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Energy Efficient Cluster Head Selection And Routing In Multilevel Heterogeneous Wireless Sensor Networks

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Abstract: Wireless Sensor Network (WSNs) is used broadly for collecting data and the data is used in performing tasks which are mission critical. The most inspiring thing in Sensor Networks deployed in mission critical jobs is the implementation of routing protocols which is energy effectual. We put forward an enhanced and stable energy effectual routing protocol for heterogeneous WSNs in this paper. The key factors analyzed for improving efficacy of routing are consumption of energy during communication in clusters and varied levels of energy in heterogeneous WSNs. In this proposed routing protocol, the probability of a node becoming cluster head (CH) is on the basis of the rate of energy consumption and the transmission area covered by the node. Apart from these, we incorporate node heterogeneity with respect to initial energy and we observe the impact in the network performance. Our results obtained from simulation confirms the fact that the proposed method can prolong the network lifespan compared to existing protocols used in homogenous WSNs, which is essential for applications which are mission critical.

Keywords: Wireless Sensor Network, Homogenous WSNs, Heterogeneous sensors, Energy effectual routing protocol, Cluster Head Selection.

1. INTRODUCTION

Mission Critical Sensor Networks offer massive connections of network devices and sensors and is used in different domains [1]. Wireless Sensor Network finds its application in countless areas for data collection to perform some mission critical operations. WSNs contains numerous tiny self-governing equipment named the sensor nodes that senses a phenomena, processes the sensed data in a basic level and communicating with each other [2]. The Sensors in WSNs are usually powered by batteries. There are large numbers of factors which causes higher battery power exhaustion in WSNs like the count of sensor nodes, monitoring purpose, local data pre-processing, and communication related activities [3]. Energy exhaustion in WSNs is a concern of supreme significance and in the past period of time it is revealed by many numbers of protocols, algorithms, and techniques to preserve energy and to prolong the network lifetime. WSNs are employed typically to observe environmental changes or habitat monitoring, various automation processes, smart cities and traffic control, etc. [4], [5]. WSNs are indispensable in various domains of day to day life [6], [7]. Due to the frequent sensing of phenomena by sensor nodes, it is obligatory for all sensor nodes to operate in a usual state, provided the sensor nodes may have constrained energy asset and failure of sensors may lead to serious disaster in the deployment environment [8].

2. RELATED WORK

Wireless Sensor Networks is categorized as two major kinds as homogeneous and heterogeneous WSNs. Homogeneous Sensor Network has a group of identical sensor nodes having same properties, while a group of well-connected dissimilar nodes forms the Heterogeneous Sensor Network [9]. In recent times, numerous heterogeneous and energy adaptive routing protocols have come into existence for wireless sensor networks [10]. H. Alami *et al* has introduced the Stable Election Protocol(SEP) in which the probability of a node becoming the cluster head (CH) is on the basis of the remaining energy left in each node, This CH selection scheme helps to prolong the life span of the network [11]. Qing *et al*. proposed the Distributed Energy Efficient Clustering (DEEC) which is an energy effectual clustering scheme developed for heterogeneous WSN with single level heterogeneity [12]. The major variance between DEEC and SEP is that in DEEC protocol, CH selection probability is on the basis of the proportion of the left out energy to the total energy consumption of the network in average but SEP scheme considers only the residual energy of the nodes. The thing common in both the schemes is the time taken for a node to become the CH is based on the estimation of initial energy and residual energy of the node. An enhanced version of distributed energy efficient clustering scheme and routing protocol for three types of node heterogeneity evolved by Saini *et al,* which extends the network life span and constancy [13] and similar to Qing *et al* here in this work also heterogeneity is involved and that to in a higher degree by adding another category of node named super node with different energy level. Aslam *et al*. proposed a Centralized Energy-Efficient Clustering and Routing protocol (CEEC) [14]. The CEEC brings heterogeneity in deployment area by partitioning the network area into three equal parts, where nodes of same energy level are disseminated in the same spatial location. Qureshi *et al.* proposed the Balanced Energy-Efficient Network Integration Super Heterogeneous (BEENISH) protocol, after investigating the consumption of energy during communication, cluster head selection and varied levels of energy in the heterogeneous WSNs [15]. According to BEENISH, it is proposed with four levels of nodes in WSN and the CH is nominated based on the available amount of energy in a node.

