RFID Highway Sensing in Malaysia

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Abstract— **RFID (Radio-Frequency Identification) technology has revolutionized various industries, including transportation systems. This paper explores the implementation of RFID technology in highway toll systems in Malaysia. It focuses on the technical aspects, benefits, challenges, and future prospects of RFID highway sensing. The deployment by PLUS Malaysia Berhad, which integrates Automated Number Plate Recognition (ANPR) and aims to achieve a barrier-less, multi-lane free flow (MLFF) system, is highlighted. This initiative is part of a broader strategy to enhance traffic management and reduce congestion on Malaysian highways.**

Keywords: Product innovation, RFID, transportation

I. INTRODUCTION

In modern transportation systems, efficient toll collection and traffic management are paramount. RFID technology has emerged as a promising solution for automating toll collection and enhancing traffic flow on highways[1]. RFID highway sensing involves the use of RFID tags and readers to detect and identify vehicles passing through toll booths or checkpoints without the need for manual intervention.

RFID technology comprises three main components: RFID tags, RFID readers, and a backend system. RFID tags, typically attached to vehicles, contain unique identifiers and can be passive, active, or semi-passive. RFID readers, installed at toll booths or checkpoints, emit radio waves to communicate with RFID tags and capture their unique identifiers. The backend system processes the data collected by RFID readers and performs necessary operations such as toll deduction, vehicle identification, and traffic analysis.

RFID technology has been adopted worldwide for various applications, including inventory management, access control, and transportation. In Malaysia, RFID is being integrated into highway toll collection systems to improve efficiency and reduce traffic congestion. This paper details the technical implementation of RFID systems in Malaysian highways, their benefits, and the challenges faced.

II. LITERATURE REVIEW

Radio Frequency Identification (RFID) technology has been globally recognized for its diverse applications, including supply chain management, asset tracking, and transportation systems. In Malaysia, RFID technology has been adopted in highway toll collection to enhance traffic management and reduce congestion. This literature review explores the development, implementation, and impact of RFID highway sensing in Malaysia.

Early Developments: The adoption of electronic toll collection (ETC) systems in Malaysia began with the implementation of Touch 'n Go and SmartTAG systems. Touch 'n Go, introduced in 1997, utilized a contactless smart card for toll payments. SmartTAG, introduced subsequently, employed infrared technology to communicate with toll plaza equipment, allowing for faster transactions compared to Touch 'n Go.

Transition to RFID: The move towards RFID technology started in the late 2010s, driven by the need for more efficient toll collection methods. RFID offers several advantages over infrared-based systems, including higher speed of operation, greater reliability, and the ability to function without direct line-of-sight. PLUS Malaysia Berhad (PLUS), one of the major highway operators in Malaysia, spearheaded the transition to RFID technology.

Technical Implementation: RFID systems in Malaysian highways comprise passive RFID tags, RFID readers, and a backend processing system. The RFID tags, linked to the vehicle owner's Touch 'n Go eWallet, are affixed to the vehicles. RFID readers installed at toll plazas detect these tags as vehicles pass through, facilitating automatic toll deduction.

Several studies highlight the benefits of RFID systems in toll collection. For instance, Gholami et al. (2016) emphasize the improved traffic flow and reduced congestion resulting from RFID implementation. Vehicles can maintain higher speeds through RFID lanes, thus minimizing bottlenecks at toll.

Integration with ANPR: An essential aspect of Malaysia's RFID highway sensing is the integration with Automated Number Plate Recognition (ANPR) systems. ANPR enhances the accuracy of vehicle identification, ensuring that toll charges are correctly applied. This integration addresses potential issues such as tag cloning and misidentification, thereby increasing the reliability of the RFID system.

Despite the technical advantages, user adoption of RFID technology faced several challenges. Public acceptance was initially slow due to the familiarity and trust in existing Touch 'n Go and SmartTAG systems. Additionally, the cost of RFID tags and the need for vehicle owners to switch to a new system posed barriers.

Wong et al. [7] discuss the implementation strategies adopted by PLUS to encourage user adoption, including public awareness campaigns and incentives for early adopters. The study also highlights technical challenges such as tag readability issues and system integration problems that needed to be addressed for successful deployment.

The literature identifies numerous benefits of RFID highway sensing, including reduced congestion, faster toll transactions, and improved traffic management. The integration with the Touch 'n Go eWallet system facilitates cashless transactions, enhancing user convenience and reducing the need for physical toll booths.

