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Review Article

Intelligent Illuminated Parking System from Cybersecurity Perspectives - A Review

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Abstract *- With the growth of smart city infrastructure, there is a need for the development and implementation of intelligent Illuminated Parking Systems (IIPS). IIPS increase parking efficiency while lowering energy costs and enhancing user experience by utilizing innovative techniques, among them smart lighting, Internet of Things (IoT), and Artificial Intelligence (AI). Nonetheless, these technologies propounds a number of cybersecurity risks that may compromise system confidentiality, availability, and integrity. This review paper promulgates a thorough cybersecurity analysis of IIPS, with emphasis on vulnerabilities, risks, and mitigation techniques. An overview of a typical IIPS architecture is presented, underlining vital elements such as data processing units, smart sensors, connected lights, and user interfaces. The article scrutinizes potential cybersecurity threats into three categories: data-centric attacks, network vulnerabilities, and physical dangers. Common attack vectors under review include malware infiltration, man-in-the-middle attacks, Distributed Denial of Service (DDoS), and data breaches. Proposed cybersecurity measures take into consideration anomaly detection systems, secure communication protocols, access control methods, and encryption approaches. The study advocates a multi-layered cybersecurity framework comprising robust encryption standards, AI-powered threat detection, frequent security audits, and user awareness initiatives. As smart cities build up, highly secure IIPS based on the proposed framework critical in public confidence preservation and urban infrastructure protection are recommended for future research directions.*

Keywords *- Cybersecurity, Intelligent illuminated parking system, IoT, AI, Smart city, Threat mitigation, Vulnerabilities.*

1. Introduction

An intelligent Illuminated Parking System (IIPS) is an outcome of an integrated development of smart city technologies. IIPS reduce energy consumption, enhance customer experience, and streamline parking operations by utilizing cutting-edge technologies like Artificial Intelligence (AI) and the Internet of Things (IoT). IIPS cuts the time and effort required to identify parking spaces by integrating smart sensors, connected lights, and data processing units to deliver real-time parking information [1, 2].

However, critical cybersecurity issues pop up as a result of growing reliance on these networked systems. IIPS is susceptible to different types of cyber threats due to the integration of multiple technologies and the enormous volume of data being transmitted. These dangers put users and the infrastructure at risk by jeopardizing the parking systems' functionality, safety, and privacy [1, 2]. This review paper's objective is to examine the IIPS research work and related cybersecurity issues, strengths and weaknesses, evaluate current cybersecurity measures in place, and propose ways to make these systems more secure. A thorough review of the cybersecurity landscape for IIPS is presented, and recommendations for future research and development areas by looking at case studies and recent research.

1.1. Evolution of Parking Lighting Systems

The necessity for providing intelligent solutions and energy economy for urban settlements, supported by technical ingenuity, has spearheaded major evolution in parking lighting systems over time. With a focus on security, particularly cybersecurity, this introduction puts forth a thorough investigation of the development of conventional lighting configurations to contemporary intelligently-lit parking systems. The core component of traditional parking lighting systems was manually operated lighting units that supplied parking lots with minimal lighting. In general, compared to contemporary intelligent systems, these systems are simpler to maintain and more reliable since they don't require sophisticated technical inputs to be managed and maintained [3]. These systems required tremendous upkeep and were frequently inefficient, using a lot of energy. There were many complications due to the lack of automation and real-time monitoring, primarily excessive operating expenses and inadequate lighting control. A significant development in parking lighting system evolution was the introduction of automated lighting control systems. These systems automatically control the lights conditionally on pre-programmed schedules or motion detection thanks to sensors and timers. This innovation enhanced user safety and convenience while also improving energy economy, as the proposed microcontroller-based energy-saving system by [3] in parking spaces can save up to 46.35% of energy compared to existing lighting systems. In order to effectively manage parking spaces and lower energy usage, for example, a study by [4] presented an intelligent car parking system employing microcontrollers, sensors, and wireless signal modules. Parking lighting systems underwent radical design changes with the introduction of the Internet of Things (IoT), enabling capabilities such as remote control and real-time data collection. Sensors are utilized by IoT-based systems to determine parking space availability and adjust the lights accordingly. In addition, the operational effectiveness of these systems can be significantly increased by enabling data-driven decision-making and predictive maintenance facilities.

