SHEEP-OC with adaptive sensing; An Energy Efficient data gathering scheme in WSNs

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Abstract **-** Wireless sensor networks have been the useful technology for monitoring in a remote and hostile environment, in applications such as prediction of landslides where the frequent sensing and data gathering of seismic parameters are required in the dynamic surroundings. Since the nodes of the sensor networks are inadequate in energy, a lifetime of the network becomes the major criteria for the effective design of data gathering schemes in wireless sensor networks. In this paper, we propose an efficient data gathering scheme adaptive to sensing requirements, where the sensor nodes are equipped with multiple sensors. To accomplish the task we adopt the response threshold model for sensing. The results are evaluated through simulations, our proposed algorithm can accomplish energy-efficient data gathering, satisfying dynamically changing sensing requirements.

Keywords **-** *Wireless Sensor Network, data gathering, adaptive sensing, response threshold model, Energy efficiency.*

I. INTRODUCTION

The Wireless Sensor Network (WSNs) [1,2] were extensively deployed and researched for many applications in recent years, by taking the advantage of smaller dimension, lower cost and simple structure of the sensor node. More restrictions come together with sensor nodes due to these characteristics. Therefore, the limited power of sensor nodes is the most direct and difficult problem we meet. The limitation on the energy of sensor node makes the bottlenecks for designing the suitable routing protocols. In order to solve the problem of limited energy, power loading of nodes have to be distributed as possible as it can. If the energy consumption can be shared averagely by most nodes, then the lifetime of sensor networks will be enlarged. In many applications of wireless sensor network, the sensor nodes are required in the form of error-free data transmission[3] to the Sink node. We proposed an energy-efficient data collection program. The method we proposed to reduce the data transmission is by adaptive sensing mechanism and transmitting the data to respective cluster heads on the basis of threshold values of the sensed parameter. In general, the sensor node in a wireless sensor networks that can be sensed and the information gathered can be transmitted to a distance are all fixed, and two are directly related. The greater the distance between the nodes makes greater power consumption[4]. The relation between the communication distance and power consumption are exponentially proportional. Therefore by transmitting the aggregated information to longer transmission distance with a lower power consumption to a data collection node (Sink Node), enormous amount of energy can be saved. The algorithms to improve the use of time and performance of the entire wireless sensor network environment becomes one of the most important research areas in the recent times.

II. PROPOSED WORK

Energy conservation techniques for the radio communication has been extensively proposed by many authors[5,6]. Here we are attempting to proposed a mechanism for sensing level. Adaptive response threshold technique can be applied to achieve energy conservation at the beginning of sensor level for sensing of a physical quantity to be monitored, it means switching off the transceivers system, reducing the amount of data to be transmitted to the base station one can reduce the energy consumption without losing the useful information. In fact, routing protocol used in wireless sensor network play an important role in balanced energy consumption. There are different routing protocols have been proposed, many of them want the same goal as much as possible, improving the survival time of the wireless sensor network, in order to enable them to have better usability. To minimize power consumption under the WSN premises, consider the application target, static use of environment. Efficiently maintaining the energy consumption of sensor nodes by balanced clustering, involving in multi-hop communication between the cluster heads and performing data aggregation or fusion in order to decrease the number of transmitted messages to base station is the main goal of the routing protocols (cluster based). In order to prolong the network lifetime, energy-efficient protocols should be designed to adapt the characteristic of wireless sensor networks. Clustering algorithm is a kind of key technique used to reduce energy consumption, which can increase network scalability and lifetime. Earlier the author has proposed two protocols, a Stable Energy Efficient cluster based protocol(SHEEP) [7]where the stability period has increased by making use of energy heterogeneity and Stable Energy Efficient Protocol with optimum clustering (SHEEP-OC)[8] where the optimum number of clusters have been used to overcome energy hole and coverage hole problems. This paper studies the performance of clustering algorithm in saving energy for heterogeneous wireless sensor networks with adaptive sensing technique, and evaluated in the (SHEEP-OC) clustering scheme.

Basically in cluster based algorithms[9,10], there are two phases of cycle in each round,

- *Setup cycle* and
- *Steady state cycle.*

In Set-up Cycle network initiation, cluster head CH selection takes place and cluster formation will be done. In *steady state cycle*, sensor nodes starts sensing and transmits the sensed data to corresponding cluster heads, subsequently received data from the nodes will be aggregated and transmitted to the base station BS.

