International Journal on Recent and Innovation Trends in Computing and Communication
ISSN: 2321-8169 Volume: 11 Issue: 8s
DOI: https://doi.org/10.17762/ijritcc.v11i8s.7202
***Article Received**: 24 April 2023 **Revised:** 18 June 2023 **Accepted:** 26 June 2023*

Congestion Detection and Mitigation Technique for Multi-Hop Communication in WSN

K. Phani Rama Krishna[1], Habibulla Mohammad[2], Ch Gangadhar[3], Riazuddin Mohammed[4]
[1]Department of ECE
Prasad V Potluri Siddhartha Institute of Technology
Vijayawada-520007, INDIA
kprkrishna007@gmail.com
[2]Department of ECE
Prasad V Potluri Siddhartha Institute of Technology
Vijayawada-520007, INDIA
honeyhabeeb@gmail.com
[3]Department of ECE
Prasad V Potluri Siddhartha Institute of Technology
Vijayawada-520007, INDIA
gangadharch1111@gmail.com
[4]University of Alberta, Edmonton, AB, Canada T6G 1H9.
riaz70md@yahoo.co.in

Abstract - The primary function of a network system is to gather information from the observation region and transmit it to the base station. The network life span and congestion are the two major concerns in wireless networks. To enhance the lifespan of the sensor system; multi-hopping has been proved as best in class. Congestion is an important factor to be taken, where multiple nodes forward data to one another in the process of communication. Hence to overcome the issue of congestion in WSN, we proposed a congestion detection and mitigation method along with the multi-hop concept. In this technique, we have considered different routes among communication units that were classified on distance, relative attainment rate (RAR) and node storage occupancy. A utility function (U) has been proposed and calculated using the above illustrated factors for every node that acts as a neighbour to the transmitting node. Neighbour node with highest U-valued will be considered as the packet forwarding node's next hop. In this manner congestion free nodes are selected for data transmission.

Keywords-MAC, Multi-hop, Relative Attainment Rate, Wireless Sensor Network.

I. INTRODUCTION

The most important area of research for any country is to build a secured and authenticate Wireless networks for civilian and military applications. A WSN is a wireless network that is designed with scattered sensor units mainly for monitoring physical as well environmental conditions [1] [2]. It is made up of a collection of miniature sensing nodes that communicate with one another. WSN nodes primarily collect and transmit information from their surroundings, such as humidity, temperature, and pollution, to the base station. The latter directs the data to the monitoring network based on the type and magnitude of the information classified.

A multi-hopping phenomena extends the network's lifespan by considering data transfer from one node to another in the network model rather than direct contact between senders and base stations [3] [4] [5] [6] [7] [8] [9].

To be more exact, in terms of network longevity, routing between nodes for data forwarding might be straightforward or in hops. In practice, direct routing is utilized in numerous circumstances since it is simple to construct and even fast in delivery; however, this method becomes inefficient as the network expands in size, hence inter-cluster routing via multi-hopping is used to improve scalability. Using multi-hop, the nodes collect data from the location and transfer it to the BS.

The congestion in network happens when accessible traffic exceeds the channel capacity [10], [11], [12]). Due to the occurrence of congestion in the system, packet drops and quality of the channel falls below the limit. Congestion in the network can be avoided to maximum by adapting efficient congestion detection techniques followed with congestion control schemes.

Congestion detection [13] is a process of identifying abnormality generated while packets transferring from one node to another in the process of communication.

Congestion control practices [14] are purely required only when congestion is detected in the network. It is to be notified that congestion can be prevented but cannot be eliminated.

The main reason of congestion is low speed wireless channels or multiple data packets forwarding towards receiver nodes/intermediate nodes through multiple routes [15]. Apart from handing capability of nodes there are others reasons like collision in the wireless channel, differential packet arrival rate, node storage and also arrival of traffic in bursts [16] [17] [18].

