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Survey on Internet of Vehicles: Sensing-Aided Transportation Information Collection and Diffusion

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Abstract*: *This —In view of the emergence and rapid development of the Internet of Vehicles (IoV) and cloud computing, intelligent transport systems are beneficial in terms of enhancing the quality and interactivity of urban transportation services, reducing costs and resource wastage, and improving the traffic management capability. Efficient traffic management relies on the accurate and prompt acquisition as well as diffusion of traffic information. To achieve this, research is mostly focused on optimizing the mobility models and communication performance. However, considering the escalating scale of IoV networks, the interconnection of heterogeneous smart vehicles plays a critical role in enhancing the efficiency of traffic information collection and diffusion. In this paper, we commence by establishing a weighted and undirected graph model for IoV sensing networks and verify its time-invariant complex characteristics relying on a real-world taxi GPS dataset. Moreover, we propose an IoV-aided local traffic information collection architecture, a sink node selection scheme for the information influx, and an optimal traffic information transmission model. Our simulation results and theoretical analysis show the efficiency and feasibility of our proposed models.

Keywords— *Internet of Vehicles (IoV), intelligent transport systems (ITS), traffic information collection, information diffusion.*

I INTRODUCTION

Vehicular Ad Hoc Networks (VANETs) has been attracted much attention in both industry and academia recently. One of the important applications of VANETs is to share information, including road condition information and entertainment application information, to nearby users. The road condition information collected by vehicles will be disseminated to others in the vehicular network, which reduces traffic accidents, avoids traffic jams, and saves fuel consumption [1]–[3]. In road condition information, the safety messages about accidents is critical to users, who are going to pass through the accident location. VANETs in highway scenarios often operate as Delay Tolerant Networks (DTNs), as a consequence of low vehicle density during certain time of a day [4]. The sparsity of DTNs often brings about frequent link interruption, while long reheeling time extends the safety messages delivery delay to tens or hundreds of seconds. Quality of Service (QoS) to users, Roadside Units (RSUs) have been deployed in VANETs to improve the network connectivity and help forward messages. Generally, RSUs can be divided into two categories. In one case, RSUs are in a standalone style, which means they are disconnected. In the other case, RSUs are connected to a backbone network, which means they are connected to each other. The benefits of deploying RSUs for the vehicular networks concerning about re-healing time have been investigated in [5], [6]. Their results show that the connectivity is significantly improved when the RSUs are interconnected. Hence, in our paper, we also consider that the RSUs are interconnected. In vehicular networks, the safety messages are time-critical for users. It is vital to deliver the time-critical safety messages to nearby RSUs within certain delay constraint. Then the RSUs can store the safety messages and timely forward the messages to the vehicles, which are in the coverage of the RSUs. Considering the constraint of delivery delay, we should set a reasonable distance between two adjacent RSUs. In this paper, we analyse the average delivery delay This has a significant impact on the vehicular network's ability to react to accidents. Due to its sparsity and highly dynamic characteristic, which affects with two ‘‘store-carry-forward’’ mechanisms, considering the interconnected RSUs. One of ‘‘store-carry- forward’’ mechanisms is general ‘‘store-carry-forward’’ mechanism, which means that a vehicle can carry the messages and forward to the front target RSU under normal driving conditions. The other is decelerating ‘‘store-carry- forward’’ mechanism, which means that a vehicle carried messages performs deceleration operation, to forward the messages to the vehicles behind. Then we can obtain the critical location, where the average delivery delay are the same with two mechanisms. According to the critical location, we can determine whether the opposite vehicles need to perform the decelerating ‘‘store-carry-forward’’ mechanism to obtain less delivery delay, compared with the general ‘‘store- carry-forward’’ mechanism.

