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Standard Protocols for Heterogeneous P2P Vehicular Networks

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ABSTRACT

Vehicular Communication Systems are developing form of networks in which moving vehicles and side road units are the main communicating nodes. In such networks, vehicular nodes provide information to other nodes via Vehicle-to-Vehicle communication protocols. A vehicular communication system can be used to support smart road applications such as accidents and traffic congestion avoidance, collision warning forwarding, forensic accidents assistance, crime site investigation, and alert notification. However, current Vehicular Communication Systems suffer from many issues and challenges, one of which is their poor interoperability as they lack standardization due to the inconsistent technologies and protocols they use. This paper proposes several standard protocols and languages for P2P vehicular networks that are built using heterogeneous technologies and platforms. These standards consist of three protocols: a Standard Communication Protocol which enables the interoperable operation between the heterogeneous nodes of a P2P Vehicular network; an Autonomous Peers Integration Protocol which enables the self-integration and self-disintegration of functionalities; and a Standard Information Retrieval Protocol which allows the P2P network to be queried using a standard high-level language. In the experiments, a case study was presented as a proof of concept which demonstrated the feasibility of the proposed protocols and that they can be used as a standard platform for data exchange in P2P Vehicular Communication Systems. As future work, Service-oriented architectures for vehicular networks are to be investigated while addressing security issues such as confidentiality, integrity, and availability.

KEYWORDS: *Vehicular Communication System, Peer2Peer Networks, Standardization*

INTRODUCTION

Vehicular Communication Systems are emerging form of networks in which road units including roaming vehicles, car sensors, weather radars, traffic detectors, base stations, and others are the main communicating nodes that provide each other with road information over wireless technologies such as Wi-Fi, 4G, or over any other proprietary networks [1]. Practically, road information can be exploited to support smart road applications such as accidents and traffic congestion avoidance, collision warning forwarding, forensic accidents assistance, crime site investigation, and alert notification to other vehicles such as “ice on the road”, “slippery bridge”, “congestion ahead”, etc. Vehicular Communication Systems require in essence a networking architecture to allow individual nodes to send and receive data to each other. In fact, two architectures exist, they are Client-Server and Peer-to-Peer (P2P) architectures [2].

Interestingly, Peer-to-Peer short for P2P architectures are becoming more pervasive these days, especially with the increase number of mobile devices and applications such as smart phones, tablet computers, portable game consoles, wireless appliances, vehicle sensors, weather apps, GPS apps, and smart home apps [3]. Basically, Peer-to-Peer is a mode of communication between two or more devices without the need of a central coordinator between them; thus, the term decentralized [4]. Furthermore, peer-to-peer devices can act as clients as well as servers at same time. This is unlike the Client-Server architecture where every node in the network has a static, pre-defined role – either client or server. Peer-to-Peer communication has several advantages, one of which is that P2P is more reliable as central dependency is eliminated. In that, if one peer fails, all other peers will continue to function without disrupting the operation of the network. Another advantage is the cost of building P2P networks which is comparatively less than client-server architectures as they eliminate the need of a central dedicated often expensive server. For instance, sharing thousands of terabytes of data requires a large server with a huge storage capacity, which can turn out to be very expensive at the end of the day. On the other hand, every node in P2P has its own independent storage and resources making it cheaper per byte/cycle. With its advantages, P2P has its own disadvantages too, one of which is administration. Since the whole system is decentralized, P2P is difficult to be managed and controlled by network administrators. Equally, due to the lack of central administration, security is a big issue in P2P networks; hence, it is susceptible for malicious attacks such as eavesdropping, denial of service, in addition to the spread of malwares such as viruses and Trojans [5]. Last but not least, P2P is often criticized for lacking standardization in that it uses inconsistent technologies and informal protocols and processes to operate making its nodes unable to interoperate with each other or with other systems [6].

