Framework Design for Performance and Safety of Vehicular Ad hoc Networking System Using Smart Devices

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Abstract: Vehicular networking systems that rely on smartphones have shown promise in improving safety and communication in moving vehicles. The goal of this research is to enhance overall system efficiency, data correctness, and communication dependability by presenting a complete framework architecture specifically suited for such systems. The framework comprises many elements like as data processing techniques, application layers, and communication protocols, which enable the smooth integration of smartphones into automobile networks. This study offers a systematic strategy to develop and execute smartphone-based vehicle networking systems, opening the door for improved connection and safety in contemporary transportation ecosystems. It does this by thoroughly analysing the potential and constraints that now exist.

Keywords: Vehicular Networking Systems, Cellular Applications, Smartphone-based VANET, Application Development Framework.

I.INTRODUCTION

Creating and disseminating efficient apps for vehicle safety will greatly lower the frequency of auto accidents and ensure the protection of numerous priceless lives. But even with the efforts of industry manufacturers and standardization agencies, several studies indicate that full deployment may not occur for over ten years. The premise behind this research is that cellphones may be a good medium for spreading automotive safety systems. In particular, smartphones that are linked to their respective cellular networks have the ability to transmit safety-related messages and submit sensing data to back-end application servers. The performance of the hardware platforms that support the vehicular ad hoc networking standards is assessed first in this article.

Subsequently, we conduct empirical assessments of cellular network performance to validate their suitability for use in automobile networking. We propose the VoCell application development framework, which is based on our observations. VoCell is a collection of components that facilitates the creation of smartphone apps for use in automotive networking applications. Developers may transfer data to servers and access internal and external sensing components with ease by using VoCell. We use a pilot deployment to assess the efficacy of many VoCell-developed example applications in both local and highway contexts. VoCell is expected to serve as a fundamental component in the development of novel smartphone-based systems intended for use in automotive networking applications.

The first steam-powered vehicle was introduced in the late 18th century, and as of 2011, there were more than 1 billion vehicles worldwide. Preserving vehicle safety is becoming a more crucial issue as a result of the growth in automotive accidents that endanger the lives of valuable individuals. In order to prevent many unfortunate situations, drivers might combine local vehicle status data, such as the travelling speed and position, with traffic circumstances, such as accidents or abrupt speed changes.

Nevertheless, this remedy just targets a single aspect of the safety concerns, or more precisely, driver-caused localised errors. The issue is that, despite advancements in mobile communication technology, cars today still lack a dependable means of communicating with other vehicles. In response to this dispute, the IEEE has been developing a standard suite that includes upper layer protocols [1], and that are appropriate for vehicle communication systems, as well as physical (PHY) and medium access control (MAC) layer specifications. This technology may be utilised to construct intra-vehicle embedded systems that enable inter-vehicle data exchange, in conjunction with appropriate industry standards and vehicular movement detecting sensors. On-Board Units (OBUs) for automotive applications are now being developed as a way to implement these requirements. Regretfully, waiting for these technologies to develop and become widely used is not something that can be accomplished anytime soon.

II. VEHICULAR NETWORKING

Many embedded computing systems have emerged in the last ten years, combining wireless networking, processing, storage, and sensor modules to enhance current applications and develop new ones across a range of industries. When implemented in automobiles, these technologies can open up a whole new range of applications that help provide information for achieving efficient and safe driving conditions. Typically, a wireless environment that makes use of these standards is referred to as WAVE (Wireless Access in Vehicular Environments). Multilayer standardisation is crucial for the widespread adoption of these technologies. The FCC designated the 5.85–5.925 GHz frequency band, or seven channels, for dedicated short-range communications (DSRC) in 1999 in order to meet this demand for standardisation for vehicle communications. This frequency range contains channels for public safety announcements, channels for vehicle entertainment, and channels specifically designated for vehicular networking control traffic.

Numerous standardisation bodies have suggested protocols and message formats for vehicle applications after the frequency allotment. As a first step towards standardising PHY and MAC layer characteristics for the adoption of the IEEE 802.11 standards to automobiles, the IEEE suggested 802.11p [12]. Beyond 802.11p, IEEE 1609 specifies the alterations and enhancements required to facilitate automotive applications. These encompass multi-channel 802.11 access (e.g., IEEE 1609.4 [9]), message formats using the WAVE short message protocol (WSMP) or UDP over IP (e.g., IEEE 1609.3, and security concerns (e.g., IEEE 1609.2). These protocols provide the greatest priority transmission of safety-related signals across the WAVE channels.

