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A Proxy-based Approach for Data Exchange and Interoperability between IEEE1888.4 Local and Global Storages

***Abstract**. This article develops a proxy-based approache for seamless data exchange and interoperability between local and global clouds in IEEE1888.4-based Internet of Things (IoT) system. The proxy operates as an intermediary, facilitating efficient communication and data transfer across cloud environments. The article discusses architectural design, implementation consideration, and benefit of proxy-based approach, including enhanced scalability, interoperability, and limitation of data accessibility using the IEEE1888 FETCH procedure via the ESP8266 microprocessor. Future research direction and potential application for seamless data exchange and interoperability are also explored.*

***Streszczenie.** W tym artykule omówiono podejścia oparte na serwerach proxy do bezproblemowej wymiany danych i współdziałania między chmurami lokalnymi i globalnymi w systemach Internetu rzeczy (IoT) opartych na standardzie IEEE1888.4. Serwer proxy działa jako pośrednik, ułatwiając efektywną komunikację i przesyłanie danych w środowiskach chmurowych. W artykule omówiono projekt architektoniczny, kwestie związane z implementacją oraz korzyści płynące z podejść opartych na proxy, w tym zwiększoną skalowalność, interoperacyjność i ograniczenia dostępności danych przy użyciu procedury IEEE1888 FETCH za pośrednictwem mikroprocesora ESP8266. Badane są również przyszłe kierunki badań i potencjalne zastosowania bezproblemowej wymiany danych i interoperacyjności. (**Podejście oparte na proxy do wymiany danych i interoperacyjności pomiędzy lokalnymi i globalnymi magazynami danych IEEE 1888.4**)*

Keywords: Proxy, ESP8266, IoT, IEEE1888, Interoperability.
Słowa kluczowe: Proxy, ESP8266, IoT, IEEE1888.4, interoperacyjność.

Introduction

Modern smart systems, like smart buildings and digital networks, require international standards for quality control and communication. IEEE 1888 establishes principles for remote control architecture, enabling seamless communication among devices within protocol networks [1]. This promotes cost-effective system integration, efficient element installation, and market competition leading to lower equipment prices. In the era of ubiquitous connectivity and the proliferation of the Internet of Things (IoT) devices, seamless data exchange, and interoperability are paramount for efficient and scalable data management [2-4]. The IEEE1888 standard has emerged as a dominant framework for local and global data storage, which enables effective communication between heterogeneous IoT systems [5, 6]. Despite this advantage, direct interactions between this diverse data repository pose significant challenges due to their varying data format, communication protocol, and security constraint [7]. address this complexity, a proxy-based approach has collected significant attention as promising solutions for facilitating seamless data exchange and enhancing interoperability within the IEEE1888.4 ecosystem [8].

A proxy operates as an intermediary between local and global data storage system, effectively mediating data transaction, format conversion, and security enforcement [9]. This empowers users with control over data sharing andmonetization, which leads to benefits such as interoperability and business model innovation in multistakeholder ecosystems [10]. To improve energy management, a system is developed to connect the Smart Energy Platform (SEP) and Smart City Platform (SCP). Leveraging the IEEE1888 protocol and a central platform, this system facilitates effective energy management by enabling seamless data exchange between the platform [11]. This paper presents a comprehensive exploration of proxy-based approache for data exchange and interoperability between IEEE1888.4-based local and global data storage system. We examine the key challenges associated with direct communication and delve into the design principle and functionality of proxy that enable homogeneous data integration. Furthermore, we discuss the implementation details of various proxy architectures and analyze their performance in real-world scenarios. Our research contributes to grow body of knowledge on data management strategy for IoT environments and offers valuable insights into the development of efficient and secure data exchange mechanism. By bridging the gap between local and global data storage system, a proxy-based approach has the potential to revolutionize the way IoT data is accessed, shared, and utilized, driving innovation and scalability across various IoT applications.

Method

The IEEE1888 methodology involves three main components: Application (APP), Gateway (GW), and Storage. APP reads sensor data, displaying and analyzing it. GW collects data, controls actuators, and manages device access. Storage stores transmitted parameter values, serving as a backup data repository. The proposed communication flow demonstrates data collection from a room meter, local storage with IEEE1888, and global storage through a Green smart home proxy via ESP8266 [11, 12]. This enables effective management, visualization, and analysis, fostering smart home connectivity and intelligence. Components include local storage, gateway, SCADA, and a smart home proxy. Figure 1 shows the system architecture.

