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Smart on-board transportation management system Geo-Casting featured

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Smart On-Board Transportation Management System Using GPS/GSM/GPRS Technologies to Reduce Traffic Violation in Developing Countries

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ABSTRACT
Nowadays, the evolution in transportation technologies makes the necessity for increasing road safety. In this context, we propose the implementation of a smart onboard GPS/GPRS system to be attached to vehicles for monitoring and controlling their speed. In case of traffic speed violation, a GPRS message containing information about the vehicle such as location and maximum speed is sent to a hosting server located in an authorized office so that the violated vehicle is ticketed. Moreover, this system can also track the vehicle's current location on a Google Map, which is mostly beneficial when vehicles should follow a specific road and in case of robbery. Also geo-casting can have a major role in this model. Some sensors, such as shock/vibration sensor usually attached to the air-bags in vehicles, are attached to the system that in case of accident, it will send notifications to the nearest hospital, police station and civil defense. Our proposed model can be utilized for different implementations, both in public and private sectors. While similar existing systems in Palestine have focalized just on the tracking aspect of vehicles' monitoring, it would be the first system supporting both ticketing and tracking.

KEYWORDS
GPS; GPRS; Transportation; Ticking; Tracking; Intelligent Transport System; ITS; Machine-to-Machine; M2M; Internet of Things; IoT; Smart City;GSM.

1. INTRODUCTION
Recent studies show that all over the world, including Palestine, there has been a rapid increase in vehicle numbers. The latest statistics show that there are approximately 140,000 licensed vehicles in West Bank in 2011. About 17,000 of them are newly registered [1]. As a result, as Figure [1] illustrates, traffic crashes increase in past few years in West-Bank. It was investigated that the lack of proper infrastructure for roads is one of the reasons for these crashes. Moreover, people by nature, are not willing to deter something unless they are obliged by laws and threatened to pay large fines or to get penalty. Thus, the resulting costs of damages add an extra burden to the development of society. As a consequence, it is worthwhile to provide solutions to these challenges.
Advances in Information and Communication Technologies (ICT) represent a good potential tool to tackle the increasing road accidents and vehicle robbery. The application of the ICT to the transportation and traffic management is called Intelligent Transportation System (ITS) [2], [3], [4].
In this work, a Smart Transportation Management System (STMS) based on GSM, GPS and large array of smart sensors integration has been developed for enhancing public and private transportation services. The system is composed of an embedded microcontroller based smart board called SmartBoard, a Cloud based web application and Google MAP Services [5].

1.1. GSM Technology
Global System for Mobile Communications, originally (GroupeSpécial Mobile), is the world's most popular mobile telephone system.
80 percentages of mobile operators use this standard, providing services to over 1.5 billion people across more than 212 countries. This is because GSM is the first mobile generation which provides services and ability to roam and switch carriers without replacing phones, and also to network operators. General Packet Radio Service GPRS represents an evolution of the GSM

standard, allowing data transmission in packet mode and providing higher throughputs compared with the circuit switched mode [6], [7].

1.2. GPS Technology

Global Positioning System (GPS) is a worldwide radio navigation system formed from the constellation of 24 satellites and their ground stations. The Global Positioning System is mainly funded and controlled by the U.S Department of Defense (DOD). The system was initially created and designed for the U.S. military use. But nowadays, it is available for civilian, without any kind of charge or restrictions. Global Positioning System tracking is a method of working out exactly the position of GPS sensor's holder based on a simple mathematical principle called trilateration or triangulation. Trilateration falls into two categories: 2-D Trilateration and 3-D Trilateration. It requires having at least four satellites transmitting coded signals from known positions. Three satellites are required to provide the three distance measurements, and the fourth to remove receiver clock error [9].

A GPS tracking system can work in various ways i.e. Active and passive tracking. In Passive tracking, the position is usually stored in internal memory or on a memory card along the ride, while in the active tracking, also refers to a real time tracker, data is to be transmitted to central database via a modem within the GPS unit [9].

