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Research Article

A Novel Architecture for the Smart Pedestrian Crossing in Cities Using IoT-Based Approach

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Pedestrian crossings have also been highlighted as one of the most dangerous locations in the transportation field. Because people and vehicles share the road, a crosswalk improves the road's efficiency in a densely populated region. However, as the population grows, more accidents and serious injuries occur, and as a result, nationalities are attempting to reduce these incidents through marketing and legal fines. Various architectures and developmental models have been proposed by authors focusing on the safeguarding of pedestrians crossing the intersections and vehicles passing by. Few proposed machine learning and deep learning-based solutions to the pedestrian lanes; others provided an Internet of Things- (IoT-) based solution to the situation. Various challenges are left unresolved, such as evidence recording, image capturing, and recognition in case of an emergency. In the proposed scenario, an IoT-based technology is utilized to assist the vehicles passing by to act over the signals depicted as a red light focusing on a real-time architecture. The proposed system will be mounted along the roadside at the traffic light pole. The system comprises various refined quality components, such as a gesture control module, High Definition camera module, etc. Based on the decision drawn from the gesture module, a specific signal will be displayed with the help of a traffic light to assist the vehicles passing by to safeguard the people crossing the proposed smart pedestrian crossing.

1. Introduction

The idea of making a city "smart" is gaining traction as a potential solution to the problems brought on by urban population expansion and urbanization. Pedestrian crossings have also been highlighted as one of the most dangerous locations in the transportation field [1]. Because people and vehicles share the road, a crosswalk improves the road's efficiency in a densely populated region. However, as the population grows, more accidents and serious injuries occur, and as a result, nationalities are attempting to reduce these incidents through marketing and legal fines. Although such steps reduce the overall number of fatal accidents, pedestrian fatalities have not decreased in a decade. In recent years, the concept of the Internet of Things (IoT) [2, 3] has aroused the interest of the scientific and industrial communities. The IoT's alleged applicability to several areas, such as smart environments, smart homes, industry, and e-health, is one of the key reasons for its popularity. Nonetheless, one IoT application category, smart cities, is likely to stand out from the others. A smart city is a mixed environment characterized by excellent Information and Communication Technology [4] management to make cities more appealing and sustainable [5], i.e., distinctive regions for innovation and entrepreneurship. An efficient and adaptive technique is optimal for sustainable development under the smart cities concept for maintaining the carbon distribution in the atmosphere [6]. Various architectures and developmental models have been proposed by authors focusing on safeguarding pedestrians crossing the intersections and vehicles passing by. However, the statistical data received via smart highways need to be analyzed and evaluated regarding road logistics transportation cost to achieve higher flexibility, optimized speed, and various other factors [7].

Several other authors proposed technology-based solutions to safeguard pedestrians crossing the roads utilizing IoT-based methods [8, 9]. Over the 21st century, traffic management systems have become increasingly technologically focused, and IoT-based automation [10] has reached a stage of technological improvement. Put another way, the automation process is limited to wealthy or emerging countries. Many undeveloped and underdeveloped countries still rely primarily on traffic managers' physical and tactical services, even though they are technology based. Orienting and handling traffic can be exhausting and difficult for a person to focus on 24 hr a day, 7 days a week, and deliver the best results by automated methods. The traffic systems of the later countries, particularly road crossings, must also be listed. Every day at work and at school, the road is quite congested. The streets of the city. Many automobiles are now on the road. There are numerous issues with crossing the road. Hundreds of people die in vehicle accidents daily, particularly at road crossings.

Various models relating to short-term traffic updates have been proposed earlier to achieve the highest accuracy rates [11]. Few models focused on constructing an efficient street planner for smart traffic flow, focusing on numerous roadside challenges [12]. In the proposed scenario, an IoT-based technology is utilized to assist the vehicles passing by to act over the signals depicted in the form of red lights. The proposed system will be mounted along the roadside at the traffic light pole. The system comprises various components of refined quality, such as a gesture control module, High Definition (HD) camera module, etc. Based on the decision drawn from the gesture module, a specific signal will be displayed with the help of a traffic light to assist the vehicles passing by to safeguard the people crossing the proposed smart pedestrian crossing. The proposed system focuses on attaining the following objectives:

(1) To develop an architecture to safeguard the pedestrians crossing the road intersections that are more reliable and efficient;
(2) To provide IoT-based solutions to the smart city challenges considering the sustainable energy concept;
(3) To improve the existing IoT-based architectures using technology-based solutions.

The detailed description of the paper can be organized in the following sections. Section 2 explains the previous inventions related to pedestrian crossing based on IoT-based solutions for smart cities. Section 3 explains the experimental setup of the proposed architecture, along with a detailed description of the modules utilized in the proposed architecture. Section 4 explains the analysis of the proposed IoT-enabled architecture compared to the existing architectures based on performance and nonperformance factors. Section 5 explains the conclusion and future scope of the proposed architecture as a basis for IoT-based solutions to smart city solutions.

