Improving Vehicle Location Based Distributed Systems with an Antenna Vehicle Ad Hoc Network

Abstract

In our ever more connected world, the need for fast, but accurate data in response to our requests is most certainly applicable to any distributed system currently in operation. The global positioning system or GPS, is one such distributed system. However, in our most populated areas, as well as in-accuracy in criss-crossing streets and roads, GPS is hampered by buildings blocking the radio signal intended to be received by our satellites. This creates a general problem of not only no reception but the time it takes to reconnect and for the device to find itself again. Time-to-first fix (TTFF) is slow regarding to a moving vehicle's needs. From the best case scenario, a *Hot* start, TTFF is supposed to be 1-3 seconds. With the new approach of GSM-R to connect our railways and Assisted-GPS now in use in our phones, I propose that a Vehicular Ad Hoc Network (VANET) should be used to improve the on-board GPS in vehicles to decrease connection time, improve the loss of reception and overall accuracy in positioning. Many different algorithms have been suggested and simulated for VANETS, such as Greedy Perimeter Coordinator Routeing (GPCR) and the Bidirectional Search Algorithm. In this paper, we will compare connection time of the different antenna approaches to VANET, with the current approach in GPS. This will be done in each of its three states, *Cold*, *Warm* and *Hot* connections. Using Microsoft Excel to calculate maximum transfer time, it should show that using a VANET will improve the time it takes to find your relative location in vehicles, in an urban environment.

Introduction

Location based systems are in use in everyday life, whether that be the Satellite Navigation system in your car or the geographical stamp on the messages you send from your smart phone.

Problem

However, due to the various errors induced by the space segment, signal propagation, receiver technology or user environment, the accuracy of global navigation satellite system (GNSS) receivers is not sufficient. (Tawk, Tomé, Botteron, Stebler & Farine, 2014, p. 3769) This has been solved with such things as Inertial Navigation systems (INS) in safety critical systems, but this solution if often large and or expensive. Furthermore, A-GPS (Assisted-GPS) was proposed and is used today to help with mobile phones. Nevertheless, GPS and therefore A-GPS, still does not work very well in high density urban areas due to limited satellite visibility, (Zandenburg, 2009 p. 6) as there is a broken line of sight to the satellites. This is the main constraint this paper has and also defines the scope in which the problem lies. By having an interrupted line of sight to the GNSS, GPS receivers are constantly having to perform hot and warm starts in order to get a location fix.

The question I intend to answer is that, is possible to create a more reliable location based system using a VANET, for an urban environment. The comparisons of data will take place in all 3 of GPS's starting procedures, Cold, Warm and Hot, compared to 3G, 4G and Wi-Fi antennas.

Hot start

Manufacturers generally claim the hot start time to be in the 1-3 second range.(Lehtien, Happen & Ikonen 2008, p. 347) This is the fastest of all its three starts and happens when a receiver has been switched off or has been out of reach for a short period of time. It has therefore retained valid information in its memory. The information is referred to as ephemeris data.

Warm start

Usually manufacturers report 28-35 second warm start times. .(Lehtien, Happen & Ikonen 2008, p. 347). A warm start happens when a receiver has not retained (or has out dated) ephemeris data, due to the receiver being off for a prolonged amount of time. For example, this could be overnight. However, a warm start requires it to possess almanac data and from this is can "predict which satellite signals it should be able to receive, and thereby, the receiver can acquire signals faster than in a cold start". Lehtien, Happen and Ikonen (2008, p. 347).

Cold start

30 – 45 second times for cold starts reported by manufacturers. .(Lehtien, Happen & Ikonen 2008, p. 347). A cold start is performed when the almanac and ephemeris data is not vaild. This can be cause by the moving of the receiver while off or if the internal battery has completely run out of power.

Although a hot start is the most likely in an urban environment, I feel that all should be compared as all have a possibility of happening.

Current Tools and proposed solutions

There are many solutions to the outlined problem which have to be taken into account when discussing the solution. Some of which, are very well thought out. However, many are limited in capability and versatility in urban areas and have not taken this area into account when providing a general solution.