Looking forward, the future prospects of RFID highway sensing in Malaysia are promising. The government's Intelligent Transport System (ITS) Blue Print envisions a fully integrated MLFF toll system, leveraging RFID technology for seamless and efficient toll collection. This development is expected to further enhance traffic flow and reduce congestion on Malaysian highways.

The transition to RFID technology in Malaysia's highway toll systems represents a significant advancement in transportation management. The literature highlights the technical, operational, and user-related aspects of this transition, emphasizing the benefits and challenges encountered. As Malaysia continues to develop its ITS infrastructure, RFID highway sensing is poised to play a crucial role in achieving a seamless and efficient transportation network.

Figure 1: The TNG RFID system together with the ANPR system

III. Implementation in Malaysia

PLUS Malaysia Berhad has deployed RFID systems along major highways, including the North-South Expressway (Table 1). The RFID tag, which is attached to a vehicle, contains a microchip and an antenna. The reader emits radio waves that activate the tag, which then transmits its stored data back to the reader. This data is processed by the backend system for toll collection and traffic management. These systems are integrated with ANPR to enhance the accuracy and efficiency of toll collection (Figure 1). The implementation allows vehicles to pass through toll plazas at higher speeds compared to traditional methods, reducing congestion and travel time.

A) System Architecture

- RFID Tags: Passive RFID tags are affixed to vehicles. These tags are linked to the vehicle owner's Touch 'n Go eWallet.
- RFID Readers: Installed at toll plazas, readers detect and communicate with the RFID tags as vehicles pass through.
- Backend System: Processes the data received from the RFID readers, verifies the information with the ANPR system, and deducts the toll fee from the eWallet.

B) Benefits

- Improved Traffic Flow: The RFID system allows for faster vehicle throughput at toll plazas, reducing bottlenecks and improving overall traffic flow. Vehicles can maintain speeds of up to 30 km/h while passing through RFID lanes, compared to 20 km/h with SmartTAG.
- Contactless and Cashless Transactions: RFID toll collection is entirely contactless and cashless, leveraging the Touch 'n Go eWallet. This reduces the need for physical toll booths and human interaction, enhancing convenience and safety, especially during the COVID-19 pandemic.
- Enhanced Accuracy and Efficiency: Integration of ANPR with RFID systems improves the accuracy of vehicle identification and toll collection. This reduces instances of incorrect charges and enhances the efficiency of toll operations.

Table 1: Malaysia's 33 toll concessions

Malaysia's 33 toll concessions

CONCESSION HOLDER/ PARENT COMPANY	HIGHWAY	SHORT NAME
PLUS Malaysia Bhd	Lebuhraya Pantai Timur Fasa 2	LPT2
	Lebuhraya Butterworth-Kulim	BKE
	Lebuhraya Utara Selatan Hubungan Tengah	ELITE
	Jambatan Pulau Pinang	JPP
	Lebuhraya Laluan Kedua Malaysia-Singapura	LINKEDUA
	Lebuhraya Utara Selatan	PLUS
	Lebuhraya Seremban-Port Dickson	SDPH
Projek Lintasan Kota Holdings Sdn Bhd (Prolintas)	Lebuhraya Bertingkat Ampang-Kuala Lumpur	AKLEH
	Lebuhraya Bertingkat Damansara-Shah Alam	DASH
	Lebuhraya Koridor Guthrie	GCE
	Lebuhraya Kemuning-Shah Alam	LKSA
	Lebuhraya Skim Penyuraian Trafik Lingkaran Kajang	SILK
	Lebuhraya Sungai Besi-Ulu Klang	SUKE
Amanat Lebuhraya Rakyat (ALR)	Lebuhraya Shah Alam	KESAS
	Lebuhraya Damansara Puchong	LDP
	Sistem Pengurusan Air Banjir dan Terowong	SMART
	Lebuhraya Skim Penyuraian Trafik Kuala Lumpur Barat	SPRINT
IJM Corp Bhd	Lebuhraya Baru Pantai	NPE
	Lebuhraya Sungai Besi	BESRAYA
	Lebuhraya Kajang-Seremban	LEKAS
ANIH Bhd	Lebuhraya Kuala Lumpur-Karak	KLK
	Lebuhraya Pantai Timur Fasa 1	LPT1
Taliworks Corp Bhd	Lebuhraya Cheras Kajang	Grand Saga
	Lebuhraya Jalan Pintas Selat Klang Utara Baru	NNKSB
Ekovest Bhd	Lebuhraya Duta-Ulu Klang	DUKE
	Leburaya Setiawangsa-Pantai	SPE
Maju Expressway Sdn Bhd	Lebuhraya Kuala Lumpur-Putrajaya	MEX
Bina Puri Holdings Bhd	Lebuhraya Kuala Lumpur-Kuala Selangor	LATAR
WCE Holdings Bhd	Lebuhraya Persisiran Pantai Barat	WCE
Jambatan Kedua Sdn Bhd	Jambatan Sultan Abdul Halim Mu'adzam Shah	JPP2
Lingkaran Luar Butterworth (Penang) Sdn Bhd	Lebuhraya Lingkaran Luar Butterworth	LLB
Senai-Desaru Expressway Bhd	Lebuhraya Senai-Desaru	SDE
SKVE Holdings Sdn Bhd	Lebuhraya Lembah Klang Selatan	SKVE

