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A Wi-SUN Network-based Electric Vehicle Charging Station using Open Charge Point Protocol (OCPP) and oneM2M Platform

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***Abstract*—Street lights are ubiquitous public infrastructure in urban areas that can be leveraged for smart city applications. In this paper, we present an electric vehicle charging station (EVCS) that communicates using Wi-SUN network integrated on a network of streetlights, and using oneM2M middleware. The proposed architecture follows the level 2 charging standards and the open charge point protocol (OCPP), ensuring compatibility and interoperability across diverse charging infrastructures. By seamlessly incorporating Wi-SUN network and oneM2M middleware, our architecture enables efficient communication and interaction with a wide array of devices and services. The utilization of the oneM2M platform further enhances the integration by establishing a seamless connection between the EVCS and the broader smart city infrastructure. We have fabricated a proof-of-concept system that consists of the EVCS connected to a Wi-SUN network integrated with the streetlight network in the institute campus. The performance of our solution was evaluated by measuring the latency associated with authentication and billing for EV users. We report the average latency observed over several iterations of charging to be 0.7±0.2 s (excluding the time required for charging). We also measured the Wi-SUN communication range in the campus environment with trees and buildings and found the maximum range to be around 370 m.**

***Index Terms*—EV charger, OCPP, oneM2M platform, Public lighting system, Smart City, Wi-SUN**

I. INTRODUCTION

Streetlights play a crucial role in cities by providing illumination to enhance the safety and security of road users and pedestrians. However, beyond their primary function, street lights can also serve as a versatile and extensible platform for smart city applications, because they are electrically operated, densely deployed, immobile and publicly owned. Augmenting street lights presents opportunities to integrate sensors, actuators, computing systems, networking capabilities, and Internet-of-Things (IoT) components. This integration can unlock a wide array of innovative services and applications for urban environments, including traffic monitoring, environmental sensing, digital signage, Wi-Fi access, and E-vehicle charging [1].

One of the promising applications of street lights is their use as electric vehicle charging stations (EVCSs), especially for e-bikes that are becoming popular modes of transportation in cities. E-bikes are bicycles or motorbikes that have an electric motor for locomotion. They offer many benefits for urban mobility, such as reducing greenhouse gas emissions, saving time and money, and enhancing accessibility and convenience [2]. However, one of the main challenges for e-bike users is to find available and reliable EVCSs in the city. Pole-mounted electric vehicle charging presents a unique solution to address this issue. Public electric vehicle (EV) chargers located at the curbside can help serve drivers without access to a private charger. Chargers attached to utility poles and streetlights, or pole-mounted chargers (PMCs), present an emerging alternative to help address these barriers. Nevertheless, it's important to consider electrical capacity limitations as not all poles can accommodate PMCs [3]. Further, PMCs require connectivity to the cloud to validate charging transactions, authenticate users, bill users, and report maintenance and errors. Connectivity can be provided using Wi-Fi or LTE. However, these are tedious to set up over a large area and require significant capital and operational expenditure. This problem can be solved by using long-range IoT wireless communication protocols to connect PMCs to the cloud. One such protocol is the Wi-SUN (wireless smart utilities network) protocol. Utilising Wi-SUN provides large area coverage, allowing communication over long distances. This is particularly advantageous for an EV charging infrastructure that may span a wide area.

In this paper, we present a demonstration of an EVCS that uses Wi-SUN network to communicate with the cloud using OCPP as the communication standard. It uses IPv6-based mesh technology that allows end nodes to connect directly and dynamically to several nearby nodes to form a mesh network. The oneM2M middleware layer provides a rich set of common services for data management, security, discovery, and interoperability. The system architecture is built on the guidelines of level 2 charging, which denotes that the charger works on 220-240 volts single phase AC supply [4].

II. RELATED WORKS

Max *et al.* have proposed street lamps as platform infrastructure and discussed the applications of connected street lights in detail [1]. The idea is to enable street lights equipped

