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Dynamic Power Management Through Clustering in Wireless Sensor Network

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Abstract: The scarcity in the productivity of power leads to management of power consumption in various fields. This leads to a major research challenge in dynamic power management. Wireless sensor network already being a highly resource constrained network, necessitates dynamic power management through various schemes. One such scheme is implementing power management through routing techniques. This study focuses on power management through clustering methods. The protocol attempts to manage power through topology control by selecting random percentage of nodes to be in active states initially and later automation of the selection of nodes through fuzzy logic techniques. The protocol outperforms better than the existing fuzzy and clustering protocols.

Key words: WSN, energy efficient, routing protocol, power management, techniques, clustering protocols

INTRODUCTION

Wireless sensor network is a highly resource constrained network as it consists of tiny sensor nodes to be placed in the region where human interventions are highly risk (Shen and Li, 2008). It is a battery operated device similar to other electronic gadgets. Hence, the lifetime of the network becomes much essential factor. If there is an increased lifetime, frequent changing of batteries are not needed. The sensor network consists of sensor nodes that contribute in sensing applications or acquiring of data, memory, microcontroller that acts as a processing unit, transceiver for communication and a battery for the entire device to be operated (Wu *et al*., 2010). Given in Fig. 1, it shows architecture of wireless sensor network. It consists of numerous sensor nodes that pass information to the remote server through gateway (Sinha and Chandrakasan, 2001; Levron *et al*., 2011).

The major research challenge of this type of network is placement of nodes in a proper fashion within the specific region (Tomar and Bhardwaj, 2016). Only proper node placement may lead to good data acquisition system. Another major challenge is to long last battery life, so that, frequent changing of battery is not essential. The energy saving can be obtained through many forms such as power management schemes, routing protocol, data fusion algorithms, etc., (Warriera and Kumar, 2016; Dargie, 2012). Hence, design of energy efficient algorithms has made a predominant research in the field of wireless sensor networks. It does not maintain the conventional

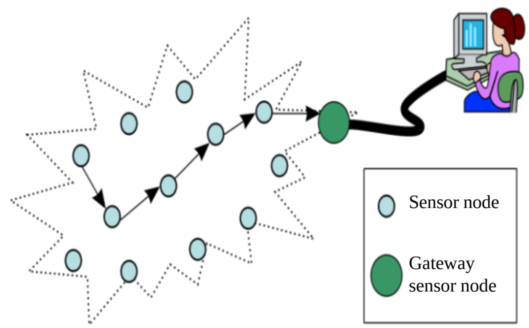

Fig. 1: Architecture of WSN

topological arrangement of traditional network. It is an infrastructure less network. Dynamic power management is a way to reduce the consumption of power by trading off the performance of the network and work load. Based on the consumption of power it is possible to operate only a set of components during an instant of time and operating the remaining at various instants (Das *et al*., 2017). The state transition of the components could be decided in these schemes.

The lifetime of the wireless battery powered network could be enhanced by making the nodes to sleep periodically. The sleep state involves minimum power consumption by a wireless device (Sarkar and Murugan, 2016). Moreover, it increases the average packet delay which is encounter by the device. The power management can also be established by varying the gating period of the system. Power management is a component that dissipates negligible power. This management has various

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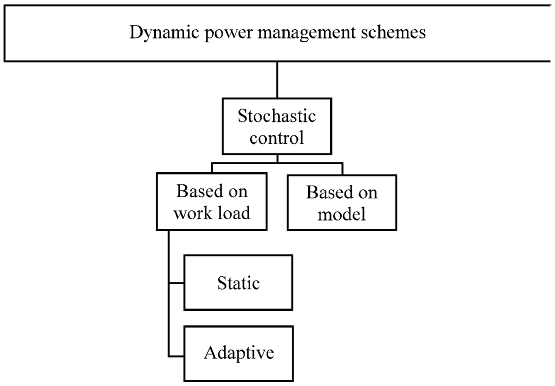

Fig. 2: Stochastic power management

techniques to implement (Karp and Kung, 2000). One such critical technique is stochastic control in which it could be implemented based on model or work load and the same has been given in Fig. 2.

