Journal of Contemporary Scientific Research, Volume 3, Issue 4, April 2020, pp. 12-35
http://www.jcsronline.com/wp-content/uploads/2020/03/Volume-3Issue4Paper2.pdf

Role of smart vehicles concept in reducing traffic congestion on the road

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Abstract

The aim of this simple qualitative review was to provide an overview of how smart vehicles concept facilitates reducing traffic congestion on the road. Google Scholar was searched for literature sources using the topic itself as the search term. The search yielded 40 usable papers for this review. Many elements of smart city are inter-mixed with the smart vehicles concept. On the other hand in the smart vehicle concept, enabling technologies like VANET, IoV, SDN, use of mobiles and even use of electric poles on the road as IoT gateway were tested in the different frameworks proposed by different researchers. Many other traffic management systems have also been tested especially in Japan and India. In general, two scenarios have been considered- one of current types of roads and the other automated highways. Understandably, the requirements and approaches are different for the two scenarios. Some limitations of this review have also been listed at the end. Maximum of works dealt with VANET technology.

Keywords: Smart vehicle, traffic congestion, IoT, traffic management

Introduction

Traffic congestion occurs when the demand for travel exceeds highway capacity. A sensible way to reduce congestion should be to use a set of policy mixes to reduce demand and increase capacity according to local circumstances and priorities. These policies may be to build more highways, reduce demand by raising tolls or other taxes, promote mass transit or greater vehicle occupancy like car-pooling and develop a high speed communication network to reduce the need to travel. One such method is use of smart vehicles.

An explanation of smart car (vehicles) (PC Mag, 2020) runs like this, “An automobile with advanced electronics. Microprocessors have been used in car engines since the late 1960s and have steadily increased in usage throughout the engine and drivetrain to improve stability, braking and general comfort. The 1990s brought enhancements such as GPS navigation, reverse sensing systems and night vision (able to visualize animals and people beyond normal human range). The 2000s added assisted parking, Web and email access, voice control, smart card activation instead of keys and systems that keep the vehicle a safe distance from cars and objects in its path. Of course, the ultimate smart car is the one that drives itself (see self-driving car). See embedded system and connected car.” This explanatory definition covers the full range of technologies used in smart vehicles along with the evolution history.

Smart vehicles are mainly intended for in-city use, as its light weight, speed and range of mileage does not support long distance use of most models. However, electric vehicles, with many technologically enabled features can be used for long trips and included in smart vehicles categorisation. In this exploratory simple qualitative review, how such cars can be useful in reducing traffic congestion is discussed with the support of research literature.

Methodology

A simple Google Scholar search was made using the topic itself as the search term to select old and recent papers. The search yielded 40 usable papers. These are discussed under different sections below.

Results

Scope of IVHS in UK, USA and Japan

Varaiya (1993) noted that Intelligent Vehicle/Highway System (IVHS) is a new way by which technology will make several major changes in highway transportation. IVHS consists of using technology for control, communication and computing. It can significantly increase safety and highway capacity without the need for new roads. A proper combination of control, communication and computing technologies can either be placed on the highway or on the vehicle or both. This can assist driver decisions enabling increase of highway capacity and safety without the need to build more roads. However, there could be different ways of doing IVHS by function separation, by system architecture, design and evaluation. Out of the main categories of tasks, in-trip path planning by the driver is the component influencing congestion. In this respect, the strategy is to influence driver decisions by changing from giving information to offering advice and exerting pre-emptive control. As the system becomes more automatic and predictable, the pressure on intelligence of the system increases. During in-trip decisions, drivers can manoeuvre their vehicles to change lanes and entry and exit from a highway. Manoeuvre requires coordination with the movement of neighbouring vehicles. Improper coordination can lead to congestion and accidents. In unautomated and automated current system, the traffic capacity is not increased; only in-traffic controls are placed through signalling systems and on-the road warning systems. At present, IVHS research in UK has progressed systematically. In USA, there had been on and off attempts, but no continuous research. In Japan, efforts by car companies are supported by the government. Martin, Marini, and Tosunoglu (1999) reviewed the work on IVHS, PROMETHEOUS, IVHS America, DRIVE, and ERTICO research and implementation attempts in various parts of the world. The results promise the usefulness of smart vehicles for reduction of traffic congestion. IVHS seems to be the only effective solution to reduce traffic congestion. A similar review of IVHS research and implementation in USA, Europe and Japan was also done by Jurgen (1991).

Smart vehicles and technologies cannot reduce congestion

Usefulness of connected vehicles as a type of smart vehicles, was discussed by Guerrero-Ibanez, Zeadally, and Contreras-Castillo (2015). Based on a detailed analysis of various challenges and current and emerging solutions, Hensher (2018) discovered that traffic congestion problem may not be solved by any of them. The only way to achieve significant reduction in congestion is to use sharing economy (by raising toll fees etc and reducing private car ownership. The author echoed this opinion in another paper dealing with the future prospects in reducing congestion (Hensher, 2017).

Smart vehicles and VANETS to enable smartness of vehicles

Vehicular Ad Hoc Networks (VANETs), have been created to facilitate communication between vehicles themselves and between vehicles and infrastructure with vehicular networks playing important role. Barba, Mateos, Soto, Mezher, and Igartua (2012) developed a framework to transmit information about the traffic conditions so that the driver or the smart vehicle itself can take appropriate decisions. The proposed system consisted of a warning system of Intelligent Traffic Lights (ITLs) to provide information to drivers about traffic density and weather conditions in the streets.

A smart vehicle is aware of its neighbourhood. This includes information of the presence and location of other vehicles. Now cars possess a network of processors connected to a central computing platform that provides Ethernet, USB, Bluetooth, and IEEE 802.11 interfaces. Newer cars have an event data recorder like the black box in planes, GPS, front end radar to detect obstacles on its line of travel, short distance radar or ultrasound to facilitate parking, These and other features of smart car have been given in a diagram by Hubaux, Capkun, and Luo (2004) and reproduced in Fig 1.

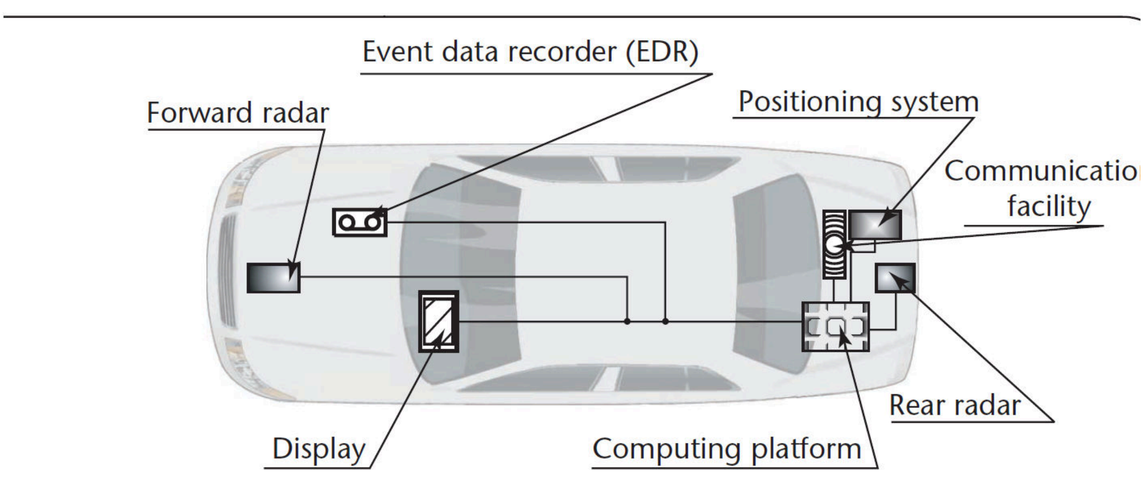

Figure 1. A smart vehicle depicting its technological capabilities (Hubaux, Capkun, & Luo, 2004)

Olaverri-Monreal (2016) noted that traffic accidents can be reduced by using autonomous vehicles, as human error causes about 90% of the accidents. Other advantages of autonomous vehicles are: uninterrupted traffic flow, lower energy consumption and increase on the road capacity through a decrease of the aerodynamic impact on the vehicles, minimising the distances between them. This view contradicts the contention that road capacity is unchanged by use of smart vehicles and therefore useless in reducing traffic congestion (Hensher, 2017;2018).