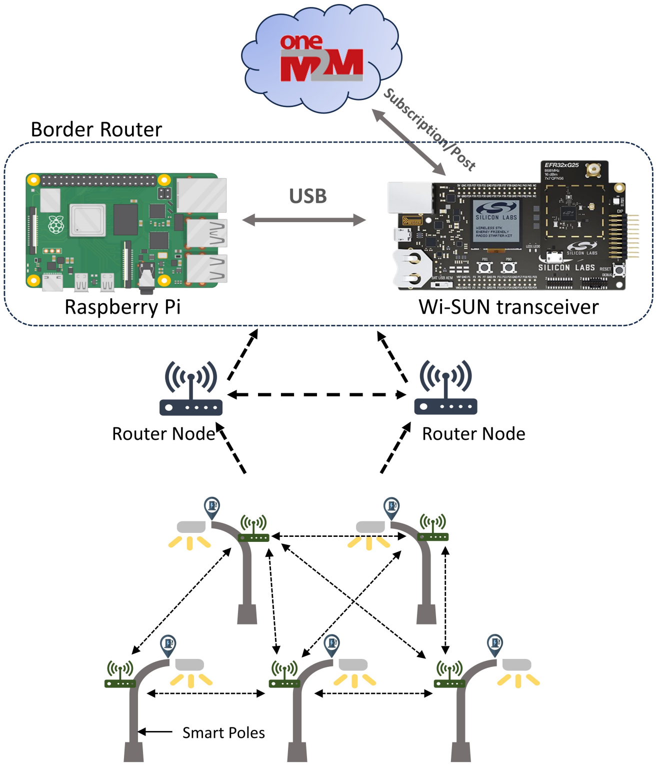
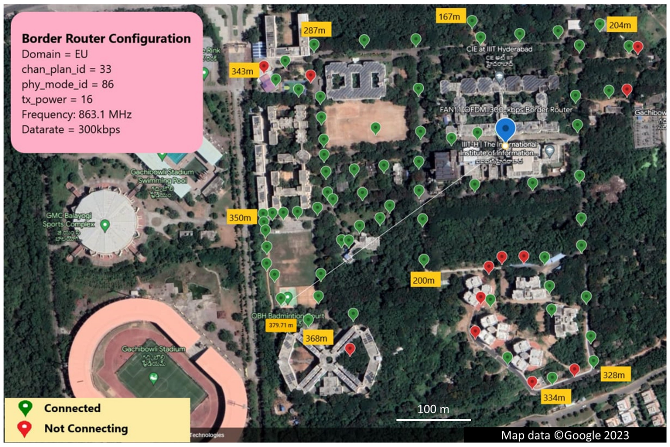


Fig. 1. Schematic of the Wi-SUN deployment on smart streetlights in the institute campus.

with low power wide area network (LPWAN) technology such as Wi-SUN, LoRa, etc., for various use cases, such as edge computing [5], to assist in solving the problem of effective communication in the era of 5G or 6G cellular network technologies because of relative advantages such as wide coverage, low power consumption and low cost [6], [7]. Similarly, Ouya *et al.* have explored the development of an efficient electric vehicle (EV) charging architecture based on LoRa communication [8]. Their study investigated the utilization of LoRa, a low-power, long-range wireless communication technology, for enabling communication between EV charging stations and a centralized management system. The authors emphasized the advantages of LoRa, such as its energy efficiency, extensive coverage range, and suitability for low-bandwidth data transmission in the context of EV charging. Ruiz *et al.* have developed EV charging infrastructure over PLS (Public Lighting system), project “TeleWatt”, and have shown using simulation that PLS are a promising solution for non-dedicated charging systems [9].

III. WI-SUN

In our development, Wi-SUN protocol was used to enable reliable and long-range communication between different nodes. It was chosen for its robustness and long-range capabilities, designed for smart utility and industrial applications. It operates on the IEEE 802.15.4g standard and offers reliable and secure communication [10].



Border Router Configuration
Domain = EU
chan_plan_id = 33
phy_mode_id = 86
tx_power = 16
Frequency: 863.1 MHz
Datarate = 300kbps

Fig. 2. Wi-SUN network connectivity and range test results on the campus map.

The Wi-SUN standard defines three different PHYs, with data rates varying from 50 kbps to 300 kbps. For the MAC layer, Wi-SUN adopts the Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA) mechanism, while the network layer utilizes RPL (Routing Protocol for Low-Power and Lossy Networks), which is specifically optimized for low-power consumption and multi-hop communication. However, RPL is prone to packet loss. The transport layer can be configured to operate with TCP/IP or UDP.

RPL is crucial in establishing a Destination Oriented Directed Acyclic Graph (DODAG) among the nodes. This algorithm computes the most efficient path for transmitting data packets from a source to a destination. In the event of any node going offline, the RPL protocol initiates a local repair process to restore the DODAG, ensuring that each node maintains at least one path to the root. In certain cases, this process may trigger a global repair, resulting in the recreation of the DODAG [11]. Each node within a typical Wi-SUN network assumes one of three roles:

1) Border Router: Oversees the network management (authentication, routing and so on), connects the Wi-SUN network to other IP-based networks, such as Ethernet, and acts as a root node of the DODAG.
2) Router nodes: Act as data forwarders to all the leaf nodes and router nodes connected to them in the tree.
3) Leaf nodes: Bottom-most nodes in the tree, send and receive data.

