

Dynamic Scheduler for WSN Applications in Precision Agriculture

Kunal Goel¹, Amit Kumar Bindal²

¹PhD Research Scholar, Department of Computer Science & Engineering, M. M. Engineering College, M. M. (Deemed to be University), Ambala, India

²Assoc Professor, Department of Computer Science & Engineering, M. M. Engineering College, M. M. (Deemed to be University), Ambala, India

¹er.kunalgoel@gmail.com, ²amitbindal@mmumullana.org

Article Info

Page Number: 390 - 398

Publication Issue:

Vol 71 No. 2 (2022)

Article History

Article Received: 05 January 2022

Revised: 20 February 2022

Accepted: 04 April 2022

Publication: 11 May 2022

Abstract

Sensors may be configured to collect the various parameters those do not change over a long interval (i.e. water level, soil attributes/ fertilizer quantity of agriculture land/ growth of crops). In case, if all sensors start transmission after a lengthy intermission, it may cause packet drop over network and excessive resources may be exhausted due to retransmission. To manage the bulk data forwarding with minimum resource consumption, in this paper, an application scheduler is introduced to enforce the discipline bulk data transmission. Its performance is analyzed using LEACH protocol under the constraints of various parameters (Throughput/remaining energy/number of dead/alive sensors) with sensor density (100-300).

Keywords: WSN, smart farming, precision agriculture, bulk data forwarding.

I. INTRODUCTION

Manual data collection of agriculture environment is very complex, time consuming and experts are required to manipulate this data to produce end results. Wireless sensors can be deployed over agriculture land to monitor and analyze this data but different types for sensors are required to sense each parameter. Figure 1 shows the various applications area that can be used for agriculture domain i.e. monitoring, resource management, forecasting and security etc.

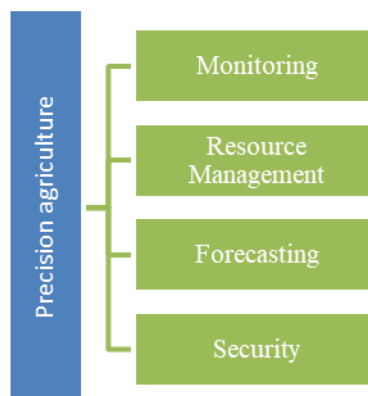


Figure 1: WSN applications for precise agriculture

Figure 2 shows the roles of a sensor based network for agriculture domain. Sensor network can be used to monitor different attributes related to environment/crop growth/soil etc. It can also be used to regulate the natural resources to meet the irrigation needs as well as estimation for natural resources/fertilizer w.r.t. crop type. It can be deployed to prevent the human or animal intrusion in field as well as early warning can be generated for pest infestations.

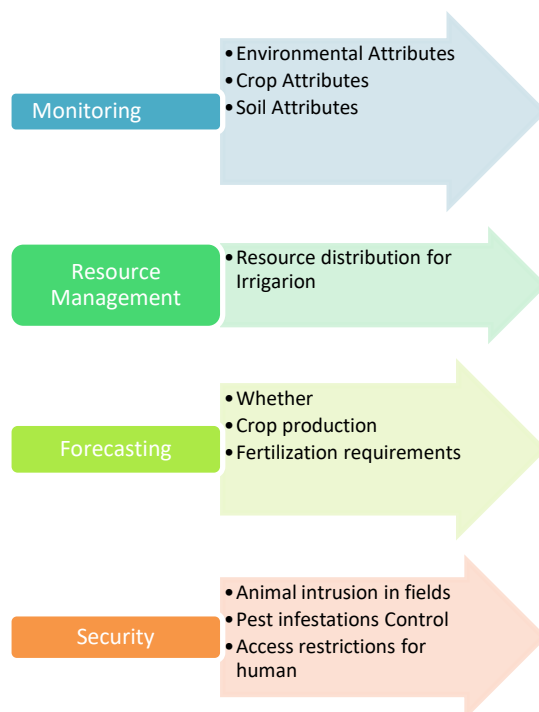


Figure 2: Sensor roles for agriculture domain

Following are the issues for precision agriculture:

- **Communication Standardization:** In case of smart farming, sensors can be deployed over surface or underwater. So different communication standards (WiFi/ Bluetooth/ Zigbee/ 802.11) are required for reliable communication under the constraints of environmental circumstances.
- **Development/ operating cost:** End user requirements changes due to parameter measuring constraints, so there is need to design/develop a specific hardware thus may increase overall development cost e.g. temperature sensors cannot be used to measure chemical attributes of soil whereas moisture sensors cannot be used for crop attributes etc.
- **Resource consumption:** Smart farming may require different types of sensors in same network thus may vary the resource consumption rate.
- **Scalability:** Agriculture landscape may vary at large-scale. Communication over scalable coverage area is a performance constraint [1-5].