To avoid congestion, the best practice is to adapt an efficient routing algorithm which can balance the communication system. Conventional congestion control protocol is suitable in WSN, which reduces congestion by following parental and child model. In this scheme packet generation rate of critical nodes that causes traffic bursts are dwindled.

II. METHODOLOGY

For diminishing, the packet production rate of critical nodes, an effective precision by speed adjustment protocol called congestion avoidance and mitigation protocol (CAM) [19] is utilized. To find the congestion occurred at every node, relative attainment rate (RAR) is calculated.

Congestion prevention utility function shown in Equ. 11 are applied for every neighbour of transmitter node. Highest utility function neighbour nodes are chosen in the packet forwarding process using two main components such as RAR factor and distance of next node.

Using Equ. (3), storage occupancy ratio from [17] is taken as another parameter for generating incoming and outgoing traffic of every node. This parameter calculates the traffic at the nodes and also provides information about dynamic connections existing w.r.t to the transmitting nodes

A. Congestion avoidance and mitigation (CAM) protocol

Using CAM protocol, the consistency and reliability of the active nodes in data transmission process has been enriched. At the same time the main problems of CAM protocol are 1) increases the regular data rate, 2) more number of packet drops 3) gradually decreases the average attainment data rate at BS.

1) Innovative model - congestion control algorithm:

This algorithmic scheme uses Feedback Congestion Control (FBCC) [20]and direct discrete sampled controlling principle. FBCC identifies the beginning of congestion by means of queue length. At the same time main drawback of FBCC is storage overflow due to inequality flow generated between incoming and outgoing channels.

III. PROPOSED WORK

A. Congestion Detection and mitigation with Multi-Hopping Technique

To overcome the drawbacks of CAM protocol and FBCC technique, a new protocol is introduced i.e. CDMM technique that functions on multi-hopping along with 3 main parameters like distance, RAR and storage occupancy. Sensor networks use efficient ways and observations to overcome restrictions such as energy consumption and traffic congestion. The network lifespan is a critical concern in wireless networks, which may be extended by addressing node energy preservation [21] [22] [23]. The research focuses on congestion identification and mitigation using the Multi-Hopping Technique, which allows for more efficient energy utilization by minimizing congestion-related concerns. In this CDMM technique, routes selection is grounded with the distance along transmitting and receiving nodes, storage occupancy and RAR significance of nodes. Using the above said parameters, a U function is applied to each neighbour of a transmitting node. Therefore, nodes with maximum U-value (non-congested nodes) are selected as next hoping nodes in data routing process. Finally, for mitigation of congestion RAR values are taken for consideration using Figure 1.

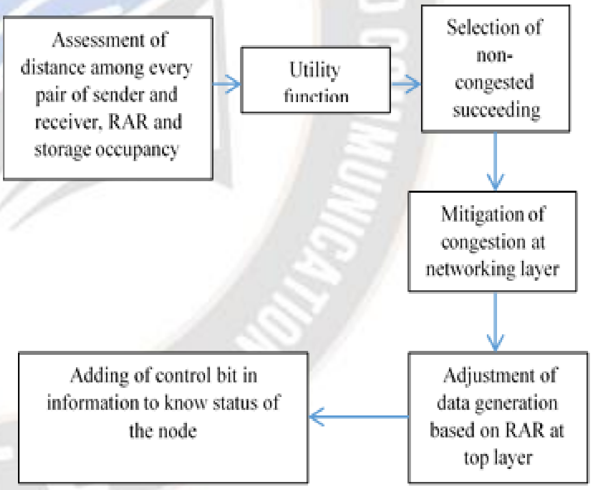

Figure 1. Working diagram of the entire system

1) Level of Congestion

For defining the level of congestion MAC of data link layer is considered. When many nodes compete for accessing a channel in a congested area they will definitely drop the packets mostly due to collision. To obtain level of congestion at small intervals of time

$$CL = 1 - RAR \tag{1}$$

where RAR denotes the relative attainment rate

$$\mathrm{RAR} = \frac{\mathrm{PT_x}}{\mathrm{PF_x}} \tag{2}$$

The number of packets transmitted and forwarded for a given interval of time at the MAC and networking layer are PT_x and PF_x.

