Wi-Fi HaLow: Literature Review About Potential Use Of Technology In Agriculture And Smart Cities in Indonesia

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***Abstract*— The development of communication technology has played an integral role in the transformation of various sectors of life, including agriculture and smart cities. One of the latest breakthroughs in wireless networking is WiFi HaLow, a WiFi standard with low speed and efficient power consumption. With wider coverage and high resistance to interference, WiFi HaLow can support the implementation of smart agricultural sensors and IoT (Internet of Things) devices on agricultural land. This can improve crop monitoring, optimize irrigation, and reduce overall resource use.The implementation of WiFi HaLow can also change the face of cities in Indonesia towards smart cities. With its ability to handle large data traffic and stable connections, WiFi HaLow can support smart infrastructure such as smart street lights, waste management and efficient traffic management. In this way, cities can become more efficient, sustainable and environmentally friendly.However, implementing WiFi HaLow in Indonesia also challenges several obstacles, including regulations, data security and infrastructure investment. Therefore, government, industry and other stakeholders need to work together to create an environment that supports the development of this technology.**

***Keywords*— Wi-Fi, Halow, IoT, 802.11ah**

I. Introduction

The development of information and communications technology (ICT) has brought about fundamental changes in the way we interact with the world around us. Wi-Fi, as a wireless technology that has become the backbone of modern connectivity, has enabled wireless internet access in various environments, from homes to public places[1]. The success of Wi-Fi in providing fast and easy-to-access internet access has shaped people's behavioral patterns in using various connected devices[2].

At the same time, the Internet of Things (IoT) has emerged as a new paradigm in the world of technology[3]. IoT involves connectivity between devices to enable broader and intelligent data exchange. One of the main challenges in IoT implementation is ensuring reliable and energy-efficient connectivity, especially for devices that work for long periods of time without frequent battery changes. It's time to introduce Low-Power Wide-Area Network (LPWAN), a technology specifically designed to support IoT by offering long range and low power consumption[4].

Wi-Fi HaLow emerged as an innovative solution to meet IoT connectivity needs. This Wi-Fi standard was developed with a focus on wider range, better wall penetration, and high power efficiency. This makes Wi-Fi HaLow an attractive option to support the growing IoT ecosystem in various sectors, from healthcare to manufacturing[5].

Indonesia, as a country with a large and geographically diverse population, has unique challenges in providing equitable connectivity. Wi-Fi HaLow offers the potential to overcome these obstacles by providing reliable connections, especially in areas that are difficult to reach by conventional wireless technology. In addition, the potential for Wi-Fi HaLow in supporting key sectors such as agriculture, health and smart cities in Indonesia is enormous, which can open the door to broader and more inclusive technological innovation. This research aims to examine the potential for using WiFi Halow technology in Indonesia based on the needs and development of IoT technology in Indonesia.

II. Literature Review

A. Wi-Fi Standart

First, Currently WiFI (IEEE 802.11) has several standards including 802.11 a/b/g, Wi-Fi 4, Wi-Fi 5, Wi-Fi 6, Wi-Fi 6E, and WiGig. Wi-Fi 4, also known as 802.11n, was introduced in 2009 and operates on both 2.4 GHz and 5 GHz frequency bands. Wi-Fi 5, also known as 802.11ac, was introduced in 2014 and operates on the 5 GHz frequency band. Wi-Fi 6, also known as 802.11ax, was introduced in 2019 and operates on both 2.4 GHz and 5 GHz frequency bands. Wi-Fi 6E is a variation of Wi-Fi 6 that adds a 6 GHz radio band in addition to the 2.4 GHz and 5 GHz bands. WiGig, also known as 802.11ad, operates on the 60 GHz frequency band and is designed for high-speed data transfer over short distances[6][2].

As a part of the Wi-Fi portfolio, Wi-Fi HaLow enables a more encompassing strategy for wireless connectivity. It brings forth numerous advantages familiar to Wi-Fi users, such as seamless interoperability between different vendors, straightforward setup without interference with current Wi-Fi networks, and state-of-the-art Wi-Fi security. Wi-Fi HaLow collaborates with various other Wi-Fi technologies to furnish low-power, high-performance, and secure wireless connectivity, broadening the spectrum of options available for diverse IoT environments[5].

