ISSN- 2394-5125 VOL 09, ISSUE 01, 2022

Study and development of medical/nursing care support classification Using Radar technology and Hybrid WSN

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Abstract - As the world's population ages, medical and nursing care facilities are becoming more reliant on fewer and fewer employees. COVID-19, which took place in 2020, was confronted with the worldwide dilemma of failing medical practise under such conditions. The fear of a COVID-19 pandemic has brought home to people all across the globe just how critical it is that health care workers take precautions to avoid being infected. Observing the state of patients and care receivers without direct interaction is regarded very useful from this perspective. Using a combination of 24GHz radar and numerous Wireless Sensor Network devices, we will use this study to gather vital signs like breathing and heartbeat in a facility without making physical touch with the subjects. With our hybrid wireless sensor network technology, we can monitor the health and well-being of patients and care receivers across the institution, as well as outlying areas and suburbs. Data from each room's 24GHz radar signals will be shared in real time by using a high-speed mesh Wi-Fi network throughout the facility. The identification of passenger activity, breathing, and heartbeat by analysing radar signals is one of our challenges since cameras, which are difficult to place in the field owing to privacy concerns, and sensors worn by the subject must be avoided. If a patient or resident has left the institution, the Wi-SUN FAN mesh network in the vicinity of the facility with a radius of approximately 500 metres may be used to determine the current state of the resident's walking area. In addition, in the suburbs, individuals without cellphones will be able to access their position data through a LoRaWAN tiny terminal. In this research, we present the Hybrid Wireless Sensor Network platform for medical and nursing care locations based on 24 GHz radar sensing technology and hybrid wireless sensor network technology, as previously stated. This technology will be put to the test in a real nursing home, and the results will be presented

Keywords - WSN, HybridWSN, FM-CW, Wi-Fi, Wi-SUN, LoRaWAN.

I. Introduction

In affluent nations, the proportion of the population over the age of 65 now stands at 20 to 25 percent, but this figure is predicted to rise to 25 to 35 percent by the year 2040 as the population ages. A shortfall of more than 370,000 caregivers is expected in Japan by the year 2025. Human resources are projected to be in limited supply, particularly in metropolitan regions. Dementia affects roughly 50 million individuals throughout the globe now, and there are an estimated 10 million new cases each year. It is projected that these concerns would grow increasingly significant over the world in the medical and nursing care sectors.

COVID-19, which took place in 2020, was confronted with the worldwide dilemma of failing medical practise under such conditions. The fear of a COVID-19 pandemic has brought home to people all across the globe just how critical it is that health-care workers take precautions to avoid being infected. As a

ISSN- 2394-5125 VOL 09, ISSUE 01,

result, it is thought to be incredibly beneficial to identify the state of patients and care receivers as much as possible without interaction.

The 24GHz radar sensing technology is combined with several wireless sensor networks in this study to capture non-contact data on the facility's living behaviour and biological data, such as breathing and heartbeat. We'll build a medical/nursing hybrid sensor network platform that can monitor patients and care receivers across the hospital, as well as outlying areas and suburbs. Multi-hop real-time sharing of 24-GHz radar signal data will be made possible at the facility through a fast Wi-Fi mesh network. When a patient or resident leaves the institution, the Wi-SUN FAN mesh network may be used in an area with a radius of roughly 400 metres to determine their current location. Residents without cellphones in the distant suburb zone may have their position data managed centrally using GPS data from a tiny LoRaWAN terminal. A hybrid wireless sensor network platform for medical and nursing care facilities is proposed in this study using 24 GHz radar sensing and hybrid wireless sensor network technology, as previously stated. The findings of a real-world field experiment of this technology at a nursing home will be presented in this article.