Tsugawa, Saito, and Hosaka (1992) described the concept of super smart vehicle system (SSVS). It is a new information system intended for automobile drivers. It can be used to solve problems caused by other automobiles and road traffic. Based on the concept of info-mobility, SSVS deals with information systems for a single vehicle, for inter-vehicles, for vehicle-to-road relations and vehicle-to-driver relations. The system components are a cooperative driving system, a control configured vehicle system, an active driver assistance system, an intelligent infrastructure, intelligent logistics and machine vision. But the main focus of SSVS is advanced vehicle control systems.

The development of a social internet of vehicles (SIoV) for social vehicle route selection was described by Lin, Li, Fortino, and Rodrigues (2018). The system has internet-enabled vehicles. In the design of the system, a social clustering method utilises both historical and current driving information. Then game evolution method is used to calculate the optimal route for vehicles. The vehicle route selection game is a proven a potential game, with the strategy selection converging to Nash equilibrium. Clustering of vehicles using this method helped to reduce traffic congestion in simulations.

A smart city traffic system with a major role for VANET for warning systems and intelligent route selection has the potential for reducing traffic congestion. Such a system was tested by Khekare and Sakhare (2013) to obtain useful results. Out of three VANET routing protocols tested, Ad hoc On-Demand Distance Vector (AODV) protocol was found most suitable.

How vehicle-to-vehicle communication can improve intelligent transport systems in which VANET plays a major role, was explained and discussed by Moloisane, Malekian, and Bogatinoska (2017).

Based on vehicular grouping technique with length as a parameter, Maddiboyina and Ponnapalli (2019) proposed a system to avoid traffic congestion at intersections. Vehicles, waiting at the intersections, were divided into small groups with highest priority given to the emergency vehicles. For grouping the vehicles, VANET was used. A pre-scheduled waiting time was allocated for the vehicles which were present in their respective group. The special focus was on emergency vehicles and pedestrian crossing. Top priority was for the zone where there is an emergency vehicle. All vehicles including EV will first cross the junction. If there are no EVs in any zone, then the priority will be automatically set out for other vehicles and pedestrian crossing. The system reduced average waiting time and congestion of vehicles significantly.

The need for context awareness for driving decisions for intelligent vehicles and smart roads was elaborated by Fuchs, Rass, Lamprecht, and Kyamakya (2007). A hierarchical decomposition strategy is suggested for handling context information. The usefulness of this strategy for collaborative driving in situations like overtaking, vehicle support systems, exchange of information on traffic objects, negative factors of speed, local context information, emergencies are possible in the case of vehicle-to-vehicle collaboration. Vehicle-to-infrastructure collaboration leads to sharing information on road conditions, warning about accidents and information on traffic objects.

A combination of intelligent vehicles and automated highways can solve most of the urban traffic problems including congestion, according to Ashley (1998). Close coordination of vehicles and harmonization of traffic flow could be achieved by installing small network of computers both in vehicles and along the roadways. This will maximize highway capacity and passenger safety. If a driver wants to use such an automated highway, he will first pass through a validation lane just like the current high-occupancy-vehicle (HOV) or carpooling lanes. On verifying that the car can correctly function in an automated mode, its destination is established, and any tolls deducted from the driver's credit account. An example of such a system is the California Partners for Advanced Transit and Highways (PATH) Program at the University of California. In their system, magnets buried at intervals in the roadbed would be sensed by magnetometers in vehicles. This method facilitates monitoring their location and velocity. A diagram of a smart car given by the author is reproduced in Fig 2. The variety of smart technologies possible to be incorporated in smart vehicles is clear here. How a future highway of such a system will look depicted by the author is reproduced in Fig 3 and a closer view of the system showing sensor activities is given in Fig 4.

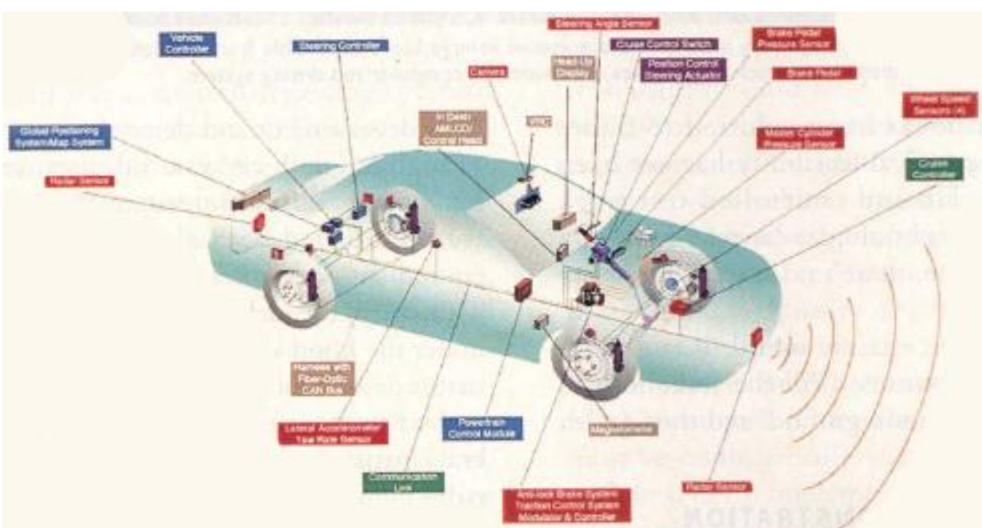

Figure 2. Features of a smart car (Ashley, 1998)

Figure 3. A system of smart vehicles and automated roads (Ashley, 1998)

