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**ORIGINAL RESEARCH ARTICLE**

# The 5G revolution: Tackling challenges in smart cities and intelligent transportation systems

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## ABSTRACT

The use of cutting-edge technology and data systems to increase the effectiveness, safety, and environmental responsibility of transport networks is known as intelligent transportation systems (ITS). In order to improve many elements of transportation, ITS incorporates a wide range of technologies, including sensors, communication networks, data analytics, and robots. By addressing the shortcomings of the current 4G network, the next mobile technology, 5G, challenges the electronic communication environment as it stands. By allowing a large number of concurrent connections and networks ubiquitous, even in high mobility scenarios or densely inhabited places, such Smart trains and smart cities (SC) are made possible by cutting-edge technology a new approach of becoming fully integrated. According to this strategy; 5G will enable the true Internet of Things (IoT) and its related automobiles on the World Wide Web (WWW). This conversation attempts to thoroughly explain how 5G wireless networks will impact urban smart transport networks, including semi-autonomous or self-driving cars, and automotive communication over the coming years, as well as any technical, economical, and regulatory issues.

***Keywords:*** 5G; vehicular communications; IoT, Smart city; autonomous driving; intelligent transportation systems (ITS)

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## 1. Introduction

The idea of a SC is to get better condition of life by learning from information gathered through connected sensors, gadgets, and people. Utilizing data to increase efficiency can help address persistent urban concerns including safety, disposal, travel, and traffic. To achieve this, every record needs to be kept in a place where it can be readily obtained and utilized by all parties, both governmental and corporate[1]. The online service will assist in removing the intergovernmental silos that prevent departments from communicating with one another and comprehending the data-based goals of other departments. This situation is thought to be a major impediment to the growth of SC. The continuous existence about the IoT has significant security risks; therefore, cybersecurity is another important component of the recently launched item. The Software-as-a-Service (SaaS) distribution system is the foundation of the idea of a Smart City, which focuses on cloud interoperability and networking scenarios. This strategy has the potential to save capital and infrastructure expenses while increasing the effectiveness of providing services within the context of smart cities. SaaS is delivered via the Internet, doing away with the need to install and run the application on private servers, streamlining maintenance, and allowing users to access applications online via the IoT from any part of the entire globe. The IoT may be implemented across automated transportation systems and SC in order to provide a cutting-edge framework for creative uses[2]. But there are also a number of concerns and challenges that occur. Intelligent transit systems for the purpose of promoting the goal of a smart town. The result is, the latest developments in intelligent and intelligent transport systems for IoT-enabled Smarter Cities which take into account both the initial development of algorithms and new applications are the main emphasis of this Special Issue. The nine original studies presented in this compilation make up an additional collection of work. A block chain-based sustainable GCU application system for smart mobility[3]. The findings indicate that addressing social issues is the key link, that financial tasks are mainly concentrated on smart contracts and impacted by issues of society, that addressing interpersonal gives is necessary for continual enhancement of sustainability, and that a block chain-based system for intelligent transportation has to be built from three levels, including the government layer, the organization layer, and the consumer layers. A computerized and physical system for controlling traffic signals on metropolitan roads. With the help of this suggested system, managers and researchers will be able to build and simulate a variety of traffic situations, develop and optimize novel control methods quickly, and adapt efficient control strategies to real-world traffic control[4]. The system's security, reliability, scaling, practicality, quick action, and validation of the new control strategy have all been demonstrated during a one-year trial in Weifang City, Shandong Province, China. In the setting of innovative banking, a somewhat thorough index for the assessment of supply chain financial danger has been developed, implementing into consideration economic circumstances, social benefits, business features, and other signs connected to the assessment of availability network financial risk[5]. This system serves as a trustworthy a reference for determining the goal fulfillment of multi objective measures[6]. In conclusion, we think that the articles in this compilation significantly expand the scope of recent developments in smart transportation systems for cloud-enabled SC and that this study area offers a theoretical and practically broad task[7].

