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Is bus overrepresented in Bluetooth MAC Scanner data? Is MAC-ID really unique?

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One of the concerns about the use of Bluetooth MAC Scanner (BMS) data, especially from urban arterial, is the bias in the travel time estimates from multiple Bluetooth devices being transported by a vehicle. For instance, if a bus is transporting 20 passengers with Bluetooth equipped mobile phones, then the discovery of these mobile phones by BMS will be considered as 20 different vehicles, and the average travel time along the corridor estimated from the BMS data will be biased with the travel time from the bus. This paper integrates Bus Vehicle Identification system with BMS network to empirically evaluate such bias, if any. The paper also reports an interesting finding on the uniqueness of MAC-IDs.

Keywords: *Bluetooth, Bus, BMS, Vehicle identification and detection system, MAC-ID, cloning, travel time*

1. Introduction

Recently there has been significant interest of researchers and practitioners on the use of Bluetooth Media Access Control Scanner (BMS) [1] as a complementary transport data. The concept behind BMS is that it scans the Media Access Control Identifier (MAC-ID) of the discoverable Bluetooth devices within its communication zone. Most of the portable electronic devices such as mobile phones, car navigation systems, headphones, etc are equipped with Bluetooth and its usage is increasing. Installing time-synchronized BMSs on the road network has the potential to provide "live monitoring" of transportation of the Bluetooth devices over the road network. Assuming the devices are transported by the vehicles, individual vehicle travel time can be easily obtained. It is one of the most cost effective sources of travel time on the road network. Especially on signalized urban arterials, where travel time estimation has always been very challenging with limited research [2-5], BMS provide a good estimate of individual vehicle travel time. Researchers have also considering travel time from traditional matching of Bluetooth as ground truth travel time for validating other travel time estimation models [6, 7] and predicting future travel time values [8]. Other applications of BMS data include the assessment of work zone impacts [9], traffic congestion analysis [10], multimodal travel time analysis [11], travel patterns of people movement in airports, shopping malls etc. [12-14], route choice analysis [15, 16], Origin-Destination analysis [17], freeway travel time variability analysis [18]; Bluetooth combination with WiFi signal analysis [19-21]; and data fusion of loops with Bluetooth [22] for the development of Macroscopic Fundamental Diagram [23].

This paper first introduces the Bluetooth communication principle and BMS data acquisition (Section 2). Thereafter, it empirically investigates the real data from Brisbane, Australia and presents the two main findings related to Bluetooth travel time data points from a Bus (Section 3) and uniqueness of the MAC-ID (Section 5). A discussion on the types of Bluetooth devices is also presented (Section 4).

2. Bluetooth communication principle and BMS data acquisition

A Bluetooth device has two major states *standby* or *connection* state and seven modes (sub-states). *Standby* implies no interaction with the other devices and *connection* implies that data is being transferred. The seven modes to establish *connection* are: *inquiry*, *inquiry-scan*, *inquiry-response*, *page*, *page scan*, *slave-response* and *master-response*. Multiple devices can be connected, given one of them acts as a *Master* and the remaining as *Slaves.* The actual procedure for Bluetooth connection is complex but can be simply modeled as follows:

a) The *Master* device has to be in *Inquiry* mode to enquire about the other devices (in *Inquiry-scan* mode) within the communication range by sending package containing its information (address and clock).
b) If the *Slave* is in *Inquiry-scan* mode then it scans the inquiry sent by *Master*. Thereafter, *Slave* can switch to *Inquiry-response* mode to respond by sending its information (address and clock) for *Master*.
c) *Master* listens to the response from the *Slave*(s) within its range and may switch to *Page* mode to

page (hopping sequence and other information) the discovered *Slave* device(s).

d) The *Slave* has to be in *Page-scan* mode to scan the page sent by *Master*, and may switch to *slave-response* mode to send its response (device access code).

e) Finally, the *Master* has to be in *Master-response* mode to send further information to establish final connection between the two.

Bluetooth communicates over the Industrial Scientific and Medical (ISM) band at 2.4 to 2.485 GHz. ISM band is shared by other wireless technologies such as Wi-Fi, Near Field Communication, cordless phone etc. To avoid interference between the wireless devices sharing ISM band, Bluetooth operates by *Frequency Hopping*, where a Bluetooth device is transmitting and receiving information alternatively at a certain frequency (defined for certain time slot) and, thereafter, it hops to another frequency. Information exchange should be in the same frequency, i.e. if *Master* sends its inquiry at frequency *k*, only those *Slaves*, which at that particular time instance are scanning at the same frequency *k*, could scan this information. Moreover, in order to save power consumption, a unit in *inquiry–scan* mode only listens for a very short period of time (11.25 ms by default) and thereafter, enters standby mode for a longer period of time (1.28 seconds). This means, more than 98% of the time the unit in *inquiry-scan* mode is not communicating. Hence, the discovery process (and connection process) is not instantaneous and requires time even in an ideal environment (where messages are not lost). Bluetooth protocol recommends a device to be in *inquiry* mode for 10.24 seconds [24].