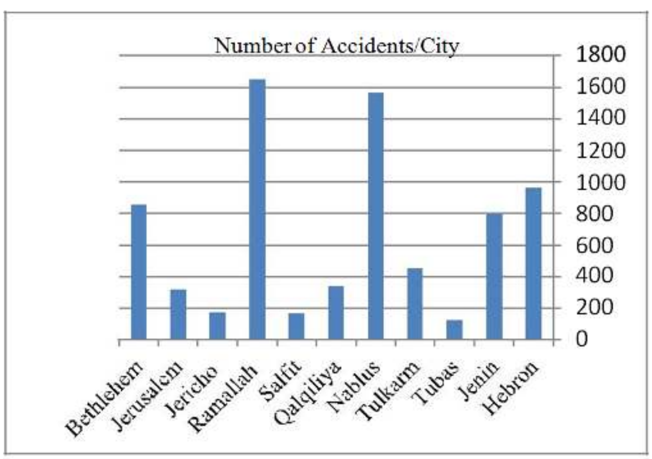

Figure 1. Number of registered road traffic accidents for major cities in Palestine 2011 [1].

The paper is organized as follows: the first section gives an overview about the problem. Related works are discussed in the second section. The model components are introduced in section three. System requirements and implementation issues are described in section four. The ticking and tracking algorithm description is proposed in the fifth section, the sixth section discuss the experiments and user experience with the STMS, while conclusions are introduced in the final section.

2. RELATED WORK

This section briefly introduces implementation and development activities in research and academia of selected smart transportation systems. Specifically, GPS and GPRS based models which have been designed for managing and organizing transportation systems.

Patinge and Kolhare developed a GPS based urban transportation management system in which the fleet tracking using GPS and GSM/GPRS technology and public information system unit mounted at bus [10].

Kumar and Prasad attempted to enhance public transportation management services based on GPS and GSM [9]. Optimizing the traffic and passenger flows and improving system management, integrated real-time information on the traffic situation in the urban area (e.g. concerning parking spaces, congestion, and public transport) can be provided by CIVITAS II [12]. Goud and Padmaja proposed a useful approach in detecting accidents precisely by means of both vibration sensor and Micro electro Mechanical system (MEMS) or accelerometer [13].

In a preliminary research paper related to this work, Saed Tarapiah and others in [14] identify a common criteria and also they provide a design guideline for such system. Furthermore, they have developed in Palestine an initial prototype to control public transportation.

3. MODEL MAIN COMPONENTS

This section provides detail descriptions for the used hardware modules by SmartBoard.

3.1. GSM-GPRS Module

A GSM module is a wireless transmission module that works with a GSM wireless network. It behaves like a dialup modem. The main difference between GSM module and dialup modem, which is a dialup modem sends and receives data through a fixed telephone line while a wireless modem sends and receives data through radio waves. The module can be connected to a computer through a serial cable or a USB cable. In our project we use the SM5100B Cellular Shield, since it is easy to deal with and more flexible, also it supports AT Commands. It has unlimited transmission range and distance, so we can use it in any place. GSM can easily send and receive data across the mobile network, and it can transmit instructions, commands, SMS and receive them from microcontroller [15].

Figure 2. GSM-GPRS module.

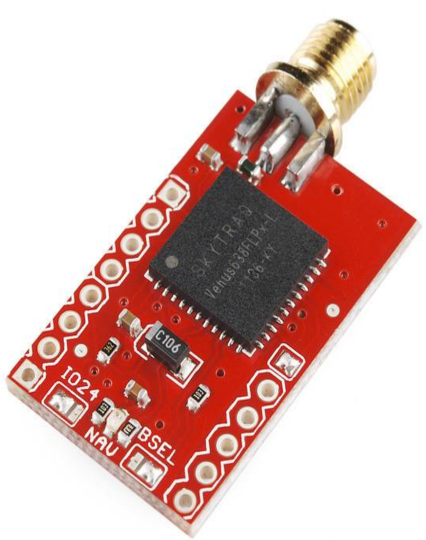

Figure 3. GPS-11058 module.

3.2. Arduino Microcontroller

The Arduino Uno is a microcontroller board, which has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz ceramic resonator, a USB connection, a power jack, and a reset button. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with an AC to DC adapter or battery to get started [15].

3.3. GPS-11058 Module

GPS-11058 is a development board that uses the smallest, most powerful, and most versatile GPS receiver. The module can be configured to an amazingly powerful 10Hz update rate, with 14 channel tracking. It has two serial ports, UART and SPI interfaces, 28 mA operating current and high sensitivity. It needs to connect it with an external battery or super capacitor to the board, to support very fast restarts after power is removed. There are even pads on the bottom of the board for the 0.2F super capacitor, which keeps the board hot start-able for up to 7 hours without power [15].