To set up the communication infrastructure, the Silicon Labs Wi-SUN SDK based on “EFR32MG12 2400/868-915 MHz 19 dBm Dual Band Radio Board (BRD4170A Rev A00)” was utilized. A campus-wide Wi-SUN network of streetlights was established in the institute campus, and the EV charger was set up to communicate over the same network. Fig. 1 shows the architecture for Wi-SUN deployment for this work.

The Wi-SUN network connectivity and range across the campus were tested using a single border router and a router node. The border router was configured to use OFDM with 300

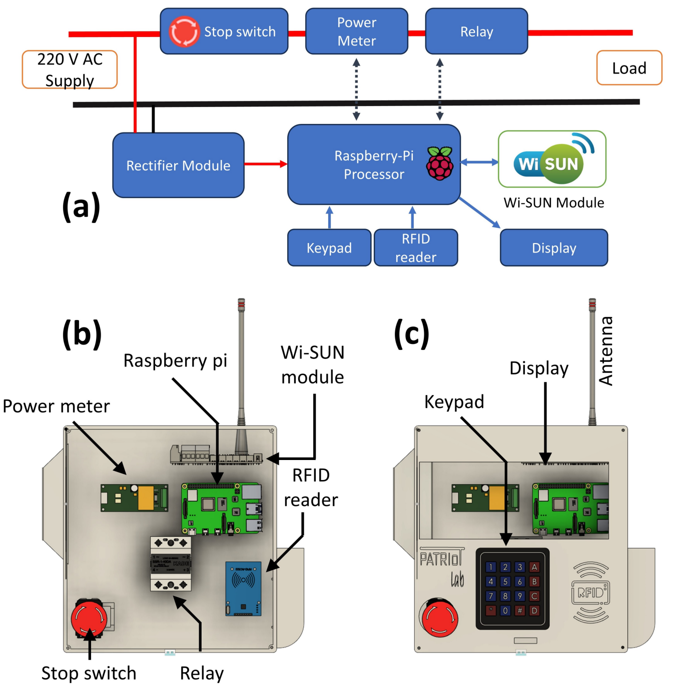


Fig. 3. (a) Block diagram of the EV charging system. (b) and (c) Design of the enclosure.

kbps data rate and was placed on the rooftop of the Himalaya building in IIIT campus. The router node was powered by a battery pack and carried to different locations on the campus. At each location, 200 ping messages of 250 byte size each were sent from the border router to the router node with a 3±1 s interval. The connectivity and range data were plotted on a map, as shown in Fig. 2. The maximum range achieved in this experiment was around 370 m (limited by the campus boundary).

IV. SYSTEM ARCHITECTURE

The hardware design of the EV charger is shown in Fig. 3. The design consists of a central processing module (Raspberry Pi 3B+), a user interface (keypad, RFID module, display) and a communication module (Wi-SUN transceiver). The dimensions of the enclosure are 25 cm×23.5 cm×8.5 cm. It has a 7-inch LCD touchscreen display at the front and a 3-pin output plug at the side to connect the load.

A. Data Flow

Upon booting, the charger establishes a connection with the Wi-SUN network. Once the connection is established, the user is greeted with a welcome screen on the display. Once the charger is in the operative state, the user can swipe an RFID card provided by the system operator. The user then enters the amount for which charging has to be done using the keypad. A user authentication service request is sent using the Wi-SUN network. The border router then sends the user authentication request to the cloud server for authentication and the charging starts once the request is approved.

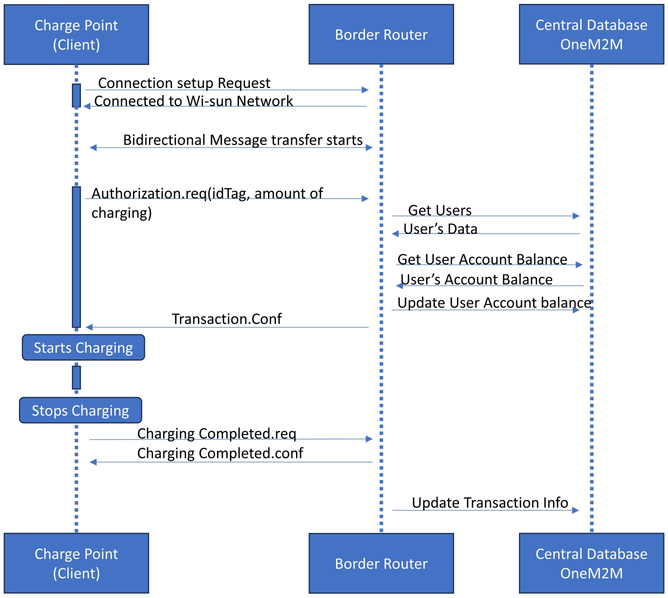


Fig. 4. Data exchange between the charge point, the Wi-SUN border router and the central database on oneM2M.