GPS and GLONASS

But first of all, GPS is the current, American, solution to a distributed system that is used to locate a position on the planet. However, a Russian solution is starting to emerge with the revitalisation of its space program. This is GLONASS. GLONASS works in a similar way to GPS, using clocks to synchronize and calculate the positing of locations on earth.

Pan, Cai, Santerre and Zhu (2014, p.17531) propose a hybrid system, combining both technologies to speed up convergence. Their tests proved that "TTFF is reduced by 27% after adding GLONASS observations". Yet, this still does not provide the answer to the problem in urban environments, as line of sight will still be disrupted by buildings. They also proved that GLONASS is poorer than GPS, by orbital and clock error. Results can be seen in Table 1.

	GLONASS		**GPS**	
	Orbit(cm)	Clock(ns)	Orbit(cm)	Clock(ns)
ESA/ESOC	7.7	0.14	3.4	0.06
IAC	8.0	0.15	5.2	0.10
Mean	7.9	0.14	4.3	0.08

Table 1 - RMS statistics of CNES satellite orbit 3D errors and clock errors on 1 February 2014. Data from Pan, Cai, Santerre and Zhu (2014, p.17533)

As a result of this, I shall only be comparing my solution with the better method of GPS and in its three states of connection.

Wi-Fi Positioning – A-GPS

This solution is one of the most applicable solutions to urban positioning as "coverage of Wi-Fi positioning is best in heavily populated areas," (Zandenburg, 2009, p. 7). Wi-Fi positioning is based on the fact that many private and public businesses now have Wi-Fi on their premises, which is stationary. You can then locate yourself by determining which access points you are in the range of. However, even though this solution was found to have an "availability >97% and time-to-first-fix <1 second," (Zandenburg, 2009, p. 7) it still has many problems.

Most access points are indoors and offer little connection outside of their premises. Whether this is accidental or to prevent security issues it can stop this method from working at all. However, Zhang and Yang (2014, p. 900) overcame this by location based on the strength of the signal from the source. Using the known transmitted signal strength, the receiving node calculates signal loss in the communication process. Nevertheless, this solution is void if the transmitted signal strength is not known. This could, more than often not, be the case as many access points are from private companies and would not share this information, due to the modern day threat in the security sector. Furthermore, a busy urban environment could easily overload a Wi-Fi network of a small business, such as a coffee shop on a high street, which would then put more load on other networks.

In conclusion, all though this solution is viable, it may have all-ready become out-dated due the threat of security and the amount of devices that use location based applications.

RFID-VANET

RFID is becoming more common recently and is now involved in many institutions, my own included. Furthermore Lee ,Oh and Gerla (2011, p.168) propose a novel localization system assisted by Radio Frequency Identification (RFID). Figure 2.

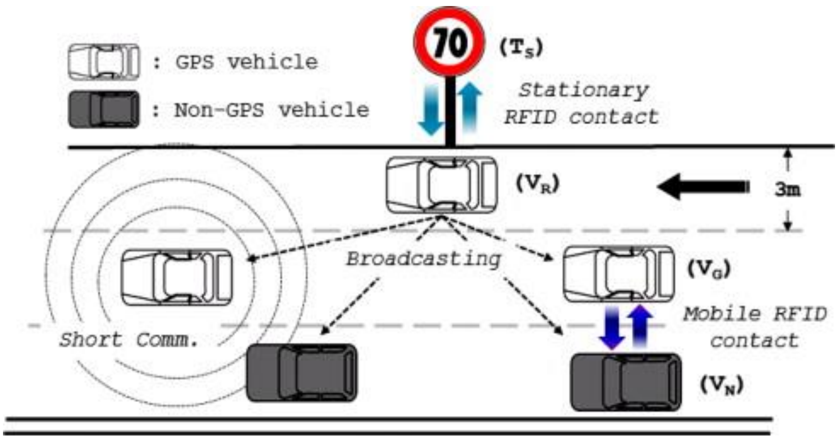


Figure 2 - The proposed localization system: RF-GPS and single peer localization. (Lee, Oh & Gerla 2011, p.169)

This solution assumes all vehicles are fitted with RFID readers and that all have IEEE 802.11 radio emitters. This allows them all to communicate with each other and locate their positions even if not equipped with a GPS receiver, the main advantage to this solution. However, one issue that this does have is that you can't locate a position until a vehicle finds itself via GPS and can tell others,(which is the problem in urban areas we are trying to eradicate), but also that you must pass and RFID sensor. Meaning your location is only known as long as there are multiple cars able to tell you your position or if you are directly passing a station.