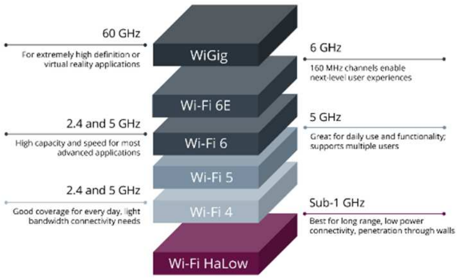

Fig. 1. Wi-Fi Standart[5]

B. *Wi-Fi HaLow*

Wi-Fi Certified HaLoW is a label assigned to products that have been certified to integrate IEEE 802.11ah technology. This enhances standard Wi-Fi functionality by utilizing frequencies below 1 gigahertz (GHz), providing extended reach and more energy-efficient connectivity. Wi-Fi HaLow is specifically designed to address the distinct needs of the Internet of Things (IoT), facilitating diverse applications in industrial, agricultural, smart building, and smart city settings.

Wi-Fi HaLow facilitates the low-power connectivity essential for various applications, such as sensor networks and wearables. It boasts a greater range compared to numerous other IoT technology choices and ensures a more resilient connection in demanding environments where the capability to penetrate walls or obstacles is a crucial factor[5]. Features and Benefit can be seen in Table 1.

TABLE I. WI-FI HALOW FEATURES AND BENEFITS[5]

Feature	Benefits
Sub 1 GHz Frequency Operation	Long Range : Approx 1 km
Narrow Band OFDM Channel	Penetration through walls and other obstacles
Several Device Power Saving Modes	Support coin cell battery device for month or year
Native IP Support	No needs propiertary hubs or gateway
Certified With Wi-Fi Security	Easy to install because wireless

III. POTENTIAL OF WI-FI HALOW FOR AGRICULTURAL AND SMART CITIES IN INDONESIA

A. *Wi-Fi HaLow as LPWAN*

The commonly known Wi-Fi range, operating under the 802.11 a/b/g/n standards, functions at either 2.4 GHz or 5 GHz frequencies. At these frequencies, the range of radio waves is comparatively limited when compared to lower frequencies. Specifically, at 2.4 GHz, the waves cover a distance of less than 259 m (820 feet)[1][2]. In contrast, LPWAN typically achieves a range between 1 km to 10 km[3]. Furthermore, barriers such as walls and doors within a building can obstruct higher-frequency waves (2.4 GHz or 5 GHz).

Illustrated in Figure 2, the operational range of Wi-Fi HaLow spans from 1 MHz to 16 MHz channels. Waves in the 1 MHz channel exhibit an extended travel distance, whereas the 16 MHz channel facilitates higher data transmission rates. The 16 MHz channel, in particular, can achieve a maximum speed of 80 Mbps[4].

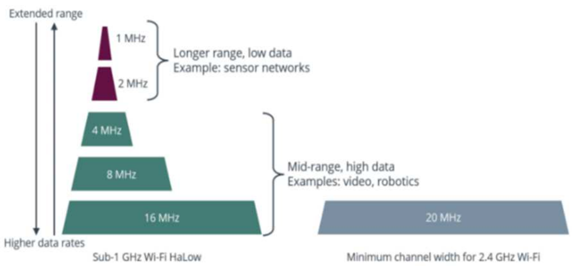

Fig. 2. Wi-Fi HaLow Channel Bandwidth[8]

B. *Wi-Fi Halow Simple Comparison*

According to [9], Wi-Fi HaLow can reach more than 80 Mbps in short range , and 150 kbps at 1 km distance , in comparison with other IoT Technology it can be seen in Figure 3 the graphic about data rate and range with technology LoRaWANm NB-IoT, Wi-SUN, Bluetooth Low Energy (BLE), Zigbee, and Sigfox[9].

