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A virtual cage for monitoring system semi-intensive livestock's using wireless sensor network and Haversine method

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Abstract — Indonesia has great livestock potential with various grazing methods. The semi-intensive grazing system is one of the efforts to increase the production of healthy and superior dairy or beef livestock. This grazing system has many advantages. However, it has several areas for improvement that can prejudice farmers, including lost or stolen livestock due to a lack of control and monitoring. Therefore, tracking livestock's position in the WSN-based grasslands monitoring will be implemented to overcome these weaknesses. Thus, it will provide benefits as a support for a modern and controlled livestock system. The built WSN consisted of several nodes installed on livestock: Arduino nano, GPS Neo Module, LoRa S-1278, DS3231 clock module, and MCU node. Tracking was visible through the application by displaying the map and livestock's GPS position. In addition, the system was notified if the livestock's position was located more than in the permitted radius of the farm. Finally, the system was analyzed using the Haversine method with various scenarios to find the maximum range transmission and perform system toughness. The results stated that the system could track the livestock's position up to 11 km, and the location error calculation obtained by Haversine is only 11.7 % of the actual location.

Keywords – haversine, livestock, LoRa SX1278, monitoring system, tracking, wireless sensor network

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I. Introduction

Indonesia has a very high potential for livestock farming cultivation. With the increasing awareness of the Indonesian people about animal nutrition, superior beef products must be increased. It is better to do livestock by grazing them in cages (intensive technique) to get fat and meaty livestock. However, livestock raised with intensive methods experiences fattening fat because the livestock rarely moves.

To maintain good quality beef from healthy and happy livestock, stockman usually grazes their livestock using a semi-intensive technique. The semi-intensive technique grazes livestock in the grassland or prairie during the day and herds the livestock back into their cages at night [1]. The advantage of this technique is making the livestock healthy and happy. The livestock gets their nutritional intake from grass freely available in the open area, compared to if the stockman feeds the livestock in the cages. Therefore, foreign countries such as Australia and America implemented this technique for their livestock [2].

However, type grazing with semi-intensive technique has weaknesses. Livestock must be supervised over grassland or prairie, which requires many supervisors. Large grassland with limited supervision is vulnerable to livestock being injured, lost, or stolen. Moreover, sometimes the grassland is located far from the rural communities making it difficult for stockman to supervise their livestock. So, it is necessary to collaborate on technological advancements in semi-intensive herding techniques to reduce supervisory personnel and improve livestock control from the possibility of accidents and cattle theft.

Wireless sensor network (WSN) is one of the advanced techniques. It is often used for monitoring, tracking, and surveillance applications, usually applied to a wide area without human supervision [3]. WSN is a collection of sensor nodes with a wireless communication system organized in a cooperative network to capture data according to the desired characteristics [4]. WSN utilizes embedded radio frequency technology, microcontroller, GPS, and sensors that can sense the surrounding conditions of the object to be monitored. WSN is then collaborated by utilizing IoT Technology to visualize the tracking and position of the monitored object [5].

Many applications in various fields have implemented WSN. Some are in forest and ecosystem sustainability, such as illegal logging detectors using sound and acceleration sensors to detect the sound of logging trees [6]. Then, air pollution monitoring observes air pollution at several points with integrated many sensors in the application [7]. WSN also has been implemented to track an animal in wildlife [8] and water quality monitoring [9].

Along with the development of WSN Technology, Wireless sensor networks also collaborate with the Internet of Things (IoT) and are used in various applications, including detection, tracking, and monitoring. Intelligent monitoring to monitor crop conditions has also been implemented using both technologies by utilizing sensors divided into several modules and connected to a Wi-Fi module [10]. Collaboration (IoT and WSN) has also been implemented in animal health monitoring [11].

Meanwhile, in the tracking application, the stage of location searching autonomously based on certain coordinates must be equipped with a GPS device integrated into the moving object. A calculation technique should be applied to have the closest position in the area to determine the absolute exact position of a moving object based on GPS parameters such as latitude and longitude on the map [12]. GPS device captures National Marine Electronics Association (NMEA) signals from satellites that produce latitude and longitude coordinates of the GPS device. The parameters are used to calculate and analyze the accuracy of object position [13]. Google map has a geolocation feature that can find the location marked based on the GPS's parameters. Haversine Formula is called a method to determine the distance between two points by calculating the length of a straight line between two points on latitude and longitude [14].