In this study, an attempt to work on adaptive stochastic control of power management scheme and also to produce an integrated approach to implement power management and routing protocol for bringing out more energy efficient network (Shu *et al*., 2008). The prediction of work load does not give a perfect trade off between latency and performance, hence, it is always better to design a system based on work load that is adopted in real time. Consequently, stochastic techniques are necessary to take the edge off the restrictions of predictive techniques. The stochastic policies are better than heuristic policies with respect to power delay trade-off. While static approach has previous awareness of different power controllable component states and inactive workload, the adaptive approach focuses on non-stationary nature of the workloads and adopts pre-characterization of policy, parameter learning and policy disruption in intriguing the resolve for power down states. Thus, at software level, the execution of dynamic power management policies are possible. Moreover, the energy efficiency of sensor nodes can rise without any specific power management hardware (Barani and Gomathy, 2011).

MATERIALS AND METHODS

Dynamic Power Management through Clustering (DPMC): Implementation of dynamic power management schemes attempts to reduce the power consumption of the network (Rajan *et al*., 2015). Consumption of every node cannot be minimized as it has to perform actions such as sensing, processing and communicating but it is possible to eliminate few nodes form the network temporally. Since, senor network is densely deployed in a region there are possibilities of more redundant data. Hence, all nodes may not be involved in sensing. Dynamic power management scheme involves one such technique where the topology of the network is frequently varied by forcing certain nodes to sleep state and others are made active to involve in participation (Ganjewar *et al*., 2018). Along with power management schemes, proper routing is also, attempted to minimize energy consumption and thereby enhancing the lifetime of the network.

In this study, a dynamic power management scheme with cluster based routing techniques are introduced (Subramanian and Katz, 2000; Akan and Akyildiz, 2005). Initially random nodes are selected and are made active to gather information. A protocol Dynamic Power Management through Clustering (DPMC) is proposed with random selection of nodes where cluster based algorithm is implemented for routing (Messaoudi *et al*., 2016). In order to achieve automatic the selection of nodes, a fuzzy based Modified Dynamic Power Management through Clustering (M-DPMC) is introduced where the selection of active nodes are implemented using fuzzy techniques (Balaji *et al*., 2016).

In dynamic power management schemes an adaptive technique is implemented. In sensor node aspects the work done is related to energy consumed by the node. If the node consumes uniform energy throughout the communication then static scheme, of power management gives better performance (Arabi, 2010). But the consumption of energy by a node cannot be made uniform in communication as it involves many parametric effects in the network. Therefore, the number of nodes made to be in active states varies depending on the residual energy. The topology taken in to account is grid topology and first order radio model. The topology is established with 200 nodes as the maximum number of nodes above which the protocol does not give better performance. The network is taken in such a way that the sink node is the destination point which is kept at a remote place or at a distance apart from the established network as shown in Fig. 1. There by leaving the destination node to be powered always.

Once, the node has been deployed with each node having an initial energy of 2800 J, an attempt to make only few active nodes is made. As a trial initially 25 % of nodes were active and clusters were formed. In the protocol Dynamic Power Management through Clustering (DPMC) each node will be given a node ID, N_ID and a specific radius r. The selection of the radius is made on trial and error basis. Initially every active node broad casts the N_ID and radius information to all the nodes thereby exchanging its ID. In return all the nodes will acknowledge the broadcasted message and the distance between each node is estimated based on signal strength. The nodes having the distance lesser than or equal to are tagged together to form clusters. The algorithm of the protocol is given in algorithm 1.

Algorithm 1; Algorithm for proposed protocol DPMC:

Step 1: Fix up the initial specifications
Step 2: Fix the transmission range as 50 m radius
Step 3: Broadcast N_ID to all nodes in a network
Step 4: Send ACK for N_ID
Step 5: Estimate distance based on RSSI
Step 6: If distance lesser than or equal to radius include in same cluster
Step 7: Update forwarding table
Step 8: Select cluster head based on residual energy
Step 9: Communicate data packets through cluster head

The distance between every node is estimated based on the Received Signal Strength (RSSI). The various propagation models are; free space model, two ray ground model and shadowing model. Two ray model is assumed to have a line of sight between sender and receiver and hence, it is implemented in this research. The total power is the summation of power between transmitter receiver and power by one ground reflection. Height of location of receiver and transmitter from the ground surface is also, considered to be the one of the major parameter with respect to the ground surface. The power at a distance d is estimated by Eq. 1:

$$P_r(d) = \frac{P_t G_t G_r h_t^2 h_r^2}{d^4 L} \quad (1)$$

Where:

P_r = Received signal power at a distance d
P_t = Transmitter power
G_t = Gain of transmitter antenna
G_r = Gain of receiver antenna
h_r = Height of receiver antenna
h_t = Height of transmitter antenna
d = Distance between transmitter and receiver
L = Path Loss component

Almost immediately after the acknowledgement signal is received by sensor node, it calculates the distance between the nodes. Now the clusters are formed with the nodes that have the distance lesser than r. Now within the framed clusters cluster head is selected based on two parameters like residual energy of the node and distance to the next cluster head. Then all the cluster head will get ahead of the aggregated data of its clusters to the sink node. Then node's residual energy is estimated. Since, the cluster head selection is depends on the residual energy it is essential to estimate the energy consumed by every component of the node. Residual energy is the difference between initial energy and sum of energy consumed by the node throughout communication. The energy estimation of first order radio model could be done in the following way. In Fig. 3 shown is the first order radio model.

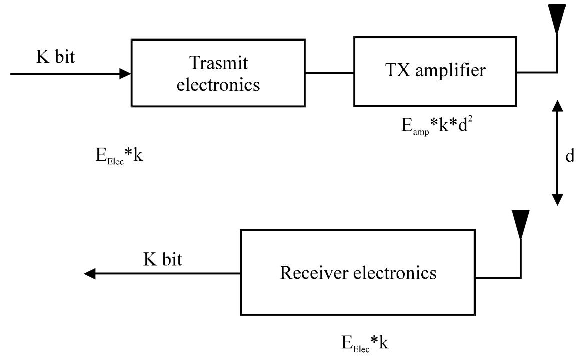

Fig. 3: First order radio model

The simple model in which the radio dissipates E_{Elec} = 50 nJ/bit to run the transmitter or receiver circuitry whereas E_{amp} = 100 pJ/bit/m^2 for the transmit amplifier. Energy consumed at receiver end is given by:

$$E_{Rx} = E_{Elec} * k \quad (2)$$

Energy consumed by the transmitter is:

$$E_{Tx} = (E_{Elec} * k) + E_{amp} * k * d^2 \quad (3)$$

Node residual energy is given by:

$$E_{RE} = E_{IN} - (E_{Tx} + E_{Rx} + E_{Ie} + E_{Se}) \quad (4)$$

Where:

E_{rx} = Receiver Electronics Energy
E_{tx} = Transmitter Electronics Energy
E_{elec} = Transmitter and Receiver Electronics Energy
k = Number of bits received or transmitted
E_{amp} = Transmitter amplifier Energy
E_{in} = Energy of the node in initial state
E_{ie} = Energy consumed of the node in idle mode
E_{se} = Energy consumed by sensor node
d = Distance between transmitter and receiver

On a trial and error basis the threshold for the residual energy has been fixed as 50 % for initial rounds, thereby declining to the worst case of 10% as the rounds increases.

In this proposed research, clustering approach integrated with dynamic power management outperforms

Table 1: Membership function

Inputs	Linguistic variables	Type of membership function	Membership function values
Number of nodes alive in the network	Low	Triangular	(10.40)
	Medium	Triangular	(35.60)
	High	Triangular	(60.100)
Residual energy Joules)	Low	Triangular	(10.1600)
	Medium	Triangular	(1400.1820)
	High	Triangular	(1600.2800)

Table 2: Knowledge base rules

Rule No.	Number of nodes	Residual energy	Selection of nodes
1	Low	Low	Low
2	Low	Medium	Medium
3	Low	High	Medium
4	Medium	Low	Low
5	Medium	Medium	Medium
6	Medium	High	Medium
7	High	Low	Low
8	High	Medium	Medium
9	High	High	High

better than traditional sensor network algorithms. The selection of active nodes in random fashion may also lead to few disadvantages such as:

- At time more number of nodes is involved within the network
- Possibilities of repeatedly nodes to involve within network

Hence, a modified approach of active node selection based on fuzzy techniques is implemented.

Modified Dynamic Power Management through Clustering (M-DPMC): The selection of active nodes if made on trial and error basis there are likely chances of lesser/greater number of nodes involved in communication. If the selection of nodes is channelized with correct policy then the performance of the network will be in a better fashion. Hence, as an attempt fuzzy technique are used selections of active nodes. Fuzzy logic can deal with contradictory situations and ambiguity in data using heuristic human analysis exclusive of need of complex mathematical modelling. Here, a soft and tuneable approach to selection of nodes is implemented. The system Modified Dynamic Power Management through Clustering (M-DPMC) is projected to alter its method to increase the network life time. The values in the membership functions of the particular linguistic variables are given in the Table 1 and rule table is given in Table 2.