Related work on promoting environmental sustainability by [5] created an IoT-based eco-parking system that employs infrared sensors to monitor parking space availability and assign places depending on vehicle emission classifications. Modern parking lighting systems have been transformed into sophisticated systems with improved security and user experience in addition to more sophisticated light control. Advanced features like integrated security cameras for monitoring and adaptive lighting, which interchangeable brightness upon vehicles and pedestrians' presence, are integrated into these systems.

With the passage of time, security vulnerabilities are gradually being detected due to the increased interconnectedness and dependencies of digital infrastructure. Protection against potential dangers and a guarantee for service dependability make it crucial to secure these sophisticated systems' security. Recent research by [6] to exploit LTE signals to improve user location estimates with an error rate of less than 10 meters in huge hypermarkets' underground parking highlights the significance of secure navigation systems in subterranean parking lots.

Parking lighting systems advancement in achieving increasing automation, sustainability, and security thrust forward innovations in blockchain, Machine Learning (ML), and AI techniques to improve further cybersecurity as well as optimize lighting control. [7] demonstrated the possibility for more developments in this subject by highlighting the application of differential evolution algorithms to the construction of energy-efficient public lighting installations and meeting the International Commission on Illumination recommendations. The development of parking light systems is indicative of a larger movement toward secure, intelligent, and energy-efficient urban infrastructures. Sophisticated cybersecurity measures must be integrated as technology develops to protect these intelligent systems from new attacks and maintain their dependability and efficiency in smart city settings.

1.2. Research Gap

Comprehensive frameworks that incorporate adaptive, real-time threat detection and mitigation strategies designed especially for the intricate cyber-physical interactions in intelligent Illuminated Parking Systems (IIPS) are lacking, despite the fact that previous studies address a variety of cybersecurity threats to IIPS. Instead of an integrated, multi-layered strategy that can adapt to changing cyber threats, current research mostly concentrates on discrete security measures. A more reliable, scalable cybersecurity approach that guarantees improved protection for IIPS within smart city infrastructures and operational efficiency may result from closing this gap.

1.3. Problem Statement

With real-time data and remote access capabilities, intelligent Illuminated Parking Systems (IIPS) provide improved safety, operational efficiency, and user convenience as they are progressively incorporated into smart cities. However, because of their dependence on networked sensors, IoT components, and data processing algorithms, these systems are also extremely vulnerable to cybersecurity threats. Notwithstanding their advantages, users and urban infrastructures are at serious risk from a lack of thorough knowledge about IIPS's cybersecurity flaws and defences. In order to protect these systems from changing cyber threats, this study examines current vulnerabilities, possible attack paths, and new mitigation techniques. It also discusses the urgent need for a comprehensive evaluation of the cybersecurity issues related to IIPS.

1.4. Research Objectives

All of these objectives work together to provide a comprehensive understanding of and improvement in IIPS cybersecurity in smart city ecosystems by addressing both present issues and upcoming requirements.

1.4.1. Examine Current Cybersecurity Weaknesses

Examine and classify the cybersecurity risks affecting Intelligent Illuminated Parking Systems (IIPS), paying particular attention to physical hazards, network vulnerabilities, and data-centric attacks.

1.4.2. Assess Current Security Measures

Evaluate how well the present IIPS cybersecurity tactics—such as encryption techniques, secure communication protocols, and anomaly detection systems—mitigate the dangers that have been discovered.

1.4.3. Provide a thorough Framework for Cybersecurity

To address potential cyber-physical vulnerabilities, create a multi-layered cybersecurity framework for IIPS that includes strong encryption, AI-based threat detection, frequent security audits, and user awareness.

1.4.4. Determine Future Direction of Research

Emphasize important areas for further study to improve IIPS security, including real-time, adaptive threat detection techniques and sophisticated encryption designed for IoT components in smart city infrastructure.

2. Literature Review

Energy efficiency, user convenience, safety, and operational management are all improved when intelligent lighting systems are integrated into parking spaces. These systems exploit sensors, ML and IoT to deliver the best lighting solutions. By integrating sensors and automatic controllers to alter lighting based on occupancy and environmental conditions in real time, intelligent lighting systems drastically reduce energy consumption.