The communication between the EVCS and the border router follows the directives provided by the Open Charge Point Protocol (OCPP), an initiative by Open Charging Alliance (OCA), an international affiliate organization [12]. OCPP is an application protocol that establishes communication between the charging system (charge point) and the central management system (CMS) [13]–[15].

B. Authentication and Billing

Fig. 4 illustrates the transfer of information through the system. The authentication and billing process includes the transfer of data through the leaf nodes to the border router, which then sends a *GET* request to retrieve the registered user ID information. If the user is not registered, a “user not found” message is sent back to the node, else in case of successful user authentication, the system compares the user balance with the amount requested for charging and approves accordingly. In case of abrupt disruption of charging due to some emergency or electric power failure, the processor at the charging point works on an in-built battery backup to update the border router about the amount of charging completed. The border router later updates the user account balance accordingly.

C. oneM2M

To enhance the functional capabilities and to facilitate the horizontal flow of information across all smart city verticals, we have used the middleware platform called oneM2M. Using this platform, the EVCS can interact seamlessly with the rest of the smart city infrastructure; for example, an EV charger can stop charging services if a smart grid or smart fire alarms detect an electrical overload or fire hazard in the vicinity [16], [17].

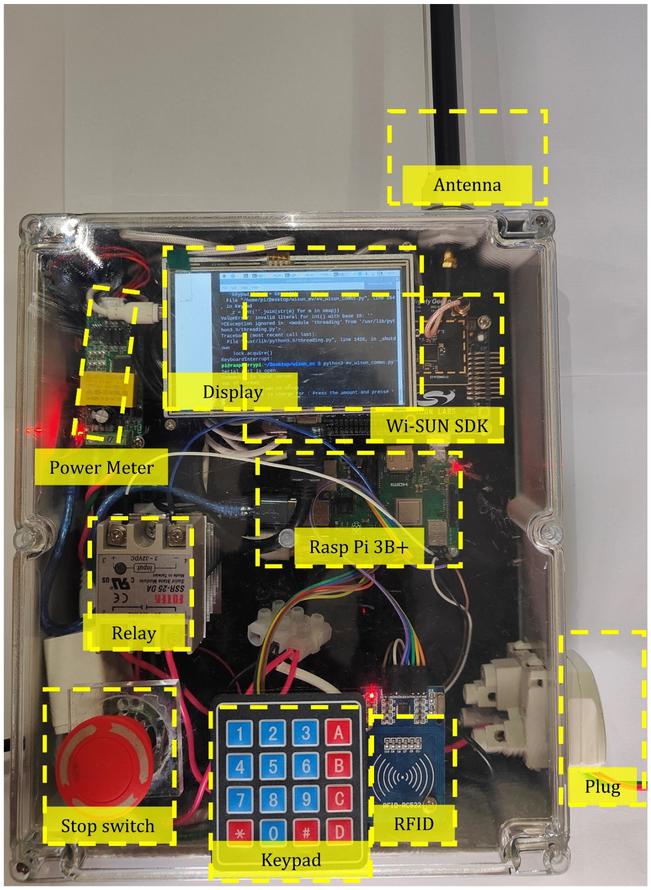


Fig. 5. Final deployed EVCS system.

D. Communication latency

The latency of the complete process from the user swiping the RFID card (authentication) to finishing the charging process (Billing) was calculated by repeating the charging process for multiple iterations. A load of 100 W and charging request for 0.9 Wh resulted in a charging time of 33±1 s, while the latency of the rest of the system including authentication, charging start and reset was found to be 0.7±0.2 s (excluding the time taken to charge).

V. CONCLUSION

In this study, we have developed a level 2 charging standard EVCS that utilizes the Open Charge Point Protocol (OCPP) over a Wi-SUN network integrated on streetlights, and oneM2M as the service layer. Fig. 5 shows the final deployed EV charger with all the components labeled. By integrating with oneM2M, the EVCS can effectively connect and exchange information with the wider smart city infrastructure. The proposed setup can be used to deploy a Wi-SUN connected network of charging stations across a local area, helping address the issue of lack of charging infrastructure. E-bike rental companies can also leverage this system at their parking stations across a wide geographical area. By combining OCPP, Wi-SUN, smart poles, and oneM2M, we provide a comprehensive solution that facilitates efficient, practical and widespread deployment of charging infrastructure for EVs. Further research directions include the use of information from disparate sources such as power grid, fire stations, etc. to stop charging at specific locations in the city based on a prevailing hazardous situation.

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