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Smart Agriculture Application Using Secured and Energy-Efficient IoT-Based WSN Framework

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Abstract: The use of wireless sensor networks (WSNs), in several sectors, including communication, agriculture, manufacturing, smart health, monitoring and surveillance is increasing in R&D. An IoT-based WSN in agricultural production has been effective in detecting yield conditions and automating agriculture precision by using multiple sensors. To collect data on crops, plants, temperature estimates and stickiness as well as to boost yields by making smart agriculture decisions, they are deployed in rural regions. Sensors, on the other hand, are constrained by their inability to handle, store, communicate, and process large amounts of data due to a lack of available resources. Additionally, the safety and security of the IoT-based agricultural sensors against damaging competitors are crucial factors, as is their efficacy. One idea put up in this article is to employ a WSN structure based on the Internet of Things (IoT) for smart agriculture. The selection of group leaders is also based on data collected by rural sensors and multi-rules choice capacity. A transmission link's SNR (signal-to-noise ratio) is used to gauge the intensity of signals being sent over it in order to guarantee accurate and timely data transfer. In addition, the direct congruential generator is repeated in order to enable data flow from agricultural sensors to central stations (BS). Compared with previous arrangements, smart agriculture obtained an average of 13.5 percent in the organisation throughput, 38.5 percent in the parcel drop percentage, 13.5 percent in the organisation inactivity, and 16 percent in energy usage. Comparatively speaking, this is a huge step forward.

Key words: Wireless sensor networks, signal noise ratio, Internet of Things, network latency.

Introduction

Various applications of WSN (Wireless Sensor Network) technologies have been developed to enhance the management of exhibitions. Sensors are widely utilised in the ecological sector because they are easy to set up. Sensor hubs, on the other hand, are self-contained systems that contribute significantly to the organisation's overall structure. It's not unusual for data centres to relocate to a better neighbour if certain conditions are satisfied. Using a few entry ways and cluster heads, sensor hubs collect data from the field and transfer it to the base station (BS). The leaders of these clusters are responsible for receiving and transmitting data packages to BS. One or more cluster heads may set up direct connections to the base station (BS) through one- or multiple-hop routes.' On top of that, they store and forward data in their internal memory.

Internet connection or unique online apps are used by the end-users of the BS to obtain the essential observation data. Static or mobile sensors can be used for data transfer. There is also a mention of the non-versatile and fixed steering tables of the static sensors. As a result, the steering tables of flexible sensors are

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dynamic and updated whenever a network geography change occurs. The Internet of Things (IoT) is a network of connected physical devices that exchange data over the network. It also helps develop IoT frameworks and observe and transmit climate-specific variables thanks to WSN innovation. Figure 1 depicts the current state of smart agriculture, which is reliant on various sensors, sink hubs, BS, the Internet, and clients.

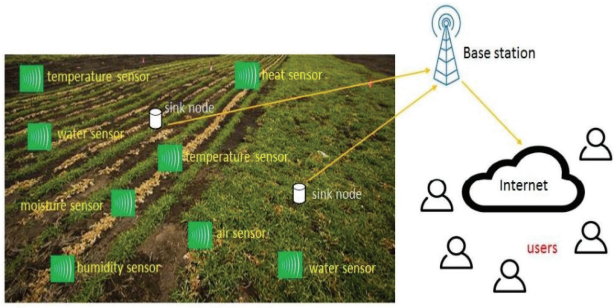

Figure 1: Smart agricultural environment based on wireless sensor network (WSN).

Agriculture's eco-framework is swayed by dramatic variations in the environment, which result in torrential downpours and dry seasons, as well as floods and unforeseen climate circumstances. Agricultural-related food security is threatened by these developments as much in the making as in the produced world. Smart agriculture using IoT gadgets, which may increase agricultural yields and products, can overcome the environment-related issues that agriculture faces. A disconnected data authority for sensors in agriculture has been provided throughout the last several years. Data collected by the BS (Backend Services) safely allows the BS to provide clients with forward-looking data for an efficient decision in the least time possible. The data collected by horticulture sensors is safely and accurately routed to BS, where it is used to verify and assess the farm's effectiveness. When compared with current systems that rely on various organisational boundaries, the results of the proposed system's replicated tests were excellent. Sections of this article include the following illustrations: It's all laid out in detail in "Related Works": the foundational work and issue description, "Proposed Energy-Efficient and Secure IoT-Based WSN Framework for Smart Agriculture" through "Simulation Setup with Experimental Result", and "Conclusion", completion of the project as well as what's to come.