BMS is only interested in the inquiry process of discovering the devices where it (acting as a *Master*) should be able to acquire the MAC-IDs of the other devices (acting as a *Slave*) within its *zone*. BMS is configured to be in continuous *inquiry* mode over a time period terms as *inquiry cycle* (C_I), where BMS are alternatively sending the enquiry messages and scanning the potential replies over the range of predetermined frequency channels. These *cycles* are repeated as a seamless train of *inquiry cycles* for uninterrupted discovery of the devices. During an inquiry process, the device can be discovered at any time and there are following two ways to acquire the MAC-IDs:

a) Group the MAC-IDs scanned during an inquiry process with the same timestamp that corresponds to the time of inquiry cycle.

b) Providing individual time stamps to each MAC-IDs read.

There can also be a capacity of the number of MAC-IDs that can be read during the scan (say 5 MAC-IDs per scan). Interested readers should refer to Bhaskar and Chung [1] for detailed discussion on the theoretical properties of the BMS data and the accuracy and reliability of travel time estimates using BMS.

The shape and size of the BMS depends on type and strength of the antenna of the BMS. For instance omni-directional antenna should receive signals from all the directions, resulting in circular shape. If the strength is 20 dBi then the range (radius of this circle) is around 100 m. Say the radius of the circle is *R*, and the BMS is at a distance of *x* (< *R*) from the road lane (refer to Figure 1, where *a* is the position of the omni-directional BMS). Then the proportion of the road sections covered in the scanning area can be expressed as $2*\sqrt{(R^2 - x^2)}$.

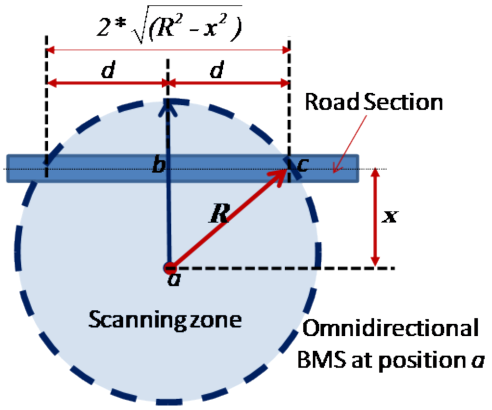


Figure 1: Example of the relationship between BMS scanning area and proportion of the road covered.

If we are interested for a vehicle to spend at least $t_{\min}$ (say 5 seconds) within the scanning area, then the maximum speed of the vehicle (v_{max}, in km/h) should be:

$$v_{\max} = \frac{2\sqrt{(R^2 - x^2)}}{t_{\min}}(18/5) \qquad 1$$

Where *R*, *x* are in meters and t_{min} is in seconds and v_{max} is in km/h (18/5 is conversion factor from m/s to km/h).

Say BMS (with *R*=100 m) is installed along the curbside of a 8 lane motorway (4 lanes each direction), if the width of each lane is 3.6 m with 5.2 m of median between the two directions then the farthest lane will be at a distance of 34 m from the BMS. Here, vehicles travelling at speed up to 135 km/h should be able to spend 5 s within the scanning zone (Substitute, *R*=100 m, *x* = 34 m, t_{min} = 5 s in equation 1). For other lanes closer to BMS, the time spend will be more than $t_{\min}$.

3. Empirical evaluation of the BMS

We analyze the BMS data from urban arterials in Brisbane, Australia. The data includes the following fields:

a) MACID (*m*): MAC-ID of the Bluetooth device detected;

b) Timestamp (t_s): This is the time when the MAC-ID *m* was first detected. The time corresponds to the observed entry time of the device at the scanning zone; and

c) Duration (*d*). This is the time gap between the first and last observation of the Bluetooth device at the scanning zone. The sum of t_s and d should corresponds to the observe exit time of the device from the scanning zone.

For a MAC-ID m the travel time ($TT_{m,u/s,d/s}$) from u/s BMS to d/s BMS can be expressed as equation 2:

$$TT_{m,u/s,d/s} = (t_{s,d/s,m} + d_{d/s,m}) - (t_{s,u/s,m} + d_{u/s,m}) \quad 2$$

Where: $t_{s,u/s,m}$ ($d_{u/s,m}$) and $t_{s,d/s,m}$ ($d_{d/s,m}$) are the timestamps (durations) for a vehicle with MAC-ID m observed at u/s BMS and d/s BMS, respectively.

Equation 2 is the raw travel time obtained between two BMS locations. The data need to be cleansed, for this we apply a statistical filter, termed as Median Absolute Deviation (MAD) filter MAD-2 filter [11].

