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Research Article

Adaptability Attribute for Smart City: Advanced Adaptive Street Lighting Systems

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Abstract

"Smart City Advanced Adaptive Street Lighting Systems" aims to build all software /hardware components of a friendly Smart lighting architecture for urban areas that allows Municipalities seem to be responsible for the management and monitoring of public street lighting. To save energy, The system was established with the goal of automatically modify the brightness of street lamps based on the presence of vehicles (buses/trucks, cars, motorbikes, and bikes) and/or pedestrians in specified locations or sections of roads/streets.

The research's main contribution is to develop a low-cost smart lighting system while also creating an IoT Implementation framework in which each lighting pole is a network component to increase the system's dimensionality. In a broader sense, the proposed smart infrastructure can be viewed as the cornerstone of a bigger technology architecture aiming at delivering value-added services for sustainable cities. The smart architecture is made up of a number of subsystems (local controllers, motion sensors, video cameras, and weather sensors) and electronic equipment, each of which is responsible for a specific function: video processing for vehicle motion detection and classification, remote street segment lamp management, single street lamp brightness control, wireless and wired data exchange, power consumption analysis, and traffic evaluation.

Key Words: Smart lighting; Lighting control; Internet of Things (IoT); Video processing; ZigBee communication.

Broad Area: Urban Planning; **Sub-Area:** Street Lighting Systems.

1. Introduction

According to various available literature [1,2], reports suggest that currently 80% of the electrical power produced is used to meet urban demands, Due to their constant operation at night, street lamps account for around 60% of the total. As a result, in the context of smart cities, energy saving is an essential aspect; This article focuses on the energy savings that may be gained by replacing traditional incandescent and fluorescent bulbs with smart lighting systems. In this context, smart lighting control systems play a critical role in minimizing energy consumption and increasing efficiency. Indeed, advances in wired and wireless networks, control technologies, and embedded systems have enabled the development of modern lighting systems that are smart and can successfully handle the issue of energy conservation.

The Internet-of-Things (IoT) paradigm has grown into a new network structure in which sensors, software, and other technologies are embedded in a wide range of devices and objects to connect data with other devices and systems. That can be exchanged. Using internet mode of Wi-Fi, GSM (Global System for Mobile Communications), Zigbee, etc. [3]. The communication technology utilized in the IoT architectural design is critical and closely tied to the application in question. For example, in wearable IoT systems, where a body sensor node is frequently provided with a limited power source, battery capacity, as well as processing and communication fee-cycling, have a significant impact on the sensor node's life-cycle. As a result, to save energy, many researchers have concentrated on the use of low-power communication systems. [4]. However, to achieve realistic and cost-effective integration of various applications, a balance between network device size, cost and connectivity range is required. Short-range wireless technologies, like Wi-Fi network devices, are energy inefficient, and long-range wireless technologies, like GSM, are prohibitively expensive and inappropriate for IoT applications. Due to its low power consumption and long-distance capabilities, low-power wide area networks (LP-WANs) have gotten a lot of attention in the IoT sector in recent years. Long-range (LoRa) and narrow-band (NB) devices [5-7] are the foundation of IoT applications (e.g., agriculture, medical, industry, etc.). Smart cities are one of the best application settings for WSNs, as they allow the rapid development of smart micro grids, smart lighting, and video monitoring, among other things [8]. Because of their simplicity and technical standards that allow power efficient wireless communication over large distances, As wireless middleware, the LoRa and ZigBee protocols have played an important role. Smart lighting systems have attracted wide attention in recent years, and various research programmers have been conducted to demonstrate the potential and good impact of smart technologies aimed at increasing street lamp control efficiency. These technologies include sensors, control algorithms, and wireless communications into street lights to provide lighting systems that can run autonomously in an IoT context [9]. A smart street is one that is made up of multi-purpose smart lighting poles that are outfitted with different technologies that allow them to connect with one another and share data with distant management systems. A smart street lighting system's main goals include a more efficient and adaptable use of the urban environment, particularly in terms of energy savings and cost reduction.

In the literature, many researches and initiatives available on smart lighting infrastructure that cover various components of smart street lighting systems [10]. Among these are the technical elements of constructing smart infrastructure for public lighting networks using IEEE 802.15.4 short-range communication technology. There's also a case study of a smart-building application that uses the LoRa low-rate, long-range communication protocol [11] The benefits of using LED DC lamps instead of traditional street lamps are highlighted. LED technology, on the other hand, has a longer lifespan, fewer maintenance costs, and higher efficiency, and the lamps are mercury-free and easily disposable. An overview of smart lighting systems for outdoor [12] and interior applications [13] is offered, along with an examination of the impact of LED street lighting and municipal street lighting policies to promote and ensure LED technology adoption. Multiple DC Street lights powered by photovoltaic (PV) panels are displayed in a smart street-lighting system prototype [14]. A motion sensor circuit is included in the prototype, as well as a battery to store the extra energy generated by the solar panel. As a result, an advanced and effective street lighting system has evolved.

Additional energy savings can be realized if the LED lamp intensity is controlled by logic that can calculate the appropriate brightness set-point for specific locations or sections of road based on current traffic and weather data. Can produce "on-demand" lighting efficiently. A case study of an adaptive street lighting system based on a model that might theoretically save up to 88 percent of energy when compared to traditional sodium lamps [15].