2.1. Advantages of Intelligent Parking Lighting Systems

There are a number of advantages to implementing intelligent parking light systems, including energy conservation, safety, user convenience, and improved operational management. Intelligent parking light systems employ sophisticated sensors, automated controls, and energy-saving technologies to cut down on energy usage drastically. An intelligent, deep learning-based indoor parking system designed by [8] effectively cuts down on human resource expenses and conserves energy use while still satisfying illumination requirements.

An IoT-based intelligent lighting control system was developed by [9] that turns lights on and off as needed, adjusting luminance upon vehicles' proximity detection. This system achieves energy-saving control. By giving consumers access to real-time information, directing them to available parking spaces, and automating numerous facets of the parking procedure, intelligent parking light systems improve the user experience.

To drastically diminish time-to-available parking space detection, [10] proposed an intelligent parking system that employs IoT and advanced Honeywell sensors technology to direct users straight to available parking spaces. By offering real-time updates and effectively managing parking, [11] presented an IoT- and Arduino-based intelligent parking system with infrared sensors that maximizes space utilization, lessens traffic, and enhances the overall user experience.

Users' and cars' safety is increased by better illumination and security measures built into intelligent parking systems. [12] discovered that raising the amount of light in parking lots greatly enhances users' perceptions of safety and visibility, improving their comfort and sense of security. Using wireless sensor networks, [13] presented an intelligent parking system that uses several sensors for vehicle recognition and navigation, improving overall safety and security. The implementation of intelligent parking light systems results in notable decreases in operational expenses through automation and optimization. In order to manage parking effectively and save processing expenses while increasing operational efficiency, [14] developed an intelligent parking system that makes use of computer vision and image processing to detect license plates with 90% accuracy.

By automating several aspects of parking management, smart parking systems like the one [15] propose to eliminate the need for manual labour, hence cutting operational expenses. Systems for intelligent parking lights have a lot to offer in terms of user convenience, safety, energy efficiency, and lower operating costs. The creation of intelligent, secure, and sustainable urban infrastructures depends on these developments in Figure 1.

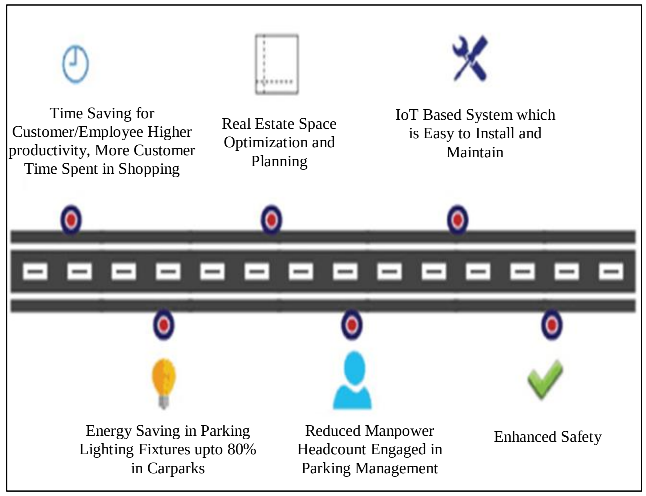

Fig. 1 Benefits of smart parking system using IoT technology [10]

2.2. Improvement in Intelligent Parking Lighting Systems Using Network Technologies

IoT and other network technologies improve intelligent parking lighting systems by enabling centralized remote monitoring and control to effect real-time changes according to the environs' requirements, such as lowering the lighting brightness during off-peak hours or raising it upon detected motion. This degree of control minimizes energy use while guaranteeing ideal lighting.

LED lighting consumes a lot less energy than conventional lighting options. Compared to incandescence lighting, LED lighting continues up to 25 times extra duration with up to 75% less energy consumption. Modern illumination systems can also be set to dim or turn off lights when not in use, which results in significant energy savings. Having the option to plan lighting according to usage trends guarantees that energy is used efficiently.