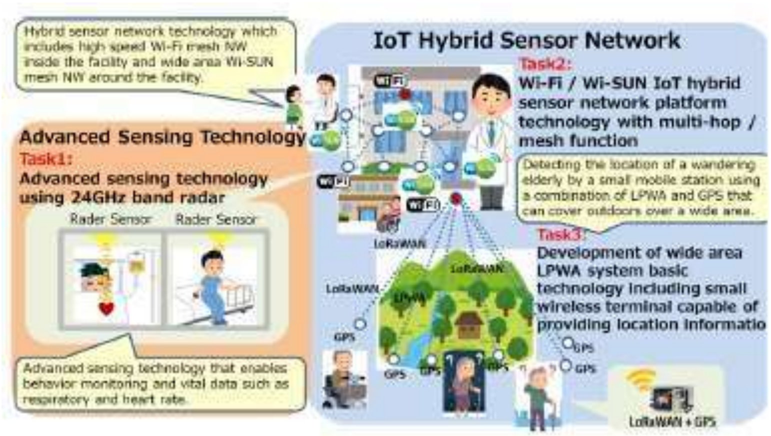

Figure 1: Hybrid Wireless Sensor Network System for Medical/Nursing Care with 24GHz Radar

II. 24GHz Radar Sensing

Because privacy is an issue in medical treatment, we utilize 24GHz radar instead of a camera to monitor a patient's actions (such as sleeping, sitting, and falling) in their room. We'll also be able to monitor heart and breathing rates without the need of touch sensors. Radar technology uses FM-CW (Frequency Modulated Continuous Wave) radar. Using the amplitude and phase components of the distance spectrum, it is feasible to detect a very small displacement.

Breathing and heart rate are recorded using minute displacement, while behaviour is assessed using distance. ARIB STD-T73, a standard for low power radio stations that do not need a licence, is used to set the radar's centre frequency at 24.15 GHz and all other configuration settings.

A Life behavior detection

The 24GHz FM-CW radar described above may be used to identify the living behaviour of a resident without the need of image analysis by a camera, which has a privacy concern. Nursing home residents were used as subjects for an experiment. When a 24GHz radar sensor is mounted on the ceiling (2.4m high) at the living room's entryway, a measurement is made to determine the resident's living habits.

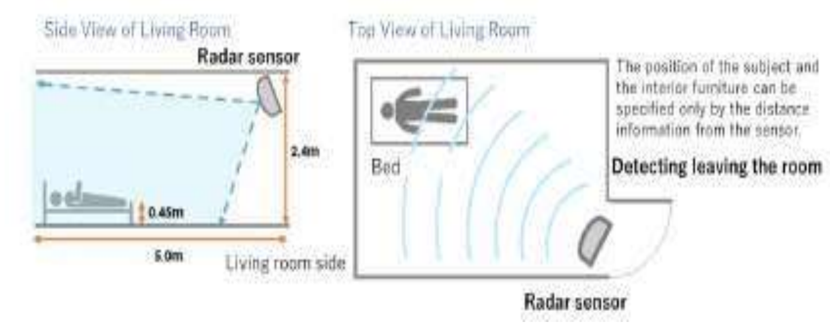

Figure 2: Installation of radar sensors in genuine nursing homes

We'll go through how to look for certain patterns in the behaviour of living things. The resident of the above-mentioned experimental environment performs five fundamental motions that we categorise as "on bed," "walking," "crouching," and "falling," and we look for continuous movements that combine these movements. First Table 1.

Table 1: 5 Life Behavior Definitions

	On the Bed	On the Floor			
Life Behavior	sleeping	walking	crouching	falling	absence

Installing a camera and a radar sensor in the living room allows researchers to determine whether or not the real behaviour being seen can be appropriately identified and utilised as a standard for comparison. Our machine learning model was built utilising the radar sensor's data and Keras, an open source neural network framework for the model, to analyse the subject's live behaviour. This machine learning model was created on a single board computer coupled to the sensor in the experimental setting. For the machine learning model, we utilised data from ten adults, three from each sexe, who were tested three times each for five distinct patterns of behaviour. Table 2 shows that the five most common forms of conduct were recognised at a specific level of accuracy.

Table 2: Basic 5 definition of Life Behavior

	On the Bed	On the Floor				average
Life Behavior	sleeping	walking	crouching	falling	absence	
Recognition rate	82.5%	72.8%	38.6%	45.0%	83.8%	75.5%

B *Respiratory rate detection*

The detection of respiratory rate will be explained first as a method for obtaining crucial data without having to make physical touch with the person, such with a wearable device. An FFT analysis of the FM-CW radar's time-varying phase component of the distance spectrum is initially used to identify a small change in the target's breathing rate.

An FM-CW radar sensor positioned on the ceiling emits a 24 GHz signal, and the top left figure depicts the temporal change of the phase component of the spectrum.