Therefore, based on the description above, this research objective is to develop a tracking and monitoring system in the form of a virtual cage for livestock that can be implemented on grazing types with semi-intensive techniques. This research will use a GPS, a LoRa communication media integrated with WSN, and Internet of Things technology. This research contributes and benefits to helping stockmen monitor their livestock remotely and reduce the livestock risk of being injured, lost, or stolen.

The rest of this paper will be described as follow. Section one presents an introduction. Section two presents the methodology and design system. Section three describes a scenario testing and discussion. Section four outlines the discussion, while section five draws the conclusions.

II. Research Method

This section discusses the method and research design.

A. Method

The research methodology used a prototype model. This methodology was structured with approaches and stages starting from defining the problem from various reviews of previous research or literature reviews. Next, determined the design research prototype, conducted testing and analysis, then drew conclusions and a report [15].

The literature review began by studying the literature related to state-of-the-art tracking and monitoring applications using WSN until the collaboration of WSN with IoT. As stated in the introduction, tracking a monitoring application with WSN integrated with IoT could produce an application that made it easier for stockmen to supervise remotely. In addition, at this step, several similar studies that utilized the integration of WSN and IoT were reviewed, such as control livestock health application [16], [17] and monitoring animal behavior application [18].

Subsequently, learned the livestock grazing techniques that were widely applied by Indonesian people [1], [2], [19]. Afterward, review the method and technique on how GPS could track an object [12], [20] and the research about low power wide area (LPWAN) LoRa SX-1278 as a wireless data communication technology that had low power consumption and long transmission [6], [21], [22].

Finally, the study looked for tools or formulas that could be used to calculate distances using the parameters of GPS. The formula for calculating livestock position would use the Haversine formula. The haversine formula has been applied by many research, such as pet tracking applications [19], e-nelayan [23], vehicle distance measurement [24], and tracking [25], also monitoring fishing vessel applications [21].

Literature reviews were also carried out on several similar studies that functioned to track and monitor animals or livestock. In previous research, livestock was tracked using GPS collaboration and GPRS signals. Unfortunately, this research could not be implemented in the area that did not have GPRS or GSM signals [26]. Other studies implement ultrasonic sensors as geofencing for livestock tracking; this research had a drawback since the ultrasonic sensors could only be used for limited virtual cage area [27].

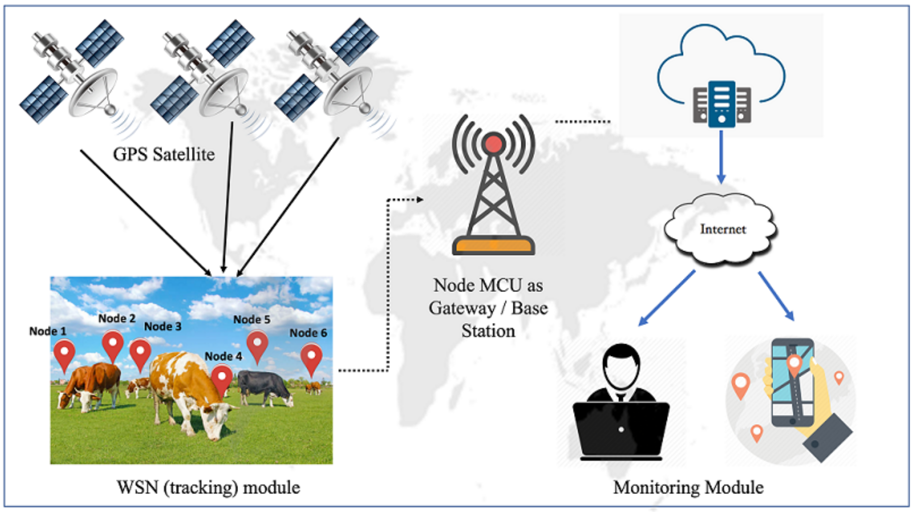

Fig. 1. Proposed tracking and monitoring system.

The next step was determining the prototype design proposed according to system requirements. This research adopted system communication media, such as geofencing research for COVID patients. The communication media, LoRA, replaced the GPRS module in the previous studies [28], [29]. Data collection was conducted in the testing and analysis phase. In this phase, the proposed system conducted a test in several scenarios. This phase also discussed the results. The last stage of this methodology was concluding the data collection results at the previous stages.

B. *Research Design*

Based on the literature study, the proposed system for monitoring dan tracking livestock is depicted in Fig. 1. The figure shows that the proposed system is built with the WSN tracking and monitoring modules. WSN tracking module was a tracking design module attached to livestock. In contrast, the monitoring module was a monitoring system design module that acted as the interface of the WSN in the grassland in a web-based and Android-based display.