Related Works

Because of its cheap cost, simplicity of transmission, and practicality, WSN technology has been extensively used in the current period (Alaparthy and Morgera, 2018; Rawat et al., 2014). Thousands of sensor hubs are installed in the field in order to collect the essential data for WSNs. A single or multi-hop data transfer worldview is used to collect and send all data to BS for post-examination purposes. Today, agriculture is an essential aspect of every country's economic and social development. As a result, advanced technologies, such as IoT-based WSNs, might help to minimise time and human effort and enhance agricultural output in a quality-oriented way (Balamurali and Kathiravan, 2015; Bandur et al., 2019). Sensors of a variety of types are used to monitor soil, climate, moisture, and temperature on agricultural lands. In fact, a number of agricultural experts have used WSN technology to enhance their displays and reduce the burden on ranchers (Zia et al., 2013). In terms of memory, handling, communication, and power, the sensors given have restricted imperatives; this is due to the limitations of the sensors. WSN-based applications face a new challenge in data insurance due to WSN's unpredictability, regulatory instability, and free-space nature in the creation of communication. Various clustering plans have been presented by scientists in WSN (Haseeb et al., 2019; Ullah et al., 2019; Yu and Lin, 2018) in an effort to increase network life and data transfer (Darabkh et al., 2019; Enam et al., 2014; Zhu et al., 2015). Every district has a cluster leader who is responsible for gathering and advancing sensory data toward the BS in such programs. In addition, the great majority of the sensor hubs were put into sleep mode in order to extend the network's life. Proposed by Heinzelman et al. (2000), the notion of a low-energy, cluster-based technique (LEACH) and the development of energy proficiency as compared with standard methodologies was presented. As needed, the LEACH convention changes the energy usage among the sensor hubs, making the cluster head's task more random. According to Karaca et al. (2012), the logical pecking order process (AHP) was presented by the designers as a way to unify the current cluster head selection method. For cluster heads, lingering energy, adaptability, and distance from the cluster center are considered to be the most important factors in their interactions. The recommended layout was shown to be the most effective in terms of network lifespan when compared with other configurations. An energy-efficient k-implies technique was presented by Jain et al. (2018) and the optimum cluster heads were determined using the EKMT. Just like the BS, the chosen cluster heads are located closer to the cluster's core. The suggested structure aims to reduce the distance between hubs and extend the life of the company. If that's not bad enough, there's the fact that the suggested setup is vulnerable to malicious extortion and may be dangerous to sensor data in an unstable and endless space environment.

In wireless sensor networks, the inventors (Azad and Sharma, 2013) advocated employing a fluffier climate to decide where cluster heads should be located. Cluster heads are selected using the MADM approach, which takes into consideration the amount of energy remaining, the distance to the BS, and the number of surrounding variables in the cluster. The life expectancy of a re-enacted network is higher than that of a DHAC network when the foundations are homogeneous (Lung and Zhou, 2010). To do an ICCHR computation, one must go through four stages: create a cluster, pick a cluster head, establish a link chain and transmit data (Wu et al., 2019]). The convention's selection and transportation of cluster heads are less than optimal, and they utilise more energy as a result.

Proposed Energy-Efficient and Secure IoT-Based WSN Framework for Smart Agriculture

