Collision Avoidance, Data Gathering, and Impact Assessment using Vehicle-to-Express (V2X) Communication and Edge/Cloud Computing

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Abstract. As infrastructure for transportation and vehicle technology enhance, and the quantity of both commercial and non-commercial cars on the road grows, traffic accidents can occur, resulting in high fatality rates.. Immediate medical care at the scene of an accident can significantly improve the odds of survival for victims. This paper presents an affordable accident detection and tracking system that utilizes a multi-tier Internet of Things (IoT) based vehicular environment, principally relying on V2X connectivity and Edge/Cloud computing. This research equips automobiles with an On-Board Unit (OBU), mechanical sensors (accelerometer, gyroscope), and a GPS module to detect accidents and identify their position. Additionally, a camera module is installed on the car to record an accident. Each vehicle's OBU has a wireless networking interface to enable inter-vehicle communication (IVC). When an accident happens, the car recognizes it and sends an alarm message. The message and accident location are sent to an intermediary device at the vehicle network's edge, also known as an edge device. This edge gadget locates the nearest medical facility after getting the notification and requests that an ambulance be sent there right away. The real-time display of data received through such systems is a major problem now facing the traffic authority. The Internet of Things (IoT) is utilized in practical applications to establish a network connecting automobiles, edge nodes, and a central server. The wireless connections have the ability to transmit sensor data in real-time, however this functionality is not yet accessible in the vehicle's OBU for commercial use. Analysis of the sufficient data collected on traffic accidents may be used to create effective action plans that might reduce the number of fatalities. To support the appropriate authorities in conducting comprehensive examination of dependable and well-researched data, a cloud-hosted adaptive front-end rendering is suggested.

Keywords: VANET, V2X, Edge computing, Crash detection, Fog Computing

1. Introduction

Increased traffic in crowded places and overstuffing of urban infrastructure are only two of the negative consequences that come with an increase in the amount of automobiles. Additionally, it contributes to a larger number of pedestrian-related fatalities each year. The most recent study conducted through the World Health Organization (WHO) [1] reveals that millions of people are wounded and 1.26 million people die annually as a result of traffic accidents, with bicycles and pedestrians accounting for about 49% of the casualties.

Because of the deteriorating road infrastructure, the above indicated percentage of deaths occurs more frequently in developing nations. By 2030, road accidents will rank as the fifth leading cause of death if preventive measures are not implemented to lower this proportion [2].

In this regard, the scientific community has long since created tools and methodical techniques to increase road safety.

The following advice might be quite helpful in dramatically lowering the amount of fatalities and injuries brought on by traffic accidents:

- provide prompt medical attention to people injured in auto accidents.
- Notifying the first responders of the specific circumstances.
- Absence of a comprehensive database that contains all relevant information and records and can be checked whenever needed

Our previous work [3,4] addressed the first two difficulties by suggesting an application for identifying accidents and management. The program has the ability to recognize traffic incidents automatically and notify the control room located in a designated area. However, a tool that generates effective real-time visualizations is required in order to increase the dependability of a crash detection system and accident data analysis. The relevant officials can then utilize the tool to formulate policies and implement their wisest judgments. In addition to correctly recognizing and responding to a traffic collision in an efficient manner, gathering and securely storing the relevant data so that it may be accessed whenever needed is equally important.

VANET accident detection system is motivated by the compelling objectives of enhancing road safety, improving traffic efficiency, optimizing resource allocation, generating data-driven insights, fostering technological innovation, and making a positive humanitarian impact. By addressing these motivations, such a system can contribute significantly to creating safer, smarter, and more sustainable transportation systems for the benefit of society as a whole.

The present project aims to develop a system that instantly and promptly notifies users of traffic congestion in order to reduce the rate of casualties by providing emergency medical attention to those involved in traffic accidents. This can be achieved by combining vehicular ad hoc networks (VANETs) with the Internet of Things (IoT) [5,6].

Researchers employed the IoT and Edge computing concepts in VANET to achieve the intended goals, where data is gathered from the sensors and subsequently processed for additional analysis, in order to get around this lag. Furthermore, the suggested mechanism analyzes the recoded statistics to identify accidents, their regularity or irregularity, their causes, and the specific location of the casualty. This analysis aids the activity specialists in establishing traffic regulations to reduce the number of road deaths.

The three distinct sub-systems that make up the proposed system are the cloud platform [8], edge gateway [7], and on-board sensors [3, 4].

On-Board Sensors: It can precisely identify an accident occurrence using the Global Positioning System (GPS) and detect traffic accidents using an OBU that consists of a speedometer and a gyroscope. It may link the collected images/data to the other information that is transmitted to the intended location. It does this by employing a high-definition camera module to take pictures from inside an automobile. 5G technology indeed represents one of the most advanced solutions for providing internet connectivity along transportation routes, especially with its capabilities for V2X (Vehicle-to-Everything) communication. 5G side link enables direct communication between nearby vehicles without relying on cellular infrastructure. An ad hoc vehicle network is used to relay the entire message to the edge node.

Edge Gateway: Entities located in the control room across all areas. Its duty is to process the detected data after receiving an accident notice. Using facial detection techniques, Edge Gateway is also accountable for determining the total amount of fatalities and the individual responsible for the incidents. In addition, it evaluates the data that it receives from the network's nodes and notifies the medical facility so that the ambulance may be sent out right away. Additionally, it can temporarily store data until the cloud server safely receives it. The choice of IoT gateway technology for VANETs is contingent upon the unique demands of the application, including connectivity range, data rate, latency, dependability, scalability, and security. Hybrid IoT gateway solutions that integrate various technologies are often used to take advantage of the unique capabilities of each technology and enable extensive connection and interoperability in VANET systems.

Cloud Platform: Data obtained from nodes at the edge must be processed and stored by the system's final, but certainly not least, layer. In this case, a query is generated by a visualization tool to retrieve the data from the database. Road accident data is also studied and analyzed for a variety of purposes, including policy making, research, and recordkeeping.

To recognize and notify incidents, two key conditions must be met: appropriate alertness and timely response. These two qualities of a system can recognize unforeseen situations on the road, such as accidents. Furthermore, a system with these features can address the cited issues. When the system is aware of an accident, it can make it easier for rescuers to assist victims, increasing their chances of survival. Optical information from the system's integrated camera may also be utilized. The camera provides imagery that helps rescue officials make better judgments. Furthermore, the system must be delay-sensitive to identify accidents. To improve system performance, accident related details should be sent to the closest medical center to ensure adequate treatment for victims and wounded individuals.

Compute-intensive programs might be challenging for authorities to perform on limited resources, such as automobiles or mobile devices. To maximize output, deploy resource-intensive jobs to cloud servers. It can handle large amounts of data with infinite resources, including computationally demanding applications that may not be accessible in a vehicle's on-board unit. Figure 1 illustrates the delay factor that occurs due to the long distance that exists between the sensor net- work and the cloud.

Cloud technology sometimes lacks capabilities such as location awareness, low latency, and mobility support for vehicle-related apps (9). In such instances, Edge or Fog Computing offers an option. A middle- ware that connects the cloud

bridged tier that connects the unified cloud and scattered sensor network, which may handle urgent jobs locally.