IV. Implementation Challenges of RFID Sensing

Radio-Frequency Identification (RFID) technology has emerged as a promising solution for automating toll collection and enhancing traffic management on highways[2]. However, its implementation faces several challenges that need to be addressed for seamless integration and operation. This section discusses some key challenges associated with the implementation of RFID highway sensing systems.

Tag Readability and Reliability: RFID tags must be readable and reliable under various environmental conditions, including high speeds, adverse weather, and different types of vehicles. Ensuring consistent tag readability is crucial for accurate toll collection and vehicle identification[3]. Challenges arise when tags fail to respond due to factors such as tag placement, signal interference, or tag malfunction.

Signal Interference and Collision: RFID readers emit radio waves to communicate with RFID tags [4]. However, signal interference from nearby readers, electronic devices, or metallic structures can disrupt communication and lead to signal collisions. Collisions occur when multiple tags respond simultaneously, making it challenging to identify individual tags accurately. Mitigating signal interference and collision is essential for maintaining system reliability and performance.

Privacy and Security Concerns: RFID highway sensing involves the collection and storage of vehicle data, including unique tag identifiers and travel patterns. Privacy concerns arise regarding the unauthorized access, misuse, or tracking of sensitive information collected by RFID systems. Ensuring data privacy and security is critical to gaining public trust and compliance with regulatory requirements.

Initial Deployment Costs and Infrastructure Requirements: The deployment of RFID highway sensing systems requires significant upfront investment in infrastructure, including RFID readers, antennas, backend servers, and network connectivity. Additionally, transitioning from existing toll systems to RFID requires careful planning and execution to avoid disruptions. Ongoing maintenance and operational costs contribute to the total cost of ownership. Balancing cost considerations with the expected benefits and long-term sustainability is essential for successful implementation.

Compatibility and Interoperability: RFID systems may vary in terms of standards, protocols, and frequencies, leading to compatibility issues between different systems deployed by various transportation authorities or toll operators. Achieving interoperability ensures seamless communication and data exchange between RFID systems, enabling cross-border travel and interoperable toll collection across different regions[5].

Regulatory and Policy Frameworks: Regulatory and policy frameworks play a significant role in the deployment and operation of RFID highway sensing systems. Compliance with regulations related to data privacy, interoperability standards, toll pricing, and user rights is essential for legal and ethical operation[6]. Engaging stakeholders and policymakers to establish clear guidelines and standards can facilitate the implementation process.

Public Acceptance and User Experience: Encouraging users to switch from existing systems like Touch 'n Go and SmartTAG to RFID can be challenging. Effective communication and incentives are needed to facilitate this transition. Public acceptance of RFID highway sensing systems depends on factors such as convenience, reliability, and perceived benefits. Providing user-friendly interfaces, seamless integration with existing payment systems, and transparent communication about system operation and benefits can enhance user experience and acceptance.

Addressing the implementation challenges of RFID highway sensing systems is essential for realizing their full potential in enhancing toll collection efficiency and traffic management on highways. By addressing issues related to tag readability, signal interference, privacy concerns, infrastructure requirements, interoperability, regulatory compliance, and user experience, transportation authorities can successfully deploy and operate RFID highway sensing systems to benefit both commuters and the transportation ecosystem as a whole.

Figure 2: RFID sensing and implementation in Malaysia

V. Case Study Enhancing Highway Management Through RFID Sensing

This case study explores the implementation of Radio Frequency Identification (RFID) technology in highway management, focusing on its application in traffic sensing and monitoring. By analyzing a real-world scenario, this study demonstrates the effectiveness of RFID in enhancing highway safety, efficiency, and overall management.

Modern highways face significant challenges in managing traffic flow, ensuring safety, and optimizing operational efficiency. Traditional methods of traffic monitoring, such as video surveillance and manual counting, often prove to be time-consuming, labor-intensive, and prone to errors. To address these challenges, transportation authorities are increasingly turning to advanced technologies such as RFID for real-time traffic sensing and monitoring.