This paper proposes a set of standard protocols and languages for P2P vehicular networks that are built using heterogeneous technologies and platforms. These standards consist of three protocols: a Standard Communication Protocol which enables the interoperable operation between the heterogeneous nodes of a P2P Vehicular network; an Autonomous Peers Integration Protocol which enables the self-integration and self-disintegration of functionalities; and a Standard Information Retrieval Protocol which allows the P2P network to be queried using a standard high-level language. Essentially, the purpose of the Standard Communication Protocol is to support data interchange among various incompatible nodes built using different technologies. The purpose of the Autonomous Peers Integration Protocol is to support network mobility and scalability, and finally the purpose of the Standard Information Retrieval Protocol is to support efficient data collection and retrieval.

II. PROBLEMS & CHALLENGES

If P2P network architecture were to be applied to Vehicular Communication Systems, many issues and challenges may arise, they can be summarized as follows:

- **Lack of Standard Communication Protocols**:

P2P does not provide common protocols and languages that enable peers to interoperate regardless of their underlying heterogeneous technologies, hardware, and programming platforms. Heterogeneous mobile computing are today the rule rather than the exception. Actually, smart phones, portable equipment, and vehicle sensors are designed by various companies, each having their own operating system, hardware architecture, and network protocols. Likewise, existing P2P technologies are proprietary and hence they are incompatible with the heterogeneity of current mobile devices and cannot interoperate together whatsoever.

- **Lack of Autonomous Integration Protocols**:

P2P is decentralized by nature, and thus it is difficult to be managed and controlled without the intervention of network administrators. For instance, system administrators have to manually do the proper configuration each time they want to add or remove a node to or from the system. This task can be considered tedious and time consuming as vehicle nodes are often in continuous mobility and always in a non-stop operation.

- **Lack of Standard Information Retrieval Protocols**:

P2P lacks a standard method to search for data and information present on the network. For instance, in case of a crime investigation, a vehicle peer, acting as a police unit, would find hard times to remotely query information from witness nodes without having to locally access their storage.

III. RELATED WORK

Several solutions were presented over the past decades for P2P Vehicular Communication Systems, most of them were new communication technologies for mobile networking such as DSRC (dedicated short-range communications) [7], MOCCA [8], or the IEEE 802.11p wireless access in vehicular environments (WAVE) [9]. However, other ideas were proposed that act as a top layer over the existing technologies such as CarTel, Car Torrent, and VANET.

CarTel [10]: It is a distributed mobile sensor computing system using phones and sensor devices that ease the gathering, processing, analysis, delivery, and reporting of data from sensors located on mobile units. CarTel is a software framework exhibiting no standards or protocols for data communication between heterogeneous distributed sensor units. Besides, it does not handle the problem of auto-discovery and self-organization of nodes.

Car Torrent [11]: It is a peer-to-peer data sharing architecture. It is based on sharing digital information such as video clips and audio podcasts by storing their metadata into a particular mobile car in the network. Then, other moving cars can search for these metadata, locate the required files, and download them from peer to peer. This approach does not take into consideration the unsecure channels over which files are to be transmitted. Furthermore, it does not tackle the problem of heterogeneous peers that are built using different platforms and architectures which may arise a compatibly issue. Finally, this solution defines no standards for unit-to-unit or vehicle-to-vehicle data communication.

VANET [12]: short for Vehicular Ad-Hoc Network is a technology based on the proprietary standard IEEE 802.11e that uses vehicles as nodes to make up a mobile network. It allows vehicles to join in the network when they are in the appropriate range and fall out when they are out of the signal range. In fact, VANET is a new hardware protocol incompatible with the prevailing communication protocols such as Wi-Fi, Bluetooth, or 3G; and hence, it cannot be incorporated with existing operating systems such as Windows, Android, or iOS. Additionally, popular programming languages such C++, Java, and C# cannot be used to develop applications for VANET.

IV. PROPOSED SOLUTION

This paper proposes a set of standard protocols and languages for heterogeneous P2P vehicular networks. They comprise a Standard Communication Protocol, an Autonomous Peers Integration Protocol, and a Standard Information Retrieval Protocol. The prime incentives behind these protocols is to allow mobile nodes in a P2P Vehicular network 1) to intercommunicate and interoperate despite being built using heterogeneous hardware and software technologies, 2) to self-integrate and disintegrate autonomously with no or little user intervention, and 3) to be queried using a standard high-level language.