Figure 4. Arduino microcontroller.

4. SYSTEM REQUIREMENTS AND IMPLEMENTATION

This section provides a more in depth look at the STMS architecture and it also elaborates on every single component of the system. This section explains the enabling technologies they are used to glue the system components together, along with the motivations why these technologies are suitable for the STMS. The STMS is composed of an embedded smart board called SmartBoard, a Cloud based web application and Google MAP

Services.
Figure [5] illustrates the high level network architecture of the system and shows the main communication technologies used for information and event flow between the system major components.

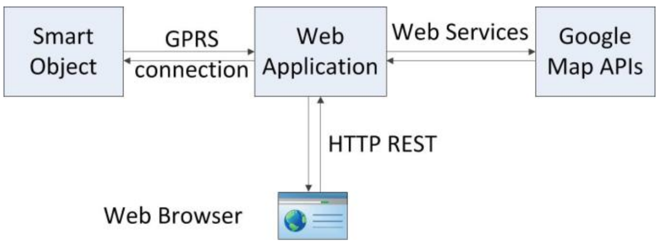

Figure 5. The high level network architecture of the system shows the main communication technologies used for information and events flow between the system major components.

4.1. Cloud Based Web Application

A Web Service (WS) [16] is a communication paradigm which allows two Internet applications or two electronic devices (such as computers, embedded processors and microcontrollers, smart sensors and actuators, smart phone, cellular mobile and tablet PCs) to interact in order to exchange information and events between each other through the WWW (World Wide Web). There are two important Kinds of Web Services, Simple Object Access Protocol (SOAP) [17] and Representation Stateless Transfer (REST) [18].

SOAP it a standard communication protocols for XML-based data exchange between peers. SOAP uses different transport protocol such as HTTP, Simple Mail Transfer Protocol (SMTP) and Java Message Service (JMS). SOAP uses the XML language to define the message architecture and the message format.
REST is a style of software architecture that describes how data is transmitted between peers over a standardized interface e.g. HTTP. It is based on client server communication paradigm and the interaction is made by a request response pairs. REST relies on a stateless and cacheable communications protocol.

In order to make our web application flexible and extendable, we have adapted the REST (RESTful) architecture. And our implemented STMS has used the three-tier architecture [19]:

1. A front-end which relate to the client side. The user interface is based on a web-browsers application. It contains a responsive web page developed using Hypertext Transfer Markup Language HTML5 , javascript , JQuery library [21] and Cascading Style Sheet (CSS) whose application is tested on both desktop and smartphone web browsers. This web page uses Asynchronous JavaScript AJAX in order to build bidirectional data flow with middle layer. This way allows the user interface to receive a real time data from the servers and also to interact with the system through issues commands to middle layer.
2. A middle layer which includes a dynamic PHP program running on top of Apache web server [22]. This program exposes its internal functionality through a RESTful interface towards the front-end and it uses the MySQL native driver for PHP for storing and retrieving data.
3. A back-end containing MySQL database server [23] used to store all known roads in the region, system users , users profiles and user alerts and tickets. This component is a relational database that is used to store and retrieve the data. Note that the positioning and speed data are time-stamped according to the UTC time reference.

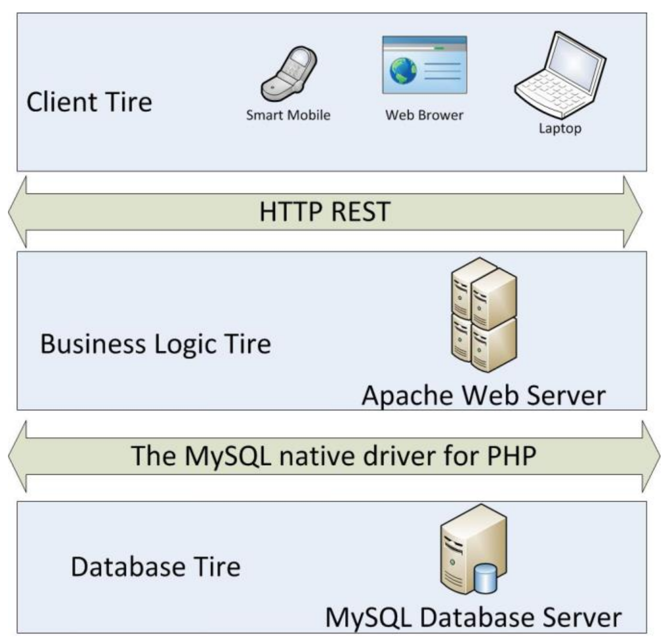

Figure 6. The High-level design and architecture of the Web Application. First tire contains the database storage.

