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IoT Based Street Light Control System

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***Abstract*: Conventional street lighting stays on for a fixed schedule regardless of ambient light or road usage, which wastes a significant amount of electrical energy. This paper presents the design and implementation of an IoT-based street light monitoring and control system aimed at reducing power consumption, monitoring energy usage, detecting faulty lights, and dimming lights according to actual need. The proposed system uses a Light Dependent Resistor (LDR) to sense ambient light and automatically switch the street light between ON and OFF/dim states, and Infrared (IR) sensors to detect the presence of a vehicle or pedestrian on the road. When no vehicle is present at night, the lights are held at a low-intensity glow; when the IR sensor detects motion, the corresponding light is switched to full brightness through pulse-width modulation (PWM). An ESP32/ESP8266-based microcontroller (interfaced as an Arduino Nano/NodeMCU board in the prototype) reads the sensor data and pushes the real-time ON/OFF status to the Blynk IoT cloud platform, so that the lighting status can be monitored remotely from anywhere through the internet. A relay-driven switching stage provides high reliability, and the modular design keeps the system adaptable to different street layouts and hardware. The prototype was tested on a scaled model road with three lighting nodes and three IR sensors and demonstrated the expected behaviour: lights dim in the absence of traffic and brighten instantly when a vehicle approaches, while status is logged to the cloud in real time.**

***Keywords*: Internet of Things (IoT), smart street light, Light Dependent Resistor (LDR), Infrared (IR) sensor, Arduino/ESP32, Blynk, energy conservation, relay switching.**

1. Introduction

The Internet of Things (IoT) extends network connectivity and computing capability to everyday objects and sensors, allowing devices to sense, exchange and act on data with minimal human intervention. Smart-city applications networked vehicles, intelligent traffic systems, and sensors embedded in roads and utility infrastructure are among the most visible uses of this technology, since they directly help reduce energy consumption and traffic congestion in urban areas.

Public street lighting is a large and largely fixed drain on municipal electricity budgets: conventional systems switch on at dusk and stay on at full brightness until dawn irrespective of whether the road is in use, and a burnt-out lamp is often reported only when a resident complains. An IoT-based street light control system addresses both problems directly. By sensing ambient light with an LDR, the system removes the need for a manual or timer-based switch and instead reacts to the actual lighting condition. By sensing vehicle or pedestrian presence with IR sensors, it allows the lights to stay dim (rather than fully off) when the road is empty and brighten only when needed, cutting energy use without compromising safety. By reporting status to an IoT cloud dashboard, it allows maintenance staff to see, from a single interface, which lights are on, off or faulty, without physically patrolling the area.

This paper describes the design, hardware, software and working of such a system, along with the block diagram, circuit connections, control-flow logic and the results obtained from a working prototype.

2. Literature Survey

Automatic street light control has been studied extensively using different combinations of sensors and communication technologies. Priya et al. proposed an automatic street light control system using a Wireless Sensor Network (WSN) triggered by vehicle movement and atmospheric conditions. Ullah et al. designed a smart street light with an intensity controller that adjusts brightness according to ambient conditions rather than operating in a simple ON/OFF manner. Swati and Parekar developed a GSM-based system for remotely monitoring and controlling street lights, while Choosri proposed an IoT-RFID testbed to support traffic-light control in a similar spirit.

Several works add vehicle-counting and adaptive dimming: Janahan et al. reported an IoT-based smart traffic-signal monitoring system that counts vehicles, and George et al. presented an IoT-based smart traffic-light control system. Revathy et al. and Rudrawar et al. focused on automating street lighting for smart cities using power-electronics-based intensity control, and Abinaya et al. combined IoT with adaptive lighting logic in street lights. Tripathy et al. and Jain et al. explored weather-adaptive lighting, adjusting brightness according to both traffic and ambient weather conditions, and Roy et al. proposed a smart street-light intensity optimiser to further reduce energy consumption. Kodali and Yerroju, and Shahzad et al., studied energy-efficient and traffic-adaptive lighting control at a broader system level, while Kumar et al. used a mobile sensor platform to monitor street-lighting infrastructure health across an urban network.