III. SMARTPHONEBASED VEHICULAR NETWORKING SYSTEMS

There are two unique methods for utilizing drivers' smartphones to form a network of automobiles. First, smartphones within the cars may communicate directly with one another by creating a mobile ad hoc network of smartphones, just as the WAVE standards. This method's low reliance on infrastructure is its main advantage. In particular, direct connections between devices lower the amount of forwarding hops and, hence, the transfer latency. Furthermore, one may argue that a system of this kind is not dependent on outside networking elements (such unforeseen cellular network connectivity problems). However, certain smartphone systems (like Apple iOS and Windows Phone) would require major modifications to enable low-level radio access, such soft Wi-Fi AP, or an extra external (dedicated) communication module in order to perform ad-hoc communication.

Moreover, a lot of radios, including Bluetooth and 802.11 IBSS [12], are not made to manage shorter encounter periods, which causes a lot of member attrition.However, using the current wireless infrastructure, such as 3G or 4G/LTE cellular networks, is the second method of creating a smartphone-based vehicle network. Through these communication channels, cellphones registered with an application server may readily share data with one another over the Internet. The cellular networks that are in use today can function as a steady communication channel, despite the fact that this strategy depends on the latency and dependability of the current wireless communication infrastructure.

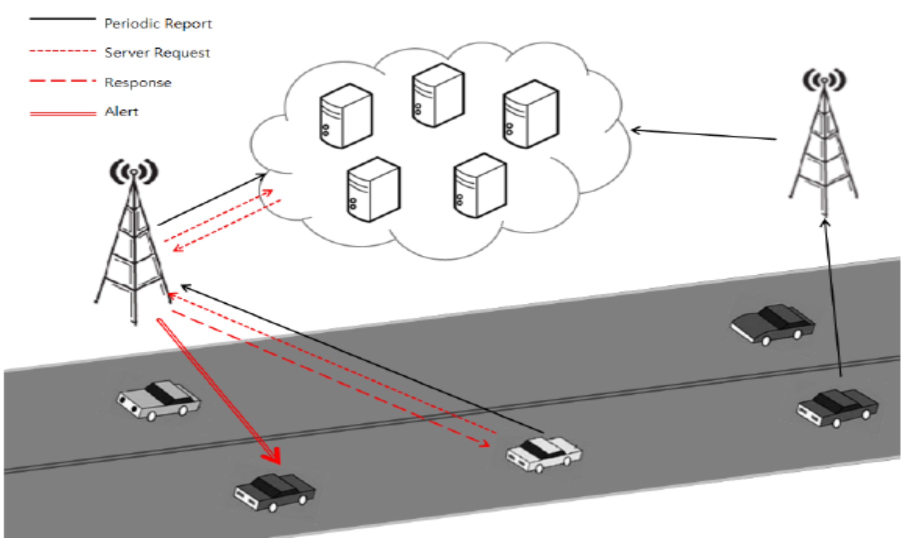

Figure 1. A system architecture of a vehicular network.
The architecture of the system is shown in Figure 1, which emphasises the three main parts: the back-end application server(s), cellular network, and smartphone(s).

From an operational standpoint, smartphones have the ability to collect sensory data externally from the car or sample data from their internal sensors (such as the GPS, accelerometer, gyroscope, etc.) and then submit this data to an application server on a regular basis. The application server gathers sensor input from several cars and is capable of computing movement-related contextual data (such as heading, acceleration, and speed). Applications can also decide to calculate the contextual data distributedly, at each smartphone, to reduce the processing cost at the server. Data distribution to cars within the same region will also be handled by the application servers.