Figure 2 and Figure 3 provide the raw and cleansed individual vehicle travel time measured, respectively from Wynnum road, Brisbane. The length of the section is around 2.2 kms with four mid-block signalized intersections. Here, each column represents the day of the week (first column is Monday, last column is Sunday). For each sub-plot, X-axis is time (in hours) and Y-axis is travel time (in seconds). Green highlighted days are working days, whereas, red highlighted days are weekends or public holiday. Figure 3 is obtained from the data of Figure 2 by applying MAD-2 filter. Figure 3*a* provides a month snapshot of the travel time profiles along the study section. Weekday traffic is different from those of weekends and holidays. 17th August 2011 was a public holiday, the profile for that Wednesday is different from other Wednesdays of the month. Travel time profile for Friday is very different from that of Monday. These results clearly indicate that the BMS data has the potential to provide travel time profiles over the road network.

Figure 4 provides a snapshot of the number of Bluetooth travel time points (after filtering) per minute during the morning peak periods (7 am to 9 am) of August 2011. It is observed that average number of Bluetooth travel time points vary from 1.2 to 3.6 Bluetooth points per minute during the working days. There are periods when no Bluetooth travel time point is available (e.g, during 1st August around 7:20 am to 7:40 am). Algorithms need to be developed to fill this gap.

Here at Brisbane, we had an opportunity to integrate Bus Vehicle Identification and Detection (VID) system with BMS network to explore the bias in the number of travel time points obtained from a Bus.

VID is used to provide priority to the buses at the signalised intersections. It consists of a set of Radio Frequency Identification (RFID) sensors installed at upstream, at stopline, and at downstream of the intersection where transit signal priority is to be provided. These sensors detect the presence of a bus by reading the RFID tag on the bus. Each bus is provided a unique tag and the system stores the time when the bus is detected at the VID sensor location. Matching the VID data at different VID sensor locations, we obtain the individual bus travel time between intersections.

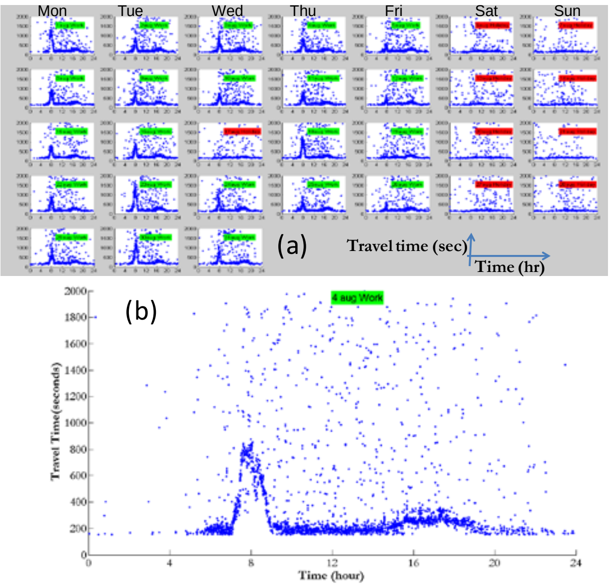


Figure 2: Raw individual vehicle travel time profile (for *a*) August 2011 and *b*) zoomed in for one day- 4th August 2011) along two BMS stations on Brisbane arterial network. X-axis is time in hours; Y-axis is travel time in seconds.

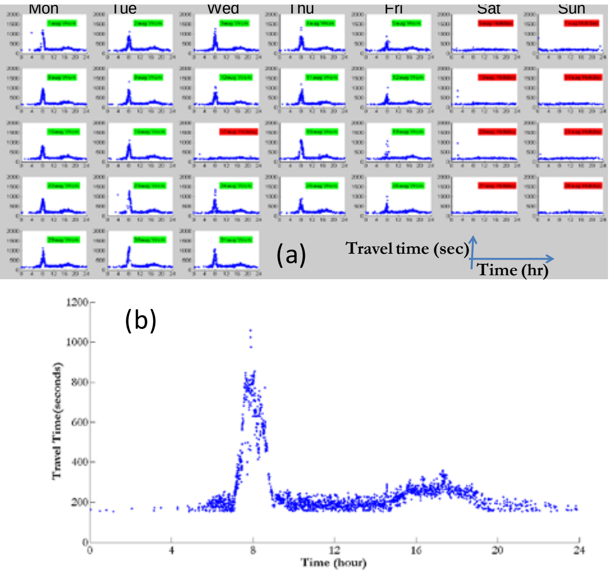


Figure 3: Cleansed individual vehicle travel time profile (for *a*) August 2011 and *b*) zoomed in for one day- 4th August 2011) along two BMS stations on Brisbane arterial network. X-axis is time in hours; Y-axis is travel time in seconds.