II.OVERVIEW OF INTERNET OF VEHICLES

An Worldwide, the number of vehicles for both private and commercial use was one billion in 2010 and is anticipated to be 2 billion by 2030 [19]. The conceptual idea of Vehicular Ad Hoc Networks (VANETs) emerged over a decade ago, and since then it has been a highly active area of research [7], [20]. The basic idea of VANETs considers vehicles as mobile nodes that can communicate to create a network [2]. Basically, due to mobility constraints, VANETs are considered as conditional networks, where their performance is affected by the vehicular density and distributions [21], [22], and various other factors such as bad drivers behaviours and tall buildings [2]. In addition, the vehicles are considered as unstable, temporary and random nodes. Thus, VANETs cannot guarantee the sustainability of applications/services for customers on large scale areas [23]. Therefore, VANETs are more suitable for limited scale applications that require ad hoc services such as preventing collisions or notifying drivers of hazards on roads. However, due to the Internet of Things (IoT) technology development and the increase in the number of Internet-connected vehicles new VANETs communication requirements are emerging. One more weakness of VANETs is their limited capabilities to process all the information that is captured by themselves and surrounding actors (such as mobile devices and sensors) [2]. To serve the new requirements of ITSs, vehicles must work as a smart platform of multiple sensors with IP-based Internet connectivity, several communication technologies, powerful computational components, and the ability to communicate with other vehicles and ITS devices [24]. In this context, the evolution of the conceptual idea of VANETs resulted in the introduction of the Internet of Vehicle (IoV) concept [8]. Thus, as a special case of IoT, IoV has distinctive characteristics and special requirements to serve the intelligent transportation systems. An IoV is defined as a platform that realizes in-depth the integration and the information exchange between humans, vehicles, things, and the environment [25]. The main goal of IoV is to enhance the safety and efficiency of transportation, improve the service level of cities, save the environment, and ensure that humans are satisfied with the transportation systems services [23]. In contrast to VANETs, IoV integrates vehicles intelligence with vehicles networking, which results in intelligent networks with communication and computing capabilities that provide transportation services on large scale areas [23]. In IoV environment, as vehicles have permanent Internet connections, they can provide information for the various ITS applications categories (i.e. road safety, management and control of traffic, and infotainment). Consequently, information exchange is enabled among sensors and electric actuators, road infrastructures, and vehicles as well as drivers and passengers [2]. IoV collects large volume of data with various structures from a large scale area, which conforms with the big data heterogeneity concept [26]. With the significant advantages that IoV has over VANETs many new opportunities are opened. IoV offers various benefits to drivers, societies and economies. Cisco IBSG Automotive and Economics practices anticipated that every year the benefits of utilizing the IoV technology may reach $1,400 US dollars for each vehicle (summarized in Figure 2) [27], [28]. Moreover, traffic congestion reductions and road safety improvements can yield to major financial savings in public health sector. Furthermore, utilizing real-time traffic solutions through connected vehicles will lead to spending less time in traffic jams and increase productivity. More importantly, through IoV deployment, service providers will find opportunities to introduce new transportation services such as real-time traffic reporting, locating parking lots, and location-based customer service.

Figure 1 some financial benefits of employing IoV

Such services have high value not only for users but also for businesses [2]. The European Union estimated that by 2020 the global market value for IoV technologies and services will reach 115.26 billion Euros [29].

III EXISTING IoV SYSTEM ARCHITECTURES

A network model of IoV was introduced in [23], which integrates humans, vehicles, things and the environment. A three layer architecture was identified in [30], which describes the different IoV environment technologies interactions. The first layer consists of all the vehicle’s sensors that collect environmental data and detect certain important events such as vehicles situations, driving patterns, and the conditions of surrounding environment. The second layer is for communications which supports different modes of wireless communications such as Vehicle-to-Pedestrian (V2P), Vehicle-to-Infrastructure (V2I), Vehicle-to-Vehicle (V2V), and Vehicle-to-Sensor (V2S). Through the communication layer, seamless connectivity is ensured to several networks such as IEEE 802.15.4, IEEE 802.11p, GSM, LTE, Wi-Fi,Bluetooth. The third layer has the IoV intelligence resources and is responsible for making decisions in risky situations (e.g. dangerous road conditions and accidents). This layer contains statistics tools as well as the collected big data storage and processing resources. A four layers IoV architecture was proposed by CISCO [31]. The end users layer includes IEEE 802.11p based V2V communications, vehicles, and required software. All technologies that are necessary for communications between IoV actors are defined in the infrastructure layer. Afterwards, for the flow-based management and to monitor the policy enforcement, the operation layer was introduced. Finally, the services offered to drivers through cloud computing are specified through a service layer. However, the aforementioned IoV architectures suffer the following weaknesses: 1) network congestions may occur due to transmitting collected data without pre- processing, especially in high vehicular density situations, 2) limited interaction with car users that uses car devices to provide notifications only, 3) they do not provide a clear integration between communication and intelligence. In [8], a layered IoV protocol stack and architecture were introduced. The architecture consists of five layers. The first layer is the perception layer which is represented by the different types of personal devices, RSUs, actuators, sensors, and vehicles. The second layer is the coordination layer which provides a virtual network that involves heterogeneous network technologies such as 4G/LTE, Wi-Fi, WAVE, and satellite networks. The artificial intelligence is the third layer which represents the virtual cloud infrastructure, where storage, processing and analysis the received information is carried out. The fourth layer is the application layer which involves the smart ITS applications. The last layer is the business layer and it represents the operational management module of IoV. In addition, the author designed a protocol stack to organize the existing protocols based on to the proposed five layers’ architecture. The designed protocol stack has three planes including management, operation and security. In [2], a seven- layered model architecture for IoV is introduced. The seven- layers are: 1) user interface, 2) data acquisition, 3) filtering and pre-processing, 4) communication, 5) control and management, 6) processing, and 7) security. A user-vehicle interface is supported by the seven-layer architecture to manage the interactions between the driver and the vehicle. Also a communication interface was introduced for optimal transmission network selection. By analysing the existing IoV architectures, it is clear that there was no consideration for the real-time Big data processing requirements. In addition, all the previous architectures assume that all the collected information must be sent to the data centres (i.e. cloud computing centres) for processing and analysis. Therefore, such architectures are not suitable for many of the ITS applications that require real-time big data analytics. In particular, high latency and communication network overloading are the expected results of deploying any of the previous architectures.