Across this body of work, the recurring design choice is to combine a light sensor (LDR or photodiode) for day/night detection with a motion or presence sensor (PIR, IR or ultrasonic) for traffic-adaptive dimming, and to add a wireless

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or IoT reporting layer for remote monitoring. The present work follows the same overall approach, using an LDR and IR sensors with an ESP32/Arduino Nano controller and the Blynk IoT platform, and adds a relay-based switching stage for reliability and PWM-based dimming for smoother intensity control.

3. Proposed System

The proposed system automatically switches each street light ON at night and OFF during the day using an LDR, and additionally brightens a light from a dim standby level to full intensity only when an IR sensor detects an approaching vehicle or pedestrian near that light. The microcontroller continuously reads the LDR and the three IR sensors, drives the lights through PWM-controlled outputs and a relay stage, and publishes the live ON/OFF/intensity status to the Blynk IoT cloud so that it can be viewed remotely. The overall block diagram of the system is shown in Fig. 1.

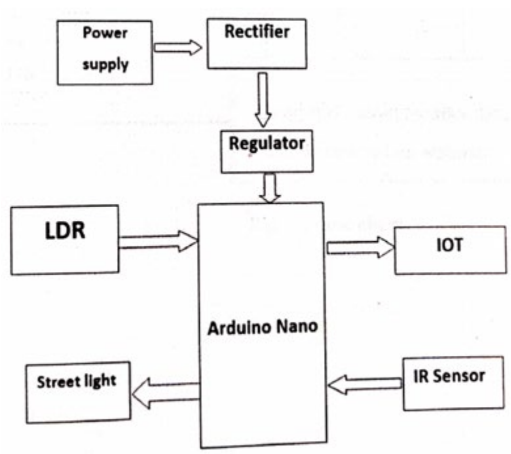

Fig. 1. Block diagram of the IoT based street light control system

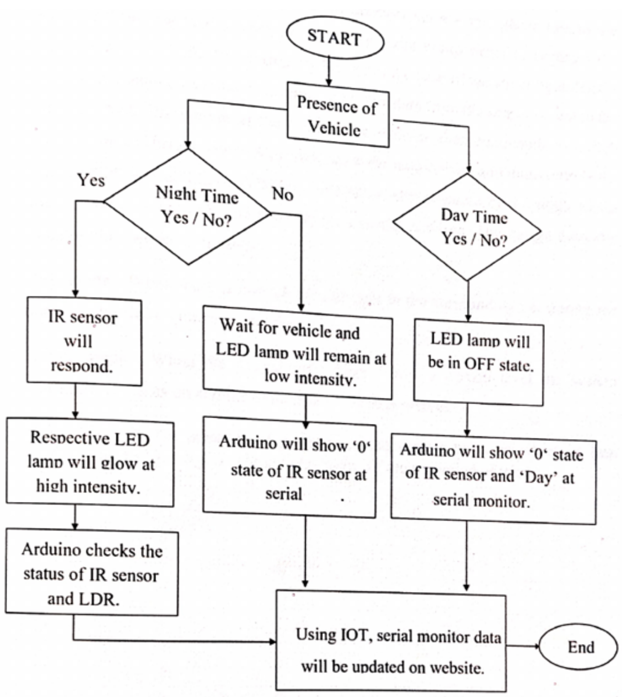

Fig. 2. Control-flow logic of the proposed system

The power-supply block rectifies and regulates the incoming supply to the DC levels needed by the controller and sensors. The LDR provides the day/night decision, the IR sensor provides the vehicle-presence decision, and the microcontroller (Arduino Nano / ESP32-class board in this prototype) combines both to decide the state of each street light and to update the IoT dashboard.

The corresponding control logic is summarised in the flow chart of Fig. 2. If it is night-time and a vehicle is detected, the IR sensor causes the associated lamp to switch to high intensity and the Arduino logs the sensor states; if no vehicle is present, the lamp is held at a low standby intensity. During the day, the lamp is kept OFF regardless of the IR sensor state. In every case, the current status is pushed to the IoT platform over Wi-Fi.

