Adoption of IoT in Vehicular Traffic Control: An Overview

Joyeeta Goswami and Ashim Saha

Abstract The number of consumer vehicles is ever-increasing, and traffic management is becoming a big challenge all over the world. In hilly or forest-covered areas, the natural calamities are also an addition to this traffic problem. This gives rise to economic difficulties as well as the environmental cataclysm of society. IoT (Internet of Things) presently became a promising technology to solve various serious problems by establishing the link between the environmental parameters with cloud intelligence. As the name, IoT or Internet of Things suggest it connects Hardware Devices like a small sensor to cloud server through the Internet or Network. It's like the cryptic wand of the technical world. In this paper, we have presented a comprehensive survey on IoT and different existing traffic management systems based on IoT and the complexities related to them. We have also tried to approach a power-efficient IoT based smart traffic management system which also incorporates the detection of different unforeseen natural events like landslides, flood, etc. for all kinds of roads in rural and urban areas, and will reduce the chances of road accidents.

Keywords IoT · Traffic control system · VANET · DSRC · LoRaWAN

1 Introduction

IoT, the modern span of technology combines all the available devices to communicate under one network using the internet. There are several reports and statistics published that indicate that IoT is one of the hottest technologies of the twenty-first century. The Term IoT is termed by Kevin Ashton, who is the co-founder of Auto-ID Centre at MIT. in 1999. As per Business Insider's Report [1], in the next five years, a whopping $6 trillion will be invested in IoT based products and will give an RoI of $13 Trillion by 2025. By 2020, M2M communication which is one of the fundamental

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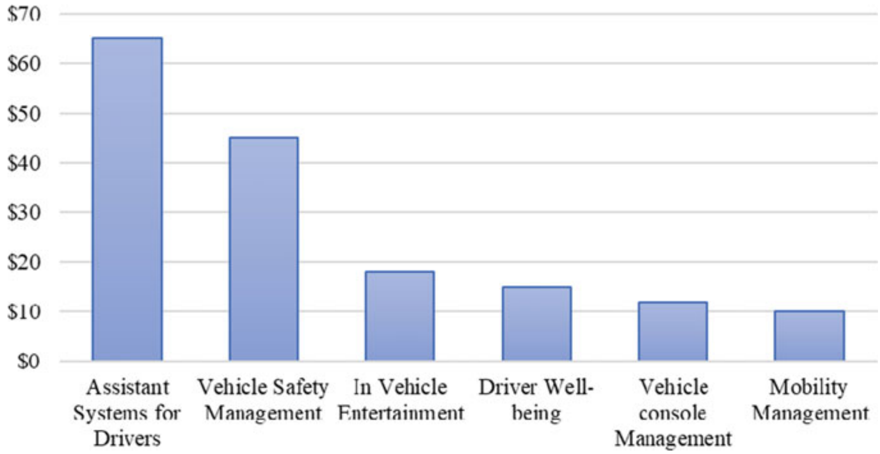

Fig. 1 IoV revenues in $Billion

for IoT communication will grow to 12.2 Billion from currently 4.9Billion globally [2]. According to another report [3] published by Forbes IoT Market will reach up to 267billion USD in 2020. And domains like discrete manufacturing, Logistics, and transportation will drive more than 50% of total IoT expenses by the companies. Another report by McKinsey, suggests the total IoT market size in 2015 was up to $900 M, growing to $3.7 B in 2020 attaining a 32.6% CAGR.

Along with this, IoT has a significant role to play on Vehicular Ad Hoc Network or VANET. The use of Wireless Sensor Network (WSN) in VANET is widely popular nowadays. It is estimated that in 2017 the Market Value of the Internet of Vehicle (IoV) was $66,075 million and it will increase to $208,107 million by 2024 with a CAGR of 18% [4]. According to a report by IDC [5] more than 70% Light-duty Vehicles will be shipped with IoT and Internet-enabled with them. There are many applications of IoT including Agriculture, Automotive, Supply chain, Industrial Manufacturing, etc. In this paper, we will discuss the basic tech architecture of IoT along with a detailed survey on the traffic control system across the globe. At last, we will also discuss some areas researchers can work in this field. IoT based services are also generating new business stream and are expected to generate around $152 B in 2020 (Fig. 1).