The major goal is to maintain the lamp brightness on a certain section of the road as low as possible while still complying with national/regional laws and/or safety limitations for both automotive and pedestrian traffic. Several studies have addressed these issues, with various reduction solutions ranging from simple to overly complex. These strategies can be complex, modifying the minimum permitted brightness at various levels depending on whether one or several vehicles are present in the road section of interest, in addition to the presence of cyclists or motorcyclists riding alongside automobiles or trucks [16]. Civil protection, as well as pedestrian and driver safety, are additional factors to consider when reducing lamp brightness. The bulb must be bright enough to meet the minimum permissible level of the safety standard. As a result, smart lighting and sensors placed in street lights (for example, by documenting anomalous conduct and informing law enforcement, a camera equipped with a video analysis electronic gadget can assist prevent local disruption. Is. Pedestrians also need adequate illumination when crossing sidewalks and streets to avoid obstacles and uneven surfaces. Similarly, for enjoyable and safe driving, drivers must see obstacles within their safety braking distance, which is determined by vehicle speed and current weather conditions. A ZigBee-based specialised wireless network [17, 18] has been proposed as a way of implementing these assumptions (Wi-Fi, based on IEEE 802.11, is a very efficient wireless technology; however, it is optimised for big data transfers using high-speed throughput rather than low power consumption). As a result, Wi-Fi is incompatible with low-power (coin cell) applications. ZigBee technology, on the other hand, is designed to transmit little amounts of data over short distances while consuming very little power. Unlike Wi-Fi, it is a mesh networking standard, which means that every node in the network is connected to each other. When it comes to power usage, ZigBee-based networks use around a quarter of the power that Wi-Fi networks do. ZigBee was created to address the demand for a distributed smart street lighting system, which is a large number of Capable of controlling and monitoring multiple road areas in the Lamp. Similar options have been considered [19, 20], such as using an LED system with sensor and control technology to detect motion and control the lamps brightness in cars.

This paper presents the findings of a recent project (SCALS-Smart Cities Adaptive Lighting System) devoted to the design and testing of smart lighting controls. The system's basis is made up of local sensors, local controllers, video-processing algorithms for motion detection, and a remote Web application. The design of a low-cost lighting system that can change street light intensity based on the presence of traffic on the monitored route is the work's key contribution. At the same time, the project aims to build an IoT infrastructure in which each light pole is connected to a network whose amplitude can be increased over time. In general, the proposed smart infrastructure can be thought of as the foundation of a larger technological architecture aimed at achieving sustainable cities, such as energy management, environmental monitoring, traffic monitoring and management, decision process assistance, and so on for providing services. A lighting pole serves a significant purpose in this context and can be considered a crucial enabler for value-added services. The basic idea is to equip street lighting with electrical components that can vary the intensity of the light in response to the presence of vehicles and pedestrians in the identified area. Furthermore, the street lamp is designed as a wireless sensor network (WSN) that may communicate data with each other and with the network coordinator via a ZigBee connection. Experiments have shown that the architecture described can provide the following advantages: Experiments have revealed that the proposed architecture can offer the following advantages:

i. Savings on energy.
ii. For the community, there will be a reduction in taxes.
iii. Improving one's overall health and happiness.

Another variable that are related is the adoption of smart lighting systems capable of automatically adjusting light intensity and features (i.e., brightness, flux, etc.) in real time as a function of "road actual needs", is recognized as an essential device for decreasing waste, light pollution, and greenhouse gas emissions in general [21–23]. In this sense, this research examines all areas of smart lighting design implementation and adds significant value to the research's original conclusions, which were published in [24]. The infrastructure functioning, network architecture, remote management web apps, and video processing process design considerations are all discussed here. The network architecture, in particular, uses the ZigBee communication protocol, which overcomes the limitations imposed by the early experiments' use of power line communication (PLC) protocols. Indeed, unlike power line communication technology, which is dependent on power line status, regardless of the transmission medium condition, the ZigBee protocol allows for the construction of long-distance multi-point secure network connections.

In addition, the video processing algorithms for traffic identification and classification used here are thoroughly discussed. The details of the data transmitted along with the security and integrity of the remote web application are also taken care of. In this case, the functions of Hyper Text Transfer Protocol Secure (HTTPS) are utilized in addition to user credentials-based access control. The remainder of the paper is laid out as follows: The suggested smart lighting system's major features are presented in Section 2, Section 3, describes the network infrastructure, while section 4 depicts the single lamp lighting controller as well as its connections to other electronic devices. The remote web application is briefly discussed in Section 5, while the video processing methods for vehicle motion detection are described in Section 6, Section 7, summarizes the findings from two pilot sites and draws some conclusions.