4. Hardware Description

A. Microcontroller (Arduino Nano/ESP32)

The controller is the decision-making core of the system: it reads the LDR and IR sensor inputs, generates the PWM signals that set each lamp's brightness, and runs the Wi-Fi stack that connects to the Blynk IoT server. An Arduino Nano built around the ATmega328P was used for prototyping and bench testing of the sensor logic; a Wi-Fi-capable ESP32/ESP8266 class module carries out the IoT connectivity and PWM-based lamp driving in the deployed circuit.

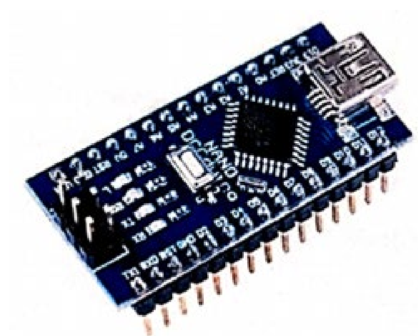

Fig. 3. Arduino Nano board used for prototyping the controller logic

B. Wi-Fi Module (ESP8266/ESP32)

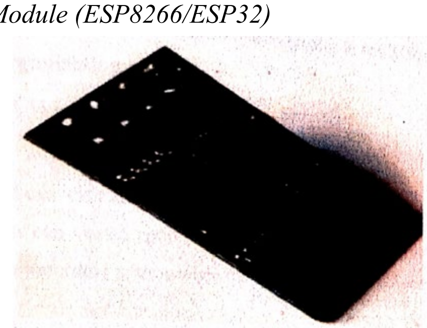

Fig. 4. Wi-Fi module used for IoT connectivity

The Wi-Fi module provides the wireless link between the street-light node and the internet. It integrates a 32-bit MCU, a TCP/IP protocol stack, an RF front end and power-management circuitry, and supports the 802.11 b/g/n standard on the 2.4 GHz band with WPA/WPA2 security in station, access-point, or combined station+AP modes. This lets the node connect to a local Wi-Fi network and exchange data with the Blynk server without any additional networking hardware.

C. Light Dependent Resistor (LDR)

The LDR is a photoresistor whose resistance falls as incident light increases: in bright daylight its resistance is low, and in darkness it rises sharply. The controller reads this changing resistance through its analog input (after conversion to a voltage) and uses it to decide whether it is day or night — switching the street light off when ambient light is adequate and enabling it once light levels fall below the set threshold.

D. Infrared (IR) Sensor

Each IR sensor module emits infrared light and measures the reflection to detect whether an object - a vehicle or pedestrian is present in front of it. Three IR sensors are placed along the road model, one per lighting zone, so that each street light can be brightened independently as traffic approaches its own zone and allowed to dim again once the zone is clear.

E. Relay and LED Lamps

A relay driven from the controller acts as an electromagnetic switch for the mains-side lighting circuit, giving reliable, isolated ON/OFF switching with a long service life. In the scaled prototype, LED lamps stand in for the street-light luminaires; their brightness is varied smoothly between the standby and full-intensity levels using PWM outputs from the controller rather than a simple relay ON/OFF, which avoids visible flicker when a lamp brightens.

5. Circuit Connections

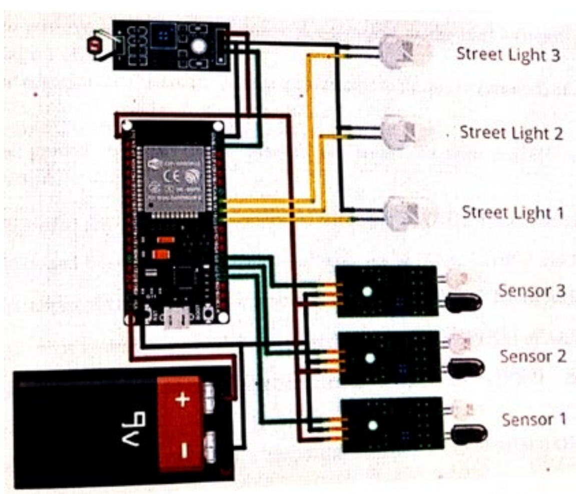

Fig. 5. Circuit connections of the prototype (controller, LDR, IR sensors and LED street-light nodes)

Fig. 5 shows the wiring used to connect the LDR module, the three IR sensor modules, the three LED street-light nodes and the battery supply to the microcontroller board. The LDR module's signal output goes to a digital/analog input pin used for day–night sensing; each IR sensor's output pin goes to a separate digital input pin (used for zone-wise vehicle detection); and each LED lamp is driven from a separate PWM-capable output pin through its own channel so that its brightness can be set independently. The board and sensors are powered from a 9 V battery through the on-board regulator.