The identification of naturally occurring data necessitates the expertise of a select group of analysts who have harnessed wireless sensor network (WSN) technology across diverse domains. These domains encompass agricultural crop yields, environmental conditions, and water resource utilisation, all of which are subjected to meticulous monitoring and management via WSN alongside conventional methodologies. Nonetheless, the prevailing limitations of sensor battery capacity and the inherently open transmission channel in rural settings introduce several intricate challenges, notably in the realms of energy efficiency, data routing, and security. The paramount objective of our proposed solution is the establishment of an Internet of Things (IoT)-based WSN system that embodies both energy efficiency and robust security attributes in the pursuit of agricultural land monitoring and enhancement. Our proposed system judiciously selects an apt cluster head based on the requisite capacity considerations, employing signal-to-noise ratio (SNR) as a determinant to gauge wireless transmission strength, thus augmenting the efficacy of sensor parcel utilisation. The architectural framework we advocate for furnishes a sound foundation for the energy-efficient revitalisation of extensive agricultural land expanses. The secure transmission of data among horticultural sensors and cluster heads, as well as from cluster heads to Base Stations (BS), is underpinned by the application of a straight congruential generator in conjunction with confidential cryptographic keys within our proposed structure. Furthermore, our methodical approach guarantees a harmonious equilibrium between energy consumption, robust data routing, and data security in the context of agricultural data collection. This section elucidates the comprehensive testing strategy employed for the proposed system. Noteworthy constituents of the system encompass the widespread deployment of horticultural sensors for data acquisition. The sensors' residual energy levels exhibit heterogeneity, a deliberate design choice aimed at enhancing the overall energy profile of the heterogeneous sensor nodes. Agricultural sensor clusters are strategically dispersed across a vast geographical expanse, with each region featuring a designated cluster head. The pivotal role of these cluster heads entails ensuring the efficient and energy-conscious transmission of agricultural data to the BS. Leveraging a multi-model selection approach, our proposed system optimally distributes the computational load among horticultural sensors while judiciously selecting cluster heads. To mitigate organisational bottlenecks and reduce dormancy periods, we advocate for a single-hop transmission paradigm over a multi-hop approach. Subsequently, our proposed security mechanism employs symmetric data encryption for secure communication between rural sensors, coupled with pseudorandom number generation to fortify data transmission integrity within the agricultural domain. Figure 2 serves as a visual representation of our proposed exploration strategy for smart agriculture.

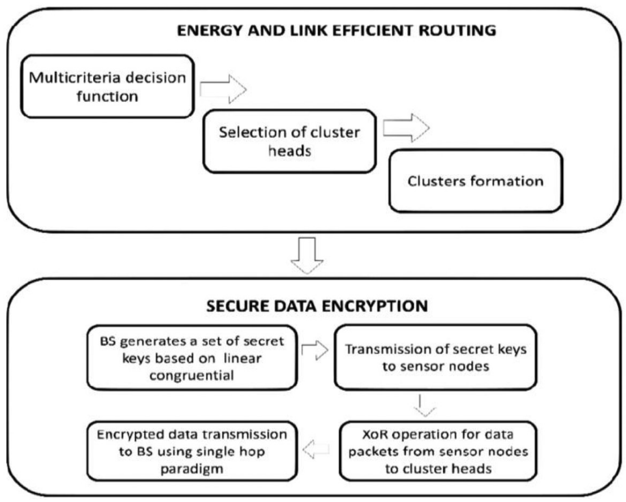

Figure 2: The research design of the proposed energy-efficient and secure IoT-based WSN framework for smart agriculture.

Network Assumptions

Before presenting the proposed Energy Efficient and Secure IoT-based WSN Framework for Smart Agriculture, the following assumptions regarding the network have been made:

i. The observed squared measured region is littered with a number of farm sensors.
ii. After the hubs are organised, all of the farm sensors and BS remain fixed.
iii. Transmission joints are asymmetrical. ‘
iv. The energy assets of agricultural sensors are diverse. The BS hub is the most extraordinary in the world, with an infinite supply of resources.
v. The agricultural sector has yet to be fully resolved with GPS.

Energy and Link Efficient Routing

In this section, the intricacies of designing a routing plan that prioritises both energy efficiency and link optimization are detailed. This discussion encompasses two pivotal tiers. Firstly, a multi-criteria decision function is employed to ascertain the optimal selection of cluster heads. Subsequently, nodes characterized by minimal energy consumption are amalgamated into distinct clusters. The second tier of our proposed energy and link-efficient routing strategy is dedicated to enhancing the stability of the routing channel over an extended duration. This augmentation serves the purpose of safeguarding the wireless link against disruptive behaviour originating from cluster heads and bound for the base station (BS). Our devised system relies on the utilisation of Equation 1 for the identification of cluster heads, leveraging key parameters such as a node’s energy level (ei), signal-to-noise ratio concerning the BS (SNRi, BS), and the distance to the backside sampling point (BS di). The assessment of signal strength and quality is executed through the evaluation of signal-to-noise ratio (SNR), which signifies the ratio of the received signal strength indicator (RSSI) to the background noise. The determination of SNRi involves the division of RSSIi by BI, where BI represents the background noise specific to the pertinent connection, and RSSIi quantifies the strength of said noise. In the context of data transmission, the link characterised by the lowest SNRi value is singled out for utilisation.