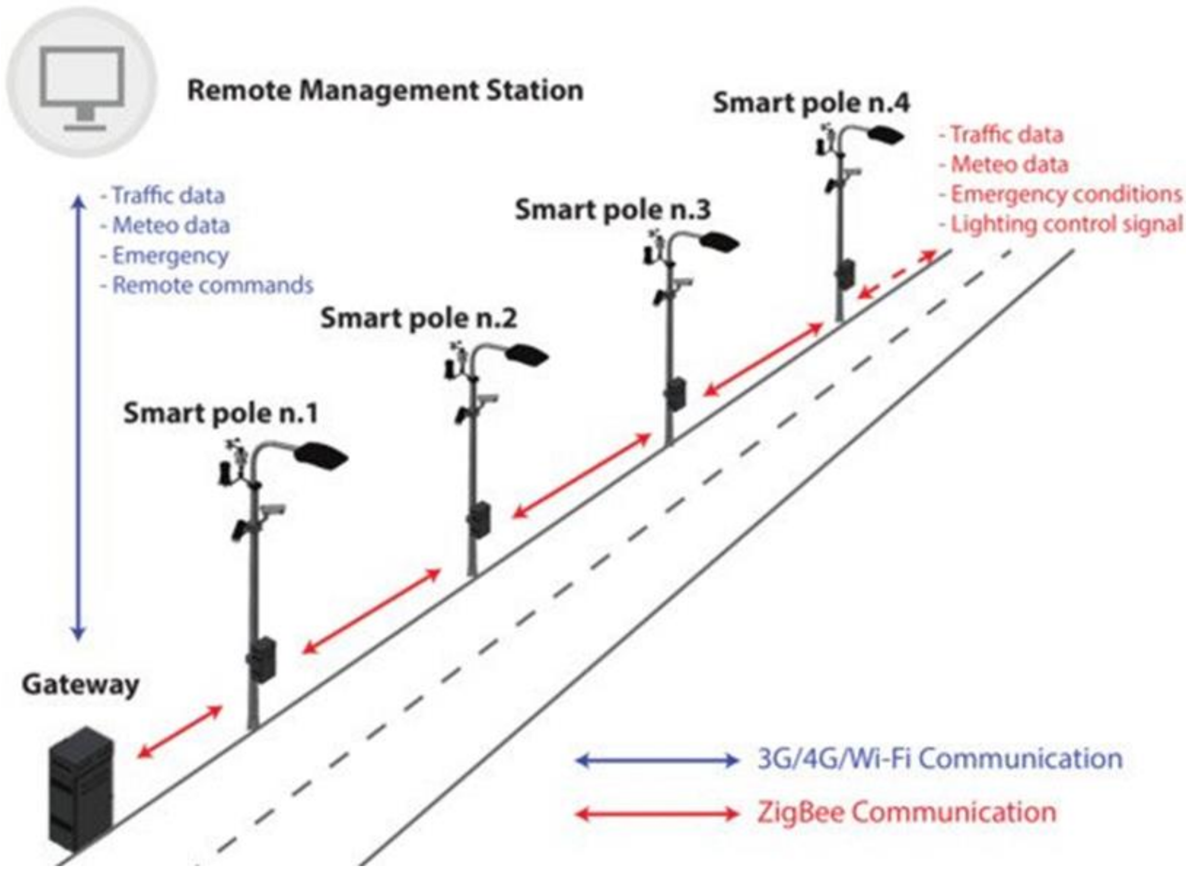

Fig. 1 Smart Street Lighting Concept.

2. Architecture For Adaptive Smart Street Lighting

The proposed system would establish an intelligent public street lighting infrastructure that will be able to:

i. The street lighting system may be controlled remotely.

ii. Intelligent street lighting bulb control that adjusts the light intensity at each lamp/group of lamps according on the time of day, the presence of vehicles and/or pedestrians, and/or the weather.

The infrastructure model depicted in Figure 1 provides the services and amenities stated below:

i. Control of a single or a group of street lamps.

ii. The high-level Zigbee communication protocol is used to create a network of local communication devices based on the IEEE 802.15.4 specifications.

iii. Monitoring of traffic and emergency situations (e.g., traffic jams and/or accidents).

iv. The evaluation of consumption.

v. Remote control and access to all functionalities for configuring the daily lighting schedules and monitoring alarms through web application.

vi. Based on a 3G/4G/Wi-Fi connection, remote communication between smart phones and the web application is possible.

The existence of so-called smart poles is highlighted by smart infrastructure. A smart pole is a type of street light lamp that includes a video camera, a computer for video processing, and a local control device, as well as weather sensors, communications equipment, and high-efficiency LED bulbs. Data (control commands and information requests) can be exchanged between smart poles and, through a gateway, with a remote administration web service. The working modalities of Smart-Poll can be stated as follows:

• Day Time: All traffic data is retrieved in real time and communicated with the web application via video processing, and only the traffic monitoring functions are turned on.

• Night Time: All smart functions are enabled, and the dimming of single/group LED lamps is controlled in response to the presence of cars or persons in the monitored area (street segment, roundabout, square, etc...). If there are no cars or people in the monitored area, the LED light intensity is decreased to the bare minimum allowed by street lighting standards. If a presence is identified, the LED light intensity is adjusted to the most appropriate level for the monitored region, based on the number and kind of vehicles observed as well as the current weather conditions. As a result, the LED light intensity is based on the presence of vehicles or pedestrians, resulting in significant energy savings when there is no traffic for long durations at night.

• Failsafe default critical situation: If the smart lighting system fails due to a loss of connectivity or component damage, to guarantee that overall safety is not threatened, a default condition is used. All smart features are deactivated in this state, and the system functions as a typical disconnected lighting system.

As a result, it is clear that infrastructure smartness is produced through the following basic steps:

i. Detection of the presence of vehicles and pedestrians in the surveillance area.

ii. Variation in lamp brightness as a function of the number of hours in the day, the presence of people, and the weather (ambient brightness, rain, fog, etc.).

iii. In all working settings, offer an acceptable degree of brightness, as specified by national/regional standard guidelines.

iv. Remote management and control station for information exchange and alerts.

It's worth mentioning that motion sensors aren't necessary at all poles in some circumstances. Smart lighting systems can be built on a straight road with no side access, for example, such that just two poles (at the start and end of the road) contain motion detecting devices. The following are the two types of smart poles:

• Motion detector, weather station, and dimming devices are all included in the smart master pole.

• Only smart slave poles with dimming devices are available.