RESULTS AND DISCUSSION

The performance of the network is monitored by varying percentage of active nodes. It has also been analysed by varying number of nodes involved with in network with cluster based routing techniques. The network size is varied from 50-200 in size. The percentage of active nodes is also varied from 25-75%. The simulation result were obtained for energy consumed by the network and packet delivery ratio. Table 3-5 depicts the performance of the proposed work (Fig. 4-6).

The performance analysis of the modified dynamic power management through clustering protocol has been tabulated and analyzed. The energy consumed by the network and packet delivery ratio is analyzed with the other existing protocol.

Table 3: Life time of DPMC

Active nodes (%)	DPMC (No. of rounds)
25	4720
35	5400
45	5646
55	6900
65	6940
75	6962

Table 4: Packet delivery ratio

No. of nodes	LEACH (J)	FEADPR	DPMC	M-DPMC
100	49	40.0	62	70
150	48	39.5	63	72
200	46	39.0	64	74
250	42	39.0	62	71

Table 5: Energy consumed by the proposed work

No. of nodes	LEACH (J)	FEADPR	DPMC	M-DPMC
50	2750	1000	256	126
100	2764	1250	294	135
150	2800	1220	300	146
200	2826	1500	321	159

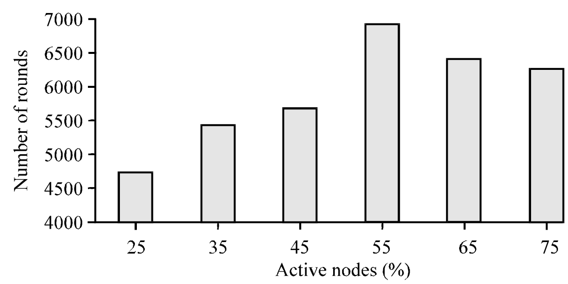

Fig. 4: Life time of DPMC

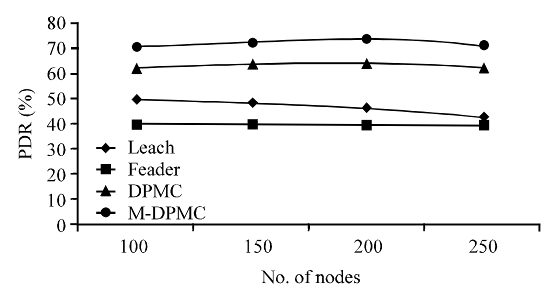

Fig. 5: Packet delivery ratio

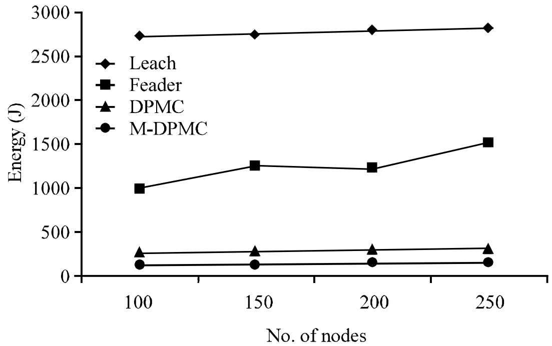

Fig. 6: Energy consumed

An average of 142 J of energy was conducted by the network with a maximum of 250 nodes. On increasing the size of the network the performance was not satisfactory. Packet delivery ratio is also reached to an average of 72%. The modified protocol outperforms better than any other protocols.

CONCLUSION

Dynamic power management schemes enhance to increase the lifetime of the network than existing protocol. Power management based on workload is much beneficial than any other schemes, since, it involves selection of nodes based on the remaining energy. Establishment of cluster based routing further increases the lifetime in the proposed work. Fuzzy based active node selection aids more for the enhancement of network lifetime. When compared to leach the average energy consumption is increased by 90% there by rising the network life time. And the performance of packet delivery ratio is also an important factor which about an average of 72%. Whereas the packet delivery ratio of the other protocol being lesser than proposed protocol. Hence, it is identified that an approach to dynamic power management leads to increase in the lifetime of the network. On avoiding redundant data transfer through proper data fusion methods may enhance the lifetime further.

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