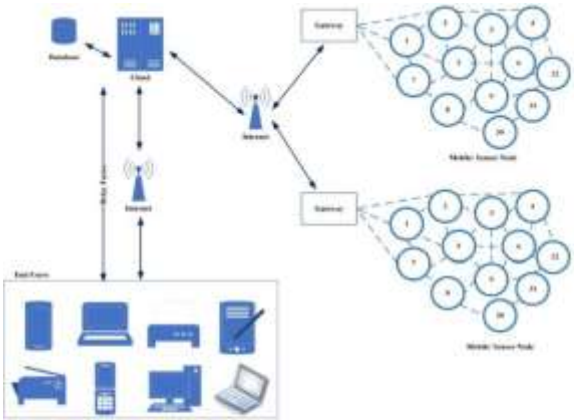

Fig 1. Delay factor occur between the communication of Cloud and End user

The suggested system's total contribution may be separated into two major procedures:

The first process automatically detects accidents and records relevant information. The system centered on the executed TestBed addresses three innovative aspects:

a. Accident detection relies on sensor data and a built algorithm to acquire and monitor relevant information. The system uses sensory information to do intellectual computations and identify accidents. When it is discovered, it sends an alarm message. This page provides practical information on data processing for the crash detection module. The contribution includes a flow schematic of the suggested system for detecting accidents accurately and immediately.
b. The second module identifies the crash location and surrounding medical services. The system tells the hospital about both the person's status and the degree of the harm. Additionally, it records relevant incident information for future reference.
c. The third portion comprises a health care module, which deploys ambulances to emergency sites and gathers passenger data, including injuries, fatalities, medical evidence of alcohol use, and personal attributes such as identity, age, and total number of passengers. Subsequently, the data is sent to a separate module for subsequent utilization.

and sensor network can act as a technological sandwich, allowing for simultaneous communication. It improves situational aware- ness and reduces the time it takes to notify emergency service fig.2.

The second approach analyzes accident data, including location, cause, injury, and mortality statistics, to identify the root cause of accidents in a certain region. The system is evaluated in a laboratory setting, and, for we utilized a library that creates data for the 'a' and 'c' modules described in procedure-1.

The data is transmitted to the TestBed and examined using conception software. We used our suggested method to evaluate real-world data from a city and produce corresponding graphs. Visualization helps authorities make informed judgments and take necessary safeguards when dealing with incidents. The lab-developed TestBed technology converts unprocessed data into information for display purposes. This work contributes by producing a useful visual result from raw data stored in the cloud.

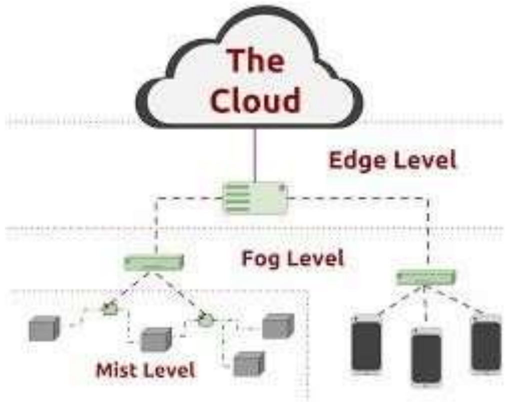

Fig 2. Multi Tier system

In summary, our suggested study has enormous potential for real-world and scientific applications. This platform enables ad hoc testing and validation of algorithms built for vehicle environments.

This study can benefit the scientific com- munity in numerous ways, depending on the ob- jectives and goals of the planned applications. This research focuses on real-time data from a rescue system for automated accident detection in a vehicular context, as well as regional road acci- dent statistics. This tool aids scientific research by displaying round-trip time based on the amount of hops between source and destination. Societies can benefit from understanding the dependability of packet delivery ratios based on hop count along network routes. Furthermore, it may be useful for intellectuals and scientists. Society should tie the delay (latency) for communication during emergencies to network parameters.

Balancing communication and computation costs in edge/IoT devices involves optimizing data transmission protocols, data processing algorithms, and resource utilization strategies to meet application requirements while minimizing resource consumption.

The remainder of this paper is arranged as follows: Section 2 explores automated techniques for detecting, managing, and analyzing traffic accidents. Section 3 proposes a framework to address the issue of growing road fatalities due to accidents. The document also offers information about the application design and hardware utilized during development. It also provides an overview of the system implementation. Section 4 describes system validation and outcomes. The data representation of a traffic accident highlights the main causes, as stated in Section 4.4, emphasizing the relevance of collected data and visualization. Finally, Section 5 wraps off the task.

2. LITERATURE REVIEW

Road accident detection and notification systems have been extensively researched by scientific researchers and engineers [4,10-12]. ITS applications [13] are more data-intensive, with devices connecting to cloud computing centers via the Internet of Vehicles (IoV) [14]. However, this technique may cause overhead and bottlenecks when transmitting large amounts of data from geographically distant devices, eventually consuming network resources. Fog technology plays a role similar to cloud computing. This serves to distribute computing resources throughout the network's edge. Developing fog computing with real-time large data processing with the lambda design might be hard in the dynamic IoV environment [15]. A cloud-based approach developed in [16] can identify accidents by using real-time average vehicle speed statistics. The technology also assisted in providing medical care and pre- dicting the impact of an accident. The system's main limitation is its viability in several circumstances.

The timely reaction is the important component in an emergency reply system, as elucidated in reference [17]. A suggested solution called "Emergency Help Alert Mobile Cloud" (E-HAMC) offers many features for IoT devices with limited resources. The service provider uti- lized the edge and cloud features to automatically relay emergency information, using their ex- panded offering of services. The program has been enhanced to include the capability of gener- ating more accurate location maps by utilizing the geographic coordinates of the event's location. In addition, a street-view function has been included, allowing users to identify the potential routes to the nearest hospital for prompt medical assistance. Research has demonstrated that the integration of Edge technologies with existing cloud and IoT resources may effectively decrease the total latency. Nevertheless, a significant drawback of the system was its reliance on the smartphone. In this scenario, an individual or the person affected is instructed to capture a photograph of the emergency situation or accident, which is then automatically transmitted to the edge node. Thus, relying on the victim or a nearby individual in the event of an accident is not a practical option for a real-time application, for many reasons. One primary reason is because the victim may be physically or mentally incapacitated and unable to use their phone to capture a photo. Additionally, it is plausible that there may be no other witnesses present in the vicinity of the accident to snap a photograph.

Moreover, due to the serious accident, the cell handset or any other equipment equipped with image-capturing capabilities may sustain damage or be completely destroyed. Due of its entire reliance on the smartphone, which may also run out of battery, this system is deemed unworthy under such circumstances.

Furthermore, apart from the aforementioned concerns with the existing methodologies in the literature, a significant and easily noticeable drawback of the current system is its failure to take into account the functioning of the system beyond recognizing accidents and notification. Storing information about events and relevant details pertaining to incidents is crucial for authorities to respond effectively with the necessary equipment. This data may also be utilized to make informed judgments aimed at reducing future road accidents. Hence, the solution must not just focus on obtaining the data, but also necessitates obtaining the data promptly and subsequently processing the information via Edge and cloud-based technologies. Additionally, it should have the capability to provide this information in real-time through visual representations. This feature might prove beneficial for authorities and rescue workers in their efforts to proactively mitigate traffic accidents with more efficiency and effectiveness.

3. PROPOSED SYSTEM

The suggested system's overall functionality is divided into dual sub tasks. The first portion improves the module to collect data, such as the number of passengers inside the car and their condition after the accident, in comparison to our previously established system [4]. The second portion focuses on analyzing recorded data pertaining to accident locations, causes, injury rates, and fatality statistics within a certain region. The goal is to uncover explanations for these incidents.

An application was created and evaluated in for the purpose of automatically detecting acci- dents and promptly providing emergency assis- tance to the victims. The program has the follow- ing attributes:

- Automatically detects accidents in real time.
- Accurately identify the location of an accident.
- Provide timely access to medical facili- ties.

In order to get accurate and comprehensive data on road collision incidences, a new and innovative system architecture has been devised and put into practice. The obtained information is transmitted to the appropriate authorities, such as emergency medical facilities or rescue services and traffic management agencies, for further data processing.

It is presumed that every control room in each area of the city is linked to a cloud platform. Consequently, an Edge node installed in each control room has the task of transmitting the data collected locally (from a specific area) to the cloud for further data processing.