$$.f(n) = ei + (1/di,BS) + (1/SNRi) \qquad (1)$$

In the context of our analysis, we investigate the two pivotal phases integral to the envisaged energy and connectivity strategy. Fundamental to the initial phase is the imperative capability of selecting from a diverse array of models for the identification of optimal cluster heads. These clusters are comprised of pivotal nodes that exhibit minimal energy consumption. A salient proposition in the subsequent phase of our meticulously planned energy and connectivity-centric approach is the imposition of constraints on wireless connections between cluster heads and the base station (BS) for diagnostic purposes. Employing a multifaceted dynamic capacity function denoted as f(n), we leverage crucial parameters such as hub energy (ei), signal-to-noise ratio at the base station (SNRi, BS), and the distance to the base station (di, BS) in the selection process of cluster heads, aligning with the first condition articulated within our proposed framework. In order to enhance the efficiency of data transmission, the proposed framework is equipped to compute the signal strength employing the concept of signal-to-noise ratio (SNR). SNR is quantified through a comparison of the Received Signal Strength Indicator (RSSI) to ambient noise levels. RSSIi signifies the received signal strength, while Bni represents an endeavour to establish a fundamental connection. It is my contention that the quotient of RSSIi divided by Bni, herein denoted as RSSIi/Bni, can record the value of SNRi. Consequently, the connection characterised by the lowest SNRi value is designated for the transmission of data.

Simulation Setup with Experimental Result

This section describes the default reproduction boundaries used in the testing of the proposed structure against major arrangements, such as PSO-ECHS and EECRP. Network Simulator2 (NS2), a famous open-source and finest reenactment tool for network direction and correspondence, is used for replication testing. There are reproduction limits and default esteems shown in Table 1. Results of the reenactment are evaluated according to a varying number of rounds. A single reproduction round has a duration of 20 seconds. Additionally, there are 100 sensors for agriculture and 15 for unexplained hubs. Every rural sensor, such as temperature, light and soil dampness detectors, area and wind stream detectors, and other unidentified hubs, is dispersed randomly. 100 sensors have been assigned to rural areas. Malevolent hubs are limited to 15 in total. The payload size (256 bytes) and bundle size (k) are both set to 64 pieces. Non-uniformly distributed 2j to 4j of energy remains in farm sensors. Constant Bit Rate (CBR) data transfer between sensor hubs is limited to a 20-meter transmission range for agriculture sensors.

Experimental Discussions

Table 1: Simulation parameters

Parameter	*Value*
Simulation area	200 m × 200 m
Deployment	Random
Sensor nodes	100
Malicious nodes	15
Packet size, k	64 bits
Energy level	2 j to 4 j
Payload size	256 bytes
MAC layer	IEEE 802.11b
Control message	25 bits
Transmission range	20 m
Simulation rounds	Oto 1000
Traffic flows	CBR
Simulation tool	NS2.35

Analysis of Network Throughput with Discussion

Network throughput under changing recreation conditions is compared between the proposed system and an existing configuration.

Based on the replication testing, it appears that the suggested system increased organisation throughput by 10% and 17% when compared with the present setup. Those in charge of the large and interconnected clusters may look forward to an improved display of organisational throughput. Instead of employing different arrangements that ignore the estimation of signal strength between sensor hubs, the proposed structure includes the SRN factor in an astute determination choice for picking cluster heads, which increases the proportion of bundle transport in agricultural land due to their steadfast behaviour. To further enhance network speed, a straight congruential generator-based encryption method is used to share secret key data, resulting in a rise in network throughput and a constant availability of the organisation. The SNR ratio between hubs for a certain data transfer interface, as assessed by the proposed system, has a significant impact on the transmission of agricultural data to BS (Figure 3).