a) Nodes Storage occupancy

Using the incoming and outgoing traffic rate, it is easy to model the change in storage occupancy.

$$b_i(t+1) = St_{bo}(b_i(t) + Ic_i(t) - g_i(t)) \tag{3}$$

The storage occupancy of a node for time interval T is $b_i(t)$. The capacity indicator indicating the finite queue size is St_{bo}. The amount intermission is I. The term $c_i(t)$ refers to controlled incoming traffic. $g_i(t)$ is outbound traffic initiated by hop node $i+1$.

b) The performance of FBCC

The behavior of FBCC protocol is exhibited using probabilistic differential calculations. For a better understanding, let us assume a queue process with parental and child model.TC is the transmission capacity of the parental node and A is taken as dynamic contacts crossing the link i. An outgoing traffic for the child node is taken with g1 (k), g2 (k), g3 (k), g4 (k) correspondingly.

Now, dynamic storage is most likely as

$$d_{g_i} = (c_i - g_i)g_i \frac{\sum g_i - \frac{b_0 - b(k)}{I} - TC}{\sum g_i} dt \tag{4}$$

The Equation 4 is linearized at $(\mathrm{c_0}, \mathrm{g_0}, \mathrm{b_d})$.

Hence

$$M = (\sum g_i)^{-2}(c_i - 2g_i)\left(\sum g_i - \frac{b_0 - b_d}{I} - TC\right) + (c_i - g_i)g_i(4 - \frac{b_0 - b_d}{I} - TC) \tag{5}$$

$$A = g_0 \frac{\sum g_0 \frac{b_0 - b_d}{I} - TC}{\sum g_i}; b_d = \frac{TC}{A_0} \tag{6}$$

The linearity form of above obtained nonlinear model is

$$\dot{z}(k) = Mz(k) + Ac(k) \tag{7}$$

Discrete form of the above Equation 7 is

$$g_i(t+1) = (M+1)g_i(t) + Ac_i(t) \tag{8}$$

Let

$$X(t+1) = (b_i(t+1), b_i(t), g_i(t+1), g_i(t))^I \tag{9}$$

Using Equation 8 and 9, the dynamic equation obtained is

$$X(t+1) = EX(t) + FC(T) \tag{10}$$

2) Congestion detection

In a static network, there is a chance of utilizing the same route multiple times, when the route opts distance as a parameter among nodes. This hints that the nodes nearby the base station might collapse sooner as they participate actively in packet forwarding. To overcome such issue, distance and multi-hopping along neighbors are taken as a selection principle of CDMM protocol.

Therefore, by applying utility function U to every neighbour of a source node that makes transmitted node to choose the utmost U-valued node between its neighbors. The functionality of U defined as

(1) Distance calculation towards next node for guaranteeing high packet attainment rate

(2) Obtaining RAR of every neighbour for eluding congested nodes

(3) To deliver feedback based congestion control at intervals storage occupancy of a node is monitored

Using the above three parameters, it is easy to evaluate utility function as

$$U(t) = p \times \frac{L_t}{L} + q \times RAR_t + r \times b_i(T) \tag{11}$$

From the above Equation

L_t - Distance of succeeding node at time t routed to base station.

L - Total distance from transmitter to base station

RAR_t - Relative attainment rate of a node at time t

$b_i(T)$ - Node storage occupancy at time T

$$p + q + r = 1 \tag{12}$$

RAR avoids cluttered nodes, resulting in lower congestion establishment. Using FBCC system along with storage occupancy (i.e. by means of queue length), the initiation of congestion is easily identified. Figure 2 states the workflow diagram for congestion avoidance.