2 Communication Protocols

As an enormous and continuously advancing network, IoT has its range of protocols also transcend. From those protocols, some are not well known but some are very usual and used extensively in every field. These protocols establish communication between devices to exchange information with each other in a secured manner. There

Table 1 IoT Communication mediums comparison

Technology	Data rate	Range	Power use	Application
GPRS/HSDPA [39, 40]	Up to 10 Mbps	Long range	High	Cellular/Remote sensing
LTE [39, 40]	Up to 20 Mbps	Long range	High	Cellular/Remote sensing
Wi-Fi [40, 41]	Up to 54 Mbps	300 ft	High	Home automation/Remote device control
BLE (Bluetooth Low Energy) [39]	Up to 3 Mbps	300 ft	Low	Home automation/Wearables smartphone control/automotive
Xbee [39, 42]	Up to 250 Kbps	Up to 2 Kms LoS	Low	Home Automation/Mesh Network/Manufacturing/Traffic control systems
LoRA [6, 40]	Up to 50 Kbps	Up to 4 Kms LoS	Moderate	Remote sensing/Smart city/Industrial
Sigfox [39–41]	Up to 1 Kbps	Long Range	Moderate	Remote sensing/Smart city

are multiple communication channels available for both Near Field and Far Field Application. For devices that are in near proximity of each other, Bluetooth, Zigbee, and NFC are dominantly used for communication. And for far-field communication, technologies like Wi-Fi, Cellular. Recently Narrowband-IoT-based communication channels are also becoming very popular due to their low bandwidth requirements. Some of the technologies are LoRAWAN, Sigfox, Zwave, etc. Researches show that [6] for Smart Cities, using LoRA the scalability of the network can be significantly improved to get around 95% of the packet success rate for serving more than 15,000 nodes. The most popular communication technologies are tabulated here (Table 1).

3 Vehicular Ad Hoc Network (VANET) and Internet of Vehicle (IoV)

Vehicle-to-Vehicle or V2V communication is the rapidly growing technology that is possible by IoT as a foundation. In this type of communication, vehicles will communicate with each other by sharing their real-time information in the around 360-degree range [7]. By virtue of this V2V communication a new traffic Management technology has been established named ITS, i.e., Intelligent Transport System. The role of IoT technology here is to gather the information from various devices and analyze them to get the most preferable data and broadcast them to the unit or device where it needed. There are many technologies that are evolved or used in V2V Communication. One of such is VANET, which stands for Vehicular Ad hoc Network. VANET is the ad hoc network that supports Inter-Vehicular and Vehicle to Roadside Device Communication. It accumulates the real-time data from passing by vehicles, analyze them, and produce some information message or alert message to the point where needed. VANET uses DTMAC protocol which is a distributed MAC protocol based on the TDMA scheme to establish communication between the moving vehicles by using the same frequency range without any interference [8]. It collects the real-time information of moving vehicles by using some combinations like Zigbee and GPS or DSRC and GPS, etc. In recent days and also for the future, the Dedicated Short Range Communication or DSRC protocol has taken a significant part in V2V communication. It is the wireless messaging technology of moving vehicles and operates on 5.9 MHz frequency. DSRC helps the drivers of moving vehicles to get the information about the surroundings (whether there is any vehicle or pedestrian is present or not) to control the vehicle according to the requirement, also gives the message about the coming vehicles to the pedestrians [9]. DSRC not only communicates between the vehicles but also sends the vehicle's data to nearby pedestrian and to VANET. VANET and DSRC commonly work together to control different causes of accidents such as Blindspot, Sudden lane change, Hard braking, Intersection movement, etc. For example, if any accident happens then DSRC will transmit the data to nearby devices and VANET collects this information and broadcast the message to the upcoming traffics so that they can control the vehicles and can avoid the congestion. VANET typically uses IEEE 802.11p, IEEE1609.1, 2, 3 and 4 communication standards [10].

IoV focuses on Intelligent integration of Vehicular communication with Environmental, drivers, and other parameters [8]. IoV integrates technologies like Telematics, Swarm Robotics, Machine Learning, Deep Learning, Artificial Intelligence, etc. to provide a credible, manageable and highly operational network which consist, multiple stakeholders, users, vehicle and decision-makers globally. A typical IoV implementation has two separate communication modes: Peer to Peer Model and Server-Client Model [11]. The communication between the Vehicles, i.e. V2V or Vehicle to Roadside Device or Control Unit communication works on Peer to Peer Model and Roadside Devices sends data to Cloud or Data Centre on Server-Client Model. Typically the Vehicle to Control Unit Communication is performed over IEEE 802.11 or IEEE 802.16 protocol [8]. The layer stack of IoV is as follows [11].

User Interaction Layer: This layer collects the data from Vehicles and it's environment.

Coordination Layer: Receives data from different sources and process them for analyzing.

Processing and Analysis Layer: Based on cloud, this layer performs all analyses and storage of the gathered data.

Application Layer: This layer offers intelligent services to end-users such as congestion management, alert, streaming, etc.