IV CRITICAL ISSUES TO CONSIDER AND FUTURE RESEARCH DIRECTIONS

IoV, fog Computing and ITS big data analytics technologies are still in their infancy stages. Many serious research problems have not yet been addressed. This section discusses various challenges facing the integration of these three technologies and introduces future research direction

A. IMPLEMENTING FOG COMPUTING IN IoV ENVIRONMENT

Fog computing is a very resource heterogeneous environment. Implementing fog computing in the IoV environment and involving vehicles as computing and communication devices (i.e. VFC) make the fog a highly dynamic environment. In particular, in IoV environment, the fog platform needs to handle extra challenges as vehicles move from one fog node to another while performing computing, communication and end-user roles. In addition, the high QoS requirements of many ITS big data applications creates unique challenges while implementing fog computing. The following points call researchers attention to important issues that need to be considered in future research work:

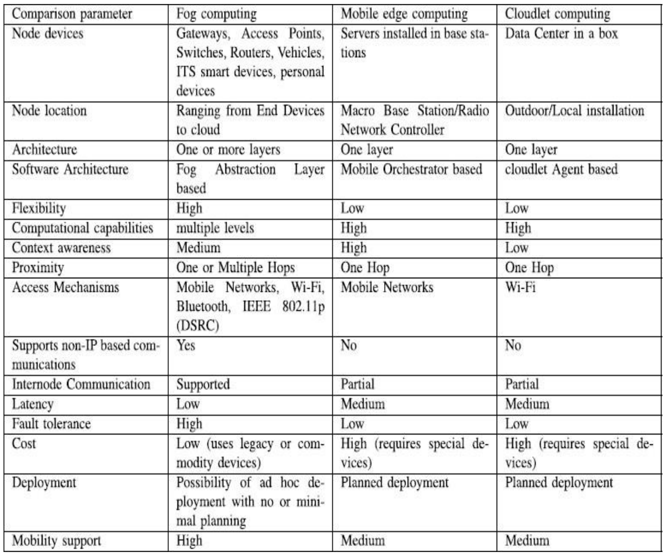
Fog network performance enhancement: With the fast development of big data mining, it is feasible to extract interesting patterns or knowledge to enhance the self-organizing capabilities in fog computing [18]. Usually, the big data presents very important features such as user mobility/activity patterns and social, spatial, and temporal correlations of data contents. Thus, using the historical data and network global view, big data analytic can be used to predict events in advance, and to make the fog Computing units aware of these events in order to utilize the networks resources more efficiently [6]. For instance, through analysing common interests and social relations of users in a specific area, the highly demanded contents can be fetched to the nearby fog units to decrease communications overhead and latency. Therefore, there is a need to introduce fog computing resource allocation prediction algorithms based on big data analytics to dynamically pre-allocated the resources based on predicted user demands.