II. Literature Survey

S. R. Schultze et al. [6] developed a WSN based solution to analyze the variations in temperature w.r.t. different seasons (i.e. summer & winter). Analysis indicates that growth of plants/trees varies as the temperature changes and extreme climate conditions may reduce the growth rate. Temperature dataset can be further utilized to enhance the existing model of precision agriculture.

D. K. Anguraj et al. [7] used support vector machine with neural network for irrigation monitoring using WSN. For decision making, a classifier is used to measure soil properties w.r.t. water resource availability and represents. Experiments show its performance in terms of accuracy & efficiency.

- E. Duncan et al. [8] investigated the impact of technology over the traditional agriculture processes. It shows that smart farming can reduce the operating cost, increase the crop production and landscape usage can be improved by the automation of decision making.
- C. Xie et al. [9] developed an automated seeding solution for agriculture. It estimates the current seeding quantity w.r.t. seeder capacity and defines a optimal seeding rate. Experimental results show its performance in terms of monitoring accuracy, optimal success rate and minimal false alarms.
- S. G. Krishnan et al. [10] designed a sensor network to measure the soil attributes using resonance frequencies. Analysis shows that it can recognize the fluctuations in frequencies due to the variations in water substance availability in soil and it outperforms in terms of sensitivity/accuracy etc.
- D. Sharma et al. [11] investigated the various solutions for the monitoring of soil attributes. Study found that Zigbee offers optimal operational cost whereas GSM based solutions can be adapted to increase connectivity range. However, study shows that these solutions are designed only for specific agriculture environment.
- S. J. ru et al. [12] introduced a real-time solution to analyze the parameters of agricultural environment. Experimental results show that it produces output with higher accuracy as well as consumes optimal energy and its integration with internet can extend the capabilities of existing network.
- M. E. Bayrakdar [13] analyzed the spectrum requirements and utilization w.r.t. Agricultural environment (i.e. over ground and underwater) and designed a solution to manage the communication for both scenarios and simulation results illustrate that TDMA method is more reliable for over ground network operations whereas CSMA can be used for underwater communication and each case, network performance varies in terms of throughput/energy consumption.
- L. Hamami et al. [14] investigated the requirement for the automation of agriculture to boost the crop production. Study shows that sensors can be used to monitor various processes associated with agriculture and feedback can be used to optimize the parameters as required but for each process & parameter, different types of sensors are required thus may increase the WSN deployment cost over agriculture land.
- S.A. Kumar et al. [15] explored the role of sensors in precision agriculture. Study found various applications that can be utilized for the automation of agriculture (i.e. Irrigation management, pest control, soil analysis & crop growth etc.) and using advance technology, crop production cost can be optimized.
- A. Triantafyllou et al. [16] proposed a model for smart farming in which the scope of WSN can be extended by cloud platform integration. It introduced different layers (Sensor, application, service & network layer etc.) for network operation over cloud platform. Analysis shows that its capabilities to extends the scope of precision agriculture.
- B. Gernert et al. [17] developed a delay tolerant filed monitoring scheme for agriculture. It analyzes the plant's temperature and irrigation system is regulated as per requirements. Analysis shows its performance in terms of optimal natural recourse conservation.
- S. Sadowski et al. [18] Investigated the role of wireless technologies to monitor parameters associated with farming. Study found that long range WAN with energy harvesting support is more efficient as compared to WiFi and Zigbee for smart farming.
- F. Ouyang et al. [19] introduced a UAV based monitoring system to monitor agriculture land at very large scale. Experimental results shows that using satellite and GPS support, more precise data with minimal error rate can be obtained. However, UAV design customization w.r.t. agriculture domain is still an open issue.
- K. R. Gsangaya et al. [20] introduced a portable monitoring system for agriculture land and its integration with cloud platform extends the data sharing capabilities of network. Experimental results show that it can resolve various issues (i.e. development cost/maximum coverage range/usage of portable devices) and crop production can be improved using this scheme.
- S. Dhillon et al. [21] developed energy forecasting scheme for agriculture domain using neural network. It observes the variations in solar energy in a day and predicts the energy availability for harvesting and other network operations. Analysis shows that it consumes less memory resources, optimal error rate and higher prediction accuracy as compared to traditional energy forecasting schemes.
- A. Bindal et al. [22] proposed the solution for the forwarding node placement problem in wireless sensor network with deploying a minimum number of forwarding nodes (FNs) in a set of candidate locations in the network to satisfy a specific requirement(s), such as connectivity or survivability, PLDP provides survivability and connectivity throughout the network life.
- Q. Zhang et al. [23] provided a navigation control scheme to control the vehicle mobility in agriculture field. Experiments shows that it can manage vehicle activities more efficiently as compared to manual vehicle control and its connectivity with WSN reduces the error rate also.