The data produced by transforming this distance spectrum's time change data into the frequency domain by FFT processing are shown in the graph below. The highest value of this data is used to determine the usual breathing rate of an adult at rest, which is between 8 and 24 breaths per minute. A respiratory rate of 11.6 breaths per minute was recorded in this case.

We compared our radar's estimated respiration rate to a wearable sensor's estimated respiratory rate in order to verify its accuracy.

III. Hybrid Wireless Sensor Network System

Many approaches have previously been suggested for WSN (Wireless Sensor Networks) networks, including some currently classed as LPWA (Low Power Wide Area) (Low Power Wide Area).

Wireless sensor networks were built in each of three zones: within the institution, surrounding it and outlying it. We then performed a demonstration experiment to show how a hybrid wireless sensor network may be used in medical and nursing care facilities, based on real use cases.

A Wireless sensor network around the facility (Zone2) (multi-hop Wi-SUN FAN network)

To convey periodic still photographs and other data throughout the facility, we will establish a wireless sensor network with a specific data speed and a radius of roughly 400 m. Due to the data rate limitations of the typical LPWA (Low Power Wide Region) approach, it is impossible to cover such a large area using Wi-Fi. We utilised Wi-SUN as a WSN for Zone2 because of these kinds of requirements.

While the Wi-SUN system's communication range is less than other LPWA systems, the data throughput is comparable to other LPWA systems, and multi-hop is supported, making it a viable alternative. An experiment with one-hop Wi-SUN FAN communication in a real elderly home may be shown in Figure 3. Figure 3 shows that the Wi-SUN FAN 1-hop connectivity was verified within the 400 m visible range of the installation. Furthermore, the Wi-SUN FAN's multi-hop capability enables communication even when the Wi-SUN FAN is not directly in line of sight.

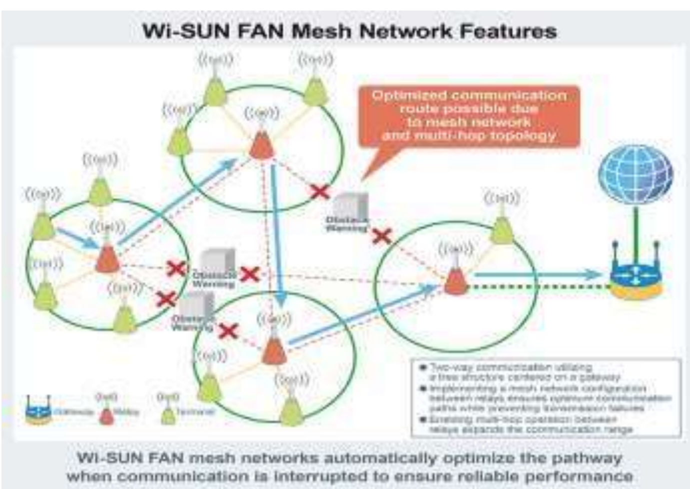

Figure 3: Wi-SUN FAN network coverage in one hop around the site (Zone2)

Wi-SUN FAN is used to demonstrate a still image transmission experiment. As previously mentioned, we ran an experiment in which a still picture that is difficult for standard LPWA to communicate was sent on a

ISSN- 2394-5125 VOL 09, ISSUE 01,

regular basis. A still picture captured by a Web camera with 1,2 million pixels, as illustrated in Figure 4, may be delivered about once per minute.

In Zone2, the Wi-SUN FAN network allows for the transmission of still picture data every minute, which is otherwise impossible with Wi-Fi or the conventional LPWA system owing to data speed limitations. A function of monitoring a hazardous location surrounding the facility may be accomplished without Wi-Fi or mobile network, for example, when the care receiver of the institution leaves.

Figure 4: Wi-SUN FAN still image transmission Experiment

B Wireless sensor network in the suburbs of the facility (Zone3) (LoRaWAN)

Assume a 10 km radius around the site while creating a wireless sensor network for monitoring. Sensor networks that value distance over speed, such as identifying when a facility resident has left the suburbs, are assumed to be in place. LoRaWAN is employed here, despite the fact that other LPWA (Low Power Wide Area) solutions have been offered.

An experiment was carried out in the field to verify the real coverage area of LoRaWAN. The received power was simulated using the radio simulation programme "Radio Moble" at the field experiment region. The LoRaWAN system design in these experiments is shown in Figure 5.