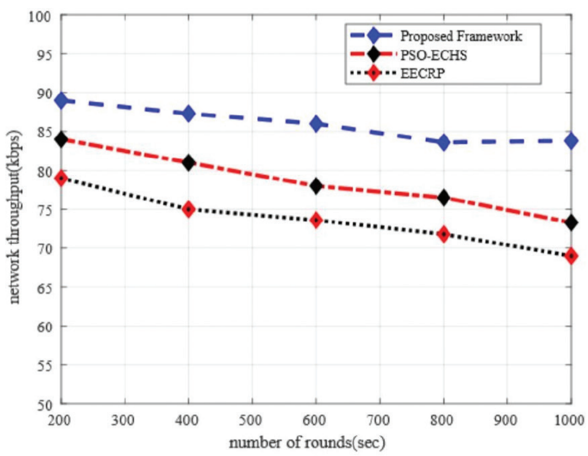

Figure 3: The impact of the simulation rounds on network throughput.

Analysis of Packets Drop Ratio with Discussion

Network throughput under changing recreation conditions is compared between the proposed system and an existing configuration. Based on the replication

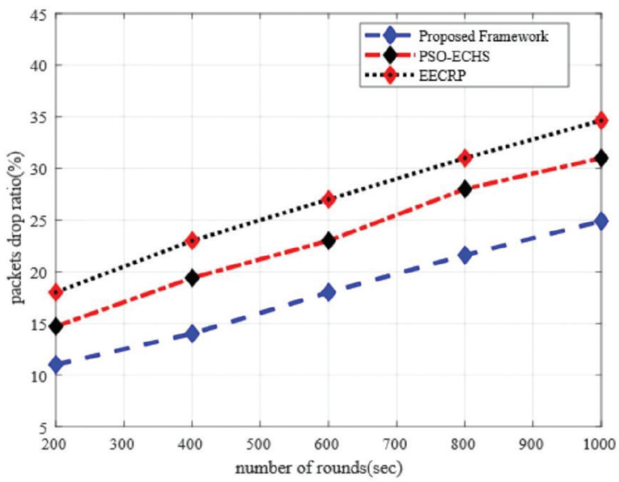

Figure 4: The impact of simulation rounds on the packets drop ratio.

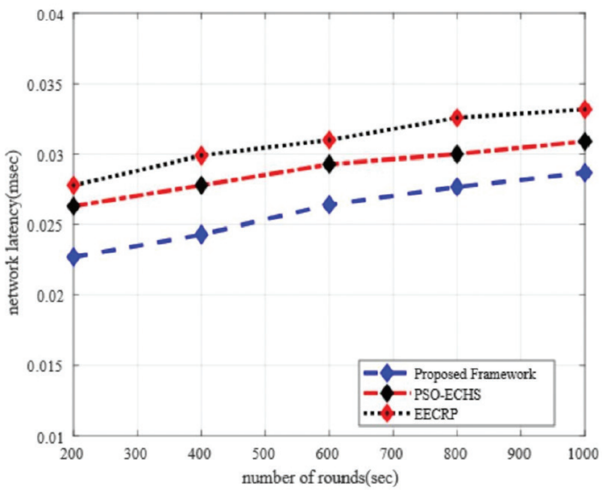

Figure 5: The impact of the simulation rounds on network latency.

testing, it appears that the suggested system increased organization throughput by 10% and 17% when compared with the present setup. Those in charge of the large and interconnected clusters may look forward to an improved display of organisational throughput. Since the SRN factor is included in an intelligent decision option for picking cluster heads in agricultural land and other arrangements do not consider indications of strength between sensor hubs, it raises the percentage of bundle delivery in agricultural land. To further enhance network speed, a straight congruential generator-based encryption method is used to share secret key data, resulting in a rise in network throughput and constant availability of the organisation. The SNR ratio between hubs for a certain data transfer interface, as assessed by the proposed system, has a significant impact on the transmission of agricultural data to BS (Figure 4).

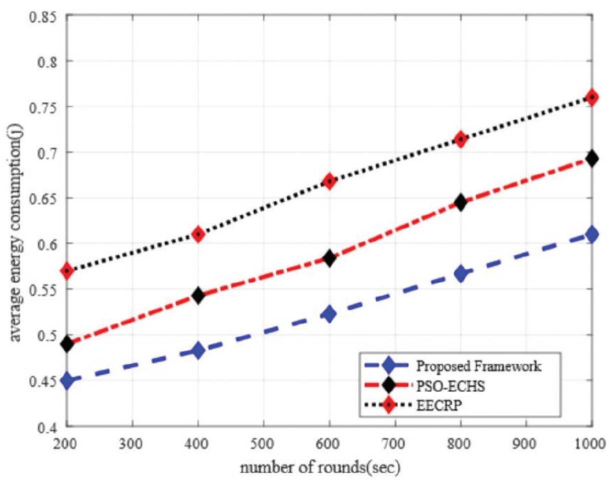

Figure 6: The impact of the simulation rounds on energy consumption.