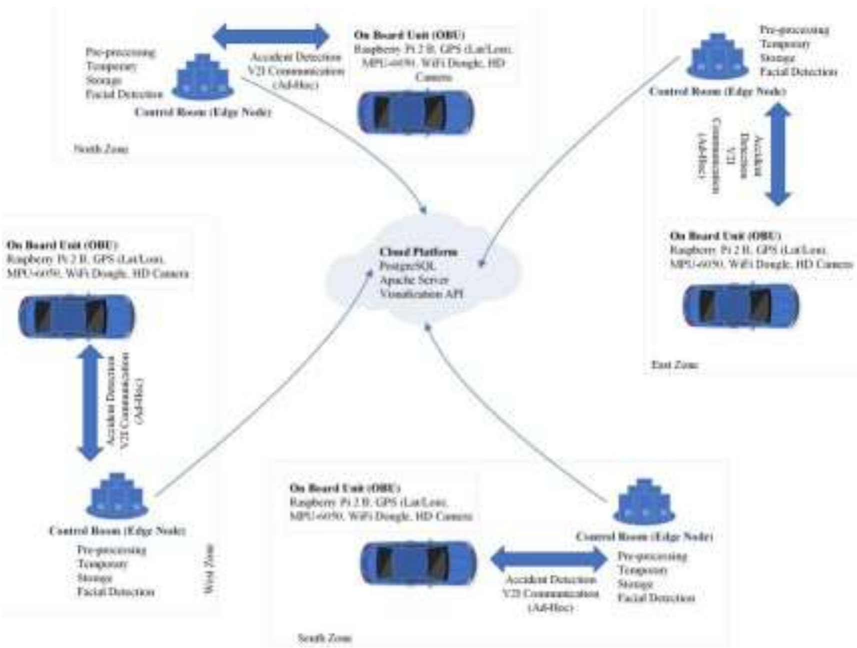

Fig 3: Proposed System arhitecture: Accident detection and Communication

Tier 1: Intrinsic Sensors The system's uppermost level comprises on-board sensors, as seen in Figure 3. The in-vehicle On-Board Units (OBUs) continuously monitor the vehicle's acceleration and orientation to identify accidents. During an accident, crucial information such as the date, time, geographical coordinates, vehicle frame number, and internal temperature are transmitted to the nearest Edge node.

Tier 1 is tasked with overseeing two primary stages: firstly, the automated identification of accidents and the subsequent emergency notification, and secondly, the management of accidents as seen in Figure 4. Subsequently, the data is processed in the cloud. Every vehicle inside a certain zone of the system is outfitted with an On-Board Unit (OBU) that has embedded Raspberry-Pi, GPS, IMU, and camera modules. These modules aid in the identification of accidents, while the computation unit of the On-Board Unit (OBU) is responsible for analyzing the collected data. Upon detection of an accident, an alarm message is generated and transmitted to the control room in a specific region via Vehicle-to-Vehicle (V2V) communication. The control room documents the inadvertent data and dispatches an emergency notification to the healthcare facility for the provision of immediate medical assistance (ambulance).

Figure 5 displays the structure of the accident module. It is evident that each of the sensors are started and updated periodically. When the collision detection over the predetermined threshold, the emergency alarm is transmitted to both the rescue services and the cars in close proximity. In contrast, if a crash identification by the IMU fails to detect above the threshold level, the system will get data from the noise sensor. The emergency alarm is triggered when the sensor circuitry detects a noise that exceeds the dawn value. If the sensor circuitry does not detect any noise, the system will get the data from the pulse sensor. An warning message will be delivered if the heart rate exceeds a specific threshold. Otherwise, a driver often cancels the alarm in normal situations. If the driver fails to deactivate the alarm, it is presumed that the motorist is unable to do so due to their condition, and another emergency notification is dispatched.

The GPS module retrieves the location coordinates, while the camera module captures an image of the vehicle's inside. These data are subsequently included in the emergency message.

When an crash is reported to a hospital's emergency service, it promptly sends an ambulance to the reported site. Due to the limited and uncertain knowledge about the victims' condition and the absence of details about the number of wounded individuals, the paramedic team may encounter challenges in assessing and providing appropriate first aid treatments. Alternatively, instead of sending further information about a specific tragedy, it would be more beneficial to provide the victims with improved emergency medical services, enhanced technological assistance, first aid kits, equipment, and medications.

Level 2: Internet of Things (IoT) Gateway All the intelligent equipment are installed on the car itself, making it more practical to handle and analyze the collected data directly at the Edge. In this scenario, the Edge node is positioned in closer proximity to the data-generation source, as opposed to being located at a remote cloud.

Furthermore, there is no requirement to transmit all of the recorded data to the cloud. Only the processed data may be transmitted, therefore conserving network capacity. Data packets are transmitted through intermediate cars in a multi-hop ad hoc network, linking a Wi-Fi module of an On-Board Unit (OBU) within the vehicle to other vehicles in the vicinity. Furthermore, this communication is facilitated via an IEEE 802.11n Wi-Fi USB dongle functioning in ad hoc mode. After completing the whole route to the Edge node, the sent data will be received at the gateway. The IoT node will do several predetermined tasks, such as classifying received data to find important information, saving the associated picture, and transmitting the processed data. These are also conferred in the following manner:

• Facial Detection: The Open Source Computer Vision Library (OpenCV) is used to extract facial information from the image in the received message. This information is then used to determine the number of casualties inside a car during an accident. The condition of victims, including their position or physical condition at the time of the occurrence, would give valuable information for the medical team responding to the situation.

By possessing such factual information, the first rescuer can predict the duration for which the accident victims can survive without any medical intervention [19].

• **Data Preprocessing:** Sensors installed on the On-Board Unit (OBU) Supervise the necessary variables and collect data as necessary. In order to minimize the latency, the collected data is transmitted to the Edge node. It is preferable to process the information collected from the crash site and hospital in the control room. There are dual benefits to this approach. Firstly, it will preprocess the data to remove any inconsistencies or erroneous information, hence reducing network bandwidth use. Secondly, the data will be formatted in a manner that is more easily understandable for the end-user accessing it from the cloud.

Furthermore, it prevents the need for additional processing of the recorded data on the cloud. Additionally, temporary storage can be offered for the information at this node prior to transmitting it to the cloud in order to prevent data loss caused by the ever-changing network conditions between the sensor nodes installed in the portable node as well as the Cloud.

After the necessary data is processed at the Edge node, it is safely stored in a cache.

Subsequently, the processed data is transmitted to the primary server located in the cloud. Furthermore, the transmission of data from the edge to the cloud platform relies on the usage of Transmission Control Protocol (TCP) due to its reliable and connection-oriented characteristics. The communication between the edge node and the central server in the cloud is established using the Internet, as the cloud service may be accessed worldwide over this network.

Tier 3 refers to the Cloud Platform. The Central Control Unit (CCU) receives accident alert alerts and executes suitable actions. The CCU is tasked with extracting data from the information it received packets. Furthermore, it facilitates data storage and manages visualization through the utilization of a front-end tool, which is likewise deployed on the Cloud.

A testbed is required to evaluate the functionality of the implemented system in the cloud. A Testbed necessitates an IaaS model.