The solution suggested in this paper, eradicates these problems.

Simulation and Solution

In this section I will be talking about a solution to this problem and how it was simulated. This solution, to this problem, has many distinctive parts that will be brought together to create a distributed system which can locate vehicles quickly.

Assumptions

However, in order to achieve constancy when comparing my solution with the current GPS model, assumptions for the test environment must be made.

The first is that *Noise* levels are at 0 Db. This means we are testing under the fact that no other signals, whether they are natural or man-made, in the area can interfere with the signal from the GPS system or the proposed solution. If this was taken into account, packet loss would have to be factored in but this is not in the scope of this theoretical proposal.

Another is that, at all times, the vehicle is in the line of sight of 3 or more stations/satellites. This means a location can always be found. This assumption has been made because we are testing for a better response time, not the % of fix's which could take up to 15 minutes, but still count as a fix. Percentage of fix is not a problem with current GPS as proved by many papers such as in Davis, Thokala, Xing, Hobbs, Miller, Han and Mishra (2013, p. 855), where they find it is at > 97.93%.

GPS systems rely on time synchronization in order to calculate the distance travelled. Even a slight slip in this timing can create large inaccuracies of 100's of meters and therefore the time it takes to get an accurate lock for position. Consequently, we assume that both systems, for the sake of fairness, are synchronized to a correct time.

Finally, we assume that all middleware such as satellites and base stations are in good condition with no defects that could affect the distance/ range of transmission. Also that the computing power of such devices is equal and that load balancing of data coming in does not affect the time for calculation of position.

Solution

The solution to this problem can be represented well in a diagram below, figure 3.

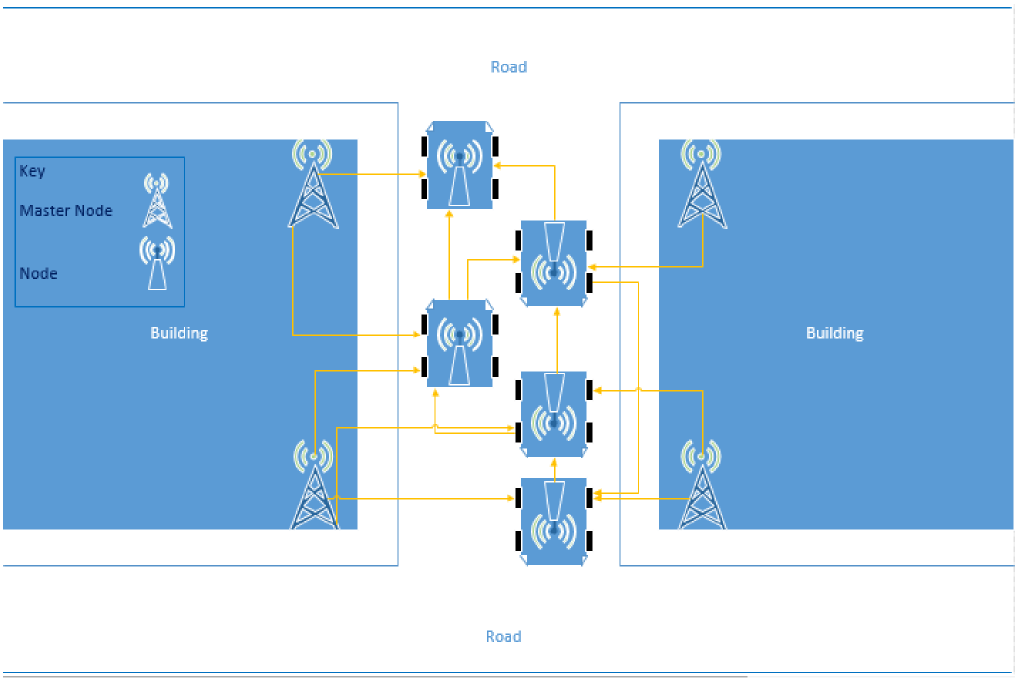


Figure 3 – Diagram of proposed solution.

