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User Friendly Advanced IOT Vehicle for Future World

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ABSTRACT

IOT vehicles are transforming transportation by integrating advanced technologies like IOT, GPS, and V2X communication, enhancing road safety, driving efficiency, and user experience. These vehicles offer features such as real-time GPS tracking, pothole detection, auto toll tax deduction, and accident detection, all aimed at improving safety and convenience. GPS enables seamless navigation, traffic management, and fleet optimization, while pothole detection systems leverage sensors to monitor road conditions and alert authorities for timely repairs. Accident detection systems enhance emergency response by transmitting crash data and location to responders. However, the popularity of connected cars has also caused about cybersecurity and privacy concerns, specifically regarding sensitive data such as location and driving behavior. MFA plays a key role in securing access to traffic data and ensuring that only authorized users can interact with connected systems. This paper interrogates the technologies and benefits of IOT vehicle and highlights the importance of security to protect against threats and preserve privacy in the cyber ecosystem.

Keyword: IOT, V2X communication, ADAS, autonomous vehicles, telematics, OTA updates, 5G connectivity, vehicle health monitoring.

1. INTRODUCTION

Internet of Things (IOT) enabled vehicles are the foundation of the future of transportation, combining advanced technologies, cloud computing, wireless communications, and data analytics to create vehicles that are connected to their environment. These vehicles are not just for transportation; they are mobile platforms that communicate with other devices, transportation vehicles, and other vehicles [1]. The growth of IOT technology and 5G networks are enabling the development of smart devices that increase safety, improve driving, and reduce human error. Among the many innovations offered by connected cars are GPS tracking, location detection, vehicle evacuation, accident investigation, and emergency response systems. Additionally, as data privacy and security become increasingly important, multi-factor authentication (MFA) has become an important way to control access to data traffic, allowing users and companies to manage and protect sensitive data[2][3].

2. LITERATURE SURVEY

IOT has tremendous potential to transform the transportation landscape, primarily by improving vehicle performance and delivering superior customer experiences. In the broader context of intelligent vehicles and connectivity, IOT frameworks support a range of advanced applications, such as driver assistance, in-vehicle data collection, and best-practice problem solving. The advent of IOT-enabled motorcycles has further expanded the IOT-enabled smart transportation landscape, adding depth and diversity. As advanced connectivity-enabled solutions and technologies continue to evolve, interest in the development and deployment of connected vehicles is growing. These initiatives include the development of intelligent transportation systems and modern vehicle-to-vehicle communication platforms supported by vehicle-to-everything (V2X) technology, which is the foundation for new connectivity [4]. The increasing curiosity and interest in the vehicle ecosystem, alongside advancements in

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automotive telematics, has captured a considerable amount of attention from both academic researchers deeply engaged in the field and industry stakeholders eager to explore new opportunities [5]. The discourse surrounding connected vehicles becomes markedly enriched when we analyze the pivotal role that connectivity plays in the formulation of a "data ecosystem," a concept wherein a broad spectrum of applications and services can be seamlessly implemented. It is strongly proposed that V2X systems not only symbolize but embody the future trajectory of smart transportation ecosystems, characterized by the significantly improved interactions among diverse road users, infrastructure components, and a variety of participants, all facilitated by the robust connectivity that IOT sensors can offer [6]. By effectively harnessing the potential of large-scale integration and deployment of IOT sensors across various platforms, it becomes wholly feasible to establish a comprehensive framework dedicated to security and privacy-aware smart transportation systems [7][8]. From a security and privacy standpoint, an exhaustive analysis of the external threats linked with the integration of IOT in automotive networks is conducted, with a key focus on identifying potential vulnerabilities that may emerge throughout different phases [9][10]. In addition to this, a sophisticated pseudonymous risk assessment is carried out, employing cybersecurity maturity models that are specifically tailored to meet the unique requirements of the automotive sector [11]. The multifaceted challenge of securing in-vehicle networks—particularly those interconnected through both IOT and cellular networks—is thoroughly addressed, highlighting the existing standards for network security and delineating their inherent limitations [12][13]. Therefore, we provide a threat assessment based on the perspective of an intelligent transportation model that includes all aspects of inter-vehicle communication and integrated air services [14]. We also call on government agencies to develop effective strategies to control access to common services and applications in vehicular cyber-physical systems. The comprehensive discussion includes a critical review of existing models and literature that address these complex issues [8][12]. We also explore complex data privacy and cybersecurity issues related to specific IOT applications, with a particular focus on connected vehicles and their integration into IOT vehicle research. The purpose of this study is to address complex social issues arising from the continuous growth of transportation, infrastructure, and users [15][16][17].

