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RFID Based Automated Toll Collection System

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***Abstract*— Transportation serves as the backbone of a country's economy, as advancements in transportation systems lead to improved lifestyles by providing greater freedom of movement, facilitating trade in goods and services, and enhancing employment rates and social mobility. Economic progress is thus closely tied to efficient transportation. However, an increase in the number of vehicles brings challenges like congestion, higher accident rates, air pollution, and other associated problems, which impact national productivity. Efficient transportation is crucial to lowering costs associated with transporting raw materials to production sites and distributing finished goods to markets a key factor in economic competitiveness. Automatic Toll Collection (ATC) is an innovative technology that enables automated, electronic toll payments, significantly enhancing efficiency. This project proposes the development of a web based platform with a robust backend server to manage Automatic Toll Collection. The web page will provide an interface for users and administrators to monitor transactions and account details, while the backend server securely handles data, processes payments, and communicates with vehicle registration databases. Through streamlined toll processing, this system will alleviate congestion, reduce wait times, and improve the overall efficiency of transportation infrastructure.**

***Keywords*— RFID, Reader, cloud computing,**

I. INTRODUCTION

1.1 Introduction

The primary goal of implementing an RFID-Based Toll Collection System is to automate the toll payment process and significantly reduce the long queues at toll booths. This is achieved by equipping vehicles with RFID tags, which enable quick and seamless transactions. Beyond facilitating toll payments, the system also aids in detecting stolen vehicles and monitoring traffic violations, such as signal breaches and speeding. For vehicle owners and administrators, the system offers various advantages, including reduced fuel consumption, lower emissions from minimized idling, and reduced acceleration and deceleration times.

The system delivers several benefits:

1. Shorter queues at toll plazas by improving service turnaround times.
2. Faster, more efficient service by eliminating the needfor manual fee exchange.
3. The convenience of preloaded balances on RFID cardsfor easy payments.
4. Postpaid toll statements, removing the need for physical receipts.
5. Reduced operational costs associated with toll collection.
6. Enhanced audit controls through centralized user accounts.
7. Increased toll-handling capacity without requiring additional infrastructure development.

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1.2 Problem Statement

The primary objective of this proposal is to develop and implement an efficient Automatic Toll Collection system that requires minimal changes to existing infrastructure while maximizing operational efficiency. This RFID-based system aims to automate toll collection, thereby reducing the need for manual intervention and long queues at toll plazas. Alongside toll collection, the system enhances vehicle theft detection capabilities, monitors traffic violations such as speeding and signal breaches, and improves overall traffic management. The use of RFID technology in day-to-day toll operations minimizes fuel wastage, saves time, reduces financial losses, and ensures smoother traffic flow.

1.3 EXISTING SYSTEM

Currently, various RFID-based systems are in use, offering distinct functionalities:

1. Active Wave Inc. Solutions: Active Wave Inc. has introduced a vehicle monitoring system using active RFID tags. These tags have a range of up to 30 metersand operate at frequencies of 916–927 MHz for transmission and 433 MHz for reception. The tags areequipped with 256 Kbits of fixed memory and are powered by a replaceable 3V battery, weighing approximately 14 grams. Basic notifications, such as blinking LEDs and beeping sounds, provide operational signals.
2. Smart Key Access Control Systems: This system employs a client-server model integrated with an SQL server for managing multiple vehicle monitoring systems. The user interface is designed using Microsoft's .NET Framework. Operating in the 900 MHz band, the system has a limited range of 30 meters.

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3. RFID-Based Toll Collection Systems: These systems utilize active RFID tags powered by the vehicle's battery. The implementation is divided into two key modules:
   - Vehicle Module: Equipped with the active tag.
   - Base Module: Communicates with the vehicle module via RF modems operating in the ISM frequency range of 902–928 MHz.

1.3.1 Drawbacks Of Existing System: The methods currently used for tax collection are time-consuming and inefficient. They also leave room for tax evasion, as some vehicles can bypass payment. Additionally, these systems often result in long queues at toll booths, causing delays and frustration for motorists.

3. LITERATURE REVIEW

Toll collection systems have seen a significant evolution from basic roadside booths to sophisticated setups essential for managing traffic flow and generating revenue. As traffic volumes continue to grow, the need for efficient toll management systems has become increasingly important.