WSN tracking modules were designed from nodes that consist of a LoRa SX-1278 hardware circuit like a radio transmission module, clock module, battery, GPS Neo 7m, and an Arduino nano as a microcontroller. Meanwhile, the central nodes as a base station or gateway were designed from LoRa SX-1278, node MCU, and battery, as seen in Fig. 2.

The proposed system was built following the system requirements requested by the stockman. The central nodes on the WSN module in Fig. 2. are built for portability. It aimed to help stockmen create virtual perimeters (virtual cages) on grassland that might be far from Wi-Fi coverage. In addition, an alert warning was integrated into the monitoring application system if the livestock was almost at the outer limit. The illustration can be seen in Fig. 3.

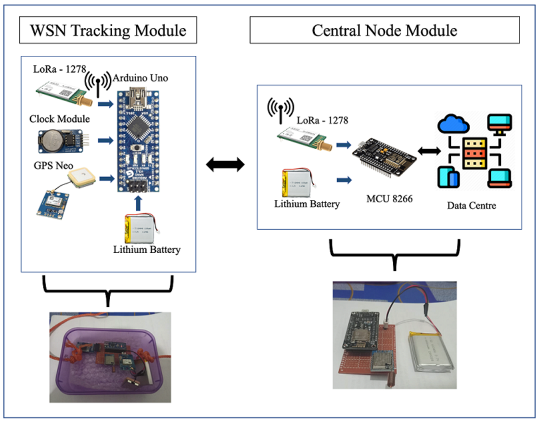

Fig. 2. WSN tracking module and central node module.

In addition, the haversine calculation (HCC) was inserted to calculate the livestock position in the grassland. HCC was inserted in node MCU and microcontroller to measure the distance between the two-geolocation point. The HCC is formulated in (1) [21].

$$D = 2R \arcsin \sqrt{sin^2\left(\frac{Clat_1 - Clat_2}{2}\right) - \cos(Clat_1)\cos(Clat_2)\sin^2\left(\frac{Clong_1 - Clong_2}{2}\right)} \quad (1)$$

The distance (D) between the livestock and the virtual perimeter, according to Fig. 3, is designed as seen in Table 1. The table describes two conditions as livestock status. Red color notification is the notification status where the livestock is in the warning area. The livestock is located between the inner warning area perimeter and the outer warning area perimeter. Meanwhile, a green color notification is a notification that informs the livestock is in the allowable range zone.

Based on the description above, the flowchart of the proposed system can be seen in Fig. 4. According to the figure, when the system is turned on, the LoRa

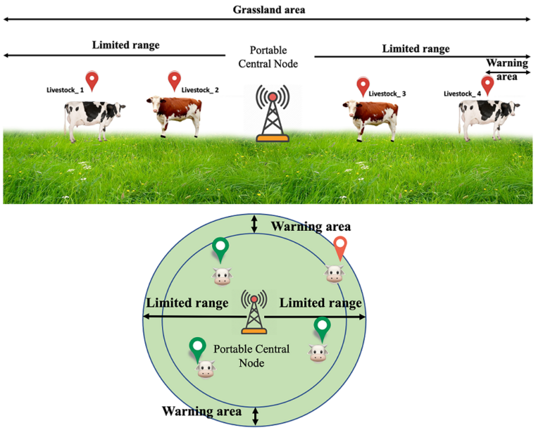

Fig. 3. Virtual perimeter.

Table 1. Livestock Notification Status Rules

Color	Rules Parameters	Location Status
Red	Inner_warning_area < Livestock_AR < Outer_warning_area	Warning Alert
Green	Livestock_AR < inner_warning_area	Safe

configuration must be connected to all livestock nodes. Then, the system continues with Google Map API configuration. Each livestock nodes have a unique ID assigned to the WSN.

