An Overview of AI-Enabled Remote Smart-Home Monitoring System Using LoRa

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***Abstract*– With the advancement of communication technology, Internet of Things (IoT) enabled smart home (SH) applications have engrossed substantial attention nowadays. However, a few meter range coverage and higher implementation cost are the main limitations of existing SH systems based on other cellular networks or short distance technologies. In this paper, a long range (LoRa) based SH system is proposed for remote monitoring and maintenance of IoT sensors and devices using artificial intelligence (AI) concept. A brief overview of what tasks LoRa can perform in SH networking are conferred. An AI-based data flow system for IoT server and cloud is also presented in this paper.**

***Keywords*– Low-power, wide area network (LP-WAN), internet of things (IoT), long range (LoRa), smart home (SH), artificial intelligence (AI).**

I. INTRODUCTION

Internet of Things (IoT) is a communication paradigm that connects devices and objects in order to harvest and process data produced by several edge devices [1]. It is predicting that with the current flow, the number of connected devices to the internet will be over 75 billion by 2025. It is predicted in [2] that the number of industrial IoT devices used for sensing, tracking, and controlling using low-power, wide area network (LP-WAN) will ascent close to 0.5 billion by 2025. These massive connected IoT devices are expected to enforce enormous demand of channel capacity of the growing number of (LP-WAN) technologies [2], [3]. The LP-WAN technologies which are currently trading the markets are: Long range (LoRa), Sigfox, narrow-band IoT (NB-IoT), LTE-machine type communication (LTE-M), extended coverage global system for mobile communication (EC-GSM), random phase multiple access (RPMA), my-things (MIOTY), and DASH7. Wherein, LoRa, Sigfox, RPMA, MIOTY uses the unlicensed spectrum and others are based on cellular licensed spectrum. Fig. 1 depicts the list of LP-WAN technologies separated by the types of spectrum used. The respective downlink data rate and operating bandwidth are also mentioned in this figure. The unique characteristics of those LP-WAN technologies can be pointed as below:

- covers wide area providing long distance communication,
- devices consume very low power,

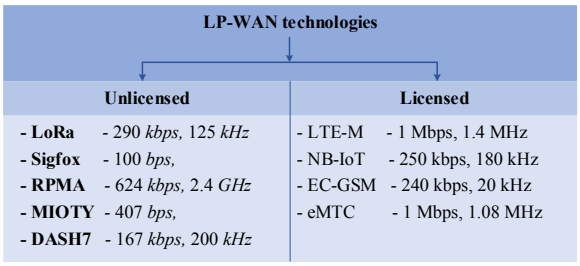

Fig. 1. List of existing LP-WAN technology protocols along with downlink data rate and bandwidth.

- low data rate,
- low deployment cost.

These network protocols have already shown the satisfactory performances in suitable sectors of diverse IoT applications [4]. The various sectors including but are not limited to transportation, healthcare, agriculture and industry where it is expected to exploit the features of LP-WAN technology. Remote patient monitoring, smart cities, smart grids, traffic lighting control and metering systems are among the applications that require communications over a large geographical area based on cheap and low-power devices. Such devices can be deployed and moved around over a wide area with the support of LP-WAN [1], [2], [5], [6].

Specifically, remote smart home (SH) monitoring systems are achieving great popularity in order to enhance the comfort and quality of life. These systems require smart IoT sensors network to sense, transmission, and control the home environment, supplies, and instruments. The devices should consume very low power and the network provider have to cover longer area to support remote monitoring. The existing short-range wireless technologies such as ZigBee [7], RFID [8], Wi-Fi [9], and Bluetooth low energy (BLE) [10] are not suitable for the applications where long range communication is required even though they consume very low power. Moreover, the conventional cellular networks consume large amount of power for large coverage area and higher manufacturing cost [11]. Therefore, to support remote control and monitoring of SH equipment among the other LP-WAN technologies LoRa is the most suitable in terms of both long range and low power consumption as the channel throughput requirement is reasonably low for this system [12].

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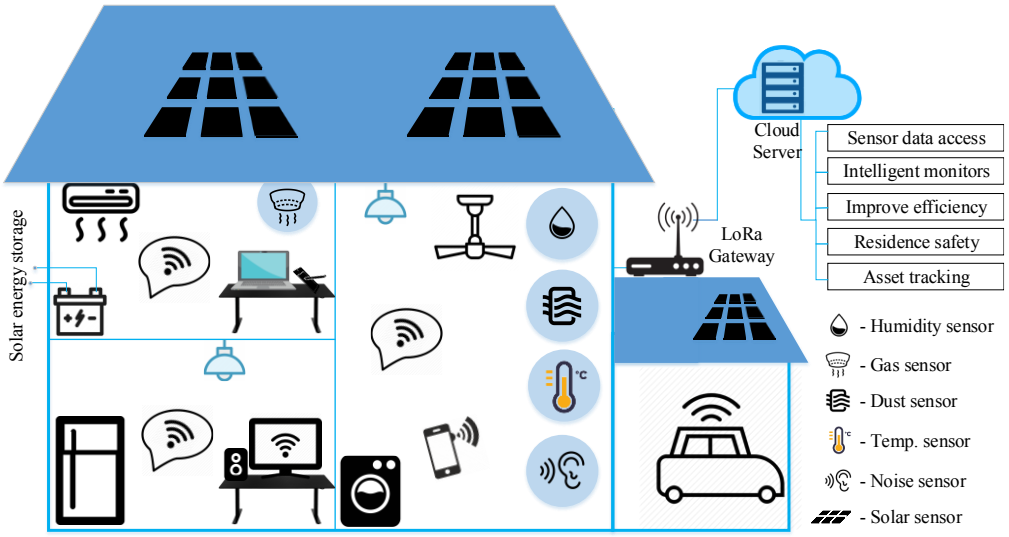