## 2. Related works

The study[8] examined thorough literature assessment of the IoT paradigm's major characteristics and uses. Together with additional technology enablers like robots, computers in the cloud, radio-frequency identification (RFID), wireless communications (WC), and micro-electromechanical systems (MEMS), and the coexistence of IoT solutions is prioritized. The study[9] demonstrated the Smart city health-related studies Japan's Kashiwanoha Smart City. It looks at how efforts to promote better health and wellbeing have expanded the scope of smart city initiatives outside advances in technology to have a noticeable effect on residents' way of life and increase their social relevance. The study[10] provided a thorough analysis of how block chain supports IoT-based smart cities. Initially, it outlines how block chain technology has developed in terms of its underlying methods, agreement formulas, and platform architectures. The study[11] presented a thorough classification of ITS Safety and privacy concerns. In addition, we explore difficulties in tackling a security and safety issue in ITS and thinks about alternative mitigating methods. In order to make ITS more secure, private, and safe; we outline possible directions for future studies. The study[12] analyzed autonomous shuttles (AS) are starting to be considered as an updated transportation aid within the city's core, because there are no tiny alleys readily covered by conventional buses. As well as lowering noise and pollution, they enable them to carry out crucial tasks with little additional infrastructure. The study[13] demonstrated current state of the art approaches of safe AD, within its key accomplishments and limitations, and emphasizes the strength of regarding reliability and scalability effective performance in real time. The study[14] examined thorough literature assessment of the IoT paradigm's major characteristics and uses. With other technologies that enable like the cloud, automation, MEMS, WC, and RFID, the coexistence of IoT solutions is prioritized. The typical system's centralized design causes safety issues including centralized fraudulent attacks. Therefore, if it is attacked or manipulated by the competitor, the risk of data leakage could arise. Since there are more IVs every day, maintaining a single cloud database cost more money and takes longer as a result[15]. The potential impact of smart city methods and instruments on environmentally friendly urban development is examined in this article. The relationship between smart and sustainable cities has to be investigated more methodically, with a focus on real-world applications that could help people grasp the included areas, types, and design principles. The article intends to fill the gap in knowledge. The study[16] presented the results of an in-depth investigation of current papers on big data principles as well as uses in the transportation industry. Examining and comprehending the latest results as well as the benefits and drawbacks of employing big data and analytics in the logistics industry are the study's main goals. The study[17] developed a by combining the research on technical advancements in the public sector and on government, public government views on intelligent cities. The key theoretical idea of data polis is how actors, rules, and games of urban government may be used to explain why intelligent cities are built. The paper[18] suggested alternative TSC system that uses Q-learning (QL) to balance the signals on the roadways and maximizes the number of cars that can cross an intersection. The suggested solution features a flexible structure that can be adjusted to fit modifications in the intersection's initial configuration. The study[19] outlined a full examination of privacy and security concerns in intelligent cities, there is, also a category scheme for the most recent and foreseeable developments in this area. The article[20] performed a field investigation on Italian metropolitan towns to determine whether and how much the Smart City paradigm, when applied to the mobility sector, may improve urban areas' productivity and livability.

# 3. Analysis

## 3.1. 5G for smart cities

With an emphasis on ease, repair, and environmental responsibility, smart towns aspire to maximize the efficient utilization of public assets while lowering the operating expenses for governments within an IoT environment. **Figure 1** shows what an IoT-based intelligent town should look like. IoT-based projects for SC can generally be divided into four main groups, as demonstrated in. The first category, Individual and Home Apps, contains pervasive and linked home products that are used in e-healthcare services that allow physicians to keep tabs on patients from a distance. The subsequent category, services programs, covers monitoring for smart water networks, public security, video-based monitoring, air quality, and rescue services. Industrial Applications, the final one category, often comprises of a network in manufacturing setting. Final area focused on Mobility Apps, or more generally ITS. The final category contains novel ideas like traffic management, vehicle networks, self-driving cars, and congestion alleviation, and more.


**Figure 1.** Representation of an IoT-based SC, while each service is associated with the grid[21].

There were numerous research initiatives on the topic of integrating 5G technology in addition to IoT service into SC surroundings, several of that were supported with business and various by academic institutions. Here, with a focus on mobile applications, we'll go over a few of the more successful strategies for every kind of program.

