SELECT OF OPTIMAL SLEEP STATE IN ADAPTIVE SMAC USING DPM

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Abstract— Wireless sensor networks are networks with low power nodes and limited processing. The main problem in these networks is energy. This resource is not replaceable or rechargeable. Therefore, optimal energy consumption for wsn protocols is a necessity. In a number of proposed protocols periodic sleep and wake is used for energy use reduction but these protocols result in increased end to end delay. If such delay is not acceptable for program, there will be a lot of problems such as real time programs.One of mac layer protocols that uses periodic sleep and wake for energy use reduction, is smac. Adaptive smac is an improvement on smac protocol that rather reduces its delay through early wake. In this paper an improvement has been made on adaptive smac algorithm. Thus dpm has been used in the algorithm. In used DPM, in several sleeping states, nodes remaining energy have been taken into account besides considering idle time. Also energy use is reduced in idle listening state through avoiding simultaneous wake of receiving and sending neighborhoods. Thus this algorithm helps in decreasing the delay as well as increasing the lifetime of network.

Keywords- WSN, energy, DPM, Adaptive SMAC, Sleep;

I. INTRODUCTION

Recent improvements in wsn have resulted in capability of environmental sense of sensor nodes from a long distance [1]. These sensors have been often located in a far distance or have improved in regions with difficult accessibility. Since disconnection for such networks is very important, increase in network lifetime is a key prospect in development of WSNs. Due to sensitivity of energy parameter main resources of energy are stated below [2].

Idle listening, collision, control pocket overhead, overmitting, half-optimal utilization from available resources and traffic fluctuations.

The main factor of such energy waste in WSNs is idle listening [3]since WSNs usually have events that occur rarely and there is no need to complete wake [1]. Also consumption power in this mode equals to that of reception mode though such networks often have low data load [4]. One thing in this case that is able to reduce energy use of senor nodes is nodes' going to sleep whenever there is no event for sensing. Another kind of sleep and wake scheduling protocols has been proposed in which sensor nodes communicate periodically some synchronized data with neighboring nodes. However, sync protocol with extra overhead is required and some energy will be used for this purpose [5].

Also sleep and wake scheduling protocols have been presented on demand in which nodes switch off the majority of their internal circuits and switch on a low power receiver to hear wake calls from neighboring nodes at time of relaying data.

Smac introduces periodic duty cycle synchronized with neighboring sensor nodes in which idle listening cost is reduced [6]. In smac [7] each node follows a periodic sleep and wake scheduling that is synchronized with neighbor nodes. Within sleep periods radios are switched off completely and within wake periods they transmit receiving messages. Although low energy duty cycle operation is efficient, it increases delay in pocket delivery. A node before introducing receiving pocket of previous stage has to wait until complete wake of receiver that is called sleep delay, and if nodes scheduling is synchronized with each another, this delay will increase proportionately with hop length. To decrease this delay, adaptive listen perspective has been developed. In this perspective, those nodes that are placed within 1 or 2 hops and forwards to that sink are able to stay awake or to wake up earlier than the usual state; however, this involves a little sleep delay. In this paper dynamic power management has been used to further decrease this delay. In former papers regarding management of dynamic power with several types of sleep states only idle time has been used, in this paper, however, due to sufficient remaining energy for wakening of node from sleep mode, this parameter is also used and type of sleep is determined according to these two parameters. Also for increasing lifetime and reducing energy use, wake of all sending and receiving neighbors is not needed here. With this perspective, nodes that are not even within the range of sending and receiving node to hear cts/rts but still are in receiving sleep mode, are able to awake earlier than usual state, i.e., when there is need to urgent data transmission; therefore, delay will reduce.

