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A Smart Electricity Metering and Billing System for Shared Accommodation

Deocles Joseph, Michael Mbughi, Alexander Amsi, Abdallah Ali, Isaya Josephat, Alirehema Azaria, Elika Lunyungu, Henry Sanga, Godson Gideon

Department of Computer Science
Ruaha Catholic University (RUCU)
Iringa, Tanzania

Abstract: *Shared accommodation has become increasingly common due to urbanization and rising housing costs, particularly in developing countries. In such settings, electricity is typically supplied through a single main meter, resulting in collective billing practices that fail to reflect individual consumption. This often leads to unfair cost allocation, billing disputes, and inefficient electricity usage. Although smart electricity metering technologies and automated billing systems have improved billing accuracy and transparency at utility and household levels, their applicability to shared accommodation remains limited. This paper presents a comprehensive review of existing smart electricity metering systems, smart grid technologies, Internet of Things (IoT)-based monitoring solutions, and sub-metering approaches. The review critically evaluates their architectures, operational principles, and limitations with respect to shared accommodation environments. The analysis reveals that most existing systems lack occupant-level billing autonomy, depend on centralized infrastructure, or incur high deployment costs. The paper identifies a clear research gap and provides a strong justification for the development of a localized, cost-effective smart electricity metering and billing system that enables independent electricity purchasing under a shared supply framework.*

Keywords— Smart electricity meter, automated billing, shared accommodation, sub-metering, energy management.

1. INTRODUCTION

Electricity metering is a fundamental component of power distribution systems, directly influencing billing accuracy, energy management, and consumer accountability. Traditionally, residential buildings are supplied through a single electricity meter that measures aggregate energy consumption for the entire premises [1], [2]. While this approach is sufficient for single-family households, it presents significant challenges in shared accommodation environments such as hostels, rental houses, and student residences, where multiple occupants consume electricity independently.

Shared accommodation has increased globally as a result of rapid urbanization, population growth, and escalating housing costs [6]. In such environments, electricity costs are commonly shared equally among occupants or estimated manually by landlords. According to Short [2], these practices are inherently inaccurate and often result in disputes, lack of transparency, and inefficient electricity usage. Occupants with low electricity consumption are frequently required to subsidize high-consuming users, which discourages responsible energy behavior.

Smart electricity metering technologies have been introduced to address limitations associated with conventional metering by enabling automated measurement, real-time monitoring, and accurate billing [1]. However, most existing smart metering systems are designed either for large-scale utility deployment or for single-household residential use. This review examines existing smart electricity metering and billing systems and evaluates their suitability for shared accommodation, with the aim of identifying gaps that justify the proposed project.

2. BACKGROUND OF ELECTRICITY METERING AND BILLING SYSTEMS

Electricity metering systems are fundamental components of power distribution networks, serving as the basis for energy measurement, billing, and consumption analysis. Conventional electricity meters are designed to measure aggregate energy usage at a single point of supply and are widely deployed in residential and commercial buildings [1], [2]. While this approach is adequate for single-family households, it presents significant challenges in shared accommodation, where electricity is consumed by multiple occupants with varying usage patterns.

Urbanization and rising housing costs have contributed significantly to the growth of shared accommodation worldwide, particularly in developing countries [6]. In such living arrangements, electricity is commonly billed through equal cost sharing or manual estimation by landlords. According to Short [2], these billing methods are inherently inaccurate and often lead to disputes, lack of transparency, and inefficient electricity use. Occupants with low consumption frequently subsidize those with higher consumption, which discourages responsible energy behavior.

The introduction of smart electricity meters has transformed electricity billing by enabling automated meter reading, real-time consumption monitoring, and improved billing accuracy. Depuru et al. [1] explain that smart meters integrate sensing, processing, and communication capabilities to eliminate manual reading errors and enhance trust between consumers and electricity providers. Smart meters also support advanced billing mechanisms and consumption analysis.

Beyond basic smart metering, smart grid technologies have been developed to support large-scale energy management and two-way communication between consumers and utilities. Gungor et al. [3] highlight that smart grid communication technologies enable real-time monitoring, system scalability, and interoperability. However, these systems require advanced infrastructure and significant investment, making them unsuitable for small-scale deployments such as shared accommodation.