### 3.2. Personal and home applications

A tiny proportion of persons currently own an exercise gadget, referred to as a tag gadget, but there are various opportunities, and 5G is expected to increase the use of intelligent tag technology. Future 5G devices will be entirely interconnected in contrast to today's models because they won't require smart phone's for accessing the worldwide web. Businesses like the company are creating healthcare but sports equipment that not only tracks workout results and offers advice for workouts, but also transmits the user's important health data to a specialist in immediate form to prevent or monitoring medical crises. Additionally, 5G is anticipated to make residences more intelligent over time through safety distant camera tracking and management and wireless-controlled door locks, as well as relief voice commands, control from afar utilizing a thermostat legislation, and smart phones, shown in **Figure 2** for further details.


**Figure 2.** The IoT includes all smart home features[22].

### 3.3. Utilities applications

Monitoring every aspect of a city's consumption of electricity with the aid of 5G for urban IoT may be possible., giving authority access to vital and in-depth data on the amount of power needed for the many municipal operations. By doing so, it will be feasible to identify the main sources of power and develop measures to increase urban efficiency in energy use. Furthermore, to the financial gain of maximizing the availability of energy, 5G is anticipated to contribute to safety for society by enhancing criminal identification and surveillance or by preventing deaths with disasters and crisis intervention. Cameras for surveillance and computer vision methods can be used to prevent suspicious baggage in airports, criminal activity, and crime verification. Safety for the public professionals will be alerted of the status of hazards when they are spotted using a 5G fast connection, which may help to coordinate reaction measures. Additionally, proposes a surveillance system that, upon recognizing an established criminal's face, even though there is still not an offense performed will take live images and communicate the precise position to neighboring police departments.

### 3.4. Industrial applications

Recent technological innovations like big data and internet-based computing, artificial intelligence, and 5G, have grown exponentially, piquing the business community's interest in integrating information and communication technology (ICT) in the manufacturing area. The integration of ICT and industrial machinery creates chances to boost productivity, cut waste, boost productivity, and enhance the atmosphere of work in a manufacturing setting. IoT holds huge potential for the agricultural industry in particular. Sensors with internet access can help farms develop as much as possible while requiring little water and fertilizer. Animals, businesses, and other farm machinery can all be remotely monitored to cut expenses and increase productivity.

### 3.5. Mobility applications

When dealing with classification issues, there are generally an excessive number of characteristics upon which to base the ultimate category. Basically, these components are traits, which are variables. More features there are, the harder it is to imagine a train set and a test set on it. The majority of the traits are often connected and hence redundant. In this case, dimensionality reduction methods are beneficial.

Urban automobiles have become more and more into mobile sensor platforms that tell drivers about their surroundings and may eventually be transmitted to the public internet. A network of self-driving automobiles that share information with one another in order to optimize certain tasks will have access to the information collected by sensors. Vehicles would then add another includes a device with connection to the internet. Self-driving vehicles should cooperate whenever possible to manage fewer holdups and more effective transport, fewer emissions, and more improved rider and driver convenience. To prevent disasters, for example, the network of cars must be able to manage evacuations of dangerous areas swiftly and effectively. This demands that they be able to communicate with other people as well as that they have access to tools like paramedics, police cars, or the information of escape routes, as shown in.

Still, it is challenging to concurrently supervise hundreds of thousands of automobiles, current 4G systems fail to deal with a high device density. To do it, more essential characteristics like inconsistency and service quality required. For instance, it would take a car with 4G around 1.5 m to apply their brakes. While a 5G-equipped automobile would just need 2.5 centimeters to do so, preventing disasters. A 4G connection also breaks down when a car drives into a densely populated or low-coverage area. In principle, a 5G connection will never lose coverage, allowing you to maintain an adequate connection wherever and at any time. Vehicles thus play a crucial part in achieving the goals of IoT and intelligent cities, leading to Internet of Vehicles (IoV), and are focused on interactions not just between vehicles but also among persons, towns and even states. The rest of the piece will discuss the theoretical framework of smart towns in this context with respect to automobiles communication, pointing out the drawbacks of present the internet, the need for 5G for ITS, and the impact of concepts such intelligent navigation and autonomous vehicles on the environment and society.