The major focus of the paper includes:

- Formulation of an energy effectual cluster head election algorithm that considers the area coverage by nodes. When the node with less coverage rate acts as the CH, it may cause early death of nodes because its energy consumption is imbalanced.

- A method for the selection of CHs bearing in mind the ratio between residual energy of the sensor nodes and energy consumption of the respective node to support the extended lifetime of the network.

3. SYSTEM DESCRIPTION

In this section, we discuss our system design and heterogeneities in the network and we will discuss its relevance and suitability.

3.1 NETWORK MODEL

The network simulated in the paper contains three-level heterogeneity [16]. In contrast to conventional homogeneous WSNs, heterogeneous WSNs will contain dissimilar types of nodes and which is most suitable for practical applications because of its heterogeneous and diversified nature.

3.2 HETEROGENEITY IN NETWORK

The proposed work involves heterogeneity in the following:

Node Heterogeneity

The proposed work uses four heterogeneous nodes in WSNs, as 50% of nodes are normal nodes, which have the similar opening energy as in the conventional homogeneous WSN, deploys 30% of extradinary nodes whose energy is double the energy of normal nodes, includes 15% of super nodes, which have triple the energy than the normal nodes, employs 5% of ultra-super nodes whose battery power is 4 times higher compared to normal nodes.

Energy Heterogeneity

There are two main causes for the prevailing energy heterogeneity.

1. Sensor Nodes in the WSN are deployed with dissimilar energy levels initially to carry out the designated operations.
2. The Energy consumption by the nodes are different because network will lead to imbalanced energy usage by nodes during different operations (i.e., CH may consume a higher energy compared to other nodes).

Link Heterogeneity

The nodes have different energy levels and so obviously the communication links are also heterogeneous. Links are heterogeneous as nodes with greater energy will have huge bandwidth and network relay distance also longer when compared to normal nodes. Link heterogeneity will not have a great impact in long distant data transmission and link quality, if appropriate nodes are selected for transmission.

3.3 BASIC ASSUMPTIONS IN NETWORK

The proposed work is implemented on making following assumptions before the simulation:

- The entire network is deployed with around 50 wireless sensor nodes deployed in a plane having dimension 100 X 100 m^2.
- The nodes are spread randomly with 4 dissimilar initial energy levels.
- The batteries of the nodes are neither replaceable nor repairable.
- Base Station is placed centric in the sensing diameter.

4. THE PROPOSED ROUTING PROTOCOL

The proposed routing protocol assumes that the nodes in the network have four energy levels, hence classified as normal nodes, extradinary nodes, super nodes, and ultra-super nodes and the CH is elected according to the proportion of remaining energy to the energy consumed by the particular node. Apart from this, node coverage by the nodes also influences the CH selection process. The protocol implementation is shown as in the Figure 1,

4.1 CLUSTER HEAD SELECTION

As an initial step of cluster head selection, the node coverage area for all the nodes is to be computed. The monitoring area in the simulator is in the form of a square and is separated as equal sized pixels. The size of the pixels differs in accordance to the real application environment.

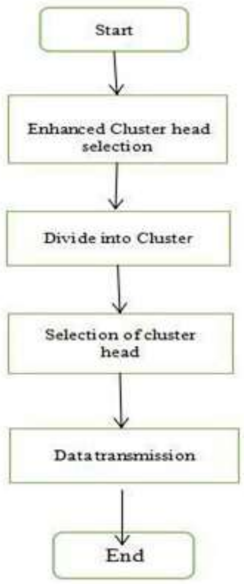

Fig. 1. The proposed System Design

The pixel coverage is estimated by the combined estimation probability of groups of nodes [17]. The area covered by a node set A is calculated as the fraction of area covered by the set of nodes A and the total monitoring area.

$$\text{Coverage Area (A)} = \frac{\sum_{i=1}^{N} P(Cov)}{A \times A} \quad (1)$$

Where,
N is the node count in the cluster.
P (Cov) represents the cumulative coverage probability of nodes in the particular cluster or group.
A x A is the area of the square shaped sensing area.