Recent studies have also explored the use of data analytics in smart metering systems to improve energy efficiency and consumption awareness. Alahakoon and Yu [4] demonstrated that smart meter data analytics can reveal consumption patterns and support demand-side management. While such approaches improve energy awareness, they do not address the core issue of fair billing among multiple occupants sharing a single electricity supply.

IoT-based electricity monitoring systems have further enhanced automation in energy management. Rahman et al. [5] proposed an IoT-based smart energy monitoring and billing system capable of real-time consumption measurement and automated bill generation. Although effective, the system was designed for single-household environments and relied heavily on continuous internet connectivity and cloud infrastructure, which may not be feasible in low-resource shared accommodation settings.

Sub-metering has been widely adopted as a partial solution in multi-tenant buildings. Sub-meters measure electricity consumption at room or apartment level, improving transparency in energy usage [1]. However, sub-metering systems remain dependent on the main electricity meter. When the main meter is depleted, all sub-meters lose power regardless of individual consumption or payments [2]. Furthermore, sub-meters do not allow occupants to independently purchase electricity, limiting their effectiveness in resolving billing disputes.

The limitations identified in existing electricity metering and billing approaches highlight the need for a smart electricity metering and billing system specifically designed for shared accommodation. Such a system must support occupant-level consumption measurement, independent electricity purchasing, and fair billing while operating under a shared main supply.

3. RELATED WORK

3.1 Conventional and Smart Electricity Metering Systems

3.1.1 Conventional Electricity Metering

Conventional electricity meters measure total energy consumption at a single point of supply and typically require manual meter reading for billing purposes [2]. Willis [1] explains that such meters provide no real-time feedback to consumers and are susceptible to reading errors, delayed billing, and estimated charges. In shared accommodation, the inability of conventional meters to differentiate consumption among occupants makes fair cost allocation practically impossible.

3.1.2 Smart Electricity Meters and Automated Meter Reading

Smart electricity meters integrate sensing elements, microprocessors, and communication modules to automatically record and transmit electricity consumption data [1]. Depuru, Wang, and Devabhaktuni [1] demonstrated that smart meters significantly improve billing accuracy, reduce operational costs, and enhance transparency between electricity providers and consumers. Automated Meter Reading (AMR) and Advanced Metering Infrastructure (AMI) systems eliminate manual data collection and enable timely billing and consumption monitoring.

Despite these advantages, smart metering systems are largely utility-centric. They assume centralized control by electricity providers and do not support occupant-level electricity purchasing or billing under a shared meter configuration [1], [2]. As a result, their direct applicability to shared accommodation remains limited.

In contrast to these passive metering devices, Roosefart *et al.* [7] demonstrate that smart meter-based systems incorporate advanced sensing, signal processing, and communication capabilities that enable continuous monitoring and system-level analysis within a smart grid environment. Their work highlights that conventional meters lack the embedded intelligence and data granularity required for tasks such as fault detection and system diagnostics. As reflected in the conceptual diagram, conventional electricity metering operates without real-time data processing or communication support, limiting its functionality to aggregate energy measurement only.

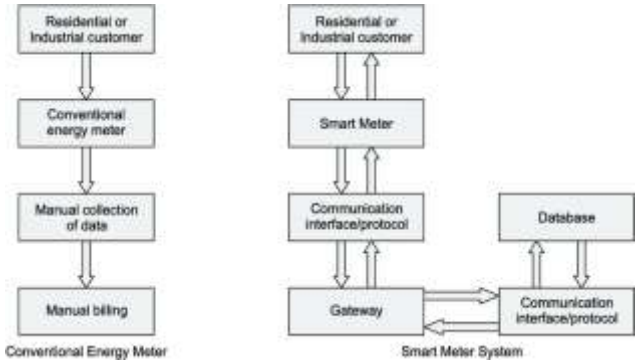

Figure 1. Illustrates the functional difference between conventional electricity metering and smart electricity metering systems.

3.2 Smart Grid Communication Technologies

Smart electricity meters form a critical component of smart grid systems, which rely on advanced communication technologies to support real-time data exchange and system scalability. Gungor et al. [3] reviewed communication

technologies used in smart grids, including wireless sensor networks, cellular communication, and power line communication. Their study emphasized that reliable communication is essential for achieving interoperability, scalability, and real-time monitoring in modern power grids.

