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# Smart Street Light Fault Identification For Multiple Smart Streets: A Review Of Iot Monitoring, Anomaly Detection And Maintenance Automation

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**Abstract—Street lighting is essential for urban safety and accounts for a significant part of municipal electricity use. Traditional maintenance depends on manual night patrols or public complaints, so faulty lamps may stay dark for days, wasting energy and creating safety risks. This paper reviews technologies for a smart street light fault identification system that covers many streets. It examines IoT nodes that measure current, voltage, power and light intensity at each pole, wireless networks including ZigBee mesh and LoRaWAN for city-wide coverage, and control platforms that switch and dim lamps. Fault detection methods are reviewed, from threshold rules on electrical parameters to unsupervised anomaly detection that identifies abnormal behaviour such as flickering, partial failure, cable faults and power theft. Smart lighting deployments, India's national LED street-lighting programme and the cybersecurity risks of networked lighting are discussed. A five-layer architecture comprising pole-level sensing, communication, a central monitoring platform with fault analytics, a maintenance workflow and a city dashboard is proposed, with research gaps, objectives, a comparison of communication technologies and challenges such as cost, interoperability and security. The review concludes that automatic fault identification reduces downtime, maintenance cost and energy use while improving public safety.**

***Index Terms—Smart street lighting, IoT, fault detection, anomaly detection, ZigBee, LoRaWAN, smart city, predictive maintenance***

## I. Introduction

### 1.1 Motivation

Well-lit streets reduce accidents and crime and make cities more liveable at night. Indian cities have replaced millions of conventional lamps with LEDs under the national Street Lighting National Programme [1], greatly reducing energy use. However, maintenance practices often remain manual: crews drive around at night or wait for residents to complain about dark poles.

When thousands of lights are spread across many streets, identifying exactly which lamp has failed, and why, becomes difficult. IoT sensors on each pole can report electrical and light measurements continuously, and analytics can detect faults the moment they occur. Zanella *et al.* [2] included smart lighting among the core services of an urban IoT.

This paper reviews smart street light fault identification and proposes an architecture for monitoring multiple smart streets.

### 1.2 Objectives of the Review

- To review sensing, communication and control technologies for smart street lighting.
- To examine rule-based and AI-based fault detection methods.
- To propose a five-layer fault identification architecture for multiple streets.
- To compare communication technologies for lighting networks.

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- To identify challenges and future improvements.

## II. Overview of Key Concepts

### 2.1 Types of Street Light Faults

Fig. 1 classifies faults: lamp failure, driver or ballast failure, partial or flickering output, cable and connection faults, power supply loss, day-burning (lamps left on in daylight) and unauthorized power tapping.

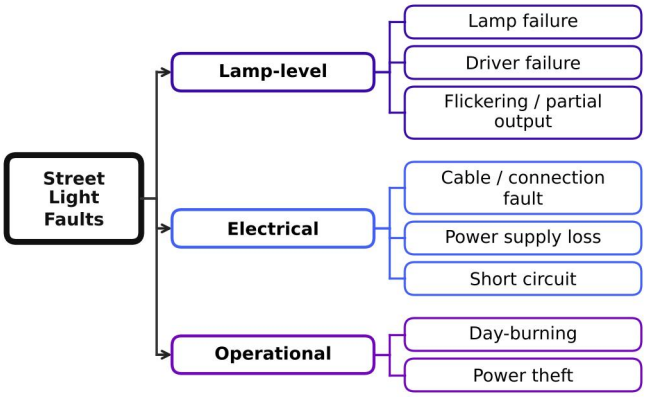



**Fig. 1. Types of street light faults.**

### 2.2 Electrical Signatures

A healthy LED lamp draws a predictable current and power at a given dimming level. A failed lamp draws almost no current, a degrading driver may draw irregular current, and a short circuit draws excessive current. Light sensors confirm whether light is actually produced.

## III. Review of Existing Work

Leccese [3] designed a remote-control street lighting system using a ZigBee network of devices and sensors, enabling remote switching, dimming and status monitoring of individual lamps. Castro *et al.* [4] reviewed smart lighting solutions and described architectures linking lamps to city platforms.

De Paz *et al.* [5] proposed an intelligent lighting control system for smart cities using a multi-agent approach that adapts lighting to conditions and reduces energy consumption. Sikder *et al.* [6] surveyed IoT-enabled smart lighting systems, their architectures, communication technologies and security concerns.

For city-wide connectivity, Centenaro *et al.* [7] examined long-range low-power networks such as LoRaWAN for smart city scenarios, and Raza *et al.* [8] compared low-power wide-area technologies. Jin *et al.* [9] described a smart street lighting platform that also hosts other smart city sensors and warned that networked lighting creates a new cyber-attack surface.

For fault analytics, Chandola *et al.* [10] surveyed anomaly detection techniques, and isolation forests [11] provide efficient unsupervised detection of unusual readings across many poles. Table I summarizes these works.