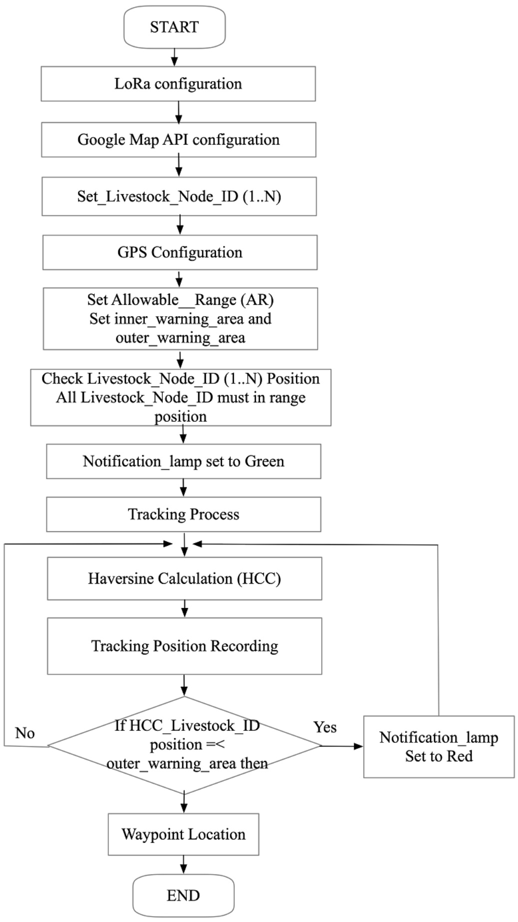

Fig. 4. Flowchart of the proposed system.

Subsequently, the perimeters, such as the allowable range (AR) parameter, inner warning area parameter, and outer warning area parameter, were set to form the virtual cage. Finally, the stockman sets all the perimeters according to Table 1. Furthermore, all the monitored cattle must be ensured that the livestock is within the allowable range.

Thus, the notification light on the display screen will be set to green. The WSN tracking module works by calculating the GPS position with AR using HCC. Every movement of livestock is recorded in the tracking position record. If the HCC Livestock Node ID position is less than 100 m from the outer warning area, the notification light on the monitor display will change from green to red. If this condition is reached, the stockman must immediately check and move the livestock back into the virtual cage.

Thus, the display screen's notification light would be green. The WSN tracking module calculated the GPS position with AR using HCC. Every movement of livestock was recorded in the tracking position record. If the HCC Livestock Node ID position were less than 100 m from the outer warning area, the notification light on the monitor display would change from green to red. The stockman must immediately check and move the livestock back into the virtual cage if this condition is reached.

III. Result

This section presents the experimental results, divided into three subsections based on the testing scenario. The first scenario was the node transmission test. Data were collected thrice for each livestock node in the non-Loss area and loss area. The second scenario was a validation test for livestock node coordinates using the Haversine method. Data collection for the second scenario was carried out also three times in each experiment for each location. The data shown in Table 2 is from the largest, smallest, and average (nearly the same deviation) on the Haversine and google maps system. The third scenario was a tracking validation test on the web interfaces. The necklace prototype was attached to the livestock in the experimental section, as seen in Fig. 5. The third data collection was carried out three times to check the livestock tracking position until the warning area.

A. *Node Transmission Test*

The node transmission test was a test of the transmission signal strength of the proposed system. The test was conducted in N-Loss and Loss area location. A node transmission tracking test illustrated the N-Loss situation if the central node was in the chamber and the livestock node was in the open area. Meanwhile, the Loss situation was described with a node transmission tracking test if both nodes were in the open area.

This scenario aimed to determine the maximum distance and execution time as measurement parameters that indicated the transmission strength of the system

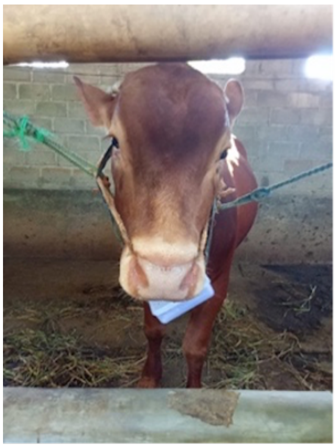

Fig. 5. Livestock with wearable device.

in the N-Loss and Loss area. The test was taken on three livestock that were paired with necklaces. The result can be seen in Fig. 6 for the N-Loss area and Fig. 7 for the Loss area.

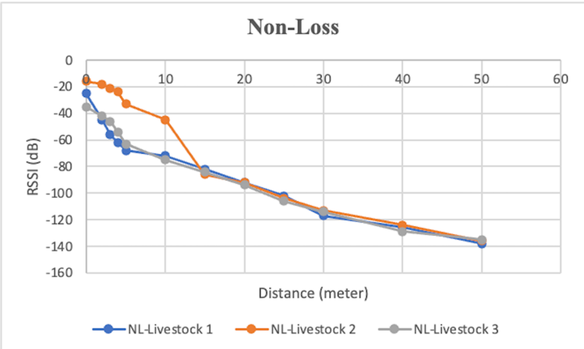

Fig. 6. Result of non-loss transmission node.