Fig. 2. Smart home monitoring system based on LoRa.

In this paper, a long range (LoRa) based SH system is proposed for remote monitoring and maintenance of IoT sensors and devices using artificial intelligence (AI). A brief overview of what tasks LoRa can perform in SH networking are conferred. An AI-based data flow system for IoT server and cloud is also presented in this paper. The rest of the paper is organized as follows. A SH network architecture based on LoRa is provided in Section II. AI-based cloud and data servers and their data flow are described in Section III. The reason behind choosing LoRa and its advantages over other technologies are briefly discussed in Section IV. In Section V, deployment challenges and future research issues are discussed in brief. Finally, the paper contributions are summarized in Section VI.

II. Smart Home Network Architecture

Home automation is nowadays becoming a part of leading quality life with the development of technology and IoT devices all over the world. SH applications would affect and change our daily lives in terms of security, comfort, convenience, power, cost, and energy savings. We already have top companies spreading the SH IoT products in the world market for example, Amazon Echo, Google Home, Bitdefender Box for security, Nest products (thermostat, cameras, lock, and alarming systems), Philips Hue, Linquet sensors, Logitech smart controller, etc. Smart lighting system can detect when and where occupants are in the room and adjust the lights dimming and direction as needed. Smart thermostats allow users to schedule, monitor, and remotely control the home temperature. Smart doors and security cameras can detect residents to improve proper safety and security of the home. Other SH or kitchen appliances such as refrigerator can keep track of expiration dates and set notification to the users.

Fig. 2 illustrates such kind of SH system enabled with LoRa networking system that can be monitored remotely. This system includes smart environmental sensors (i.e., humidity, temperature, gas, dust and noise sensors) and other IoT-enabled home appliances. All the IoT sensors and devices are set to take power from solar smart energy storage system (i.e., solar panel and battery). An artificial intelligent (AI) based data server can be designed to control and monitor the home appliances. All the sensors and IoT devices data are sent periodically to the data center of that server by using LoRa gateway. By necessary training of the system the devices can predict the required control and precaution. The possible power efficient control and monitoring strategies of LoRa based SH system are described below [13]:

- LoRa uses unlicensed spectrum and that supports both private and nationwide networking.
- Updates over air is possible for few LP-WAN technologies and LoRa-WAN is one of them.
- This technology is licensed by device vendors. Hence no payment is required to the network operators.
- Some operators have already give a trial of this technology proving its feasibility.
- Being operated in lower bandwidth the data rate may not be an issue because home automation services demands very low data rate.

III. AI-based Cloud & Server Architecture for LoRa

AI-based dataflow design for LoRa-enabled SH IoT system has been presented in Fig. 3. The Sense HAT is an add-on board for the Raspberry Pi. The board allows to make measurements of temperature, humidity, pressure, and orientation, and to output

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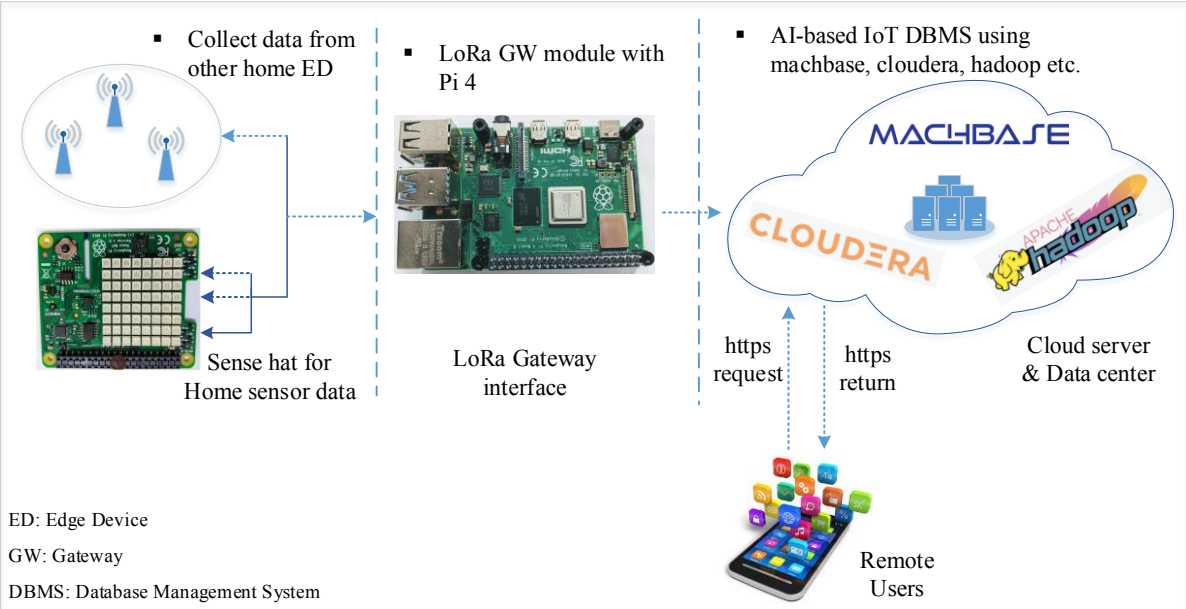