### 3.6. Fifth-generation (5G) networks for IVS

The number of automobiles on the highway keeps growing gradually. By 2030, it is anticipated that they would consist of more than two billion people. This is a result of global gentrification, where the United Nations predicts that by 2050, up from only 12% in 2013, 21% of humanity would reside in city. The latter highlights significant issues that must be addressed, including the rising number of fatalities from automobile crashes and the deteriorating global natural environment. Applications should be prioritized that have the ability to increase safety, energy savings, congestion control, and riding convenience, it is for the foregoing reason that the concept of ITS is crucial to solving the challenges of transportation using ICT, as mentioned in.

## 4. Vehicular communication

A smart car is now a sensors platform that gathers data from surroundings. An on-board machine analyzes this data, which is then applied, between other things, to navigation, pollution control, and traffic enforcement. However, a very potent on-board processor is necessary to accomplish quick data interpretation. The elevated cost of expensive automobiles with driver aid systems is due to this. It ought to be possible to upload cloud storage for data over using the World Wide Web conduct high processing workload in order to minimize the usage of costly machinery. In order to supplement the data already gathered by automobiles, IoT can help traffic control centers obtain additional data. This presumption makes the Mobile computing paradigm a challenging environment to test possible capabilities for 5G. Vehicles can communicate data among each other, with pedestrians, with wayside facilities, with the World Wide Web, and with each other in an intelligent town.

### 4.1. Autonomous driving

In theory, levels 1 and 2 of self-driving cars, in which an actual driver observes their driving surroundings, are compatible with V2X connectivity. Level 5 sans any assistance from cellular networks, or one that relies solely on on-board processor and sensing structures, is not, nevertheless, practicable. Ambiguity has to be considered in the absence of vehicle interaction because it is hard to anticipate what one particular or another vehicle will do in the next few seconds. If automobiles communicated what data they are entitled to, it might assist motorists feel less apprehensive. Local V2V communication can therefore make self-driving cars nimbler to movements and prevent collisions. Cooperative collision avoidance is a well-known application of autonomous driving. According to the European Union, junctions were to blame for 20% of deaths over the previous ten years. After the all other traffic safety measures where unsuccessful self-driving cars must communicate with one another so as to initiate measures and prevent collisions. When here is a potential of collision in unexpected and complex surroundings, vehicles are unable to make decisions on their own since a variety of actions chosen without previous planning may lead to additional collisions or unmanageable conditions. As a result, all involved vehicles should work together to identify the most effective collision prevention strategies.

### 4.2. Tele-operated driving

In extra modes for driverless and supported navigation, it is anticipated that self-driving cars will also be able to be handled remotely via an automated mode. This is helpful an autonomous operation occurs malfunctions or when human aid is needed in a challenging and dangerous situation. As traveling occurs from a distance, it is safer for drivers to operate in hazardous areas like mines or robotic fish.

### 4.3. Road safety

Due to increased car industry competitiveness and the popularity of electric mobility, the production of fully autonomous cars is increasing quickly. However, certain possible uses do not require a high degree of automation. Information through on-board detectors like webcams or lasers may be sent to the cloud, where alert applications can be sent to the operators. It is expected that vehicles are going to utilize local V2V and worldwide V2X interactions to make driving safer, more efficient, and more enjoyable in this scenario. This is because the vehicle will be able to anticipate potentially hazardous conditions, even if they were previously out of view due to a bend in the road or another vehicle ahead. This will be made achievable by employing communication technology known as V2V to exchange data with neighboring automobiles.

## 5. Result and discussion

### 5.1. QoS metrics

The **Figure 3** displays the complete delay of Cooperative Awareness Messages (CAMs) for the hypothetical case. The discrepancy from step-10, the data payload is transferred to the software layer at the receiver and end-to-end delay is known as a delay from end to end. At various Tx-Rx distance lengths, the delay from beginning to end stays below 2 ms with a security measure. End-to-end latency increases when the ECDSA-256-SHA-256 technique is utilized about CAM digital signatures appropriate with added the packet latency in addition to assurance processing time. A speedier processing causes a total delay of 8 ms, while slower safety causes a delay of ninety ms. Fast security (FS) results in a complete delay that is closer to the scenario where no encryption is employed because the verify method only takes a little over 1ms of time, which prevents overcrowding of the safety backlog at the point of receipt.