3. PROPOSED WORK

Proposed work provides different features i.e. pothole detection, accident detection etc. and advanced security protocol (MFA). Pothole detection system use sensors such as GPS and cameras to update maps and detect potholes and alert drivers. Accident detection aims to ease traffic congestion from minor accidents via efficient detection and information sharing, yet adoption remains a challenge. IOT vehicles enhance accident detection by using GPS and sensors for driver behavior monitoring to facilitate quicker responses. An Intelligent Transport System for toll collection relies on continuous car-toll communication, charging fees based on distance rather than fixed points, which helps reduce traffic congestion, pollution, and infrastructure requirements while improving road safety and sustainability. Algorithm of the proposed work is given below:

Step1: Start

Step 2: V = VehicleID // Initialize vehicle ID

Step 3: U = Authenticate() // Authenticate user via MFA

Step4: IF U == Success THEN

Proceed.
ELSE

Access Denied → End.

Step5: GPS, Traffic = GetData() // Retrieve GPS & traffic data

Step6: Route = Navigate(GPS, Traffic) // Determine route based on traffic

Step7: Toll = CalculateToll(GPS) // Calculate toll based on distance

Step8: DeductToll(Toll) // Deduct toll amount from user account

Step9: IF PotholeDetected() THEN

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ReportPothole() // Report pothole location
ELSE

Proceed.

Step10: IF AccidentDetected() THEN

SendEmergencyAlert(), CallEmergencyServices() // Notify emergency services
ELSE

Proceed.

Step11: EncryptData(VehicleData) // Encrypt vehicle and user data

Step12: UploadToCloud(EncryptedData) // Upload encrypted data to cloud

Step13: End

Here, figure 1(a) represents the flowchart of the proposed work and figure 1(b) shows underlying technologies for the proposed system.

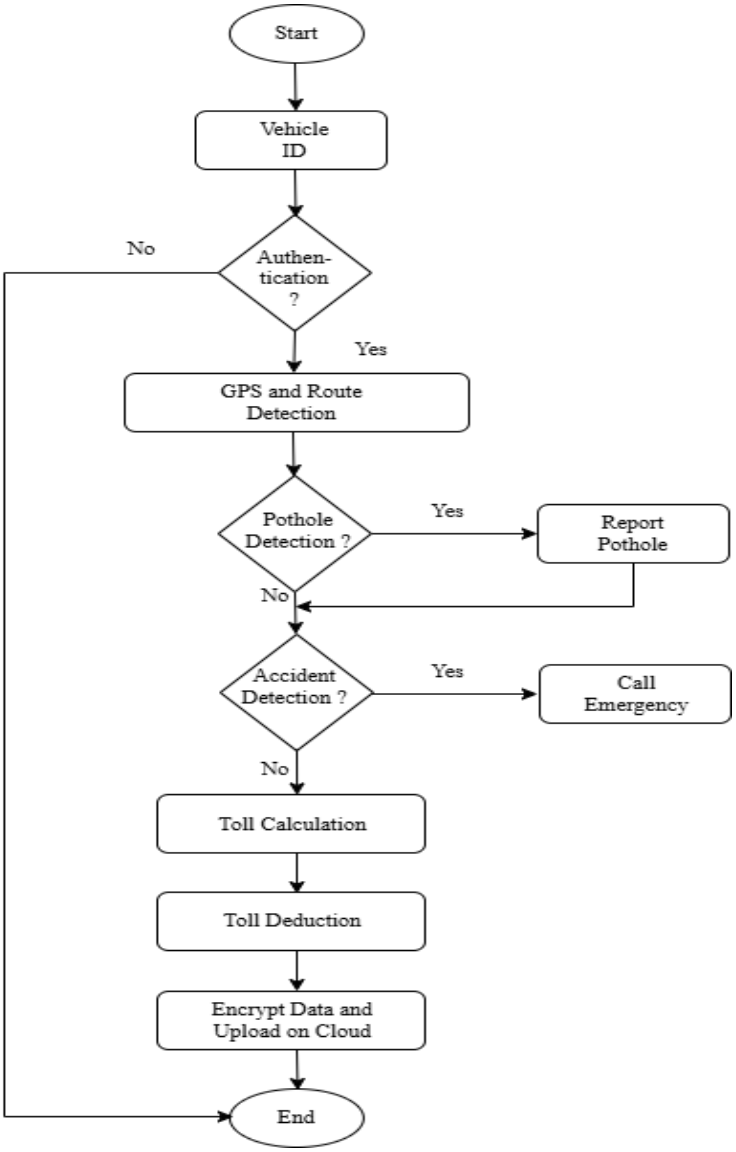

Figure 1(a): Flowchart of the Proposed Work

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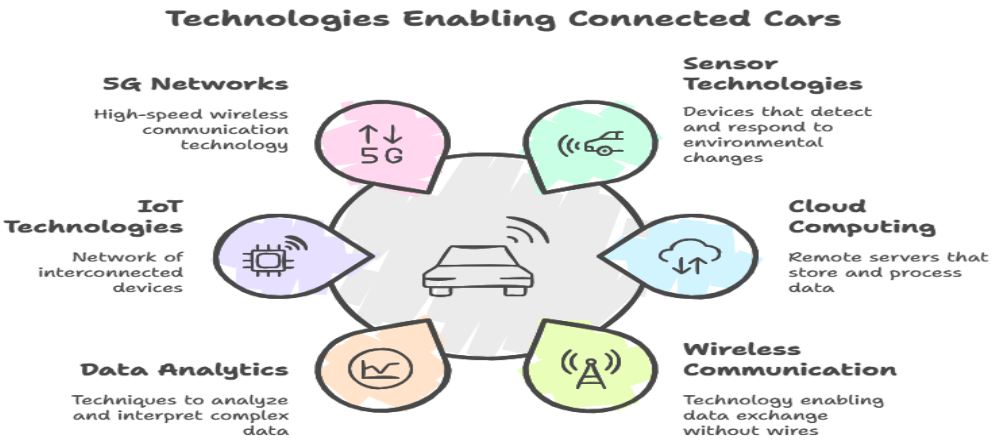