Overlaying the VID detector map over the BMS stations maps we identify pair of intersections where both VID and BMS data is available. For the current analysis we present the results from Wynnum Road, Brisbane. We estimate Bluetooth and bus travel time independently from BMS data and VID data, respectively. Appropriate filters are applied to filter the travel time profiles [11]. Thereafter, we integrate the bus travel time profile with the Bluetooth travel time profile. For instance Figure 5 presents a graph where travel time profiles from VID are overlaid over the travel time profiles from BMS, here blue dots represents travel time from BMS and black stars represents bus travel time from VID.

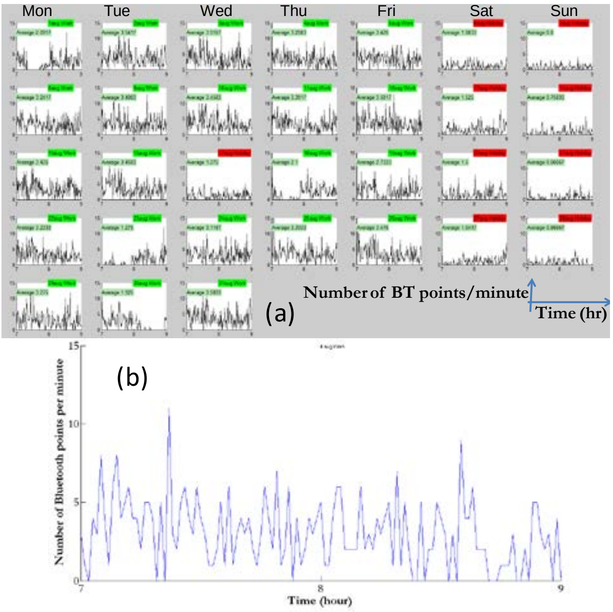


Figure 4: Number of Bluetooth (BT) point per minutes (for *a*) August 2011 and *b*) zoomed in for one day- 4th August 2011) during the peak periods (7:00 am to 9:00 am) X-axis is time in hours; Y-axis is number of BT points per minutes.

If a bus provides multiple Bluetooth MAC-IDs in BMS dataset, then matching these profiles we should observe multiple Bluetooth travel time points close to the bus travel time point. For each bus travel time point, we look a precision window (*see* Figure 6), and count the number of BMS data points. These data points can be considered to be from the bus. The algorithm for this is as follows: Say for a given day and corridor, BMS dataset is represented as a list of time (t_{BMS}) and corresponding Bluetooth travel time (TT_{BMS}) values. Similarly, the VID dataset is represented as a list of time (t_{VID}) and corresponding bus travel time (TT_{VID}) values. Then for each data in VID dataset ($t_{VID}(j)$, $TT_{VID}(j)$) we look at the number of samples in BMS dataset satisfying the following conditions:

$$\forall i \in BMSdataset$$

$$t_{BMS}(i) \in [t_{VID}(j) - \Delta t_x,\ t_{VID}(j) + \Delta t_x] \qquad 3$$

$$and$$

$$TT_{BMS}(i) \in [TT_{VID}(j) - \Delta t_y,\ TT_{VID}(j) + \Delta t_y]$$

Where: Δt_x and Δt_y are the dimensions of the precision window along *time* (x-axis) and *travel time* (y-axis), respectively.

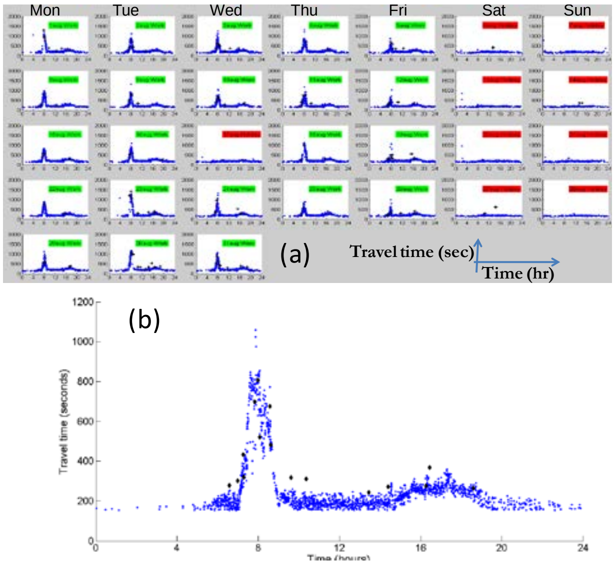


Figure 5: Results from the integration of BMS and VID dataset. Blue dots: Cleansed individual vehicle travel time profile (for *a*) August 2011 and *b*) zoomed in for one day- 4th August 2011) along two BMS stations on Brisbane arterial network; Black star: Bus travel time profile from VID data. X-axis is time in hours; Y-axis is travel time in seconds.