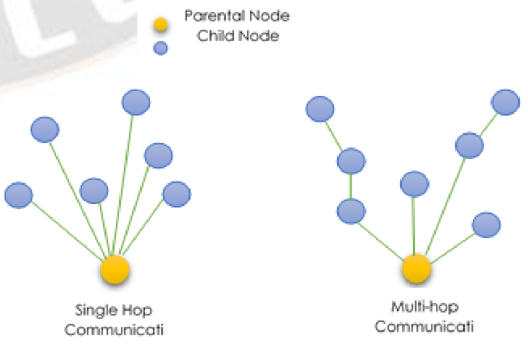

Figure 2. Working diagram for congestion avoidance

3) Congestion mitigation

Congestion mitigation is done at the network layer using RAR calculation and hence communicates the RAR significance to application layer

(1) If RAR significant is lower than one, the upper layer decreases the productivity rate to the current rate's RAR value.

(2) If the RAR value is 1, the top layer has the least significant productivity rate as compared to the direct rate. In such instances, the data production rate improves by at least 10% while waiting for the next RAR value generated by the networking layer.

(3) In case packets emanated from non-required nodes, then RAR values of such packets are forwarded to MAC layer where such packets are avoided in the transmission process.

(4) A control bit is attached towards a packet, to find out the node closeness towards the event.

4) Overall algorithm

(1) To avoid congestion in WSN, selection of non-congested nodes plays an important role in route selection.

(2) Transmitting node selects the next hop i.e. neighbour node using utility function (distance calculation), RAR of every node and storage occupancy ratio.

(3) Route selected using distance among sender-receiver combination guarantees high packet success rate.

(4) At network layer, using active congestion conditions of nodes, RAR values of each node is obtained.

(5) To deliver feedback based congestion control, each nodes storage occupancy is taken in consideration.

(6) Finally using the working parameters, U- Function is assessed.

(7) Using the highest U-Function of surrounding nodes, next node is considered for data transmission

(8) For congestion mitigation, RAR value is considered. Using RAR factor data productivity rate is diverse.

(9) Only RAR value added packets obtained through other nodes is forwarded by the network layer

(10) As a result, congestion is mitigated consistently.

IV. SIMULATION RESULTS

The suggested Congestion Detection and mitigation through Multi-hopping (CDMM) scheme is simulated using MATLAB. In the simulation process 100 nodes are taken with a varied data rates from 100 to 500 Kb. Table 1 provides setting parameters.

TABLE I. VARIABLES FOR SIMULATION

Parameters	Values
Nodes	100
Coverage	750X750m
Time	50s
Size of the packet	512 bytes
Initial energy	8.5J

Evaluation of CDMM performance is provided in comparison with CAM and FBCC protocols considering the following metrics.

Delay: Packet reaching time towards receiver

Packet delivery average ratio: The total number of packets sent divided by the number of packets that arrived at their destination.

Energy: The average amount of energy used on computation.

Throughput: The total number of packets sent divided by the number of packets that arrived at their destination.