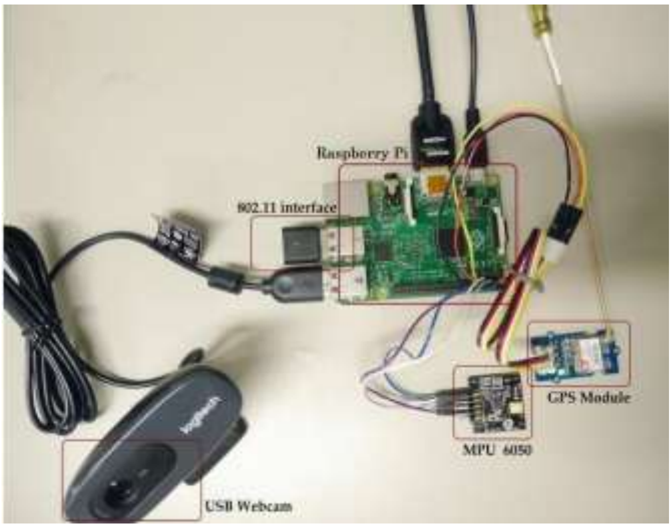

Fig 4. Proposed system Implementation for ADR

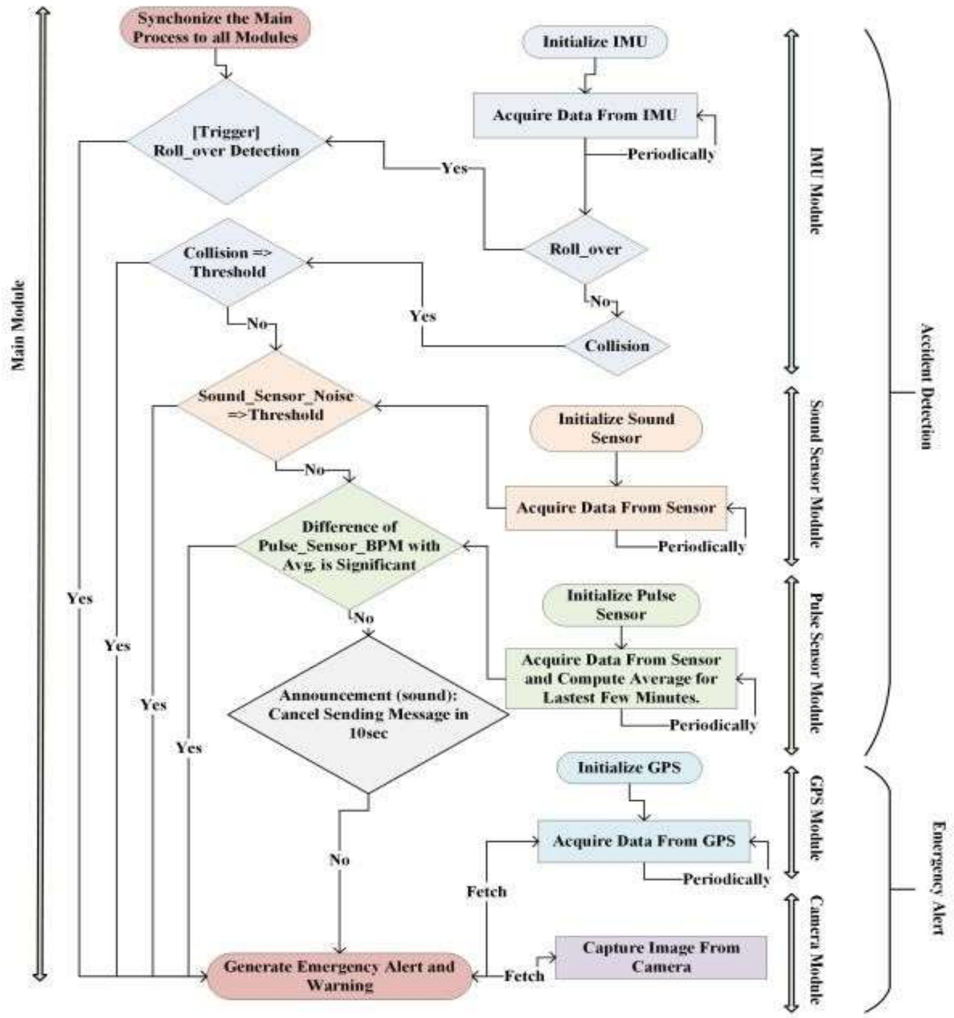

Fig 5: Workflow of the Proposed Architecture

Therefore, a private cloud is utilized to develop and test the suggested system that has been built. Start-up enterprises and medium-sized businesses mostly employ commercial cloud computing platforms to save costs related to creating bespoke applications, hosting on exterior web-servers, and servicing. Therefore, the utilization of the Apache web server program allows for the creation of an individual web host on a Linux-based operating system.

3.1. System Implementation

The suggested system is executed by partitioning it into two distinct jobs. One approach is to develop a system that can automatically identify and promptly alert about traffic congestion, in order to reduce the number of casualties. This system would also facilitate the timely provision of medical assistance to the victims of road accidents. The second step involves analyzing the recorded data to differentiate between accidents and the patterns or anomalies of the occurrence, as well as identifying the causes and specific areas of casualties. This analysis assists professionals in formulating traffic regulations aimed at reducing fatalities on the road. The system was deployed in the laboratory. In order to address the initial task, namely the automatic detection of accidents and the subsequent reporting of emergencies to the control room, the sequence of events unfolds as follows:

The crash detection module identifies accident occurrences by utilizing the IMU MPU6050, while the OBU retrieves geographical data (latitude and longitude) via its embedded GPS sensor. Thus, the system functions as an opaque entity that can assist in determining the precise whereabouts of an incident, as described in Section 3.

• Upon successful detection of an accident occurrence, the system's camera module captures a picture of the inside perspective of the vehicle responsible for the collision. The collected data is transmitted to the control room to manage specific data, as explained in Section 3 Tier 1. It facilitates the provision of an internal perspective of the vehicle to enhance the victims' critical situational awareness.

The Edge node is responsible for doing pre-processing tasks on the data, such as utilizing face detection to determine the number of victims, extracting and organizing important data, as outlined in Section 3 Tier 2.

• When the hospital receives an alarm, it promptly sends an ambulance and medical personnel to the accident site. The paramedical personnel are accountable for administering initial medical assistance to the casualties at the site of the accident and transporting them to medical facilities, if required.

• The traffic department requires crucial information on the accident's location, comprehensive car characteristics including drivers, and the condition of the victims. Consequently, the traffic department follows its established procedure and obtains valuable information on the collision and the driver's credentials.

• Ultimately, the compiled data is stored in the central database on the cloud platform. The stored data can be accessed at any time to obtain the specific accident details required. The execution of this procedure takes place at Tier 3 of the suggested system framework, as described in Section 3 Tier 3.

To demonstrate a Proof of Concept, a theoretical dataset has been created. The chauffeur's credentials and reasons of these incidents were produced using a Python package called Faker. The objective is to evaluate the effectiveness of the visualizations using a well-organized dataset.

Once the suggested system design has been successfully implemented in one location, it may be duplicated in other regions using the same approach. The information collected from all locations where the collision-related data were first captured locally is then sent to the cloud via an Edge node for additional processing of the collected information. In order to assess the viability of the system that has been created, it is subjected to testing inside a controlled laboratory environment. The accident scenario was manually initiated, and thereafter, an immediate warning signal was sent across an ad hoc network using nearby automobiles. To achieve this objective, a temporary network is established and set up utilizing Robot Cars as referenced in [20,21].

4. System validation and Result

In order to verify the functionality of the system that was created, we obtained the outcomes pertaining to accident identification and the subsequent delivery of emergency alerts. In addition, the system has undergone analysis to determine the rate of packet delivery and latency.

4.1. Phase for Detecting Accidents

The test results of the implemented system are included to confirm its capability in accident detection.

The technology has the capability to identify occurrences of accidents and roll-overs. Figure 6 displays the recorded values of the accelerometer and gyroscope, denoted as AcX = $a_x(t)$, AcY = $a_y(t)$, AcZ = $a_z(t)$, and GyX = $v\varphi(t)$, GyY = $v\psi(t)$, and GyZ = $v\zeta(t)$. In this context, Delta_X, Delta_Y, and Delta_Z represent the disparity between two successive values recorded from an accelerometer, specifically expressed as $Delta_i = a_i(t) - a_i(t - \delta t)$ where $i \in \{x, y, z\}$. These measurements are recorded at regular intervals of $\delta t = 2$ seconds to identify any occurrence of an accident.

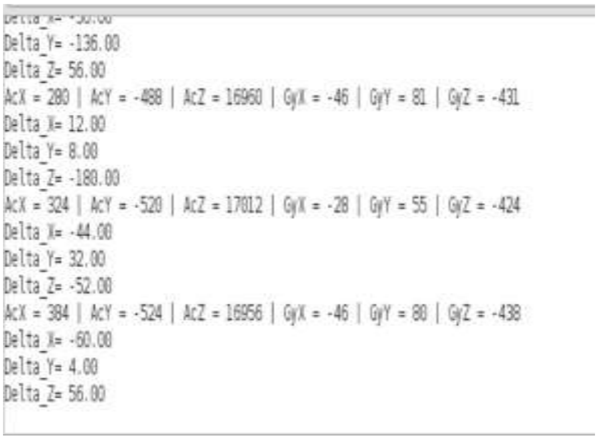

Fig 6. Captured data from MPU-6050.