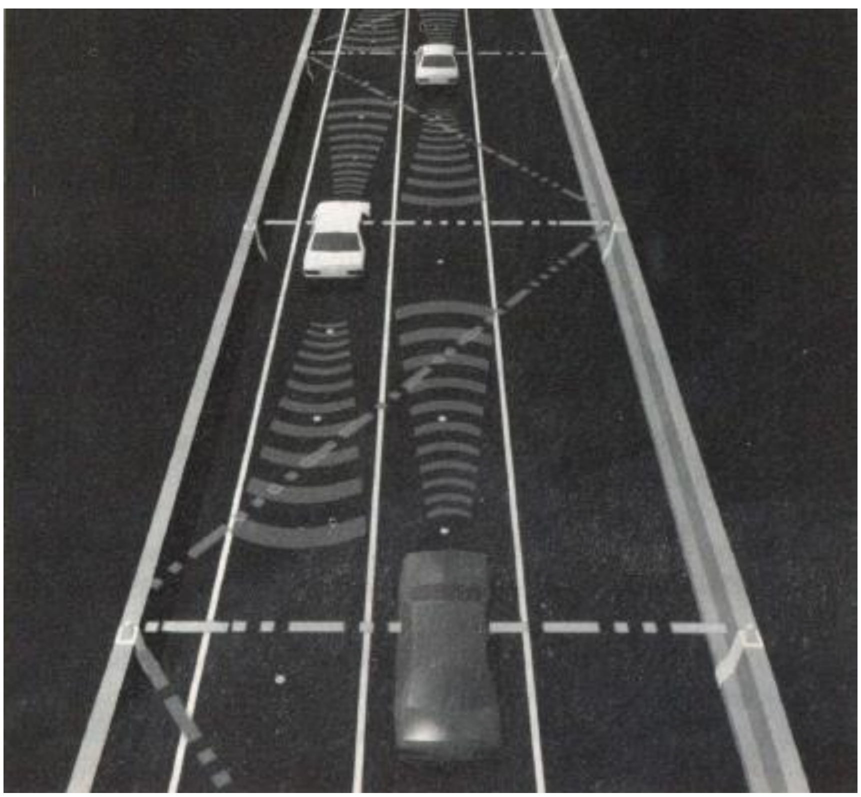

Figure 4. Smart vehicles and automated roads, showing sensor activities (Ashley, 1998).

Although IEEE 802.11p is regarded as the de facto standard for ITS communications in VANETS on-the-road communications, researches on the usability of a new application, Long Term Evolution (LTE) were reviewed by Araniti, Campolo, Condoluci, Iera, and Molinaro (2013). It is a wireless broadband technology with high data rate and low latency for mobile users. A large coverage area, high penetration rate and high-speed terminal support can be beneficial for LTE. However, the centralised architecture requires communications to be only across infrastructure nodes, even if only a localized V2V data exchange is required for it. With respect to safety-critical applications, negative consequences are possible on message latency. In dense traffic areas, the heavy load due to periodic message transmissions from several vehicles may be more than what the LTE capacity can handle. These issues have potential adverse effect on the delivery of traditional applications. LTE is suitable for safety messages of both cooperative awareness messages (CAMs) and decentralized environmental notification messages (DENMs) types and traffic efficiency applications. In its applications, LTE can play a critical role in overcoming range limiting situations of no 802.11p-equipped vehicle as in the case in rural areas where the car density is low, or buildings intervene in intersections. It can disseminate information messages faster over large areas. Some diagrams related to LTE architecture and applications by the authors are reproduced in Fig 5-7.

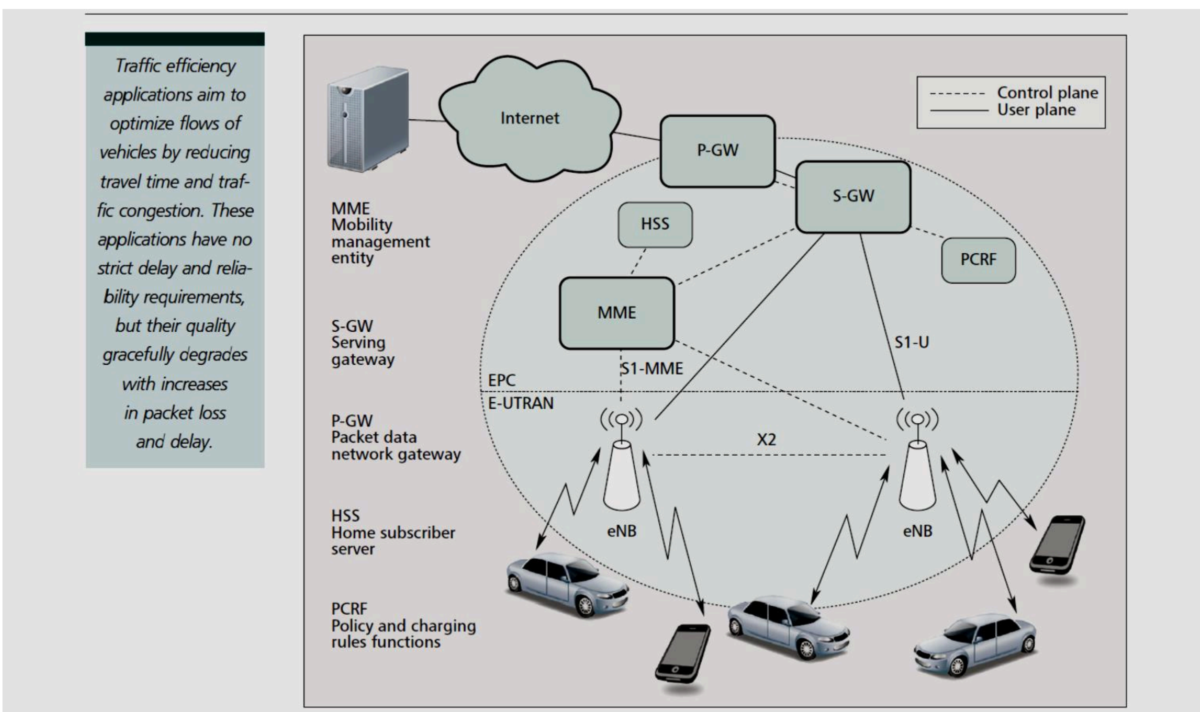

Figure 5. LTE architecture (Araniti, Campolo, Condoluci, Iera, & Molinaro, 2013)

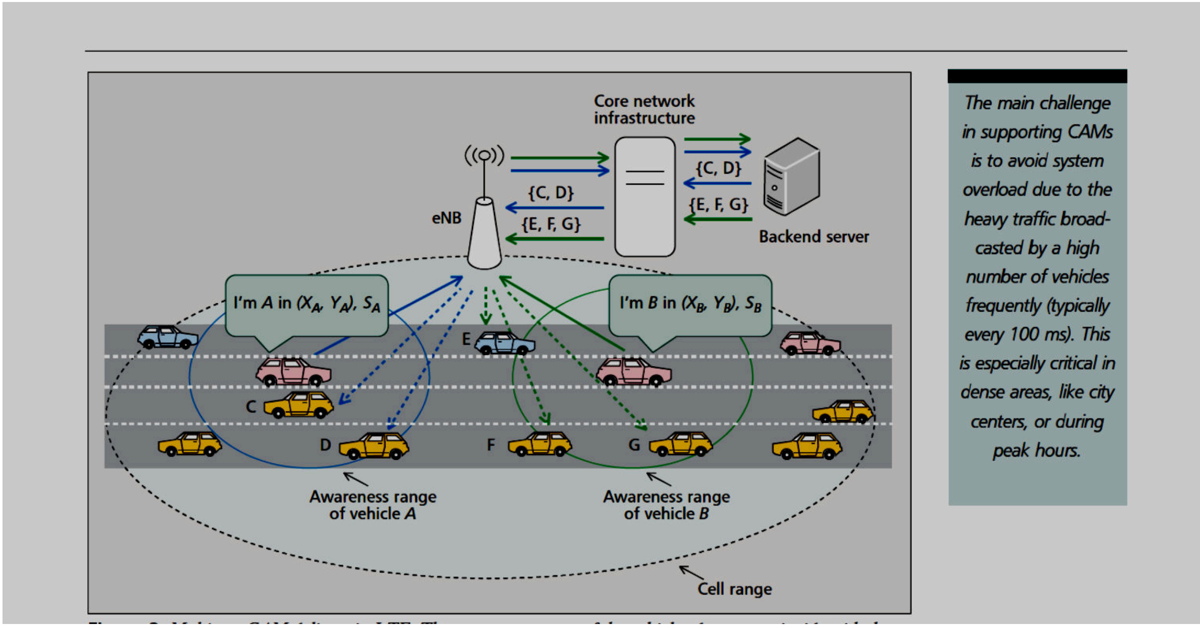

Figure 6. Range of communication affected by message overload (Araniti, Campolo, Condoluci, Iera, & Molinaro, 2013).