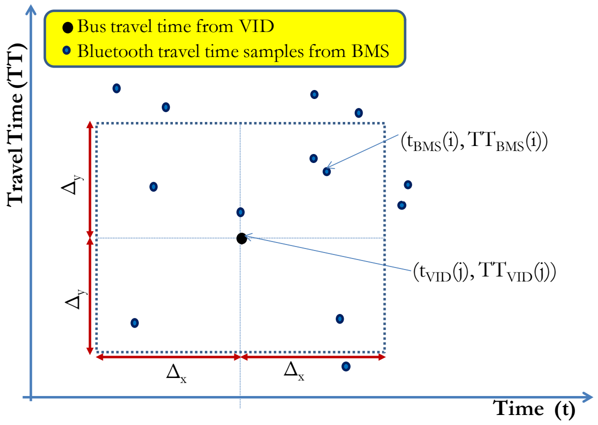


Figure 6: An example of a search window for the potential BMS travel time data points from a bus

Bhaskar and Chung [1] have shown that the magnitude of the error for individual vehicle travel time estimation from BMS data depends on the BMS data noise in reporting the arrival and departure time of the Bluetooth device from the BMS scanning zone. The later depends on the *scan cycle* of the BMS. It has been shown that the magnitude of the error is independent of the section length (though the error expressed in percentage depends on the section length). The BMS data used for the current analysis has *scan cycle* of 20 seconds. The results of the analysis performed in [1] indicates that the magnitude of the error for 20 seconds of *scan cycle* is generally less than 20 seconds. However, the outliers can reach 60 seconds. Therefore, to be conservative we choose 60 seconds as the dimensions of the precision window (equation 4) to define the travel time data points that can be from the Bus.

$$\Delta t_x = \Delta t_y = 60 \text{ seconds} \qquad 4$$

Figure 7 presents the empirical cumulative probability of the number of BMS travel time points within the precision window of each VID bus travel time point, obtained from the aforementioned analysis over six months of the data. It is observed that the empirical probability of a bus providing:

i. Less than two travel time point is between 30%-60%
ii. Less than three travel time points is between 50%-75%
iii. Less than four travel time points is between 70%-85%
iv. Less than five travel time points is between 80%-90%
v. Less than six travel time points is between 85%-95%
vi. More than six travel time points is less than 5%

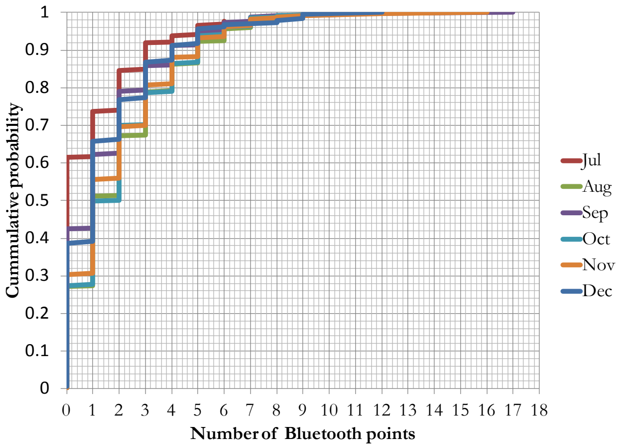


Figure 7: Empirical cumulative probability of number of Bluetooth samples from a bus (six months of data from Brisbane, Australia)

The above analysis indicates that it is rare to observe more than six Bluetooth travel time points from a bus. Average travel time along a corridor is estimated by taking the average of all the cleansed Bluetooth travel time points during an estimation period. Say the estimation period is of 5 minutes interval. Figure 8 represents number of Bluetooth travel time points per 5 minutes during morning 7:00 am to 9:00 am observed along the study corridor for the month of August 2011. Here, green triangles, red square and blue diamond points represent maximum, average and minimum number, respectively. It can be seen that on average we observe around 15 Bluetooth points per 5 minutes, though peak is around 37 Bluetooth points per 5 minutes. Average number of Bluetooth travel time points from Bus is around 2 to 3 (see Figure 7). This indicates that if a bus is present during an estimation period then around 13% to 20% of the Bluetooth data points can be from bus. Thus there is a bias in the average travel time estimation.

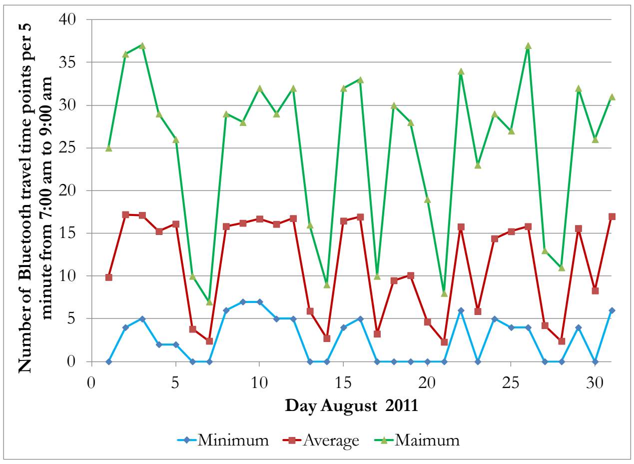


Figure 8: Number of Bluetooth travel time points per 5 minutes interval from a study corridor in August 2011. X-axis is the day of the August 2011.