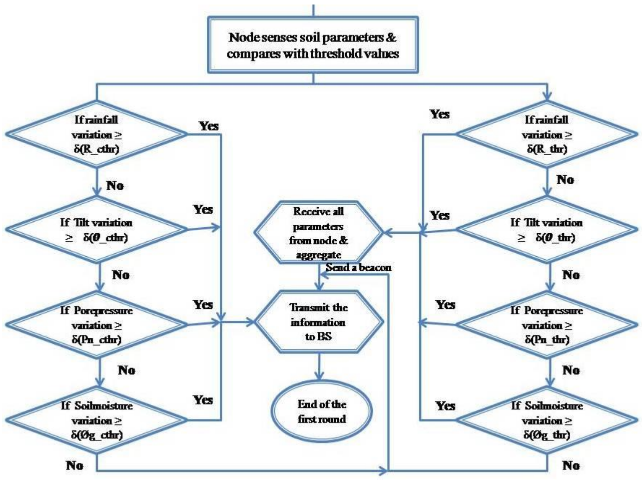

Fig. 1 Adaptive sensing algorithm during steady state phase

After one round of setup and steady state cycle, network goes back to second round of steady state phase. In the proposed algorithm, we are going to apply the adaptive sensing algorithm on **SHEEP-OC** routing protocol, where after network initialization and clustering phase, during the data transfer phase (*steady state phase*) proposed algorithm will be applied. During the steady state phase before transmission of data to cluster heads, each node measures the sensed parameters, compares the data with the defined threshold values, if they crosses the threshold then data will be transmitted to corresponding cluster heads else the node will transmit a beacon and transceiver will switch off but sensor will remain in sensing state. For the analysis purpose we have chosen an application on the landslide prediction. A spatially distributed soil information of the landslide prone area is necessary to predict the landslides. The parameters to be sensed includes, Tilt measurement (using inclinometer), Amount of rainfall (using rain gauge), Soil moisture sensor and Pore pressure (using piezometer).

Normal threshold levels for the purpose of comparison: The transceiver will be switched off in WSN node but sensor will be in sensing state, if the change in the parameters is less than mentioned below values:

1. Rainfall (reading from the rain gauge) $\delta(R_{thr}) = 1\ mm$
2. Tilt measurement (inclinometer reading) $\delta(\theta_{thr}) = 1^{\circ}$
3. Pore-pressure (Piezo-meter reading) $\delta(P_{n,thr}) = 0.1\ kPa$
4. Soil moisture (soil moisture sensor reading) $\delta(\emptyset_{g,thr}) = 3\ \%$

Nodes are connected with multiple sensors, whole sensed information will be transmitted to the CH if the variation in any of the parameters crosses the threshold value.

Critical Threshold: In case if there is significant change in the soil parameter, nodes switches on the transmitters and immediately sends the information to CH, same time CH relays the information to the Base station without delay. Following are the Critical threshold values:

1. Rainfall (reading from the rain gauge) $\delta(R_{cr}) = 10\ mm$
2. Tilt measurement (inclinometer reading) $\delta(\theta_{cr}) = 5^{\circ}$
3. Pore-pressure (Piezo-meter reading) $\delta(P_{n,cr}) = 0.5\ kPa$
4. Soil moisture (soil moisture sensor reading) $\delta(\emptyset_{g,cr}) = 5\ \%$

Fig. 1 shows the adaptive sensing algorithm implemented during the steady state phase of the round in SHEEP-OC (adaptive sensing) algorithm.

III. SIMULATION RESULTS

Table 1: Simulation Parameters

Description	Value
N, Number of sensors	100
Area (meter square)	100 x 100
E_0 , Initial energy	0.5 J
E_{elec} , Electronics energy	50 nJ/bit
E_{DA} , Energy of data aggregation	5 nJ/bit
K, Data packet size	500 bytes
k_{broad} , Broadcast packet size	25 bytes

Simulation was performed using the above scenario as shown in the Table 1. Comparison has been made with the proposed mechanism SHEEP-OC with adaptive sensing and LEACH, SEP, SHEEP. The base was assumed to be at the top middle of the area. Sensing targets are assumed to be amount of rain fall, pore pressure, soil moisture and tilt angle. For the purpose of simulation and analysis each node is assumed to be generating random number [0,1]. if the generated random number is less than set threshold value then the nodes do not transmit any information to the CH.