Figure 1(b): Technologies Used for IOT Enabled Vehicle

3.1 GPS Tracking and Location-Based Services

GPS tracking is one of the most fundamental features of connected cars. With the integration of GPS technology, connected vehicles can constantly monitor their location in real-time. This enables a variety of features that benefit drivers and fleet operators are shown below in figure 2.

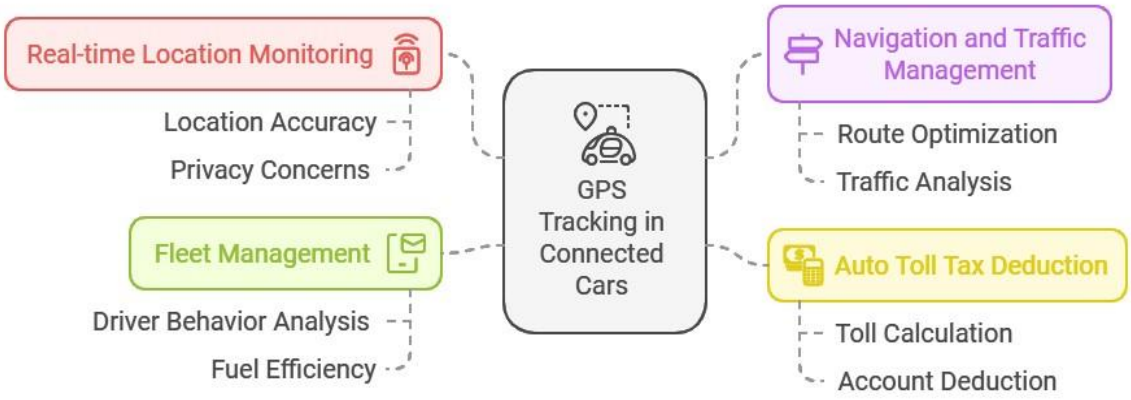

Figure 2: GPS Tracking and Location Based Services

Navigation and Traffic Management: GPS allows for seamless navigation, guiding drivers through the most efficient routes while factoring in real-time traffic data. The vehicle can automatically reroute if it detects congestion, accidents, or road closures, minimizing delays [1].

Auto Toll Tax Deduction: By using GPS data, connected cars can automatically calculate toll fees based on the distance covered on toll roads. Traditional toll systems require vehicles to stop and pay at toll booths or use electronic tags, but GPS-based toll systems streamline this process. If a vehicle is driving on a toll road, the system records the distance traveled and deducts the toll amount from the user's bill. This system eliminates human error, reduces traffic in phone booths, and allows phone numbers to be recorded[2]. The temporary list and vehicle counting formula are as follows:

$$T_{rate}\,(R_{road}, V_{vehice}) \quad \ldots 1$$

$$L_{start}, L_{end}, V_{type}, R_{road} \quad \ldots 2$$

$$D = Distance(L_{start}, L_{end}) \quad \ldots 3$$

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$$T_{toll} = D_i \times T_{rate}(R_{road}, V_{type}) \quad ...4$$

$$T_{total} = \sum_{i=1}^{n} \left(D_i \times T_{rate}(R_i, V_{type}) \right) \quad ...5$$

Fleet Management: For companies operating trucks, GPS tracking provides valuable information about the location, performance, and driving behavior of vehicles. This enables immediate service and route optimization, reducing fuel consumption and improving the performance of the entire fleet. However, the widespread use of GPS has also raised concerns about data privacy. Data stored on vehicles is sensitive and can pose privacy risks if misused. Therefore, a secure approach to profile management is needed that ensures profile security.

3.2 Pothole Detection and Road Condition Monitoring

Pothole detection is another important function of connected vehicle technology. Road maintenance is often done reactively. Potholes in the road are not repaired until they cause serious damage or lead to an accident. However, connected IOT-based vehicles can monitor road conditions and provide immediate warnings [3]. The source detection and system recovery process is shown in figure 3.