Consider the total amount of nodes in the cluster is N and are named as ND1, ND2, ND3……. NDN. A set of optimal nodes which will have eligibility to become CH with large coverage rate are selected from all clusters using (1) and a pool of optimal node set NODE opt is formed and after the first node is selected as CH based on the selection scheme in the appropriate clusters. We need to select the next node iteratively in each cluster from the pool of optimal nodes and additionally the CH selection scheme involves the collection of energy consumption and residual energy information from all nodes, as shown in figure 2. Energy consumption of all CHs in NODE opt pool is collected as Econsp and initial energy of all CHs in NODE opt pool is recorded as Einit.

$$E_{Consp_i} = \sum_{i=1}^{n} E_{Consp_i} (i \in 1,2 \ldots \ldots \ldots \mathrm{NODE_{opt}}) \quad (2)$$

$$E_{init_i} = \sum_{i=1}^{n} E_{init_i} (i \in 1,2 \ldots \ldots \ldots \mathrm{NODE_{opt}}) \quad (3)$$

The residual energy is calculated from (2) and (3) as

$$E_{Res_i} = E_{init_i} - E_{Consp_i} \; (i \in 1,2 \ldots \ldots \ldots \mathrm{NODE_{opt}}) \quad (4)$$

The purpose of collecting Energy information of the CHs is that, apart from coverage rate in our proposed method we consider energy also an important factor in electing the CH. A numerical measure named, Vitality Factor (VF) is calculated for each CH by taking the ratio between residual energy and energy consumed using (2) and (4) as

$$VF_i = \frac{E_{Res_i}}{E_{Consp_i}}, (i \in 1,2 \ldots \ldots \ldots \mathrm{NODE_{opt}}) \quad (5)$$

Higher residual energy of a CH leads to a higher value for vitality factor. When a node having high VF is elected as CH then inevitably life time the network also increases.

4.2 BROADCAST PHASE

Once the Cluster Head is chosen in the current round, it will start transmitting initial broadcast messages to the rest of the nodes in the network. The Carrier Sense Multiple Access (CSMA) MAC protocol is used by the current CH to broadcast the messages among the nodes [18]. After broadcasting is over, each non-cluster head node will receive the message and now it is the time for the nodes to determine the appropriate cluster it should belong, and this happens in the next phase [19]. The selection of appropriate cluster by the nodes is dependent on the acquired signal stability of the broadcast.

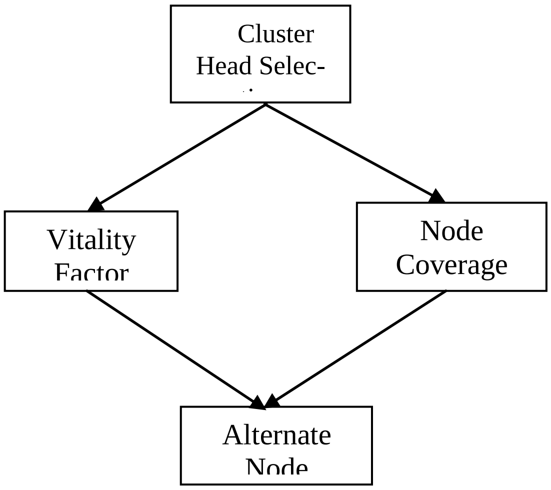

Fig. 2. CH Selection Model

4.3 CLUSTER FORMATION

In this phase, nodes will start to decide about the cluster it has to join and once decided, it should report to the corresponding Cluster Head. Each node employs CSMA - MAC protocol to get synchronized with CH [20]. At the end of this phase, the nodes would have been grouped into definite number of clusters.

