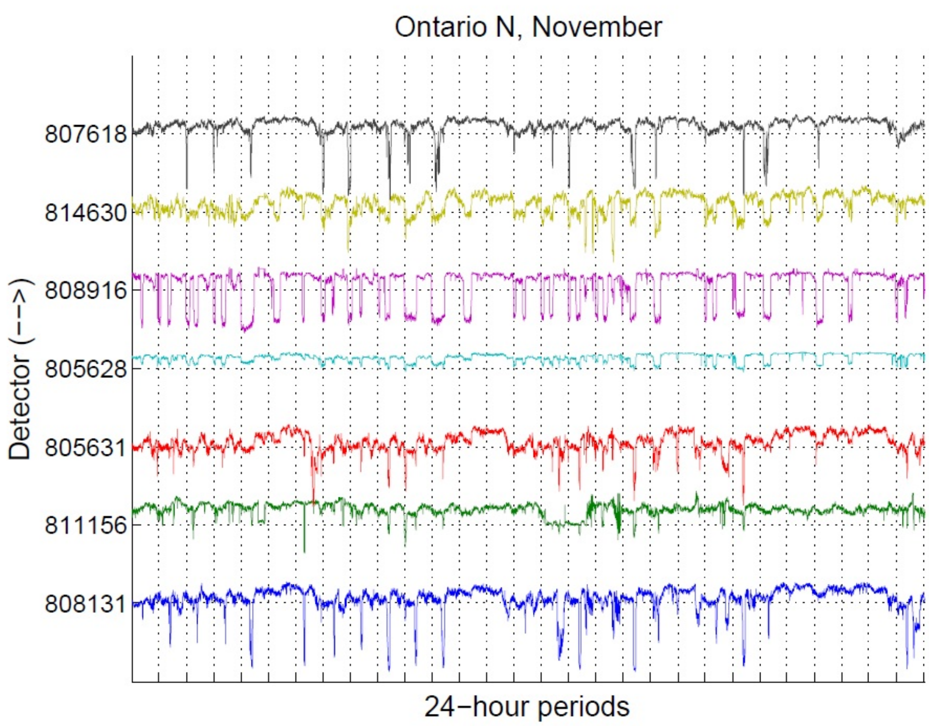


Figure 10: Ontario Northbound Variability

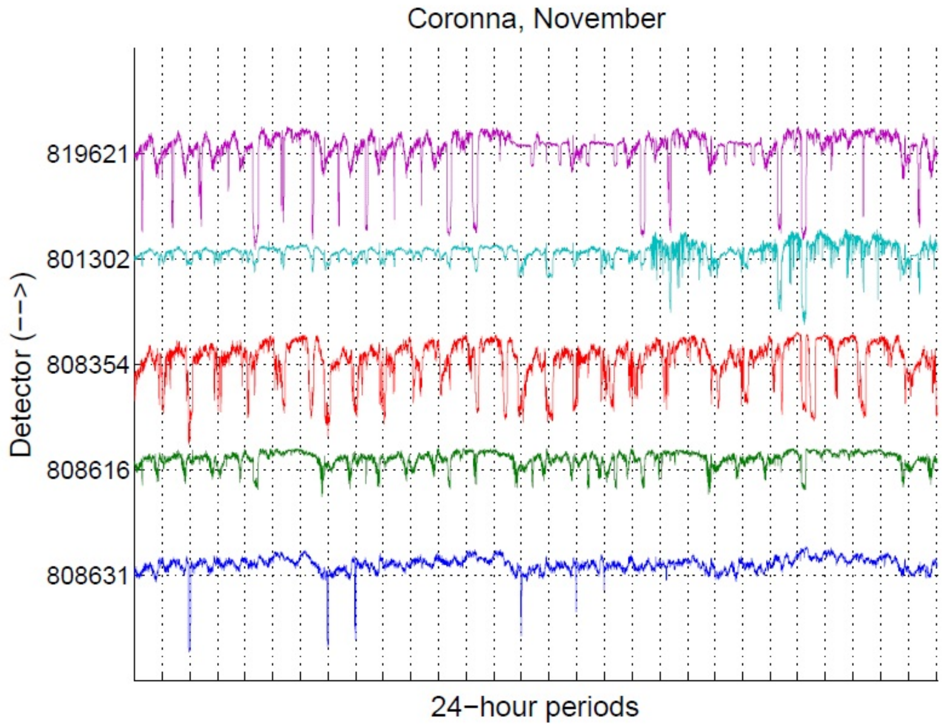


Figure 11: Coronna Southbound Variability

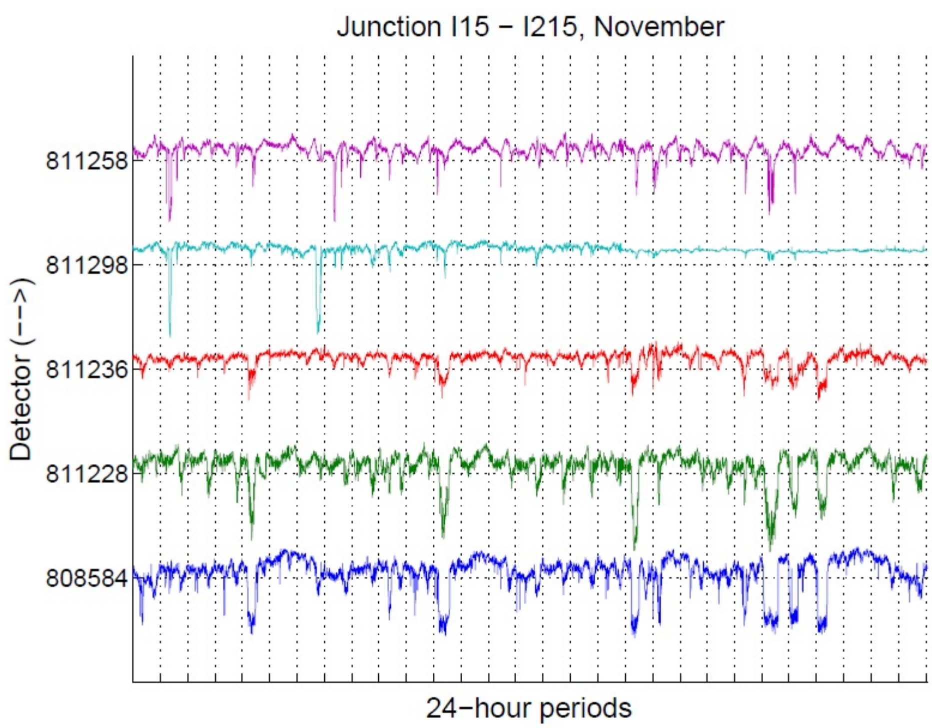


Figure 12: Junction with I-215 Northbound Variability

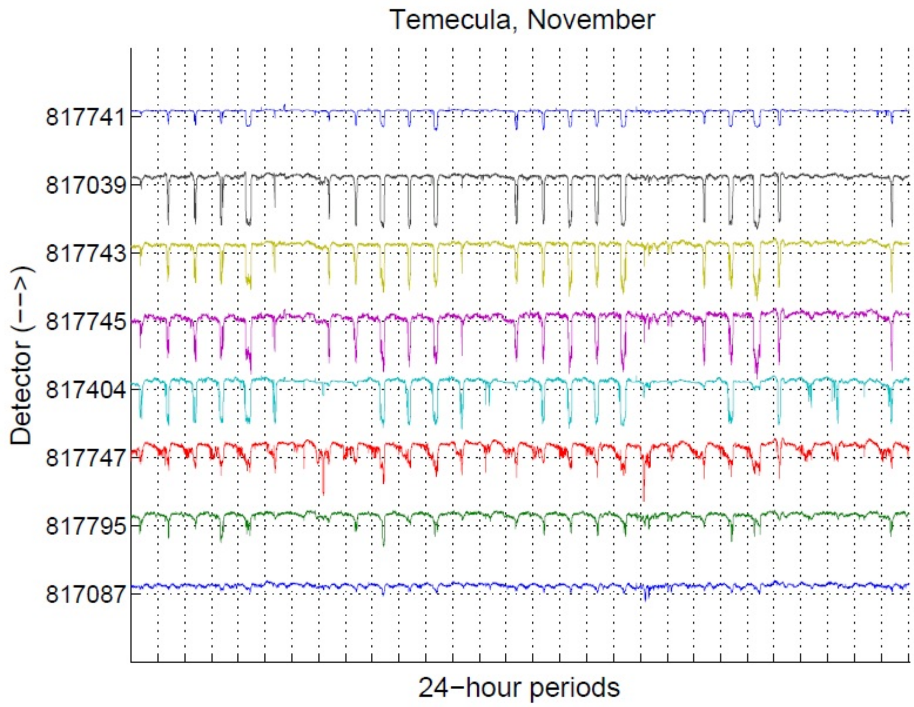


Figure 13: Temecula Southbound Variability

	1	2	3	4	5	6	7	8	9	10
1		1,03	2,67	4,07	5,51	6,8	8,29	9,29	10,21	11,37
2			1,64	3,04	4,48	5,77	7,26	8,26	9,18	10,34
3				1,4	2,84	4,13	5,62	6,62	7,54	8,7
4					1,44	2,73	4,22	5,22	6,14	7,3
5						1,29	2,78	3,78	4,7	5,86
6							1,49	2,49	3,41	4,57
7								1	1,92	3,08
8									0,92	2,08
9										1,16
10										

Figure 14: Distances between sensors on I-880 segment

	1	2	3	4	5	6	7	8	9	10
1		2,5	3,6	5,0	6,6	7,3	8,2	9,3	10,9	12,2
2			1,1	2,5	4,1	4,8	5,7	6,8	8,4	9,7
3				1,4	3,0	3,7	4,6	5,7	7,3	8,6
4					1,6	2,3	3,2	4,3	5,9	7,2
5						0,7	1,6	2,7	4,3	5,6
6							0,9	2,0	3,6	4,9
7								1,1	2,7	4,0
8									1,6	2,9
9										1,26
10										

Figure 15: Distances between sensors on Ontario Segment

	1	2	3	4	5	6	7	8	9	10
1		1,29	2,83	6,14	7,8	11,35	14,2	15,65	17,99	19,96
2			1,54	4,85	6,51	10,06	12,91	14,36	16,7	18,67
3				3,31	4,97	8,52	11,37	12,82	15,16	17,13
4					1,38	4,93	7,78	9,23	11,57	13,54
5						1,4	4,25	5,7	8,04	10,01
6							1,35	2,8	5,14	7,11
7								1,53	3,87	5,84
8									1,54	3,51
9										3,13
10										

Figure 16: Distances between sensors on Victorville segment