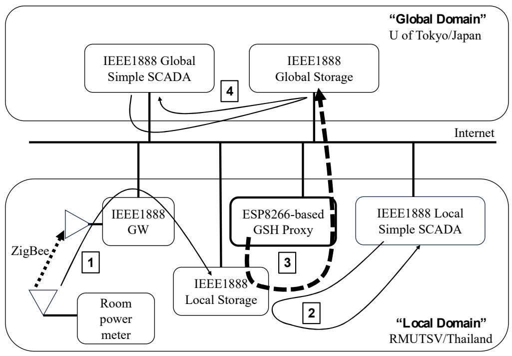


Fig.1. System architecture

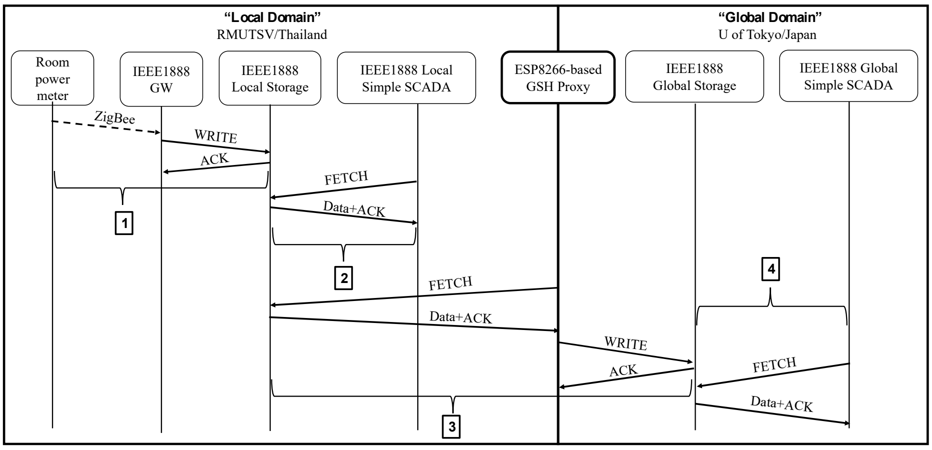


Fig.2. System information flow diagram

Figure 2 shows the system timing diagram. The described system outlines a seamless data exchange and management process between a room power meter, local storage, global storage, and SCADA systems. The step-by-step process is summarized as follows:

Step 1: Data Collection and Storage Locally The room power meter collects power consumption-related data and sends it to both the IEEE1888 local gateway and the IEEE1888 local storage using the WRITE procedure. This step ensures that the power consumption information is recorded and stored in the local domain.

Step 2: Real-time Display and Reporting at Local SCADA [13]. The IEEE1888 Local simple SCADA system retrieves the power consumption-related information from the IEEE1888 local storage using the FETCH procedure. This real-time data retrieval enables the local SCADA system to display and report the power consumption information, providing users with immediate insights into energy usage within the local domain.

Step 3: Data Exchange to the Global Domain, the ESP8266-based proxy plays a critical role in this step. It retrieves the power consumption information from the local storage using the FETCH procedure, and then it exchanges this data to the global domain by employing the WRITE procedure. The proxy acts as an intermediary, facilitating the transfer of data between the local and global domains seamlessly.

Step 4: Real-time Display and Reporting at Global SCADA The IEEE1888 Global simple SCADA system is responsible for retrieving the power consumption information from the IEEE1888 global storage using the FETCH procedure. With this data retrieval, the global SCADA system displays and reports the power consumption information from various locations, enabling a comprehensive view of energy usage across the global domain.

This system provides an efficient data flow for power consumption information. The room power meter records data in the local domain, and the local SCADA system promptly displays and reports this information. The ESP8266-based proxy then facilitates the exchange of data from the local domain to the global domain, allowing the global SCADA system to visualize and report the power consumption data from multiple locations. This seamless communication between the various components ensures real-time monitoring and efficient data management, making the system highly valuable for energy consumption analysis and decision-making in both local and global contexts.

Referring to the IEEE 1888 standard results home networking, office, building, or factories are used as infrastructure for energy management. Thus, consuming energy efficiently and effectively is considered a key factor in creating a green community or environmentally friendly community because it can reduce energy consumption. There is surveillance and inspection through the use of sensors, including command or control of various devices through actuators, which are mechanisms or main devices for controlling the use of energy systems.