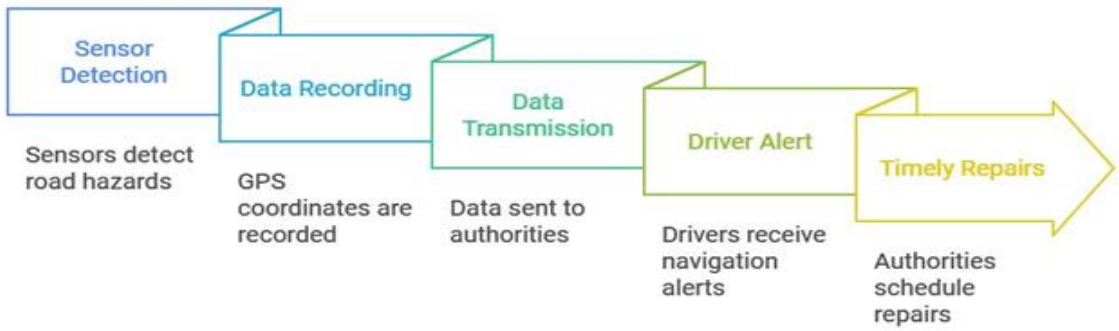

Figure 3: Pothole Detection and Reporting Process

Detection Mechanism: Connected cars are equipped with sensors such as accelerometers, cameras, and proximity sensors that can instantly detect collisions when driving through lakes or other hazards. These sensors track the weight of the ball and automatically record the GPS coordinates of potholes.

Reporting System: When a deep pothole is detected, the vehicle sends information in real time to the local police or traffic control center. This leads to timely repair and maintenance of roads, improving overall infrastructure and safety.

Driver Assistance: Additionally, GPS-based navigation systems can warn drivers of impending traffic conditions, allowing them to slow down and prevent damage to the vehicle. The mathematical equations for source detection and road monitoring are as follows:

$$T_{toll} = (Alert\ Driver(L_{Pothole,} Severity) + Report(L_{Pothole,} Severity)).\left(f(D_{a,} D_c, D_p).1_{|Da|>Threshold} + 1_{Pothole\ e\ in\ Dc} + 1_{Hazard\ in\ Dp}\right).(L_{pothole} = D_g))$$

This real-time reporting system provides a clear advantage over traditional methods of reporting road damage and helps prevent further damage to vehicles. By improving road safety and helping authorities maintain infrastructure, pothole detection contributes to a smarter, more responsive transportation system.

3.3 Accident Detection and Emergency Response Systems

Integrating accident detection into connected vehicles is a significant advancement in vehicle safety. These systems use airbag sensors to detect accident and respond quickly.

Airbag sensors: These sensors detect sudden movements or impacts that cause the airbags to deploy. When the sensors detect an accident, they initiate a series of actions, such as deploying the airbags and sending information to

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emergency services. The proposed work's monitoring and emergency response process diagram is shown below in figure 4.

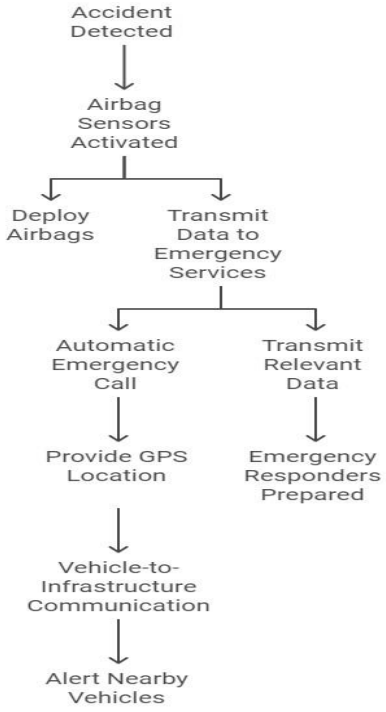

Figure 4: Accident Detection and Respond System Process

Emergency call: In the event of a major accident, an emergency call can be made to the nearest police station, ambulance service or emergency response team by vehicle. The system retrieves the exact location of the vehicle from GPS, allowing emergency teams to respond quickly.

Vehicle-Infrastructure Communication: In some systems, connected vehicles can communicate directly with emergency service kiosks, allowing response teams to be dispatched more quickly. These vehicles can also send alerts to other nearby vehicles about potential collisions or hazards on the road, reducing the risk of further collisions.

Data transmission: System Analysis can also transmit relevant data (such as collision severity, airbag deployment events and vehicle inspection data) to help personnel prepare before arriving at the scene of an emergency. The accident investigation and emergency response results are shown in Figure 5 below.

Emergency Calling: In the event of a serious accident, the vehicle can automatically place an emergency call to the nearest police station, ambulance service, or emergency response team. The system provides the vehicle's precise location using GPS, ensuring that emergency services can respond quickly.

Vehicle-to-Infrastructure Communication: In some systems, connected vehicles can communicate directly with emergency assistance booths, allowing for even faster dispatch of emergency responders. Additionally, these vehicles can send alerts to other nearby vehicles to warn them of an accident or road hazard, reducing the likelihood of further collisions.

Data Transmission: Accident detection systems can also transmit relevant data, such as the severity of the crash, airbag deployment status, and vehicle diagnostics, to emergency responders, helping them prepare for the situation before they arrive at the scene. Console output for the accident detection and emergency response system is given below in the figure 5.