Business Layer: This layer is used for making business decisions and models from the IoV infrastructure (Fig. 2).

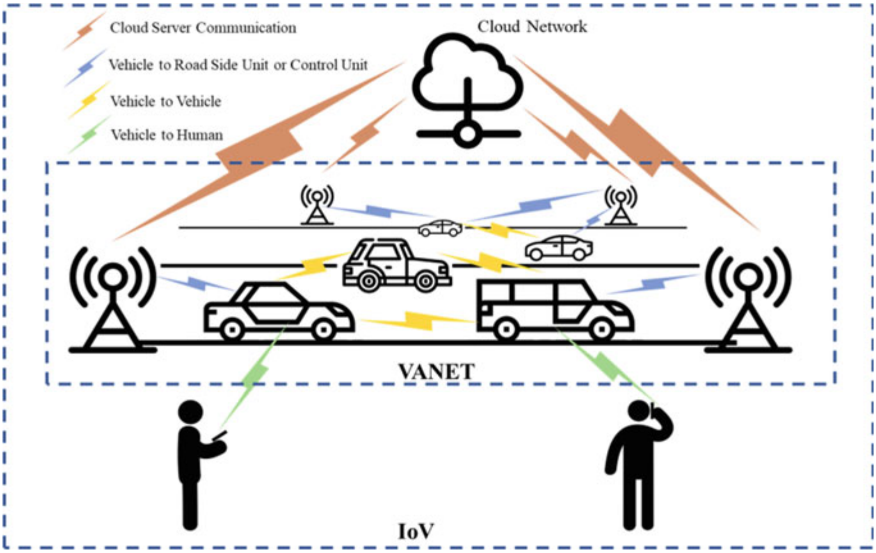

Fig. 2 VANET and IoV

4 Existing IoT Applications in Traffic Control

As day by day, the traffic problem is increasing, people from different corners of the world also developing advanced solutions with the help of the latest technologies. Some are trying to make it with wireless sensor networks [12, 13], some with RFID [14], some with the neural network [15], and so on. But the well-liked in recent times is the IoT based solutions. The Roadmap of IoT Based system is like this (Fig. 3).

Due to its mystic features, researchers are using this technology frequently. At the very beginning, people started with the M2M communication process, consisting of three parts: M2M devices, the server part, and a web-based user interface [16]. In this approach, the M2M server does the work to link the M2M devices with the authentication server or AAA (authentication, authorization, accounting), where authentication server will provide the number of vehicles in a particular area. The user interface (INVENTOR) gives all the information about the operation of the working unit to the authorized operator such as faulty units, errors, etc. [16]. After the basic

Fig. 3 IoV roadmap

structure, some improvisations had started. Cameras, snow sensors, fog monitors are placed in the place of normal sensors in the perception layers, in the network or server part cloud computing, data accuracy and validation has included, and the Service-Oriented Architecture (SOA) part was improvised with intelligent traffic control systems [17]. With the development people start to think of the separate parts of the traffic system using IoT. Some researchers thought about the crowd indexing system by using IoT structure to reduce the congestion on the roads [18]. Some started to think about the speed limit of vehicles to reduce accidents due to rash driving [19]. In [20] the system consisting of two parts the electronic system and the Software system. The electronic system detects and gathers the traffic data by utilizing the inductive loop detection method and transfers them to the base stations through Wi-Fi. And the second part consists of Green Light Phase Time (GLPT) Calculation Algorithm in cloud server which analyses the green light phase time and acknowledges back to the base station [20]. With the advancement of technology, people are analyzing the causes of traffic-related problems more deeply and try to solve them with more accuracy. Some are analyzing the accidents happen by sudden traffic slowdown due to other accidents, peak traffic time, work-in-progress, etc. [21]. Here it found that the sudden slowdown of traffic is mainly affected by inadequate visibility of drivers as a result of fog, tunnels, or any other reasons. In this case, Google maps are quite helpful but not for all kinds of roads. Here, the main focus is on the cloud server. By using the 4G network the real-time data from the sensors mounted in vehicles are transferred to an OpenGTS server which will load the information in a SQL database and gives a real-time OpenStreetMap traffic scenario [21]. In addition, those data are also put in a MongoDB distributed database by GeoJSON parsing, which will perform the marking of other vehicles on the same road in close proximity and to notify them about the sudden slowdown of traffic [21]. Some designs are working on the priority of traffic lanes using Wi-fi protocols [22], some are modifying the sensors to IR sensors [23]. As a whole of those modifications, the ultimate is the ITMS or Intelligent Traffic Management System to build a smart city. In this ITS or ITMS system the sensors (Ultrasonic, IR, Inductive loop detector) on the roads or in the moving vehicles will get the real-time information about the traffic density and broadcast them through IoT protocols (like wi-fi [22, 23], LoRaWAN [24, 25] and other above-mentioned protocols) to the nearest local units, other vehicles or pedestrian in the working range and also to the nearest communities, it means all the units in one system will get all the required information about other [26–29]. After collecting that information the cloud server analyzes them and works according to the given algorithm [29–32]. With the advancement, these smart systems have some challenges also like security, interoperability, connectivity, energy consumption, etc. [33]. But those problems are also been analyzed and solved by the researchers.

