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Real-Time Data Transfer Using VITP Protocol in Smart City Transportation System

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Abstract

Cars are the predominant means of mobility for millions of people globally. In light of the increasing popularity of this mode of transportation, it is imperative to build vehicle-to-vehicle communication in order to ensure the safety and satisfaction of the passengers. Developers built the Vehicular Information Transfer Protocol (VITP) as an application-layer communication protocol. Its purpose is to enable the establishment of a decentralized and spontaneous service framework across Vehicular Ad-Hoc Networks (VANET). It specifically tailors the protocol to address the unique challenges of the vehicular context, including dynamic changes in link topology resulting from fast vehicle movement, frequent network disconnections, the need for data compression and aggregation to accommodate limited wireless bandwidth, and the potential for partially predicting vehicular position due to vehicles typically following unchanged pre-existing roads over time. This study proposes the utilization of the Vehicular Information and Traffic Management Protocol (VITP) for the transmission of real-time data between vehicles and infrastructure in public transit systems. Utilizing this data can enhance the efficiency of public transit systems, alleviate traffic congestion, and enhance the overall passenger experience. The research also informed that the potential advantages of employing VITP for instantaneous data transmission in public transportation systems, including enhanced safety, diminished pollution, and heightened efficiency. Additional investigation is required to examine the possible uses of VITP in public transportation systems and to determine the most effective methods for adopting this technology.

Keywords: Component, Data Transfer, VITP, VANET, Smart City, Transportation

Introduction

The exponential growth of the human population in recent decades has presented numerous obstacles and necessitated the resolution of various problems. In terms of statistics, it took several hundred thousand years for the global population to reach 1 billion. However, during a mere 200 years or so, the population increased by a factor of seven. The global population hit 7 billion in 2011 and currently stands at over 7.9 billion in 2021. Projections indicate that it will increase to approximately 8.5 billion by 2030, 9.7 billion by 2050, and 10.9 billion by 2100 (UN, 2011). Furthermore, this resulted in a swift surge in the urban population and the number of automobiles on the roads.

The proliferation of automobiles globally has resulted in the exacerbation of traffic congestion and the occurrence of accidents. As per the World Health Organization, road traffic accidents are the primary source of fatalities due to injuries and rank as the tenth most common cause of death worldwide (Bohr & Memarzadeh, 2020). Approximately 1.2 million individuals lose their lives in car accidents annually, with up to 50 million sustaining injuries. These injuries account for 30 to 70 percent of the orthopedic beds in hospitals located in poor nations. Road traffic injuries are projected to account for the third most significant factor contributing to the worldwide burden of disease and injury by 2020, according to current patterns (Worley, 2006).

There has been a significant advancement in technology over the last twenty years, particularly in the fields of communication and information technology. This has led to the emergence of novel concepts and sectors that have played a crucial role in driving the progress of human civilization. Artificial intelligence (AI) and the Internet of Things (IoT) have emerged as popular areas of focus for researchers and developers. Consequently, the Smart City concept has emerged as a highly sought-after area for development and enhancement.
A smart city is a contemporary urban environment that employs diverse technological techniques and sensors to gather specific data. The data gathered is utilized to effectively oversee assets, resources, and services, thereby enhancing operational efficiency throughout the city (Fourtané, 2018). Smart cities employ the phrase "smart city" in several domains including urban planning, government, transportation, energy, environment, health, and education. Various technologies, such as the Internet of Things (IoT), mobile solutions, big data, artificial intelligence (AI), and blockchain, build the foundation of smart cities (Khang et al., 2023). Nevertheless, there are apprehensions regarding how smart cities will effectively tackle matters about data privacy and socioeconomic exclusion (Ismagilova et al., 2022).

Streets are crucial elements and essential conduits of a city, serving as significant navigational markers for the movement of its inhabitants (Mohammed & Ismail, 2021). Within the framework of smart cities, the Internet of Things (IoT) plays a vital role in gathering and examining data from many sources, including traffic sensors, air quality monitors, and energy meters. City operations are optimized, public services are increased, and the quality of life for inhabitants is improved by utilizing this data (Rai et al., 2023). IoT-enabled traffic management systems can mitigate congestion and enhance road safety through the provision of real-time traffic updates and alternative routing choices. Smart waste management systems can enhance garbage collection routes and schedules by utilizing the fill level of waste bins, thereby minimizing operational expenses, and enhancing effectiveness (Lingaraju et al., 2023).