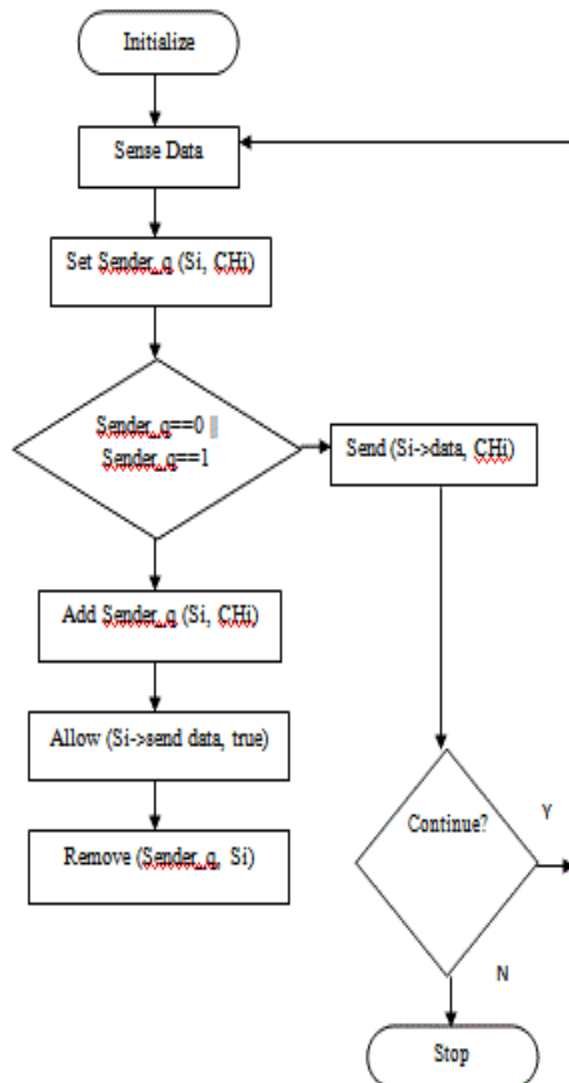
K.N. Bhanu et al. [24] proposed a multi-agent data collection scheme for smart farming. It deploys different agents to collect various parameters (soil attributes/environmental variables etc.) for analysis purpose. Experiments indicate that agents can handle different parameters at same time as well as these can be used to extend the processing capabilities of sensors under the constraints of inadequate resources.

G. E. John et al. [25] introduced a prototype for smart farming. It measures soil/moisture attributes and offers efficient data acquisition under the constraints of packet size variations over large scale network. Shortest links are chosen to forward the data. Simulation results show its performance in terms of optimal resource utilization/processing time.