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| Ref. | Author(s) / Year | Technique / Approach | Key Contribution | Limitation / Gap |
|---|---|---|---|---|
| [3] | Leccese, 2013 | ZigBee remote-control street lighting | Per-lamp monitoring and control | Limited fault analytics |
| [4] | Castro et al., 2013 | Smart lighting solutions review | City platform architectures | Conceptual |
| [5] | de Paz et al., 2016 | Multi-agent lighting control | Adaptive, energy-saving control | Fault detection not central |
| [6] | Sikder et al., 2018 | Survey of IoT smart lighting | Architectures and security issues | Survey only |
| [7] | Centenaro et al., 2016 | LPWAN for smart cities | Wide-area low-power connectivity | Low data rate |
| [9] | Jin et al., 2016 | Smart lighting as city platform | Highlighted cyber-security frontier | Case-study based |
| [10] | Chandola et al., 2009 | Anomaly detection survey | Techniques for unusual readings | General survey |
| [11] | Liu et al., 2008 | Isolation Forest | Fast unsupervised anomaly detection | Threshold tuning |

**TABLE I Summary of Literature Survey**

## IV. Identified Research Gaps

- **G1:** Many deployments monitor only on/off status and miss partial or developing faults.
- **G2:** Fault localization across very large networks with mixed vendors is difficult.
- **G3:** Predictive maintenance of LED drivers before failure is rarely implemented.
- **G4:** Interoperability between lighting systems and city platforms is limited.
- **G5:** Security of lighting networks is often an afterthought.

## V. System Architecture

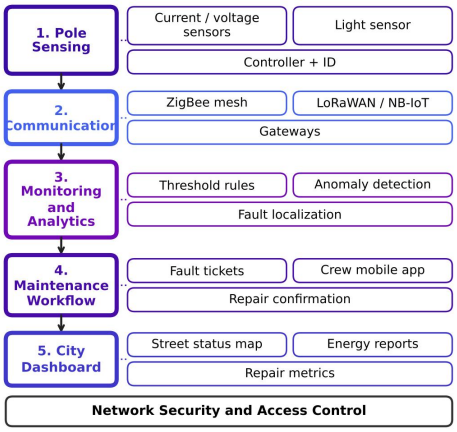



**Fig. 2 shows the proposed architecture.**

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**Fig. 2. Proposed fault identification architecture for multiple smart streets.**

### 5.1 Pole Sensing Layer

Each pole has a controller with current and voltage sensors, a light-dependent resistor, a relay or dimming driver and a unique identifier linked to GPS coordinates.

### 5.2 Communication Layer

Poles form a ZigBee mesh within a street and connect through gateways, or use LoRaWAN directly, to send readings every few minutes.

### 5.3 Monitoring and Analytics Layer

A central platform stores readings, applies threshold rules for clear faults and runs anomaly detection to find abnormal patterns, identifying the exact pole and likely fault type.

### 5.4 Maintenance Workflow Layer

Fault tickets with location and fault type are sent to crews through a mobile app; repair confirmation closes the ticket.

### 5.5 City Dashboard Layer

A map shows the status of all streets, energy use, open faults and repair times.

## VI. Implementation Methodology

Fig. 3 describes the workflow. Power drawn by a lamp is

$$P = V \cdot I \cdot \cos \varphi \quad (1)$$

and a fault is flagged when the measured power deviates from the expected value at the current dimming level by more than a tolerance, or when the light sensor reports darkness while the lamp is switched on. Anomaly scores from an isolation forest highlight poles whose behaviour differs from their neighbours.

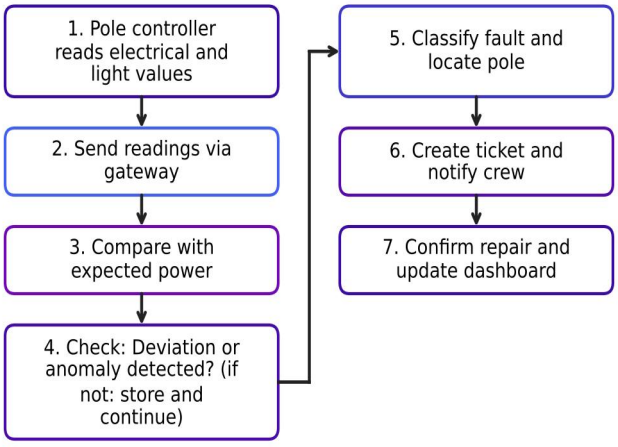



**Fig. 3. Street light fault identification workflow.**

## VII. Performance Comparison

Table II compares communication technologies. ZigBee mesh suits dense streets, LoRaWAN covers wide areas at low power, cellular NB-IoT uses existing networks and power-line communication reuses existing cables.

| Technology | Range | Power | Best Use |
|---|---|---|---|
| ZigBee mesh | Short, multi-hop | Low | Dense streets |
| LoRaWAN | Several km | Very low | City-wide coverage |
| NB-IoT | Cellular | Low | Existing networks |
| Power-line comm. | Along cables | Low | Reuse wiring |
| Wi-Fi | Short | High | Few poles, hotspots |

**TABLE II Comparison of Communication Technologies**

## VIII. Open Issues and Future Directions

Table III summarizes challenges. Future work includes predictive maintenance of LED drivers, adaptive dimming based on traffic and pedestrian presence, integration of cameras and environmental sensors on poles, and standard secure protocols across vendors.

| Challenge | Mitigation |
|---|---|
| Installation cost | Retrofit controllers; phased rollout |
| Mixed vendors | Open protocols and APIs |
| Partial faults | Anomaly detection on trends |
| Cyber attacks | Encryption; authenticated firmware |
| Communication gaps | Mesh redundancy; store-and-forward |

**TABLE III Challenges and Mitigation**

## IX. Conclusion

Smart street light fault identification replaces slow manual inspection with continuous, automatic monitoring. The reviewed literature shows mature sensing, ZigBee and LoRaWAN communication, and control platforms, while anomaly detection adds the ability to find partial and developing faults. A multi-street architecture that pinpoints faulty poles and dispatches crews automatically reduces downtime, maintenance cost and energy waste, and improves public safety, provided it is designed with interoperability and security in mind.

## 9.1 Acknowledgment

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