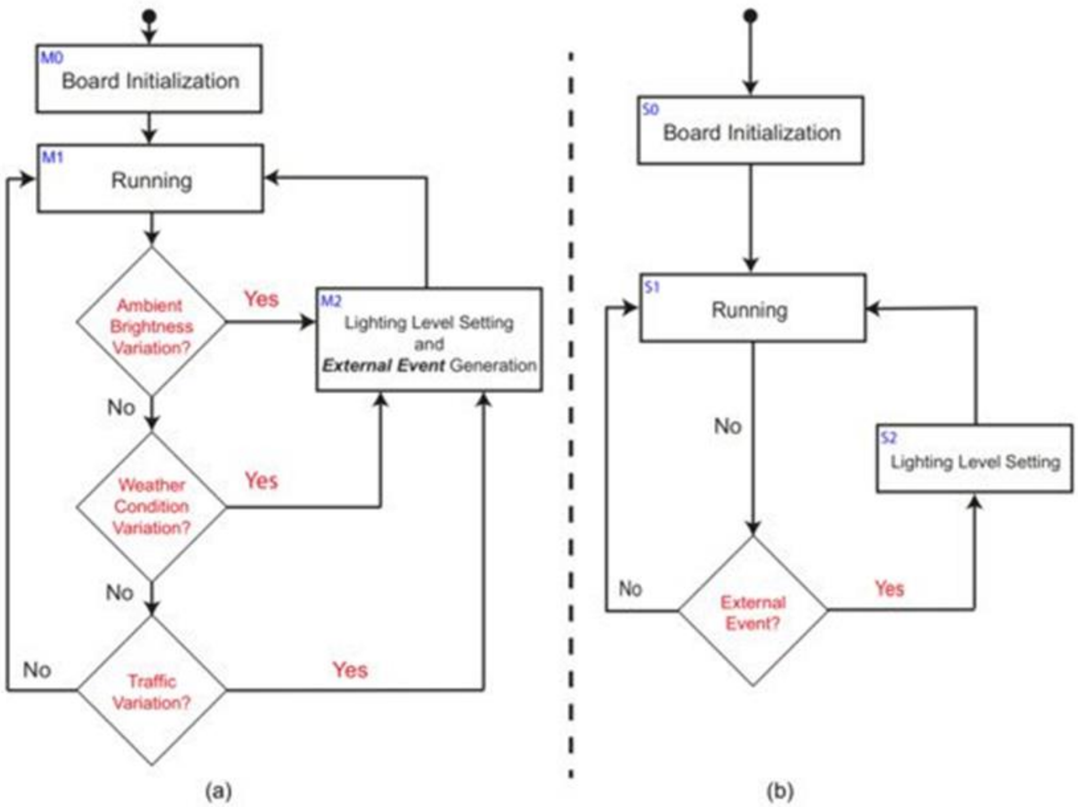

Fig. 2 Flow charts: (a) master pole (b) slave pole.

On the other hand, even though the smart lighting system is capable of verifying in real-time both vehicular and pedestrian traffic and then providing in all conditions, it may not be necessary to equip the lighting pole with a motion detection device to provide the appropriate lighting level in some specific scenarios (e.g., squares, crossroads, etc.). In this instance, the smart system can only be equipped with a dimming device and set to work remotely, ensuring that the needed light intensity is delivered to each lamp/group of bulbs based on daily time.

Figure 2 depicts a flow chart depicting the master (A) and slave (B) poles' operating processes. The master pole maintains the current lighting setting after the startup phase until a change in ambient brightness, weather, or traffic circumstances is recognized, as indicated in the operating procedure. In this situation, the master pole creates an external event that is communicated with the slave poles via a local communication channel and sets a new lighting level depending on the new conditions. In contrast, the slave pole maintains the current lighting setting until an external event happens. The light level is altered in this situation as a result of the master pole instruction.

3. Infrastructure of the Network

Local and distant communication channels are used in the system design (Figure 3). Smart poles can share data over a local communication channel. Remote communication channels, on the other hand, allow data to be sent between smart poles and remote servers, allowing centralized data consultation (For example, energy use, traffic conditions on various roads, weather conditions, and so on.).

The IEEE ZigBee wireless protocol, an open and worldwide standard for wireless device communication, is used to communicate between smart poles. The ease with which Zigbee devices may be connected into IoT applications via a Zigbee gateway is one of the most appealing advantages of adopting them. Another essential aspect of adopting such protocols is that the MAC layer, which offers basic security services and device interoperability, is provided by the IEEE standard 802.15.4 ZigBee protocol stack. Basic security services allow you to create an access control list and use symmetric encryption to safeguard data transport [25]. Devices in the ZigBee network can be set up as follows:

i. Coordinator / gateway: The device is in charge of creating the network and routing traffic to other devices in this setup. Only one coordinator is required for each network.

ii. Router: This device is capable of routing traffic to and from other devices.

iii. End device: This device is not capable of routing traffic to other devices. As demonstrated in Figure 3, the system architecture provides for:

a. It's possible to set up several local networks.

b. A coordinator (gateway) device manages each local network.

c. A ZigBee radio module is installed in each local network's electrical equipment (e.g., video processing boards, lighting control boards, and all other system components).

d. Radio nodes serve as routers and are placed in a mesh topology, with each node connecting to the signal and passing it on to the next device.