A. Design Specifications

As aforementioned previously, the proposed protocols consist of a Standard Communication Protocol, an Autonomous Peers Integration Protocol, and a Standard Information Retrieval Protocol:

Standard Communication Protocol:
It delivers transparency and interoperation among the communicating peers in a P2P vehicular network. This protocol is a standard language specified using a universal standard language such as XML. Similar to the HTTP protocol that connects applications on the World Wide Web, this proposed XML-based protocol could be the foundation of data communication between the peers of a P2P vehicular network. Inherently, the Standard Communication Protocol is based on an open data standard, namely XML, for exchanging structured information between the different peers of the P2P network. The language itself is based on XML syntax to format messages sent to and received from inner-system peers and nodes. In practice, a given node requesting an operation sends a message with the appropriate parameters to a destination node. The node returns an XML-formatted response with the requested data. Being based on a standard message format, the standard communication language promotes interoperability and standardization for all units regardless of their implementation, target-platform, and underlying technologies. Following is a sample request using the standard communication protocol. It consists of a sender node whose IP is 192.168.5.16 and ID is 21 invoking a function called "GetWeather" located on another destination node whose IP is 192.168.5.102 and ID is 72

```
<protocol>
  <sourceIP>192.168.5.16 </sourceIP>
  <destinationIP>192.168.5.102</destinationIP>
  <sourceID>21</sourceID>
  <destinationID>72</destinationID>
  <functionInvoked>GetWeather</functionInvoked>
  <functionParams>
     <param>Celsius</param>
     <type>bool</type>
  </functionParams>
<functionReturnType>double</functionReturnType>
  <stamp>3/12/2019 02:16:15PM</stamp>
  <version>1.2</version>
</protocol>
```

Another example could be that of a certain node that needs to send road information to other vehicles in the same city such as "ice on the road" or "traffic congestion ahead". The source node whose IP is 192.168.5.16 and ID is 21 needs then to broadcast this information to all connected nodes in the P2P network. This could be accomplished as below:

```
<protocol>
  <sourceIP>192.168.5.16 </sourceIP>
  <destinationIP>255.255.255.255</destinationIP>
  <sourceID>21</sourceID>
  <destinationID>ALL</destinationID>
  <functionInvoked>SendData</functionInvoked>
  <functionParams>
     <param>message</param>
     <type>string</type>
     <value>traffic congestion ahead @ Hempton Rd,
      Atlanta, GA</value>
  </functionParams>
  <functionReturnType>void</functionReturnType>
  <stamp>3/12/2019 02:16:15PM</stamp>
  <version>1.2</version>
</protocol>
```

Autonomous Peers Integration Protocol:
It delivers self-integration and self-organization capabilities for peers by automating their discovery, reconnaissance, and integration. Some of the theories that can be exploited in this regards are Graph theory, routing protocols, distributed hash tables, and graph operations such as adjacent, incident, and neighbor operations. In practice, self-integration is ensured when a new comer node (a node that needs to be integrated in the network) automatically discovers the other exiting peers and figures out a way to connect to them and make them aware of its arrival. As for self-organizing mechanism, this is about how peers are connected together, what are the root peers, what are their neighbors, and their adjacent peers. The proposed Peers Integration Protocol facilitates the discovery, self-integration, and dis-integration of units in and out of the existing network. The process starts when a new node needs to integrate into the present infrastructure. Every node has what is called a Node Description Language (NDL) which is an XML abstract text that describes the node such as its functionalities, its ID, among other data. A central registry intervenes to validate the NDL of the node that is requesting integration. If validation is successful, an acknowledgement is sent to the corresponding node and a new record is created in the central registry containing important details such as node ID, node protocol, node IP, node functions, parameters, and return data type. This information is then propagated from the central registry to all the nodes contained in the P2P network. Figure 1 depicts the various steps required to self-integrate a new node into the network.