In addition, smart cities employ various technologies to enhance the well-being of their residents. Smart lighting systems may optimize the intensity of streetlights by considering factors such as the time of day and the presence of walkers. This leads to a decrease in both energy usage and light pollution. Intelligent irrigation systems can enhance water use in parks and gardens by considering weather conditions and soil moisture levels. This results in a reduction in water waste and ensures that plants receive the appropriate amount of water (Kumar et al., 2023).

Smart cities have the potential to decrease carbon emissions and alleviate the impacts of climate change. Smart buildings can employ sensors and automation to efficiently utilize energy and minimize waste, as exemplified. Intelligent transportation systems have the potential to promote the utilization of public transportation and diminish the quantity of vehicles on the road, thereby mitigating traffic congestion and air pollution (Ryan & Gregory, 2019). Nevertheless, there are apprehensions regarding the potential adverse ramifications of smart cities. Concerns regarding data privacy and security, as well as the possibility of social exclusion, exist. Moreover, there are apprehensions regarding the possibility of smart cities aggravating pre-existing disparities, as certain individuals may lack the means or access to the necessary technology and resources required to derive advantages from these systems.

Communication is nerve of technology, and to keep up with the rapid expansion of information technology, a revolution in communication is necessary. Cars serve as the primary mode of transportation for millions of individuals worldwide. With the growing popularity of this method of transportation, it is essential to establish vehicle-to-vehicle communication to guarantee the safety and enjoyment of the passengers. The widespread presence of automobiles has resulted in the accumulation of traffic congestion and hazardous circumstances, hence augmenting the probability of accidents. The aforementioned factors have served as a driving force behind the creation of applications that facilitate driver decision-making and guarantee the safety of all those present in the vehicle. Moreover, these programs assist drivers in circumventing traffic congestion by selecting the most optimal route, thereby enhancing vehicle economy, and mitigating environmental repercussions. Constructing a vehicle-to-vehicle communication system will yield numerous advantages for occupants in terms of entertainment. This system will enable them to exchange music and films, engage with those traveling in other vehicles, and access information points along the road (Wang, 2016).

In the field of information and communication technologies (ICT), particularly in the area of road and vehicle technologies, the vehicular communication environment faces numerous challenges. These challenges arise from the nature of the environment, which is characterized by the frequent movement of vehicles, the limited or uneven distribution of vehicles, and the restricted communication between nodes due to the constraints imposed by the layout of highways and urban roads. Furthermore, we constructed and employed a unique communication model specifically for this instance (Albattah et al., 2022).

The integration of IoT in smart settings involves the interaction between wireless sensor networks (WSN) and mobile ad-hoc networks (MANET), resulting in increased appeal and economic viability. The integration of wireless sensor networks and mobile ad-hoc networks with the Internet of Things enables the development of novel MANET-IoT systems and IT-based networks. These systems enhance user mobility and decrease expenses (Alameri, 2018). Vehicular ad hoc networks (VANETs) are formed by implementing the principles of mobile ad hoc networks (MANETs)—the automatic establishment of a wireless network of mobile devices—in the context of cars. Vehicular ad hoc networks (VANETs) were initially mentioned and implemented in 2001 (Toh, 2001) and later received a more inclusive designation as inter-vehicle communication (IVC) in 2015 (Sommer & Dressler, 2014). Furthermore, it has emerged as a crucial component in intelligent transportation systems (ITS), smart cities, and several Internet of Things (IoT) applications (Figure 1).

