

OPTIMIZATION OF NETWORK ARCHITECTURES AND COMMUNICATION TECHNOLOGIES IN IOT-BASED ENERGY-EFFICIENT LIGHTING SYSTEMS

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Abstract: *This article provides a scientific analysis of network architectures and communication technologies for energy-efficient smart lighting systems. In particular, wired and wireless communication approaches required to ensure centralized control in street lighting systems are considered. The advantages and limitations of wired networks, especially architectures based on data transmission through power lines, are analyzed. In addition, wireless networks based on IoT technologies, their flexibility, and scalability are described. Technical and economic issues related to the use of cellular and LPWAN technologies are also examined. According to the research results, a hybrid approach that combines wired and wireless technologies is evaluated as a promising solution for ensuring efficient operation of smart lighting systems.*

Keywords: *smart lighting, IoT, wired networks, wireless networks, PLC, LPWAN, cellular communication, smart city, network architecture, energy efficiency.*

One of the main issues to be addressed in designing a smart lighting infrastructure is the establishment of an efficient and reliable communication system between each street lamp and the centralized control center. This communication system must enable real-time control, monitoring, and optimization of energy consumption [1]. Considering the static nature of lighting infrastructure, various architectures based on wired and wireless networks can be applied. Therefore, this article provides a scientific analysis of the technological aspects of these two approaches.

Wired networks are one of the simplest and most widely used approaches for organizing energy-efficient lighting systems. This approach is based on the use of existing power transmission lines not only for energy delivery but also for data signal transmission [4]. As a result, the traditional electrical grid is transformed into a communication infrastructure, reducing the need for installing additional communication lines. Typically, in such systems, communication between luminaires and the electrical cabinet (segment controller) is carried out through low-voltage power cables, while the electrical cabinet is connected to the central control system via a wide area network. This architecture is shown in figure 1.

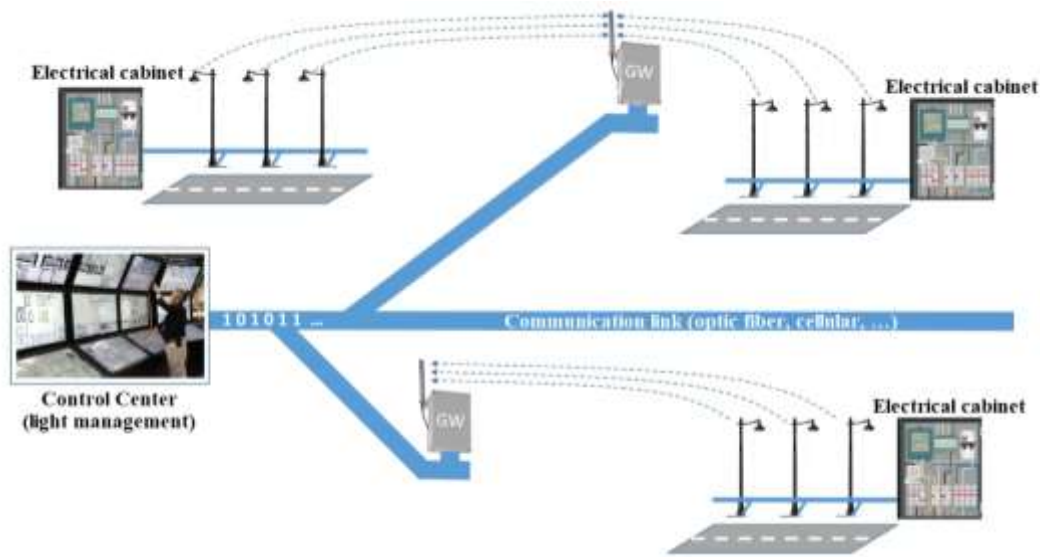


Fig.1. Architecture of a smart lighting system based on wired transmission.

This architecture is currently widely used and is considered a technologically mature and practically proven solution [1]. Standardized systems are offered by many manufacturers, which confirms its reliability. At the same time, the main limitation of wired systems is their relatively low flexibility and limited scalability. In the concept of modern smart cities, street lighting systems are no longer limited to their traditional function but are considered an important element of IoT infrastructure [2]. Each street lamp interacts with surrounding devices such as sensors, smart vehicles, parking systems, and others, actively participating in data collection and exchange processes. Therefore, the use of wireless communication technologies is of great importance in the organization of such systems. A single wireless network can support both smart lighting and IoT services, which increases system efficiency and simplifies the infrastructure. In practice, the main communication is carried out between the electrical cabinet and the luminaires; however, additional radio frequency networks are formed through radio modules installed on each luminaire. This network enables communication with nearby IoT devices and enhances the flexibility of the system [5].

Cellular communication and LPWAN technologies are considered convenient solutions for connecting smart lighting systems. However, several challenges arise when applying these technologies. First, in dense urban environments, it is difficult to ensure complete signal coverage, and communication disruptions may occur due to various obstacles. Second, cellular networks are managed by third-party operators, which leads to additional costs for infrastructure owners [3]. Third, dependence on external networks limits full control over the system and reduces the ability to implement additional IoT services.

Conclusion. The article presents a comprehensive analysis of network architectures and communication technologies used in energy-efficient smart lighting systems. The results show that while wired networks provide high reliability and stability, their flexibility is limited.

Wireless technologies, on the other hand, enhance integration with IoT and enable system scalability, but are associated with issues related to coverage, cost, and management.

Based on this, the use of a hybrid network architecture that combines wired and wireless technologies is recommended as the most suitable solution for modern smart cities.

Such an approach improves system reliability, ensures energy efficiency, and enables the implementation of additional IoT services in the future.

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