III. DYNAMIC SCHEDULER FOR PA APPLICATIONS

In this paper, a dynamic application scheduler is introduced as in case of PA, data transmission may occur after a long interval, but at same time all intermediate sensors may start data forwarding to their cluster heads and these CHs forward the bulk data at same time to base station, that may consume unnecessarily resources. To overcome from this issue, a scheduling method is used that keeps the track of data forwarding. At initial stage, when sender queue is empty or its size is 1 means sensor can forward the data to its CH and queue size increase as number of sensors start data forwarding to their CH. At this stage, request of all sensors are added to sender queue and one by one these sensors are allowed to forward the data to CH to avoid the bulk transmission and after completion of data forwarding, process, sensors are removed from queue to avoid starvation.

Flowchart I of Dynamic Scheduler with Single CH



Algorithm of Flowchart I

Step 1: Initialize WSN

Step 2: Sense Data

Step 3: Forward data from sensors to CH

For each member node in current CH

Set Sender_q (Si, CHi)

If (Sender_q==0 || Sender_q==1)

Send to CH

Else

Add Sender_q (Si, CHi)

For each Si in current Sender_q

Allow (Si->send data, true)

Remove (Sender_q, Si)

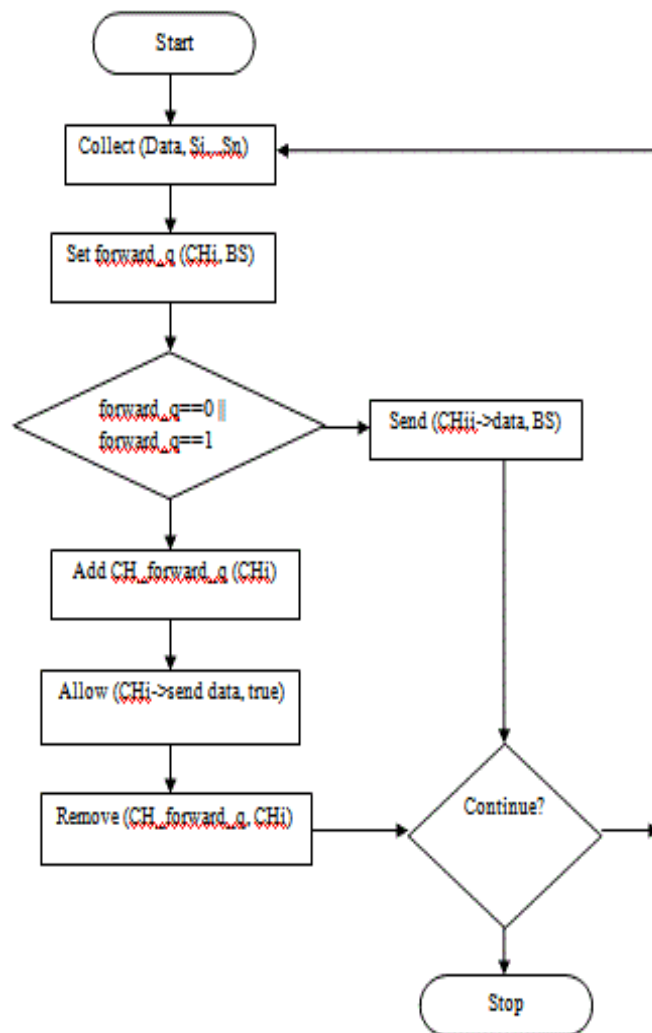
end

End if

End for

On other hand, there may be more than one CH in WSN, so a forwarding queue is maintained and request of each CH is added to this queue and CH are allowed to forward the data after completion of data forwarding, to BS, CHs are removed from queue to avoid starvation.

Flowchart II of Multiple Cluster Head



Algorithm of Flowchart II

Step 4: Forward data from CH to BS

For each CH in WSN

Set CH_forward_q (CHi, BS)

If (CH_forward_q ==0 || CH_forward_q ==1)

Send to BS

Else

Add CH_forward_q (CHi)

For each CHi in CH_forward_q

Allow (CHi->send data, true)

Remove (CH_forward_q, CHi)

end

End if

End for

IV. SIMULATION CONFIGURATION

For simulation, Ns-3.30.1 was used and for experimental purpose, simulation scenarios are: No scheduler for LEACH (NSHL) and LEACH with (WSHL), In configuration, terrain size is 1500x1500, sensor density varies from 100-300 only, sampling interval 1ms, simulation time 10 seconds, 802.11 MAC protocol, Friss Model Propagation Model with Rx/Tx 7.5 and 7j is Initial Energy.