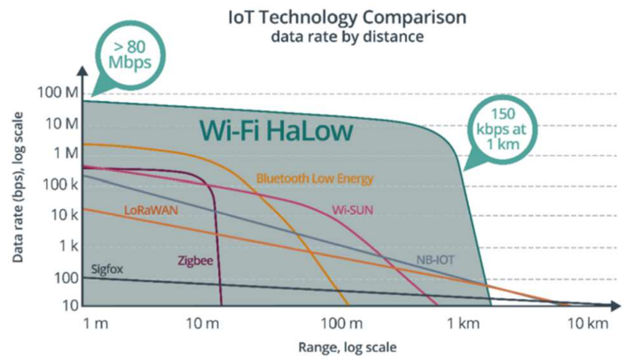

Fig. 3. Wi-Fi HaLow : IoT Network Comparison [5]

C. *Wi-Fi HaLoW Regulation in Indonesia*

Wi-Fi HaLow regulations in Indonesia are still not clearly regulated in accordance with the standards contained in international standards, for example, according to [11] the frequency and bandwidth rules if Wi-Fi HaLow is included in LPWAN, it can be seen in table 2.

TABLE II. LPWAN FREQUENCY AND BANDWIDTH[11]

Spectrum Frequency	Bandwidth maximum each channel
433,05 – 434,79 MHz	125 kHz
920 – 923 MHz	250 kHz
2400 – 2483,5 MHz	1 MHz

Apart from that, if Wi-Fi Halow is included in the Radio Local Area Network (RLAN) section, the frequency and bandwidth are in accordance with regulations [11] which can be seen in table 3.

TABLE III. RLAN FREQUENCY AND BANDWIDTH[11]

Spectrum Frequency	Bandwidth maximum each channel
2400 – 2483,5 MHz	20 & 40 MHz
5150 – 5250 MHz	80 MHz
5250 – 5350 MHz	80 MHz
5150 – 5350 MHz	160 MHz
5725 – 5825 MHz	20 & 80 MHz
57 – 64 GHz	2,16 GHz

Based on table 2, the LPWAN frequency is in accordance with the Wi-Fi HaLow standard at frequency 920 -923 MHz because Wi-Fi HaLow has a Sub 1 GHz standard, but there is a problem with bandwidth where Wi-Fi HaLow requires a minimum bandwidth of 1 MHz whereas in LPWAN regulations 920-923 MHz only has a maximum bandwidth per channel of 250 kHz. In table 3 of RLAN communication there are also no frequencies included in the Sub 1 GHz category, however in this frequency group there is 1 frequency at 2.4

GHz with a maximum bandwidth per channel of 20 & 40 MHz where this frequency is used by other Wi-Fi standards .

To overcome this problem in document [11] the Short Range Device (SRD) group is also explained with various frequencies, one of which is the frequency that intersects with LPWAN, namely the frequency 920 – 923 MHz without being limited to a minimum bandwidth per channel. This can be used as a basis for Wi-Fi HaLow frequencies in Indonesia, provided that Wi-Fi HaLow is not included in the LPWAN network group but is included in the SRD group. According to [11], networks included in the SRD group are Telecommunications Equipment and/or Telecommunications Equipment that have a low risk of causing harmful interference.

D. Wi-Fi HaLow for Agriculture Sector

Several studies regarding the use of Wi-Fi technology in the agricultural sector in Indonesia are quite diverse, such as in the fields of field agriculture[12][13][14][15][16], Farming/poultry[17][18][19][20][21], greenhouse[22][23][24][25][26],aquaculture[27][28][29][29], hydroponics[30][31][32][33] and other research that supports technological development in Indonesia.

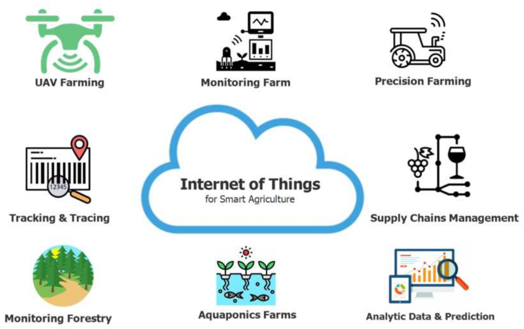

Fig. 4. IoT Solution in Agriculture[6]

Some of this research uses Wi-Fi connectivity to transmit sensor data and control actuators with the advantages of real-time monitoring and control, ease of installation of devices and equipment commonly found on the market. However, in the use of Wi-Fi networks, some of this research is limited by the reliability of communication over long distances, so it requires more costs to create a Wi-Fi-based IoT system if you have a large agricultural area.