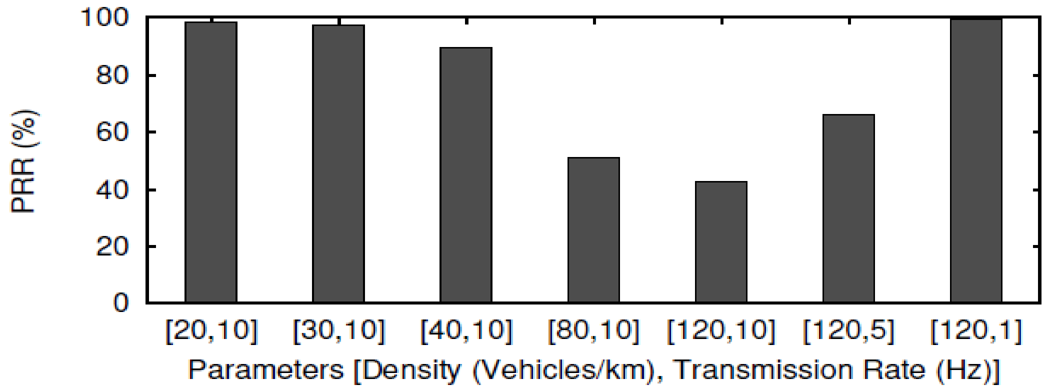

Figure 2. Packet reception ratio (PRR) of the smartphone's LTE communication for different vehicle densities.

III.FRAMEWORK APPROACH

The design of a unique on-board device based on a Raspberry Pi hardware module is covered by the authors in [3]. It controls 3G and Wi-Fi connections and allows users' smartphone apps to choose a network communication interface. Specifically, apps use a REST API (application programming interface) to communicate with the hardware module. Using an application to broadcast video from a car to another passing vehicle, the suggested platform is evaluated. In the experimental settings, the major focus is on transmission latency and throughput. A similar method was used in, where car information (such as position and engine temperature and revolutions) are collected by an Arduino hardware, analysed by a smartphone, and sent via Wi-Fi or 3G wireless interfaces to a remote storage entity for traffic study reasons. Observe that the primary focus of references and is data processing and acquisition from either a particular application or sensors mounted on the customised hardware. Additionally, in the discussed V2V and V2I communications, respectively, both ideas employ a smartphone to interact with an infrastructure and do not offer any security procedures for such message exchange. Wi-Fi Direct is used to distribute location data throughout the vehicle network derived from a smartphone's built-in GPS sensor. That method uses a broadcast technique for message exchange (single-hop communication) between two nearby entities, but it is not compatible with multi-hop message dissemination, which is required to offer a wider coverage area for the distribution of safety-related information. Furthermore, integrity checking and authentication techniques are not supported.

In [5], a platform for a parking spot locator application is provided. It is built on a mobile device architecture and a website for user registration and advertising. This platform takes into account security features such user privacy anonymity through the use of a zero-knowledge proof process for node authentication and an aggregation approach for alert message signing to prevent transmitting misleading information. This platform is being used for studies primarily in the areas of parking spot detection, traffic congestion, parked car location, and advertisement display. But no information is provided on communications or security measurements, therefore it remains an unanswered question how to measure the time and space overhead of the security method.

Finally, a VANET-based distribution system for emergency vehicles is suggested in the work in [8]. The writers took security and distribution concerns into account when defining the design requirements. A public key infrastructure (PKI)-based authentication method that attaches digital signatures and the public key certificates that go along with them to every message that is sent is used to handle the latter. Using laptops, a prototype is installed in emergency vehicles, and its functionality is mostly confirmed by actual trials. Nevertheless, the effect of using the security service that is, the PKI's certificate validation on the distribution procedure isn't assessed. Therefore, it is impossible to assess whether using PKI techniques on mobile devices for VANETs is feasible.

We list a set of design objectives for a software development framework that makes developing smartphone-based vehicular applications easier, based on the needs of the various vehicular networking applications we surveyed and the findings of our feasibility studies of realising vehicular networking applications using smartphones.

A framework like this should, in particular,

- make internal sensor modules easily accessible and offer software components that make it easier to extract contextual information about a vehicle, such as speed and direction of travel.
- provide interfaces that integrate sensor components with programmes through the use of lightweight software drivers.
- choose the network interface with the highest traffic-energy ratio to transfer data between backend servers and smartphone apps.
- Provide real-time information (such as traffic and weather updates) from public services.
- Provide simple interaction with many geolocation providers (like Google Maps).
- supply general-purpose back-end elements that function as the foundation for various vehicle networking applications' back-end services.

One of the main objectives of this work is to build and provide an application development framework that meets the above requirements, in addition to analysing the networking features of smartphone-based vehicular networking systems. We want to stimulate future research in this application sector and thrill consumers by demonstrating a variety of vehicular networking apps that can enhance everyday driving routines by giving developers access to a customised collection of software resources focused on vehicular networking. The remainder of this section delves into the various VoCell software development framework components and explores how they meet the aforementioned standards.