4. A discussion on the types of the Bluetooth devices being scanned by BMS

MAC-ID is a 48 bits long number expressed as a sequence of twelve hexadecimal digits (six groups of two hexadecimal digits separated by colon), such as 00:22:CE:28:18:81. The first six hexadecimal digits correspond to the vendor/manufacturer unique identifier termed as Organizationally Unique Identifier (OUI). OUI is regulated by the standard organization. For instance, 00:22:CE (first six digits of 00:22:CE:28:18:81) indicates the vendor of the device is Cisco [25].

Here, we evaluate the types of devices being extracted by BMSs located along Gateway Motorway, Brisbane Australia by mapping the first six digits of the scanned MAC-ID with the available IEEE database [26] of MAC-ID's and respective vendor/manufacturer. Figure 9 represents the proportion of the devices observed along the study site. For the current analysis, around 34% (one third) of the devices were registered with Nokia. Other mobile phones in decreasing order of observations are Samsung (9%), Sony (0.7%), LG (0.7%), Motorola (0.4%), and Apple (0.3%). Smart devices (such as Apple iphones) by default, are in discoverable mode only for 120 seconds once the discovery is imitated by the user. Hence, these devices have relatively low chances of being discovered by the BMS. Interestingly, TomTom and Garmin the car navigation systems only represent a small portion of 4.3% and 1.2%, respectively.

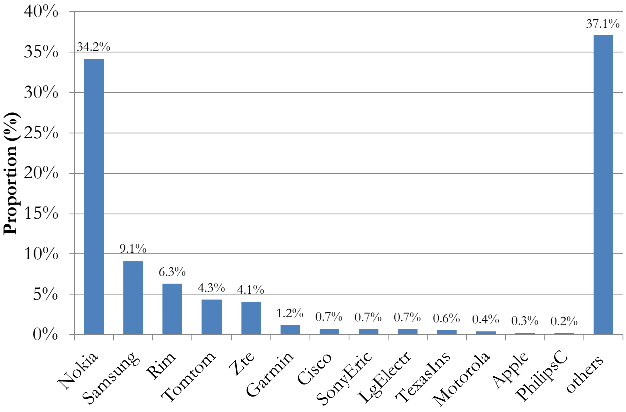
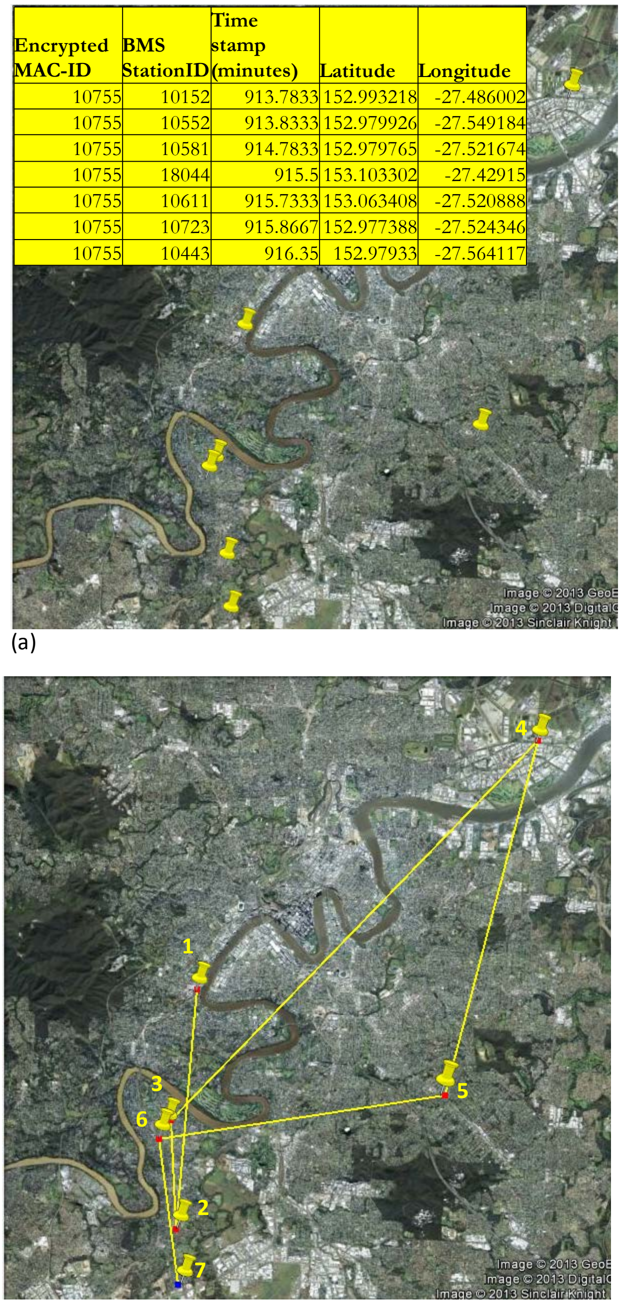