One approach discussed by Sachin Bhosale and colleagues focuses on the use of RFID (Radio Frequency Identification) technology for automating toll collection. An RFID system generally includes a transmitter, receiver, and processing unit. The study details two types of RFID tags: active and passive. Active RFID tags, which contain built-in batteries, provide a longer range and larger data capacity. However, these tags are more expensive, larger in size, and have a limited operational lifespan because they depend on battery power. Conversely, passive RFID tags operate without a battery, drawing power from the RFID reader. They are more cost-effective, smaller, and have a longer lifespan, but with a reduced identification range.

The research also outlines the components of an RFID-based toll collection system. The RFID reader communicates with the tags, sending collected data to a control unit. The setup includes an LCD for displaying vehicle information, a GSM module for connectivity, and an IR sensor for vehicle detection. Additionally, an alarm system alerts authorities about unauthorized vehicles. The microcontroller (8051) processes data from the tags, verifies account balances, and allows or restricts vehicle passage accordingly. While active RFID tags offer better range, their dependency on batteries is a drawback, which is why the use of passive tags is recommended to improve cost-efficiency and longevity.

Another proposed system, detailed by Asif Ali Laghari and his research team, addresses issues of long waiting times and manual payment inefficiencies. Their model includes transponders, antennas, a centralized server, and a traffic management system. A Lane Allocation Algorithm dynamically assigns vehicles to different lanes to streamline traffic flow, and a speed controller manages vehicle speed as they approach toll booths. However, the system's reliance on this algorithm poses a risk: any malfunction could lead to severe traffic congestion and disrupt the entire process.

Abhishek Sharma's research adds to the discussion by integrating load sensing technology with RFID-based toll systems. In his model, RFID tags are placed on vehicle windshields and are read by sensors at toll gates, with an additional load sensor to measure vehicle weight. This setup helps ensure accurate tolling and adds an extra layer of data verification. The system operates through a central control booth, where a computer and operator manage the process. Data from the RFID tags is transmitted to a server using serial communication, enabling efficient and automated toll transactions while reducing the chance of errors and manual intervention.

4. OBJECTIVES

- Streamline Toll Collection Process: Automate toll transactions to reduce wait times and eliminate the need for manual payment, thereby enhancing traffic flow and minimizing congestion at toll plazas.
- Real-Time Data Processing: Connect the ATC system to a web server to enable real time tracking, processing, and updating of toll transactions for accurate and timely payment collection.
- Enhance User Convenience: Provide a user-friendly web page where drivers can view transaction histories, manage account balances, and receive notifications about toll payments or violations, promoting transparency and user control.
- Accurate Vehicle Identification and Verification: Use technologies like RFID or ANPR integrated with the web server to accurately identify registered vehicles, ensuring that tolls are correctly assessed and processed.
- User-Friendly Web Interface: Design an intuitive web page that allows users to interact with the toll system seamlessly, facilitating easy payments, registration, and access to support resources.

5. APPLICATIONS OF THE PROJECT:

SEND PROOF OF PAYMENT AS TO SMS ACCOUNT OWNER'S PHONE The Automated Toll Collection (ATC) System has a wide range of applications, primarily in areas where efficient toll management is crucial for smooth traffic flow and revenue collection. Here are some of its key applications:

1. Highways and Expressways: ATC systems are widely used on highways to manage toll collection without requiring vehicles to stop. This helps reduce congestion, especially during peak travel times, and ensures a faster, more efficienttolling process.

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2. Bridges and Tunnels: ATC is commonly applied at toll bridges and tunnels where traffic flow needs to be uninterrupted. By automating toll collection, vehicles can pass through these structures without slowing down, reducing wait times and enhancing travel experience.

3. Urban Toll Roads and Congestion Zones: In busy urban areas, ATC systems can be used to charge vehicles entering high-traffic zones or congestion-prone areas. This can help regulate traffic, reduce congestion, and generate revenue to support urban infrastructure.

4. Parking Facilities: ATC systems can be adapted for parking lots and garages, where automated payment can streamline entry and exit, improve space utilization, and provide a more convenient experience for users.

5. International Border Crossings: ATC systems are useful at border checkpoints to manage toll payments for cross-border travel. This speeds up processing at international crossings and helps manage high vehicle volumes[11].

6. METHODOLOGY:

Queuing theory using a single server model, infinite queue model and infinite population model was used to determine how efficient the service offered by our proposed solution will be. A prototype was created to test the concept using the following materials:

1 Arduino Mega 2560/ Wi-Fi microcontroller: Microcontroller is the heart that controls all operations to be carried out by the system. All components are connected to this microcontroller using specific pinouts.