2. Materials and Methods

Previously various technology-based solutions have been provided by the authors worldwide, focusing on methods that safeguard people while crossing the road intersections under the smart city concept. Pau et al. [8] proposed one system that manages the traffic lights dynamically for pedestrian crossings based on a fuzzy logic technique. The proposed system works in different phases to depict appropriate signals for the vehicles based on the possibility of the number of pedestrians and time of the day. It acts accordingly to allow people to cross the road. The architecture prepared by the authors is based on the VisSim simulation [13], which is further utilized for the assessment processes focusing on the pedestrian flow and count of stoppages, and several other parameters. The author provided a detailed description of the configuration of a fuzzy logic controller, summative assessments, and an in-depth analysis of the proposed scenario. Pathak et al. [9] has proposed an Arduino UNO 3-based device to reduce accidents on roads while crossing. The proposed device works autonomously to calculate the different parameters related to the smart pedestrian crossing using object tracking.

Hong et al. [14] proposed a system that analyzes various pedestrian safety services to safeguard people while crossing the pedestrian lane. The system proposed by the author works on the speed of the vehicles at different demonstration points, focusing on child, and normal zones. The system proposed by the author comprises of thermal image recognition sensor, radar detection sensor, and vehicle information collection device mounted along the roadside in parallel. Once the data are collected, it will be shared among the pedestrians and vehicles passing using an appropriate signaling mechanism.

Tsai et al. [15] proposed a smart crosswalk system based on embedded systems and machine learning. The proposed system works with an architecture comprising traffic signals, including specific pedestrian signals and barrier gates for vehicles every 18 s. The barrier gates will alert the driver to stop the vehicle while people are crossing the pedestrian lanes. Hazarathaiah and Likhitha [16] proposed a smart crossing for pedestrian lanes that acknowledges the driver to stay away while people are crossing pedestrian lanes. The proposed architecture focuses on dynamically administrating the traffic signals for the pedestrian crossing. Considering the time and quantity of pedestrians crossing the road, an appropriate signal will be displayed, focusing on various parameters of well-being. Hardiyanto et al. [17] proposed a system that detects the violation of the traffic lights to prevent accidents by spraying water. The author has utilized a decision tree-based method to detect the violation that triggers the water spray depending on the decision made through ultrasonic sensors. An et al. [18] proposed a smart crossing

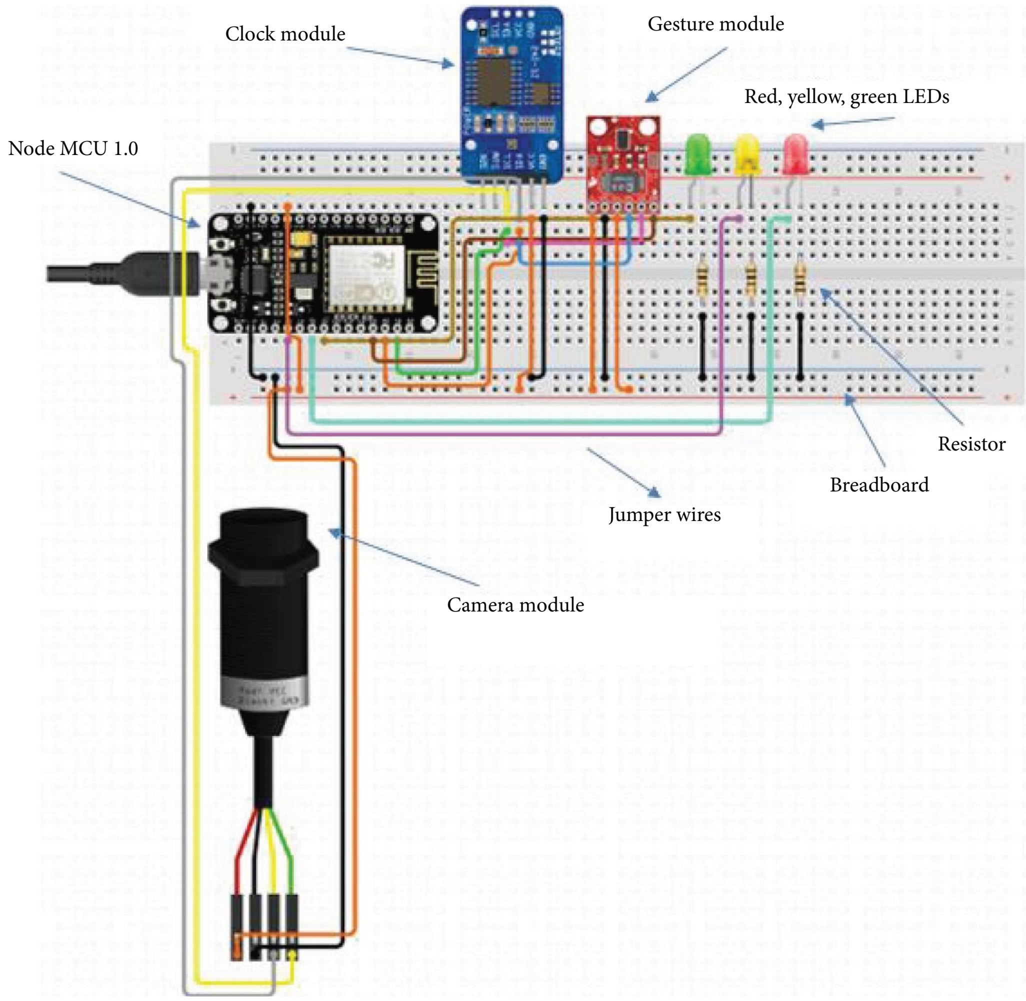

Figure 1: Circuit diagram of the proposed architecture for IoT-enabled smart pedestrian crossing.

system using IoT-based technology that tracks the abnormal movement of vehicles and pedestrians that may be accidental by recording the video and applying certain algorithms to fetch updates. The system proposed by the author focuses on collecting the evidence for the hit-and-run accidental case. The algorithm proposed by the author works based on the availability of the pedestrian to cross the road and the detection of an abnormal movement.