Case Description: In a bustling metropolitan area, the Department of Transportation (DOT) embarked on a project to improve highway management using RFID technology. The project aimed to deploy RFID sensors along key sections of the highway to collect real-time data on vehicle movements, speeds, and traffic density. The implementation process involved (Figure 3).

Sensor Deployment: RFID sensors were strategically installed along the highway, embedded in the road surface at regular intervals. These sensors utilized passive RFID

technology, allowing them to detect passing vehicles without requiring a direct power source.

Data Collection: As vehicles passed over the RFID sensors, unique identification codes assigned to RFID tags installed on each vehicle were captured. This data, along with timestamps, was transmitted wirelessly to a central control center for analysis.

Data Analysis and Integration: The collected data was processed in real-time using sophisticated algorithms to derive valuable insights into traffic patterns, congestion hotspots, and average speeds. Integration with existing traffic management systems allowed transportation authorities to make decisions and implement proactive measures to improve traffic flow.

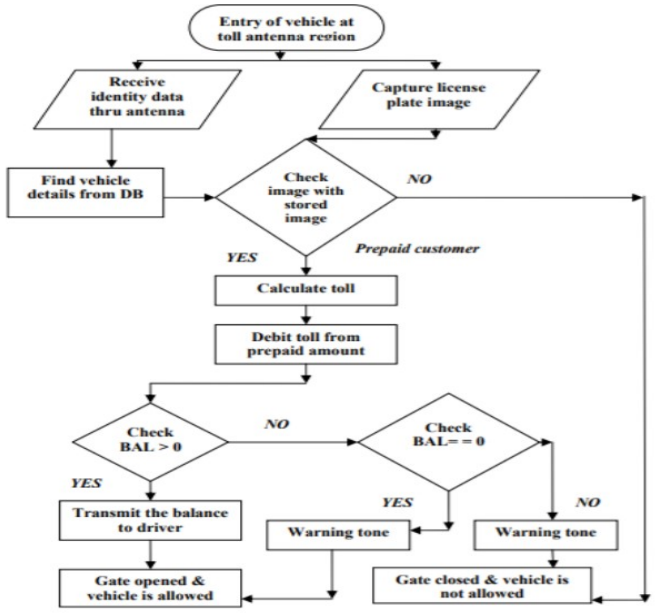

Figure 3: Flowchart of the RFID based automation identification [1]

VI. Performance Evaluation

Regular assessments were conducted to evaluate the performance of the RFID sensing system, including its accuracy in vehicle detection, data transmission reliability, and overall system uptime. The deployment of RFID highway sensing yielded several noteworthy outcomes:

Real-Time Traffic Monitoring: The RFID sensors provided transportation authorities with real-time visibility into traffic conditions, enabling them to promptly identify congestion, accidents, and other traffic incidents.

Enhanced Safety: By promptly detecting and responding to traffic incidents, the RFID sensing system contributed to improved highway safety by reducing the secondary accidents and minimizing response times for emergency services.

Operational Efficiency: The automated nature of RFID sensing reduced the reliance on manual data collection methods, leading to greater operational efficiency and cost savings for the transportation agency.

Data-Driven Decision Making: The data collected through RFID sensors empowered transportation authorities to make data-driven decisions regarding highway management, infrastructure improvements, and future planning initiatives. The case study exemplifies the successful implementation of RFID technology in highway management, demonstrating its efficacy in enhancing safety, efficiency, and overall performance. By leveraging RFID sensors for real-time traffic sensing and monitoring, transportation authorities can address traffic challenges and ensure a smoother, more reliable highway experience for commuters and cargo alike.

VII. Prospect of RFID in Highway Sesning

The successful implementation of RFID systems on the North-South Expressway sets a precedent for expanding this technology to other highways in Malaysia. Future developments include enhancements in RFID technology and further integration with intelligent transportation systems (ITS).

RFID technology is a crucial component of Malaysia's ITS Blue Print for achieving MLFF highways. This blueprint envisions a future where toll collection is seamless, and traffic management is optimized using advanced technologies.

VIII. Conclusions

RFID highway sensing in Malaysia represents a significant advancement in toll collection and traffic management. The deployment by PLUS Malaysia Berhad demonstrates the potential benefits of this technology, including improved traffic flow, contactless transactions, and enhanced accuracy. However, challenges such as initial costs, user adoption, and technical issues need to be addressed. The future prospects of RFID systems in Malaysia are promising, with plans for expansion and integration with ITS.

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