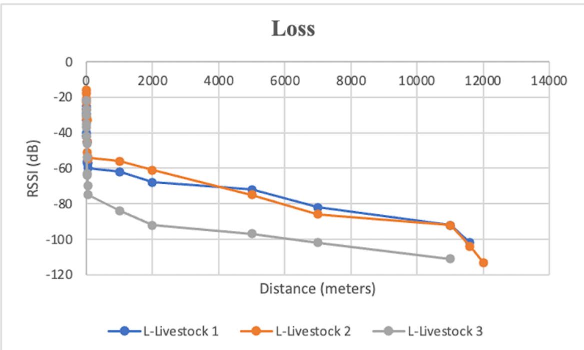

Fig. 7. Result of Loss transmission node.

Fig. 6 and Fig. 7 are graphs of the testing results of the transmission signal strength of LoRa SX-1278, which measure LoRa's RSSI value against distance. Fig. 6 shows the testing result on the non-Loss area. The test result indicated that at more than 50 m, the central node could no longer receive the transmission signal. As a result, the three positions of the livestock could no longer be detected because of the barrier between the transmitter and receiver.

While Fig. 7 shows the testing result on the Loss area. The test results indicated that the position of the three livestock could still be detected at 1,100 m or 11 km. This means that the central node could still receive the transmission signal up to 11 km. The position of Livestock 1 is detected up to 11.6 km from the central node, the position of Livestock 2 was detected up to 12 km, while the position of Livestock 3 was only detected up to 11 km. In the Loss area test, the strength of the transmission signal could be received further than in the N-Loss area. This was because the position of the three livestock nodes and the central nodes were located in an open area.

B. Node Coordinate Validation Test and GPS Tracking

This test aimed to measure the accuracy level of the livestock position on the map. The test was conducted by measuring the livestock position point on google maps and comparing it with the livestock position point on the system. The test results will be displayed by comparing the manual calculation with the Haversine method. The result can be seen in Table 2.

Table 2 indicates the result of testing of livestock position on the map and in the system. Livestock was in three different locations inside the virtual cage. Then, the livestock's position was calculated based on the GPS coordinate on the system and maps. Each measurement was carried out three times in a different place. In Table 2, livestock ID indicates the ID of each livestock in an open area. Haversine coordinates showed the livestock's positions using the Haversine method, while maps coordinates showed the livestock's position indicated on google maps. DWH parameter denoted distance deviation without the Haversine calculation method, while DH parameters stated the distance deviation using the Haversine calculation method. Deviation stated the position differences between DWH and DH in the meter unit. Error percentages (%) reflected the percentage error or the difference in calculating the distance from the livestock's actual position.

Table 2 shows that the livestock position is more accurate using the Haversine method than conventionally calculating deviation.

C. Monitoring and Tracking Test

This test aimed to examine and validate the tracking and monitoring of livestock's position on the web service. Fig. 8 is a web service display of the three livestock on the map. The figure shows that livestock one and two are in the allowable range from the central node. Meanwhile, livestock three had been out of range or in the warning area.

Fig. 8 can be seen from the notification color on the tracking display's right. Again, the green is where the livestock position is in the allowable range, and the red is the notification where the livestock is out of allowable range or at the warning area.

Meanwhile, Fig. 9 shows the tracking test from one position to the warning area in the middle of the

Table 2. Comparison Results of Haversine Method and Map's Actual Location

Livestock_ID	Haversine Coordinate	Maps Coordinate	DWH Meter	DH Meter	Deviation Meter	% Error
Livestock_1	-7.781473,110.342772	-7.782377,110.357702	190	165	25	15.2
	7.7779604,110.342894	-7.779345,110.343137	160	155.5	4.5	2.89
	-7.767810,110.295380	-7.766120,110.290885	600	529.9	70.1	13.2
Livestock_2	-7.781053,110.349863	-7.780735,110.349847	73	35.2	37.8	107
	-7.782910,110.366750	-7.782707,110.367064	46	41.3	4.7	11.4
	-7.783039,110.373698	-7.782911,110.37473	120	114.7	5.3	4.62
Livestock_3	-7.775717,110.346386	-7.775666,110.346311	6	10	4	40
	-7.772256,110.347639	-7.772269,110.347590	5	5.6	0.6	10.71
	-7.770756,110.347175	-7.771048,110.347118	35	32.9	2.1	6.38