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```
Monitoring airbag sensors...
Deceleration detected: 13.50 m/s^2
Accident detected! Deceleration: 13.50 m/s^2
Airbags deployed!
Initiating emergency response actions...
Sending location to emergency services: (29.9460, 76.8507)
Communicating with nearby emergency booths from vehicle 1.
Sending accident alert to nearby vehicles from vehicle 1.
Sending accident data to emergency responders...
{'crash_severity': 'High', 'airbag_deployed': True, 'vehicle_diagnostics': {'engine_status': 'Normal', 'tire_pressure': 'Good'}}
Confirming with emergency services that they received the alert.
Emergency services confirmed receipt of alert.
Continuously monitoring system for updates...
Resetting system and ready for next incident.

Monitoring airbag sensors...
Deceleration detected: 9.89 m/s^2
No accident detected, continuing normal monitoring...

Monitoring airbag sensors...
Deceleration detected: 14.12 m/s^2
Accident detected! Deceleration: 14.12 m/s^2
Airbags deployed!
Initiating emergency response actions...
```

Figure 5: Console Output of Accident Detection and Emergency Response Systems

3.4 Authentication and Data Security with Multi-Factor Authentication (MFA)

MFA is a security mechanism that requires users to provide two or more authentication factors before accessing systems or data [3].

Access control: MFA ensures that only authorized users can access vehicle data, including location information, driving habits, and personal information stored on the aircraft. This is particularly important because connected vehicles store large amounts of personal data that can be vulnerable to cyberattacks.

Secure data access: With MFA, connected cars can access a variety of systems, including infotainment systems, navigation settings, and remote controls (such as remote start or climate control). MFA typically combines something the user knows (e.g., PIN), something the user has (e.g., smartphone or smart key), and something the user knows (e.g., biometric data such as fingerprint or facial recognition) [3]. Figure 6 expresses the key security features of the proposed work.

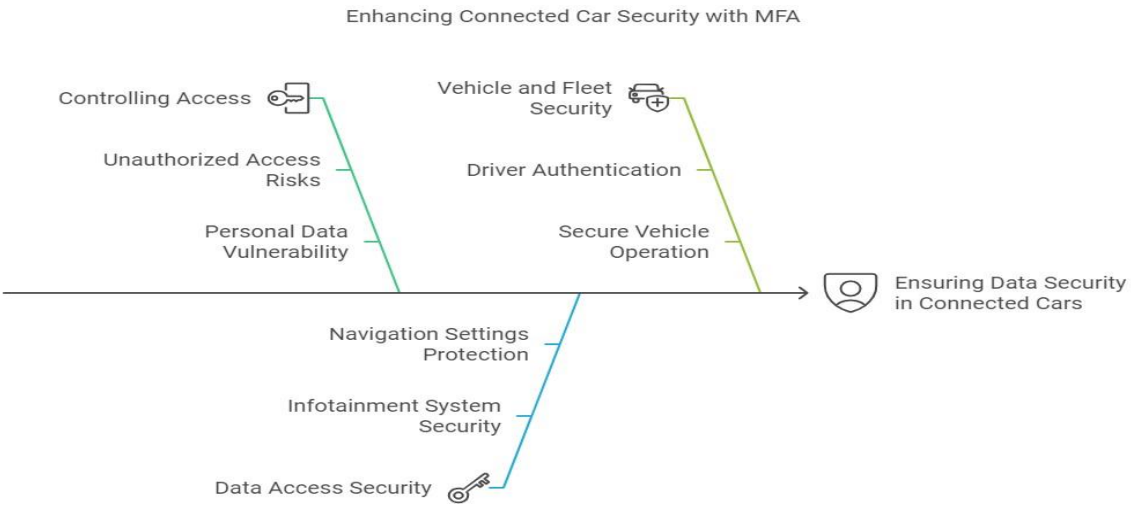

Figure 6: Security Features of Connected Car

Vehicle and Fleet Security: In fleet management, MFA can be used to identify drivers and ensure security for vehicle use. This ensures that only authorized personnel can use the vehicle and interact with the ship's procedures.

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Step 1: User enters PIN code (something he/she knows).

Step 2: User's smartphone or smart key is verified (something they have).

Step 3: User's biometric data is verified (something they are).

Step 4: If all factors match, the user is granted access to the vehicle's systems.

The growing concerns around data privacy and hacking threats, MFA is becoming an essential feature in connected vehicles, as it adds an extra layer of protection against unauthorized access to both vehicle systems and sensitive data.

4. RESULT & DISCUSSION

Result of the different activities of the proposed work are given as follow: (i) authentication process of the proposed work for normal and emergency scenarios, (ii)total distance covered per day, (iii) access attempts i.e authorized or unauthorized attempts, (iv) speed per day vs weekly average speed, (v) toll deduction,(vi) vehicle weekly activity report.

```
Attempting to access vehicle systems...
Starting Multi-Factor Authentication...
PIN verified.
Mobile location verified.
Fingerprint verified.
MFA Authentication successful!
Access granted. Securing vehicle systems...
Navigation system secured.
Infotainment system secured.
Remote access controls activated.
Emergency Operation: Vehicle operated by JohnDoe with correct MFA.