During the bootstrapping stage, the application uses VoCell's pass-through component to activate the GPS. Periodic packets can be reported to a pre-configured server by simply setting up a sample interval and server reporting interval, and supplying parameters that indicate the current vehicle conditions (e.g., rapid turn, emergency braking, accidents, etc.). In our solution, the server provides two different kinds of answers in response to these reports. The first is a triggered (high priority) alarm, while the second is a periodic (low priority) review of the state of traffic on the roads. Our application snapshot is displayed in Figure 13(a) to demonstrate how VoCell uses a map overlay to better visualise the server answers. Furthermore, we see that VoCell provides APIs for the issuance of visual and auditory alerts to convey vital signals.

We next go over the primitives and methods that VoCell provides for vehicular applications, such as speed calculation, surrounding vehicle identification, and anomalous vehicle detection.

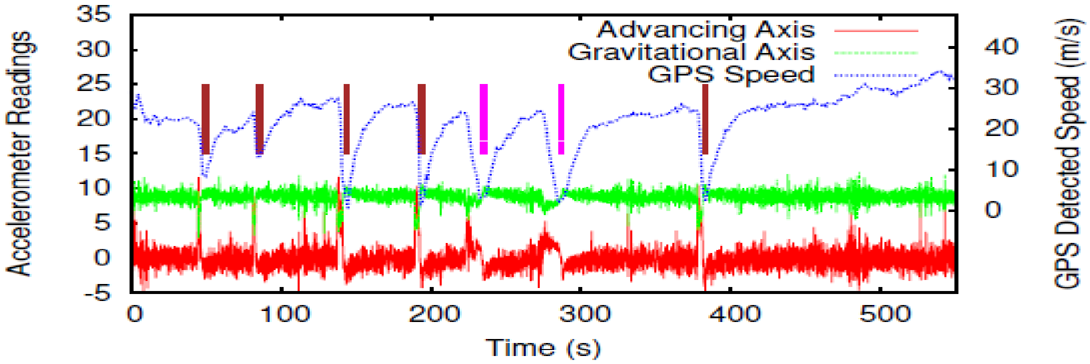

Figure 3. Accelerometer traces with GPS-based speed readings for the highway environment.

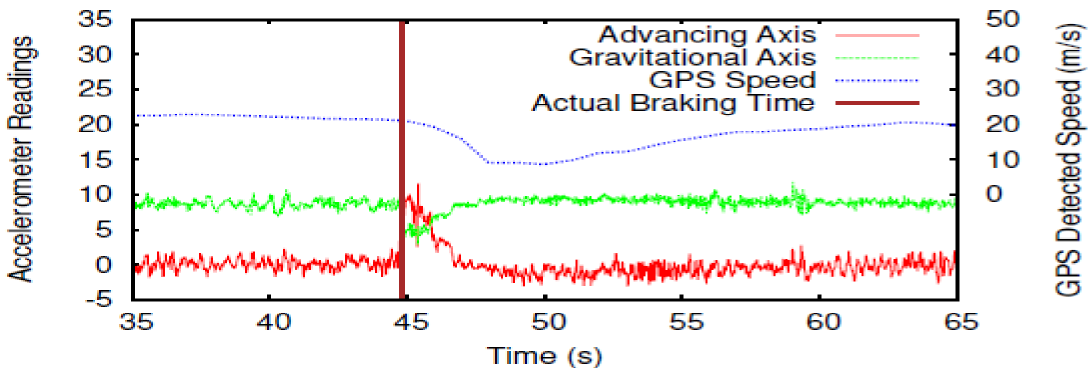

Figure 4. A close up view of an emergency braking pattern in a highway environment.

IV. RESULTS AND DISCUSSION

We are now going to discuss the lessons we learnt from a small-scale implementation of our VoCell-developed emergency braking application. In particular, as the list below illustrates, we were able to pinpoint certain important considerations for next significant advances based on our experiences.

• *Adjusting the Accelerometer on a Smartphone*. Three-axial accelerometers, which detect force on fixed axes, are often found in modern smartphones. The orientation of the device affects these axes' values. Applications may interpret these values incorrectly if orientation calibration is not performed. For instance, our emergency brake detection component may miss braking activity from a vehicle if it does not modify its forward axis and the gravitational axis appropriately. In order to solve this issue, we included a new component (such as CalibrateAccelerometer(t)) that determines the heading of the vehicle by using the first t seconds of steady accelerometer values. In addition, we continually adjust for the orientation change using the gyro.