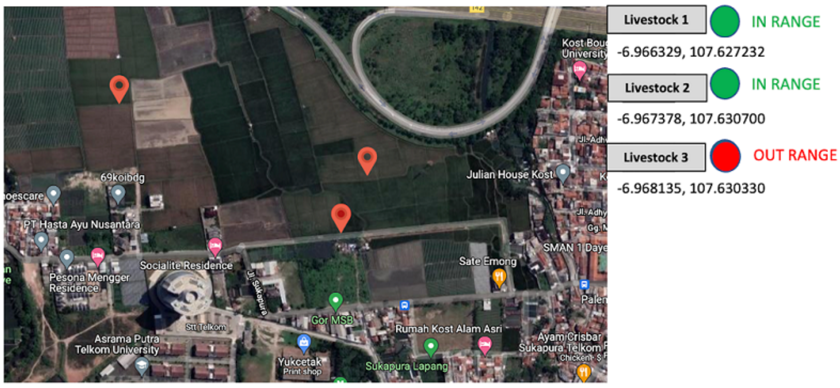

Fig. 8. Actual location livestock on maps.

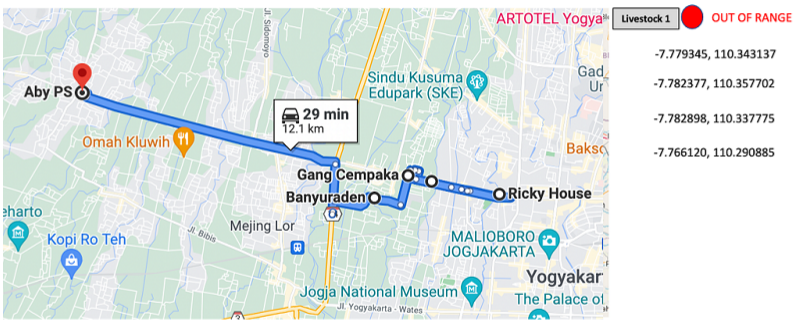

Fig. 9. Livestock tracking on maps.

town. It shows the tracking position of one of the livestock. The livestock moved from one place into the designated area as a warning area (100 m. from the coordinate where the LoRa's signal might be lost). The figure shows that the livestock location notification is turning red. It is indicated that the livestock is in a warning area.

IV. Discussion

Based on the test results, the virtual cage was created successfully. In the previous research, the communication transmission media used GSM or GPRS, but these networks have weaknesses if the system is placed in grassland areas surrounded by hills and has difficulty receiving signals. These drawbacks can be overcome by applying LoRa as in this research. Using LoRa, the virtual cage's range can reach a coverage radius of up to 11 km from the central node's position. It depends on the central node's location and the surrounding environment's density. LoRa has more robust characteristics for networks with a wide range between transmitter and receiver, but LoRa is not suitable to place indoors or in places where there are any obstacles between the transmitter and receiver (N-Loss area).

In this research, virtual cages are built by inserting the haversine calculation methods to obtain accurate livestock positions compared to systems without haversine methods. According to Table 2, the system with haversine methods is more accurate than the system without haversine methods. The average deviation in location position between DWH and DH is 11.7 %. Therefore, validating the location accuracy measurement using the Haversine method is better than measuring the deviation using conventional calculation. This is because the Haversine calculations involve the earth's curvature beside the geolocation coordinate. Therefore, the shortest deviation is 0.6 m, while the farthest deviation is 70.1 m. Therefore, livestock can still be detected by sight at a distance for monitoring in wide and open areas. However, if it is in a densely populated area, the monitoring point of view will be limited by the presence of the buildings or the trees that might be blocking the stockman's viewpoint.

Meanwhile, in the discussion of monitoring results test from the application side, as seen in Fig. 8 and Fig. 9, using the haversine method can ignore the differences in the distance because monitoring can be carried out if the system is still within the range of the virtual cage network area or communication network area between transmitter and receiver. In this case, the transmitter is the central node, and the Livestock ID is the receiver. However, the Haversine method assists the stockman in finding the livestock's actual position, especially if the livestock is already in the warning area.

Based on the discussion above, the livestock monitoring and tracking system can provide benefits for stockmen to graze their livestock using semi-intensive techniques and flexibility in supervision with a wide range of virtual cages. In addition, the stockman can also keep an eye on livestock from the possibility of being injured, lost, or stolen.

V. Conclusion

This study proposes the construction of a virtual cage intended for stockmen who use a semi-intensive grazing system on the grassland. In addition, this system can also identify, track, and monitor the livestock position in a virtual cage in real-time. Implementing the SX-1278 LoRa module system as a transmitter and receiver can detect the livestock's positions as far as 11 km in the loss area network and can only detect positions as far as 50 m from the central node in the non-Loss area network. Using a portable central node gives practice contribution for the stockman to monitor the livestock position. Using the Haversine method, the system can detect the livestock's position more accurately than without the Haversine method. The tracking and monitoring livestock position application also properly represents the actual location status in the system.