Daily Vehicle Movement Report for JohnDoe:
Total Distance Covered: 163.54 km
Unauthorized Attempts: 0
Hourly Vehicle Movement:
6:00 - 12.59 km
7:00 - 7.56 km
8:00 - 7.86 km
9:00 - 13.40 km
```

Figure 7(a): Terminal Output Showing Authentication Behavior in Standard and Emergency Scenarios

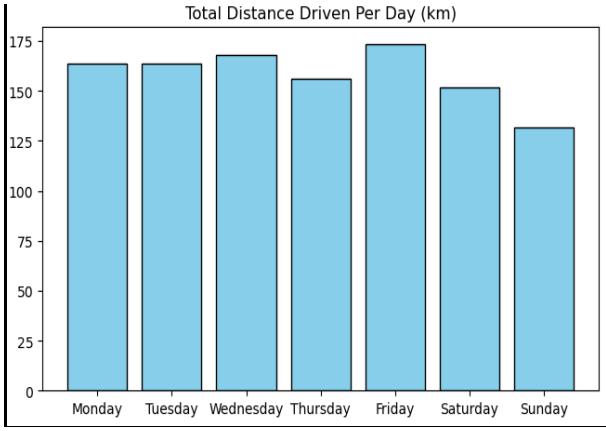

Figure 7(b): Total Distance Driven Per Day

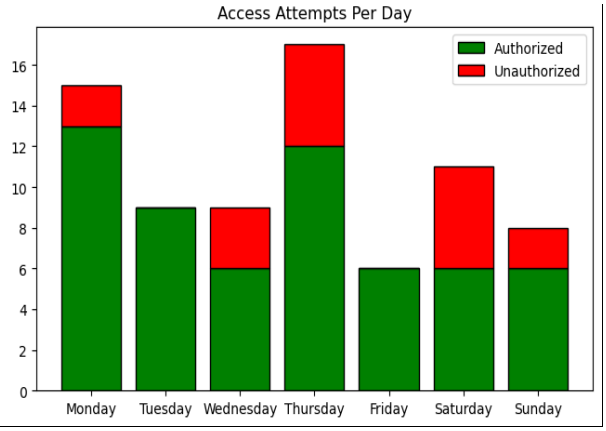

Figure 7(c): Access Attempt (Auth & Un-auth)

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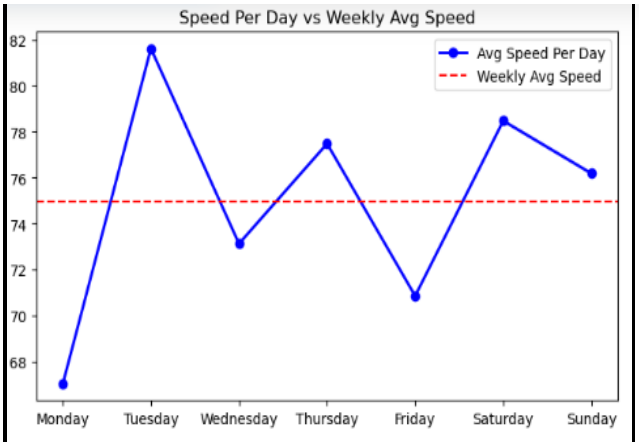

Figure 7(d): Speed Per Day vs Avg. Speed

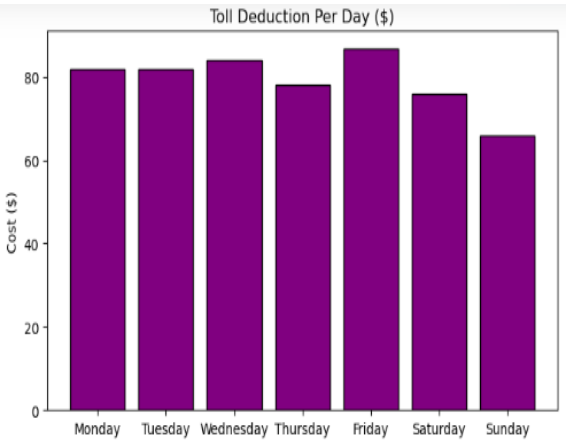

Figure 7(e): Toll Deduction

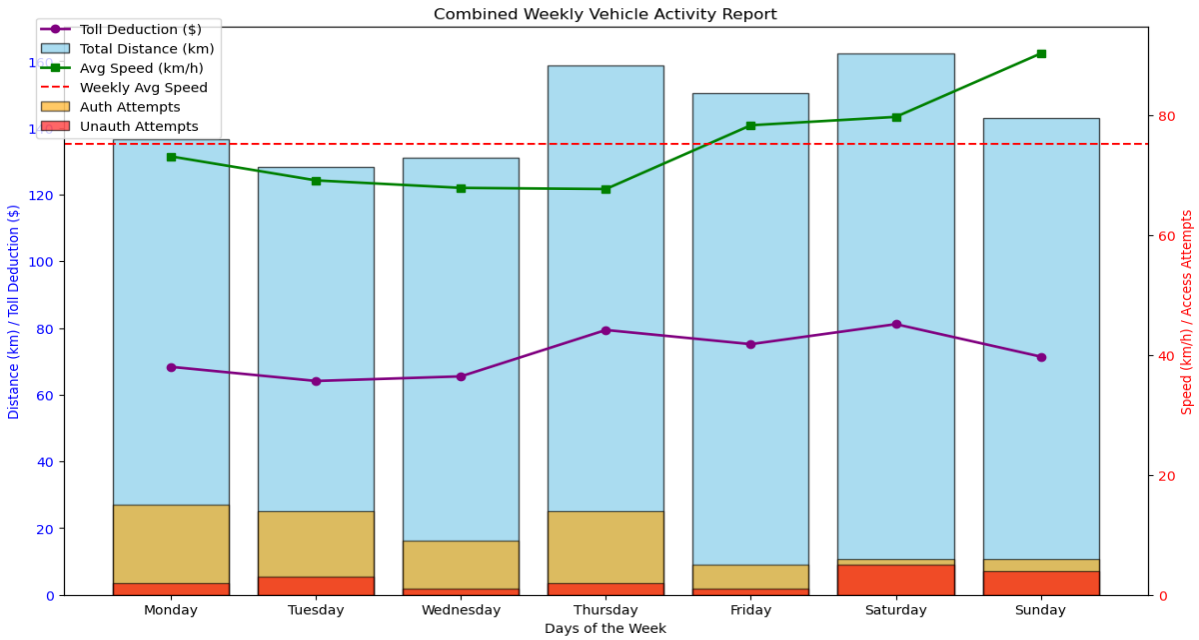

Figure 7 (f): Vehicle's Weekly Activity Report

During an emergency operation, user successfully performed multi-factor authentication (MFA) with PIN, mobile location, and finger print to the vehicle system, therefore strong authentication security was demonstrated. The vehicle showed efficient performance with average speeds ranging from 67 km/h on Monday, 82 km/h on Tuesday, and 75 km/h over the entire week. Between 6:00 AM and 9:00 AM the distance covered in the course of the emergency session amounted to 163.54 km (interquartile range 7.56–13.40 km). Total distance driven over the week peaked at 172 km on Friday and hit the bottom at 133 km on Sunday, leading to daily toll deductions between $88 (Friday) and $66 (Sunday). The distance travelled by the vehicle is directly proportional to how much the toll is deducted; the more mileage the vehicle has done, the more toll expense it incurs. The vehicle covered its longest distance of 172 km Friday which made it the highest toll at $88 while Sunday with the shortest distance of 133 km had the lowest at $66. This pattern represents more classic toll systems in which charges rise with distance, particularly for longer trips or for routes with higher toll charges (toll rate are changeable as per the rules of highway authority and government policies). Figure 7(c) shows most access attempts on Thursday (17 total, 5 unauthorized) and the least on Friday (6 authorized) and there is a clear need for mid-week security attention and overall usage looked steady and well managed. Security activities, including multi factor authentication, ensure access is controlled though days with a higher number of access attempts, for example, on a Thursday, may be concurrent with increased use of vehicles and therefore higher toll fees.

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A detailed comparison of the proposed work with the existing system w.r.t. different aspects is given below in table 1.

Table 1: Comparison of Proposed Work and Existing Systems

Sr. No.	Aspect	Proposed Work	Existing Systems
1	Key System Functionality	Secure V2X communication for preventing spoofing and jamming; VPN management for applications, big data analysis, cloud data management, and security reinforcement.	The cited references explore different aspects of V2X technologies, such as secure IOT-enabled transportation frameworks [4], privacy preservation in vehicular networks [5], and the role of V2X in future mobility [3].
2	Security Concerns	Challenges include rising cyber threats, confidentiality breaches, and mobile connectivity exposing vehicles to cyber attacks.	Multiple references discuss security measures and threats in connected vehicles, including the analysis of vulnerabilities in automotive IOT [6][7] and cybersecurity maturity models for automotive industries [8].