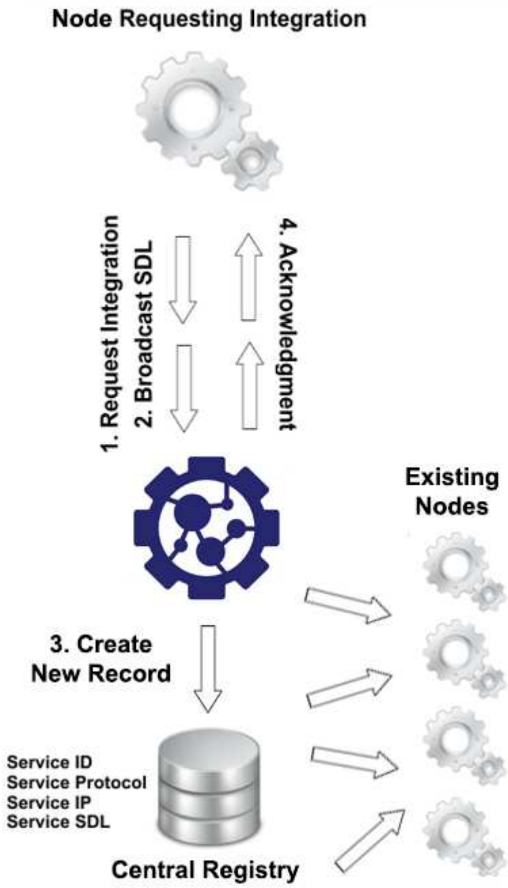

Figure 1: Self-Integration Process

Standard Information Retrieval Protocol:

It delivers a high-level interface to query peers in the network and search for sharable data stored in them. The language is syntactically close to SQL. Characteristically, the query language should provide some transparency to the user by hiding the complexities of searching the P2P network. An Information Retrieval Protocol could be beneficial for a variety of applications. For instance, it could be used by police or ambulance to retrieve information about urban surveillance such as disturbance, act of terrorism, accidents, and crimes. Another possible usage is searching peers to locate and download a certain radio show or advertisement. Moreover, it can be used for real-time high-resolution weather reporting by querying data from onboard weather sensors. Following is a sample query written using the standard information retrieval protocol whose task is to retrieve data images from three nodes whose IDs are 67, 68, and 69 respectively. The condition applied here is that images must have been captured on 3/12/2019 between 1:00PM and 2:00PM.

SELECT column1, column2....columnN
FROM nodeID →tableName
WHERE condition1 {AND|OR} condition2 {AND|OR} conditionN

SELECT image, timestamp
FROM 67→Images, 68→Images, 69→Images
WHERE timestamp>'3/12/2019 13:00' AND timestamp<'3/12/2019 14:00'

B. Contribution to Knowledge

The proposed protocols would contribute to a new knowledge which the research community didn't have before. They can be summarized as follows:

- A *Standard Communication Protocol* based on XML syntax and notation that encodes data communication between the different heterogeneous peers of a Vehicular P2P network has the benefit of supporting seamless data exchange between different incompatible systems built using different technologies.
- An *Autonomous Peers Integration Protocol* for integrating new comer nodes and disintegrating leaving nodes in and out of the Vehicular P2P network can promote peers mobility and network scalability by allowing the network itself to grow and shrink dynamically without administrators' intervention.
- A *Standard Information Retrieval Protocol* for searching for data collected by individual peers in a Vehicular P2P network could prove to be beneficial for a variety of applications; for instance, it could be used by police or ambulance to retrieve information about urban surveillance such as disturbance, act of terrorism, accidents, and crimes. Another possible usage of a query language could be searching peers to locate and download a certain radio show or advertisement. Moreover, it can be used for real-time high-resolution weather reporting by querying data from onboard weather sensors.