Nodes transmit the data in their assigned TDMA slot with following condition:

$$T_{i,tr} = \begin{cases} R_{value} + \theta + P_n + \emptyset_g;\ if\ \ RN_R \geq R_{thr} \cup RN_\theta \geq \theta_{thr} \cup RN_{P_n} \geq P_{n,thr} \cup RN_{P_n} \geq \emptyset_{g,thr} \\ beacon \quad\quad otherwise \end{cases} \quad ----(1)$$

In case of critical threshold condition, nodes transmit the information with a critical flag to the CH, when the CH receives any critical information immediately it transmits to the BS without delay. The following condition refers to critical information.

$$T_{i,tr,em} = \begin{cases} R_{value} + \theta + P_n + \emptyset_g; if\ RN_R \geq R_{cr} \cup RN_\theta \geq \theta_{cr} \cup RN_{P_n} \geq P_{n,cr} \cup RN_{P_n} \geq \emptyset_{g,cr} \\ beacon \quad\quad otherwise \end{cases} \quad --(2)$$

On the basis of threshold values nodes of WSN send sensed data to the respective cluster heads CH. As a result, few nodes will be in idle condition transmits a beacon and go to sleep, some of the nodes transmits sensed information if there is variation of parameters and some of nodes may send critical information if there is drastic change in the sensed parameters. Cluster Heads will collect the data and transmits to Base Station after aggregation.

For the purpose of energy efficiency analysis, radio model considered as in [7,8], Energy required to transmit information (L bit) over a distance 'd' is given by

The energy required to transmit L bit of message over a distance of d is given by the equations below:

$$E_{Tx}(l,d) = \begin{cases} L.E_{elec} + L.\epsilon_{fs}.d^2 & if\ d \leq d_0 \\ L.E_{elec} + L.\epsilon_{mp}.d^4 & if\ d > d_0 \end{cases} \quad ---- \ ---- (3)$$

Where E_{elec} represents energy required by the circuit(transmitter and receiver) to transmit one bit. The energy required by the cluster head in one round is given by the formula,

$$E_{CH} = \left(\frac{n}{k} - (1 + N_{non-tr})\right) L.E_{elec} + \left(\frac{n}{k} - (1 + N_{non-tr})\right) L.E_{DA} + L.E_{elec} + L.\epsilon_{fs}\ d^2_{to\ BS} \quad ----(4)$$

Where E_{CH} is the energy dissipation of Cluster head, N_{non-tr} is number of non transmitting nodes, $d_{to\ BS}$ is the distance between BS and CH; $d_{to\ BS} = M\sqrt{\frac{1}{2\pi\, k}}$ where M is the length of the network area.

$$E_{non-CH} = \left(\frac{n}{k} - (1 + N_{non-tr})\right)(L.E_{elec} + L.\epsilon_{fs}\ d^2_{to\ BS}) \quad ---- (5)$$

E_{non-CH} is the energy dissipated by all non CH nodes of the cluster, $d_{to\ BS}$ represents the distance between the cluster head and the node. Now the total energy dissipation during the one round of transmission is given by

$$E_C = E_{CH} + E_{non-CH} \quad ----------(6)$$

if 'k' is the total number of the clusters,

$$E_t = k\ X\ E_C \quad -----------------(7)$$

'*k*' represents the number of clusters, 'E_{DA}' is energy required for data processing.

and energy expended by cluster member node is given by the equation,

$$E_{nonCH} = L.E_{elec} + \mathrm{L}.\epsilon_{fs}\ d^2_{to\ BS}$$

Total energy consumed by the network is given by,

$$E_{tot} = L\ (2n.E_{elec} + n.E_{DA} + \epsilon_{fs}\ (k\ d^2_{to\ BS} + n\ d^2_{to\ BS}))$$

a. Evaluation of simulation results

Fig. 2 shows the number of alive nodes with respect to number of rounds, it is observed that the proposed algorithm outperforms the LEACH, SEP, SHEEP AND SHEEP-OC due to reduced number of transmissions by using adaptive sensing algorithm, as a result the algorithm can increase the lifetime of the network by 33% compared to the SHEEP-OC without implementation of adaptive sampling technique

In fig.3 it can be observed that the length of stable region has been extended for different values of energy heterogeneity, proposed protocol SHEEP-OC-AS has longer stable region, almost 50% improvement over SHEEP-OC