3	Pothole Detection	Pothole detection systems use GPS and cameras to identify potholes and update maps for driver alerts.	While pothole detection is not directly discussed in the cited references, the use of IOT sensors for road condition monitoring and connected vehicle services aligns with discussions on the broader smart transportation systems [14].
4	Accident Detection	Aims to reduce traffic congestion and improve accident response times using GPS and sensors for monitoring driver behavior.	References focus on enhancing accident detection in connected vehicles through real-time information sharing and sensor usage, improving response times [7], driver behavior monitoring [3], and traffic congestion reduction [15].
5	Toll Collection	Intelligent transport system for toll collection that charges based on distance, rather than fixed points, to reduce congestion and pollution while improving sustainability.	The concept of dynamic toll collection based on distance aligns with discussions of smart transportation systems and IOT integration for real-time tolling and congestion management [14][15].
6	Data Management & Cloud	Use of cloud servers for data management, along with big data analysis for transport authorities.	The integration of cloud-based solutions for data management and big data analytics in smart transport systems is discussed, especially in the context of secure IOT-enabled transportation [7] and data privacy implications [15].

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7	Privacy and Scalability	Challenges related to privacy and scalability in connected vehicle systems.	Privacy preservation in vehicular networks is examined [8], with further discussions on data privacy and societal challenges due to increased IOT integration [15][16]. Scalability challenges are addressed in smart transport frameworks [6].
8	Vehicle-to-Everything (V2X) Communication	Focuses on secure V2X communication for vehicle interaction with entities like toll booths, traffic management systems, and infrastructure.	V2X technologies as the foundation for future mobility and smart transportation ecosystems are elaborated on in the referenced works [6][17].
9	Security & Privacy Framework	Reinforces security through a dedicated VPN, ensuring secure communication channels for all connected vehicles and entities.	Security frameworks and identity federation models for connected vehicles are discussed in detail, with a focus on securing IOT networks and vehicular systems [7][13].
10	Cybersecurity & Vulnerabilities	Addressing rising cybersecurity threats and vulnerabilities in connected vehicle systems, particularly in mobile connectivity services.	Detailed analyses of cybersecurity vulnerabilities and potential threats in automotive IOT systems are provided, with a focus on external threats, network security, and cybersecurity maturity [9][10][12].
11	IOT and Vehicle Ecosystem	The system involves IOT sensors and cloud-based data management for the seamless operation of connected vehicle systems.	The integration of IOT sensors for creating a comprehensive smart transportation system is explored, focusing on how V2X facilitates real-time communication, decision-making, and management in vehicular networks [5][17].