Fig. 3. Dataflow design for the LoRa-based home monitoring using artificial intelligence.

information using its built-in LED matrix. Hence, this board can be used along with other gas, dust, stored energy, noise sensors, and other SH appliances to the network. These smart sensors can produce vast amount of data that are sent to cloud and data server through LoRa gateway for further processing with AI.

Cloudera is an open source platform with open compute architectures and data storage. It supports on-premises, public and multi-cloud deployment. Multi-function data analytics, governance, and metadata management with vast amount of data generated by SH devices over a long period can be performed with Cloudera. When enormous amount of structured and unstructured data need to be processed, Hadoop framework can be a solution to provide parallel processing with distributed storage. In addition, Machbase is a database management system which can rapidly manage large volume of data in real-time. Hence, the next task is building an accurate machine learning model by using those vast amount of IoTs' data for predictive maintenance, enhanced security, voice controlled appliances etc., using such IoT and big data platforms. Various tasks that can be performed in AI powered SH system are summarized below:

- *Predictive maintenance* – Using data analytics of service equipment possibility of failure or damage can be predicted. That's help to mitigate unplanned damage.
- *Maximum efficiency* – AI-based IoT system can learn house owners' behavior and automatically modify settings to provide residents with maximum comfort and efficiency. Also these systems can notify users about any vulnerable situations.
- *Improving security* – AI-based face and key recognition system would help to make door lock security in home automation.
- *Enhancing services* – Natural language processing based on AI would help the IoT devices and home appliances to control with voices.

IV. LoRa Over Other LPWA Networks

LoRa is a physical layer proprietary LP-WAN technology that modulates the signal in sub-GHz Industrial, Scientific, and Medical (ISM) frequency band. This is developed and commercialized by Semtech Corporation [14]. It can be implement for commercial usage as well as personal home network at very cheaper rate compared to other technologies [15]. This is a bidirectional communication that is provided by a special chirp spread spectrum technique. At the medium access control layer, a simple ALOHA scheme is used that is combined with LoRa physical layer. This enables multiple device to communicate simultaneously using different spreading factors. No extra signaling overhead is required to hop any end users. End devices are linked with the LoRa access point via a backhaul to network server that suppresses duplicate receptions, adapts radio access links, and forwards data to suitable application servers. The application servers then process the received data and perform as user requests to the server. The bandwidth requirement for this technology is quite flexible and that can be varied in 7.8~500 kHz range. The battery lifetime can be more than 10 years. Moreover, LoRa can cover up to 15 km in suburban area and up to 5 km in urban area. The most significant advantage of LoRa technology for small application like home automation is that it

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uses unlicensed spectrum although it provides slightly lower data rate compared to other popular LP-WAN technologies.

V. CHALLENGES & RESEARCH DIRECTION

A major challenge in LoRa-WAN is the data rate this networking system can provide. Very low data rate and short payload size are provided by ultra-narrowband modulation in the shared ISM bands. Hence supporting the use cases which requires higher data rate, the development of multiple modulation schemes that provides higher data rate is a challenge to be meet up.

Increased number of devices will case higher level of interference to each other. Same shared ISM bands and densely deployed LoRa access points cause cross technology interference and self-interference.

Low power end devices use simple ALOHA channel access scheme may deteriorate performances.

Interoperability is a major challenge for deploying LP-WAN technologies because open source frameworks are not widely available.

VI. CONCLUSION

Wide area coverage, low power consumption, and inexpensive wireless connectivity are the main characteristics of LP-WAN systems. LoRa is considered cheaper and longer battery life among other LP-WAN technologies that can be best suitable for remote operations in an IoT-based SH presented in this paper. LoRa integrated with AI learning models for IoT servers and clouds could serve intelligent tasks in home environment. A dataflow design for the LoRa-based home monitoring using AI was presented. The advantages of using LoRa technology for home automation over other LPWA networks were also summarized in this work.

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