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"GPS Based Toll Collection and Accident Detection"

RS AMRUTH
Department of Electrical and Electronics Engineering Sri Siddhartha Institute of Technology Tumkuru
Sri Siddhartha Academy of Higher Education

SAMPRITH BASHA ENNI
Department of Electrical and Electronics Engineering
Sri Siddhartha Institute of Technology Tumkuru
Sri Siddhartha Academy of Higher Education

NANDEESH J
Department of Electrical and Electronics Engineering Sri Siddhartha Institute of Technology Tumkuru
Sri Siddhartha Academy of Higher Education

SANDESH S
Department of Electrical and Electronics Engineering Sri Siddhartha Institute of Technology Tumkuru
Sri Siddhartha Academy of Higher Education

NAYANA G B.E,M.Tech.,(Ph.D)
Asst.Professor Department of Electrical and Electronics Engineering Tumkuru
Sri Siddhartha Academy of Higher Education

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Abstract— The increasing demand for efficient transportation infrastructure has highlighted the limitations of conventional toll collection systems, which often rely on physical checkpoints and manual processing.

This project presents a smart, GPS-based automated toll collection system that leverages the ESP32 microcontroller, NEO-6M GPS module, and wireless communication technologies to calculate toll charges dynamically based on real-time vehicle movement.

The system continuously monitors location data using the GPS module and calculates the distance traveled through the Haversine formula.

To ensure accuracy, a movement threshold is implemented to filter out negligible GPS drift. Once a predefined distance threshold is reached, the ESP32 communicates with the Twilio API over Wi-Fi to send an SMS alert to the user, detailing the total distance covered and the corresponding toll amount.

I. Introduction

With the rapid expansion of intelligent transportation systems, the need for automated and efficient toll collection mechanisms has grown significantly. Traditional toll booths often lead to congestion, increased travel time, and fuel consumption.

To address these challenges, this project introduces a GPS-based automated toll collection system built around the ESP32 microcontroller.

The system is designed to monitor vehicle movement in real-time using geolocation data and automatically compute toll charges based on the distance traveled. Notifications regarding toll

updates are sent directly to the user's mobile phone through SMS, ensuring seamless communication and transparency.

The proposed system eliminates the need for traditional toll booths, thereby reducing congestion, minimizing human error, and improving cost-efficiency.Real-world testing confirmed the system's reliability in tracking motion, calculating tolls accurately, and delivering timely notifications.

The project demonstrates how modern microcontroller platforms can be used to create scalable and flexible tolling systems that support real-time communication and billing.

It lays the groundwork for future enhancements such as GSM-based messaging, mobile app integration, and cloud data storage. This automated toll solution offers a practical and innovative approach toward smart transportation and the development of intelligent road infrastructure.

II. LITERATURE REVIEW

Several researchers have contributed toward intelligent transportation and accident monitoring systems.

1. *RFID Based Automatic Toll Collection System (2018)*
   R. Kumar and P. Sharma developed an RFID-based toll collection system to reduce manual toll operations and traffic congestion.
2. *IoT Based Vehicle Accident Detection and Alert System (2020)*
   S. Naveen and K. Rakesh proposed a smart accident detection system using GSM and GPS modules for emergency communication.
3. *Smart Transportation Monitoring System Using GPS and IoT (2022)*
   A. Prakash introduced a vehicle monitoring system for real-time tracking and transportation management.
4. *AI Integrated Intelligent Traffic and Safety System (2024)*
   M. Farooq discussed the integration of IoT and AI for accident .

In summary, the papers as a whole highlight the need to integrate embedded systems, GPS, IoT, and cloud computing to solve the inefficiencies of conventional tolling.

From microcontroller based embedded solutions to cloud-enabled smart gates, each solution has its own strengths.

III. NOVELTY AND CONTRIBUTION

The key contributions of the proposed research include:

- GPS-based vehicle location tracking
- Automatic RFID toll collection
- Real-time accident detection
- GSM-based emergency alert system
- LCD-based monitoring system
- Reduced traffic congestion
- Improved emergency response system
- Low-cost and scalable transportation solution

Unlike traditional toll systems, the proposed design integrates toll automation and accident detection in a single intelligent platform.

IV. SYSTEM ARCHITECTURE

The overall system architecture consists of sensing units, communication modules, embedded controllers, and monitoring interfaces.

Major Components

- ArduinoUNO
- GPS Module
- GSM Module
- RFID Reader and RFID Tags
- Vibration Sensor
- Tilt Sensor
- LCD Display
- Buzzer
- Relay Module
- Power Supply

The RFID reader identifies the vehicle at toll booths and automatically deducts toll charges. The GPS module continuously tracks the vehicle location.