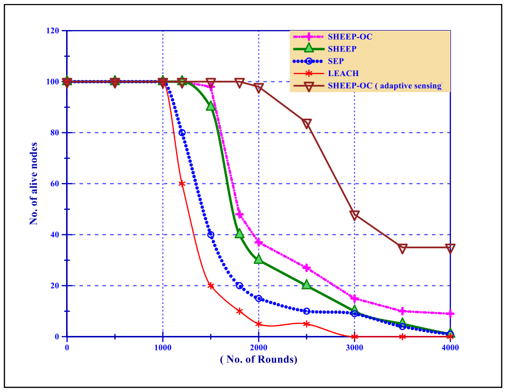

Fig.2 Network lifetime (No. of alive nodes VS simulation time) SHEEP-OC (adaptive sampling) with LEACH, SEP & SHEEP-OC

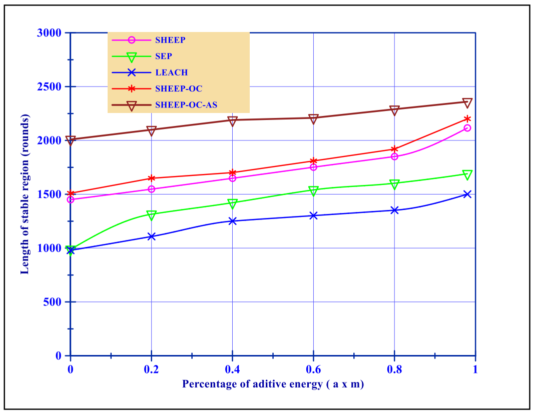

Fig.3 Length of the stable region for different values of heterogeneity comparison of SHEEP-OC-AS with LEACH, SEP, SHEEP & SHEEP-OC.

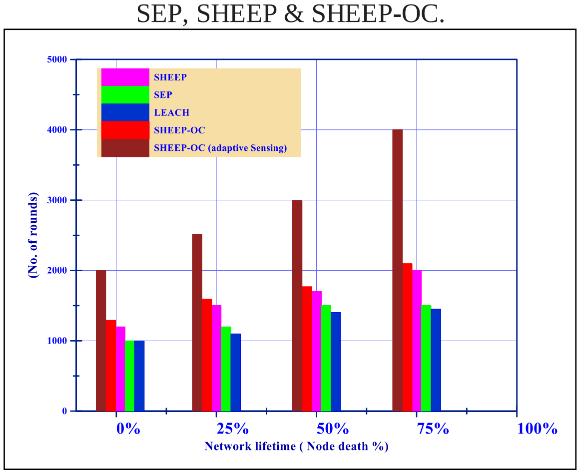

Fig.4 Node death percentage per analysis of SHEEP-OC(adaptive sampling) with LEACH, SEP, SHEEP& SHEEP-OC protocols.

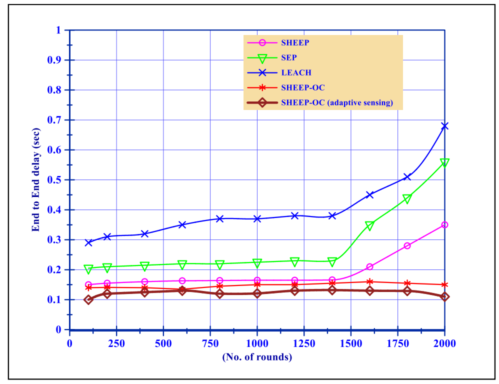

Fig.5 End to End delay comparison for the proposed with LEACH, SEP , SHEEP & SHEEP- OC.

Fig.5,6&7 shows the end to end delay, throughput analysis and PDR perfomance of the proposed SHEEP-OC-AS with the existing LEACH, SEP, SHEEP & SHEEP-OC Protocol. From the results, it shows that the proposed system can successfully transmits the data in lesser time with high rate due reduced number of transmissions.

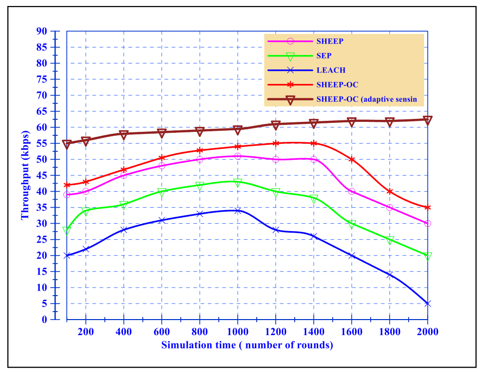

Fig. 6 Throughput analysis for proposed SHEEP-OC (adaptive sensing) with the existing LEACH, SEP, SHEEP & SHEEP-OC Protocols.