Power Meter

The power meter [14, 15] operates a vital role in measuring electrical parameters like current, voltage, power factor, and consumption within buildings. It collects this data and transmits it to the Gateway. To measure current, current transformers (CTs) are deployed, utilizing the Hall effect to sense magnetic flux density generated by electron movement in a wire. This flux density corresponds directly to current flow. CTs prove effective for current measurement across applications. When linked to an Arduino MEGA microcontroller, they provide reliable, accurate current data through Hall effect-based analog voltage signals proportional to conductor current. Voltage collection employs voltage transformers, converting 230VAC to 9VAC, suitable for measurement. This ensures safer voltage levels for the measurement circuit. Integration with Arduino MEGA's analog input pins becomes seamless, facilitating measurement and processing of current values. The combination of CTs and voltage transformers presents a comprehensive solution for accurate current and voltage measurement, crucial for energy management and data-driven decisions. Figure 3 shows the power meter board.

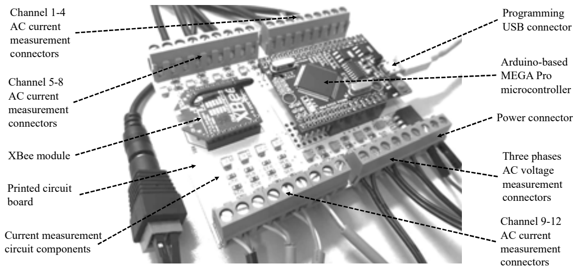


Fig.3. Power meter board [14, 15]

IEEE1888 Local Gateway

The IEEE1888 Local Gateway [16] operates a crucial role in the system architecture as a communication bridge between the power meter and other components. It serves as an intermediary device that receives data from the power meter using the ZigBee communication protocol [17]. The Gateway is responsible for processing and forwarding the received data to the appropriate destinations within the system. By utilizing the ZigBee communication protocol, the Gateway enables seamless and reliable data transmission from the power meter to other components. It ensures that the data collected by the meter is accurately and efficiently delivered to the intended recipients, such as the Local Storage or the Simple SCADA system. Figure 4 shows the GW device.

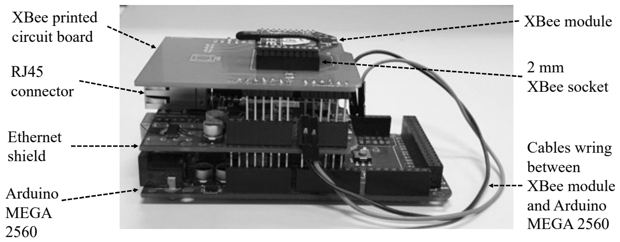
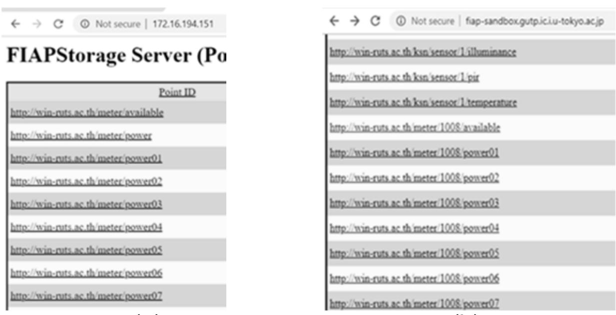


Fig.4. IEEE1888 Local GW [16]

Local and Global Storages

The local storage, installed within the VMWare program, serves as a data repository for storing the collected energy data. It receives data from the Gateway and stores it for further processing and analysis. The Simple SCADA system is used to display the data obtained from the local storage. It retrieves the energy data from the storage in VMWare and provides a user-friendly interface for monitoring and visualizing the information [13]. The Global Storage component serves as a central repository for storing energy consumption data from multiple smart homes or devices. It operates according to predefined standards, such as the IEEE1888 standard, to ensure compatibility and interoperability with other systems. The Global Storage enables long-term data storage and analysis, allowing for comprehensive insights and trends related to energy consumption across multiple homes or locations. The global storage, based on the IEEE1888 standard, serves as a central data repository that stores energy data from various sources. It receives data from the GSH proxy and operates according to the IEEE1888 standards, ensuring data integrity and accessibility. Figure 5 shows the Simple SCADA GUI.



(a) (b)

Fig.5. Simple SCADA of (a) the local storage and (b) the global storage

ESP8266-based Green Smart Home Proxy

ESP8266-based Green Smart Home Proxy facilitates communication between the local storage and the Global Storage based on the IEEE1888 standard. It requests data from the local storage using the FETCH protocol and retrieves the response. Simultaneously, it uses the WRITE protocol to send a set of data to the global storage for information exchange and future access. Figure 6 shows the ESP8266-based Green Smart Home Proxy.