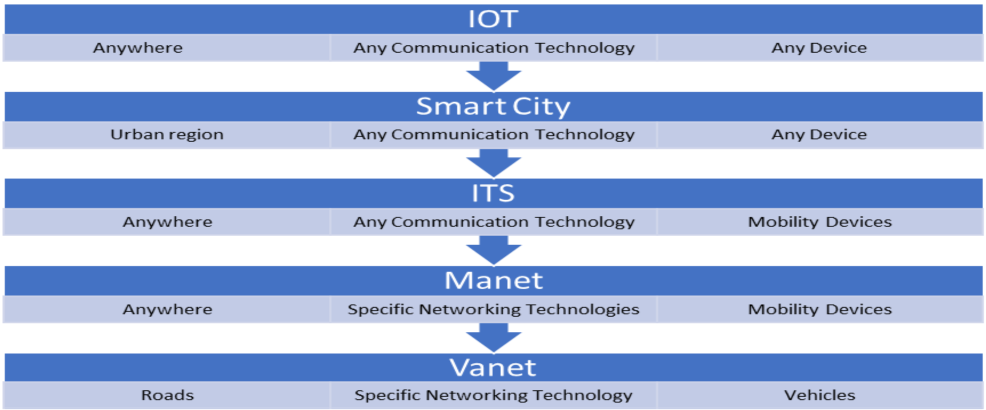

Fig. 1. Vanet in IoT.

Fig. 2.

Developers specifically designed the Vehicular Information Transfer Protocol (VITP) as an application-layer communication protocol to facilitate the creation of a decentralized, impromptu service framework across Vehicular Ad-Hoc Networks (VANET). The protocol is stateless and defines the structure and meaning of VITP messages. VITP peers in VANET use these messages to exchange location-based requests and responses. The VITP infrastructure enables the provision of location-based, traffic-oriented services to drivers by utilizing data obtained from vehicular sensors and leveraging on-board GPS navigation devices (Dikaiakos et al., 2005). According to Kazi and Khan, a Vehicular Ad-hoc Network (VANET) is a specialized type of wireless ad-hoc network that is commonly employed in automobiles and roadside equipment. It is utilized in a range of domains, such as ensuring passenger safety, implementing intelligent traffic solutions, and facilitating vehicle communication. VANET serves as the fundamental infrastructure for the Intelligent Transport System (ITS), facilitating wireless connectivity among vehicles (Kazi & Khan, 2021).

The protocol is specifically designed to tackle the distinct challenges of the vehicular context, including the rapid changes in link topology caused by the fast movement of vehicles, frequent network disconnections, the need for data compression and aggregation to accommodate the limited bandwidth of the wireless medium, and the possibility of partially predicting vehicular position due to vehicles typically following pre-existing roads that remain unchanged over time. The protocol facilitates the implementation of automotive services on VANET infrastructures. The VITP infrastructure enables the provision of location-based, traffic-oriented services to drivers by utilizing data obtained from vehicular sensors and leveraging onboard GPS navigation devices (Dikaiakos et al., 2007). Experts have suggested the protocol as a method to provide automotive services by implementing an expanded client-server computing model on the VANET. The protocol facilitates the creation of a decentralized, spontaneous service framework across VANET (Loulloudes et al., 2010). The emergence of IoT and smart cities has necessitated the development of technologies that can efficiently convey information and engage with users more dynamically. Therefore, it is imperative to collaborate with application layer protocols to create, expand, and advance the technologies used in smart cities (Syed et al., 2021).

Application layer protocols facilitate intercommunication among disparate devices. The application layer resides at the highest level of the OSI model and offers services to the end user. Application layer protocols fulfill various essential functions necessary for any application or communication process. Application layer protocols enable the transmission of data between diverse devices across a network. They offer a uniform method for software to transmit and receive data and convey significant information to users. There is a significant disparity between the number of protocols in the lower layers of communication compared to the protocols at the application layer. Furthermore, there is an even greater disparity between the amount of research conducted on network-layer communication protocols and the amount of research conducted on application-layer protocols.

VITP and HTTP are application-layer protocols that provide communication between diverse devices. VITP is an application layer protocol used in VANETs to facilitate communication in vehicular networks inside the Intelligent Transport systems. VITP is similar to HTTP, which is used for worldwide web browsing. However, it is specifically designed for limited network environments. Within the realm of smart cities, application layer protocols like VITP can facilitate the establishment of a distributed service architecture across vehicular ad-hoc networks (VANETs). VITP is a protocol that allows the implementation of location-based services on VANETs, considering the geographical position of the vehicles (Dikaiakos et al., 2005).

Research Methodology

The study employed a systematic approach to search for relevant publications, which involved multiple processes. These steps included the establishment of a protocol, filtering research papers based on their title, keywords, and abstract, and extracting data from the selected papers. We conducted a keyword search to identify relevant publications in the literature. The search was limited to scholarly research papers that had undergone peer review. The scope of our search encompasses the terms "Smart Cities," "VANET," and "VITP." We searched for these keywords using the Google Scholar database.