Dow et al. [19] proposed a crosswalk pedestrian recognition system by utilizing zebra crossing recognition and deep learning techniques focusing on reducing road accidents and improving pedestrian safety. Kaluvana et al. [20] proposed an intelligent transportation system by utilizing IoT-based techniques focusing on determining the traffic flow on the road using ultrasonic sensors. The proposed system measures the average traffic flow every 5 min and displays it to the cloud platform [21] using machine learning algorithms. Pavlović [22] proposed an architecture that defines various development models for urban areas focusing on improving the traffic flow at intersections across the city. The architecture proposed by the author aids in determining the average time required to extend the interval required for the pedestrian to cross the road at busy schedules using an IoT-based technique. Xiong et al. [23] proposed an intelligent transportation system that automatically focuses on flowing traffic updates, forecasting relevant information to the vehicles passing that route.

3. Proposed Method

This section describes the proposed IoT-based architecture for a smart pedestrian crossing in smart cities. This section underlines the complete details of the architecture, including the key components and the workflow diagram comprising the steps necessary to design the smart architecture to improve the existing pedestrian crossing.

3.1. Key Components. The circuit diagram of the proposed IoT-enabled smart pedestrian crossing can be elaborated more accurately with the help of Figure 1. The proposed novel architecture for IoT-enabled smart pedestrian crossing is a system comprising of a set of refined modules, such as gesture module, HD camera module etc. the detailed description of the components utilized in the proposed architecture can be as follows:

(1) LEDs: three different kinds of LEDs are utilized in the proposed architecture, i.e.,red,yellow, andgreen LEDs. Each LED represents an appropriate message to the vehicles passing by the route. The function of each LED will remain the same, which works with the default traffic light system, along with a special panel depicting whether a person is about to cross the pedestrian crossing or not.

(2) Gesture sensor module: APDS 9690 gesture module [24] is utilized in the proposed IoT-based smart pedestrian crossing. The gesture module initiates when a person signifies an appropriate gesture notifying that they must cross via the pedestrian crossing. A special timer (ST) will initiate whenever an individual notifies of an appropriate gesture in front of the gesture module.

(3) Microcontroller: node MCU 1.0 microcontroller is utilized for the proposed scenario, for the IoT-enabled smart pedestrian crossing. The microcontroller has an in-build module for Wi-Fi connectivity, with the router placed nearby [25]. Every other module will coordinate and communicate with other modules based on the connectivity specified in the microcontroller itself.

(4) HD camera module: HD camera modules are integrated to capture the images of the person initiating the proposed gesture-based technique for smart pedestrian crossing. These modules will help government officials better understand and diagnose the people in case of any causality or mishap while crossing the pedestrian crossing.

(5) Clock module: the clock module initiates a special clock timer ST in case an individual has given a gesture to cross the pedestrian crossing. The clock module will also maintain the Timer (T), i.e., the default timer for any default traffic light system. Based on the value calculated by ST, an event of crossing smart pedestrian crossing may start if an appropriate value has been received.

Figure 1 represents the circuit diagram for the proposed IoT-enabled architecture for a smart pedestrian crossing in smart cities. The proposed architecture comprises a set of refined components such as Node MCU 1.0 as a microcontroller, APDS gesture sensor module to capture the gesture to depict an appropriate sensor, LEDs to depict an appropriate signal for the vehicles passing by the route, and clock module to monitor and maintain the timer value so that an event can be initiated at a particular time slot to allow the people to cross the smart pedestrian crossing. And an HD camera module to capture the images of the people who are notifying the proposed system to cross the pedestrian crossing so that an individual can be diagnosed and detected in case of any causality if required.

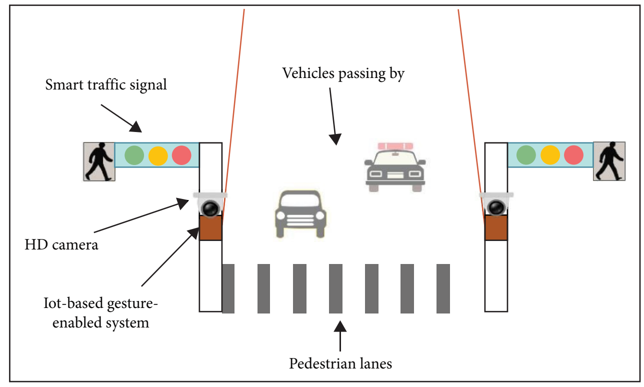

Figure 2: Proposed scenario for IoT-enabled smart pedestrian crossing in smart cities.