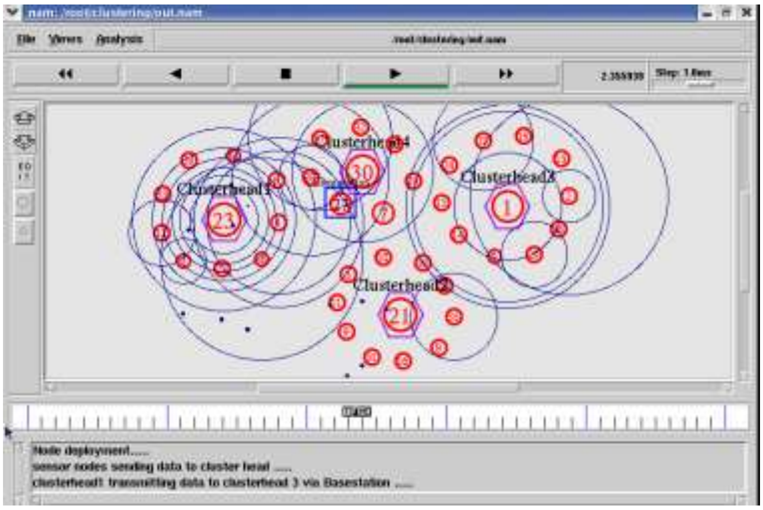

Fig. 3. Network Setup

4.4 DATA TRANSMISSION PHASE

Once clusters are formed, the TDMA (Time Division Multiple Access) scheduling of data packets starts. The nodes in the clusters will start to transmit data packets to the Cluster Head in the stipulated transmission slot. A simple energy management is achieved here by making the each non-cluster head nodes to turn off the transmitter as per its transmission time slot meanwhile the Cluster Heads must have their receivers on all the time for receiving data packets from the member nodes in the cluster. During every round of transmission in the network begins with node initialization phase during which the clusters are established that is followed by that is the steady state, during which the data are forwarded to the Base Station.

5. RESULTS AND FINDINGS

The whole network is simulated in NS3 simulator and in order to estimate the outcome of the proposed protocol, it is compared with homogenous WSN with LEACH protocol (taken as existing system). The energy model is developed in this simulation as 50% of nodes are normal nodes, which have the similar initial energy as a node contains in the conventional homogeneous WSN, 30% of extradinary nodes whose energy is double than the normal nodes, 15% of super nodes, which have triple the amount of energy when compared to the normal nodes, 5% of ultra-super nodes, whose battery power is 4 times higher compared to normal nodes as shown in figure 3.

The number of living nodes decides the life span of the WSN. Lack of proper energy management in the WSN may lead to reduction of residual energy of nodes, untimely decease of sensor nodes in the network, and which in turn condense the life time of the network. Lesser the energy exhaustion, greater the number of living nodes and lengthier the life time of

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WSNs. Energy is an important factor here which influences the life time of the WSN. The overall Energy consumption and network life time in comparison with the existing system is presented in Figure 4 and Figure 5 respectively.

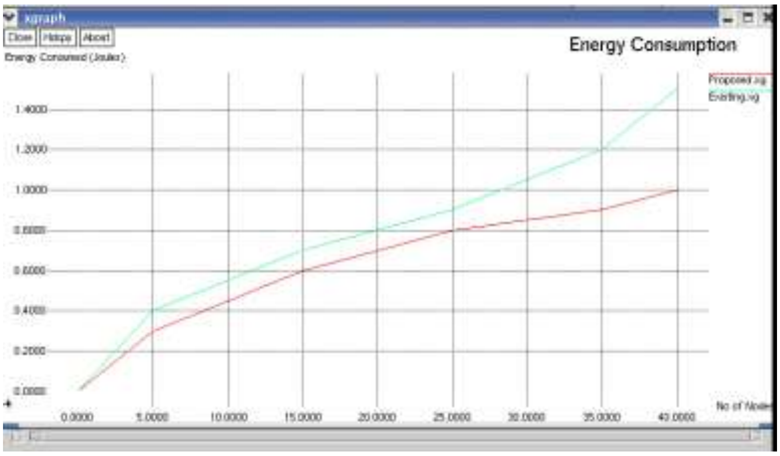

Fig. 4. Energy Consumption

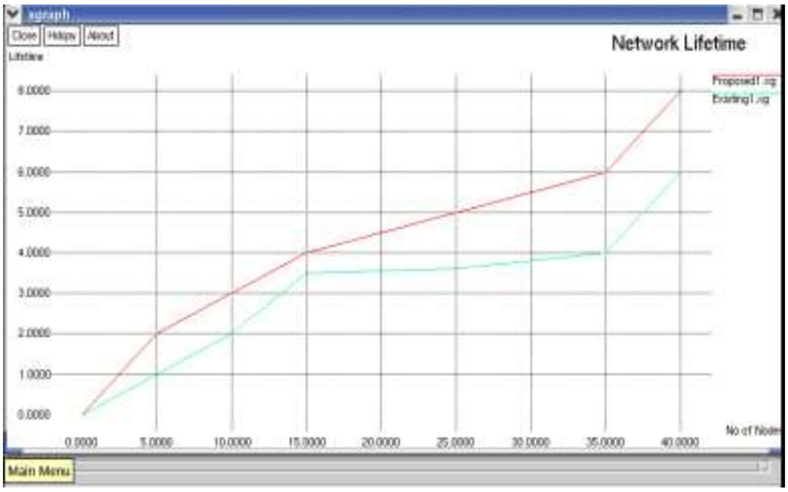

Fig. 5. Network life time

Throughput is considered to be a performance measure in any network. Throughput is calculated by taking the rate data transferred from source to destination in a given point of time. From Figure 6, we can observe that the introduced algorithm provides optimal throughput rate.