The roll-over is identified by measuring the angular velocity. A roll-over is recognized when the angular velocity value beyond a predetermined threshold, denoted as ΘR, as shown in Figure 7.

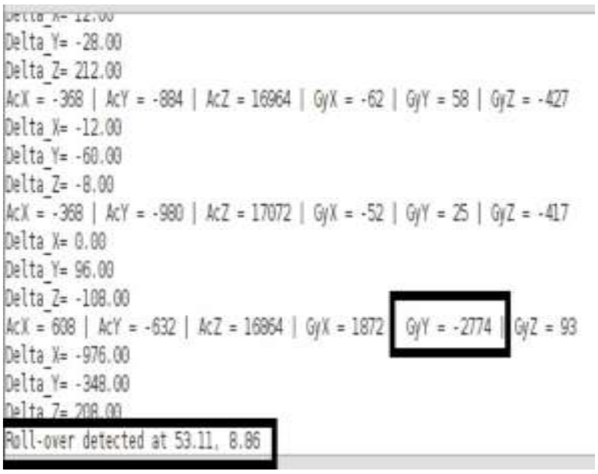

Fig 7. The detection of roll-over as a result of an accident.

Similarly, when the difference between two consecutive readings of an accelerometer exceeds the specified threshold, denoted as ΘC, an accident event is triggered, as shown in Figure 8.

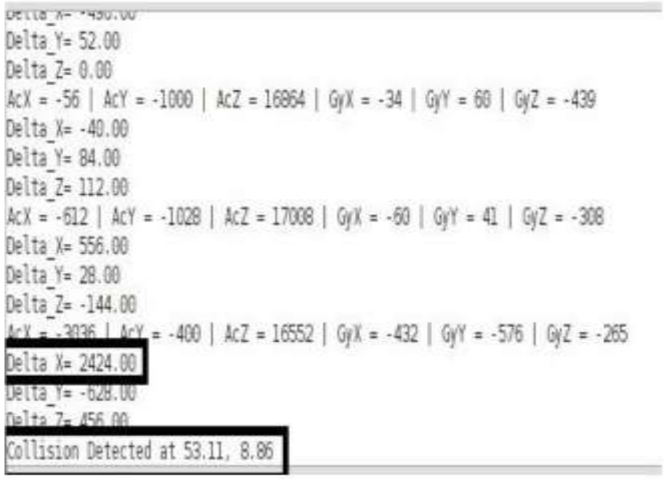

Fig 8. The detection of a collision as a result of an accident.

If the modification falls below the predefined threshold, represented as ΘC, then the potential reasons might be either a crash or the engagement of emergency brakes. In this scenario, we first include the data acquired from the ambient sensor. An accident detection occurrence is initiated when the noise sensor recognizes any sound and its calculated level exceeds a specified threshold, as shown in Figure 9.

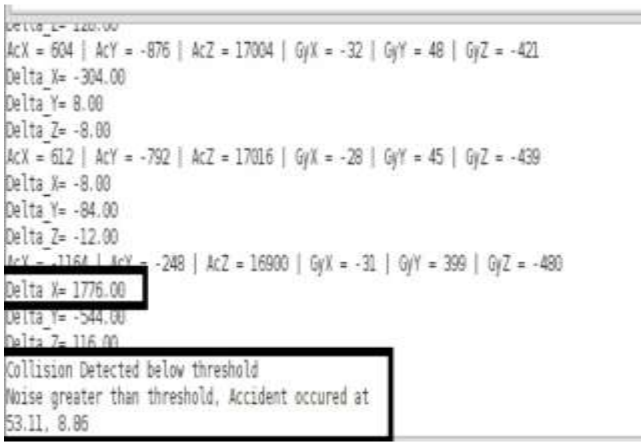

Fig 9. The detection of noise when glass breaks or a vehicle crash

We conducted several experiments in the laboratory, and a subset of them have been addressed in this section. The results indicate that the suggested system is capable of identifying events within microseconds following an accident.

If the measured sound level is below the specified threshold, the pulse sensor values are utilized for processing in order to identify an occurrence. If the heart rate increases, the system determines that a collision has occurred and sends an emergency notice to the control room, as shown in Figure 10, based on the obtained data.

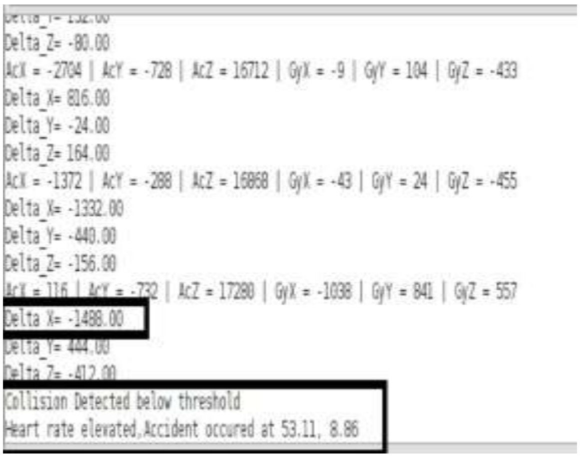

Fig 10. Heart rate elevated

4.2. Phase of Communication

The software for the server is located in the command room of a certain area. After starting up, the application begins the process of initializing and remains in a state of readiness for any connection requests from cars. These connections are necessary for the vehicles to join the ad hoc network that supports the emergency help service, as shown in Figure 11.

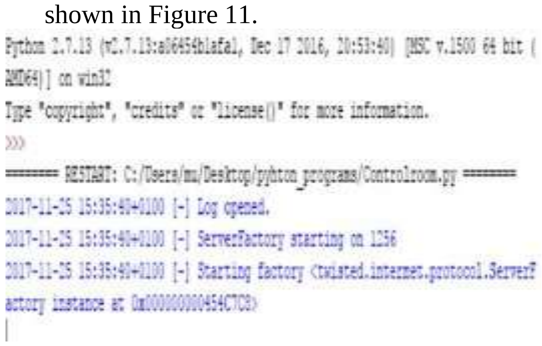

Fig 11. The server-application is ready in the control room to process any emergency notification.

Upon receiving an alert message, the server extracts the precise location of the crash scene and using the Haversine formula to determine the closest medical facility or hospital to the accident site. Subsequently, it transmits an urgent communication to the designated hospital, urging them to promptly deploy an ambulance accompanied by paramedical staff to the site of the occurrence, as seen in Figure 12. In order to guarantee the provision of the service, the hospital sends an acknowledgment to the control room.

Fig 12. Action taken in the control room by the server

The counter client program, which is deployed in the emergency control center of the hospital, is started and prepared to receive a notification of an emergency from the server, as shown in Figure 13.

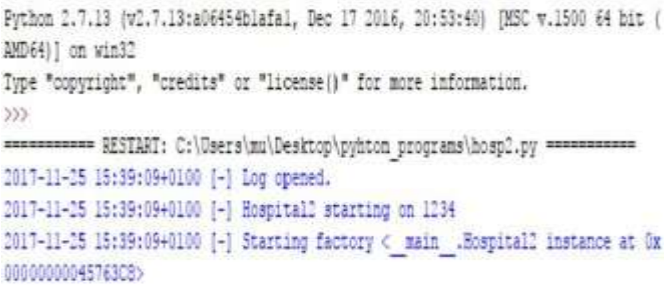

Fig 13. The application in the hospital ready to receive an emergency alert for ambulance.

Upon receiving an emergency alert from the administration room, the customer counter program at the hospital promptly summons a rescue vehicle to the accident area. Additionally, it sends a response to the server after receiving the alert message, as seen in Figure 14. While en route to the accident site, the ambulance transmits urgent messages to other cars in order to request clearance of the way.

