Routing Algorithm for Delay Tolerance in Wireless Sensor Networks

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***Abstract*—In a regular sensor node, there are three activities that are the core sources of energy consumption i.e. sensing, computation, and radio operations. Multi-Group, a novel routing algorithm based on LEACH (MG-LEACH) that has been utilized in redundant deployed sensor nodes to improve the network lifetime is explored. It has been suppressing the correlated data gathered by the sensor nodes by monitoring the similar event, thus not only reducing the data transmission inside the clusters but also conserving the energy of deployed sensor nodes consequently to improve the overall network lifetime. The proposed routing algorithm has been simulated using MATLAB to verify the efficiency in enhancing network lifetime. A critical evaluation of routing algorithm is conducted to determine the relevance and applicability in increasing network lifetime. Simulation results demonstrated that it has performed better than LEACH and enhanced network lifetime by up to approximately 90%.**

***Index Terms*—MG-LEACH, network lifetime, delay tolerant, wireless sensor networks**

I. INTRODUCTION

WSNs has primarily focused on monitoring applications, such as agriculture[1] and environmental monitoring [2], which based upon low-rate data collection, while existing WSN applications support more composite operations ranging from health care [3] to industrial monitoring and automation [4]. The ability of the sensor networks to collect information accurately and reliably enables building both real-dine detection and early warning systems. In addition, it allows rapid coordinate responses to threats such as bushfires, tsunamis, earthquakes, and other crisis situations[5-6].

WSNs have revolutionized the design of emerging embedded systems and triggered a new set of potential applications but the limited capacity of sensor nodes has brought many design challenges. One significant challenge is the resource constraints nature of sensor nodes such as energy and communication bandwidth is inadequate than those used in a conventional wireless networks. These limitations require innovative design techniques and protocols to utilize available resources efficiently [7-9].

This paper covers a novel routing algorithm called Multi-Group based LEACH (MG-LEACH) that has been utilized the redundant deployed sensor nodes to improve the network life time. It has been suppressing the correlated data gathered by the sensor nodes by monitoring the similar event. Thus reduces not only the data transmission inside the clusters but also conserve the energy of deployed sensor nodes consequently improve the overall network lifetime. The proposed routing algorithm has been simulated using MATLAB to verify the efficiency in enhancing network life time. A critical evaluation of routing algorithm is conducted to determine the relevance and applicability in increasing network life time. Simulation results confirmed that it has performed better than LEACH and enhanced network life time up to approximately 90%.

II. METHOD AND ALGORITHM

The throughput typically cannot increase beyond the utilization of all existing slots. TDMA schemes ensure fairness among nodes as unique slot is assigned to every node in each frame. TDMA based protocols guarantee collision-free communication and reduce idle listening. This results in significant energy savings. By scheduling node communication, TDMA based protocols protect energy as nodes that do not participate in message transmission may sleep till their next communication activity e.g. transmit, forward, or receive a message. As time scheduled in TDMA based MAC protocols is assigned after coordination, fairness for all nodes in the network can be guaranteed.

With all attractive features, TDMA schemes have some shortcomings because of their dependency on network topology and time synchronization. The main challenges of TDMA approach are nodes synchronization, adaptation of variable traffic load and changing network topology and to determine collision free slots to be assigned to nodes in multiple hop networks. A specified network topology is used to set up a collision free arrangement with inflexible synchronization to guarantee a common schedule among nodes. It requires huge overheads also expensive hardware thus renders TDMA solutions in not fit for large networks.