While these technologies are effective at national and regional grid levels, their deployment requires substantial infrastructure investment and technical expertise [3]. Such requirements make smart grid-based solutions unsuitable for small-scale shared accommodation environments, where cost, simplicity, and ease of maintenance are critical considerations. Furthermore, smart grid architectures focus on utility-managed billing rather than tenant-specific electricity purchasing.

3.3 Smart Meter Data Analytics and Energy Awareness

The deployment of smart meters has enabled the collection of high-resolution electricity consumption data, which can be analyzed to improve energy efficiency and consumption awareness. Alahakoon and Yu [4] emphasized that smart meter data analytics play a vital role in future energy systems by enabling demand-side management and informed decision-making. Their study demonstrated that consumption pattern analysis can encourage responsible energy usage and optimize load management.

However, data analytics approaches primarily address energy efficiency rather than billing fairness. While consumption awareness may influence user behavior, it does not provide mechanisms for independent billing or electricity purchasing among multiple occupants sharing a single supply [4]. Consequently, such approaches alone are insufficient for resolving billing challenges in shared accommodation.

3.4 IoT-Based Electricity Monitoring and Billing Systems

Recent research has explored the application of Internet of Things technologies in electricity monitoring and billing systems. Rahman et al. [5] proposed an IoT-based smart energy monitoring and billing system that uses sensors and microcontrollers to measure real-time electricity consumption and generate automated bills. Their system demonstrated improved billing accuracy and reduced manual intervention.

Despite these benefits, the system was designed for single-household environments and relied on continuous internet connectivity and cloud infrastructure [5]. Such dependency increases operational costs and limits deployment in low-resource settings. Moreover, the system does not support multiple occupants purchasing electricity independently under a shared main meter.

Table 1. Summarizes selected smart electricity metering and billing systems reviewed in this paper and highlights their applicability to shared accommodation.

Reference	Target Environment	Core Contribution	Limitation for Shared Accommodation
[1]	Utility-scale	Automated meter reading, accurate billing	No occupant-level billing
[3]	Smart grid	Reliable communication standards	High cost and complexity
[4]	Residential	Data analytics for energy efficiency	No billing autonomy
[5]	Single household	IoT monitoring and automated billing	Not designed for shared use

3.5 Sub-Metering in Shared Accommodation

Sub-metering is widely used in multi-tenant buildings to measure electricity consumption at room or apartment level. According to Willis [1], sub-metering improves transparency and allows landlords to allocate electricity costs more accurately. However, sub-meters remain dependent on the main meter and do not function independently.

When the main meter runs out of electricity credit, all sub-meters lose power regardless of individual payments [1], [2]. This dependency limits occupant autonomy and fails to fully eliminate billing disputes. Additionally, sub-metering systems do not support independent electricity purchasing, which is a critical requirement in shared accommodation.

4. OBSERVATION AND RESEARCH GAP

The reviewed literature demonstrates that existing smart electricity metering systems primarily target centralized utility billing or single-household environments. Sub-metering solutions improve consumption visibility but lack billing autonomy. IoT-based systems introduce automation but often rely on costly infrastructure and continuous connectivity. There is limited research focusing on localized, affordable systems that allow individual occupants to purchase electricity independently while operating under a shared main meter. This gap necessitates the development of a smart electricity

metering and billing system tailored specifically for shared accommodation.

The proposed Smart Electricity Metering and Billing System for Shared Accommodation is motivated directly by the identified research gap. By associating electricity consumption and credit with individual occupant identifiers rather than the entire household, the system aims to promote fair billing, reduce disputes, and encourage responsible energy usage. The proposed approach emphasizes affordability and practicality, making it suitable for shared accommodation in developing regions.

5. System Architecture of Smart Electricity Metering for Shared Accommodation

A typical smart electricity metering system for shared accommodation consists of sensing, processing, communication, and billing layers. According to Depuru et al. [1] and Rahman et al. [5], smart metering architectures commonly follow a layered structure that separates energy measurement, data processing, and billing functions to improve scalability and reliability. In shared accommodation, this architecture must additionally support occupant-level identification while operating under a single main supply.

The conceptual system architecture relevant to this review is illustrated in Fig. 2. The architecture consists of a shared main electricity supply, room-level sensing units, a local processing controller, a billing and credit management module, and user interfaces. Similar architectural decomposition has been adopted in smart metering and IoT-based energy systems to improve modularity and cost-effectiveness [1], [5].