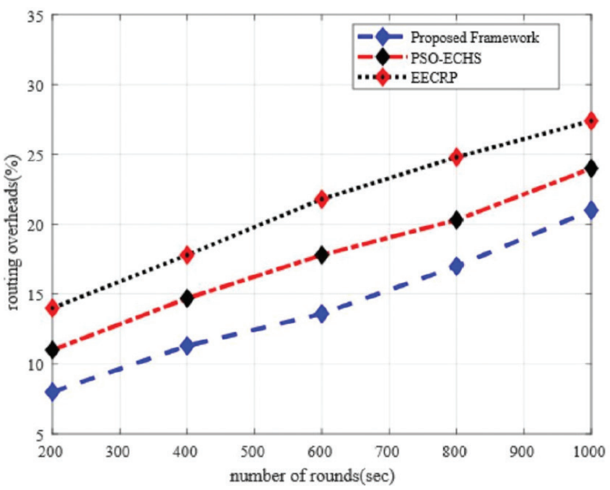

Figure 7: The impact of simulation rounds on routing overheads.

Analysis of Network Latency with Discussion

The proposed system and an existing configuration are evaluated in terms of network throughput under shifting recreation settings. When compared with the current configuration, it seems that the proposed approach boosted organisation throughput by 10% and 17%.

Large and linked clusters might expect to get a better depiction of organisational throughput. In agricultural land, the SRN factor increases the percentage of bundle deliveries since it is part of an intelligent choice option for choosing cluster heads and other arrangements do not take strength signals between sensor hubs into account. Straight congruential generator-based encryption is utilised to communicate secret key data, increasing network performance and consistent organization availability. The SNR ratio between hubs is a key factor in how successfully agricultural data is delivered to BS for a certain data transfer interface (Figure 5).

Analysis of Energy Consumption with Discussion

Investigation of the suggested structure's presentation in various configurations under variable reenactment adjustments is defined. Reproduction findings show that the suggested system uses between 11% and 21% of available energy depending on how it is configured. This is to be expected, as the proposed system is designed to distribute energy usage across sensor hubs in a predictable manner. On the suggested method, the optimum hubs for clusters in agricultural land are selected using multi-criteria choice capacity. Another benefit is reduced energy fatigue in the observation field due to BS constraining cluster head selection and cluster development rather than in an adequate manner. In addition, the suggested approach avoids the path of intermittent clustering and steering once again due to the choice capacity of many models. Energy consumption in agricultural areas is reduced mostly because cluster heads are selected based on parameters such as energy efficiency, distance to BS, and sign strength (Figures 6 and 7).

Conclusion

The advancement of agricultural practices significantly hinges upon the utilisation of wireless sensor networks (WSNs). In this study, we have introduced an Internet of Things (IoT) WSN architecture specifically designed for intelligent agricultural applications, characterised by a judicious balance of energy efficiency and security considerations. A pivotal aspect of this research involves the application of multi-criteria decision-making techniques to discern the optimal cluster leaders. This determination relies on parameters such as signal-to-noise ratio (SNR) and SNR-dependent residual energy. The rationale for employing this strategy lies in its capacity to minimise the likelihood of bottlenecks in the system, given the adoption of a single-hop data transmission model connecting agricultural sensors and the base station (BS). Consequently, this approach leads to enhancements in data delivery efficiency coupled with reduced power consumption, both of which are instrumental to the overarching framework's effectiveness. Furthermore, the incorporation of the SNR factor as a metric for signal strength assessment confers a performance advantage over prevailing alternatives within the network, particularly in the context of communication between farm sensors and the BS. In this manner, the proposed framework outperforms existing solutions in this critical aspect. Subsequently, the next phase of this research endeavours to subject the framework to rigorous evaluation within an IoT network characterised by mobile devices and an Intelligent Transportation System (ITS).

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