3.2. Working Methodology. This section emphasizes the detailed description of the proposed IoT-enabled smart pedestrian crossing in smart cities. The section highlights the necessary steps to operate in the proposed IoT-enabled smart pedestrian crossing scenario. The architecture of the proposed scenario can be more represented in Figure 2. The establishment of the refining sensors can be seen more subtly in Figure 2.

Figure 2 represents the architecture for the proposed scenario for the smart pedestrian crossing lanes under the smart city concept. In the proposed scenario, an IoT-based technology is utilized such that it assists the vehicles passing by to act over the signals depicted in the form of a red light. The proposed system will be mounted at the traffic light pole along the roadside. The system comprises various refined quality components, such as a gesture control module, HD camera module etc. Based on the decision drawn from the gesture module, a specific signal will be displayed with the help of a traffic light to assist the vehicles passing by and safeguard the people crossing the proposed smart pedestrian crossing.

Figure 3 represents the process flow diagram of the proposed IoT-enabled smart pedestrian crossing system for the smart city concept. The process diagram is categorized into various phases, depicting the situation at the pedestrian crossing at a particular time state. In Phase 1, at time "t_1" when no person arrives to cross the smart pedestrian crossing, a timer value "T" initiates to 2 min. The red lights are updated every time based on the default timer values. In Phase 2, at the time "t_2", when a person arrives to cross the smart pedestrian crossing lane and shows the specific gesture, a clock for special timer "ST" is initiated. Based on the value maintained for ST, if the ST value is greater than the T value, then the proposed system will initiate and accept the gesture made by the person to cross the lane. The signals will change gradually to safeguard the person and allow him to cross the lane. Also, the vehicle owner will act upon the signals to safeguard the person crossing the lane for a specific time interval.

If the ST value is found to be less than the T value, then a person needs to wait for the specific time interval to initiate the proposed system. In Phase N, when no person arrives to

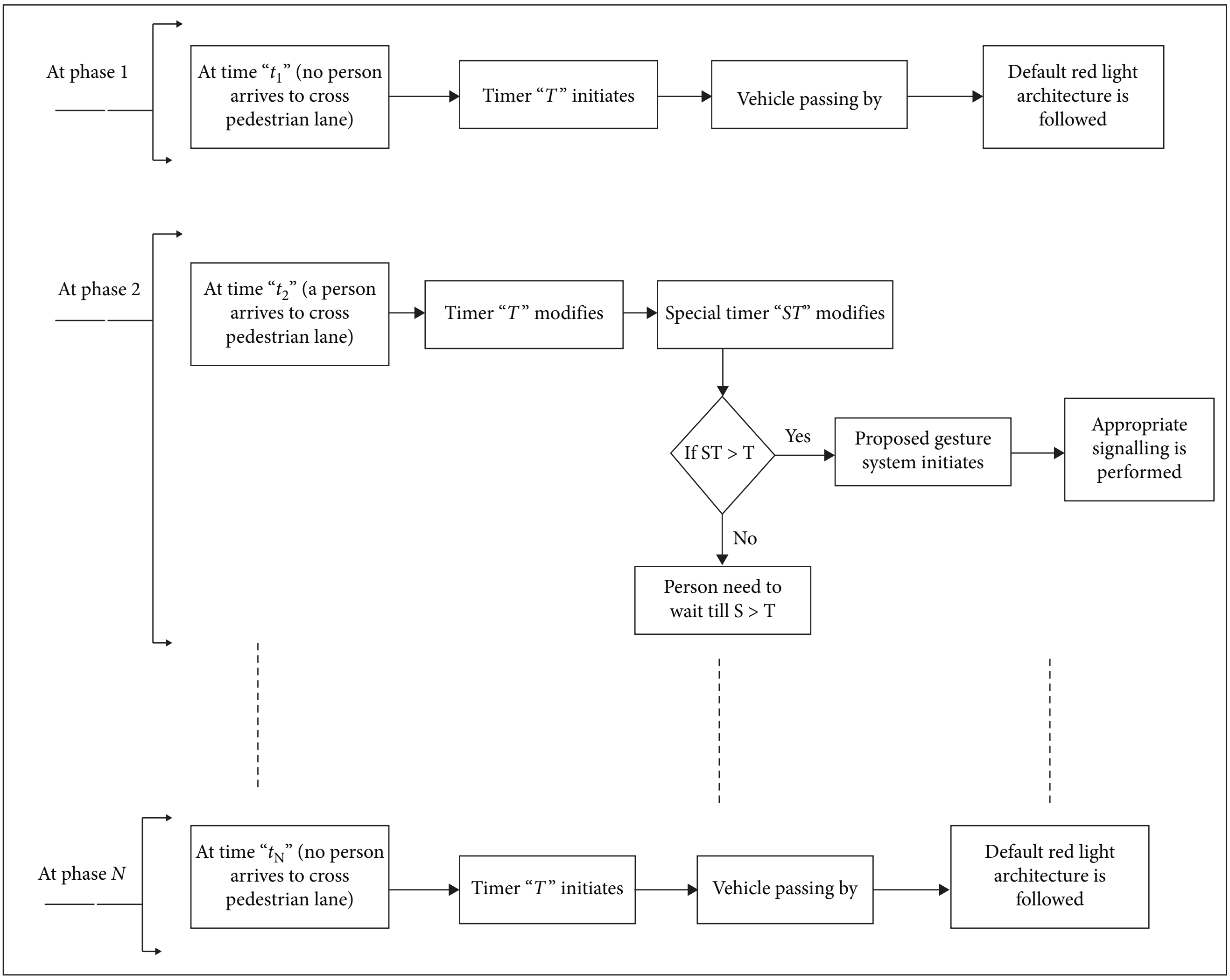

Figure 3: Process flow diagram of the proposed IoT-enabled smart pedestrian crossing system in smart cities.