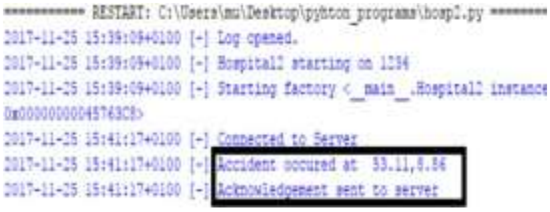

Fig 14. An emergency alert received at the terminal of application installed in the hospital for the ambulance

4.3. System Performance Analysis

In order to assess the system's performance, a series of tests were conducted in three distinct environments. These tests involved simulating accident events by executing the suggested applications on the constructed ad hoc TestBed. In order to assess the feasibility of the system, an analysis has been conducted on a densely populated area, ensuring that each relay node is surrounded by a minimum of two adjacent nodes. The number of relay nodes was gradually increased in each trial, with random values ranging from 1 to 10 in the first, second, and third tests, respectively. For each scenario, we have taken into account a slot time of 16×10^{-6}, a Short Interframe Space (SIFS) of 2 × Slottime, which is 3.2×10^{-5}, and a DCF Interframe Space (DIFS) of 2 × Slottime + SIFS, which is 6.4×10^{-5}. In addition, the TwoRayGround model is employed as a radio-propagation model in conjunction with the wireless access technology of IEEE 802.11p. Furthermore, the network is designed with a specific configuration for the highest transmission range and the IVD of each node. This allows for easy adjustment of the total number of nodes placed in the Lab.

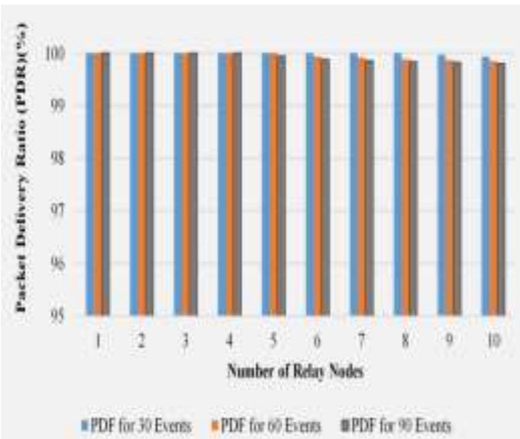

Fig 15. packet delivery ratio (%) with increasing relay nodes.

Furthermore, this study does not employ a predefined architecture. However, the nodes are interconnected in a manner that ensures there is no disruption in the network. The lab where the network has been established covers an approximate area of 500 square meters. The automobiles are traveling at varying speeds ranging from 20 to 60 km/h. However, in the event of a collision, the speed reduces significantly. The nodes are deployed in a deterministic manner, with the specific requirement that 1 to 10 OBUs must function as relay nodes according to the given scenario. Relay nodes provide the purpose of forwarding traffic to the subsequent hop on its way to its intended location or control room. The communication being transmitted to the monitoring room consists of Constant Bit Rate packets, with a maximum size ranging from 200 to 400 bytes. When an event such as a collision or rollover happens, the traffic is sent to the control room. The average Packet Delivery Ratio (PDR) has been calculated for each configuration by incrementing the number of relay nodes, as shown in Figure 15. The PDR (Packet Delivery Ratio) achieved a maximum value of 100% while the number of relay nodes ranged from 1 to 4. This implies that the destination node successfully received all the transmitted packets. Nevertheless, as the number of relay nodes exceeded 4, the observed value of PDR declined, indicating a loss of messages in the network. The occurrence of data loss can be attributed to noise and channel contention resulting from the proliferation of nodes in a wireless medium. Figure 16 presents the comparison of average end-to-end delay with respect to the number of relays.

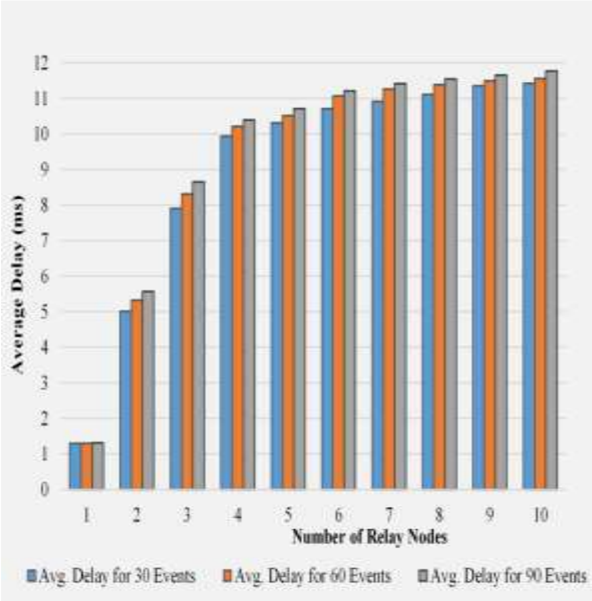

Fig 16. packet delivery ratio (%) with increasing relay nodes.

Efficient and dependable data distribution is essential for safety and emergency applications. The suggested application is specifically built to fulfill the demands of an emergency situation, nevertheless, it is crucial that the program operates with minimal latency. The TestBed consists of a small number of vehicle nodes, and the detected latency meets the minimum criteria for the safety application.

4.4. Data analysis of road accidents: empirical statistics

An individual lacking technical expertise, who holds a position of authority or is affiliated with a relevant institution, would need accurate and easily understandable data in order to derive practical and useful conclusions from it. Frequently, it is necessary for them to oversee alterations in road usage trends and scrutinize patterns of driving conduct. A visible, intuitive, and interactive open-source technology is needed. Google Charts encompasses all of these capabilities. After executing a SQL query to retrieve specific data from the database, it may be passed to the API, which will generate a graph on the screen based on the data. It will ensure that the data is easily understandable for the end-user. The primary objective of visualizing the recorded records was to evaluate the data and derive meaningful insights that might facilitate the development of effective solutions for enhancing overall road safety.

Once the data modeling front end is implemented using HTML, PHP, and Google Charts API, it can be easily duplicated with any dataset. To ensure the accuracy of data analysis, the German authorities' official road accident statistics available on the Internet are obtained.

The requested dataset is formed by the appropriate agencies' accumulation of statistics on traffic accidents throughout the years. GENESIS is a via the internet databank that contains comprehensive statistics on road accidents. These statistics include information on the number of injuries over different time periods, road accidents resulting in personal injury, the number of people seriously or moderately injured in these accidents, and the parties participating in the accidents. Furthermore, the data are derived from variables such as gender, age, level of damage, and incidents involving the transportation of water-hazardous chemicals.

The data is imported into a PostgreSQL database and visualized by SQL queries, resulting in the creation of various charts and graphs to show the data. The data for the year 2018 has not been submitted to the database yet. Hence, the existing data spans from 1991 to 2017. It primarily includes information on the number of individuals who had severe or minor injuries, personal injuries, and fatalities in these incidents. This data has been analyzed over a period of 27 years. The data is categorized based on road types and whether they are located within or outside the built-up region. A built-up area, also known as a suburban or urban area, is a phrase predominantly utilized in urban planning, building design, and the real estate development sector.. Typically, these are found within a larger developed setting, such as a district, town, village, or city.

4.5. Analysis of Accident Patterns on Various Road Types

This section focuses on the examination of fatalities, severe injuries, and minor injuries resulting from accidents on federal, district, provisional, and motorway roads between 1991 and 2017. • Analysis of Federal Roads: Figures 17 and 18 demonstrate that the incidence of injuries within urban areas on federal roads is greater than that outside of urban areas. A primary factor may be the abundance of activity within residential or commercial areas in comparison to the periphery. Consequently, a higher number of accidents take occurred within these densely inhabited areas as opposed to outside of them.