Existing systems and proposed work both emphasize the critical importance of cybersecurity and privacy in connected vehicle systems. Certificates provide a deep understanding of external threats, vulnerabilities in IOT vehicles, and appropriate security measures [9-12]. This work introduces remote call recording based on smart call recording, which is consistent with the discussions in the literature on passive call recording and collision management of connected vehicles [17][18]. Although pothole detection is not widely discussed in the literature, the concept fits well into the broader context of connected vehicles and IOT applications in smart transportation [14]. This study presents an integrated approach to secure communication, data management, and vehicle performance via connected vehicles. It conducts research and development activities in the transportation field, particularly in cybersecurity, IOT integration, and privacy issues in connected systems. The evidence provides in-depth information on the security landscape, V2X communications, and data privacy, revealing the importance and potential of the proposed framework in overcoming current issues in the transportation and automotive industries.

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5. CHALLENGES AND FUTURE DIRECTIONS.

Although the above-mentioned features provide significant benefits in terms of security, performance, and user convenience, there are still many challenges to be solved for connected vehicles.

- Cybersecurity and data privacy: Since smart vehicles generate and transmit large amounts of data, it is vital to take cybersecurity measures.
- Interoperability and Standardization: As smart vehicle's ecosystem grows, the lack of standardization across manufacturers, communication protocols, and data formats could lead to compatibility issues. Industry-wide cooperation and the development of universal standards are needed to ensure seamless integration between vehicles, infrastructure, and service providers. The main key points where researches have to pay more attention are shown in figure 8 below.

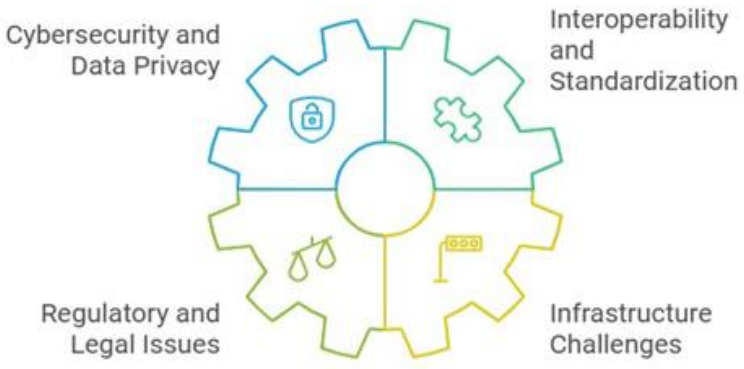

Figure 8: Challenges of IOT Vehicle

- Regulatory and Legal Issues: The introduction of autonomous features and data-driven services raises important legal questions regarding liability in the case of accidents involving connected cars. In addition, the regulation of personal data, especially with regard to GPS tracking and personal data needs to be strengthened.
- Infrastructure Challenges: The full potential of IOT enabled vehicle technology depends on the development of smart devices. These include road sensors, intelligent vehicle control systems, and connected communications (e.g. 5G) that can process large amounts of data from connected vehicles. Data breaches and hacking attempts are growing concerns, and manufacturers must implement strong encryption protocols and security practices to protect vehicle systems and user information.

6. CONCLUSION

IOT vehicle's technologies, including GPS tracking, pothole detection, auto toll tax deduction, accident detection, emergency response, and data security through MFA, represent significant advancements in automotive innovation. These technologies are revolutionizing the driving experience by improving safety, reducing costs, and enhancing the overall convenience of travel. However, as the industry continues to evolve, challenges such as data security, regulatory frameworks, and infrastructure development must be addressed to unlock the full potential of connected cars. With the ongoing integration of these advanced technologies, connected cars are poised to play a central role in the future of transportation, providing a safer, more efficient, and more connected driving experience for all.

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