cross the smart pedestrian crossing lane, the default traffic light architecture is followed again until a person arrives and shows the specific gesture, "G," to the proposed system. The HD cameras will maintain the facial image of the person showing gestures to the proposed system so that a person can be identified in the near future in case of any causality.

3.3. Proposed Algorithm for Smart Pedestrian Crossing. This section represents the proposed algorithm to safeguard the pedestrian crossing at busy schedules. The proposed smart pedestrian crossing system relies on the steps described in Algorithm 1. The necessary steps required to implement the proposed architecture can be as follows:

Step 1. **Initialize** the IoT device to detect the gesture.
Step 2. **Initialize** the variables ST, T and Gesture 'G' in accordance with the clock module.
Step 3. **Repeat** detecting the gesture 'G'
    IF (G == TRUE)
        Initialize ST.
        Calculate T.
        Share the update with pedestrians with the help of LEDs.
        Maintain the database for every G on a cloud-based platform.
    ELSE
        No action is required.
        T is set as default.
Step 4. **Output:** Performance metrics

Algorithm 1: IoT device to safeguard the pedestrian crossing.

4. Performance Analysis of the Proposed Smart Architecture for Pedestrian Crossing

The section underlines the experimental setup of the proposed IoT-enabled smart pedestrian crossing in smart cities

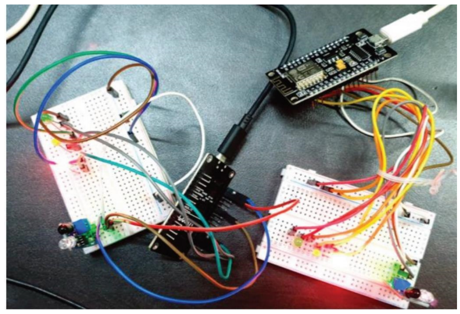

Figure 4: Prototype of the proposed IoT-enabled smart pedestrian crossing.

Table 1: Comparison of proposed IoT-based architecture with the existing solutions.

S. No.	Factor	Existing architecture for pedestrian crossing	Proposed IoT-enabled architecture for smart pedestrian crossing
1	Cost	Less cost-conscious as it consists of expensive sensor modules	Highly economical to implant for public usage
2	Reliability	The existing solutions are found less reliable and acquire less accuracy	The proposed system is more reliable in updating the data to the cloud platform for triggering an event
3	Features	The existing smart pedestrian system comprises fewer features in order to analyze the data collected for future processes	The proposed system consists of various relevant features compared to existing ones, such as gesture-based recognition mechanism, image recognition mechanism, etc.
4	Utilization	Since the existing architectures are complex to implement at various levels to safeguard the people, acknowledging the drivers is way too complicated	The proposed smart pedestrian crossing system can be utilized at various levels to safeguard the people crossing the road intersections
5	Usability	Existing smart solutions for pedestrian lanes are less cost-conscious and comprise complex architectures	The proposed system is highly economical to be implemented under the smart city concept
6	Power consumption	Since the solutions provided previously by various authors comprise a larger set of sensor modules for the proposed system, they consume huge amounts of energy and increase power consumption	The proposed architecture comprises fewer sensor modules, and the modules act dynamically, reducing power consumption
7	Evidence records	Few solutions provided by authors emphasize collecting the evidence records in case an emergency has been met	A feature for evidence collection is integrated into the proposed system so that further analysis can be performed in case of an emergency

and the proposed scenario analysis based on the performance factors using the ThingSpeak cloud platform [26]. The ThingSpeak platform is a highly secure application interface platform that ensures reliable communication between devices using Internet-based services [27]. The experimental setup of the proposed system is performed with the help of a prototype that resembles the real-time environment. Figure 4 represents the experimental setup of the proposed IoT-enabled smart pedestrian crossing in the smart city concept [28].

Figure 4 represents the experimental setup of the proposed IoT-enabled smart pedestrian crossing architecture through a real-time prototype. The prototype comprises a set of refined sensors, including two NODE MCU 1.0 modules with an in-build Wi-Fi module for Internet connectivity and communication between the hardware devices. Also, the proposed architecture includes two APDS RBG gesture modules to capture the gesture made by the people seeking to cross the path. Few jumper wires are utilized to make connections possible and work appropriately through signal-based communication. And two pairs of red, green, and yellow LEDs for appropriate signaling so that the vehicles can act accordingly. The reliability and efficiency of the proposed IoT-enabled smart pedestrian crossing can be measured based on performance and nonperformance factors such as cost, features, technology, etc. Table 1 represents the comparative analysis of the proposed IoT-based architecture for smart pedestrian crossing based on the nonperformance factors.