As you can see from the diagram, each vehicle has a node and every corner of building has a master node. This means, in a grid system which many cities use, a vehicle should always be in the line of sight of 4 or more nodes/master nodes. The problem that arose in Lee,Oh and Gerla (2011) RFID solution is solved here. This is because you can always receive data rather than just when you pass a RFID station.

A master node can send data, but not receive it, but a node can send and receive. By implementing this VANET, you can have a constant feedback of polling to each node around it. By using the closet 3 nodes which have a position lock, you can then secure a lock in the shortest amount of time. For example, if a vehicles 3 closest nodes were other vehicles, which already had position, then it would use these positions to calculate its own position. But then again, if node 1 is transmitting to node 2, node 1 cannot then receive from node 2. This would create a race condition and potential errors in accuracy.

A lot of research has been done into the most efficient way to calculate the position using radio signals to do with Received Signal Strength Indication (Zhang and Yang, 2014, p. 900) as well as the usual technique of using time synchronisation. (Zandenburg, 2009, p. 6). I shall be using this method as it makes the comparison of the calculation of position between both GPS and this solution equal because both use time synchronisation.

The master nodes are static, so once a location has been imputed to it, it never needs to find its self again. This is one of the reasons that, I believe, this system will be quicker, on the grounds that the amount of time it takes the signal to travel alone, to and from the satellites for GPS systems has become void here.

Method of Simulation

This has been simulated by calculating the time it takes a node to receive a packet of information, from 3 stations, in order to have necessary data to locate its position and compared it to the time it takes a vehicle to do the same using GPS. This is tested when the device interacts with the network for the first time, time to first fix (TTFF). In the case of GPS, this is the receiver in the car and for my solution, when a node enters the VANET.

My solution will be compared to all GPS's states, Hot, Warm and Cold as explained in the introduction.

The data sent in my simulation, has a bench mark packet size of 500000 bytes. It is then tested at a 3G network speed, 4G and at the speed of standard Radio Emitter, of which any could be used in the solution to act as master nodes. These speeds are shown in the Table 4. Table 5 shows the specifications for the "consumer grade" products that would be used in vehicles for GPS and Table 6 then shows the results of a TTFF tests on these.

Equipment	Speed (Mbit/s)
3G Network	6.1
4G Network	15.1
Wi-Fi Emitter (2.4GHz band)	11

Table 4 - Data for networks through put taken as an average of the current UK networks from Ofcom (2014, p.3). Data for Wi-Fi emitter through put as specified in IEEE 802.11b.(2001, p. 1)

Device	WondeX – BT760Y	Globaltop – G33	Nokia LD-3W	Nokia N95
Chipset	Skytraq Venus 5	MTK MT3318	SirfStar III	TI NavLink 5300
Hot Start	1s	1s	2s	-
Warm Start	28s	34s	-	-
Cold Start	30s	36	45s	-
Refresh Rate	1 Hz	5 Hz	1 Hz	-
Channels	54	51	20	-
A-GPS	Offline A-GPS	-	-	A-GPS

Table 5 – Specifications of devices. Data from Lehtien, M. Happen, A. Ikonen, J (2008, p. 346)