Resource management: Dynamic allocation is necessary for communication, storage, and computing resources in fog nodes in order to handle the massive and variable rate ITS data in real-time [6]. Further investigation is required on how to manage the available vehicular computation and storage resources. In addition, an adaptive optimization mechanism to allocate computing tasks effectively is necessary. Moreover, to fully utilize vehicles computational and communication capabilities, enhanced mobility models that describe vehicular behaviours accurately are highly required. In fact, modelling vehicles mobility is essential for efficient vehicular fog resource allocation as well as task distribution and scheduling. As vehicles can form vehicular data centre in the fog layer, management policies and computational capacity estimation models in vehicular data centres are open research problems

Cross layer collaboration: Multiple interface definitions is required to create suitable interfaces between fog layers and the cloud centre, among multiple fog nodes, and between fog nodes and IoV objects/devices. Such interfaces are essential to cope with the multiple communication technologies in IoV environment Constructing efficient fog nodes: How to dynamically select the fog devices in order to guarantee the availability of fog services in a certain region or certain users. The mobility of fog devices (e.g. vehicles) and end users highly affect this choice [77]. Therefore, studying the relationship between mobility patterns and the services demand is essential. In addition, fog nodes resources' capabilities and coverage area are significant parameters to consider while forming fog nodes in IoV

Reliability in fog computing: periodical check pointing and rescheduling might be two useful techniques to provide high reliability, however, in the dynamic environment of fog networks such techniques might increase the latency [77]. Replication is a good choice but it should be considered in the early stage of fog network resource allocations and management.

V Comparison of Edge Computing Parameter [3]



Comparison parameter	Fog computing	Mobile edge computing	Cloudlet computing
Node devices	Gateways, Access Points, Switches, Routers, Vehicles, ITS smart devices, personal devices	Servers installed in base stations	Data Center in a box
Node location	Ranging from End Devices to cloud	Macro Base Station/Radio Network Controller	Outdoor/Local installation
Architecture	One or more layers	One layer	One layer
Software Architecture	Fog Abstraction Layer based	Mobile Orchestrator based	cloudlet Agent based
Flexibility	High	Low	Low
Computational capabilities	multiple levels	High	High
Context awareness	Medium	High	Low
Proximity	One or Multiple Hops	One Hop	One Hop
Access Mechanisms	Mobile Networks, Wi-Fi, Bluetooth, IEEE 802.11p (DSRC)	Mobile Networks	Wi-Fi
Supports non-IP based communications	Yes	No	No
Internode Communication	Supported	Partial	Partial
Latency	Low	Medium	Medium
Fault tolerance	High	Low	Low
Cost	Low (uses legacy or commodity devices)	High (requires special devices)	High (requires special devices)
Deployment	Possibility of ad hoc deployment with no or minimal planning	Planned deployment	Planned deployment
Mobility support	High	Medium	Medium

VI. CONCLUSION

The ITS concept was introduced to increase road safety, improve transportation systems efficiency, and preserve our environment. However, as most of the ITS applications are becoming data-intensive applications, there is a need to fully utilize the power of big data analytics in ITSs. Nevertheless, employing big data analytics in the conventional way by depending on cloud computing services is not sufficient for ITS applications in the environment of IoV. This is because many ITS applications are delay-sensitive and processing the data at the cloud centers creates long delays. In addition, transferring the geo-distributed data to the cloud centres causes high network overhead and consumes network resources. Moreover, many of the ITS applications require location awareness and mobility support which are not provided through cloud based analytics. Recently, the fog computing technology is introduced as a promising solution to support real-time big data applications. Fog computing complements the cloud computing by providing distributed, intelligent, and fast data processing at the network edge. In addition, fog computing node can consider the location awareness and mobility requirements while serving end users. However, big data applications cannot depend solely on fog computing as its computational and storage capacity is still limited in comparison to cloud platforms. Therefore, both cloud and fog computing should be used to support the real-time ITS big data analytics in IoV environment. Real-time big data analytics consists of three main stages including batch, speed, and serving. However, performing these three stages in the cloud is not going to serve the latency-sensitive applications. On the other hand, the fog platform cannot handle the batch processing stage. Therefore, big data analytics stages need to be distributed among the cloud and fog computing layers. Furthermore, the IoV environment must provide the required coordination and communication between the different layers and components. By considering these aspects this paper proposed a novel architecture of three dimensions (intelligent computing, real time big data analytics, and IoV) to enable the real-time ITS big data analytics in IoV environment. In addition, the opportunities and challenges that IoV and intelligent computing platforms are creating have been discussed. Moreover, a comparison between different edge computing technologies has been presented. Furthermore, critical issues and future research directions have been highlighted, which should be considered to improve the real- time big data analytics for many ITS applications. Finally, the proposed architecture presents a good basement for future research in this field and it can be used as part of the intelligent transportation systems to enable the real-time applications such as collision avoidance, hazardous warning, advanced driver assistance systems, autonomous driving. As a result, many people lives will be saved by using more safe transportation systems. In addition, transportation systems will become more efficient and environmental friendly.

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