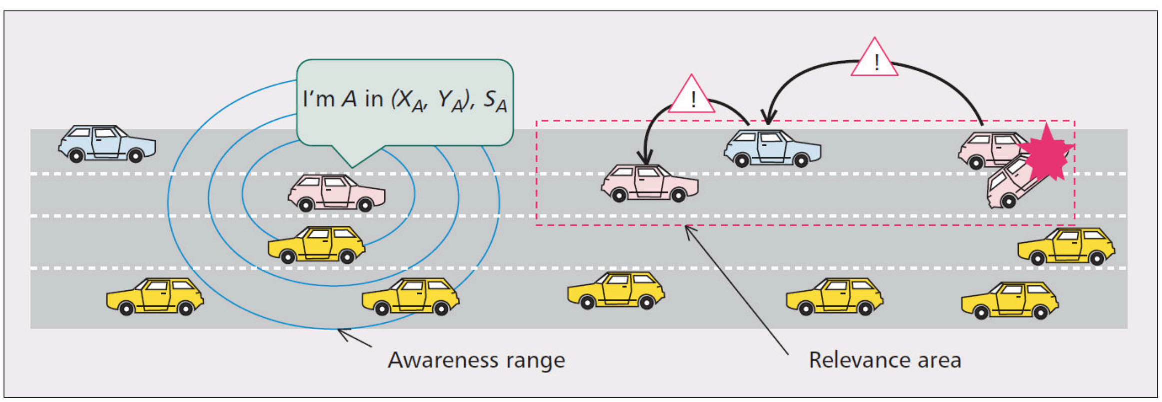

Figure 7. Local V2V broadcasting of messages (Araniti, Campolo, Condoluci, Iera, & Molinaro, 2013).

Vehicular sensing networks (VSNs) play a critical role in maintaining the efficient operation of smart cities. Wang, et al. (2017) constructed a VSNs-aided smart city model and discussed a range of intelligent applications both for public services and for urban flow management. Based on the maturing technologies in the vehicular ad hoc networks (VANETs), vehicular sensing networks (VSNs) may be invoked both for vehicle-to-vehicle (V2V) communications and vehicle to-infrastructure (V2I) interactions, as well as for sensing, transmitting and integrating important information related to a city's operation for preventing traffic jams. VSN applications in smart cities include: traffic management, smart (early) warning of accidents and other emergency situations, multimedia and internet service, reliability of intelligent services and urban planning. Technological challenges are: wireless channel characteristics like limited band width, high Doppler shifts, building occlusions; mobility and dynamic topology from unpredictable mobility of each vehicle; efficient routing strategy for bandwidth allocations; congestion control and security issues due to flow of large amount of data. The authors provide VSN application scenarios as reproduced in Fig 8.

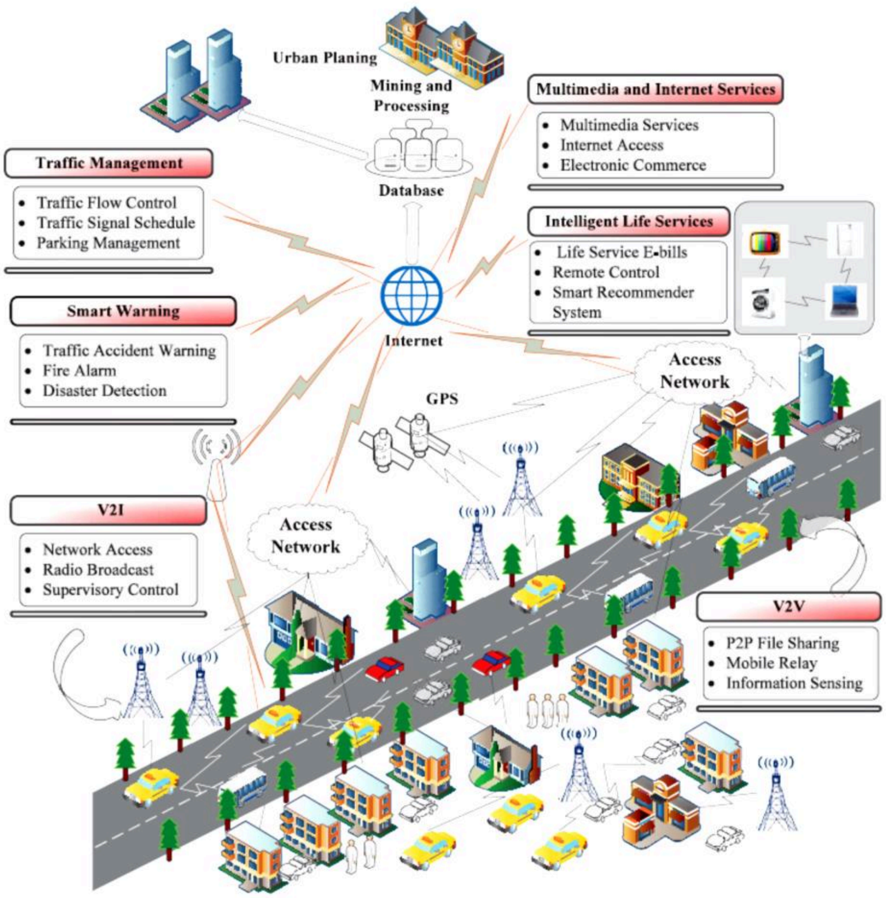

Figure 8. Architecture and applications of VSN in a smart city (Wang, et al., 2017).

According to de Souza and Villas (2016), the current traffic management systems (TMS) are inefficient to manage traffic congestion. A fully distributed TMS is required instead. The authors proposed FASTER, a VANET based distributed TMS as a solution. In comparison trials, FASTER performed better than other solutions in different scenarios and with regard to the key requirements of TMS.

A distributed predictive road traffic management system for Vehicular Ad-hoc Networks (VANETs) was proposed by Mejdoubi, Fouchal, Zytoune, and Ouadou (2019) to reduce traffic congestions. This is achieved by predicting the future road traffic with simultaneous and continuous adaptation of routes for each vehicle at each junction. The aim is to minimise driving time and to avoid future congestions in the network. Both V2V and V2I are used. There is no central server. The proposed system was better than some other systems in certain conditions.

A mobile-enabled VANET technology was proposed by Jayapal and Roy (2016) to detect congestion and divert vehicles. The system is a distributed, collaborative traffic congestion detection and dissemination system. The smart phones of drivers are equipped with a Traffic App which capable of detecting location using GPS. This information is relayed to a remote server to detect traffic congestion. Once congestion is confirmed, it is transmitted to the phones of end users through RSUs. The Mobile App transmits the location information of each vehicle at periodic intervals. This enables determination of the distance moved by the vehicle within a time interval. If the distance moved by several vehicles in the area are below a threshold, congestion is identified in that area. The vehicles approaching the congested area are informed about the traffic through display boards in the nearest RSUs (traffic signals). The congestion information is also transmitted through the mobile App in the vehicles approaching the problem area. This enables the approaching vehicles to divert and thus congestion is reduced.