Google Scholar is an open and unrestricted web search engine that offers a straightforward method to comprehensively search for academic material. Through a single platform, you can explore a wide range of subjects and references, including articles, theses, books, abstracts, and court judgments. Academic publishers, professional associations, online repositories, universities, and other websites provide these sources. Google Scholar facilitates the finding of pertinent academic material from various fields of scholarly inquiry on a global scale (Gusenbauer, 2019). Hence, this database is valuable for efficiently searching and locating a significant fraction of the published peer-reviewed research papers in the field of smart cities research.

The researchers included only peer-reviewed works published in English, using the Google Scholar database. The writers thoroughly examined and processed all the papers and subsequently reviewed them based on their titles, keywords, and abstracts. Verifying their validity and relevance ensured that the research made a valuable contribution to the conversation on smart cities in the context of employing VITP. Applying the specified criteria, we found a mere six articles published within the past five years during the examination of the papers.

We extracted each study paper to gather information on the year of publication, the journal it was published in, and the names of the authors. Five different journals have published the chosen articles. The Security and Communication Networks journal published two articles, the International Journal of Scientific & Technology Research published one, the Scientific Programming journal published one, the Gedrag & Organisatie Review journal published one, and the Complexity Journal published one.

Literature Review

The use of VITP in traffic monitoring systems in smart cities

The Vehicular Information Transfer Protocol (VITP) facilitates the exchange of data between automobiles and infrastructure in vehicular computing systems. Its purpose is to facilitate the transfer of data in many media, encompassing voice, video, and text (Phull, 2022). VITP is an application-layer communication protocol specifically developed to facilitate a dispersed service infrastructure across vehicular ad-hoc networks, while also being capable of determining the location of vehicles. Dikaiakos et al. Illustrated the feasibility and efficiency of VITP in delivering location-aware services over VANETs (Dikaiakos et al., 2007). The existing body of literature has predominantly concentrated on the subject of the Internet of Things, which encompasses smart cities. Researchers study intelligent transportation systems and are primarily focused on communication levels, specifically the transport, network, and data connection layers. However, there is insufficient research on the investigation of application layer protocols, such as VITP. Table 1 displays the number of published papers regarding transportation communication in smart cities.

Table 1

The Number of Published Papers on Transportation Communication in Smart Cities

Keywords	**Number of studies***
“Smart Cities”	2,580,000
"Smart Cities" AND "VANET"	9,980
“Smart Cities” AND “VITP”	137

*Number of studies in Google Scholar

Compared to the revolution of studies about application protocols in normal networks, which contain thousands of application protocols to serve several purposes these days, there is a lack of studies about vehicular networks. For example, in normal networks, there are application protocols like HTTP to access data from the worldwide web, POP and SMTP for transmitting mail messages, DNS for translating IP’s and names, and many other protocols. In transportation communication, most of the studies focused on the lower communication layers, and very few studies focused on application transport data.

Currently, it is crucial to expand the investigation to the application layer environment. To meet the requirements of the next generation of apps that can analyze and process vast amounts of information on the network, communication must elevate from data transportation to information transportation. Vehicular Information Transfer Protocol (VITP) is one of the limited number of protocols that operate specifically in the application layer of vehicular transportation. The VITP protocol used in transportation communication closely resembles the HTTP protocol used for obtaining data from the worldwide web. By searching for studies on Google Scholar in the past 5 years, only 6 studies have acknowledged the potential of VITP in facilitating communication between vehicles in smart cities, offering both syntactic and semantic capabilities.

Phull stated that the push-based solution presented by VITP delivers alarm messages to vehicles as they approach the affected region. Upon detecting such a condition, a vehicle generates an alert message and transmits it across the VANET (Phull, 2022). Mahmood et al. stated that the Vehicular Information Transfer Protocol (VITP) is a communication protocol at the application layer that facilitates dispersed and ad hoc service infrastructure in VANET (Mahmood et al., 2021). Nampally and Sharma proposed utilizing the VITP (Vehicle Information Transfer Protocol) infrastructure to deliver traffic-oriented and location-based services to users. This would involve extracting information from embedded sensors in vehicles and leveraging the on-board GPS (Global Positioning System) navigation system (Nampally & Sharma, 2019). According to Phull et al, the creation of a distributed service infrastructure through VANETs is facilitated by a vehicular computing information transfer protocol (VITP), which defines the structure and meaning of communications between cars (Phull et al., 2022).