The system can be developed for further work by adding a health monitoring feature of the recorded livestock for a certain period. Therefore, the livestock system can become more modern and controllable. Besides, the system can also add a camera at the central nodes to give a moving picture of the situation around the central node, and the stockmen can control the situation around the virtual cages.

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References

[1] D. B. Lasfeto and T. Setyorini, "Desain sistem monitoring ternak sapi berbasis jaringan sensor nirkabel untuk sistem," in *Seminar Nasional Teknologi Informasi*, 2017, no. November, pp. 1–2.

[2] S. Volkandari, P. Sudrajad, D. Prasetyo, Subiharta, A. Prasetyo, J. Pujianto, and M. Cahyadi, "Dampak sistem pemeliharaan intensif dan semi intensif terhadap ukuran tubuh sapi Bali jantan Di Balai Pembibitan Ternak Unggul (BPTU) Sapi Bali," in *Prosiding Seminar Nasional Kesiapan Sumber Daya Pertanian dan Inovasi Lokasi Memasuki Era Industri 4.0*, 2017, pp. 547–551.

[3] G. A. Mutiara, N. Suryana, and O. Bin Mohd, "Wireless sensor network for illegal logging application: A systematic literature review," *J. Theor. Appl. Inf. Technol.*, vol. 97, no. 1, pp. 302–313, 2019.

[4] C. Buratti, A. Conti, D. Dardari, and R. Verdone, "An overview on wireless sensor networks technology and evolution," Sensors, vol. 9, no. 9, pp. 6869–6896, 2009, doi: 10.3390/s90906869.

[5] Z. A. Khan and U. Abbasi, "Evolution of wireless sensor networks toward Internet of Things," *Emerg. Commun. Technol. Based Wirel. Sens. Networks Curr. Res. Futur. Appl.*, no. April 2016, pp. 179–199, 2016, doi: 10.1201/b20085-16.

[6] G. A. Mutiara, N. S. Herman, and O. Mohd, "Using long-range wireless sensor network to track the illegal cutting log," *Appl. Sci.*, vol. 10, no. 19, pp. 1–17, 2020, doi: 10.3390/app10196992.

[7] W. Y. Yi, K. M. Lo, T. Mak, K. S. Leung, Y. Leung, and M. L. Meng, "A survey of wireless sensor network based air pollution monitoring systems," *Sensors*, vol. 15, no. 12. 2015.

[8] F. Lalooses, H. Susanto, and C. H. Chang, "Approach for tracking wildlife using wireless sensor," in *Proceedings of the 7th International Conference on New Technolo- gies of Distributed Systems*, 2007, pp. 1–7.

[9] K. S. Adu-Manu, F. A. Katsriku, J. D. Abdulai, and F. Engmann, "Smart River Monitoring Using Wireless Sensor Networks," *Wirel. Commun. Mob. Comput.*, vol. 2020, 2020, doi: 10.1155/2020/8897126.

[10] B. P. Sreeja, S. Manoj Kumar, P. Sherubha, and S. P. Sasirekha, "Crop monitoring using wireless sensor networks," in *Materials Today: Proceedings*, 2020, no. xxxx, pp. 1–5, doi: 10.1016/j.matpr.2020.10.373.

[11] T. A. Shinde and D. J. R. Prasad, "IoT based animal health monitoring with naive bayes classification," *Ijett*, vol. 1, no. 2, pp. 8104–8107, 2017, [Online]. Available: http://www.ijett.in/index.php/IJETT/article/view/323.

[12] A. Atthari, "Sistem tracking position berdasarkan titik koordinat GPS menggunakan smartphone," *J. Infomedia*, vol. 2, no. 1, pp. 25–29, 2017, doi: 10.30811/.v2i1.464.

[13] A. P. Kurniawan, G. A. Mutiara, and G. Indah, "Transmitting GPS as text form through wireless on drone 2.0," *J. Teknol.*, vol. 1, no. 72, pp. 1–6, 2015.

[14] R. H. D. Putra, H. Sujiani, and N. Safriadi, "Penerapan metode haversine formula pada sistem informasi geografis pengukuran luas tanah," *J. Sist. dan Teknol. Inf.*, vol. 10, no. 2, pp. 1262–1270, 2015.