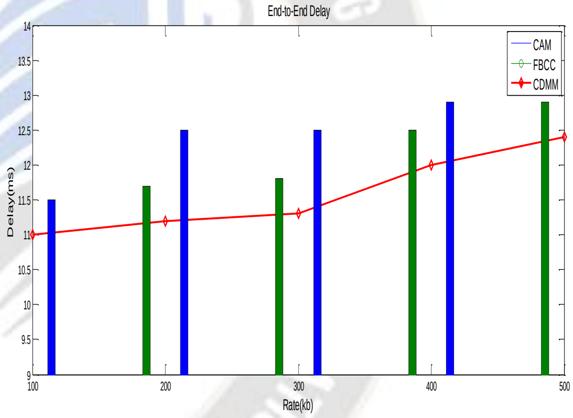

Figure 3. Delay factor

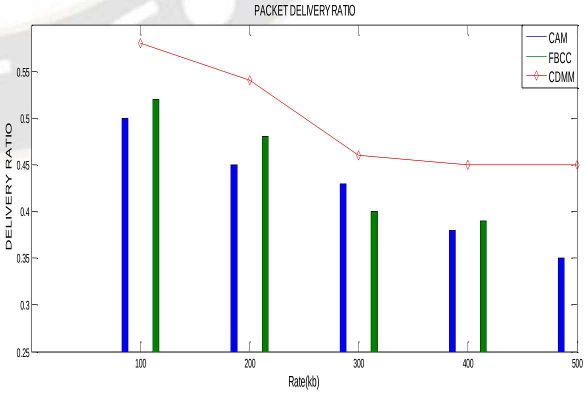

Figure 4. Delivery ratio Vs. Rate

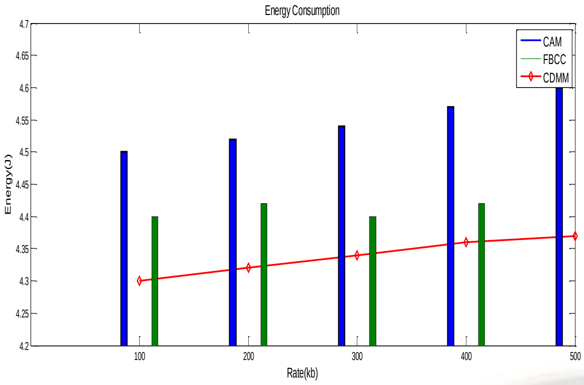

Figure 5. Energy Utility

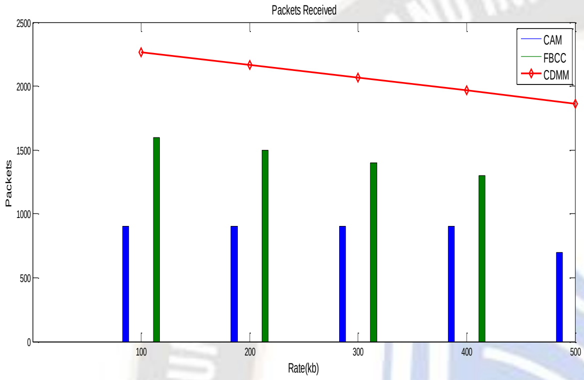

Figure 6. Throughput

The performance of the three protocols are calculated based on the above metrics with variable data rates ranging from 100-500Kb. Simulation results are achieved for latency, delivery ratio, packet loss, and throughput.

Figures 3, 4, 5, and 6 depict the simulation results for the CDMM, FBCC, and CAM protocols in terms of latency, delivery ratio, loss rate, and performance. It clearly implies CDMM leaves behind CAM by 10.4 % (delay), 16 % (delivery ratio), 4.44 % (energy utilization) and 151.66 % (throughput). Similarly, CDMM outclasses FBCC by 4.27 % (delay), 11.53 % (delivery ratio), 2.27 % (energy utilization) and 41.56 % (throughput).

V. CONCLUSIONS

In this paper, congestion detection and mitigation along with Multi-hopping concept is introduced for sensor networks. The main purpose is to avoid congestion by routing data through non congested nodes. Using the hopping concept, next node for transmission is selected rather than direct path. The succeeding hop nodes are elected depending on the factors such as RAR, distance among nodes and storage occupancy.

Using the assessed RAR value, the data productivity rate is balanced. Finally, based on the results obtained, it is clear that the network lifetime has been increased by improving packet delivery rate and decreasing packet loss rate.

ACKNOWLEDGEMENTS

The authors would like to thank PVP Siddhartha Institute of Technology. This research is supported by Research and Development cell, Electronics and Communication Engineering Department.

Funding

The authors state that this work has not received any funding.

Conflict of Interest

On behalf of all authors, the corresponding author states that they have no conflict of interest.