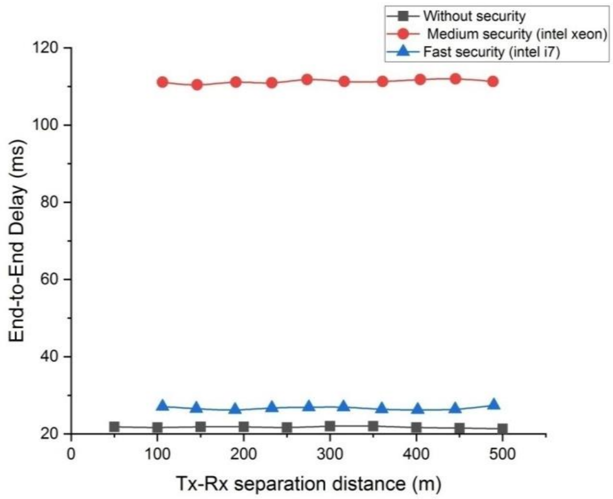


**Figure 3.** End-to-End Delay across various security levels.

In **Figure 4**, we show the CAM's packet delivery ratio (PDR). The findings indicate that over Tx-Rx space of 300 m, PDR for alerts sans safety procedure maintains up to 0.8. Losses are a result of collisions brought on by a large number of cars transmitting signals at once. A decrease in the transmitted signal strength is an additional factor of packet loss. The PDR further decreases through higher packet overhead and security processing time when the safety process is applied. The PDR is equal to 0.48 for Medium security (MS), and it rises to 0.22 for high-speed protection.

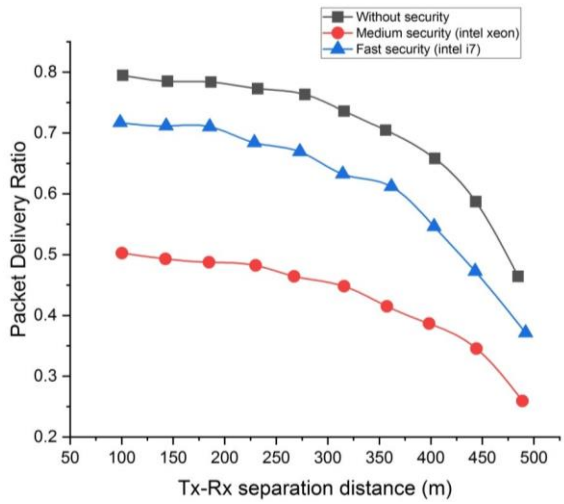


**Figure 4.** PDR at different levels of security.

### 5.2. Security metrics

The **Figure 5** shows the effect of security on safety messaging. To sending a packet requires delay for security measures raise packets expenses, that raises channel occupancy times. Additionally, dependent on the processor's speed, it requires some delay to check the packet's information. Dangerous alerts need to wait in order to verified as a result. As a CAM could not be validated within a 100 ms expiry period, it is dropped a queue and is referred to as a cryptographic loss. The cryptographic loss ratio (CLR) is the amount of those incoming to the queue for confirmation to packets that are drop to delay. The CLR of CAMs is 0.33, as can be seen in **Figure 5**, and it depends on the Tx-Rx separation distance. It makes sense that security speed would be inversely related to the CLR. Since of the quick security velocity, CLR is less than 0.01 since packets incoming at the recipient's safety line don't require waiting around for a while.

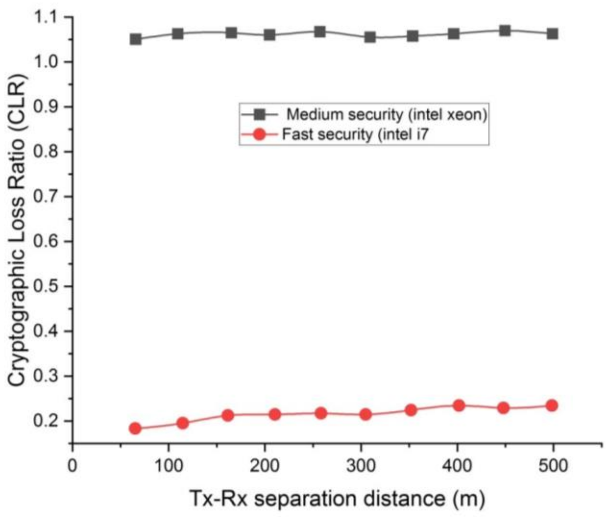


**Figure 5.** CLR at different levels of security.

### 5.3. Success rate

At various levels, the effectiveness of security features in SC and ITS ranges. The achievement value is 75% without security (WS). Achievement value reduces to 56% with MS for decryption and encryption. The achievement percentage of the FS system is 57% shown in **Figure 6**.