Table 1. Energy consumption comparison

Lighting Type	Energy Consumption (Watts)	Lifespan (Hours)	Cost Savings (%)
Incandescence	60	1200	-
Fluorescence	15	8000	75
LED	10	25000	85

Table 1 compares three lighting types—Incandescence, Fluorescence, and LED—based on energy consumption, lifespan, and cost savings. Incandescent bulbs consume the most energy at 60 watts, with a short lifespan of 1,200 hours and no cost savings. Fluorescent lights use 15 watts, last 8,000 hours, and save 75% in costs compared to incandescent. LED lights are the most efficient, consuming only 10 watts, lasting 25,000 hours, and providing 85% cost savings. This highlights LEDs as the most energy-efficient and cost-effective lighting option.

2.3. Cost-Saving Analysis

There is a considerable potential cost-saving for modern parking lighting systems. By proactively reducing energy consumption, businesses can significantly lower their electricity bills. Additionally, the durability of LED lights means fewer replacements and lower maintenance costs. Over time, these savings add up, making the initial investment in a modern lighting system worthwhile. Tables 1 and 2 provide a comparison of energy consumption over 10 years for Incandescent, Fluorescent, and LED lighting.

Incandescent lights consume 720,000 watt-hours over 10 years (60W x 1200 hours/year x 10 years), while Fluorescent lights consume significantly less at 120,000 watt-hours (15W x 8000 hours/year x 10 years). LEDs are the most energy-efficient, consuming only 250,000 watt-hours over the same period (10W x 25,000 hours/year x 10 years). This comparison underscores the superior efficiency and energy savings of LED lighting. Figure 2 compares the total cost savings of LED, fluorescent, and incandescent lighting over a 10-year period. Incandescent lighting has the highest cost over time, increasing steadily due to higher energy consumption and replacement frequency. Fluorescent lighting shows moderate costs, reflecting better efficiency but still requiring periodic replacements. LED lighting demonstrates the lowest and most consistent costs, emphasizing its superior energy efficiency and longevity, which result in significant savings over time. This visualization highlights LEDs as the most cost-effective lighting solution.

Table 2. Total energy consumption over 10 years

Incandescence	Fluorescence	LED
60 W × 1200 hours/year× 10 years = 720000 Wh	15 W × 8000 hours/year ×10 years = 1200000 Wh	10 W × 25000 hours/year × 10 years = 2500000 Wh
720 kWh	1200 kWh	2500 kWh

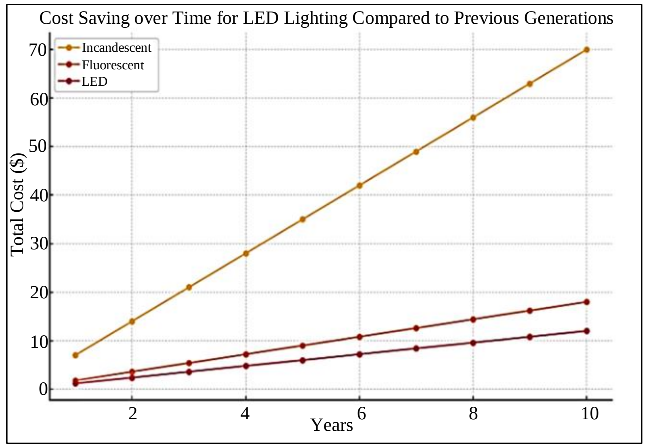

Fig. 2 Cost saving over time for LED lighting compared to previous generations

2.4. LED, Incandescent, and Fluorescent Lighting Differences

The energy efficiency, lifetime, and environmental effects of LED, incandescent, and fluorescent lighting vary greatly. Light Emitting Diode (LED) lights use about half the power of fluorescent lamps and a tenth of that of incandescent bulbs, making them extremely energy-efficient. Additionally, they have extended lifespans, produced little heat, and had a variety of uses, including in data transfer and healthcare [39]. Despite being cheap, incandescent lights are quite inefficient; they use a lot of energy and don't last as long as alternative solutions [40]. Although they are quite efficient, fluorescent lights have problems, including flickering and dangerous mercury levels, which makes disposal difficult. Because LEDs are more energy efficient and have a smaller environmental impact than fluorescent or incandescent lights, they are gradually replacing both [41]. When compared to incandescent and fluorescent lighting solutions, LEDs offer unparalleled efficiency and variety, making them the most practical and ecological option for modern lighting.