Exponential enlargement of wireless communications has increased in several issues in radio propagation. Great effort is now dedicated to refine radio propagation path-loss models not only for urban and suburban, but also for other environments along with proof by field data. The radio propagation in urban districts is quite complex because it frequently consists of reflected, scattered, and diffracted waves created by multipath propagation. Thus, radio propagation in open areas that free from obstacles is the simplest one for treatment, but, generally, propagation over the earth and the water has at least one reflected wave. In the closed areas, for example, indoors, tunnels, and underground passages, there are no models are established or developed as yet, because the environment has a complicated structure. On the other hand, when the environmental structure is random, then Rayleigh's model can be applied for urban area propagation. If, the propagation path is on line of sight, like that in tunnel and underground passages, in that case environment can be treated by using either the Rician replica or waveguide theory. Generally, radio wave propagation has three main features: reflection, diffraction and scattering as in figure 1. In wireless propagation the signal is transmitted at a given strength with a power concentration at distance from the source, which is proportional to the surface of the sphere of radius d that centered on the source. Thus, attenuation according to this distance can be calculated as an inverse function of the distance square. Therefore, absorption is a loss that takes place if the signal passes through different mediums or obstacles where some of the transmitted signal is changed into another form of energy, usually thermal, while some of it continues in propagation. If any material or even atmospheric condition is not transparent to electromagnetic signals will lead to absorption of the transmitted signal. Therefore, the conversion of energy happens at the molecular level, which resulting from the interaction between the energy of the radio wave and the obstacle and other material of the medium. The diffraction is a physical phenomenon which is made propagating electromagnetic waves bends in the neighborhood of obstructions: Diffraction produces from the propagation of wavelets into a shadowy area caused by obstacles such as walls, buildings, and mountains. However, diffraction can be a reason of great levels of attenuation at high frequencies. In opposition, at low frequencies, diffraction really extends the range of the radio transmission. The reflection happens when propagating electromagnetic wave impinges upon an entity that has different electromagnetic properties. Reflection may occur from the surface of the ground, from walls, or from furniture.

The scattering is a case that takes place when a radio wave comes upon small disturbances of a medium, which can change the direction of the signal. This causes the wave energy to spread out in all directions.

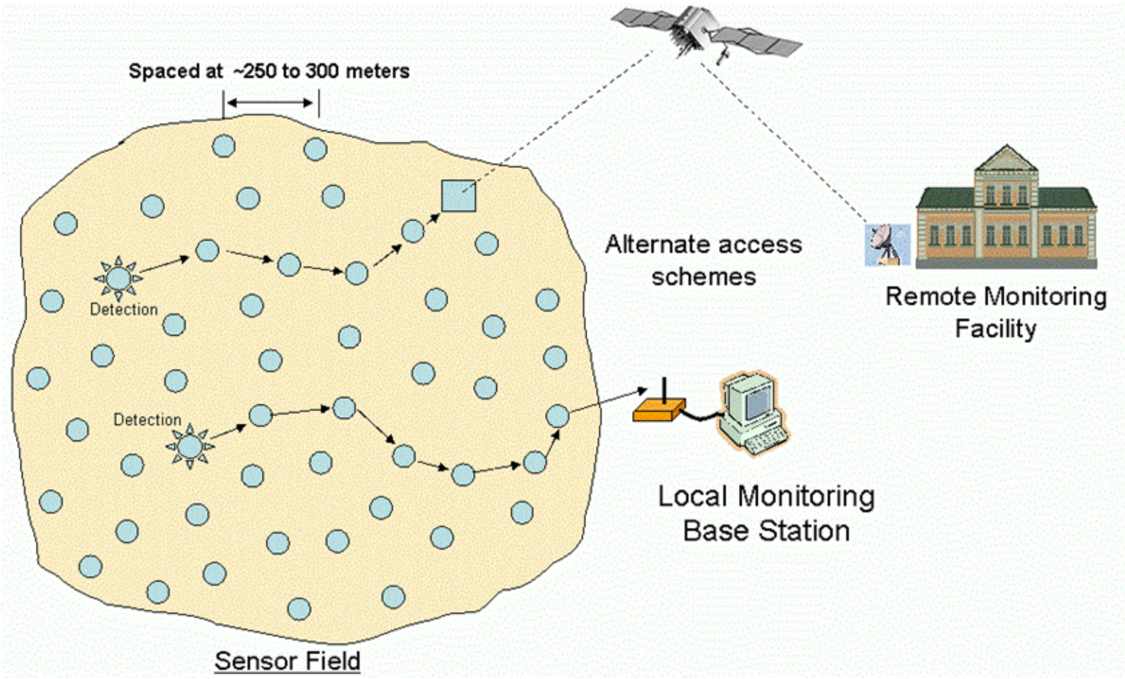

Figure 1. The wireless sensor network tree topology

The equation of basic function is as equation (1) as follows:

$$\partial_j(C_{ijkl}\partial_k u_l + e_{kij}\partial_k\varphi) - \rho\ddot{u}_i = 0 \quad (1)$$