The second tire runs the business logic and computations. Finally, the clients tire.

Figure [6] shows the Web application high-level architecture as well as the HTTP REST communication between the user web browser and the Apache web server. The whole Apache and My SQL systems are tested and run over windows server platform [24].
It is important to note that the middle and back-end layers can reside in two separate physical server machines - to improve the scalability of the STMS - or both of them can be resided in the same physical server machine - this case is suitable for small and medium scale applications.

In RESTful vocabulary things are resources. Each resource is an uniquely addressable entity by a Universal Unique Identifier (URI) attached to it. Also each resource has representation that can be transferred and manipulated by means of four verbs. These verbs are create, read, update and delete (CRUD).

4.2. SmartBoard

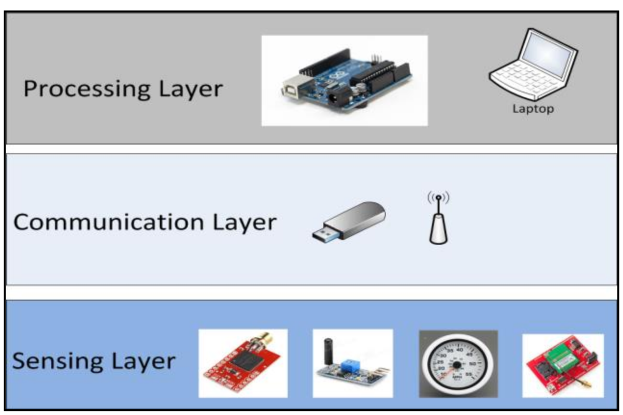

Figure 7. High Level Architecture of the SmartBoard.

The software architecture of the proposed SmartBoard (shown in Figure [7]) is organized as follows:

- Sensing layer. This layer depends on off-the-shelf sensors used to collect information regarding the vehicle status, such as geographical location and speed. More specifically, we have GPS sensors which is used to collect location and speed information of the vehicles; accelerometer sensors - such as vehicle built-in speed meter - providing the vehicle's speed information and shock and vibration sensors which are usually attached to the air bags in vehicles. In case there is an accident, these latter sensors will send notifications to other components.
- Processing layer. This layer uses Arduino Uno microcontroller [8] and it runs the ticketing and tracking algorithm as we will explain it in section[5].
- Communications layer. This layer contains wired and wireless communication technologies. The former connects the sensors layer to the microcontroller using Universal Synchronous Asynchronous Receiver and Transmitter (USART) [25], while the latter (GPRS) are used to connect the smart board to the internet.

4.3. Google Maps API

Google MAP API [5] is a public and free service offered by Google cooperation. This service composed of a set Application Programming Interfaces (APIs) which aims to facilitate the integration of Google Maps and services into newly created geographical applications and services by developers. We embedded a Google Map in our web application. After that, we used Google Map APIs to put over this Map a series of geographical location information they are longitude and latitude pair values. Google MAP APIs are based on Web Services technology. In Web Service, retrieving, creating, deleting and updating geographic data is made through HTTP request to specific Uniform Resource Identifier URI. The response of Google MAP APIs is based on JavaScript Object Notation (JSON) or Extensible Markup Language (XML) data format.