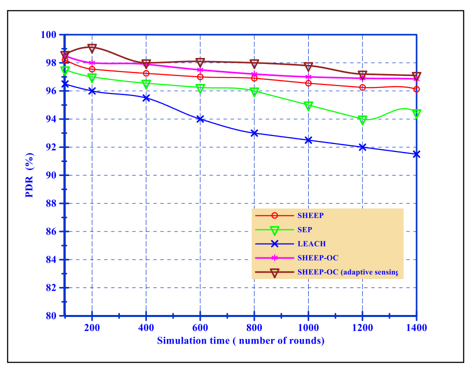

Fig. 7 Packet delivery ratio of SHEEP-OC with the existing LEACH, SEP and SHEEP Protocols.

IV. CONCLUSION

Performance evaluation of these protocols are performed by conducting comparative simulation study along with discussions in terms of well defined performance measures. These performance measures are stability period, network lifetime, throughput, end to end delay, packet delivery ratio. It has been noticed that the lifetime and stability period of the network. Fig. 2 & 4 shows that how many nodes are alive as the number of rounds increases. Results show that SHEEP-OC(adaptive sensing) has maximum network lifetime as compared to the other protocols. Maximum stability of SHEEP-OC(adaptive sensing) is also a significant achievement. Stability period of SHEEP-OC(adaptive sensing) is almost 150 %, 100 %, 75 %, 50 % greater than LEACH, SEP, SHEEP and SHEEP-OC, respectively. Main reasons behind this drastic improvement are threshold based transmissions.

V. REFERENCES

[1]. Akyildiz, Ian F, Weilian Su, Yogesh Sankarasubramaniam, and Erdal Cayirci. “A survey on sensor networks.” IEEE communications magazine 40, no. 8 (2002): 102-114.

[2]. Akkaya, Kemal, and Mohamed Younis. “A survey on routing protocols for wireless sensor networks.” Ad hoc networks 3, no. 3 (2005): 325-349.

[3]. Zhengwang Ye, Tao Wen, Zhenyu Liu, Xiaoying Song, "A security fault-tolerant routing for multi-layer non-uniform clustered WSNs" EURASIP Journal on Wireless Communications and Networking, 2016:192 https://doi.org/10.1186/s13638-016-0692-3.

[4]. Jinglong Zhou, Martin Jacobsson and Ignas Niemegeers," Link Quality-Based Transmission Power Adaptation for Reduction of Energy Consumption and Interference" EURASIP Journal on Wireless Communications and Networking, 2010:92013.

[5]. C. Tang, C. Raghavendra, “Compression Techniques for Wireless Sensor Networks”, Wireless sensor Networks, Kluwer Academic Publishers, Boston, USA, 2004.

[6]. Mukesh Kumar, Kamlesh Datta, "LDAT: LFTM based data aggregation and transmission protocol for wireless sensor networks" ournal of Trust Management20163:2 https://doi.org/10.1186/s40493-016-0023.

[7]. Mohammed Moyed Ahmed, Dr.D. Sreenivasa Rao," Stable Heterogeneous Energy Efficient Cluster Based Protocol (SHEEP) For Application-Specific WSNs" International Journal of Emerging Technology and Advanced Engineering (ISSN 2250-2459, ISO 9001:2008 Certified Journal, Volume 8, Issue 1, January 2018).

[8]. Mohammed Moyed Ahmed, Dr.D. Sreenivasa Rao, "Stable Heterogeneous Energy Efficient Protocol with Optimum Clustering (SHEEP-OC) in Wireless Sensor Networks" International Journal of Emerging Technologies in Engineering Research, ISSN 2454-6410, Volume 6, Issue 3, March 2018).

[9]. Liu C, Liu Y, Zhang ZJ (2013) Improved reliable trust-based and energy-efficient data aggregation for wireless sensor networks. Int J Distrib Sens Netw 2013(652495):1–11.

[10]. Wenjing Guo, Wei Zhang " A survey on intelligent routing protocols in wireless sensor networks", Journal of Network and Computer Applications 38 (2014) 185–201.

[11]. Baranidharan B, Shanti BA. "Survey on energy efficient protocols for wireless sensor networks". International Journal of Computer Applications 2010;11(10):35–40.