V. EXPERIMENTS

In the experiments, a case study is created. It is based on P2P Vehicular network made up of three nodes: a passenger car (ID 17), a police car (ID 305), and a police control station (ID A12). The scenario goes as follows: The passenger car moves around the city while capturing different imagery from mobile sensors attached to it. The car processes every image it captures and replicates it to the nearest police control station using the Standard Communication Protocol. Meanwhile, a terrorist shootout occurs in street '342 Ashford Rd' leading to many casualties. As a result, the police intervenes and starts to investigate. The police car then issue a query command using the Standard Information Retrieval Protocol on the control station in an attempt to pick up evidence and footage of the crime. The whole scenario can be summarized as follows (also depicted in Figure 2):

1. The passenger car uninterruptedly collects images on the road via attached high definition cameras.
2. The images are then processed by the passenger car using digital image processing and computer vision algorithms to detect and extract patterns, events, and intelligence out of them. Metadata are generated for these collected data including date, time, location, GPS position, Vehicle Identification Number (VIN), etc.
3. The images and their metadata are uploaded to a local police control center using the Standard Communication Language.
4. The control center further processes the received information and stores them in database.

5. Investigators (e.g. Police in our case) intervene and query for data from the control center using the Standard Information Retrieval Protocol based on search parameters and other convenient criteria.

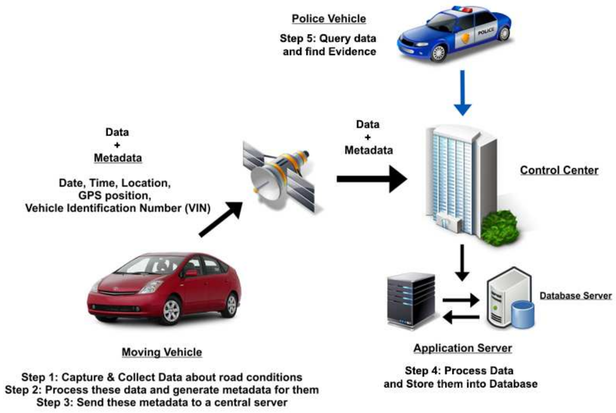

Figure 2: The Case Study Process Flow

Next are two sample messages, one using the Standard Communication Language to upload images to the police control center, and another one using the Standard Information Retrieval Protocol to query and search for data in the police control center database.


```
<protocol>
  <sourceIP>192.168.5.13</sourceIP>
  <destinationIP>10.0.0.15</destinationIP>
  <sourceID>17</sourceID>
  <destinationID>A12</destinationID>
  <functionInvoked>SaveImages</functionInvoked>
  <functionParams>
    <param_value>img</param_value >
    <type>bytes[]</type>
<value>00110110111001011101101101…</value>
    <param>timeStamp</param>
    <type>string</type>
    <value>3/12/2019 02:16:15PM</value>
    <param>location</param>
    <type>string</type>
    <value>342 Ashford Rd</value>
  </functionParams>
  <functionReturnType>bool</functionReturnType>
  <stamp>3/12/2019 02:16:15PM</stamp>
  <version>1.2</version>
</protocol>
```


SELECT img
FROM A12→Images
WHERE timestamp>'3/12/2019 13:00' AND timestamp<'3/12/2019 14:00'
AND location='342 Ashford Rd'

VI. CONCLUSIONS AND FUTURE WORK

This paper proposed several standard protocols for heterogeneous P2P vehicular networks. They comprise a Standard Communication Protocol to allow the different peers of the network to interoperate despite being built using heterogeneous hardware and software technologies; an Autonomous Peers Integration Protocol to allow the different peers of the network to self-integrate and disintegrate autonomously with no or little user intervention; and a Standard Information Retrieval Protocol to allow the different peers of the network to be queried for data and information using a standard high-level language. All in all, the proposed protocols could provide a standardization platform for vehicular P2P networks to communicate uniformly using a standard format. Likewise, they could provide an autonomous mechanism to dynamically scale the size of P2P networks and the number of their communicating units. Last but not least, the proposed protocols could also provide a comprehensive standard way to locate and search for data and information stored inside the network.

As future work, client-server architectures for vehicular networks are to be investigated especially Service-based and Service-oriented models. Furthermore, security issues are to be addressed especially those related to confidentiality, integrity, and availability.

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