In the working prototype: the LDR output is read on the controller's ADC pin used for day/night sensing; sensors 1, 2 and 3 are wired to three separate digital input pins for zone-wise vehicle detection; and LEDs 1, 2 and 3 are driven from three independent PWM channels (configured at a 5 kHz switching frequency with 8-bit resolution) so that each lamp's intensity can be commanded from 0 (off) through a low standby duty cycle up to full brightness.

6. Software Implementation

The controller firmware is written in the Arduino IDE using C/C++ and the Blynk library for ESP32/ESP8266. On start-up, the firmware configures the sensor pins as inputs, sets up three PWM channels for the LED outputs, and connects to the configured Wi-Fi network before registering with the Blynk cloud using an authentication token.

In the main loop, whenever the internet connection is available the firmware runs a with-internet routine: it checks the LDR state, and if it is night-time checks each IR sensor in turn, driving the corresponding LED to full duty cycle when that sensor detects an object and otherwise holding all three LEDs at a low standby duty cycle; the live status is also written to a Blynk virtual pin so it can be viewed on the dashboard. If the Wi-Fi/Blynk connection is lost, a parallel without-internet routine keeps the same LDR/IR-based dimming logic running locally from a manual override switch, so the lights continue to respond correctly even without connectivity. A representative excerpt of the control routine is shown below.

```
if (digitalRead(Ir1) == LOW)  ledcWrite(ledChannel1,
1000);  // zone 1 vehicle -> full brightness
if (digitalRead(Ir2) == LOW)  ledcWrite(ledChannel2, 1000);
// zone 2 vehicle -> full brightness
if (digitalRead(Ir3) == LOW)  ledcWrite(ledChannel3, 1000);
// zone 3 vehicle -> full brightness
else {
  ledcWrite(ledChannel1, dutyCycle);
  ledcWrite(ledChannel2, dutyCycle);
  ledcWrite(ledChannel3, dutyCycle);   // otherwise -> low
standby glow
}
Blynk.virtualWrite(V2, 250);   // report ON status to the IoT
dashboard
```

Monitoring and control on the user side are provided by the Blynk IoT application, which exposes virtual pins that mirror the sensor and lamp status and allow the operator to view the real-time ON/OFF state of the street lights from a smartphone from anywhere with internet access.

7. Working

Every device in the system - the LDR, the three IR sensors, the microcontroller and the relay-driven lamps operates on the same locally-networked architecture, with the microcontroller acting as the central decision-making unit. During daytime, sunlight keeps the LDR's resistance low and the lights are held

OFF. As ambient light falls at dusk, the LDR's resistance rises past the configured threshold and the controller switches the lights on at a low standby intensity rather than full brightness. As a vehicle or pedestrian approaches a given zone, the corresponding IR sensor output goes low, and the controller immediately raises that lamp to full intensity via its PWM channel; once the zone is clear again the lamp returns to the standby level. Throughout this cycle, the controller reports the aggregated ON/OFF and sensor status to the Blynk cloud so that the lighting condition of the entire stretch of road can be checked remotely at any time.

8. Results and Discussion

The system was assembled on a scaled model of a road segment with three street-light nodes and three corresponding IR sensor zones, and tested under simulated night conditions. With no vehicle on the road, all three lights were held at their low standby intensity, confirming correct night-time detection by the LDR (Fig. 6).