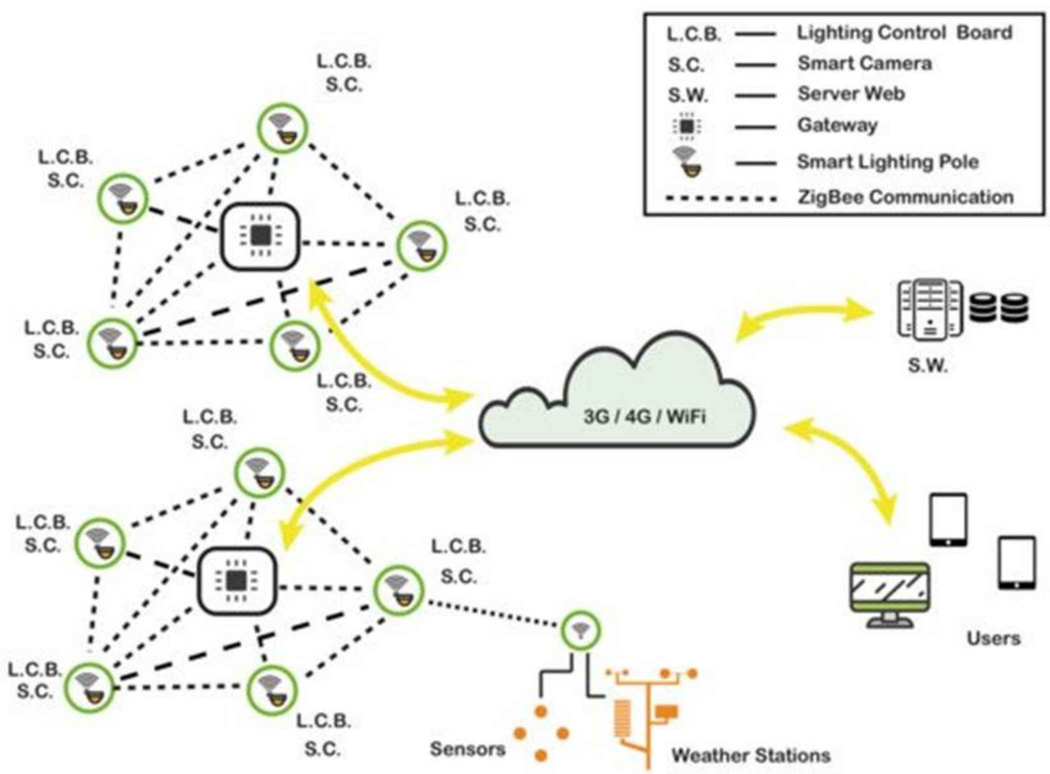

Fig. 3 System architecture

In theory. the Zigbee protocol (https://zigbeealliance.org/solution/zigbee/) can manage up to 65,000 devices in a network. However, in practice, due to the presence of environmental disturbance components (e.g., obstructions such as buildings and trees or other transmission equipment), the size of the network must be significantly reduced to maintain signal strength and data transmission efficiency. As a result, network size is a variable that varies depending on the application and the surrounding environment. As a result, specific software (for example, Digi International Inc.'s XCTU Configuration Platform for XBee Solutions, https://www.digi.com/products/embedded-systems/digi-xbee/digi-xbee-tools/xctu) It allows you to evaluate the quality of connections between connected devices, as well as device addresses and other network information, and is recommended for network sizing.

The network utilizes multiple routing strategies for the exchange of messages (commands or requests for information) between intelligent poles. The gateway can deliver information requests / directives to a single smart pole (unicast routing), a group of smart poles (multicast routing), or the complete smart pole network (broadcast routing), as shown in Figure 4. (Broadcast routing).

A 3G / 4G / WiFi communication network is used to communicate between a network coordinator (gateway) and a server or users' smartphones. Furthermore, the connection between network nodes, gateways and smartphones is based on a custom communication protocol, the specification of which can be found in [24].

4. Electrical Control System

The electrical control system currently has daily time, traffic power and lamp brightness rate modified on classification to save on power consumption and ensure proper light level in all traffic and atmospheric conditions. The control system is primarily based on two electrical devices (a smart camera and a lighting control board), as well as a network connection. Figure 5 depicts the basic notion of the smart camera's interaction with the lighting control board as well as the light control technology.

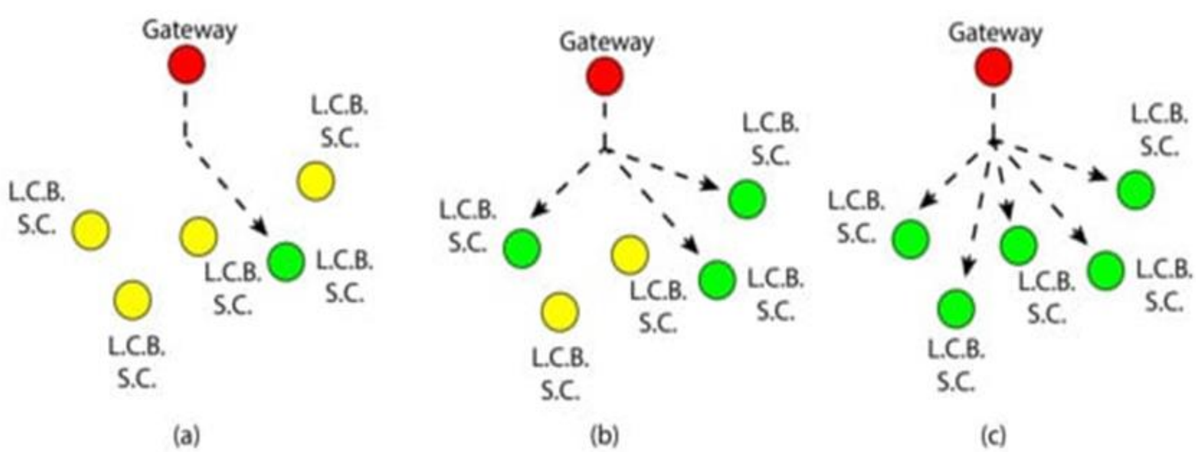

Fig. 4 Message Routing: (a) Unicast Routing (b) Multicast Routing and (c) Broadcast Routing

Both devices are built, manufactured and optimized for our smart lighting applications, as well as equipped with ZigBee devices for data interchange (information requests/commands) with other intelligent cameras and controllers. The smart camera and the lighting control boards communicate using the previously established communication protocol. Video streaming may be processed by the Smart Camera. To detect moving objects in the observed region, it uses the video processing technique described in Section 6. As a result, when cars or walker are spotted, the master pole generates a 'motion detected' event, which is transmitted to all poles equipped with the electrical control board via the local communication channel (Zigbee based communication).