Under the linear relationship, basic equation is shown in equation (2):

$$\partial_j(e_{ijkl}\partial_k u_l - \eta_{kij}\partial_k\varphi) = 0 \quad (2)$$

The linear differential equation can be expressed into the following simplified forms:

$$L(\nabla,\omega)f(x,\omega) = 0,$$

$$L(\nabla,\omega) = T(\nabla) + \omega^2\rho \mathrm{J} \quad (3)$$

In which,

$$T(\nabla) = \begin{Vmatrix} T_{ik}(\nabla) & t_i(\nabla) \\ t_k^T(\nabla) & -\tau(\nabla) \end{Vmatrix}, \ \mathrm{J} = \begin{Vmatrix} \delta_{ik} & 0 \\ 0 & 0 \end{Vmatrix},$$

$$f(x,\omega) = \begin{Vmatrix} u_k(x,\omega) \\ \varphi(x,\omega) \end{Vmatrix} \quad (4)$$

$$T_{ik}(\nabla) = \partial_j C_{ijkl}\partial_l, \quad t_i(\nabla) = \partial_j e_{ijk}\partial_k,$$

$$\tau(\nabla) = \partial_i \eta_{ik}\partial_k$$

Consider an infinite situation, we have the equation (5) in the following:

$$L^0 = \begin{Vmatrix} C_{ijkl}^0 & e_{kij}^0 \\ e_{ikl}^{0T} & -\eta_{ik}^0 \end{Vmatrix} \quad (5)$$

Consider the propagation, instead the equation (6) with the following form:

$$C(\mathrm{x}) = C^0 + C^1(\mathrm{x}), \quad e(\mathrm{x}) = e^0 + e^1(\mathrm{x}),$$

$$\eta(\mathrm{x}) = \eta^0 + \eta^1(\mathrm{x}), \quad \rho(\mathrm{x}) = \rho_0 + \rho_1(\mathrm{x}) \quad (6)$$

Then we have equation (15) to (18):

$$C^1 = C - C^0, \quad e^1 = e - e^0,$$
$$\eta^1 = \eta - \eta^0, \quad \rho_1 = \rho - \rho_0 \quad (15)$$

The containing inclusions can be simplified into the following integral equation set:

$$f(x,\omega) = f^0(x,\omega) + \int_V \boldsymbol{S}(x - x')(\mathrm{L}^1 F(\mathrm{y}') + \rho_1 \omega^2 \boldsymbol{g}(R)\mathrm{T}_1 f(\mathrm{y}')]S(\mathrm{y}')\mathrm{d}y' \quad (7)$$

In view of the following relationship

$$\frac{1}{2\pi}\int_{-\infty}^{\infty} e^{-ik_3 x_3'} dx_3' = \delta(k_3) \quad (8)$$

Equation (8) can be converted into the following form:

$$f(y,\omega) = f^0(y,\omega) + \int_s S(y - y',\omega)\mathrm{L}^1 F(\mathrm{y}',\omega)\mathrm{d}y' + \rho_1\omega^2 \int_s \mathbf{g}(y - y',\omega)\mathrm{J} f(\mathrm{y}',\omega)\mathrm{d}y' \quad (9)$$

In which, S is cylinder cross section, $y = (x_1, x_2)$, and

$$\mathbf{g}(y - y',\omega) = \frac{1}{(2\pi)^2}\int_0^{\infty} \bar{k}\, d\bar{k} \int_0^{2\pi} \mathbf{g}(\bar{k},\omega)\exp(-i\mathrm{k}g(\mathrm{y} - \mathrm{y}'))d\phi \qquad \bar{k} = (k_1, k_2) \quad (10)$$

After selection of cluster head, sensor nodes send message to register with the cluster head of their choice. Cluster head send the time schedule to the registered nodes so that can send the data using TDMA approach. In the next phase known as steady state phase sensor nodes can send the observed data to the cluster heads on their time slot using the approach.