The vibration and tilt sensors monitor accident conditions. When an accident occurs, the Arduino controller processes the sensor signals and sends the accident location through the GSM module.

The system continuously updates:

- Vehicle location
- Toll payment status
- Accident status
- Emergency alert information

- LCD-based monitoring system
- Reduced traffic congestion
- Improved emergency response system
- Low-cost and scalable transportation solution

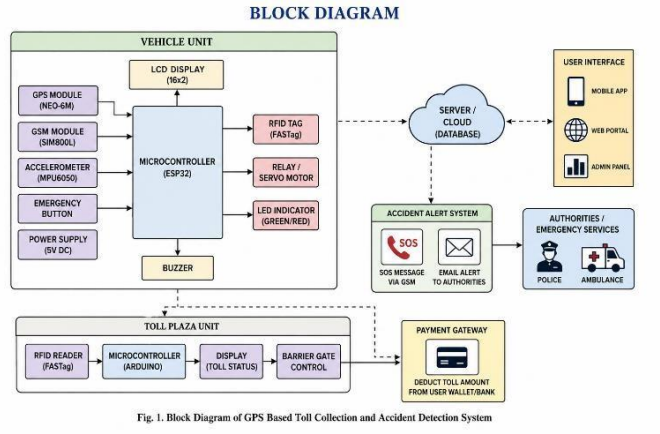


Fig. 1. Block Diagram of GPS Based Toll Collection and Accident Detection System

V. HARDWARE COMPONENTS AND FUNCTIONS

Sl. No	*Component*	*Function*	*Purpose*
1	Auduino UNO	Main Controller	Processes System Operation
2	GPS Module	Vehicle Tracking	Identifies Accident Location
3	GSM Module	Wireless Communication	Sends emergency alerts
4	RFID Reader	Vehicle Identification	Automatic toll collection
5	RFID Tag	Vehicle Authentication	Toll payment acess
6	Vibration Sensor	Accident Detection	Detects impacts
7	Tilt Sensor	Vehicle Tilt Monitoring	Detects abnormal vehicle angle
8	LCD Display	Local Monitoring	Displays system status
9	Buzzer	Alaram Indication	Accident warning
10	Power Supply	DC Supply	Power electronic circuits

VI. MATHEMATICAL MODELING

Vehicle Speed Calculation

genui {"math_block_widget_always_prefetch_v2":{"content":"v = \frac{d}{t}"}} Where:

- v = Vehicle speed
- d = Distance travelled
- t = Time taken

Toll Deduction Logic

If RFID authentication is successful:

Toll Amount = Account Balance − Toll Fee

Accident Detection Logic

If vibration or tilt exceeds threshold value:

Accident Status = 1 (Accident Detected) Else:

Accident Status = 0 (Normal Condition)

VII. WORKING METHODOLOG

The operational workflow of the proposed system is as follows:

1. Vehicle approaches toll booth.
2. RFID reader scans RFID tag.
3. Toll amount is deducted automatically.
4. LCD displays payment confirmation.
5. GPS module continuously tracks vehicle location.
6. Vibration and tilt sensors monitor vehicle condition.During accidents:
   - Sensors detect abnormal condition
   - GPS identifies accident location
   - GSM sends emergency SMS alerts
   - Buzzer activates for warning

   The system continuously monitors:
   - Vehicle location
   - Toll collection status
   - Accident conditions
   - Emergency communication

The GSM module sends SMS notifications to emergency contacts and nearby hospitals

VIII. SOFTWARE IMPLEMENTATION

The software is developed using Arduino IDE.

Software Functions

- RFID authentication
- Toll fee deduction
- GPS data acquisition
- Accident detection
- GSM communication
- LCD interfacing
- Sensor monitoring
- Alert generation

The GSM module sends SMS notifications to emergency contacts and nearby hospitals.

IX. RESULTS AND DISCUSSION

The developed prototype was tested under different operating conditions.

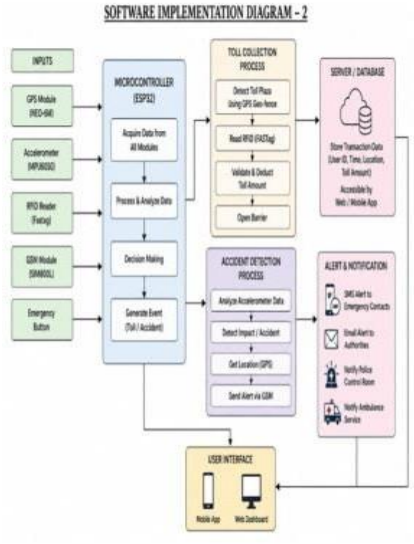
1. Normal Toll Collection Condition Observed:

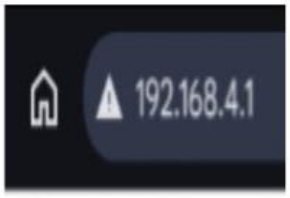
- **RFID tag detected successfully**
  - **Toll deducted automatically**
  - **LCD displayed "Payment Successful"**

2. Accident Detection Condition Observed:

- **Vibration sensor detected impact**
  - **GPS location identified accurately**
  - **GSM sent emergency SMS instantly**
  - **Buzzer activated successfully**Performance Evaluation

SI.NO	Parameter	Result
1	RFID Detection	Accurate
2	Toll Collection	Fast
3	GPS Tracking	Reliable
4	Accident Detection	Immediate
5	GSM Communication	Stable
6	System Reliability	High





Toll System

Amount: 0 Rs

Gate: CLOSED

X. ADVANTAGES OF THE PROPOSED SYSTEM

- Automatic toll collection
- Reduced traffic congestion
- Fast accident detection
- Real-time vehicle tracking
- Improved road safety
- Reduced manual operation
- Wireless communication capability
- Easy scalability

XI. APPLICATIONS

The proposed system can be used in:

- Highways and toll plazas
- Smart transportation systems
- Emergency vehicle monitoring
- Smart city infrastructure
- Fleet management systems
- Road safety monitoring
- Public transportation systems

XII. SDG MAPPING

SDG 9 – Industry, Innovation and Infrastructure

- Smart transportation development
- Intelligent toll automation
- Infrastructure modernization

SDG 11 – Sustainable Cities and Communities

- Reduced traffic congestion
- Improved road safety
- Smart mobility support

SDG 3 – Good Health and Well-Being

- Faster emergency response
- Reduced accident impact
- Improved public safety

Sustainable Development Goals (SDGs) & Its Mapping

The **GPS Based Toll Collection and Accident Detection System** supports multiple Sustainable Development Goals (SDGs) by improving transportation safety, reducing traffic congestion, promoting digital infrastructure, and encouraging environmentally friendly operations.

1. *GPS-Based Toll Collection*

- Reduces traffic congestion and waiting time.
- Saves fuel and supports seamless transportation.
- Promotes smart road infrastructure.

Mapped SDGs:

- SDG 9 – Industry, Innovation and Infrastructure
- SDG 11 – Sustainable Cities and Communities
- SDG 13 – Climate Action

2. *Accident Detection & Alert System*

- Detects accidents quickly and sends emergency alerts.
- Helps reduce fatalities and improves road safety.
- Enables faster emergency response.

Mapped SDGs:

- SDG 3 – Good Health and Well-Being
- SDG 11 – Sustainable Cities and Communities
- SDG 17 – Partnerships for the Goals

Mapped SDGs:

- SDG 9 – Industry, Innovation and Infrastructure
- SDG 11 – Sustainable Cities and Communities
- SDG 17 – Partnerships for the Goals

4. *Paperless & Cashless Operations*

- Reduces paper usage and carbon emissions.
- Encourages eco-friendly and digital transactions.
- Supports green transportation systems.

Mapped SDGs:

- SDG 13 – Climate Action
- SDG 12 – Responsible Consumption and Production
- SDG 15 – Life on Land

5. *Public Convenience & Transparency*

- Improves user experience and accountability.
- Provides transparent toll collection processes.
- Enhances public trust in smart transportation systems.

Mapped SDGs:

- SDG 11 – Sustainable Cities and Communities
- SDG 16 – Peace, Justice and Strong Institutions
- SDG 17 – Partnerships for the Goals

Vision

"To create a safer, smarter, and sustainable transportation ecosystem for a better future."

3. *Digital Data & Analytics*

- Provides real-time traffic and toll data.
- Supports better infrastructure planning and management.
- Enables data-driven decision making.

XIII. FUTURE SCOPE

Future improvements include:

- AI-based accident prediction
- Cloud-based vehicle monitoring
- Mobile application integration
- Face recognition vehicle authentication
- Smart traffic signal integration
- Automatic emergency calling system

XIV. CONCLUSION

The GPS Based Toll Collection and Accident Detection System was successfully designed and implemented for intelligent transportation monitoring and safety enhancement.

The system automates toll collection using RFID technology and detects accidents using vibration and tilt sensors. The integration of GPS and GSM modules enables real-time location tracking and emergency communication.

Experimental results demonstrate reliable toll automation, accurate accident detection, and fast alert transmission. The proposed system reduces traffic congestion, improves road safety, minimizes manual monitoring, and supports smart transportation infrastructure.

The project provides an efficient, scalable, and low-cost solution for modern transportation systems.

XV. REFERENCES

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