Safi, et al. (2018) used a cloud-based smart vehicle parking system in VANET. A unique algorithm was used to identify vacancy in parking area. long with booking and recommendation options to facilitate vehicles in an effective, real-time and precise manner. Related factors like drive time, distance to the parking facility, parking fee, walking time from parking facility to destination and traffic congestion were also utilised in the system. Parking side units installed alongside the parking area coordinated the management between cloud infrastructure and roadside units. Traffic congestion caused by roaming vehicles searching for parking space was also reduced.

A VANET-LTE advanced technology was proposed by Pal and Pali (2018) for signal-free passage of emergency vehicles like ambulances in urban areas of Delhi. LTE (Long term evaluation) considered here was LTE-A (A for advanced to be 5G ready in 2020). Roadside electric poles could be used as antennas. Thus, VANET-LTE-GPS system is equipped in all vehicles for effective functioning of the system. Some diagrams given by the authors are reproduced in Fig 13-17.

Figure 9. An IoT enabled TMS (Pal & Pali, 2018).

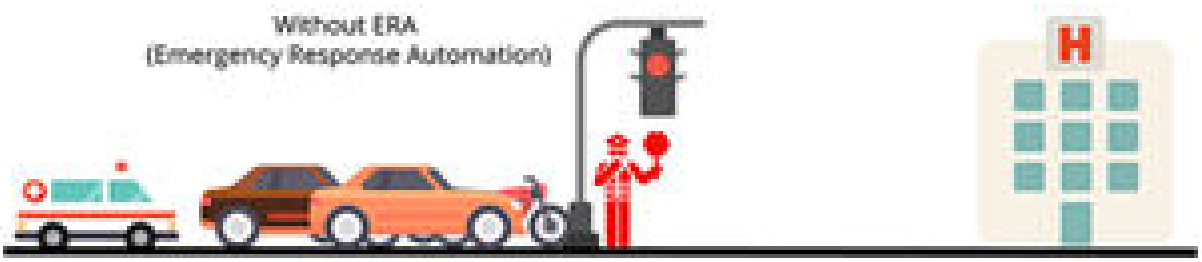

Figure 10. Current Emergency Response System (Pal & Pali, 2018).

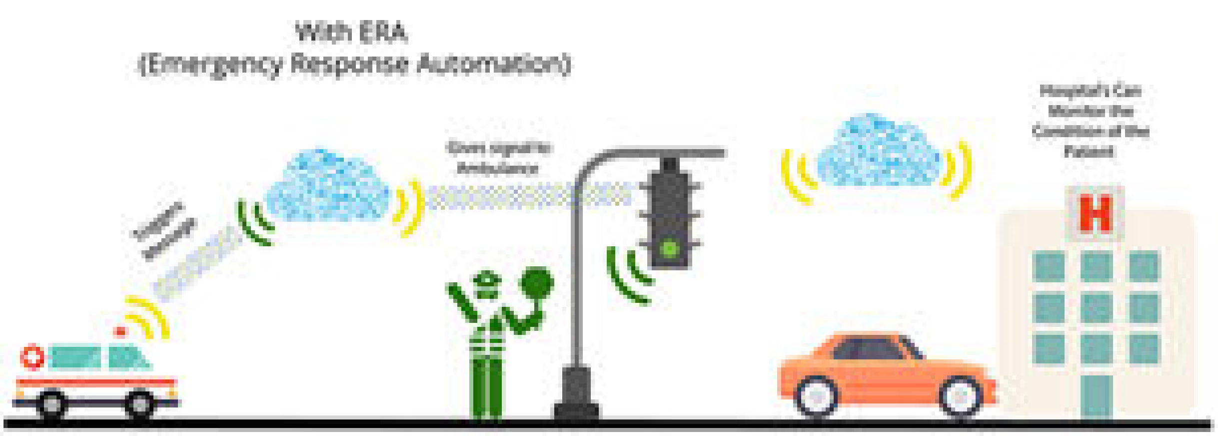

Figure 11. The proposed VANET-LTE based system (Pal & Pali, 2018).

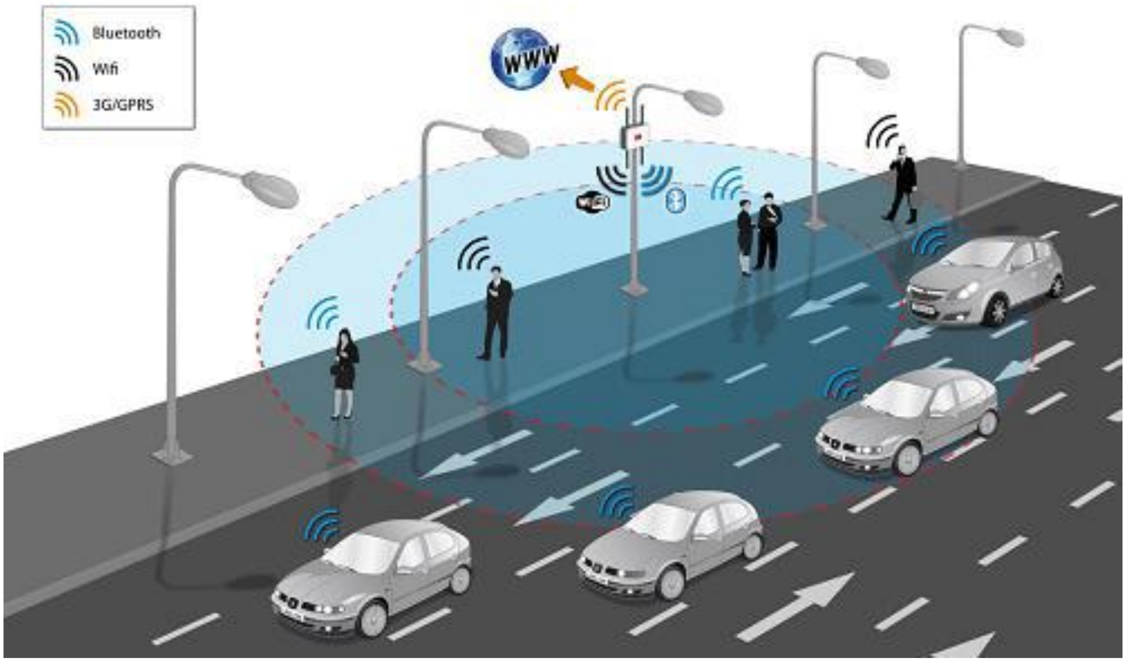

Figure 12. Using electric poles for connectivity between users and vehicles through Wi-fi and Bluetooth (Pal & Pali, 2018).

Figure 13. How an electric pole is made smart as an IoT gateway (Pal & Pali, 2018).

IoV technology

Hamid, Zamzuri, and Limbu (2019) reviewed the concept of Internet of Vehicle (IoV). IoV provides an improved connectivity between the driverless vehicles. IoV allows the vehicle to share data of sensory, risk, environmental perception and localization types and purposes. In addition, IoV also facilitates the interactions among vehicles, with the environment, pedestrians using vehicle-to-x (V2X). The autonomous vehicle are prevented from unwanted collisions, improved in its localization aspects, path planning and motion guidance. These will help to optimise the intelligent transport system to run smoothly and efficiently to reduce traffic congestions.