Each room or apartment is equipped with current and voltage sensors that measure electricity consumption locally. These sensors are connected to a microcontroller responsible for computing energy usage and associating it with a unique occupant identifier. The processed data are forwarded to a billing module that manages electricity credit allocation and consumption records. This localized architecture avoids dependence on large-scale smart grid infrastructure, which is known to be costly and complex for small deployments [3].

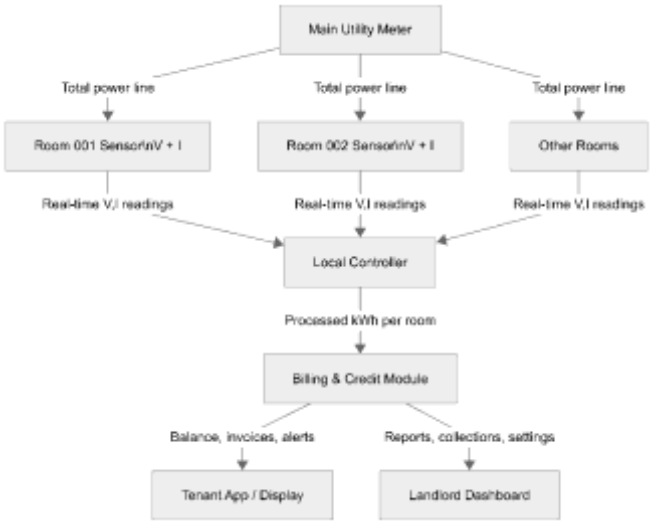

Figure 2. Conceptual system architecture of a smart electricity metering and billing system for shared accommodation, adapted from smart metering and IoT-based energy management architectures [1], [3], [5].

6. Data Flow in Smart Electricity Metering and Billing Systems

Data flow modeling is essential in understanding how electricity consumption information is collected, processed, and transformed into billing records. According to Gungor et al. [3], reliable data flow is a core requirement for smart metering systems, while Alahakoon and Yu [4] emphasize that accurate data handling is critical for billing integrity and consumption accountability.

In shared accommodation environments, electricity data must flow from room-level measurement points to a billing mechanism capable of associating consumption with individual occupants. Fig. 3 presents a high-level data-flow diagram illustrating how electricity usage data and credit information move through the system.

The process begins with electricity consumption measurement using sensors installed at room level. The measured voltage and current values are converted into energy units and tagged with an occupant identifier. This data is then processed locally to update remaining electricity credit and generate consumption records. Billing information is subsequently made available to occupants and landlords through a user interface. Similar data-flow patterns have been reported in IoT-based energy monitoring systems [5], although most existing implementations target single households.

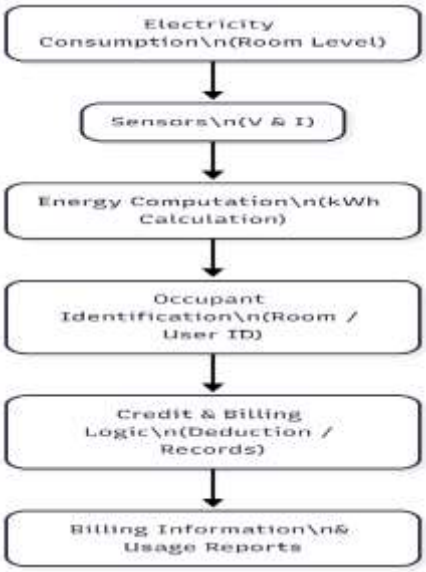

Figure 3. Data-flow diagram of electricity consumption measurement and billing in shared accommodation, based on smart metering and IoT energy monitoring models [1], [4], [5].

7. CONCLUSION

This paper reviewed existing literature on smart electricity metering, smart grid communication technologies, data analytics, IoT-based monitoring, and sub-metering approaches. While these technologies have improved electricity management in various contexts, they do not adequately address the unique challenges of shared accommodation. The absence of occupant-level billing autonomy and continued dependence on main meters remain unresolved issues. The reviewed works provide strong evidence supporting the need for a dedicated smart electricity metering and billing system for shared accommodation, thereby justifying the proposed project.

8. ACKNOWLEDGMENT

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