[15] T. J. Ellis, Y. Levy, and F. Lauderdale, "Framework of problem - based research - A guide for novice researchers on the development of a research - Worthy problem," *Int. J. an Emerg. Transdiscipl.*, vol. 11, pp. 17–33, 2008.

[16] S. K. Lenka, "Wireless sensor network based cattle health monitoring system for early detection of disease," in *International Conference on Intelligent Network and Computing (ICINC 2010)*, 2010, no. Icinc, pp. 337–341.

[17] K. H. Kwong, T.-T Wu, H. G. Goh, K. Sasloglou, B. Stephen, I. Glover, C. Shen, W. Du, C. Michie, and I . Andanovic, "Practical considerations for wireless sensor networks in cattle monitoring applications," *Comput. Electron. Agric.*, vol. 81, pp. 33–44, 2012, doi: 10.1016/j.compag.2011.10.013.

[18] R. N. Handcock, D. L. Swain, G. J. Bishop-hurley, K. P. Patison, T. Wark, P. Valencia, P. Corke, and C. J. O'Neill, "Monitoring animal behaviour and environmental interactions using wireless sensor networks, GPS collars and satellite remote sensing," *Sensors*, vol. 9, no. 5, pp. 3586–3603, 2009, doi: 10.3390/s90503586.

[19] M. Aldino, I. S. Sumaryo, and D. D. S. Si, "Desain dan implementasi sistem pelacak untuk bluetooth dan GPS (Design and implementation of tracking system for the position of cat using bluetooth and GPS module)," in *e-Proceeding of Engineering*, 2019, vol. 6, no. 3, pp. 10028–10035.

[20] R. J. Fauziah, G. A. Mutiara, and Periyadi, "Smart tracking and fall detection for golden age's citizen," in *Procedia Computer Science*, 2019, vol. 161, pp. 1233–1240, doi: 10.1016/j.procs.2019.11.237.

[21] F. J. Candido, R. Flores, and P. Forcadilla, "Haversine method and lora for monitoring entry of fishing vessel in marine protected areas," in *2019 7th International Conference on Information and Communication Technology, ICoICT 2019*, 2019, pp. 7–10, doi: 10.1109/ICoICT.2019.8835243.

[22] G. A. Mutiara, O. Mohd, N. Suryana, and A. N. C. Pee, "Weights-based energy-efficient wireless sensor network protocol with firefly synchronization for illegal logging," *Int. J. Intell. Eng. Syst.*, vol. 14, no. 3, pp. 374–387, 2021, doi: 10.22266/ijies2021.0630.31.

[23] S. Fuada, S. F. Anindya, F. Dawani, A. Rifai, and E. Adinugraha, "Prototype of long-range radio communication for e-Nelayan devices using LoRaWAN performance case study within city boundaries," *J. Infotel*, vol. 10, no. 4, pp. 202–209, 2018.

[24] A. Sofwan, Y. Alvin, and A. Soetrisno, "Vehicle distance measurement tuning using haversine and micro-segmentation," in *International Seminar on Intelligent Technology and its application (ISITIA)*, 2019, pp. 239–243.

[25] V. Gupta, N. Batra, and S. Gautam, "Android based travel planner using haversine formula," *Int. J. Innov. Sci. Res. Technol.*, vol. 3, no. 5, pp. 260–263, 2018, [Online]. Available: www.ijisrt.com.

[26] D. Setiawan, M. W. Sari, and R. H. Hardyanto, "Geofencing technology implementation for pet tracker using Arduino based on Android," *J. Phys. Conf. Ser.*, vol. 1823, no. 1, pp. 1–11, 2021, doi: 10.1088/1742-6596/1823/1/012055.

[27] Q. M. Ilyas and M. Ahmad, "Smart farming: An enhanced pursuit of sustainable remote livestock tracking and geofencing using IoT and GPRS," *Wirel. Commun. Mob. Comput.*, vol. 2020, pp. 1–12, 2020, doi: 10.1155/2020/6660733.

[28] A. Syahrin Idris, H. Malik, and S. Fauziah Toha, "Geo-fencing location tracking system using IoT and LoRa LPWAN for covid-19 mandatory self-quarantine monitoring," *Perintis e-Journal*, vol. 12, no. 2, pp. 56–68, 2022.

[29] L. Simoyi and C. Mugauri, "Low cost IoT based livestock tracking system for Zimbabwe," *Int. J. Sci. Res.*, vol. 11, no. 2, pp. 890–898, 2022, doi: 10.21275/SR22216224924.