Figure 17 displays the data collected from federal roadways inside urban areas from 1991 to 2017. The data reveals a total of 1,044,451 incidents of personal injury, with 1,149,046 individuals experiencing minor injuries. In the same time period, Figure 19 displays recorded data on federal roadways located outside urban regions. The data reveals a total of 858,154 reported incidents of injuries, with 936,236 individuals experiencing minor injuries. The disparity arises when tallying the statistics in reverse, namely the count of those who have been killed or gravely injured as a consequence of these incidents. The first scenario had a total of 10,408 death instances, whereas the other situations had 41,869 deaths, resulting in a fourfold increase. Moreover, inside the urbanized region, a total of 208,959 individuals experienced severe injuries, while 357,817 were involved in incidents outside this area. Consequently, urban areas may see a higher frequency of accidents compared to rural areas. However, accidents occurring outside of cities are deemed more perilous as a result of the absence of necessary amenities. Simultaneously, it is worth acknowledging that German authorities are executing their responsibilities with considerable efficiency, resulting in a consistent decline in the number of fatalities and injuries over time.

Figure 20 depict the recorded data on traffic accidents for the years 1991-2017 specifically on district roads. The data in both figures show a similar pattern. While the number of casualties and casualties on district roads is far lower than on federal highways, the decrease in minor injuries or small wounds over the past decade is unsatisfactory, particularly for roads within urban areas. On district roads within urban areas, there were 16,526 incidents of personal injuries in 2008, compared to 15,997 cases in 2017. This is a drop of only 529 cases over a span of ten years. In the same vein, there was a decline in the number of individuals who experienced minor injuries, with 17,788 instances in 2008 and 17,109 cases in 2017, representing a reduction of 679 cases. While the general trend is encouraging, there is a pressing need for a significant decline in the mentioned data, particularly given the current perception of German roads as the safest.

In 1991, there were 943 fatalities resulting from vehicle accidents within developed regions on a federal route. In 2017, this figure decreased by a factor of seven to 134. In 1991, there were 2713 fatalities outside urban areas on a federal road, however in 2017, there were only 688, representing an almost fourfold decrease. This also applies to the district roads. Furthermore, in the year 1991, a total of 325 individuals lost their lives in traffic accidents within built-up regions, while 999 fatalities occurred outside of these areas on district roads. The numbers for 2017 show a similar trend, suggesting a decline of around one-third.

• Analysis of Provincial Roads: Figures 22 and 23 depict the number of injuries and wounds that took place within and outside the developed regions on provincial roads, indicating a higher level of loss compared to district roads, but lower than federal roads. There has been a favorable decline in the number of injuries both within and outside urban regions between 2015 and 2017.

• Examination of the Federal Motorway: The Bundesautobahn is Germany's nationwide system of federally-controlled access highways. This freeway is unusual and famous worldwide since it does not have a speed restriction for certain types of vehicles.

4.5. Primary Factors Contributing to Road Accidents Categorized by Vehicle Types

Regarding roads and highways, several categories of vehicles coexist, encompassing more than simply passenger automobiles. The road traffic includes bicycles, public transit buses, and heavy goods vehicles such as trucks and lorries. Moreover, accidents can arise from a variety of scenarios with distinct underlying causes. Hence, the raw data is subjected to data analysis in order to elucidate the prevailing factors responsible for road accidents, contingent upon the type of vehicle employed, as seen in the graph below.

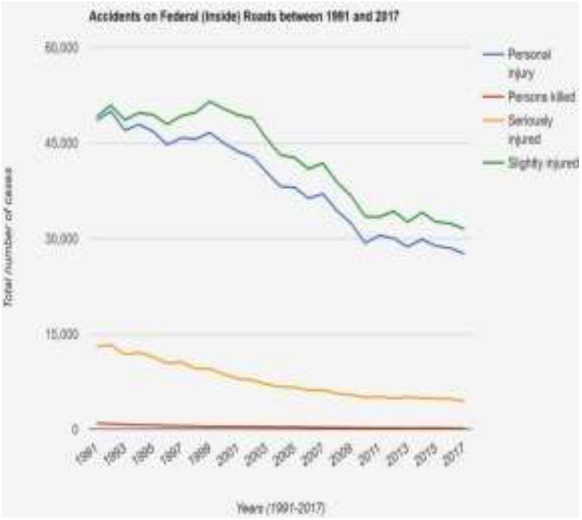

Fig 17. Levels of injuries that occurred on federal roads in big cities and big towns

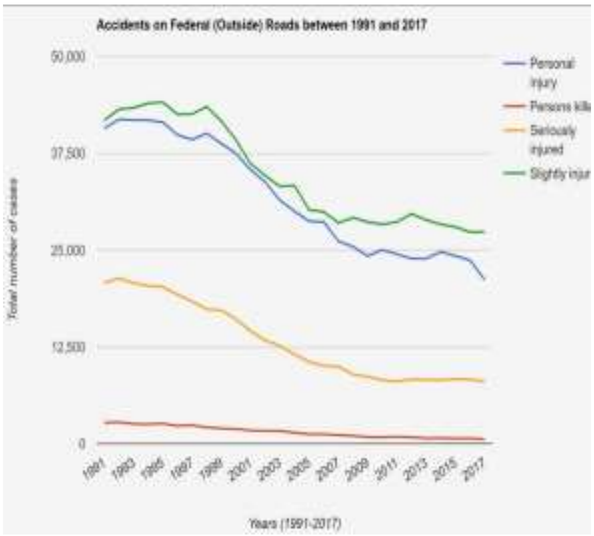

Fig 18. Levels of injuries that occurred on federal roads in small towns and rural areas

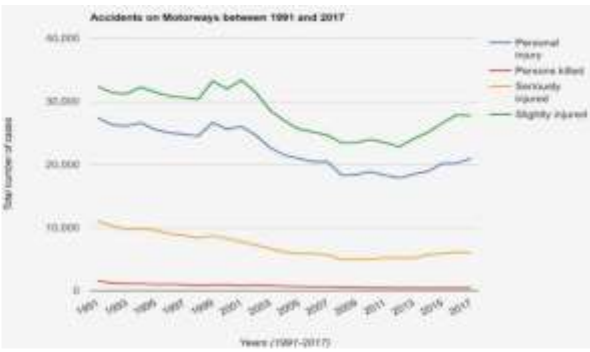

Fig 19. Analysis of injuries that occurred on motor-way

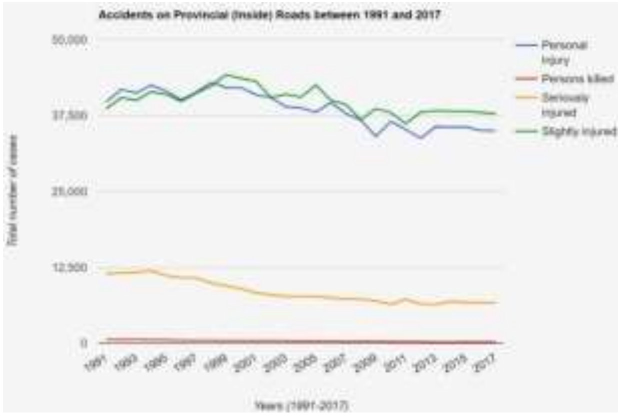

Fig 20. Levels of injuries that occurred on provincial roads inside the built-up areas

Figure 21 displays the 12 primary causes of accidents involving two-wheel vehicles on the highways. In Germany, many categories of motorcycles exist, all of which are required to adhere to the following regulations: the rider must consistently wear a protective helmet, possess valid insurance coverage, and hold the necessary documentation.