Research on IoV is mostly related to optimizing the mobility models and communication performance. However, interconnection of heterogeneous smart vehicles is becoming increasingly important in the realistic scenario. Wang, Jiang, Han, Ren, and Hanzo (2018) set up a weighted and undirected graph model for IoV sensing networks and verified its time-invariant complex characteristics using a real-world taxi GPS dataset. An IoV-aided local traffic information collection architecture was also proposed along with a sink node selection scheme for the information influx and an optimal traffic information transmission model.

Vehicles present on the Internet of Vehicles (IoV) can communicate with each other in order to determine the status of the road and vehicle in real time. These parameters are used to estimate the average speed and identify the optimal route to reach the destination. However,

The government traffic departments are unable to use the IoV traffic data. Therefore, traffic jam, congestion and road accident are not controlled. Kumar, Manogaran, Sundarasekar, Chilamkurti, and Varatharajan (2018) segmented the street maps into a small number of distinct maps. Ant colony algorithm was applied to each map to identify the optimal route. Fuzzy logic based traffic intensity calculation function was also used to model the heavy traffic. The proposed IoV-based route selection method was compared with the existing shortest path selection algorithms. Experiments gave good results for the proposed system.

Others

Makino, Tamada, Sakai, and Kamijo (2018) reported about how Japan had been implementing ITS nationwide using the vehicle information communication service (VICS) and the electric toll correction (ETC). It is based on the SMARTWAY concept using cooperative vehicle-infrastructure systems (V2I). A diagram of the SMARTWAY concept given by the authors is reproduced in Fig 9.

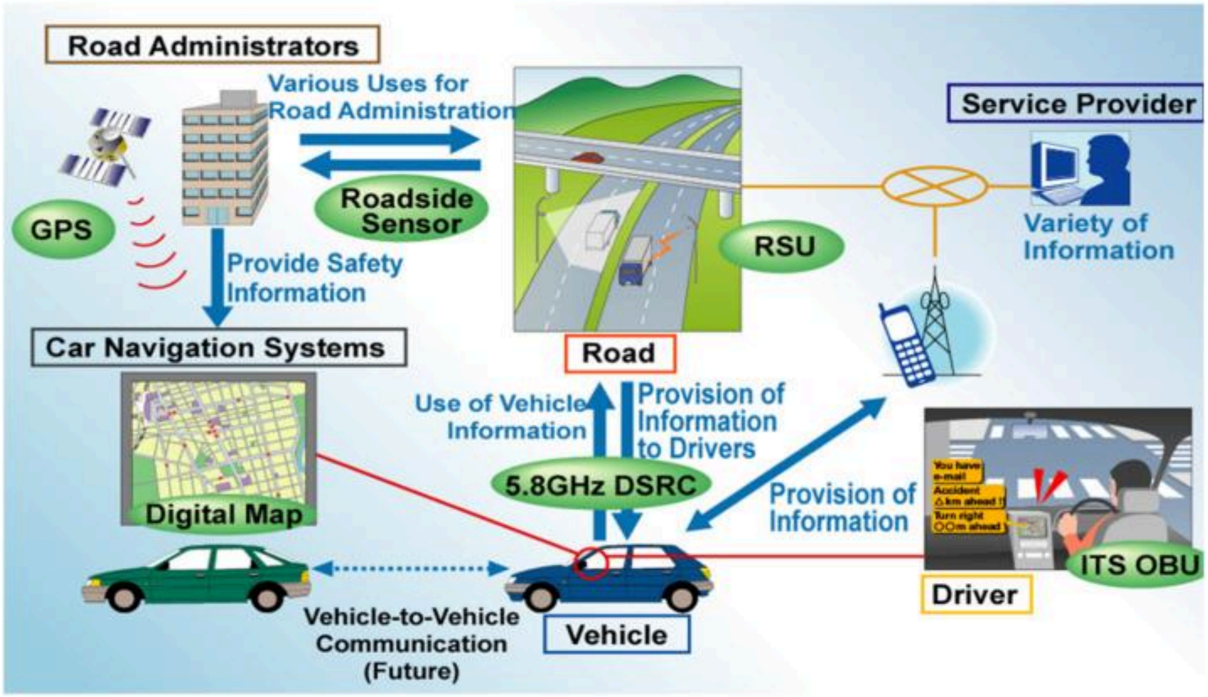

Figure 14. SMARTWAY CONCEPT OF ITS IN JAPAN (Makino, Tamada, Sakai, & Kamijo, 2018).

A novel project, ETC 2.0, combining VICS and ETC functions as an on-board unit (OBU) and with many added functions, was launched in 2011. ETC 2.0 has facilitated use of a variety of applications with high-speed, high-capacity communications. A dedicated short-range communications (DSRC) at 5.8 GHz has been used here. This system helped to solve many traffic problems. Features of this ETC 2.0 given as a diagram by the authors is reproduced in Fig 10.

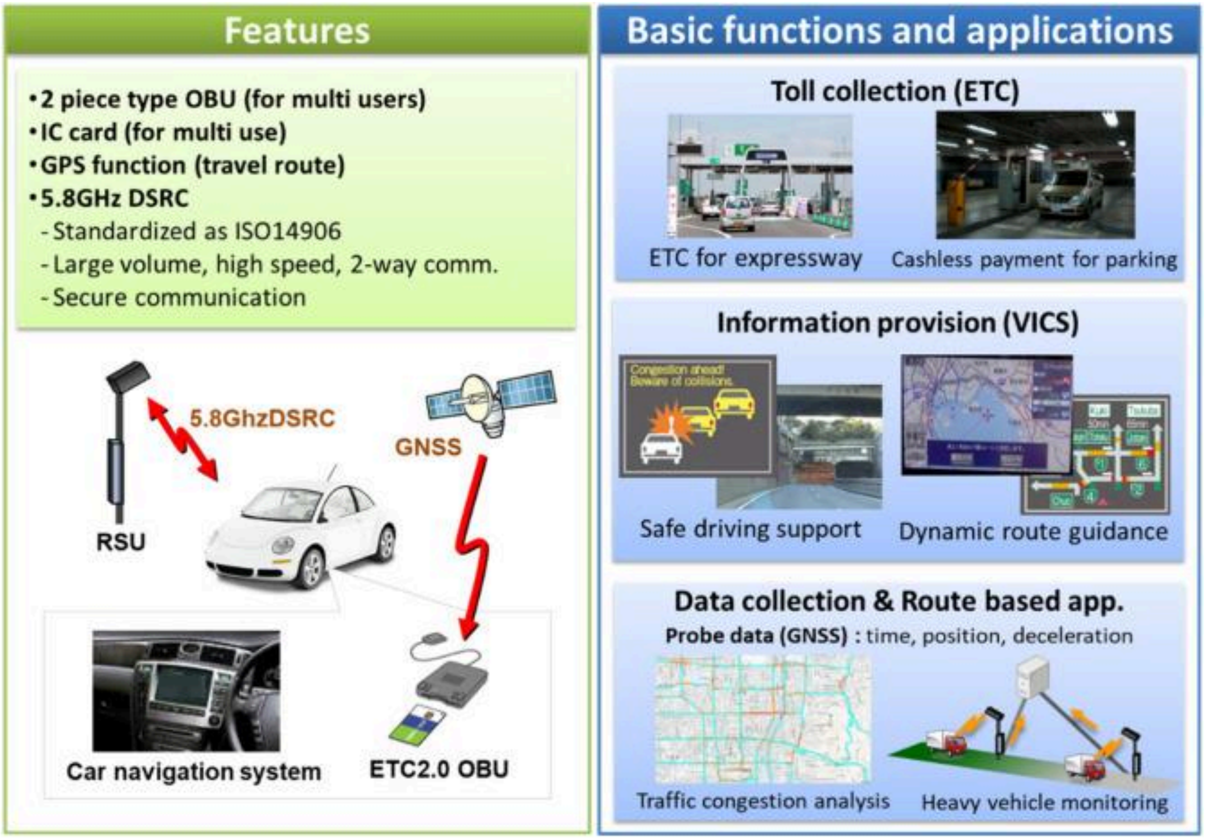

Figure 15. Features of ETC 2.0 (Makino, Tamada, Sakai, & Kamijo, 2018).