V. SIMULATION ANALYSIS & RESULTS

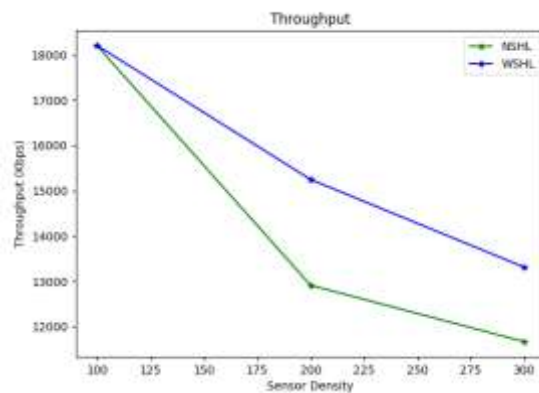


Figure3: Throughput

Figure 3 shows the Throughput of LEACH w.r.t sensor density (100-300). Without using application scheduler, Throughput of LEACH varies and it is highest with 100 sensors, with 200 sensors it is at moderate level but with the 300 sensors it is at lowest level. In case of 100 sensors, it is 18198.18Kbps, 12913.04Kbps for 200 sensors and 11669.76Kbps for 300 sensors.

On other hand, using application scheduler, LEACH maintains Throughput under the constraints of sensor density. However with 300 sensors, it is declined slightly. It is 18202.8Kbps for 100 sensors, 15247.97Kbps for 200 sensors and 13315.37Kbps for 300 sensors.

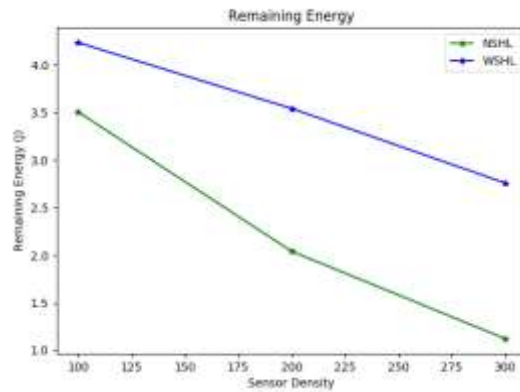


Figure 4: Remaining Energy

Figure 4 shows the remaining energy of LEACH w.r.t sensor density (10-300). Without using application scheduler, remaining energy of LEACH varies and it is highest with 100 sensors, with 200 sensors it is at moderate level but with the 300 sensors it is at lowest level. On other hand, using application scheduler, LEACH maintains its level under the constraints of sensor density. However with 300 sensors, it is dropped marginally

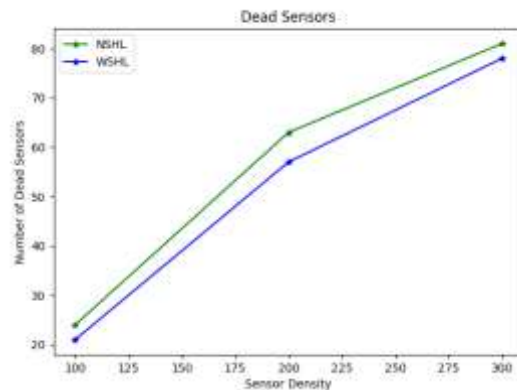


Figure 5: No. of dead sensors

Figure 5 shows the no. of dead sensors using LEACH w.r.t sensor density (10-300). Without using application scheduler, LEACH could not retain the life time of sensors. No. of dead sensors increase w.r.t. sensor density. 24 sensors are dead out of 100 sensors, 63 out of 200 sensors and and 81 out of 300 sensors. Using application scheduler, LEACH triedto retain the life time of sensors and there are less no. of dead sensors, however, its count increases w.r.t. sensor density. Only 21 sensors dead out of 100 sensors, 57 out of 200 sensors and and 78 out of 300 sensors.