Author Contribution

K. Phani Rama Krishna – Data collection, Reviewing.

Habibulla Mohammad – Study conception and design

Writing original draft, Methodology

Ch Gangadhar – Analysis and interpretation of results

Riazuddin Mohammed – Conceptualization, Reviewing and editing.

All Authors read and approved the Manuscript.

REFERENCES

[1] M. Li, Z. Li and A. V. Vasilakos, “A survey on topology control in wireless sensor networks: Taxonomy, comparative study, and open issues,” Proceedings of the IEEE, vol. 101, no. 12, pp. 2538-57, 2013, July. https://doi.org/10.1109/jproc.2013.2257631

[2] I. F. Akyildiz, W. Su, Y. Sankarasubramaniam and E. Cayirci, “A survey on sensor networks,” IEEE Communications magazine, vol. 40, no. 8, pp. 102-114, 2002. https://doi.org/10.1109/mcom.2002.1024422

[3] H. Mohammad and A. S. Chandrasekhara Sastry, “Implementation of three-tier multihop technique in Advance Coupling Network Model-Deterministic Energy-efficient Clustering of Wireless Sensor networks,” Journal of Computational and Theoretical Nanoscience, vol. 16, no. 5-6, pp. 2581-2589, 2019. https://doi.org/10.1166/jctn.2019.7934

[4] H. Mohammad, A. S. ChandrasekharaSastry and G. Vaddeswaram, “Implementation of Multi-Hop Technique in Dec Protocol,” International Journal of Simulation systems, Science & Technology (UAE), vol. 19, no. 4, p. 1, 2018. https://doi.org/10.5013/ijssst.a.19.04.20

[5] H. Mohammad and A. S. ChandrasekharaSastry, “DSWS-Distributed Sleep/Wake Scheduling Scheme for DEC Protocol in Wireless Sensor Networks,” International Journal of Recent Technology and Engineering, vol. 8, no.

2, pp. 2695–2701, 2019. https://doi.org/10.35940/ijrte.b2810.078219

[6] Y. Xiao, M. Peng, J. Gibson, G. G. Xie, D. Z. Du and A. V. Vasilakos, “Tight performance bounds of multihop fair access for MAC protocols in wireless sensor networks and underwater sensor networks,” IEEE Transactions on Mobile Computing, vol. 11, no. 10, pp. 1538-1554, 2011. https://doi.org/10.1109/tmc.2011.190

[7] T. Meng, F. Wu, Z. Yang, G. Chen and A. V. Vasilakos, “Spatial reusability-aware routing in multi-hop wireless networks,” IEEE Transactions on Computers, vol. 65, no. 1, pp. 244-255, 2015. doi: 10.1109/TC.2015.2417543

[8] J. Wang, “Level-based routing protocol design for multi-hop wireless sensor networks,” Journal of Computer Applications, vol. 28, no. 7, pp. 1844–1846, 2008. https://doi.org/10.3724/sp.j.1087.2008.01844

[9] A. M. Ahmed and R. Paulus, “Congestion detection technique for multipath routing and load balancing in WSN,” Wireless Networks, vol. 23, pp. 881-888. https://doi.org/10.1007/s11276-015-1151-5

[10] A. Bohloulzadeh and M. Rajaei, “A survey on congestion control protocols in wireless sensor networks,” International Journal of Wireless Information Networks, vol. 27, pp. 365-384, 2020. https://doi.org/10.1007/s10776-020-00479-3

[11] U. S. Visweswaraiya and K. S. Gurumurthy, “A Novel, Unified Dynamic Data Dissemination [D-Cube] and Traffic Classification Technique for Congestion Avoidance in High Speed Wireless Multimedia Sensor Networks,” International Journal of Simulation--Systems, Science & Technology, vol. 14, no. 2, pp. 26–34, 2013. https://doi.org/10.5013/ijssst.a.14.02.05