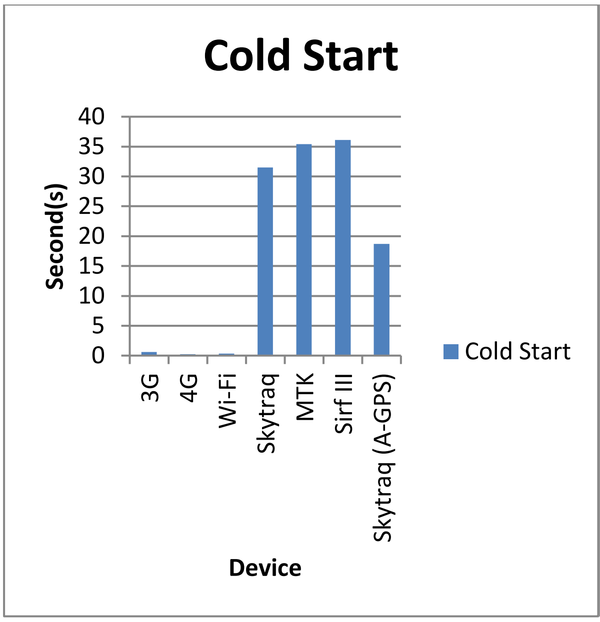
Chipset	Skytraq	MTK	Sirf III	Skytraq(A-GPS)	N95	N95(A-GPS)
Cold Start	31.5	35.4	36.1	18.7	-	-
Warm Start	33.2	33.0	33.4	12.1	143.4	13.1
Hot Start	1.5	2.4	1.2	-	-	-
Average	22.1	23.6	23.6	15.4	143.4	13.1

Table 6 – Time to first fix results (seconds). Data from Lehtien, M. Happen, A. Ikonen, J (2008, p. 347)

The results for the proposed solution have been produced using the following equation:

$$Maximum\ Packet\ Transmission\ Time\ (seconds) = \frac{Packet\ size(bytes) * 8\ bit}{Bit\ Rate * 2^{20}\ bit/s}$$

Results



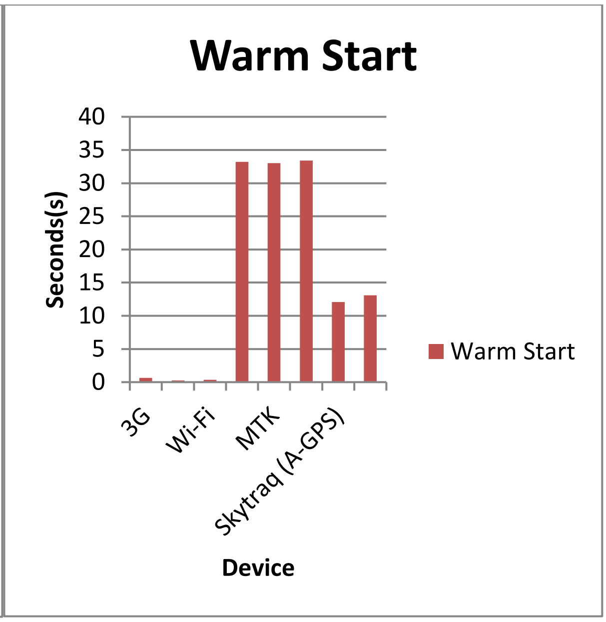
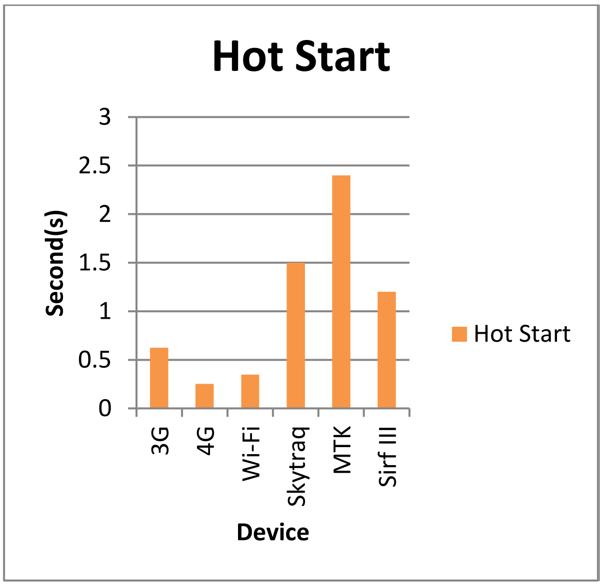