II. LITERATURE REVIEW

[8] has proposed Dynamic Power Management(DPM) using Hybrid Automata. Hybrid automata use a general framework for presentation of continuous processes disconnected systems in ever changing environments. Changes in these automata in real time occur like sensor networks. In [9] a Extended Power State Machine (EPSM) has been presented that includes node

states in preparing power state machine. In [10] Adaptive Learning Tree is used in which quality of switch off control algorithm depends on user knowledge. Using Adaptive Learning Tree sleep states with sufficient low power is predicted at the beginning of each idle period. In this perspective several sleep states are used. The main structure of the tree is decision nodes, bough, history, prediction bough, and leaf nodes. Prediction Confidence Level occurs in each leaf. Sleep state of a leaf with higher Confidence Level will be selected as node sleep state. In [11] Balancing Energy Aware Sensor Management (BEASM) is used in which each node has 5 states:

Primary state: completing structural settings like synchronization, node places, etc

* Sleep state: to be Waite in random time and then disquisition state

* Disquisition state: spreading the message across node range and then sleep or active states

* Active state: performing action and processing and communication

* Dead state: node break down or use up of related whole energy

In [12] dynamic power management has been proposed using learning machine. System model in this algorithm includes the 3 following parts:

Controller (machine learning algorithm) part, expert (policies of dynamic power management) part, and a device for managing the power. The expert part with respect to one of mentioned policies awakes. When the device is busy, all others are inactive. When idle period occurs, controller activates an expert with maximal action probability. This expert has a control across whole device and makes decisions for power management in idle period. After idle period finishes, it returns to operational state. In [13] several sleep states as well as one wake state have been used. With numbering sleep states, the smaller number will have more energy use but less delay. With respect to idle period, it selects one of sleep states. This will result in energy use reduction in idle state. In this algorithm, temporal cost of transition from sleep state with less energy preservation to a sleep state with more energy preservation is lower than that of its reverse situation; but it is usually overlooked. Each sleep state is selected by power consumption and delay overhead.

In [14] dynamic power management is used for time based programs. In this algorithm sensor nodes reduce external data reports and preserve energy based on neighbors distances and data search information.

Since energy is regarded a limited resource in wireless sensor networks, power energy reduction with the purpose of increase in lifetime seems essential. Several perspectives from dynamic power management have been proposed for energy use reduction. However, few of them consider program limitations for optimization. In this algorithm program based dynamic power management has been proposed that has modeled sensor node operation and program limitations using hybrid automata.

In [15] a digital system has been modeled for evaluation of energy use and environmental display and monitoring control for electronic systems with WSNs equipped with dynamic power management. This system has formed based on two responsible of hardware topologies for signal acquisition, processing, and transmission: intelligent sensor modules and distance data acquisition units. Sensor nodes use dynamic power management to increase lifetime of network.

III. DYNAMIC POWER MANAGEMENT

Dynamic power management techniques can be divided into Hardware centric and Software centric [8].

Most of Dynamic power management techniques are hardware centric. In hardware policy, power management reduces energy use through data received from transmission device. This perspective is based on timeout and predictive techniques. Timeout technique switches off the idle device after idle period according to a time value. Until timeout begins, energy in idle state may be used. Predictive techniques try to predict future idles through analysis of carrier working load in past. In Dynamic power management several sleep states are used [13]. In case that cost for transition into one of these sleep states is less than idle cost, then the node goes into sleep state. Node selects type of its sleep state according to its own idle time and the used energy for changing the state. The deeper sleep marks with higher number and lower used energy. The typical sleeps used in this paper are presented in Fig.1.

Sleep state	StrongARM	Memory	Sensor, analog-digital converter	Radio
s_0	Active	Active	On	Tx, Rx
s_1	Idle	Sleep	On	Rx
s_2	Sleep	Sleep	On	Rx
s_3	Sleep	Sleep	On	Off
s4	Sleep	Sleep	Off	Off

Tx=transmit, Rx=receive.

Figure 1. Sleep states in power aware sensor model Sleep states transition policy

The amount of preserved energy from transition to sleep states can be stated by Eq.(1) that is the space area of trapeze circled in Fig.2[13].

$$E_{Save,k} = \frac{1}{2}(p_0 - p_k)(t_i - \tau_{0,k} + t_i + \tau_{k,0}) = (p_0 - p_k)\left(t_i - \frac{\tau_{0,k} - \tau_{k,0}}{2}\right) \quad (1)$$