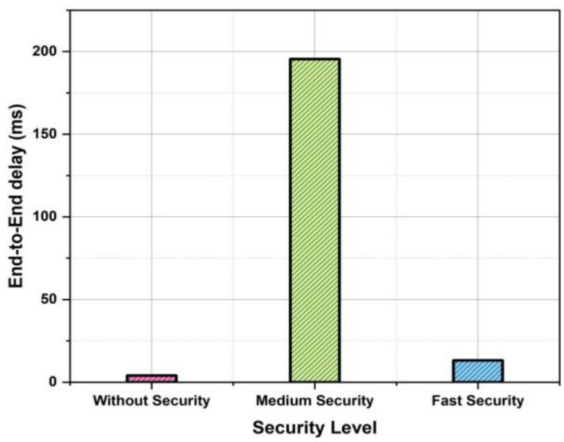


**Figure 6.** Graphical representation of end-to-end delay.

### 5.4. End-to-end delay

A minimal delay of only 4ms is achieved WS measures, providing quick data transfer and real-time responsiveness. There is an alternative with security and latency while more layers of security are added to including the MS with a median delay of 195.4 ms and FS with a delay of 13.2 ms shown in **Figure 7**.

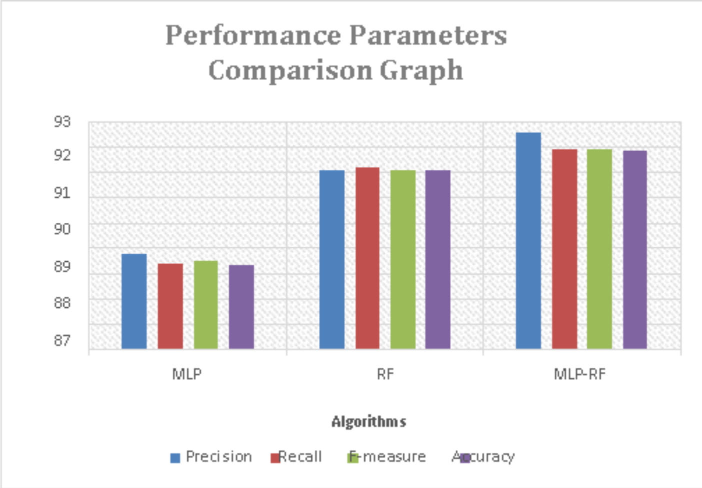


**Figure 7.** Performance parameters comparison graph.

### 5.5. Delay inter-arrival times for packets at various security settings

The packet inters arrival time is shown in **Table 1** to calculate the interval between successive CAMs among the similar level correspondent. An inter arrival delay that is closer to the number is regarded as more desirable since CAMs are broadcast every 100 ms. In fact; the packets inter-arrival duration is under 200 milliseconds while there is no usage of security measures. The inter-arrival duration is increasing through the initial value of 100 ms as a result of lost packets among collision and departure.

**Table 1**. Packet inter-arrival time.

| Tx and Rx separation distance (m) | Packet inter-arrival time | | |
|---|---|---|---|
| | **Without security** | **Medium security** | **Fast security** |
| 50 | 120 | 190 | 120 |
| 100 | 121 | 192 | 123 |
| 150 | 125 | 197 | 130 |
| 200 | 127 | 200 | 135 |
| 250 | 130 | 205 | 139 |
| 300 | 131 | 220 | 147 |
| 350 | 135 | 231 | 159 |
| 400 | 140 | 250 | 165 |
| 450 | 155 | 260 | 195 |
| 500 | 200 | 300 | 225 |

### 5.6. Safety awareness level

It possessed by two processors used in simulations is compared in **Table 2**. While the FS is employed, the safety awareness is increased to 0.62 at a distance of 300 m, although while MS is used, the safety awareness remains at 0.4.