5. THE PROPOSED TICKETING AND TRACKING ALGORITHM

Our proposed model performs online monitoring, ticketing and tracking. Moreover, our module supports geo-casting features. The geo-casting function is activated if an accident occurs in a certain area, all the vehicles within a range of specific geographical coordinates will receive a message to choose another road trip. So, traffic jamming and unnecessary delays can be avoided and help in saving time and money. GPS receiver is used to determine the position and speed of vehicles. The location is used for tracking, while the measured speed is to be compared with a limited, predetermined value stored in the microcontroller, extracted from legal maps. When the vehicle's speed is approaching the specified limit, alarm will go on to warn the driver. If the driver does not slow down, and the speed is still increasing and exceeding the maximum allowed speed, GPRS packet containing the speed will be sent to the hosting server. The ticket will be registered at the server side. Moreover, SMS will invoice the driver about his ticket. Because, GPS signal requires Line Of Sight (LOS), in case, there is no valid GPS signal; accelerometer is used to measure the vehicle's speed.

For accidents prevention and notification, we will use vibration sensor which is attached to the vehicle's air-bags. When air-bags are launched, then an accident is detected. So the nearest hospital is informed to help and send paramedics to handle the situation and all other vehicles near the crash will receive a message to configure another route. GSM/GPRS module and GPS sensor are being controlled using an Arduino microcontroller. Not all the available data will be sent to the web server from the microcontroller. On the contrary, just a selected set of data will be send - i.e, location and speed – after having been processed and analyzed.
Figure [8] illustrates the proposed model.

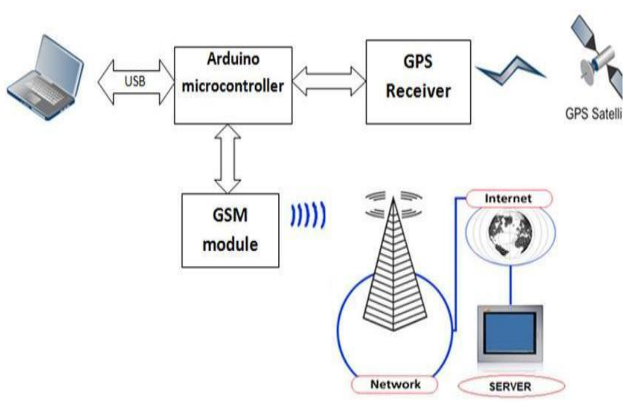

Figure 8. GSM-GPRS module.

5.1. Flowchart

Figure 9 depicts the flowchart of our project, starting with measuring the speed and location of a vehicle, as longitude and latitude points. These readings will be compared with standard specified value stored in the microcontroller. If the new measured speed is about to exceed a certain level, an alarm will be activated. If the driver is still speeding up and exceeding the maximum allowed speed or threshold for about 10 seconds, GPRS packet will be sent to a server, so the driver would be ticketed. If there is a need for tracking, coordinates will be transmitted to our web application to be plotted over Google map. Tracks can be online, by sending the coordinate periodically or offline by storing location on the located memory.

In order to apply the ticketing algorithm, we need to determine the maximum speed in each road, since in the West Bank there are no available vector maps typically used for navigation, we have decided to divide the whole area into many small areas and for each single subarea, we have used different maximum speed values.

For simplicity, we have considered only two types of subareas where each subarea is identified with a polygon contained in its geographical borders. The first subarea corresponds to the specific territory of the cities – Jerusalem, Bethlehem Ramallah, Nablus, Jenin, Tubas/Salfit, Tulkarem, Qalqiliya, Hebron and Jericho - whilst the second one coincides with all the remaining territory outside the Palestinian cities' borders.

For the first subarea, the maximum speed has been set at 50 kilometer per hour (km/h) whilst for the second one, it has been set at 90 km/h.

In order to check if a certain vehicle is in the first or in the second subarea, we used a ray casting algorithm which will be explained in the following subsection.

5.2. Ray Casting Algorithm

The Ray Casting Algorithm [26] has been used to determine if a given point P is inside a polygon or outside the polygon.

```
function checkInOrOut(Polygon $pol,
Point $pt )
{
$count = 0;
foreach ( $side in $pol){
if ( $pt ray_intersect $side){
$count = $count + 1;
}//end if
}//end foreach
if ( is is_odd($count) ){
retrun inside;
}//end if
```

```
else {
retrun outside;
} // end else
}// end function
```

The pseudo code above shows a function which takes as input parameter both:

1) a given point which represents the longitude and latitude values of the vehicle's location;
2) a given polygon which surrounds the border of a given geographical region on the map.

The function, after completing calculations, will return either if the point is inside the region or outside the region.