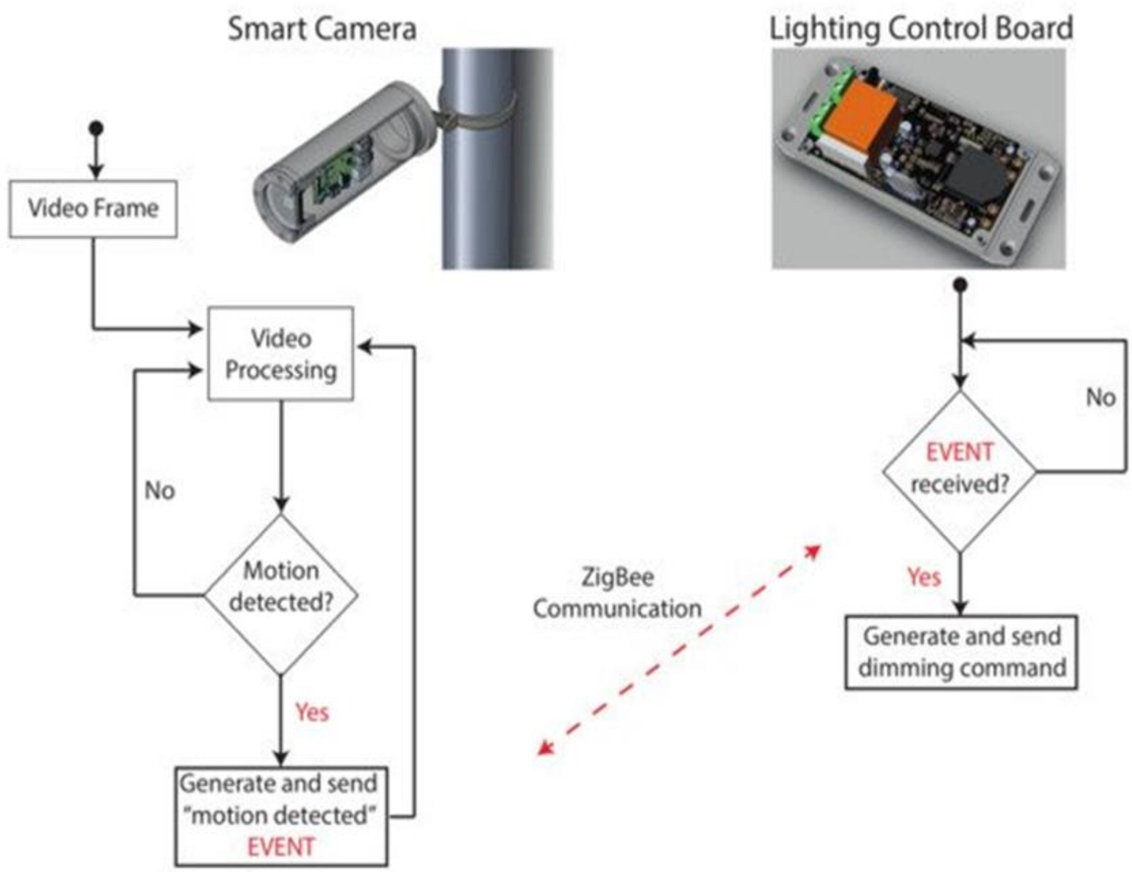

Fig. 5 Electrical control procedure and boards interaction

The control board, on the other hand, is compliant with IEC standards (Standard 60929 Annex E) and allows the intensity level to be controlled using a 0–10 V analogue electrical control protocol [26]. In essence, a control instruction gives a voltage ranging from 0 to 10 DC volts to produce various levels of light intensity. Changes in DC voltage are proportional to changes in light output. When the control voltage is 10 volts, the ballast (or driver) must supply full light output according to the specification. The ballast (driver) generates its minimum light intensity at a control voltage of 1 volt.

Minimum voltage is defined as less than 1 volt.

When the Electric Control Board gets a 'Motion Detection' event, it issues a control command to all poles in the controlled street segment. If no other "motion detection" events occur, the control board sets the LED bulb to the minimum brightness values defined by street lighting rules after a given number of seconds.

The lighting control board supports a variety of control modes in addition to the mentioned control approach. It can, for example, follow daily lighting profiles (the lamp's light intensity follows a temporal profile) or light intensity levels programmed based on events. In addition, the control architecture allows for the split of poles into groups that may work with a variety of control modalities.

The electric control board is also in the process of being replaced:

i. Using data from medium brightness sensors and weather stations to change light levels in response to environmental conditions;

ii. Identifying unusual activity in the web of poles and street lamp problems When such unusual situations transpire, the board sends an event to a remote web service, which activates the failsafe default emergency operation mode.

5. Mobile Application and Network Application for Remote Direction and Control

The amount of friendliness of interchange between the system organizer and the infrastructure is another essential factor in smart lighting systems. As a result, our system incorporates a web application and a mobile application that provide the following functions to enable remote direction and control: i. Account executive enables the management to define sanction and entry levels for the online application and mobile application (Super-administrator, system manager, system operator, user, and so on are only a few examples).

ii. Select a control modality.

iii. Monitoring and control of the lighting system.

iv. Detection of abnormal circumstances and creation of alarms.

v. Monitoring of traffic and metro information.

vi. Assessment of energy consumption.

A remote web application can be used to access the settings of the smart electric system. Each individual street lamp or a group of them, for example, have a different illumination profile. To avoid abrupt brightness fluctuations, a light level variation range can also be specified. The user can also examine data on current/average consumption, energy savings, traffic intensity and classification, weather conditions, and other alarms.

In addition to standard access control based on user credentials checking, the remote web application uses the Hypertext Transfer Protocol Secure (HTTPS) to increase the privacy and integrity of the transferred data while in transit. HTTPS is a variant of HTTP that uses a secure socket layer (SSL) or transport layer security (TLS) protocol connection to add a layer of protection to data in transit. The HTTPS properties of the web application enable for encrypted communication and a secure connection between remote users and the web server.