[12] C. Busch, R. Kannan and A. V. Vasilakos, “Approximating Congestion+ Dilation in Networks via “Quality of Routing” Games,” IEEE Transactions on Computers, vol. 61, no. 9, pp. 1270-1283, 2011. https://doi.org/10.1109/tc.2011.145

[13] Z. Shelby, C. Pomalaza-Raez, H. Karvonen and J. Haapola, “Energy optimization in multihop wireless embedded and sensor networks,” International journal of wireless information networks, vol. 12, pp. 11-21, 2005. https://doi.org/10.1007/s10776-005-5166-1

[14] J. H. Lee and I. B. Jung, “Adaptive-Compression Based Congestion Control Technique for Wireless Sensor Networks,” Sensors, vol. 10, no. 4, pp. 2919–2945, 2010. https://doi.org/10.3390/s100402919

[15] N. Chilamkurti, S. Zeadally, A. Vasilakos and V. Sharma, “Cross-layer support for energy efficient routing in wireless sensor networks,” Journal of Sensors, vol. 2009, p. 9, 2009. https://doi.org/10.1155/2009/134165

[16] Y. Zeng, K. Xiang, D. Li and A. V. Vasilakos, “Directional routing and scheduling for green vehicular delay tolerant networks,” Wireless networks, vol. 19, pp. 161-173, 2013. https://doi.org/10.1007/s11276-012-0457-9

[17] P. Li, S. Guo, S. Yu and A. V. Vasilakos, “Reliable multicast with pipelined network coding using opportunistic feeding and routing,” IEEE Transactions on Parallel and Distributed Systems, vol. 25, no. 12, pp. 3264-3273, 2014. https://doi.org/10.1109/tpds.2013.2297105

[18] M. M. Bhuiyan, I. Gondal and J. Kamruzzaman, “CODAR: Congestion and delay aware routing to detect time critical events in WSNs,” In The International Conference on Information Networking 2011 (ICOIN2011), pp. 357-362, 2011, January. IEEE. doi: 10.1109/ICOIN.2011.5723128

[19] M. M. Bhuiyan, I. Gondal and J. Kamruzzaman, “CAM: congestion avoidance and mitigation in wireless sensor networks,” In 2010 IEEE 71st Vehicular Technology Conference, pp. 1-5, 2010, May. IEEE, doi: 10.1109/VETECS.2010.5494190

[20] Juan Garcia, Guðmundsdóttir Anna, Maria Jansen, Johansson Anna, Anna Wagner. Exploring Decision Trees and Random Forests for Decision Science Applications. Kuwait Journal of Machine Learning, 2(4). Retrieved from http://kuwaitjournals.com/index.php/kjml/article/view/211

[21] M. Li and Y. Jing, “Feedback congestion control protocol for wireless sensor networks,” In 2012 24th Chinese Control and Decision Conference (CCDC), pp. 4217-4220, 2012, May. IEEE, doi: 10.1109/CCDC.2012.6244675

[22] S. J. Baek, G. De Veciana and X. Su, “Minimizing energy consumption in large-scale sensor networks through distributed data compression and hierarchical aggregation,” IEEE Journal on selected Areas in Communications, vol. 22, no. 6, pp. 1130-1140, 2004. https://doi.org/10.1109/jsac.2004.830934

[23] X. Y. Liu, Y. Zhu, L. Kong, C. Liu, Y. Gu, A. V. Vasilakos and M. Y. Wu, “CDC: Compressive data collection for wireless sensor networks,” IEEE Transactions on Parallel and Distributed Systems, vol. 26, no. 8, pp. 2188-2197, 2014. doi: 10.1109/TPDS.2014.2345257.

[24] X. Xu, R. Ansari, A. Khokhar and A. V. Vasilakos, “Hierarchical data aggregation using compressive sensing (HDACS) in WSNs,” ACM Transactions on Sensor Networks (TOSN), vol. 11, no. 3, pp. 1-25, 2015. https://doi.org/10.1145/2700264.