2 Ultrasonic HC-SR04 proximity sensor: In this prototype it is deployed as a proximity sensor to detect that an object has completely crossed the tollgate barrier and message is sent to microcontroller unit (MCU) so that an interrupt signal is sent to the servo motor to now close the barrier(gate).

3 Micro servo motor SG90: It is used to open and close the barrier on the gate in this prototype, thereby controlling what should pass through and what should not.

4 IR flying fish MH8 sensor: In this prototype it is being deployed as an object detection sensor. In this scenario it detects the presence of a vehicle in the range of 10cm.

5 Breadboard: It is used in this scenario to build the circuits for the prototype instead of using printed circuit boards that requires soldering components to the printed circuit board. Being used to connect different components to the MCU.

6 RC522 RFID reader: In this prototype it is used to read information (unique ID) from the RFID tag and pass it to the Arduino Mega 2560 MCU which is then send to the cloud using an on-board ESP8266 Wi-Fi module for authentication and checking if the account linked to the unique ID on the tag has the required balance to pay the toll fees. It's reading distance is 5cm. It uses the frequency range 13.56 MHz ISM band.

7 RFID tags: To store an ID that links the vehicle to its details on the database that is hosted in the cloud.

8 Arduino power supply 12v- 3A: This is used to supply power to the MCU using UART port that is on the MCU and also supplying power to different components that are connected to the MCU.

9. 16*2 LCD1602: In this prototype the liquid crystal display is used to display messages for the user such as "insufficient balance", ''tag not found "and "authorised". It is a 16*2 LCD that means it can only display a maximum of 32 characters from the system.

10. Arduino IDE: It was used to write code for the embedded system using C programming language and was also used to upload the code to the MCU (Arduino mega 2560/Wi-Fi).

11. Django Web Application: It is a Python framework which I used to create the system interface is used for registering vehicles. It is also the one that was used to code the text steganography utility for securing the communication between the reader and the tag.

12. No SQL: It is the database engine which I used to create the system database that is being hosted on the cloud.

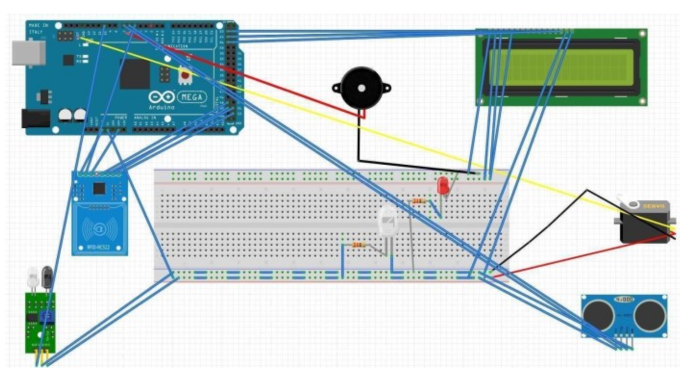

Figure 1: Automated toll collection system

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The System architecture is shown below:

1) Architecture of RFID based toll collection system:

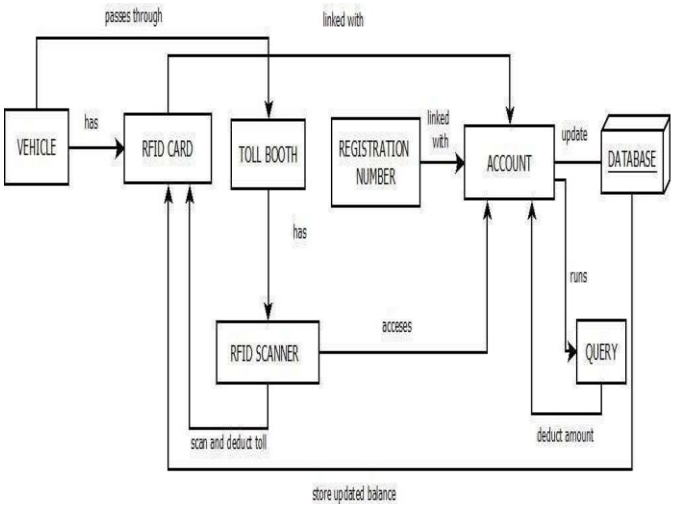

Figure 5: RFID based toll collection system The main system components are as follows:

2) RFID tagged vehicle
3) Toll booth equipped with RFID scanners
4) Vehicle registration plate
5) Centralized database
6) Cameras
7) Laser transponders

These components of the RFID based toll collection system technology work as follows:

1. Automatic Vehicle Identification (AVI): AVI systems use technology to identify vehicles and link them to the owner's account, ensuring that tolls are automatically and accurately charged. This component simplifies toll collection by eliminating the need for manual payment and streamlining the process.
2. Automatic Vehicle Classification: Vehicles arecategorized into different classes, which determine thetoll rate based on specific characteristics. These factors include the size and weight of the vehicle, the number of passengers, the number of axles, and the intended use of the vehicle. While some toll systems may have as many as 15 different classes for detailed toll assessments, most commonly, toll agencies use four or five classes to simplify fee structures.
3. Video Enforcement Systems (VES): VES technology is implemented to capture images of vehicle license plates for vehicles passing through toll points without valid tags. Although the initial investment in these systems is significant, the long- term benefits—such as improved compliance and minimized toll evasion—make them a valuableaddition to toll infrastructure. The advantages of VEStechnology are further explored in the next section.

7. PROPOSED SOLUTION:

The proposed system will use RFID technology for vehicle identification but will use RFID readers and tags that are fully anti-collision compliant. They should operate in ultra-high frequency range(uhf) thereby offering a higher bandwidth and faster data transfer rates between reader and tag. We willadopt the current vehicle classification systems already available at toll gates that uses pre-recorded weight of vehicle as well as the Optical character reader cameras that are currently at the toll gatesfor violation enforcement. The system will use cloud authentication services for tag integrity and confidentiality. The system will have its database hosted on thecloud. As for privacy preservation between reader and tag steganography techniques will be used. Text steganography will be the best option considering the limitation in processingcapabilities of the tag and also the limitation in the tag's memory The components of the proposed automated solution will be as follows:

1 Automatic Vehicle Identification (AVI): AVI systems utilize RFID technology to recognize vehicles and associate them with the respective owner's account. This process ensuresthat the toll amount is accurately calculated and deducted automatically. By eliminating the need for manual checks or payments, AVI systems enhance operational efficiency and reduce the chances of errors or delays. Additionally, AVI can integrate with other databases, such as vehicle registration systems, to verify ownership details and ensure compliance with toll regulations.

2 Automatic Vehicle Classification: Vehicles are systematically classified based on their weight and type during the registration process. Examples include light vehicles such as passenger cars and heavier vehicles like trucks or recreational vehicles. This classification determines the toll rate assigned to each vehicle category. In this system, physical attributes, including weight and size, are used for categorization. For enhanced accuracy, classification is performed during registration, and the data is stored in a secure cloud-based database. This approach reduces processing time at toll plazas, allowing vehicles to pass through without delays. Such categorization aligns with established systems, like those in Zimbabwe, where vehicle mass serves as the primary classification criterion. Moreover, integrating the database with real-time toll systems ensures consistent updates and streamlined operations.

2 Payment Process: Once a vehicle is identified and classified, the system automatically calculates and deducts the toll amount from the owner's account. This automated payment process minimizes human intervention and improves transaction speed. Notifications can also be sent to vehicle owners via SMS or email to provide a record of the transaction, ensuring transparency. For users with insufficient account balances, the system may offer options such as online top-ups, immediate card payments, or manual toll payment.

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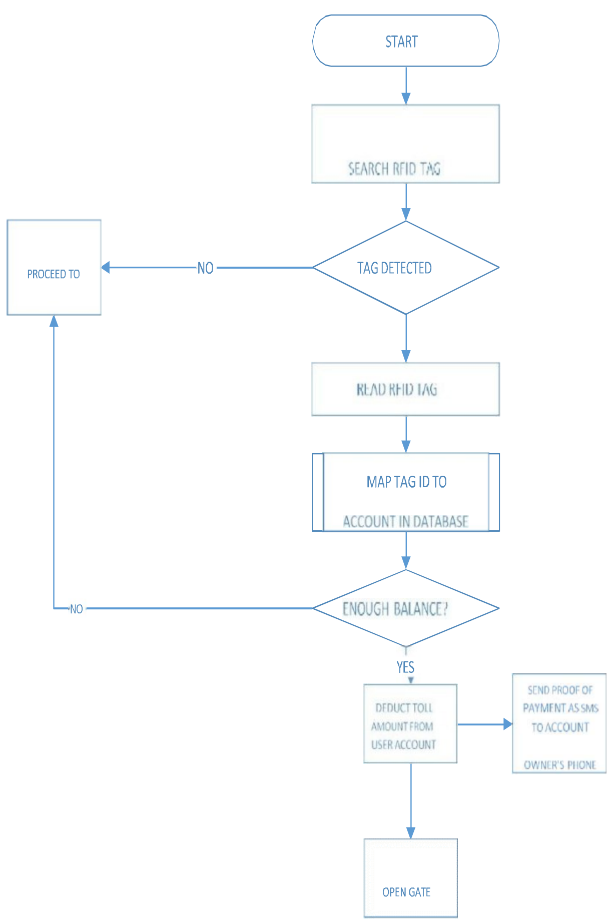
3 Video Enforcement System (VES): The VES uses advanced imaging technology to capture and analyze license plates of vehicles passing through toll gates. It ensures compliance by identifying vehicles without valid RFID tags or with insufficient account balances. This system is particularly useful for detecting toll violations, such as unpaid dues or unauthorized access. Existing implementations, have demonstrated the effectiveness of VES in maintaining accountability and reducing revenue losses. Integration with proposed systems would enhance enforcement capabilities, allowing for swift identification of defaulters and generating automated penalty notifications.