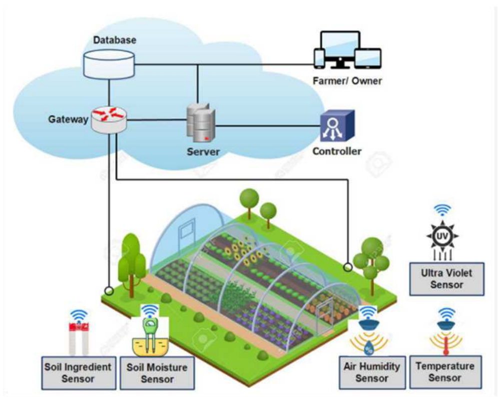

Fig. 5. llustration of IoT application for monitoring farming conditions in a greenhouse using Wi-Fi Connectivity[34].

WiFi HaLow contributes to solving power issues associated with sensors in agriculture by operating at low power, enabling sensors to utilize batteries effectively. In research by [35] conducted testing to better understand how the range of Wi-Fi Halow could perform in rural environments. This test utilized the Morse Micro MM6108-EKH01 Wi-Fi HaLow evaluation kit on two farms in Southern Australia to determine the maximum range to cover IoT sensors, actuators, and cameras across paddocks and pastures.

The initial tests revealed several significant findings. Firstly, Wi-Fi HaLow displayed impressive resilience up to a distance of 2 km in scenarios with a clear line of sight, with the potential for further extension under specified configurations. Secondly, in shorter paths without a direct line of sight, the technology maintained effective performance, possibly due to factors such as knife-edge diffraction or scattering caused by vegetation. While fluctuations in throughput were noted, potentially influenced by factors like the movement of people, equipment, and foliage, these variations had minimal overall impact throughout the conducted tests.

A notable advantage of Wi-Fi HaLow is its elimination of the need for proprietary hubs or gateways. This feature allows a single access point to support over 8,000 IoT devices, making it particularly beneficial for applications such as livestock monitoring or field condition surveillance. Additionally, with long-range connectivity spanning over 1 km from the access point and the ultra-low power consumption of Wi-Fi HaLow, IoT devices can operate on batteries for extended periods, offering significant advantages for the deployment of IoT infrastructure in agricultural settings.

E. Wi-Fi HaLow for Smart City

A Smart City is essentially the use of technology to make cities smarter and more efficient in utilizing resources (saving costs and energy), improving services and quality of life and thereby reducing the ecological footprint, supporting innovation and a low carbon economy[36]. IoT can help develop smart cities in several fields such as utilities, infrastructure and also health facilities.

Some research about that can use Wi-Fi Connectivity as a IoT Network. In utilities [37][38][39][40] some case use Wi-Fi for first connectivity in research, but the next research using LPWAN network for the connectivity so Wi-Fi HaLow has the opportunity to be used in this use case. However Wi-Fi HaLow is more suitable for use in dense urban areas that have a high building density with coverage that can reach around 1 km.

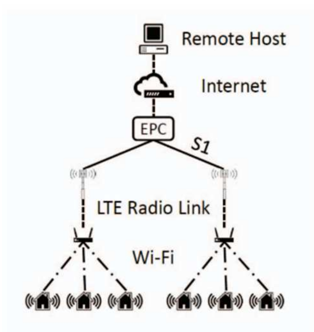

Fig. 6. IoT Solution for Smart Meter[6]

IoT smart cities incorporate smart infrastructure to enhance efficiency and sustainability. This includes smart grids for optimized energy distribution, smart lighting systems that adjust the brightness based on usage and conditions, Smart home, and Smart building for the smart cities[42].

Fig. 7. IoT Solution for Smart Building[6]

Wi-Fi HaLow can facilitate connectivity needs with good bandwidth in building and home areas, so that it can connect several devices in these areas such as camera sensors, house and building control, room temperature control (requires real-time connectivity) and so on[3][44].

IV. Conclusion

Based on literacy results, it is known that Wi-Fi HaLow has quite good potential for the development of IoT technology in the fields of agriculture and smart cities in Indonesia, although from a regulatory perspective it still requires more in-depth study in terms of frequency and bandwidth, but this does not reduce development HaLow Wi-Fi technology in Indonesia by including it in the SRD group with provisions in accordance with regulations in Indonesia.

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