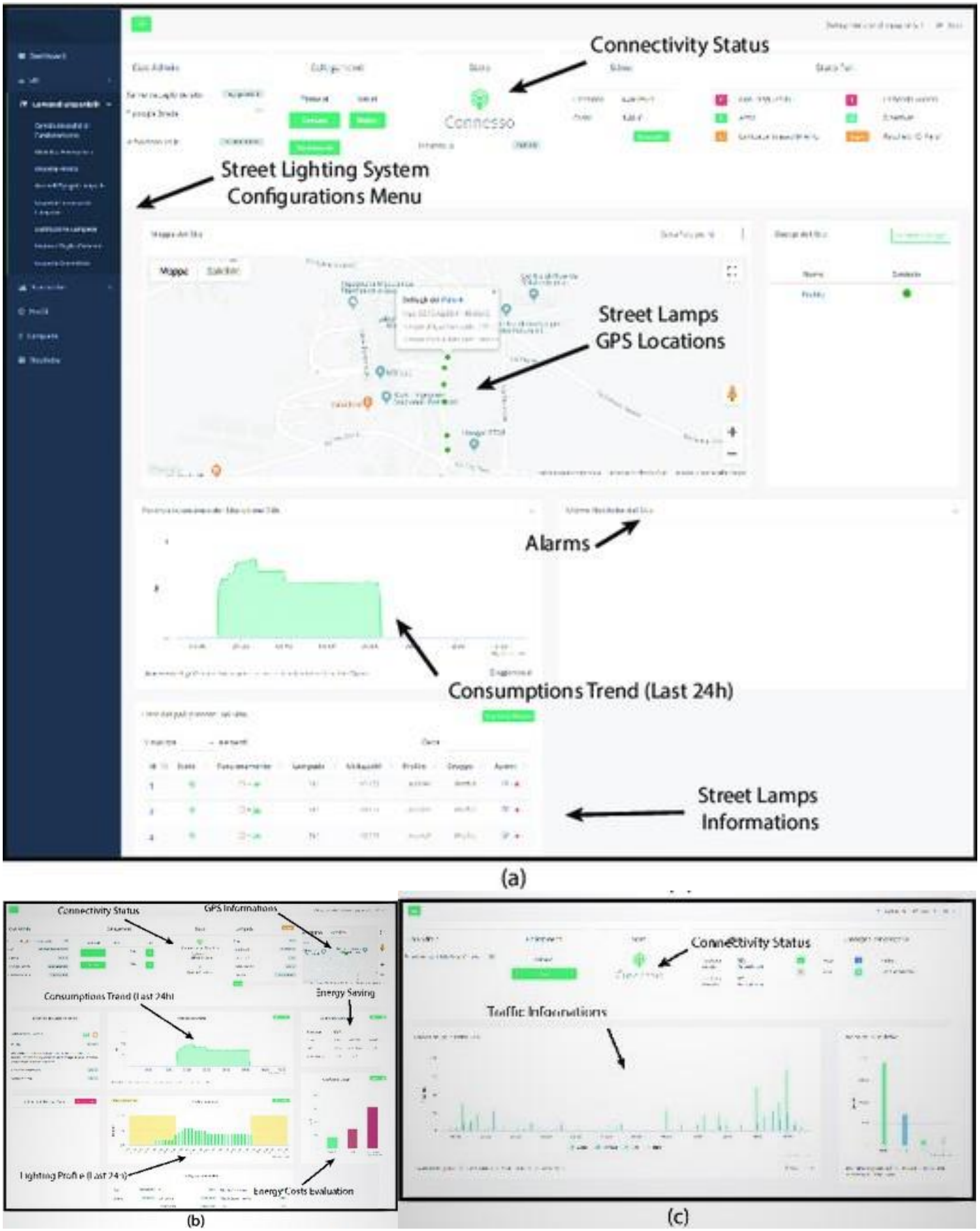

Fig. 6 Web application: (a)remote management page, (b) pole management page and (c) traffic monitoring.

Figure 6 depicts several sample pages from the web platform. Figure 6a depicts the street lighting remote administration page, where the user can adjust street pole functions and specify operating modes. This website also contains information regarding street pole locations and status (as determined by GPS data displayed on street maps), lighting system usage patterns, and defect alarms. Figure 6b, on the other hand, depicts the pole management: Data on consumption patterns, GPS position, lighting profile, energy cost evaluation, and the energy savings provided by the smart system over a normal system are displayed on this page. (For instance, traditional sodium vapor street lights or an LED street lamp system. Finally, Figure 6c depicts the web page for traffic monitoring.).

The mobile APP offers all of the features of the online application while also allowing authorized users to control the illumination brightness of individual lamps. Any user who has been granted access (for example, a police officer) can engage with the system and take the appropriate actions to improve general visibility in the event of a street emergency

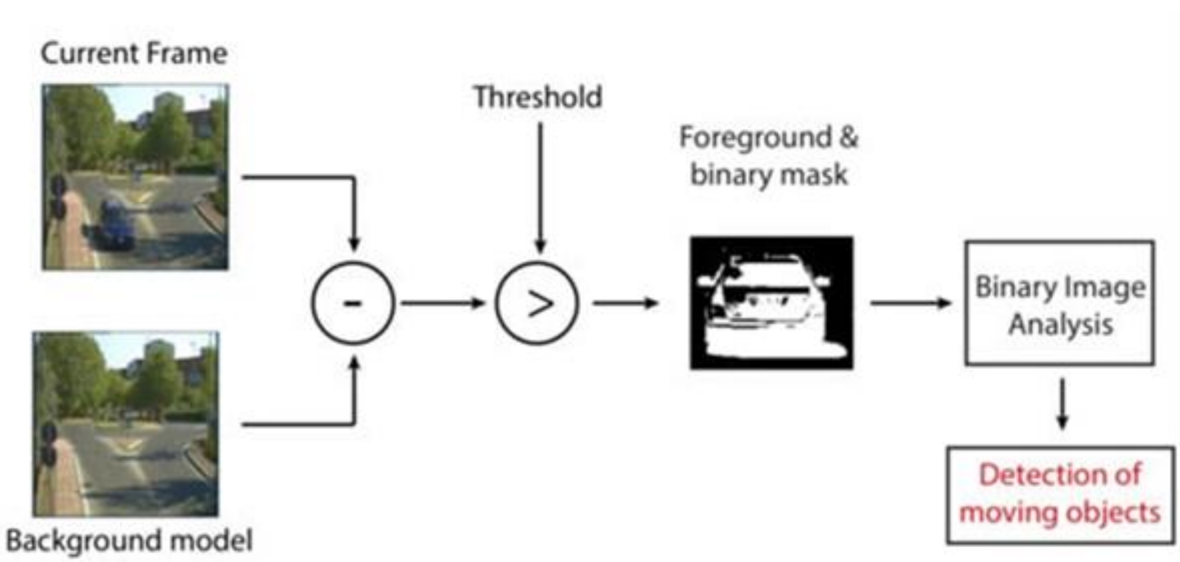

Fig. 7 Processes for background reduction and detection: a general approach

6. Video refining for automobile and walker Detection

Working object detection (vehicles and people) is crucial in congestion detection and categorization, as well as smart street electric management systems, where traffic data is taken into account.

In a video stream, video processing units are employed to detect the presence of moving autos or pedestrians. To do so, each frame of the video series is separated into two logical sections [27]: the foreground, which collects pixels belonging to things of interest (e.g., walker, vehicles, etc.) and the background, which collects pixels belonging to objects that remain constant in following frames (e.g., buildings, sky, trees, etc.). The backdrop subtraction method is a widely used technique for separating moving objects from their surroundings The idea is to "subtract" the current image, which is represented by a matrix Fi, from a reference image Bi acquired from a static background over time. If the difference between the two is higher than a particular threshold Th, i.e.,

$$|Fi-Bi|>Th \quad (1)$$

then a moving object is detected (Figure 7).