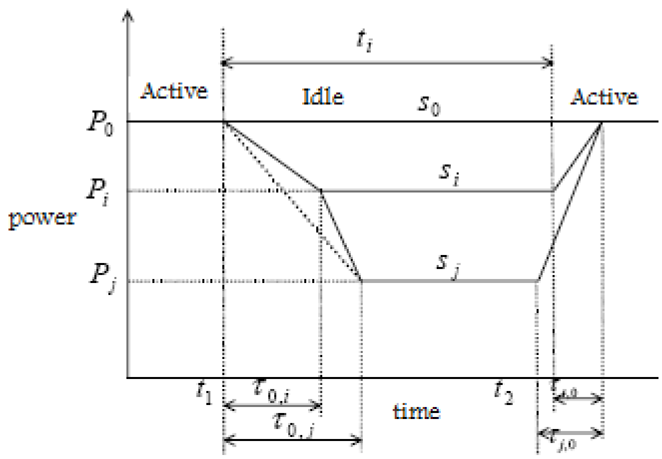

Fig 2. Sleep states transition in Dynamic power management

This Transition to sleep states is useful when preserved energy equals at least the amount of used energy in node's wakening from sleep state, i.e.,

$\Delta E_{k,0} \geq E_{Save,k}$ ، $\Delta E_{k,0}$ as extra energy use will be as S_0 because of sensor node wake. If we consider the minimal value of $E_{Save,k}$ that is $\Delta E_{k,0}$, then the threshold value will be obtained through Eq.(2):

$$T_{th.k} = \frac{1}{2}(\tau_{0,k} - \tau_{k,0}) + \frac{\Delta E_{k,0}}{p_0 - p_k}$$
(2)

In this equation $\tau_{0,k} = \tau_{0,1} + \tau_{1,2} + \cdots$. It is clear that $\tau_{k,0} < p_0 \quad \Delta E_{k,0}$. However, reserved energy increases and results in increased lifetime.

IV. SELECTION OF THE BEST SLEEP STATE IN DYNAMIC POWER MANAGEMENT IN THE PROPOSED ALGORITHM

With respect to figure 2 the whole used energy for going to sleep and wake can be obtained through Eq.(3).

$$E_{tot}=(\frac{P0+Pk}{2})(\tau_{0,k}+\tau_{k,0})+P_k(t_i-\tau_{k,0}) \quad (3)$$

$$\Delta E_{rem}>E_{tot} \quad (4)$$

As seen in Eq.(4), this used energy should be less than nodes remaining energy so that the node is able to transfer into this sleep state and to be remaining energy for transition into wake state. This is because node with long idle time will go to deeper sleep and hence will require more energy for wake. In previous works, nodes remaining energy was not taken into account and with long idle time the deepest sleep was selected regardless of node's remaining energy. In this article, however, nodes' remaining energy has been taken into account since despite a long idle time, there may be insufficient energy for wake and since a deeper sleep requires greater energy for wake, it would not be optimal that the node with long idle time goes to the deepest sleep. Eq.(5) shows how the remaining energy for selection sleep k should be defined and Eq.(6) shows relation between idle time of the node and its remaining energy as well as the sleep state.

$$\Delta E_{rem}>(\frac{P0+Pk}{2})(\tau_{0,k}+\tau_{k,0})+P_k(t_i-\tau_{k,0}) \quad (5)$$

$$t_i<\frac{\Delta Erem-(\frac{p0+pk}{2})\tau 0,k-(\frac{p0+pk}{2})\tau k,0+pk\tau 0,k}{p_k} \quad (6)$$

Thus, for optimal use of dynamic power management in this paper, considering idle time, remaining energy, and saved energy, the best sleep state k is selected with respect to Eq.(7).

$$\frac{1}{2}(\tau_{0,k}-\tau_{k,0})+\frac{\Delta E_{k,0}}{p_0-p_k}<t_i<\frac{\Delta Erem-(\frac{p0+pk}{2})\tau 0,k-(\frac{p0+pk}{2})\tau k,0+pk\tau 0,k}{p_k}$$
(7)

V. SMAC

One of MAC layer protocols for WSNs is S-MAC. In this protocol a large number of nodes are covered in the region each possessing short range and multi hop connections instead of high range connections in order to save energy. This protocol has 3 main components:

Listening and periodic sleep for reduction in idle listening, coincidence, and overhearing avoidance through RTS/CTS pockets, communication via message passing with the purpose of reducing competition delay.