Advantages of using VITP in Traffic Monitoring Systems in Smart Cities

There are several advantages of employing Vehicular Information Transfer Protocol (VITP) in traffic monitoring systems within smart cities. The Vehicular Information and Traffic Protocol (VITP) can enhance traffic management in smart cities by offering location-aware services through car-to-car communication over vehicular ad-hoc networks (VANETs). The protocol specifically engineer's location-based services to assist drivers in navigating through traffic and evading congestion in VANETs. Moreover, the VITP protocol is versatile and can facilitate diverse data traffic flows among distinct components of smart city systems, including smart grid, smart home energy management, smart water, UAV and commercial aviation safety, and pipeline monitoring and control systems. The VITP protocol also offers a significant benefit to traffic monitoring systems by effectively mitigating traffic congestion and enhancing traffic flow in smart cities. The protocol facilitates the transmission of up-to-the-minute traffic data to drivers, enabling them to make well-informed route choices and steer clear of crowded regions. Implementing this solution can effectively decrease trip duration and enhance the overall efficacy of the transportation infrastructure in intelligent urban areas. Furthermore, using the VITP protocol has the additional benefit of enhancing road safety in smart cities. The protocol enables the dissemination of up-to-the-minute data regarding road conditions, accidents, and other potential dangers to drivers. This can aid motorists in circumventing perilous circumstances and minimizing the likelihood of collisions on the roadways.

Challenges of using VITP in Traffic Monitoring Systems in Smart Cities

The Vehicular Information Transfer Protocol (VITP) facilitates the exchange of data between automobiles and infrastructure in vehicular computing systems. Its purpose is to facilitate the transfer of information in many media, such as audio, visual, and written content (Dikaiakos et al., 2007). Although VITP offers numerous benefits, such as expedient data transmission, greater traffic control, heightened safety, and improved efficiency, it also presents certain challenges. VITP is susceptible to several security vulnerabilities, including eavesdropping, message manipulation, and denial-of-service attacks. These vulnerabilities can undermine the reliability, secrecy, and accessibility of data transferred using VITP. Moreover, VITP lacks interoperability with other protocols often employed in vehicular computing systems, such as the Dedicated Short-Range Communications (DSRC) protocol and the Cellular Vehicle-to-Everything (C-V2X) protocol. This can impede the capacity of VITP to establish communication with other systems and devices. Furthermore, VITP is dependent on wireless communication channels, which are susceptible to interference, signal weakening, and various environmental conditions. This can impact the reliability and accuracy of data delivered over VITP. Challenges of using VITP include also the scalability issues. The scalability of VITP may be limited when used with extensive vehicular computing systems, such as those present in smart cities. The reason for this is that VITP depends on ad-hoc networks, which might experience congestion and inefficiency as the quantity of devices and users grows.

Propositions

The proposed suggestion, derived from the preceding debate, could potentially serve as a foundation for future empirical study in the field of smart city communication and applications.

Proposition 1

Due to the disparity in their operational scope, Network layer protocols and application layer protocols exhibit differences. Network layer protocols operate at a higher level of abstraction and direct data packets between devices on a network, regardless of the specific application being used. However, application layer protocols tailor themselves to specific applications or services and facilitate communication between those applications and the rest of the network. By prioritizing application layer protocols such as VITP, it is possible to develop sophisticated software that serves as the foundation for traffic management, safety applications, environmental software, and service software.

Proposition 2

Another distinction lies in the manner in which these protocols manage data. Network layer protocols are tasked with managing data packets at a higher level of abstraction without much consideration for the precise substance of the data. Their primary focus is on directing data packets to the appropriate destination, rather than analyzing the content of the message. The interpretation and processing of the transmitted data is the task of application layer protocols. They may also encompass specialized protocols for encoding and decoding the data. This grants priority to application layer protocols in order to enhance the reliability and efficiency of software programs. Protocols such as VITP are inherently application-aware, location-aware, and stateless, which greatly enhances the functioning of informative apps.