• *Flexible Reporting Schedules.* Periodic reporting overhead is one issue we saw. There are several instances in which the automobile condition remains unchanged, such when it is stopped at a red light. It is possible to drastically minimise network traffic without compromising application performance by varying the reporting frequency between 1 Hz and 10 Hz based on the kind of surrounding region (suburban, city, or highway) and the condition of the automobile, according to empirical data. We intentionally designed the VoCell APIs to enable dynamic reporting interval adjustment for this reason. We also observe that this method provides a new tradeoff between network bandwidth saving and movement tracking precision that is tied to system policies. Although the safety applications in our current sample applications require the utmost data accuracy, determining the lowest bound helps preserve network capacity. VoCell's architecture will allow for more study on this trade-off.

• *Efficient Communication with Operators.* Because vehicle safety apps include a lot of user interaction, it's critical to specify how users will engage with them. To be more precise, even if the system is able to send out an alarm in a matter of hundred milliseconds, its usefulness would be diminished if drivers require multiple seconds to decide what to do next. To overcome this issue, VoCell's current user interface options have undergone many changes.

We've discovered that beeping or other auditory alerts are effective in drawing users' attention. Three degrees of severity are covered by VoCell, which also permits variations in text size and colour. These are warning, caution, and informative.

We now place our work in the context of the body of literature that already exists in the fields of cellular network-based systems for automotive applications and smartphone-based sensing systems for vehicular networking.

Previous study suggested employing cellular networks for vehicle communications, which is closely connected to VoCell. For instance, the developers of enhance LTE transmissions to offer a tailored communication system for car networks. Abid et al. have reported simulated findings for throughput, packet loss ratio, and latency when automotive applications use the cellular networks [2] in order to analyse the performance of LTE-based vehicular networks. Although the idea of merging cellular networks with vehicle applications is similar, most of the research that has already been written bases its conclusions largely on simulation, which only partially captures the actual performance of wireless networks.

From a more pragmatic standpoint, Corti et al. assess UMTS network performance in an actual vehicle setting [5]. This study assesses the delay caused by cellular networks and suggests a centralised Advanced Driver Assistance System. Although the authors' study is significant since it offers one of the earliest empirical performance assessments for automotive networks based on cellular networks, they only address packet delivery delay and ignore other crucial metrics like system scalability and dependability. In addition to conducting a thorough analysis of the LTE/3G latency performance in actual settings, our study also includes assessments of the cellular systems' scalability and dependability. Moreover, our analysis goes one step further and presents comparisons with the most recent standardised hardware created for VANETs. Lastly, our study presents prototype application implementations and extends the findings to construct a development environment.

V.CONCLUSION

In order to enable vehicular networking applications with smartphones, this work includes a feasibility analysis, recommendations, and the VoCell application development framework. The discoveries in this paper indicate that everything is in place to make such systems a reality. All the same, we recognise wholeheartedly that throughout the course of the ensuing ten years, automobiles built on the WAVE specifications will begin to be equipped with vehicle networks. This study presents the VoCell architecture and applications, which can serve as catalysts to expedite the realisation of critical vehicular applications. Driver engagement can revolutionise road safety efforts by actively offering drivers with pertinent ideas, since research and commercial efforts imply that such cellular-based vehicle networking systems can be well-accepted by a broad population. To lessen the impact of the overhead caused by the cryptographic algorithms, the platform facilitates the implementation of energy-efficient techniques. We employed straightforward yet reliable message distribution and data aggregation techniques in our experimental trial, which makes the platform's module validation manageable. The modular nature of the platform allows for the adoption of more advanced energy-efficient techniques and message dissemination protocols, taking into account both functional and non-functional needs. Given the significance of latency and energy usage in high priority communications, a thorough investigation into these topics is part of the possible future work. In a similar vein, we want to use the suggested platform to conduct experimental trials in order to assess the main security vulnerabilities in VANETs. As this is a relatively unexplored sector of the field, we hope that the concepts provided in this work will inspire academics and practitioners to create additional security-oriented techniques to improve the dependability of VANET systems.

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