4 Securing RFID Tag IDs: To safeguard vehicle and account data, RFID tag identifiers are protected using advanced techniques such as text steganography. This method embeds tag IDs within Unicode zero-width characters, which are imperceptible in the text. The benefits of this approach include high data embedding capacity, minimal memory usage, and low processing requirements, making it ideal for lightweight systems. By enhancing data confidentiality, text steganography prevents unauthorized access or cloning of RFID tags, ensuring the integrity of the toll collection process.

Figure 2: Proposed System Flowchart.



FLOWCHART 1: WORKING OF THE RFID BASED TOLL COLLECTION SYSTEM AND THEFT DETECTION SYSTEM:

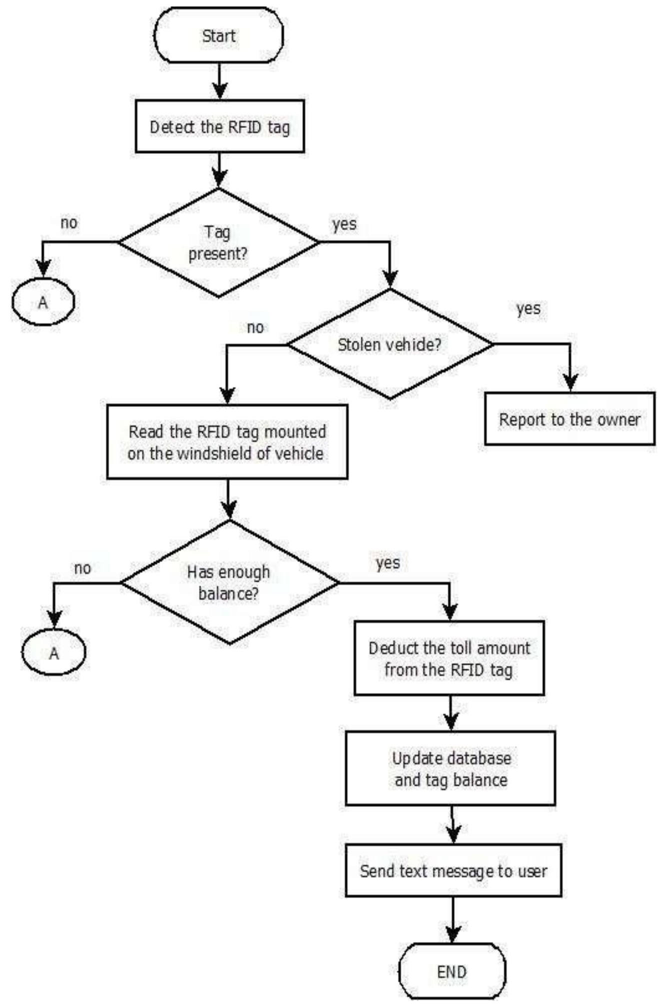


Figure 3: Working of system

The above flowchart illustrates the sequence of operations involved in an RFID (Radio Frequency Identification) based toll collection system and theft detection system. It begins when a vehicle approaches a toll booth and ends with the successful deduction of the toll amount or detection of a stolen vehicle.

Step-by-Step Breakdown:

1. Start: The process begins.

2. Detect RFID Tag: The system checks if an RFID tagis present on the vehicle's windshield.

- Tag Present: If a tag is detected, the systemproceeds to the next step.
- No Tag: If no tag is found, the processterminates.

3. Stolen Vehicle? If a tag is present, the system checksif the vehicle is flagged as stolen in its database.

- Stolen Vehicle: If the vehicle is flagged as stolen, the system reports the incident to the vehicle owner.
- Not Stolen: If the vehicle is not stolen, the process continues.