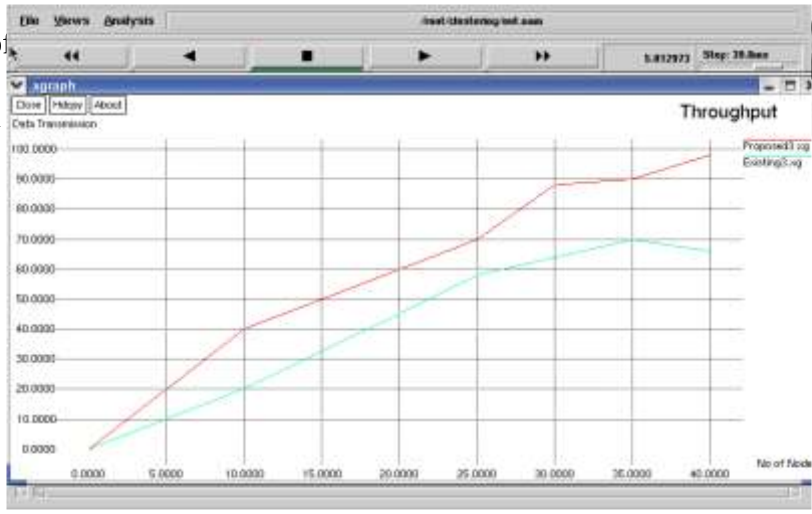

Fig. 6. Comparison of Throughput

Network delay is a critical design and performance issue in mission critical WSNs, where data has to be taken swiftly. Delay shall be calculated by considering the time taken for a bit of data to travel across the network from one communication endpoint to another. The unit for delay is multiples or fractions of a second. Figure 7 shows proposed scheme shows a minimum delay.

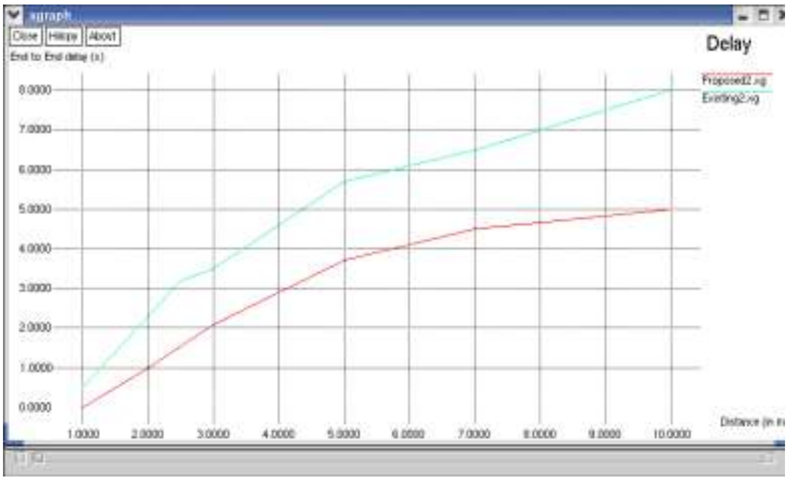

Fig. 7. Network delay comparison

6. CONCLUSION

In this paper, a novel and energy effectual routing algorithm for multilevel heterogeneous WSNs with single-hop communication is proposed. To improve the life span of the network and to make the algorithm energy efficient, CH selection is done on the basis of node coverage area and vitality factor of nodes which is the fraction of the remaining energy and the energy consumed by nodes. The results obtained from simulation showcases that the proposed algorithm outperforms existing algorithms used in homogenous WSNs in terms of energy consumption, network delay, throughput and network lifetime