Fig. 6. Street lights at standby intensity with no vehicle present

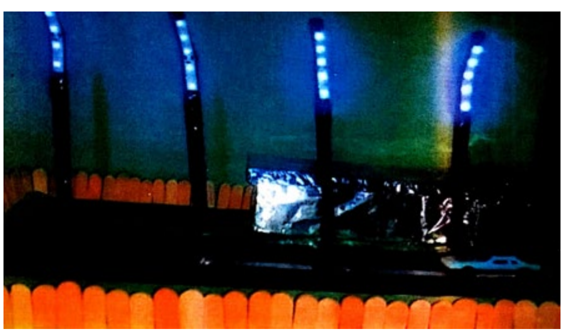

Fig. 7. Street light switching to full brightness as the vehicle reaches the first IR sensor

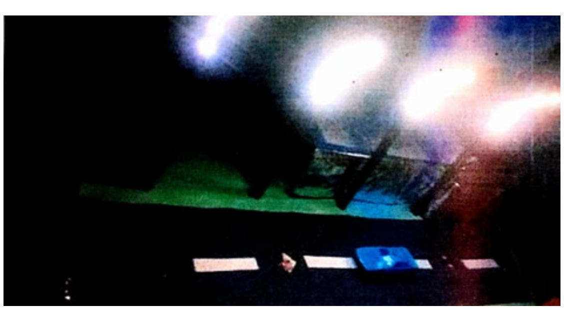

Fig. 8. Street light switching to full brightness as the vehicle reaches the second IR sensor

When a model vehicle was moved past the first sensor zone, the corresponding street light immediately brightened to full intensity while the remaining lights stayed dim, as seen in Fig. 7; the same behaviour was repeated as the vehicle reached the second sensor zone (Fig. 8), confirming that each lighting zone responds independently to local traffic.

Across repeated trials the prototype consistently distinguished day from night through the LDR and responded to vehicle presence at each of the three zones independently through the IR sensors, while the Blynk dashboard reflected the corresponding ON/OFF/standby status in real time. These results confirm that the combination of ambient-light sensing, zone-wise motion sensing and PWM-based dimming can substantially reduce the time each lamp spends at full brightness compared with a conventional dusk-to-dawn street light, without leaving any stretch of road unlit when it is in use.

9. Advantages

- Reduces electricity wastage by dimming lights when no traffic is present and switching them off completely during daylight hours.
- Zone-wise IR sensing brightens only the section of road that is actually in use, rather than the whole street.
- Remote, real-time monitoring of light status through the Blynk IoT platform reduces the need for manual patrolling.
- Relay-based switching combined with PWM dimming gives reliable, flicker-free operation and a long switching life.
- The modular hardware and software design can be adapted to different street layouts, numbers of lighting zones, and controller boards.

10. Applications

- Energy-efficient street lighting for residential colonies, highways and urban roads.
- Lighting for university, industrial and corporate campuses where traffic is intermittent.
- Smart-city infrastructure projects that require centralized, remote monitoring of public lighting assets.
- Parking areas and pedestrian walkways where presence-based dimming improves both safety and energy savings.

11. Future Scope

The present prototype can be extended to draw its primary power from a solar panel, storing harvested energy in a battery and using an inverter/converter stage to supply the lighting and control circuit, which would make each lighting node largely self-sufficient and further reduce grid dependence. The IR-based sensing can also be extended to estimate vehicle speed, recognise number plates, or flag possible accidents on the monitored stretch of road. Additional features such as automated fault/failure reporting for individual lamps, smart-parking integration, and support for autonomous-vehicle-friendly lighting cues would further extend the system's usefulness in a smart-city deployment.

12. Conclusion

This paper presented the design, hardware, software and testing of an IoT-based street light control system that combines LDR-based day/night sensing, IR-based zone-wise vehicle detection, PWM-controlled LED dimming and Blynk-based remote monitoring. The prototype demonstrated that street lights can be dimmed to a low standby level in the absence of traffic and brightened instantly when a vehicle approaches, while their live status remains visible on an IoT dashboard from anywhere with an internet connection. Given the scale of energy currently spent on fixed-schedule street lighting, this combination of ambient-light sensing, presence-based dimming and cloud-based monitoring offers a practical and modular way to cut wastage while keeping roads adequately lit when they are in use.

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