**Table 2.** Safety awareness level.

| Tx and Rx separation distance (m) | Safety awareness level | | |
| --- | --- | --- | --- |
| | **Without security** | **Medium security** | **Fast security** |
| 50 | 0.79 | 0.491 | 0.7 |
| 100 | 0.78 | 0.45 | 0.68 |
| 150 | 0.77 | 0.441 | 0.67 |
| 200 | 0.76 | 0.42 | 0.66 |
| 250 | 0.74 | 0.418 | 0.64 |
| 300 | 0.71 | 0.4 | 0.62 |
| 350 | 0.7 | 0.39 | 0.58 |
| 400 | 0.68 | 0.37 | 0.55 |
| 450 | 0.6 | 0.31 | 0.48 |
| 500 | 0.45 | 0.23 | 0.37 |

### 5.7. Discussion

The amount of security is applied to the system, such as encryption, certificate inclusion, and signature that affects the calculation cost. The application with the greatest packet cost to represents the necessitates signing, encrypting, and channel occupancy of ITS packets. The processor speed is a second aspect that affects the amount it spends to compute security. The FS procedure handling at the receiver and transmitter turns up being the outcome of a more efficient processor. To ensure the dependability of communications, and the security requests utilize a digital signature technique. The quality of service is significantly reduced with MS. Based on the findings, it is obvious the ITS application needs high-speed security to facilitate the efficient transmission of encrypted communications. The cryptographic procedures are enhanced for this purpose by using a Trusted Platform Module (TPM) or specialized Hardware Security Module (HSM) of the higher Processor frequencies is used. A limitation with the modules is more expensive than a basic model of automobile. Additionally, more examination is required to evaluate the greater rate of module QoS is advantage to ITS-based smart cities.

The use of adapted safety systems, that automatically alter the privacy settings at runtime based on the environment and application requirements, present a solution to improve the QoS of ITS systems while maintaining a high degree of security. The technique explained uses of importance security validation of ITS signals among the close-by automobiles that pose a greater hazard to security to increase safety awareness. The dependability of SC based on ITS is significantly increased by the application of traffic social networking. Based on their interactions with the community, vehicles are acquiring a reputation level system based on trust. Vehicles that have successfully exchanged secure data in the past are able to lower the degree of protection for future exchanges. Additionally, it is less probable vehicles with a high level of social contact, and these cars serve as data forwarders for ITS communications. SC operates different systems and services within urban areas in the intent of improving resource efficiency. The organization is made up of complex and interlinked accumulations of electronic gadgets, ICT facilities and IoT devices[23]. An ITS affects all government, urban residents, and corporations within pollution, traffic congestion, citywide travel times, and additional information. Poor transportation infrastructure can limit a city’s economic development, liveliness, and use of urban space[24].

## 6. Conclusion

The ITS improving the transport network efficiency, safety, and environmental impact using advanced technology and data systems. ITS uses communication networks, data analytics, sensors, and robotics to enhance transportation. 5G addresses the electronic communication ecosystem by fixing the deficiencies of

4G. By enabling an extensive amount of simultaneous connections that are ubiquitous, especially in mobility-intensive scenarios or densely occupied regions, advanced technology makes SC fully networked. WS, 75% of attempts succeed. With MS, the achievement percentage declines to 56%. The FS system has a 57% success rate. It is required to overcome the problems such as security, cost, and regulatory concerns to properly capitalize on the possibilities of 5G with these areas. The use of traffic considerably improves the dependability of SC based on ITS. Vehicles are developing reputation level systems based on trust as a result of interacting with the community. Vehicles have the ability to modify the level of security for future exchanges after successfully exchanging secure data in the past. Inadequate attention to security and privacy issues is lead to vulnerabilities in 5G networks' greater connection and data exchange that continues to a serious restriction. Future study is exploring the dynamic interactions among the 5G technology and new urban mobility paradigms like Mobility-as-a-Service (MaaS) and autonomous vehicles.

## Author contributions

Conceptualization, SKG and SKV; methodology, SKG; software, SKG; validation, VSK, RK and PM; formal analysis, BH; investigation, NS; resources, SKG; data curation, SKV; writing—original draft preparation, SKG; writing—review and editing, SKV; visualization, SKG; supervision, BH; project administration, RK; funding acquisition, SKV. All authors have read and agreed to the published version of the manuscript.

## Conflict of interest

The authors declare no conflict of interest.

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