Cluster head send compressed aggregated data to the central station usually know as base station. After predetermined time period, new cluster head are elected again randomly. This repetition of electing new cluster heads is known as new round so LEACH is based on large number of rounds. Randomization process is used in LEACH to rotate cluster heads, which achieves a factor of 8 improvements as compare to the direct approach before the first node die.

III. EXPERIMENT RESULT

In developing the routing algorithm, the network model presents the operating environment that consists of N deployed sensor nodes with one base station. Nodes are randomly deployed in an L X L area with the base station located in the middle of the deployed monitored area. The sensor nodes sense the environment for fulfilling applied application scenario and send the monitored data to the sink node normally known as base station. While the base station is accountable for receiving data from nodes and provides the end-user a description about application so that appropriate action could be taken when required. The network model has the following properties:

1) All sensor nodes are identical (Homogeneous it means have similar capabilities of sensing, processing, and communication)

2) Deployed sensor nodes are energy constrained

3) Sensor nodes are deployed randomly.

4) As homogeneous so initial energy of the sensor Nodes are same or identical at the time of deployment

5) All sensor nodes and the base station are stationary after deployment phase.

6) The nodes are equipped with power control capabilities to vary their transmission power. It means nodes can change their transmitting range based on the requirement

7) All nodes are aware about their position as equipped with GPS.

8) Base station need not to be located far away from the sensing region so positioned in the middle of deployed region.

Moreover, in spite of the energy constrain, all the nodes have enough energy directly addition communicate with any other deployed sensor nodes as well as the base station. Each node has enough processing power to prop up the different protocols and signal processing tasks. Same as those in most wireless sensor networks applications, nodes are left unattended after deployment. Therefore, battery recharge is not possible.

The simulation results show that with increasing number of sub-groups, network life time has been extended. Fig. 2 shows the graphical representation of different number of sub-groups on equal number of deployed nodes. Fig. 3 illustrates the pictographic for number of live sensor nodes with respect to the number of rounds for MG-LEACH in support of the experiment data.

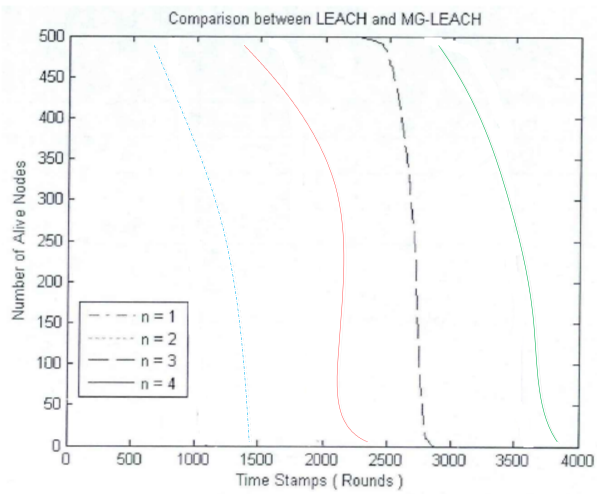

Figure 2. Graphical representation of simulation results presenting effect of creating different sub-groups on network lifetime

In the preceding paragraphs, comparative analysis of MG-LEACH and LEACH has been done. Simulation result shows that MG-LEACH performs better in extending life time. We will attempt to test out the result of different number of sub-groups on network life time in tile. Consider N number of deployed nodes that have been divided in to different sub-groups. In our Simulation platform we have taken N=500 nodes while the sub-groups ranges from 1 to 4.