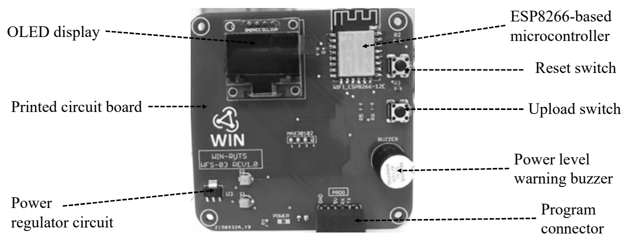


Fig.6. ESP8266-based Green Smart Home Proxy

For the operation of each section, the meter measures energy parameters, the Gateway facilitates communication, the Local Storage stores the data, the Simple SCADA system visualizes the data, the GSHG enables the communication between local and global storage, and the Global Storage serves as a central repository for energy data. This system architecture allows for efficient data management and analysis in a smart, green home environment.

Experimental results and discussion

The proposed system for data exchange and interoperability between the room meter, IEEE1888 local storage, and global storage using the ESP8266 Green smart home proxy demonstrates promising results, providing efficient data communication. The key findings derived from the experiments and data analysis are summarized in Table 1:

Table 1: The time-based analysis in the system

Operation time (min)	Average Time of FETCH procedure (ms)	Average Time of WRITE procedure (ms)	Average Time of Total operation time (ms)	Maximum number of recorded results
1	149.14	280.66	429.80	118
2	124.30	310.93	435.23	118
3	145.85	271.31	417.16	124
4	133.21	323.70	456.91	121
5	147.63	342.12	489.75	115
Average	140.02	305.74	445.77	119

For Local-to-Global communication time, the average result time for data retrieval (FETCH) from the global storage via the ESP8266 Green smart home proxy is approximately 140.02 ms. The average result time for data storage (WRITE) to the global storage via the ESP8266 Green smart home proxy is approximately 305.74 ms. These average times indicate reasonable response times for exchanging data between the local and global storage systems, considering the potential network latency and the complexity of remote data access. And, for operation time and recorded results, the summation of operation time, which includes both FETCH and WRITE times, is calculated to be 445.77 ms. The total number of recorded results is 119 recorded. The system's performance shows that it is capable of efficiently handling data exchange tasks over time.

The recorded results demonstrate consistency and stability in the system's response, which is crucial for real-time applications and critical data transfers. It is important to consider that the system's efficiency may be influenced by various factors, including network conditions, server responsiveness, and the data volume being exchanged. The observed FETCH and WRITE times are within acceptable ranges, ensuring that data can be effectively retrieved from and stored into the global storage system. As a result of this study, several areas for potential improvement have been identified. Optimizing the global communication procedures could further enhance the system's response times, reducing the time taken for data transfers between local and global environments. Additionally, scaling up the system to handle higher data loads and exploring mechanisms for load balancing could be explored to ensure consistent performance in larger deployments. Furthermore, this research offers valuable insights for IoT applications and smart home environments, emphasizing the importance of proxy-based approaches in achieving seamless data interoperability. Future developments may focus on enhancing security measures, ensuring data privacy, and exploring advanced caching techniques to further optimize data retrieval and storage processes.

Conclusion

The system presented in this study showcases an effective and efficient approach for data exchange and interoperability between the room meter, IEEE1888 local storage, and global storage using the ESP8266 Green smart home proxy. The conducted experiments and analysis have provided valuable insights into the system's performance and response times during data retrieval (FETCH) and storage (WRITE) operations. The local-to-local communication within the IEEE1888 environment demonstrates rapid data exchange with low average response times, indicating successful integration between the room meter, local storage, and local SCADA system. This seamless local data management fosters real-time monitoring and visualization of room parameters within the local environment. The local-to-global communication process, facilitated by the ESP8266 Green smart home proxy, exhibits reasonable average response times during FETCH and WRITE procedures. These results demonstrate the system's ability to efficiently exchange data between the local and global storage systems, albeit with slightly higher response times due to the nature of remote data access. Overall, this research lays a solid foundation for future advancements in data exchange paradigms, enabling the realization of an interconnected and intelligent ecosystem that empowers users with real-time data insights, efficient data management, and enhanced decision-making capabilities.

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