2.5. Parking IoT Lighting with Photocell

The consolidation of Internet of Things technology and photocell sensors in parking lighting systems signifies a noteworthy progression in energy automation and management. Photocell sensors are essential to intelligent lighting systems since they can automatically modify illumination based on ambient light conditions. This promotes environmental sustainability and saves a substantial amount of energy. The installation of photocell sensors in public street lighting (PJU) systems was proven by [16]. This led to autonomous lighting control, improving energy efficiency and decreasing the need for manual intervention.

LED parking lot illumination may be easily controlled with photocell lights that turn on during nighttime and off at dawn. Thus, parking lot light with dusk to dawn sensor capability is alternatively called parking IoT light with photocell. A photocell's primary feature is its integrated photoresistor, which gathers ambient light. The photocell's resistance will drop below a certain point when the brightness of the surrounding light falls below the threshold. Next, the parking lot light is switched on, and the driving transistor's relay is closed, effectively turning it on. Conversely, the illumination fixture turns off.

There are two methods for using photocells. Installing photocells on every parking lot light, similar to how cities install streetlights, is one method. A remotely installed photocell on the line that runs from the power source to the parking lot lights is an additional method. When installed in this manner, all of the lights can be switched on and off simultaneously. There are many benefits to integrating photocell sensors and IoT into parking lighting systems, such as increased safety, convenience of use, and energy savings. But there are drawbacks as well, like expensive startup expenses, difficult maintenance, and cybersecurity threats. According to [10], implementing IoT systems with photocell sensors may need a sizable upfront investment for hardware, software, and installation.

2.6. Parking IoT Lighting with Photocell and Timer

An important development in urban infrastructure is the incorporation of Internet of Things technology into parking lighting systems, which combines photocell sensors and timers. These systems attempt to solve the problems associated with manual lighting control while improving safety, energy economy, and user convenience. IoT lighting systems with photocell and timer technologies' role and effects in parking situations are examined in this review of the literature. By using timers to switch lights on and off at predetermined intervals, energy use can be optimized both during peak and off-peak hours, significantly improving energy efficiency [10]. The notable increase in energy efficiency is one of the main benefits of combining IoT with photocell sensors and timers. While timers provide scheduled lighting management to optimize energy use during peak and off-peak hours, photocell sensors automatically adjust lighting based on ambient light levels, ensuring that lights are only on when necessary.

Photocells and mechanical or electronic clocks can easily control LED parking lot lights. They work well together to control LED parking IoT lights. The timer indicated here often has an LED driver built-in. Although it is somewhat different from an electric clock, it is similar. For instance, the parking lot lights with the timer and photocell will operate as shown below. The parking lot lights will be at full brightness when the photocell turns them on at 16:00 and off at 7:00. It is always operating at 100% output between 16:00 and 22:00. However, after 4 hours, it will switch to 50% brightness starting at 22:00 and lasting for 8 hours till 6:00. At last, it will be completely brilliant for one hour from 6:00 to 7:00.

This lighting control strategy is effective and frequently conforms with more stringent lighting standards. Photocells activate the parking lot's LED lights as darkness falls. The photocell switches off the light when it's time to do so. The integrated clock will modify the lamps' output during the second half of the lighting operation, which occurs at midnight, to make sure that the illumination corresponds with the movement of people and cars. [17] demonstrated an optimized IoT-based intelligent parking and street lights system that minimizes electricity waste and eliminates the need for manual control by using exterior light sensors to automatically alter illumination settings.

Photocell sensors and timers also work together to automate lighting control, which lessens the need for human labour and frees up maintenance personnel to work on other projects [15]. By automating lighting control and offering real-time data on parking space availability, IoT lighting systems with photocells and timers improve operational convenience. As a result, the user experience is enhanced, and less manual intervention is required.

2.7. Parking IoT Lighting with Motion Sensor

One kind of occupancy sensor is the motion sensor, which detects when a person is nearby and turns on a light. The light will remain on for a predetermined amount of time. The time length will be changed back to the predetermined time if the motion sensor continues to work. After the person leaves, the light remains on for a predetermined period of time instead of turning off. The parking lot light will turn off if no one is there throughout the motion sensor test's holding period. More sophisticated motion sensors now reduce the lights to a proportion of the maximum amount of light when no one is around after a certain amount of time, rather than just turning them off entirely as technology develops. In this manner, places with less lighting are kept secure and well-lit. With preset times (holding and standby) and adjustable luminaire brightness percentages, this kind of occupancy sensor is programmable.