Figure 9: Proportion of the different devices observed along the Gateway Motorway, Brisbane, Australia

5. A discussion on the uniqueness of MAC ID

Ideally MAC address should be unique, but it can be cloned [27]. This is not a normal practice but it is observed that some Bluetooth devices carried by taxi fleet have devices which are cloned with the fleet operator requirements. The availability of MAC-ID from these cloned devices can result in unambiguous results from the Bluetooth MAC-ID matching. To demonstrate this, we present the results from the analysis of one month (January 2012) of data from Brisbane. Here, similar MAC addresses observed at different BMS locations (more than 10 km in Euclidean distance) within a time window of 1 minute and 5 minute are filtered. On urban arterials it is not possible for a vehicle to travel more than 10 km in 5 minutes (approximately 120 km/h in space mean speed) or 1 minute (approximately speed of 600 km/h). Hence these similar observations should be from cloned Bluetooth devices. Figure 10 illustrates an example of a Bluetooth device ID 10755 (encrypted) is observed at seven BMS stations within a short time window of 5 minutes. The geo-locations of these seven stations is presented on *Google Earth* map (Figure 10*a*). Figure 10*b* illustrates the respective air-trajectory of the BMS device from one location to other, where the number in the figure represents the order in time in which the device is observed at the respective BMS station. One can clearly see that it is impossible for the device to travel though these BMSs within 5 minutes.



Encrypted MAC-ID	BMS StationID	Time stamp (minutes)	Latitude	Longitude
10755	10152	913.7833	152.993218	-27.486002
10755	10552	913.8333	152.979926	-27.549184
10755	10581	914.7833	152.979765	-27.521674
10755	18044	915.5	153.103302	-27.42915
10755	10611	915.7333	153.063408	-27.520888
10755	10723	915.8667	152.977388	-27.524346
10755	10443	916.35	152.97933	-27.564117

(a)

(b)

Figure 10: An example of a cloned Bluetooth device observed at different locations on the network within a very small time period

Figure 11 presents the result for the number of “duplicated” MAC-IDs from Brisbane, Australia. Here, X-axis is the day of the month (January 2012); Y-axis is the number of times similar MAC-ID’s are observed within: a) 5 minutes time window (blue solid line) and b) 1 minute time window (red solid line) at two BMS locations which are more than 10 km in Euclidean distance. This can be termed as *duplications per day*. It is observed that the number of *duplications per day* for 5 minutes time window has daily fluctuations, with the highest observation on 18th January, 2012.

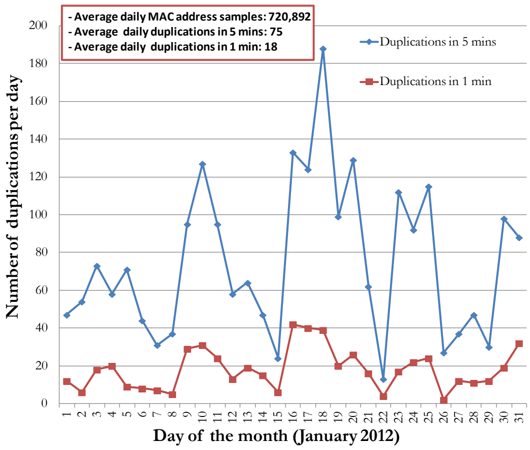


Figure 11: Empirical number of MAC-ID duplication from January 2012, Brisbane Australia

Figure 12 presents the percentage of the number of *duplications per day* to the total daily MAC-ID observations from all the BMSs for the month of January 2012. Here, blue triangles and red dots are for duplications within 5 minutes and 1 minute, respectively. It is observed that such observations are quite low with probability of occurrence less than 0.025%.

From the above analysis we can conclude that currently the *cloning* of MAC-IDs is not a big issue for the use of BMS data for traffic monitoring. The percentage of such observations is negligible compared to the massive data collected by BMSs. Unrealistic high or low travel time values should be identified as an outlier by any standard filtering algorithm.