Proposition 3

In smart cities, the presence of nodes with varying characteristics necessitates the use of specialized protocols to handle certain services. Additionally, specific sources can request transmitting sessions to one or more nodes, depending on certain criteria. The accomplishment of this task necessitates the utilization of sophisticated protocols that possess the capability to comprehend and classify the information they handle. Application layer protocols that are capable of handling data with information awareness may effectively manage transmission sessions and determine whether the data is relevant to the necessary session. They can then choose to either drop or transmit the data accordingly.

Conclusion
This paper offers a comprehensive analysis of the existing body of knowledge on smart cities, with a specific emphasis on vehicular communication, and a detailed examination of the application layer protocol VITP. This study serves as a comprehensive and relevant framework for academics and practitioners who are analyzing the various possibilities and capabilities of vehicular networks, specifically focusing on informative protocols. The VITP protocol, being a rare application protocol in this field, offers a wide area of study for contributors interested in working on smart cities and traffic-related fields. The examination of the current literature reveals a general deficiency in both quantitative and qualitative data pertaining to the implementation of smart cities and mobility systems. A significant deficiency must be addressed to achieve more efficient solutions that enhance the development of successful applications in various areas of smart cities, such as traffic management, emergency response, and environmental software.

Limitations and Future Research Directions
Currently, smart cities are only implemented in a small number of cities worldwide, restricting this study to a specific setting. As a result, these specific domains restrict practical study and development. Furthermore, while analyzing all the studies completed in this sector, it is evident that there is a dearth of research on the vehicular environment. This poses a significant difficulty for developers in this field. Regulations in most regions and locations may be a hindrance, as this information and systems could be deemed sensitive data, potentially infringing upon privacy rights. This will restrict the capacity to engage in career or academic pursuits within the framework of government oversight.

Understanding other communication layer protocols is essential for studying and working on application layer protocols like VITP. The role of the application layer protocol is to facilitate interaction between users and applications rather than directly transmitting data in the network. This will necessitate greater exertion from the researchers in their study of this subject. The significant progress in the technology infrastructure of smart cities has led to several instances of smart city implementation. Nevertheless, to guarantee the acquisition of advantages at both the local and broader levels, encompassing regional, national, and global dimensions, The existing challenges related to heterogeneity, lack of communication protocol and standardization, and the predominantly proprietary and closed nature of smart city infrastructure hinder intercommunication between different smart cities. In order to facilitate communication, it is imperative to address these concerns (Allam & Jones, 2020).

A network of smart cities would significantly enhance the predictive capability of environmental models, resulting in clear advantages for urban residents. This would also facilitate the development of proactive policies at regional, national, and international levels, which would involve regulatory, legal, economic, and broader research implications. Additionally, it would enable the implementation of large-scale countermeasures. Future research should investigate and draw lessons from the effective implementation of citizen-centric services enabled by information technology (Ismagilova et al., 2022).

The Theoretical and Contextual Contribution of the Research
The research on Real-Time Data Transfer Using VITP Protocol in Smart City Transportation Systems makes significant theoretical and contextual contributions to the fields of vehicular

ad hoc networks (VANETs) and smart city infrastructure. Theoretically, it introduces and validates the Vehicular Information Transfer Protocol (VITP) as an efficient solution for real-time data exchange in dynamic urban environments. By addressing critical challenges such as latency, scalability, and reliability in data transmission, the study expands the existing body of knowledge on communication protocols tailored for smart transportation systems. It provides a robust framework for integrating VITP with emerging technologies like IoT and AI, offering a theoretical foundation for future innovations in intelligent transportation networks. Contextually, the research is highly relevant to the development of smart cities, where efficient data transfer is essential for optimizing traffic flow, reducing congestion, and enhancing public safety. The findings demonstrate how VITP can be applied in real-world scenarios, such as adaptive traffic signal control, emergency vehicle prioritization, and real-time route optimization, making it a practical tool for urban planners and policymakers. By bridging the gap between theoretical models and real-world applications, this research contributes to the broader goal of creating sustainable, connected, and intelligent urban ecosystems, thereby playing a pivotal role in advancing smart city initiatives globally.

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