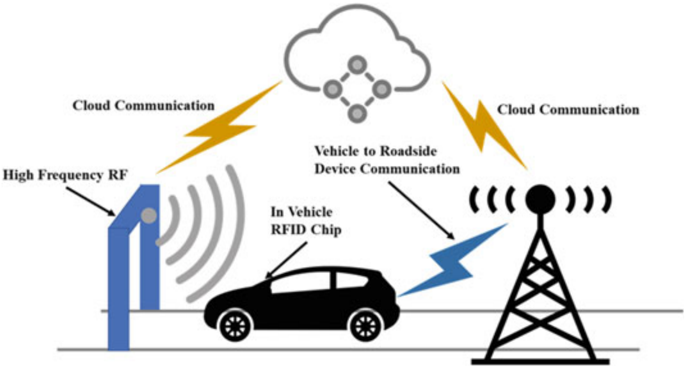

Fig. 4 Localization using RFID and vehicle to roadside communication

5 Way Forward

There are numerous researches are performed in this field as discussed in the previous section. Many were also implemented nationally or internationally. Though in India due to several reasons, not many actual implementations are done.

5.1 Location Issues

In [34] many issues of Internet of Vehicle such as localization, security and Radio Propagation, etc. The GPS module has a location accuracy of 50 m in IoV systems. Also, the problem of signal lost is pretty dominant in dense areas. Using High-Frequency RFID along with GPS data can be helpful to mitigate localization issues. Some researchers are already conducted to use BLE beacon as an indoor navigation tool [35]. The security and privacy concerns are also important issues, that need to be taken care of. Researches may be conducted to implement a single global identifier and use the encryption algorithm for the same (Fig. 4).

5.2 Network Issues

As discussed in the last section, most of the system relies on the internet for communication between the sensor and cloud server. Based on the data sent from the sensors, the cloud server analyses the data and generates a proper flag based on the logic set by the administrator. This system heavily relies on internet connectivity but due to geographical extremities, it is very possible that in remote hilly areas the internet may not be available. So due to poor network connectivity, the cloud may not get the sensor information and may not be able to generate an alarm. There are multiple ways to solve it. One approach could be using satellite communication instead of mobile networks as used by Ramesh [13]. But using VSAT increases the total cost of deployment. Also, the energy required for powering the VSAT satellites is also significant. To reduce the bandwidth requirement of the cellular network technologies like Narrowband IoT (NB-IoT) may be used. NB-IoT is an LP-WAN technology which uses an unused 200 kHz band and has a lower bit rate compared to LTE-M1. NB-Iot is supported by existing mobile networks and can support as long as 10 years of battery life [36].

5.3 Data Analytics

Data Analysis is the big challenge for the Internet of Vehicles as the Volume of Data generated is huge and mostly there is no trusted central authority. The automotive business and traffic controller authorities need to understand the type and nature of the data they required and integrate the solution to provide a rich contextual user interface in the IoV network. The trigger for any alarm should be contextual data-driven. That means the Analytical Model should be able to trigger the alarm based on the present data intent. Based on the data generated, the researchers may device predictive models which will help the drivers and other decision-makers to take informed decision about any situation.

6 Societal Impacts of IoV

With the Advancement of IoV along with Artificial Intelligence and Machine Learning, companies are coming up with autonomous vehicles, that will surely benefit the society by helping persons with special ability to commute easily and make driving a safer experience for all [37]. Around 90% of cases of car accidents are due to human error only [38]. IoV along with Autonomous technologies can help to save millions of people every year. The environment can also be less polluted by them as the usage of fossil fuel will reduce substantially.

7 Summary/Conclusion

In this paper, we have briefly discussed the various communication mediums used in IoT Implementation with their comparative study. We have discussed the overview of Vehicular Ad Hoc Network or VANET along with IoV. Then we reviewed some of the implementation and researches performed on the application of IoT in the traffic

Management system. Lastly, we have proposed multiple research options available for this domain, where researchers can work on the practical implementation of Traffic Management.

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