4.1. Performance Metrics. The performance of the proposed smart pedestrian crossing system can be measured using certain performance and nonperformance-based factors, such as accuracy, performance, cost etc. The following formula can be utilized to compute the factors where:

(1) VE stands for “Valid Events,” i.e., the total number of events that were accurately detected by the proposed system;

(2) IVE stands for “Invalid Events,” i.e., the total number of events that were not detected by the proposed system in the meantime;
(3) NL stands for “Network Latency,” i.e., the amount of delay in updating the database to the cloud-based network;
(4) OP stands for “Observed Performance,” i.e., the amount of time when the proposed system accurately detected the event;
(5) NP stands for “Normal Performance,” i.e., the total amount of time when the proposed system is assumed to detect an event in a particular time slot.

The accuracy of the proposed invention can be computed through Equation (1) using parameters such as VE and IVE, depicting valid and invalid events.

$$\text{Accuracy} = \frac{\text{VE} + \text{IVE}}{\text{TE}}. \quad (1)$$

Maintaining reliable connectivity throughout communication is big cumbersome in wireless communication-based architecture. To examine the connectivity of the proposed invention, Equation (2) comprises an average of NL at time t_i where $i = 1, 2, 3, \ldots, n$.

$$\text{Connectivity} = \sum_{t_i}^{t_n} \text{average (NL)}, \text{ where } i = 1, 2, 3, \ldots, n. \quad (2)$$

To measure the performance of the proposed invention under a real-time scenario, three factors have been considered, namely, connectivity, NP and OP in Equation (3).

$$\text{Performance} = \frac{\text{OP} + \text{connectivity}}{\text{NP}} \times 100. \quad (3)$$

The cost of the proposed invention relies on three factors, mainly module cost, labor cost, and overhead cost, along with the default overhead cost in Equation (4).

$$\text{Cost} = \frac{\text{module cost} + \text{labor cost} + \text{overhead cost}}{\text{default overhead cost}} \times 100. \quad (4)$$

One of the most important factors of any invention relies upon its usability. According to the proposed invention, usability relies on module cost, labor cost, overhead cost, and number of units produced in an Equation (5).

$$\text{Usability} = \frac{\text{module cost} + \text{labor cost} + \text{overhead cost}}{\text{nunber of units produced}} \times 100. \quad (5)$$

Communication in any network or network-based architecture should have an aspect of reliability to ensure the communication link and reliable information exchange. In the proposed invention, reliability can be computed using Equation (6) with parameters such as, accuracy, performance, and usability.

$$\text{Reliability} = \frac{\text{accuracy} + \text{performance}}{\text{usability}} \times 100. \quad (6)$$

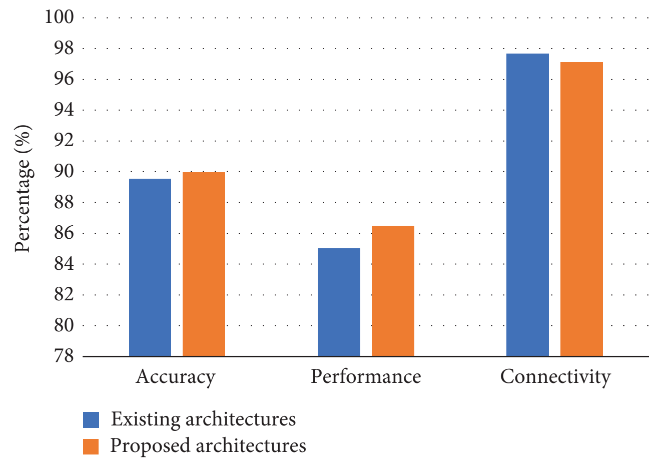

Figure 5: Comparative analysis of the proposed IoT-enabled smart architecture with the existing architectures.

4.2. Experiment Findings and Analysis. This section underlines the comparative analysis of the proposed IoT-enabled architecture for smart pedestrian crossing lanes in the concept of smart cities. The comparison has been performed on the basis of the performance and nonperformance factors comprising accuracy, connectivity, reliability etc. The input for a comparative study has been generated through the proposed IoT-based architecture to compute results for various performance and nonperformance based factors. Figures 5 and 6 depict the comparative analysis for the proposed scenario.

Figure 5 represents the results from the comparative analysis of the proposed IoT-enabled architecture for smart pedestrian crossing with the existing IoT-enabled architectures in smart cities based on the performance factors. The comparative analysis depicts that the proposed smart pedestrian crossing system performs much more efficiently in terms of accuracy in measuring and depicting the output, enhanced performance, and reliable connectivity and communication between the devices.

Figure 6 represents the results drawn from the comparative analysis of the proposed IoT-enabled smart pedestrian crossing system with the existing IoT-enabled architectures based on nonperformance factors. The proposed smart architecture is cost-conscious, highly usable, and reliable for the generalized public all around the world compared to the existing architectures for pedestrian crossing under the concept of smart cities.