Figure 7 - Cold Start Data Representation

Figure 8 - Warm Start Data Representation



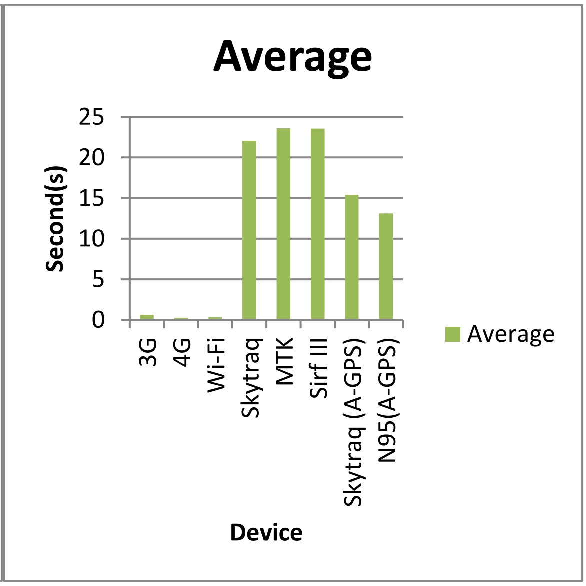


Figure 9 - Hot Start Data Representation

Figure 10 – Average of Hot, Warm and Cold starts

Discussion

On initial interpretation you can see that all methods of the VANET solution are faster than all methods of GPS. However, the comparison I wish to discuss is Figure 10, the average.

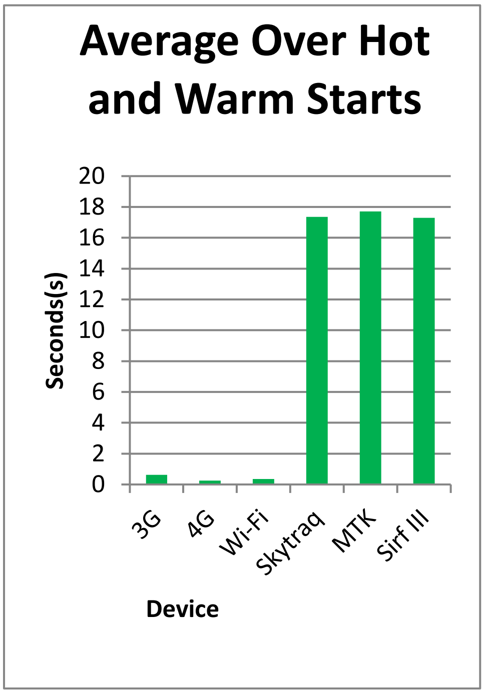


Figure 11 - Warm and Hot Start Average

Figure 10 shows the average of all the starts and reflects the times over all cold, warm and hot starts. This is a more accurate picture of comparison that just one graph as not all starts will be just hot, warm or cold starts. However, cold starts are very rare in this sort of setting and influences the average far more than the Warm or hot starts do. Therefore I have produced an average just over Warm and Hot starts (Figure 11), with devices that have this capability.

The 3G, 4G and Wi-Fi are still much lower as they are not depending on the state or data currently available to it on start up. Whereas, with GPS the time to first fix is dependent on whether you have almanac and or ephemeris data available. This is also reproducible over each node in the solution for the reason that each node is connected to another node if and only if it has a position lock.

When there are many vehicles in the network, it would not hamper its ability to detect its location. This is because it mirrors the system used in GPS that does not rely on other cars for a fix, which is the downfall to other solutions. This is because of the fixed location of the master nodes.

However, as with all solutions, there is a physical cost. With GPS already available and at a liveable quality, this more radicle and high physical cost solution and may be something for cities of the future.

Conclusion

Keeping the future in mind, many new technologies that are currently being researched and not so far away, could have a major impact on this and other suggested solutions.

5G is a very real possibility in the next couple of years, with predicted speeds of 1Gbps to 800Gbps and a large range. This could improve this system greatly. However, with the new private space programs, a new generation of satellites could be launched with better capabilities at a much lower cost. Either way, a distributed system will be used to achieve the goal of highly accurate and reliable location system, and using a Vehicular Adhoc network to improve this would be a logical enhancement and step in a better direction.

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