The line of the pseudo code "`if ( $pt ray_intersect $side)`" checks if a horizontal line, which begins from the "$pt" point and ends to the infinity point, intersects the segment "$side" of the polygon. If this is the case, the result will be true otherwise false.

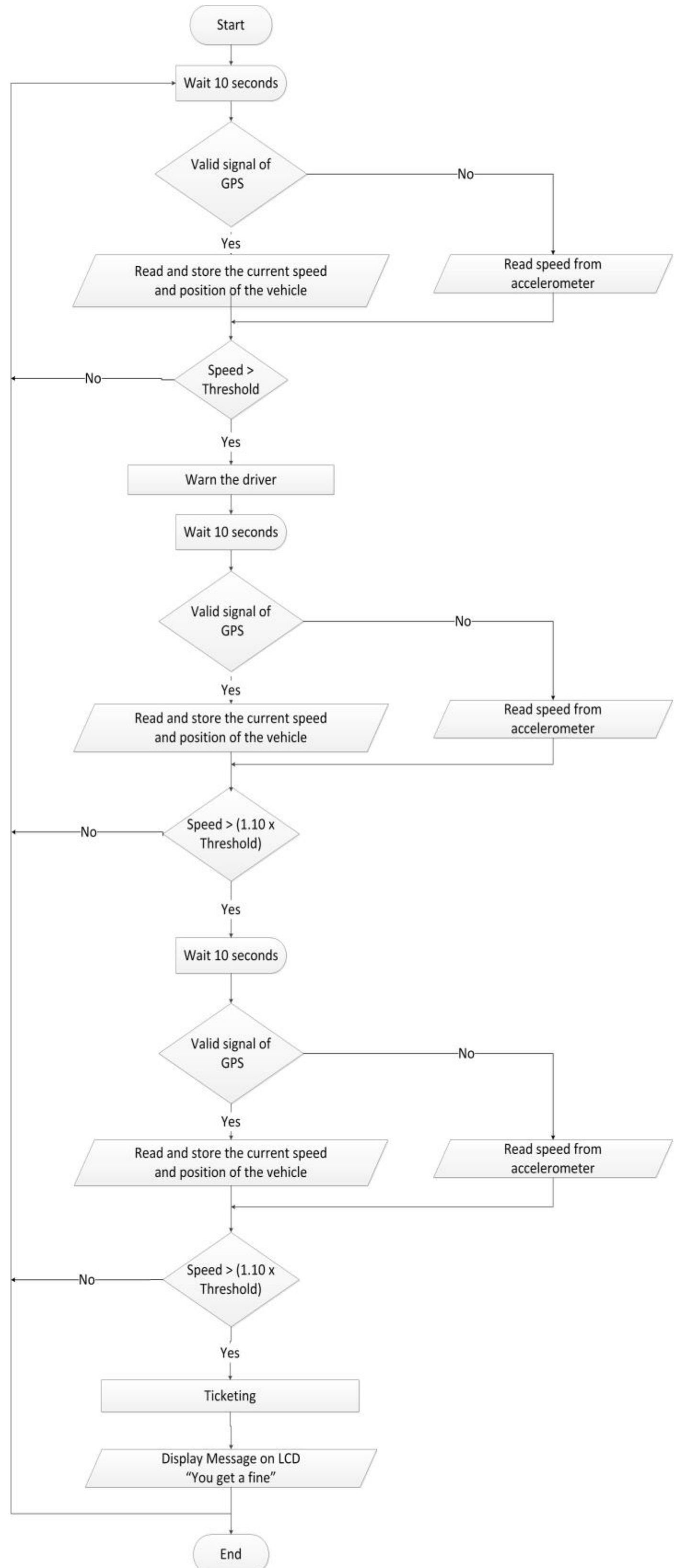

Figure 9. Model Flow Chart. This algorithm runs inside Arduino Uno microcontroller. Both online and offline modes are supported by this algorithm.

6. EXPERMENTAL RESULTS

This section presents selected results from our experiments with the established Ticketing and tracking module in our laboratory.
The purpose of these experiments is to validate the proposed system under different real driving environments and to show a functional prototype. We mounted two SmartBoards into two cars belonging to our faculty teachers. And within the university campus, we used a laptop to track the cars on Google map. Furthermore, for the proposed demonstration, we print all the communication messages on another screen.