Several background removal techniques have been presented [27], with the majority of them based on the four phases shown in Figure 7: picture pre-processing, background modelling, foreground detection and binary mask construction, and binary image analysis are all steps in the process.

The first work is an image processing task, which is responsible for turning the raw input video into a format that the subsequent steps can readily process. The RGB (Red-Green-Blue) image is often transformed to a gray-scale image during this job. The background modelling procedure, which builds a background model from the first or preceding frames [28], is the second duty. The foreground detection and binary mask construction procedure compares the input video frame to the background model and selects candidate foreground pixels [29]. The grey scale image is then converted into a binary mask using threshold logic, which separates the objects of interest from the background. Finally, a binary image analysis is performed to delete pixels that do not belong to the current moving item. The binary image is also processed to detect moving objects, as well as to recognize cars and pedestrians.

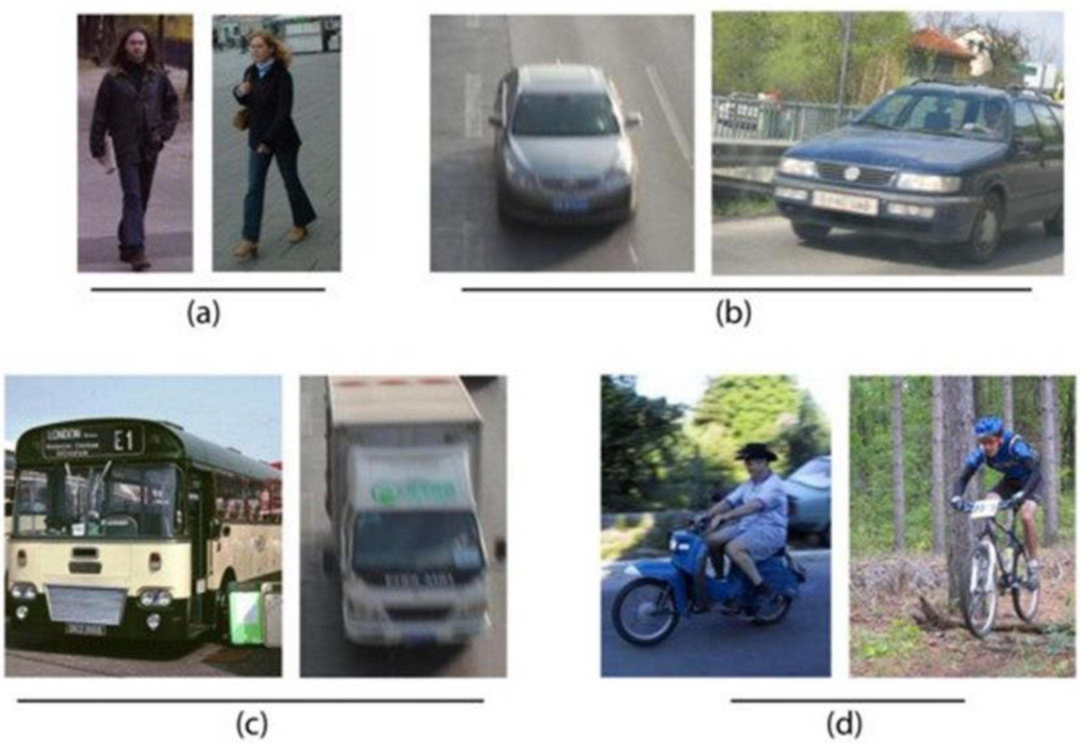

Fig. 8 Examples of moving object categorization basis sets: (a) Pedestrians (b) Automobiles (c), Lorries (d) Motorcycles.

Despite the fact that there are other options, the chosen video-processing approach makes use of a background modelling procedure based on the recursive mixture of Gaussians model presented in [30,31] addition to the moving object detection technique, an algebraic strategy based on the Eigen face approach, which was first presented in for face recognition and is now specialized for pedestrian and vehicle classification, is investigated [32]. This algorithm ensures that low-cost boards run efficiently. Classification can be accomplished by comparing how items are represented by the basics set, which is made up of photos of cars and pedestrians (Fig. 8).

However, although being speedy and well founded, this classification technique is not immune to misclassification episodes: the algorithm may fall into the wrong category because the target objects contain some bogus feature. For example, SUVs may be mistaken for small trucks, walkers carrying large things may not be recognized as people, bicycles with luggage may be mistaken for motorbikes, and so on. Like.

Table 1 Classification Procedure—Performance Analysis

% Mis-Classification					
Object	% Success	Walkers	Four-Wheeler	Heavy Vehicle	Two-Wheeler
Walkers	93	-	0	0	7
Four-Wheeler	89	0	-	7	4
Heavy Vehicle	94	0	6	-	0
Two-Wheeler	91	5	4	0	-

Table 1 displays error rates based on examining our 100-piece hand-curated dataset for each type of moving object z.

Furthermore, the technique provided here improves on the earlier one described in [24], which used a raw analysis of moving object dimensions as the basis for the classification algorithm.

Conclusions

This study describes a smart street lighting prototype, and its usefulness has been proved in two pilot locations. The suggested system is designed as an IoT infrastructure, with each light pole serving as a facilitator of value-added services for long-term community sustainability (such as energy management, environmental monitoring and light pollution reduction among others). It's effective for you. By linking smart devices to the network, the total architecture becomes scalable, functionally extensible, and implementable. The research began with a comprehensive overview of the system before moving on to the major principles and essential features of the smart lighting prototype. The technology can identify which lighting profile is ideal for each lamp based on traffic and weather conditions. The experimental phase revealed that, when compared to conventional street lamp systems, the proposed method can save a significant amount of energy while also allowing for precise traffic classification. Furthermore, because of the low installation cost, smart lighting systems can quickly pay for themselves, which is a benefit of employing such technology.

Conflict of interest

The author declares no conflict of interest.

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