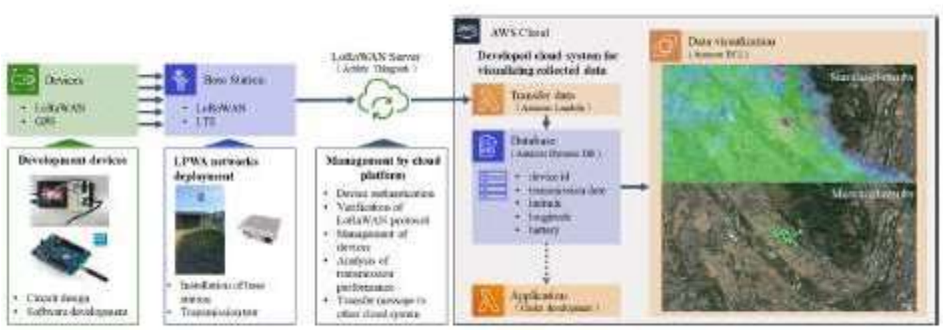

Figure 5: LoRaWAN system setup

There are 26 real measurement points shown in the simulation results shown in Figure 12. The "Radio Mobile" topography elevation difference simulation and the observed data are almost identical. It's clear that communications are working within a radius of around 10 kilometres of these findings.

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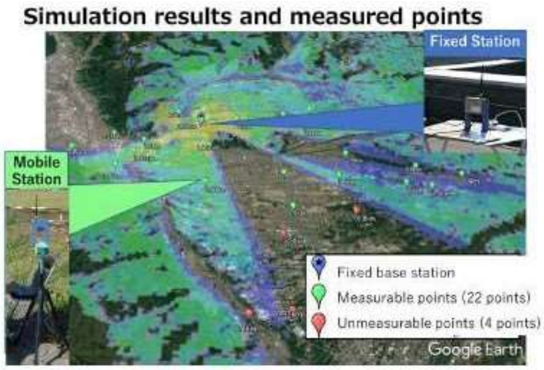

Figure 12: Training in LoRaWAN

IV. Discussion and future research

We've been employing 24 GHz radar sensing technology to collect vital signs like breathing and heartbeat from patients and care receivers without having to make any physical contact. A hybrid WSN environment for medical and nursing care has also been created by merging this non-contact sensing technology employing radar with numerous WSNs that are appropriate for each zone of the institution.

Using 24GHz radar, we studied the definition and detection of five essential life activities. Efforts to enhance the identification rate will continue in the future, while the machine learning model will be fine-tuned, as it has been for the core five categories of living activity detection so far. An 80% to 90% identification success rate was achieved in both the supine and sideways positions when utilising 24GHz radar sensing for respiratory rate detection, but heart rate detection is still challenging unless in the case of supine and a relatively small detection distance. The detecting method for heart rate will be improved in the future.

With the use of Wi-SUN FAN and LoRaWAN, Zone1 at the facility, Zone2 surrounding the facility, and Zone3 in the suburbs were all established as a hybrid wireless sensor network. The Zone1 facility was able to exchange radar sensor data thanks to its hybrid WSN environment. When it detects that a resident has left the institution, it has activated still picture surveillance in the Zone 2 region surrounding it. When a resident leaves Zone3 for the suburbs, a check to see whether the location information has been enabled will be performed. In a real nursing home, we were able to confirm the existence of hybrid WSN settings.

The hybrid WSN platform may be built using the WSN technologies in a scalable and adaptable way, depending on the IoT application's needs. By merging Wi-Fi 6 or local 5G high-speed networks, it is possible to create an environment that is faster and more responsive. We'd want to build a hybrid WSN platform that can handle a wide range of IoT applications, including smart cities, agriculture, forestry and fisheries, disaster mitigation, manufacturing, and other areas that aren't only medical or nursing care-related.

V. Conclusion

Patients and caregivers' important data may be detected without any physical touch thanks to a 24GHz radar sensing technology and a hybrid WSN environment that uses several wireless sensor networks in each of the three zones. We built a hybrid WSN environment for medical/nursing institutions and tested it in the field at real nursing homes to verify its usefulness. We think that the technology developed in this study may help address not just the medical issues associated with an ageing population that are becoming more prevalent throughout the globe, but also situations like the global medical crisis seen at COVID-19.

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