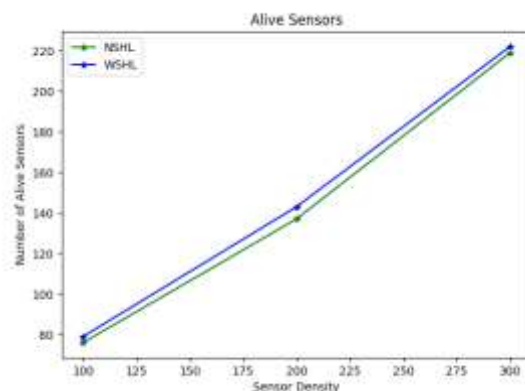


Figure 6: No. of Alive Sensors

Figure 6 shows the no. of alive sensors using LEACH w.r.t sensor density (10-300). Without using application scheduler, LEACH offers less no. of alive sensors w.r.t. sensor density. 76 sensors are alive out of 100 sensors, 137 out of 200 sensors and 219 out of 300 sensors whereas using application scheduler, LEACH tried to retain the higher life time of sensors. Only 79 sensors are alive out of 100 sensors, 143 out of 200 sensors and 222 out of 300 sensors

VI. CONCLUSION

In case of PA, sensors may sense the field parameters for a long interval and after that immediate start the data forwarding to CH thus may cause the data loss due to packet drop over congested network. To overcome bulk transmission over network, in this paper, a data forwarding scheduler was introduced for sensors to manage the bulk data forwarding situation.

Simulation based analysis was performed using LEACH protocol and results shows that without using application scheduler, Throughput of LEACH varies w.r.t, sensor density (100-300) , its remaining energy also less thus decrease the overall lifespan of sensors and LEACH could not manage the life-time of seniors and there are higher number of dead sensors.

If application scheduler is used with LEACH, results show the significant improvement in Throughput, higher level of remaining energy thus results in less number of dead sensors and higher number of alive sensors.

In current scenario, scope of application scheduler is limited up to LEACH protocol. In future, it will be integrated with other WSN routing protocols (TEEn/SPIN/PEGASIS).

VII. REFERENCES

- [1] J. Devare, N. Hajare, "A Survey on IoT Based Agricultural Crop Growth Monitoring and Quality Control" International Conference on Communication and Electronics Systems (ICCES), IEEE-2019, pp. 1624-1630.
- [2] Y. Hamouda, M. Msallam, "Variable sampling interval for energy-efficient heterogeneous precision agriculture using Wireless Sensor Networks, Journal of King Saud University - Computer and Information Sciences, Vol.32 (1), Elsevier-2020, pp.88-98.
- [3] Goel, Kunal, and Amit Kumar Bindal, "Regulated Energy Harvesting Scheme for Self-Sustaining WSN in Precision Agriculture." Proceedings of Data Analytics and Management. Springer, Singapore, 2022, pp, 367-385.
- [4] R. Kamath, M. Balachandra, S. Prabhu, "Raspberry Pi as Visual Sensor Nodes in Precision Agriculture: A Study," in IEEE Access, Vol.7, IEEE-2019, pp.45110-45122.
- [5] J. G. Mora, N. E. S. Reyes, G. C. Altamirano, D. N. Rodriguez, C. E. Teran, E. Q. Arequipa, "Energy Efficiency in a Wireless Sensor Network (WSN): Case Study in Precision Agriculture", 14th Iberian Conference on Information Systems and Technologies, IEEE-2019, pp. 1-6.
- [6] S. R. Schultze, M. N. Campbell, S. Walley, K. Pfeiffer, B. Wilkins, "Exploration of sub-field microclimates and winter temperatures: Implications for precision agriculture", International Journal of Biometeorology, Vol.65, Springer-2021, pp.1043-1052.
- [7] D. K. Anguraj, V. N. Mandhala, D. Bhattacharyya, T. h. Kim, "Hybrid neural network classification for irrigation control in WSN based precision agriculture", Journal of Ambient Intelligence and Humanized Computing, Springer-2021, pp.1-12.
- [8] E. Duncan, A. Glaros, Dennis Z. Ross, Eric Nost, "New but for whom? Discourses of innovation in precision agriculture", Agriculture and Human Values, Springer-2021, pp.1-19.
- [9] C. Xie, D. Zhang, L. Yang, Tao Cui, Xiantao He, Zhaohui Du, "Precision seeding parameter monitoring system based on laser sensor and wireless serial port communication", Computers and Electronics in Agriculture, Vol.190, Elsevier-2021, pp.1-11.
- [10] S. G. krishnan, J. Waimin, N. Raghunathan, S. Bagchi, A. Shakouri, R. Rahimi, "Battery-Less Wireless Chipless Sensor Tag for Subsoil Moisture Monitoring," in IEEE Sensors Journal, Vol.21 (5), IEEE-2021, pp.6071-6082,
- [11] D. Sharma, G. S. Tomar, "Comparative Energy Evaluation of LEACH Protocol for Monitoring Soil Parameter in Wireless Sensors Network", Vol.29 (2), Elsevier-2020, pp.381-396.
- [12] S. J. ru, C. x. Ning, "Design and research of agricultural environmental monitoring system based on wireless sensor", 5th International Conference on Automation, Control and Robotics Engineering (CACRE), IEEE-2020, pp.251-255.
- [13] M. E. Bayrakdar, "Employing sensor network based opportunistic spectrum utilization for agricultural monitoring", Sustainable Computing: Informatics and Systems, Vol.27, Elsevier-20220, pp.1-10.