In ETC 2.0, vehicle information and personal information are separated and thus the security and privacy protection are made more efficient. The high-speed, high-capacity active DSRC at 5.8 GHz is capable of providing information required for safe driving as the area coverage is about 1000 km for traffic congestion information. It is certified as ISO 14906 and is compatible with conventional ETC. Recent advances in vehicular control technology include adaptive cruise control (ACC), lane keeping assist (LKA) and automatic braking. All these can contribute to actualisation of automated driving vehicles. To achieve automated driving vehicles, a combination of vehicle control technology and the ETC 2.0 information provision is required. This is shown in Fig 11, reproduced from the article. It can be seen that traffic congestion also is addressed by this system. The requirements of implementing ETC 2.0 have been listed by the authors. A conceptual illustration of ETC 2.0- ITS deployment, the physical architecture and the roadmap for implementation have all been diagrammatically explained by the authors.

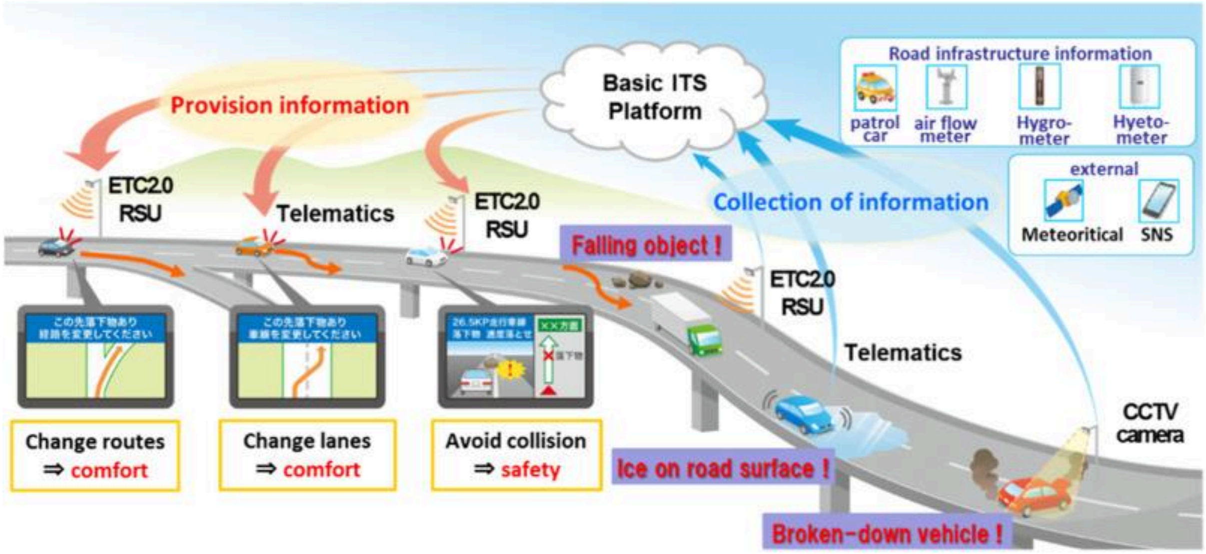

Figure 16. Automated driving with ETC 2.0 (Makino, Tamada, Sakai, & Kamijo, 2018).

There is need to include decision support systems for traffic management personnel in handling non-recurrent traffic congestions and related incidents. Ritchie (1990) suggested, a hierarchical model, which was based on artificial intelligence and multiple real-time knowledge-based expert systems (KBES). The system integration was done through a distributed blackboard problem-solving architecture.

Edge computing facilitates computing and storage facilities near end users as compared to the traditional cloud-computing- based infrastructure. Widespread popularity of unmanned aerial vehicles (UAVs) causes sharing of huge amounts of information between edge devices and UAVs. Traffic surveillance using UAVs and edge computing devices might become an essential part of the next generation ITS. UAVs can be used as an intermediary aerial nodes between vehicles and edge nodes and transfer data from vehicles to the edge for real-time analysis. Use of open channels can pose security problems for the data. Garg, Singh, Batra, Kumar, and Yang (2018) proposed a model for cyber threat detection in smart vehicles.

Lazar, Coogan, and Pedarsani (2017) developed two models for a traffic scenario of a mixed traffic profile, in which, some vehicles are smart and able to form platoons. The remaining are ordinary and manually driven. The models were designed for road capacity under this mixed autonomy. These models were based on the fundamental behaviour of autonomous technologies like adaptive cruise control. An optimal routing problem of mixed traffic for the first capacity model with two parallel roads was also framed. A case, in which, the aim is minimization of the social cost of the system with control over both regular and smart traffic flows was also studied. Another case was also studied, in which, only smart vehicles are controllable and the choice of routes by regular vehicles is by their own preference, according to the best response to the routing choice of smart vehicles. Numerical studies were used for validation of models.

To reduce congestion, an innovative technology, Intelligent Guardrails (IGs), was tested by Jabbarpour, Nabaei, and Zarrabi (2016). IGs use Internet of Things (IoT) and vehicular networks, in which, IGs sense the traffic condition and uses this information to dynamically set the road capacity.

An iNET framework was presented by Zaheer, Malik, Rahman, Zahir, and Fraz (2019). Wi-Fi Direct–enabled Android-based smartphones were used as embedded devices in vehicles. With the use of vehicular ad hoc network, route selection based on real-time data received from neighbouring vehicles was done in an ad hoc fashion. In this system, route selection support is provided in the absence of physical devices and internet connectivity. The framework provides implementations of commonly used route selection algorithms for congestion-aware traffic routing. A detailed analysis of time, energy, and memory consumption showed lower resource use, maximum CPU usage around, less memory and network bandwidth. There was significant reduction in travel time and due to congestion reduction. A representative diagram of V2X communication given by the authors is reproduced in Fig 12.