Motion sensor integration with Internet of Things technology in parking lighting systems is a major development in urban infrastructure. While addressing the shortcomings of conventional lighting control, these solutions seek to improve user experience, safety, energy efficiency, and operational convenience. The role and effects of IoT lighting systems with motion sensors in parking areas are examined in this review of the literature. The notable increase in energy efficiency is one of the main advantages of combining IoT with motion sensors in parking lighting systems. By ensuring that lights only turn on when movement is sensed, motion sensors help to cut down on wasteful energy use and operating expenses. To detect motion and effectively control lights, [18] presented an intelligent parking system that uses Passive Infrared (PIR) sensors, among other sensors. By only turning on the lights when motion is detected, this method dramatically lowers energy consumption. For optimized lighting control, [19] showed how PIR sensors may be used to control street lighting in a smart way that changes illumination in response to the presence of cars and pedestrians. The energy consumption of this system was reduced by 64%. By automating lighting control and giving real-time data on parking space availability, IoT lighting systems with motion sensors improve operational ease. As a result, the user experience is enhanced, and less manual intervention is required.

For real-time monitoring and control, [15] used IoT technology to install a motion sensor-based smart parking system that tracks parking space occupancy in real time. As a result, less manual management is required, and operational effectiveness is increased. By providing consumers with up-to-date information about parking availability, [20] explored the advantages of combining NB-IoT technology with motion sensors for real-time monitoring and management of parking spaces. This integration enhances user satisfaction.

Enhanced safety in parking lots is partly attributed to better management of lighting. By ensuring that parking spaces are well-lit when needed, IoT lighting systems with motion sensors lower the chance of accidents and increase overall security. [21] proposed a smart lighting system that uses heat sensors to identify human presence in order to increase parking lot security. This system, which can be combined with motion sensors, ensures energy efficiency and safety by only turning on the lights when motion is sensed. [22] showed how motion-sensor-equipped smart parking systems may optimize energy use and cut down on idle time spent looking for parking spaces, both of which reduce total carbon emissions.

2.8. Parking IoT Lighting with Wireless Control

An important advantage of combining IoT with wireless control for parking lighting systems is a significant increase in energy efficiency. Real-time monitoring and lighting management based on multiple factors, including occupancy and ambient light levels, are made possible by wireless control. The deployment of a wireless control system manages fundamental tasks like dimming and turning lights on and off. The control device may simultaneously gather information and notify administrators of any problems. For instance, administrators won't need to send staff members to search the building for a broken light because they will know right away if one fails. In order to satisfy the lighting requirements of various situations, we can simultaneously configure various lighting schemes based on the lighting scene. Additional hardware is needed for wireless control in order to send and receive signals. Because the device is connected to the driver, the driver needs to be compliant in order to communicate data that can take dimming signals such as DALI or 0-10v. Once the parking lot lights are set, they all communicate with a central control unit.

For optimal lighting regulation, [17] proposed an IoT-based application that uses wireless control to automatically alter illumination levels in parking systems and smart street lights. This lessens the need for human control and minimizes electricity loss. With wireless control, the system improves operational convenience by automating lighting control and offering real-time parking space availability data.

Thus, there is an improved user experience with less manual intervention. Wireless sensors are also being implemented by [15] in a smart parking system to track parking space occupancy in real time, leading to less manual management and increased operational effectiveness. This can also be seen in the NB-IoT-based system built by [20], where real-time parking availability updates enabled by real-time monitoring and parking space administration capabilities improve customer satisfaction and enhance parking lot safety. Wirelessly controlled parking systems are well-lit with the right amount of illumination, lowering the possibility of accidents and enhancing visibility and security [12].

Similar work by [23] focuses on ZigBee wireless smart lighting system that allows for real-time control and monitoring, guaranteeing energy efficiency while upholding safety, thus enhancing security. The combination of wireless control and Internet of Things lighting systems lowers carbon emissions and energy consumption, which promotes environmental sustainability. This is proven by [22], whose energy-efficient smart parking system with wireless control may minimize idle times spent looking for parking spaces and help optimize energy use, both of which reduce total carbon emissions.