7. REFERENCES

[1] M. G. Alvarez, J. Morales and M.-J. Kraak (2019) Integration and exploitation of sensor data in smart cities through event-driven applications In: Sensors, vol. 19, pp. 1372.
[2] M. Xia and D. Song (2018) Application of wireless sensor network in smart building In: Machine Learning and Intelligent Communications, Springer, pp. 315-325.
[3] H. E. Alami and A. Najid (2016) (SET) Smart Energy Management and Throughput Maximization: A new routing protocol for WSNs In: Security Management in Mobile Cloud Computing, IGI Global, pp. 1-28, 2016.
[4] C. Li, H. Zhang, B. Hao and J. Li (2011) A survey on routing protocols for large-scale wireless sensor networks" In: Sensors, vol. 11, no. 4, pp. 3498-3526.
[5] Zhu W, Cao J, Raynal M (2018) Energy-efficient composite event detection in wireless sensor networks In: IEEE Communication Letter, Vol. 22, no.1, pp. 177–180, 2018.
[6] Mohammed Fauzi Othman and Khairunnisa Shazali (2012) Wireless Sensor Network Applications: A Study in Environment Monitoring System In: Procedia Engineering, Elsevier, Vol. 41, pp. 1204 – 1210.
[7] Bushra Rashid and Mubashir Husain Rehmani (2016) Applications of Wireless Sensor Networks for Urban Areas: A survey In: Journal of Network and Computer Applications, Elsevier, Volume 60, No. January 2016, Pages 192-219.
[8] Agrawal D.P (2017) Applications of Sensor Networks In: Embedded Sensor Systems, Springer, Singapore.
[9] V. Mhatre and C. Rosenberg (2004) Homogeneous vs heterogeneous clustered sensor networks: A Comparative Study In: IEEE International Conference on Communications Paris, France, pp. 3646-3651.
[10] H. E. Alami, A. Najid (2015) SEFP: A new routing approach using fuzzy logic for clustered heterogeneous wireless sensor networks In: International Journal on Smart Sensing & Intelligent Systems, vol. 8, no. 4, pp. 2286–2306.
[11] G. Smaragdakis, I. Matta, A. Bestavros (2004) SEP: A Stable Election Protocol for clustered heterogeneous wireless sensor networks In: Proceeding of 2nd International Workshop on Sensor and Actor Network Protocols and Applications (SANPA 2004).
[12] L. Qing, Q. Zhu, M. Wang (2006) Design of a distributed energy efficient clustering algorithm for heterogeneous wireless sensor networks In: Computer Communication, ELSEVIER, vol. 29, no.12, pp. 2230- 2237.
[13] P. Saini, A. K. Sharma (2010) Enhanced Distributed Energy Efficient Clustering Scheme for heterogeneous WSN In: Proceeding of 1st International Conference on Parallel, Distributed and Grid Computing (PDGC - 2010).
[14] M. Aslam, T. Shah, N. Javaid, A. Rahim, Z. Rahman, Z. A. Khan (2012) CEEC: Central-

ized Energy Efficient Clustering a new Routing Protocol for WSN's In: Proc. 9th annual IEEE communications Society Communications and Networks (SECON), Seoul.

[15] T. N. Qureshi, N. Javaid, A. H. Khan, A. Iqbal, E. Akhtar, M. Ishfaq (2013) BEENISH: Balanced Energy Efficient Network Integrated Super Heterogeneous Protocol for Wireless Sensor Networks In: Procedia Computer Science vol.19, pp.920-925.

[16] Chakraborty, R. Rout, A. Chakrabarti, and S. Ghosh (2013) On network lifetime expectancy with realistic sensing and traffic generation model in wireless sensor networks In: IEEE Sensors J., vol. 13, no. 7, pp. 2771–2779.

[17] Mengjia Zeng, Xu Huang, Bo Zheng, Xiangxiang Fan (2019) A Heterogeneous Energy Wireless Sensor Network Clustering Protocol In: Wireless Communications and Mobile Computing, vol. 2019, 11 pages.

[18] K. Pahlavan and A. Levesque (2005) System and Standards In: Wireless Information Networks, 15nd ed. New York, USA: Wiley, 2005, pp. 663-687.

[19] H. Zhang, X. Feng, H. Liu, P. Guo, S. Krishnamoorthy and C. Zhang, "Cloud-Based Class Attendance Record System," 2019 IEEE 5th International Conference on Computer and Communications (ICCC), Chengdu, China, 2019, pp. 283-287, doi: 10.1109/ICCC47050.2019.9064482.

[20] Amin Salih Mohammed, Saravana Balaji B, Saleem Basha M S, Asha P N, Venkatachalam K(2020),FCO — Fuzzy constraints applied Cluster Optimization technique for Wireless AdHoc Networks,Computer Communications, Volume 154,Pages 501-508.