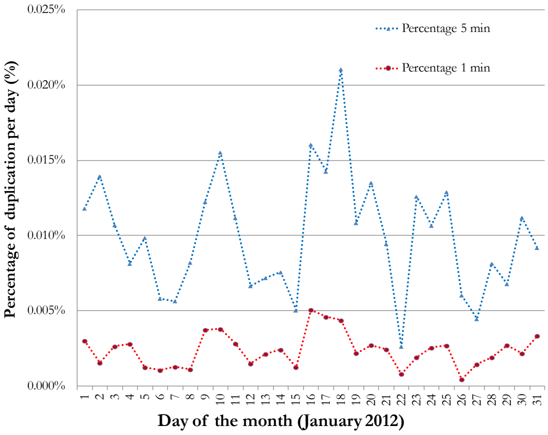


Figure 12 Empirical percentage of the MAC-ID duplication from January 2012, Brisbane Australia

Table 1 presents the data for 1 minute *duplications per day* for 18th January 2012 where we have observed 39 duplications. However, it can be seen that these 39 observations are represented by only 7 unique MAC-IDs. One can think of analyzing the historical database for identification of MAC-IDs which are potentially *cloned* (using the aforementioned procedure) and "black-list" them for future applications.

Table 1: MAC-ID duplication for 18th January 2012, Brisbane, Australia

Encrypted MAC-ID	BMS StationID	Timestamp (minutes)	Latitude	Longitude
337	10262	507.1667	153.0883	-27.43161
337	10345	507.4	152.9664	-27.50056
7419	10021	728.5833	153.0243	-27.47169
7419	10492	729.4167	153.1292	-27.47466
8012	10552	1052.8167	152.9799	-27.54918
8012	10077	1053.45	153.0338	-27.45963
10755	10152	913.7833	152.9932	-27.486
10755	10552	913.8333	152.9799	-27.54918
10755	10581	914.7833	152.9798	-27.52167
10755	18044	915.5	153.1033	-27.42915
10755	10611	915.7333	153.0634	-27.52089
10755	10723	915.8667	152.9774	-27.52435
10755	10443	916.35	152.9793	-27.56412
26025	10182	427.0167	153.0126	-27.46605
26025	10183	427.4667	153.0133	-27.46493
26025	10492	427.6333	153.1292	-27.47466
26025	10671	601.5667	153.0139	-27.53789
26025	10310	602.0167	153.0069	-27.4369
178072	10030	400.25	153.0708	-27.43741
178072	10443	400.9667	152.9793	-27.56412
178072	10439	405.8333	152.983	-27.5324
178072	10275	405.85	153.0417	-27.44985
178072	10685	406.3	153.0886	-27.49573
178072	10275	469.4833	153.0417	-27.44985
178072	10439	470.3	152.983	-27.5324
178072	10030	476.7833	153.0708	-27.43741
178072	10508	477.1333	152.973	-27.50761
178072	10157	477.5833	153.0797	-27.43413
788831	10506	373.5667	153.0116	-27.54137
788831	18044	374.5	153.1033	-27.42915
788831	10262	512.1167	153.0883	-27.43161
788831	10506	512.1333	153.0116	-27.54137
788831	10671	512.7833	153.0139	-27.53789
788831	10506	634.2	153.0116	-27.54137
788831	10030	634.3833	153.0708	-27.43741
788831	10157	635.2667	153.0797	-27.43413
788831	10085	1248.2	153.0178	-27.46758
788831	10072	1248.7333	153.0213	-27.46864
788831	10443	1249.4833	152.9793	-27.56412

6. Discussion and Conclusion

This paper contributes to the increase in the understanding of the Bluetooth MAC Scanner. Conceptual model for the Bluetooth communication and BMS data acquisition is summarized. The empirical analysis of the real Bluetooth and VID data from Brisbane, Australia discovers some interesting facts about the use of these advanced complementary transport data sources.

BMS captures the MAC-IDs of the discoverable devices passing through its communication zone. No information about the type of the mode, and number of devices within the same mode is available. This raises a question about the Bluetooth travel time points that can be obtained from a mode carrying multiple Bluetooth devices. For instance, a bus carrying multiple passengers with active Bluetooth devices can provide multiple records. If we observe multiple Bluetooth records from a vehicle then the average travel time estimate will be biased. This paper has empirically analyzed the probability of multiple Bluetooth travel time records from a bus. It is observed that bus is overrepresented in the BMS dataset and it is rare to have overrepresentation by more than six travel time points. The chances of observing more than three travel time records for a bus, is less than 20%. The objective of this research is to empirically evaluate such probability. The reasons for this low number of Bluetooth detections from a bus will be investigated as further research. The reasons include: a) Limited active devices carried by the bus passengers; b) Bus have higher clearance and passenger seats are higher than that of cars. BMS scanner antennae are normally at the height of the signal controller box with low vertical coverage, resulting in lower capture of Bluetooth devices in the bus.

Few instances are reported where a Bluetooth device is observed at multiple BMS stations within a very short period. This is due to the cloning of the Bluetooth devices. The analysis shows that this is not frequent. The findings do answer some of the unambiguous travel patterns observed from the BMS data. Currently the presence of non-unique MAC-IDs is very low. However, it does raise a question, what if in future the use non-unique MAC-ID increases? If so, it can have significant impact on the application of the BMS data.

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