After getting the model tested, one of the cars made a short trip around the university campus. The university campus is located in rural area (in an open space with scattered buildings around with very wide streets). This campus is close to Nablus city where we found that there is a good GPS signal quality. Hence, the algorithm always reads the speed and the geographical location in terms of longitude and latitude values from the GPS module and it never needs to read the vehicle speed from the vehicle's accelerometer.

The second car's driver performed a longer trip starting from Tulkarem city heading to the university campus in Nablus city. A long with the trip path, in some crowed regions having long buildings and narrow streets, the quality received by the GPS module was poor or even worst with no signal received at all. This scenario allows us to verify all the algorithm branches such as reading the vehicle's speed either from the GPS module or from the vehicle's accelerometer depending on the received GPS signal quality. Figure [10] depicts the trace of the vehicle on Google Map and Figure [11] lists the geographical location as well as the speed of the vehicle in 10 minutes period.

A separate technical report containing a more detailed discussion of STMS characteristics and implementations is also available [27].

Figure 10. Nablus-Tulkarem Trip. The picture above is automatically generated by the system. The Map source is Google Maps [5]. The red line represents the trip path. This path is generated through the insertion of GPS module readings into Google Maps. The blue lines depict the locations where the vehicle driver exceeds the threshold speed.

Lat: 32.2232.215916 Long: 35.271702E Speed: 41.25
Lat: 32.2232.215946 Long: 35.271671E Speed: 41.38
Lat: 32.2232.215977 Long: 35.271641E Speed: 41.50
Lat: 32.2232.215007 Long: 35.271580E Speed: 41.63
Lat: 32.2232.215038 Long: 35.271610E Speed: 41.63
Lat: 32.2232.215007 Long: 35.271610E Speed: 41.75
YOU ARE IN NABLUS
ALARM ← Inside the city
Lat: 32.216068N Long: 35.271568E Speed: 43.17
Lat: 32.216084N Long: 35.271557E Speed: 44.46
Lat: 32.216099N Long: 35.271545E Speed: 45.75
Lat: 32.216144N Long: 35.271534E Speed: 47.04
Lat: 32.216129N Long: 35.271523E Speed: 48.33
Lat: 32.216145N Long: 35.271511E Speed: 49.62
Lat: 32.216160N Long: 35.271500E Speed: 50.91
Lat: 32.216175N Long: 35.271488E Speed: 52.20
Lat: 32.216190N Long: 35.271477E Speed: 53.49
Lat: 32.216206N Long: 35.271477E Speed: 54.78
Lat: 32.216221N Long: 35.271454E Speed: 56.07
Lat: 32.216236N Long: 35.271442E Speed: 57.36
Lat: 32.216251N Long: 35.271431E Speed: 58.65
Lat: 32.216267N Long: 35.271420E Speed: 59.94
Lat: 32.216282N Long: 35.271408E Speed: 61.23
YOU HAVE A TICKET ←

Figure 11. Nablus City Trip. GPS module reading. Including the geographical location as well as the speed of the vehicle in 10 minutes period.

7. CONCLUSION AND DISCUSSION

Saving and protecting souls needs both government and drivers' corporation and commitment. Much efforts and money will be essential to accomplish and maintain a very good level of road safety. Our target is to design a Low cost GPS/GPRS based wireless controlling model. Due to the wide spread of GSM network which increases the chance for applying this model in many areas around the world. The proposed model hope to be able to achieve what is meant for, reducing road traffics, leading to cut in crashes expenses, decreasing the number of resulting casualties. All these are in favor of human road safety.

The economic study shows the feasibility of our project. After running our model for long enough period, we expect that tracking and ticketing system can be fed by authorized department which can be utilized to get clear view about infrastructure which can be used for developing and planning to improve the infrastructure on some field or apply some regulation which will aim to reduce traffic accidents.

We will keep working to expand the experimental section of the proposed model, and also we will consider additional features (such geo-casting feature) to the designed model. To add the vibration sensor and complete the geo-casting procedures, all the vehicles within a range of specific geographical coordinates will receive a message to choose another route, so traffic jamming and unnecessary delays can be avoided, help in saving time and money, leading to cutting in crashes expenses and decreasing the number of resulting casualties. All these are in favor of human road safety.

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