4.3. Technical Implications and Possible Outcomes. Introducing the proposed IoT-enabled smart pedestrian crossing

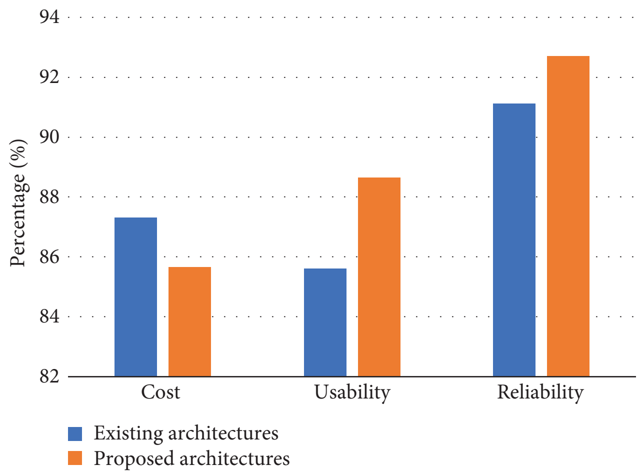

Figure 6: Comparative analysis of the proposed IoT-enabled smart architecture with the existing architectures.

lanes has numerous technical implications for the concept of smart cities in the near future. The technical implications of the proposed novel architecture can be as follows:

(1) The proposed IoT-enabled architecture works on the gesture-based input made by an individual to cross the lanes;
(2) A special time factor is maintained to trigger the proposed IoT-enabled architecture whenever the system receives the gesture;
(3) The proposed architecture is an additional feature to the default traffic light system that is usually followed worldwide;
(4) The proposed architecture maintains the image of a person showing a specific gesture to the system to initiate the ST;
(5) The proposed system can be used as an alternative to maintaining the database of individuals crossing the street for security purposes;
(6) Government officials can utilize the database maintained through the system to track a person who is found to be a defaulter;
(7) The database maintained through the proposed system is highly secure and reliable to be utilized for various operations in the near future by concerned authorities;
(8) The system will continue to perform the operations as default when no gesture is being shown by an individual.

5. Conclusions and Future Work

The research suggests a revolutionary architecture for IoT-based smart pedestrian crossings. The suggested system uses IoT-based technologies to help passing vehicles react to the signals shown as appropriate signal patterns. When a certain circumstance arises, the relevant LED will blink to let vehicles know whether or not someone is using the designated pedestrian lane. The suggested system will be fixed to the traffic signal pole at the side of the road. To help passing vehicles and protect pedestrians crossing the pedestrian lane, a specific signal will be flashed on the traffic light based on the decision made by the gesture module. As most occurrences have been recorded globally, the suggested solution will help protect persons using pedestrian lanes during busy schedules. The suggested method can potentially serve as a preventive strategy to protect countless lives. Compared to earlier proposed systems, the proposed system has achieved higher accuracy and dependability measures. Future potential for the suggested system includes enhancing the feature that flashes a person's identity in the event of an accident.

Data Availability

The data that was utilized to support the conclusions of this research may be obtained from the corresponding author upon written request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

References

[1] R. Almodfer, S. Xiong, Z. Fang, X. Kong, and S. Zheng, "Quantitative analysis of lane-based pedestrian-vehicle conflict at a non-signalized marked crosswalk," *Transportation Research Part F: Traffic Psychology and Behaviour*, vol. 42, Part 3, pp. 468–478, 2016.
[2] H. Nguyen-An, T. Silverston, T. Yamazaki, and T. Miyoshi, "IoT traffic: modeling and measurement experiments," *IoT*, vol. 2, no. 1, pp. 140–162, 2021.
[3] S. Singh, H. Chaudhary, and A. K. Tripathi, "IoT-enabled intelligent public transportation system," *Design Engineering*, vol. 9, pp. 3459–3474, 2021.
[4] W. Chatti, "Moving towards environmental sustainability: information and communication technology (ICT), freight transport, and CO_2 emissions," *Heliyon*, vol. 7, no. 10, Article ID e08190, 2021.
[5] S. Singh, "Green technologies and sustainable environment, a need to sustain in near future," in *International Conference on Frontiers of Science & Technology (ICFST 2017), Science and Engineering Research Board Department of Science and Technology Govt of India, Council of Science and Technology Uttar Pradesh*, pp. 978–993, Indian Society for Technical Education, New Delhi, 2017.
[6] M. Lu, G. Sun, and Z. He, "Analysis and evaluation of factors influencing the low-carbon effect of urban high-rise settlement planning schemes based on AHP-fuzzy comprehensive evaluation method," *Mathematical Problems in Engineering*, vol. 2022, Article ID 9529110, 9 pages, 2022.
[7] S. Liu, "Deconstruction of road logistics transportation cost management evaluation based on optimal solution of linear programming," *Mathematical Problems in Engineering*, vol. 2022, Article ID 5784053, 12 pages, 2022.
[8] G. Pau, T. Campisi, A. Canale, A. Severino, M. Collotta, and G. Tesoriere, "Smart pedestrian crossing management at

traffic light junctions through a fuzzy-based approach," *Future Internet*, vol. 10, no. 2, Article ID 15, 2018.

[9] A. Pathak, M. Adil, M. J. Hossain, T. S. Rafa, and U. S. Pushpa, "Pedestrian-safer IoT-based smart crossing system with object tracking," *International Journal of Recent Technology and Engineering (IJRTE)*, vol. 9, no. 1, pp. 1848–1853, 2020.