2.9. Comparative Analysis of Current Intelligent Connected Streetlights Systems from a Cybersecurity Perspective

A cybersecurity comparison of the current smart connected streetlight systems, highlighting their advantages and disadvantages. Before beginning this research, it is crucial to review earlier studies in order to gain a better understanding of what has been investigated, what approaches and strategies have been employed, and any gaps or restrictions that may exist.

This analysis makes it possible to find important insights, gain knowledge from past research achievements and difficulties, and ascertain how the suggested study might provide something fresh or enhanced (Table 3). This comparative analysis highlights the strengths and weaknesses of various intelligent illuminated parking systems from a cybersecurity perspective, providing a comprehensive overview for understanding their effectiveness and potential vulnerabilities. Key gaps from the comparative analysis above can be summarized as limitations on data transmission, threat detection capability, network security, vulnerabilities and limited range.

Table 3. Current research work comparative analysis

No	System	Strengths	Weaknesses	Citation
1	IoT-Based Low-Delay Smart Streetlight Monitoring System	Instantaneous monitoring with minimal delay, Data filtering reduces storage consumption by 88.57%	Limited focus on cybersecurity measures for data protection	[24]
2	Intelligent Dimming Algorithm Based on Fuzzy Neural Network	Enhanced energy efficiency, Adaptability to human eye habits	Basic reporting system without advanced security features	[25]
3	Secure and Low Energy Consumption System using LoRa Network	Secure and long-range communication, Adaptive lighting based on pedestrian movement	Limited focus on real-time threat detection	[26]
4	Smart Streetlight with Intelligent Sound Detection System	Emergency vehicle detection, High accuracy (96%) using CNN model	Potential privacy concerns with sound data	[27]
5	Robust Cellular Connectivity-Based Smart LED Street Lighting System	Reliable P2P 4G LTE connectivity, Supports mission-critical applications	High dependency on cellular network stability	[28]
6	IoT-Based Energy Efficient Smart Street Lighting with Air Quality Monitoring	Comprehensive monitoring, including air quality, Significant energy savings (up to 84%)	Potential vulnerabilities in IoT communication	[29]
7	Self-Powered Intelligent Street Light Management System	Utilizes solar power, Long operational duration (8+ days on solar charge)	Limited cybersecurity measures in data communication	[30]
8	A Smart Parking Solution by Integrating NB-IoT Radio Communication Technology into the Core IoT Platform	Utilizes NB-IoT technology for efficient data transmission and low power consumption. Provides geolocation and navigation services.	Security concerns related to NB-IoT implementation. Potential vulnerability to cyber-attacks.	[20]
9	IoT System for Car Parking, Street Lights, and Automatic Irrigation with Real-Time Updates on Mobile App	Combines multiple smart systems (parking, street lighting, irrigation) for energy efficiency. Real-time updates enhance user experience.	Complex integration of multiple systems can increase maintenance requirements. Security risks with online payments.	[17]
10	Design of an IoT based Smart Parking Lock	Incorporates LORA wireless network for real-time monitoring and remote control. Improves utilization of parking space.	LORA network may face interference issues. Security measures need to be robust to prevent unauthorized access.	[31]
11	Home Intelligent Lighting Control System based on Wireless Sensor	Uses a ZigBee wireless network for low power consumption and efficient control. Ensures good communication range and user satisfaction.	Limited to indoor applications. Additional security measures may be required for wireless communication.	[32]
12	Internet-of-Things for Smart Street Lighting System using ESP8266 on Mesh Network	ESP8266 module provides efficient wireless control and mesh network capabilities. Easy access via web server.	ESP8266 may have a limited range in large areas. Security protocols need to be robust to prevent breaches.	[33]
13	Smart Car Parking System using Wireless Sensor Networks	Utilizes low-cost sensor nodes for efficient slot allocation and real-time status updates. Enhances user convenience and safety.	Reliance on wireless sensor networks can lead to interference issues. The security of data transmission needs enhancement.	[34]

2.10. Real-World Case Study

A relevant real-world case study of implementing an IoT-based system while taking cybersecurity into consideration is the 2023 study on an IoT-based smart parking system by Sherin et al. This system uses NodeMCU microcontrollers and infrared sensors to monitor and control parking spaces in real time. Users may find available parking spots instantaneously thanks to a mobile application that receives data from each parking spot via the Internet of Things devices [35]. Through controlled data collection and real-time updates, this instance demonstrates how the system may efficiently solve parking congestion concerns while integrating security considerations, improving user confidence and operational efficiency. This example shows how to secure IoT data flows and safeguard user interactions in high-demand urban parking settings by implementing effective cybersecurity techniques [35].