- [14] L. Hamami, B. Nassereddine, "Application of wireless sensor networks in the field of irrigation: A review", *Computers and Electronics in Agriculture*, Vol.179, Elsevier-2020, pp.1-17.
- [15] S.A. Kumar, P. Llango, "The Impact of Wireless Sensor Network in the Field of Precision Agriculture: A Review", *Computers and Electronics in Agriculture*, Vol.179, Elsevier-2020, pp.1-14.
- [16] A. Triantafyllou, D. C. Tsouros, P. Sarigiannidis, S. Bibi, "An Architecture model for Smart Farming," 15thInternational Conference on Distributed Computing in Sensor Systems, IEEE-2019, pp.385-392.
- [17] B. Gernert, J. Schlichter, L. Wolf, "PotatoScanner – A Mobile Delay Tolerant Wireless Sensor Node for Smart Farming Applications", 15thInternational Conference on Distributed Computing in Sensor Systems, 2019, pp.106-113.
- [18] S. Sadowski, P. Spachos, "Wireless technologies for smart agricultural monitoring using internet of things devices with energy harvesting capabilities", *Computers and Electronics in Agriculture*, Vol.172, Elsevier-2020,pp.1-8.
- [19] F. Ouyang, H. Cheng, Y. Lan, Y. Zhang, X. Yin, J. Hu, X. Peng, G. Wang, S. Chen, "Automatic delivery and recovery system of Wireless Sensor Networks (WSN) nodes based on UAV for agricultural applications, *Computers and Electronics in Agriculture*, Vol.162,Elsevier-2019,pp.31-43.
- [20] K. R. Gsangaya, S. S. H. Hajjaj, M. T. H. Sultan, L. S. Hua, Portable, wireless, and effective internet of things-based sensors for precision agriculture, *International Journal of Environmental Science and Technology*, 17, Springer-2020, pp.3901–3916.
- [21] S. Dhillon, C. Madhu, D. Kaur, "A Solar Energy Forecast Model Using Neural Networks: Application for Prediction of Power for Wireless Sensor Networks in Precision Agriculture", *Wireless Press Communication*, 112, Springer-2020, pp.2741–2760.
- [22] Bindal AK, Mangla A, Prasad D, Patel RB. PLDP: Possible Location Deployment Protocol for Energy Harvesting in WSNs. In 2012 2nd IEEE International Conference on Parallel, Distributed and Grid Computing, IEEE, 2012, pp. 574-579.
- [23] Q. Zhang, Q. Chen, Z. Xu, "Evaluating the navigation performance of multi-information integration based on low-end inertial sensors for precision agriculture. *Precision Agriculture*, 22, Springer-2021, pp.627–646.
- [24] K.N. Bhanu, T. Bhaskara Reddy, M. Hanumanthappa, Multi-agent based context aware information gathering for agriculture using Wireless Multimedia Sensor Networks, *Egyptian Informatics Journal*, Vol.20, (1), Elsevier-2019, pp.33-44.
- [25] G. E. John, R. G., N. K. Thomas, R. J. Mammutil, "Application-specific WSN for precision agriculture," 8thInternational Symposium on Embedded Computing and System Design, IEEE-2018, pp. 241-245.