[10] S. Muthuramalingam, A. Bharathi, S. R. kumar, N. Gayathri, R. Sathiyaraj, and B. Balamurugan, "IoT based intelligent transportation system (IoT-ITS) for global perspective: a case study," in *Internet of Things and Big Data Analytics for Smart Generation*, V. Balas, V. Solanki, R. Kumar, and M. Khari, Eds., vol. 154 of *Intelligent Systems Reference Library*, pp. 279–300, Springer, Cham, 2019.

[11] S. Jiang, "Short-term traffic prediction of the urban road network based on the intelligent transportation system," *Mathematical Problems in Engineering*, vol. 2022, Article ID 7593443, 6 pages, 2022.

[12] F. Bi and H. Liu, "Numerical analysis and calculation for urban street landscape spatial pattern," *Mathematical Problems in Engineering*, vol. 2022, Article ID 2183373, 12 pages, 2022.

[13] L. Bloomberg and J. Dale, "Comparison of VISSIM and CORSIM traffic simulation models on a congested network," *Transportation Research Record*, vol. 1727, no. 1, pp. 52–60, 2000.

[14] K.-M. Hong, S.-H. Son, and J.-H. Kim, "Effectiveness of pedestrian safety service provision using sensing technology," *Sustainability*, vol. 13, no. 16, Article ID 9333, 2021.

[15] W.-C. Tsai, K.-C. Chen, J.-S. Lai, and J.-I. Guo, "Front moving object behavior prediction system exploiting deep learning technology for ADAS applications," in *2020 IEEE 63 rd International Midwest Symposium on Circuits and Systems (MWSCAS)*, pp. 1052–1055, Springfield, MA, USA, August 2020.

[16] A. Hazarathaiah and P. Likhitha, "Smart crossing for pedestrians using IOT," *International Journal of Engineering Trends and Applications (IJETA)*, vol. 5, no. 2, pp. 214–217, 2018.

[17] D. Hardiyanto, Iswanto, D. A. Sartika, and M. Rojali, "Pedestrian crossing safety system at traffic lights based on decision tree algorithm," *International Journal of Advanced Computer Science and Applications (IJACSA)*, vol. 10, no. 8, pp. 375–379, 2019.

[18] K. E. An, Y. J. Jeong, S. W. Lee, and D. Seo, "Smart crossing system using IoT," in *2017 IEEE International Conference on Consumer Electronics (ICCE)*, pp. 392-393, IEEE, Las Vegas, NV, January 2017.

[19] C.-R. Dow, H.-H. Ngo, L.-H. Lee, P.-Y. Lai, K.-C. Wang, and V.-T. Bui, "A crosswalk pedestrian recognition system by using deep learning and zebra-crossing recognition techniques," *Software: Practice and Experience*, vol. 50, no. 5, pp. 630–644, 2020.

[20] H. Kaluvana, P. K. Baskar, S. Ramanathan, S. Sundar, and S. Jeyaram, "Intelligent transportation system and smart traffic flow with IOT," *Indian Journal of Radio & Space Physics*, vol. 50, pp. 64–67, 2021.

[21] A. K. Tripathi and S. Singh, "Ensuring reliability in cloud computing and comparison on IPv6 encouraged with protocols," in *Proceedings of International Conference on Science*, pp. 9–14, Technology, Humanities and Business Management, Bangkok, July 2016.

[22] Z. G. Pavlović, "Development of models of smart intersections in urban areas based on IoT technologies," in *2022 21st International Symposium INFOTEH-JAHORINA (INFOTEH)*, pp. 1–4, IEEE, East Sarajevo, Bosnia and Herzegovina, March 2022.

[23] L. Xiong, W. Ding, X. Huang, and W. Huang, "CLSTAN: convLSTM-based spatiotemporal attention network for traffic flow forecasting," *Mathematical Problems in Engineering*, vol. 2022, Article ID 1604727, 13 pages, 2022.

[24] A. Yatsuda, T. Haramaki, and H. Nishino, "A robot motion design scheme for watching the elderly based on human gesture sensing," *Internet of Things*, vol. 5, pp. 168–179, 2019.

[25] A. K. Tripathi and S. Singh, "A comparative analysis on internet protocols in cloud-mobile environment," *International Journal of Control Theory and Applications (IJCTA)*, vol. 9, no. 19, pp. 9161–9169, 2016.

[26] P. Mishra, S. Kumar, U. Garg, E. S. Pilli, and R. C. Joshi, "Security perspectives of various IoT cloud platforms: a review & case study," in *2021 International Conference on Computing, Communication, and Intelligent Systems (ICCCIS)*, pp. 727–731, IEEE, Greater Noida, India, February 2021.

[27] F. A. Tsvetanov and M. N. Pandurski, "Security of the sensory data in the cloud," *IOP Conference Series: Materials Science and Engineering, IOP Publishing*, vol. 1032, no. 1, Article ID 012005, 2021.

[28] M. Bhardwaj, "Research on IoT governance, security and privacy issues of internet of Things," in *Privacy Vulnerabilities and Data Challenges in the IoT*, CRC Press, Article ID 20, 2020.