2.11. Regulatory Framework Compliance

The General Data Protection Regulation (GDPR), the National Institute of Standards and Technology (NIST) Cybersecurity Framework, and the ISO/IEC 27001 Standard for Information Security Management are among the cybersecurity laws that smart cities' IIPS must abide by.

Strong data protection measures, such as encryption, anonymization, and user consent, are required under GDPR [36]. The NIST framework provides guidelines for identifying, protecting, detecting, and responding to cybersecurity threats [37], while ISO/IEC 27001 emphasizes information security management systems [38]. Best practices for compliance include implementing secure IoT frameworks, conducting regular security audits, and minimizing data collection. These measures strengthen IIPS's resilience against cyber threats.

2.12. Cybersecurity Incident Response and Recovery Framework

IIPS in smart cities should implement a comprehensive cybersecurity incident response and recovery framework. This includes real-time monitoring, alerts, incident containment, investigation of attack vectors and entry points, secure communication protocols, and system restoration.

Regular backups and verified recovery points are crucial for quick restoration. Post-incident analysis and reporting are vital for future planning and compliance. Continuous improvement is achieved by refining response strategies, updating detection algorithms, and patching vulnerabilities. This approach can create a safer, more responsive parking infrastructure in smart cities.

3. Proposed Materials and Methods

After a thorough review of existing work, a step-by-step methodology is being proposed for conducting future research for a cybersecure intelligent parking lighting system.

- Conduct a risk assessment of current IoT and wireless lighting control systems.
- Identify potential vulnerabilities and attack vectors.
- Develop advanced security protocols and encryption methods tailored to lighting control systems.
- Implement and integrate security measures in a test environment.
- Perform penetration testing to evaluate the robustness of the security protocols.
- Refine and finalize the security measures based on testing results.
- Deploy updated systems and monitor for security breaches.
- Publish a comprehensive security framework for intelligent lighting systems.

Implementing these step-by-step methodologies can lead to significant advancements in cost-saving efforts for intelligent lighting control in parking systems, enhancing efficiency, security, user satisfaction and particularly cybersecurity concerns while promoting sustainable practices.

4. Conclusion

A breakthrough development in urban infrastructure is the incorporation of smart streetlight technology with increased safety into intelligent parking systems to produce illumination that is safer, more efficient and more user-friendly. The integration of parking management and lighting via cyber-physical systems provides cutting-edge challenges, including cybersecurity, financial ramifications, operational considerations, and safety concerns.

As these systems are progressively becoming more intelligent and connected, they also become more vulnerable and exposed to cyberattacks from threat actors. The perils of cyberattacks and data breaches offset the advantages of using technologies to better monitor and manage metropolitan illumination.

These can interfere with traffic flow and personal safety by upsetting not just specific units but also the larger network. It is imperative to put modern cybersecurity measures into practice, such as optimizing intrusion detection systems through the use of hybrid feature reduction approaches. These techniques reduce the danger of cyberattacks while managing the enormous volumes of data that these systems process. Cost considerations significantly influence the acceptance and sustainability of smart streetlight systems within intelligent parking infrastructures.

Considering the sophisticated technologies involved, initial setup expenses may be substantial. The total cost of ownership is also increased by recurring costs for software upgrades, cybersecurity safeguards, and maintenance. These upfront costs, however, may be compensated for overtime by long-term savings from increased energy efficiency and fewer personnel needed for upkeep and monitoring.

In conclusion, while the integration of smart streetlights into intelligent parking lighting systems presents several advantages in terms of operational efficiency and safety, it also necessitates a robust framework for managing cybersecurity risks and substantial initial and ongoing investment. The successful deployment of these systems hinges on a balanced approach that addresses these challenges while leveraging the strengths of modern technology to enhance urban living spaces. As these technologies evolve, continuous assessment and adaptation of cybersecurity strategies and system designs will be essential to mitigate risks and capitalize on new opportunities for improving city infrastructure.

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