4. Read RFID Tag: The system reads the information stored on the RFID tag, including the vehicle's identification and the user's account details.

5. Has Enough Balance? The system checks if the user'saccount has sufficient balance to cover the toll amount.
- Insufficient Balance: If the balance isinsufficient, the process terminates.
- Sufficient Balance: If the balance is sufficient, the system proceeds to the next step.

6. Deduct Toll Amount: The system deducts the toll amount from the user's account balance.

7. Update Database and Tag Balance: The system updates its database with the transaction details and the new tag balance.

8. Send Text Message: The system sends a text message to the user confirming the successful toll payment.

9. END: The process ends.

8. CONCLUSION

In this paper we analysed and synthesized what other researchers proposed as solutions to automate road toll collection systems using RFID technology. In our proposed system we incorporating security in design and implementation and not as an afterthought. RFID technology is being used for vehicle identification and need to be secured against all the mentioned possible RFID security attacks. Due to limitations in resources in RFID tags only lightweight to ultra-lightweight cryptography techniques are possible and they seem not to protect against all RFID systems attack. In this paper we suggest the use of steganography to solve these RFID system attacks. Furthermore, results obtained from testing the prototype showed that it only takes five seconds to complete all of the necessary processes at the toll plaza for a vehicle to pass through. There is a high chance that delays at toll plaza will never be experienced again.

FUTURE WORK

- The main power of ATCS is the technology which isused, that is the RADIO FREQUENCY IDENTIFICATION. The basic power of this technology is that it's very flexible. Even with the slightest of change in ATCS, the product can be shaped into a completely different implementation and all that can be because RFID is independent of every other hardware that can be used to boost up the system's performance.
- Radio frequency technology finds applications across a wide range of fields, including healthcare, defense, and emerging innovations. Its versatility makes it a core component in various solutions, such as animal monitoring, human implant devices, vehicle tracking systems, speed monitoring, and other practical implementations.

REFERENCES

[1]RFID based toll collection system,2011 IEEE third international Conference

[2] D. M. Grimes and T. O. Jones, ―Automotive radar: A brief review,‖ Proc. IEEE, vol. 62, no. 6, pp. 804–822, Jun. 1974.

[3] ActiveWaveInc. http://www.activewaveinc.com

[4] Smart key Access Control System http://www.smartkey-rfid.com

[5] D. M. Grimes and T. O. Jones, ―Automotive radar: A brief review,‖ Proc. IEEE, vol. 62, no. 6, pp. 804–822, Jun. 1974.

[6] Wu, N., Shang, P., Fan, J., Yang, Z., Ma, W. & Liu, Z. (2019). Research on Coverless Text Steganography Based on Single Bit Rules. Journal of Physics: Conference Series, 1237(2). https://doi.org/10.1088/1742-6596/1237/2/022077

[7] Wu, N., Yang, Z., Yang, Y., Li, L., Shang, P., Ma, W. & Liu, Z. (2020). STBS Stega: Coverless text steganography based on state transition-binary sequence. International Journal of Distributed Sensor Networks, 16(3). https://doi.org/10.1177/1550147720914257

[8] Forman, G. 2003. An extensive empirical study of feature selection metrics for text classification. J. Mach. Learn. Res. 3 (Mar. 2003), 1289-1305.

[9] Brown, L. D., Hua, H., and Gao, C. 2003. A widget framework for augmented interaction in SCAPE.

[10]Y.T. Yu, M.F. Lau, "A comparison of MC/DC, MUMCUT and several other coverage criteria for logical decisions", Journal of Systems and Software, 2005, in press.

[11] Spector, A. Z. 1989. Achieving application requirements. In Distributed Systems, S. Mullender

[12] D. M. Grimes and T. O. Jones, ―Automotive radar: A brief review,Proc. IEEE, vol. 62, no. 6, pp. 804–822, Jun.1974.

[13] Klaus Finkenzeller, "RFID Handbook: Radio-Frequency Identification Fundamentals and Applications". John Wiley & Sons, 2000.

[14] Active Wave Inc. http://www.activewaveinc.com

[15] Smart key Access Control System http://www.smartkey-rfid.com

[16] Bowman, M., Debray, S. K., and Peterson, L. L. 1993. Reasoning about naming systems.

[17] Ding, W. and Marchionini, G. 1997 A Study on Video Browsing Strategies. Technical Report. University of Maryland at College Park.