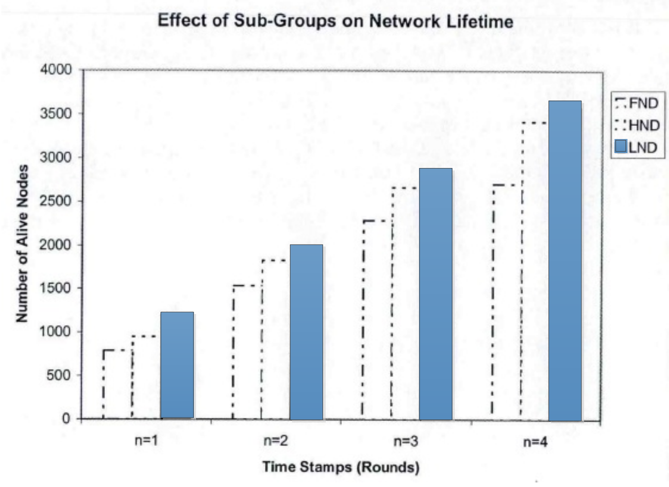

Figure 3. Pictographic of simulation for effect of sub-groups on network lifetime in MG-LEACH

IV. CONCLUSION

We have implemented our basic idea upon the frame work of LEACH protocol and comparative performance analysis has also been performed both for MG-LEACH and LEACH protocol for different values of parameter. Shortcomings associated with LEACH protocol has also been outlined in paper. Proposed idea for utilizing redundant nodes for enhancing network life time is equally valid for all clustering based routing protocols. We choose LEACH for evaluation of proposed idea as hundreds of variants of LLACH protocol exist and it is equally valid for rest of variant based upon it.

Analyses for MAC and routing protocols have also been done and included in this paper. While providing the detail comparative analysis of energy efficient MAC protocols used in Wireless Sensor Networks, Performance requirements needed in WSN has also been discussed. Comparative analysis of MAC used for wireless sensor network with traditional ad-hoc networks and ordinary wireless network has also been presented. Design drivers for MAC protocols used in Wireless sensor networks have been illustrated in detail. The proposed routing algorithm has been simulated using MATLAB to verify the efficiency in enhancing network life time. A critical evaluation of routing algorithm is conducted to determine the relevance and applicability in increasing network life time. Simulation results confirmed that it has performed better than LEACH and enhanced network life time up to approximately 90%.

REFERENCES

[1] C. Huang, Y. Tseng, and L. Lo, "The coverage problem in three-dimensional wireless sensor networks," *Journal of Interconnection Networks,* vol. 08, no.03, pp. 3182-3186, 2015.

[2] H. Yang, et al., "Toward resilient security in wireless sensor networks, " *Proceedings of the 6th ACM international symposium on Mobile ad hoc networking and computing ACM,*pp.34-45, 2015.

[3] D. Jiang, X. Ying, Y. Han, et al., "Collaborative Multi-hop Routing in Cognitive Wireless Networks," *Wireless Personal Communications,* vol. 86, no.2, pp. 901-923, January 2016. https://doi.org/10.1007/s11277-015-2961-6

[4] Z. Sun, et al., "CASMOC: a novel complex alliance strategy with multi-objective optimization of coverage in wireless sensor networks," *Wireless Networks*, pp. 1-22, 2016. https://doi.org/10.1007/s11276-016-1213-3

[5] H. Jing, "Node deployment algorithm based on perception model of wireless sensor network," *International Journal of Automation Technology*, vol.9, no.3, pp. 210-215, April 2015. https://doi.org/10.20965/ijat.2015.p0210

[6] H. Jing,"Routing optimization algorithm based on nodes density and energy consumption of wireless sensor network," *Journal of Computational Information Systems*, vol. 11, no.14, pp. 5047-5054, July 2015.

[7] D. Zhang, et al., "An Energy-Balanced Routing Method Based on Forward-Aware Factor for Wireless Sensor Networks," *IEEE Transactions on Industrial Informatics,* vol. 10, no.1, pp. 766-773, 2014. https://doi.org/10.1109/TII.2013.2250910

[8] R. Alavinia, et al., " Design and Simulation of a Meteorological Data Monitoring System Based on a Wireless Sensor," *International Journal of Online Engineering,* vol. 12, no.5, pp. 27-32, May 2016. https://doi.org/10.3991/ijoe.v12i05.5733

[9] X. Zhang, et al., "Rotation-based privacy-preserving data aggregation in wireless sensor networks," *ICC 2014 - 2014 IEEE International Conference on Communications,* pp. 4184-4189, 2014. https://doi.org/10.1109/icc.2014.6883977

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