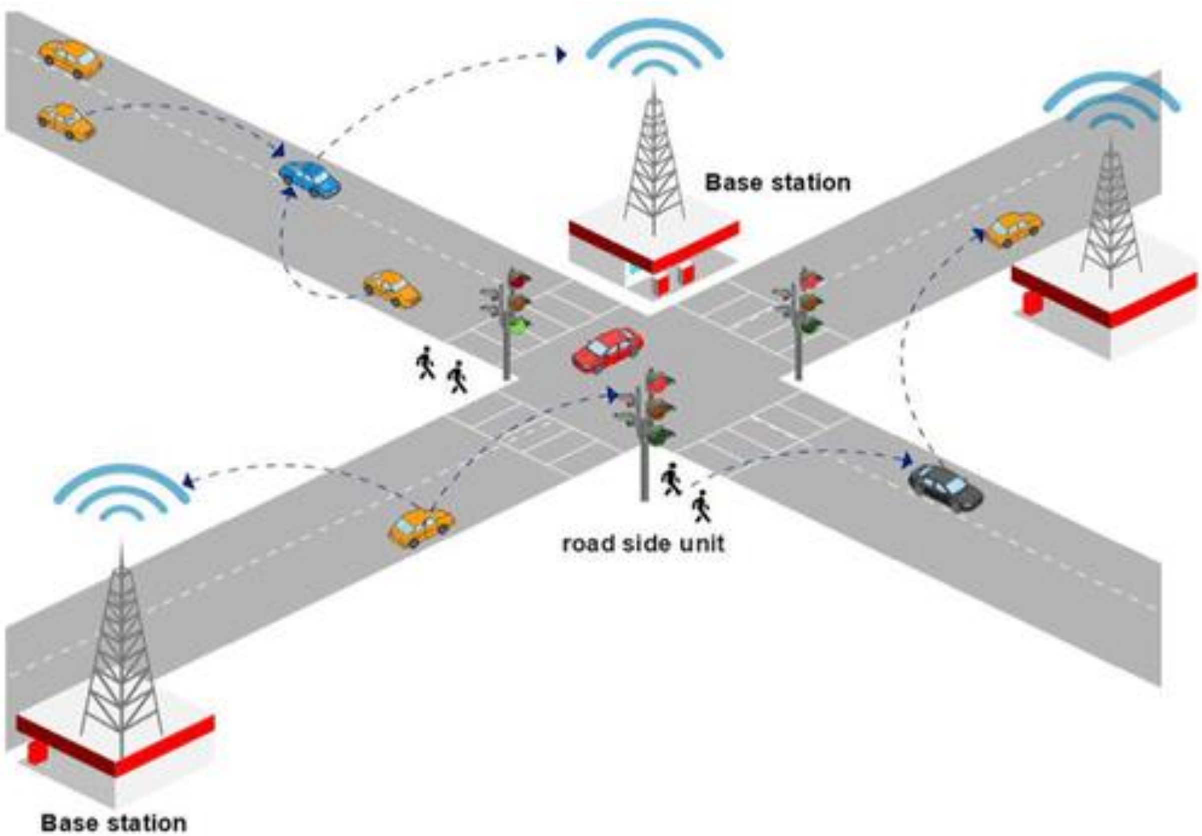

Figure 17. V2X communication scenario (Zaheer, Malik, Rahman, Zahir, & Fraz, 2019).

Balid, Tafish, and Refai (2017) reported on the development and implementation of a novel smart wireless sensor for traffic monitoring. It has high computational efficiency and reliable algorithms. These were used for full developed vehicle detection, speed and length estimation, classification, and time-synchronization. These were integrated, and evaluated. Comprehensive analysis of system evaluation and other data validated the system for its reliability and robustness in operation. Several field studies conducted on highway and urban roads for different scenarios and under various traffic conditions produced 99.98% detection accuracy, 97.11% speed estimation accuracy and 97% length-based vehicle classification accuracy. The system being portable, reliable, and cost-effective, it can be used for short-term or long-term use on surface of highway, roadway, and roadside. For implementation, a single node costs only about 50 USD.

Ahmed, et al. (2019) proposed a route suggestion protocol aimed to identify an optimal congestion aware route in the network. It considers both equipped and non-equipped vehicles to estimate congestion index formulation factored for driving distraction factors. Simulation results showed better performance of proposed protocol in effectively reducing travel time, if it works with IoV rather than the traditional route suggestion protocols.

Lenka, et al. (2017) proposed a scheme of real-time navigation service to the parking space which calculates a probabilistic emptiness value based on the Estimated Time of Arrival (ETA) to the location. This can be accessed using personal devices. This intelligent system reroutes to the next nearest parking space if the desired one is already filled while still on journey. The system has showed potential of reducing traffic congestion caused arising from searching for parking spaces.

Rath, Pati, and Pattanayak (2019) proposed an improved traffic control and management framework for automatic and efficient control of traffic congestion control using a mobile agent paradigm. The system performs even better if VANET system is already in place.

Advanced Traveller Information Systems are useful for trip and travel plan. An advance travel time prediction system is helpful to travellers, riders and transportation systems to reduce travel time and road traffic congestions through optimum trip generation. Azad, Akhter, and Hossain (2019) presented a smart travel time prediction system for an urban road network using a Long Short-Term Memory (LSTM) model assuming the traffic flow pattern as a continuous time series. It uses the historical travel time data collected from an observation route for a length predetermined through the Google Maps for past three 3 weeks at convenient time intervals. Predictions are possible one stop or mores stops ahead.

The following technological prospects of reducing traffic congestion were reviewed by Talib, Hussin, and Hassan (2017). The currently trending technologies are the ITS based VCC, Fog and IoV facilitate real-time responses to drivers. SDN paradigm delivers flexibility, low-latency and high-bandwidth communication. Integrating VANETs, 5G, SDN, MEC and VCC can provide enhanced vehicular networks to optimize traffic management. If these technologies merge in

ITS, the foundation for change towards the global automation environment can be laid. Roadside sensors and using electric posts for IoT gateways with cameras and information technology can sense and transmit real-time information on the vehicles' direction, speed, location, road state and weather conditions and stream data continuously. Design of different types of the 5G vehicular cloud networks will be the next step as 5G becomes increasingly popular.

To address the security risk problems of cloud computing, fog computing using local level fog servers and its integration with IoV for regional level CFC-IoV architecture was proposed by Zhang, Zhang, and Chao (2017). The four functions of mobility control, multi-source data acquisition, distributed computation and storage and multi-path data transmission, can be integrated in this manner. A hierarchical resource management will help performance optimisation.

Conclusions

The main points of this review can be summarised in the words of Talib, Hussin, and Hassan (2017) as, "Optimizing the traffic management operations represent an urgent issue in this era due to the massive increasing in number of circulating vehicles, traffic congestions and road accidents. Street congestions can have significant negative impact on the life quality, passenger's safety, daily activities, economic and environmental for citizens and organizations. Current progresses in communication and computing paradigms fetched the improvement of inclusive intelligent devices equipped with wireless communication capability and high efficiency processors. IoT will permit the evolution of the Internet of Vehicles (IoV) from existing Vehicular Ad hoc Networks (VANETs). In these days, cloud and fog computing approaches have been recognized for different applications of the fifth generation (5G) vehicular networks. The Software Defined Networking (SDN) has been recently considered as a flexible technique for linking wireless access networks and clouding computing (CC) centres in 5G vehicular networks. The inflexibility, short connectivity and non-intelligence shortages in VANET can be overcome now by integrating new emerging technologies. These emerging technologies are vehicular cloud computing (VCC), IoV, Fog computing, Network Function Virtualization (NFV), Mobile Edge Computing (MEC), SDN and 5G. Integrating these technologies can create new developed technologies and services. These technologies can play a crucial role in building the Intelligent Transport System (ITS). Achieving such dream by creating novel ITS will have a significant impact on traffic management and street congestions." (Abstract).

Limitations of this review

It may seem a systematic review would have been better. But such a review limits the references to briefly tabulate the findings rather than elaborate discussions as has been done here. To understand the different dimensions and factors involved, it is necessary to discuss the works individually and provide diagrams as the authors had given in their papers.

The search strategy was intended for quick identification of papers directly related. Other methods may be to try different search terms in databases and from the probable thousands of papers, select (perhaps the same number of papers) through filtering and screening. From that angle, the method used for selection of papers here is simple and more efficient.

Considering that different methods of presentation of results were followed in different paper and large amount of graphical results and mathematical equations were given, a meta-analysis seems difficult and complex by itself. So, it was not attempted.

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