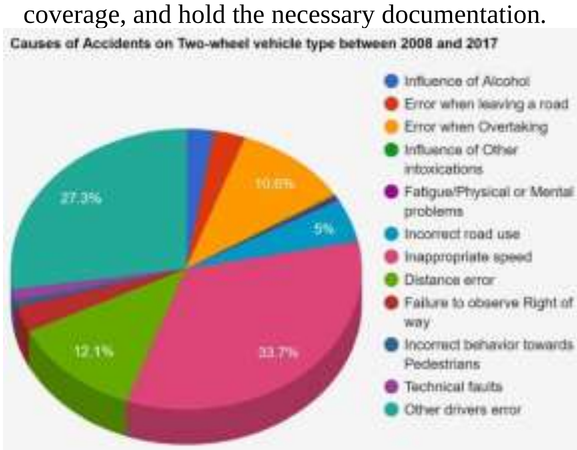

Fig 21. Major causes of road accidents that occurred in two-wheel vehicles

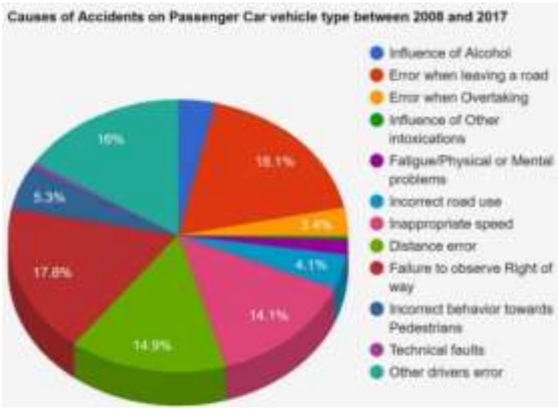

Fig 22. Major causes of road accidents that occurred in passenger cars

Attained the minimal age prerequisite for operating a vehicle [22]. Although these laws are well enforced, accidents still happen. Among the 12 factors described earlier, excessive speed is the primary factor, accounting for 33.7% of all accidents. This represents one-third of all events involving two-wheel vehicles in the past decade. Furthermore, it has been scrutinized that the responsibility for an accident does not always lie solely with the driver. Oftentimes, the loss of lives can be attributed to the errors made by other drivers. Hence, it is crucial to maintain a safe distance from the preceding vehicle. Subsequently, a mistake occurs while passing another car, and the road is used incorrectly, ranking fourth and fifth, respectively.

As reported by the Federal Statistical Office of Germany (Destatis), road accident deaths have increased by around 13% compared to the previous year, as of October 2018 [23]. Figure 22 provides a comprehensive overview of the primary factors that contribute to traffic collisions involving a Passenger Car. In addition, there are certain supplementary regulations that must be adhered to by the driver and passengers inside a passenger automobile [22].

• It is mandatory for all individuals inside a vehicle to wear seat belts, such as passengers in the back seat.

• The kids who are 150 cm or shorter must be secured in a child seat.

• The use of mobile phones or chat applications while driving is strictly prohibited.

• It is important to adhere to the designated speed limits on various sections of the road.

• Operating a vehicle while under the effect of alcohol is strictly prohibited.

The primary factor contributing to traffic accidents involving passenger vehicles is the act of veering off the road due to driver mistake. In addition, it involves using the reverse gear or moving in a backward direction while exiting a major route in order to enter a narrower road or alley. Over the past decade, it contributed to about 440,000 traffic collisions, or 18.1% of all reported incidents. The second most prevalent cause is the failure to adhere to the right of way. Motor vehicle drivers are required to always give priority to pedestrians who are nearby and crossing the road at a designated crosswalk. Failing to do so is perilous and can lead to disastrous incidents.

The primary factors contributing to road accidents with 4-wheel autos are driver negligence, misjudgment of distance, and excessive speed.

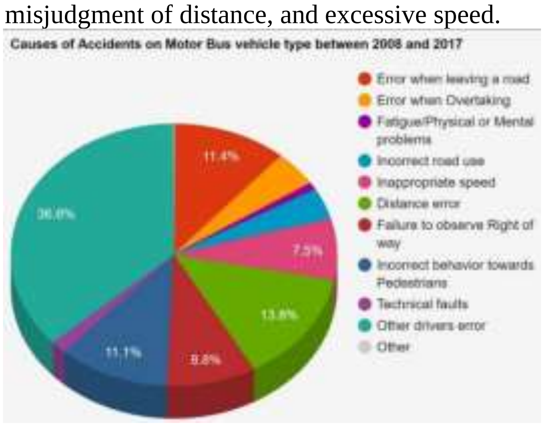

Fig 23. Major causes of road accidents that occurred on public buses

To conduct more in-depth research, we will also take into account the two additional forms of transportation that are present on the road: public buses and goods transport vehicles. Efficient transportation is essential for the functioning and prosperity of a contemporary civilization. Motor buses are often used by the general populace as their primary mode of transportation in several European nations. Hence, it is crucial to acknowledge the underlying factors that contribute to traffic accidents involving public buses. According to Figure 23, 36.6% of motor bus accidents are caused by 'another driver's mistake of judgment', which accounts for more than one-third of all accidents. It is very paradoxical that a single error made by one individual while driving can have a significant impact on several other lives, whether intentional or not. Therefore, it is imperative to rigorously enforce driving laws and regulations in any community. The second most significant factor, which was also present in the previous two instances, is 'distance inaccuracy', accounting for 13.8% of motor bus incidents. Other significant factors contributing to accidents include "deviation from the road," "inappropriate conduct towards pedestrians," and "failure to adhere to right of way." Figure 24 shows the cauuses of accident that occurred in goods vehicle.

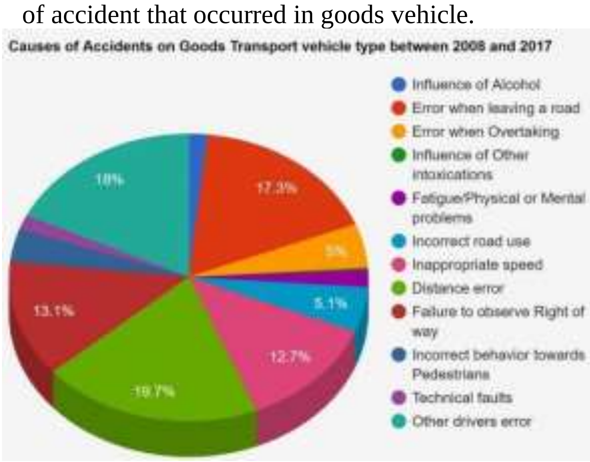

Fig 24. Major causes of road accidents that occurred in goods transport vehicles

Distance mistake is the primary cause of crashes involving vehicles and lorries transporting goods, representing 19.7% of all such incidents. This explanation has been present in all of the aforementioned categories, underscoring the need of maintaining an appropriate spacing between cars on the road. Oneself. If a countermeasure could be implemented, it has the potential to significantly decrease the number of fatalities resulting from traffic accidents. This crucial piece of evidence is acquired by extensive data collection, meticulous compilation, and efficient analysis. This is a clear demonstration of the advantages that may be gained by leveraging the extensive range of data analytics tools that are readily accessible to everyone.

5. Conclusion

With the increasing urban population worldwide, there is a corresponding rise in the incidence of traffic accidents, leading to a higher number of fatalities and injuries. Prompt identification of a collision and appropriate response to it can significantly preserve more human lives. Thus, a suggested automated system has successfully identified and promptly alerted concerning incidents. This study has created and implemented a test environment for vehicles that use Internet-of-Things technology. The system is capable of autonomously detecting collisions and roll-overs, and promptly notifying the appropriate organizations. Cloud and Edge computing are two significant developing concepts for managing vast quantities of data created by the Internet of Things (IoT). Nevertheless, these technologies had distinct benefits and limits. However, if employed simultaneously, they would prove advantageous for the entire system. Thus, in this study, these technologies have been effectively utilized in conjunction. The proposed automotive TestBed utilizes Edge technology to handle resource-intensive operations such as offloading and preprocessing of data. Cloud technology is employed for data storage, enabling further data analysis. It has significantly decreased the time it takes to transmit data and has improved the whole communication process. In addition, this research project involved the implementation of a web server application that acknowledged accident notifications from all vehicles in the system using properly equipped On-Board Units (OBUs). Upon receiving a warning, the fully completed system would promptly alert the closest hospital to mobilize a rescue crew. Consequently, it facilitated prompt medical assistance to individuals involved in vehicle accidents. The paramedic personnel have also been provided with the present condition of the victims through a picture attached to the remaining data. After the rescue operation is finished with the suggested method transmitted to the central database for permanent storage. The data may be retrieved from the database at a later time and subjected to a thorough analysis. The data kept in the cloud can enable authorities to formulate policies and implement effective actions to decrease the incidence of damages and fatalities resulting from road accidents.

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