LiFi-BMS Connect: An Integrated Smart Lighting System for Dynamic Building Management and Contextualized Indoor Services

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***Abstract*— *LiFi-BMS Connect* is a smart lighting system that integrates indoor lighting control with real-time positioning and contextual services. By combining Wi-Fi and optional Visible Light Communication (VLC), it enables data exchange and high-precision localization through LED fixtures. A DALI-BACnet gateway connects lighting to building management systems, allowing granular control and monitoring. The platform also delivers proximity-based content to users while ensuring privacy through anonymized data collection. Designed for scalability and energy efficiency, LiFi-BMS Connect offers a flexible, privacy-conscious solution for smarter, more responsive building environments.**

Keywords*— *Smart Building and Infrastructure, Context and Situation Awareness, Smart Energy, IoT, Indoor Positioning, BACnet, DALI, Industrial Track

I. Introduction

The rapid evolution of Smart Cities and Communities necessitates innovative ICT solutions for optimizing urban infrastructure and enhancing the quality of life within built environments. Traditional building management systems (BMS) often lack real-time granularity in lighting control and the ability to deliver personalized services to occupants. This extended abstract presents **LiFi-BMS Connect**, a novel integrated system designed to transform conventional indoor lighting infrastructure into an intelligent, multi-functional network capable of granular indoor lighting control and advanced location-based services. Our work addresses critical challenges in energy efficiency, operational flexibility, and occupant experience in smart buildings.

II. System Architecture and Scientific Contribution

LiFi-BMS Connect proposes a robust, multi-layered architecture for comprehensive lighting management and indoor spatial awareness. In this section, the architecture of each system module will be explained.

A. Integrated Wi-Fi/VLC Hardware Module

A miniaturized hardware module is developed for seamless integration within existing or new lighting fixtures. This module provides Wi-Fi connectivity for data exchange and, optionally, Visible Light Communication (VLC) capabilities. The VLC component leverages the modulated light from LED fixtures to create a high-precision indoor positioning system, while simultaneously enabling data transmission without additional radio frequency infrastructure. The design focuses on minimizing form factor and power consumption for widespread applicability.

B. DALI-BACnet Gateway

A core component is a dedicated gateway that acts as a bridge between the DALI (Digital Addressable Lighting Interface) subnet of the lighting fixtures and a Building Management System (BMS) via the BACnet protocol. This gateway translates DALI commands and lighting status data into BACnet objects, allowing the BMS to gain granular control over individual luminaires (e.g., on/off, dimming, color transitions) and to monitor real-time lighting performance. The architecture prioritizes robust and secure communication protocols to ensure reliable operation within enterprise environments.

C. Contextualized Indoor Services Platform

A distinct subnet, leveraging the Wi-Fi/VLC capabilities of the lighting modules, enables the delivery of proximity-based content. By geo-referencing the Wi-Fi signals (e.g., RSSI triangulation) or utilizing VLC for more precise localization, the system identifies the occupant's position. This allows for the delivery of highly relevant, contextualized information (e.g., navigation, product information in retail, exhibit details in museums) directly to occupants' mobile devices. Data collection for geolocalization is designed with privacy-by-design principles, implementing anonymization techniques at the source (e.g., random identifiers).

D. Contextualized Indoor Services Platform

GPS location data are managed within a dedicated database service (potentially a NoSQL solution like Firebase or Google BigQuery) for efficient storage and retrieval. Data synchronization occurs via HTTPS calls, ensuring secure and scalable operations. Key performance indicators for the location-based service include "first time to fix," accuracy, and refresh frequency, with a data collection approach optimized for both time and distance intervals.

III. Practical Relevance and Impact

LiFi-BMS Connect offers significant practical relevance for Smart Cities and Communities.

A. Enhanced Energy Efficiency

By integrating lighting control with BMS, buildings can optimize energy consumption through precise dimming, scheduling, and adaptive lighting based on occupancy and daylight.

B. *Improved Building Management*

A unified BACnet interface simplifies the integration of lighting into existing BMS, providing a comprehensive view and control of building infrastructure.

C. *New Revenue Streams & User Experiences*

The proximity content delivery enables businesses and institutions to offer innovative, hyper-localized services, enhancing visitor engagement and operational efficiency.

D. *Scalability and Adaptability*

The modular design ensures scalability for various building sizes and types (e.g., commercial, residential, cultural sites).

E. *Privacy-Conscious Innovation*

The focus on anonymization at the source addresses growing concerns regarding personal data privacy in location-based services.

IV. Conclusion

LiFi-BMS Connect represents a significant advancement in smart building technology, merging dynamic indoor lighting with sophisticated indoor positioning and contextual content delivery. By leveraging an integrated hardware-software approach, our system provides a versatile and secure platform for optimizing building operations and enriching the human experience within urban environments. Ongoing development focuses on refining prototype performance, validating real-world application, and exploring further integrations for a more interconnected and intelligent urban fabric.