Basic perspective from S-MAC

In S-MAC sleep and wake range is selected according to each program. To modify clock deviance, neighbor nodes use periodic synchronization. Duty cycle S-MAC is presented in Fig.3. In protocol S-MAC wake period equals to sleep period.

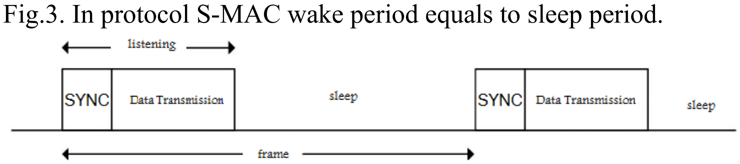

Fig 3. A more detailed profile of duty cycle in S-MAC

Listening period includes SYNC, RTS, CTS, and data transmission. In sync range, each node selects its scheduling and communicates with neighbors. Upon reaching to data transmission range, the node communicates rts/cts messages and upon detection of device idleness, data is transmitted. Sender numbering nodes hearing nav within cts and nodes adjacent to receiver upon hearing nav within rts, can be aware of period of data transmission by sender. This is helpful for avoiding coincidence and overhearing. In compromising smac, nodes hearing nav within ets/cts wake up earlier to the usual state with this probability that they will be next hope node, and in this way delay reduces.

In topology illustrated in Fig.4, it can be seen that in equal situation S-MAC delay is stated with coefficient Tf that equals to frame length and in compromising situation it is stated with $\frac{Tf}{2}$ coefficient whose delay has been reduced rather to the half.

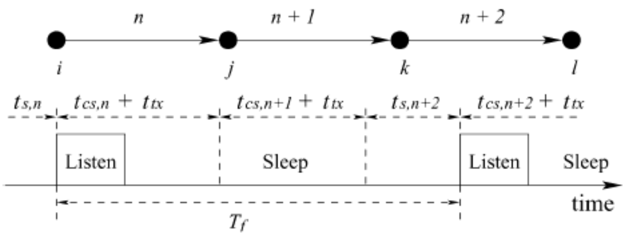

Fig 4. Illustration of delays in compromising hearing in determined topology

VI. PROPOSED ALGORITHM

This algorithm works with compromising smac. Regarding figure above, node i for communicating with the selected neighbor j in the protocol, awaits until mode j reaches its listening range as well; although neighboring nodes are usually synchronized, this is not regarded as a necessity and they may not be synchronized; even if they are synchronized, they may have clock_deviation. After the neighbor node reaches its listening range, node i sends a RTS to it while node j responds with CTS. Node j sends a CTS in which identity of next node k is determined with respect to energy and its delay. When the node responds with CTS, all neighboring nodes including next hope node hear the message. In this algorithm unlike compromising S-MAC in which all nodes wakened, only next hope node will wake up leading to preservation of energy in nodes and increase in network lifetime. Node k despite field NAV in CTS, that represents the end of data transmission between i and j, wakes up after this ending with respect to dynamic power management and type of the selected sleep in order to allow node j to transmit data to it. For this connection to be made, node j sends a RTS to k which in turn responds with a CTS that exists in identity number of node 1. Now if node 1 is sleeping and this sleep is either states of 1 or 2 with respect to dynamic power management, then it means that in reception state, it is able to hear this CTS and to wake up at the time that i to j transmission ends. But if the sleep state is 3 or 4, it should be waiting until complete wake of node 1. In case that node is in either sleep states of 1 or 2, transmission delay will reduce since it would not wait until complete wake and would wake up earlier than usual state. This will result in a decrease in delay compared with compromising S-MAC algorithm. First, node k sends a RTS to node 1. If the node responds with CTS, it indicates that node has been in sleep state of either 1 or 2 that has been able to hear previous CTS and wake up earlier than usual state; and if node k does not hear any response, it shows that node 1 is sleeping not hearing previous CTS and hence remaining in either sleep states of 3 or 4. Thus this algorithm using dynamic power management helps to network increased lifetime as well as reduced delay by early wake (before reaching listening range). Also by using neighbors with higher energy and less delay to sink, they can give the same results. They also save energy and increase network lifetime through avoiding synchronized wake of sending and receiving nodes' neighbors after completion of transmission.

VII. ENERGY MODEL

Energy model used in this paper is leach [16] that can be stated as follows.
Energy model of transmission and reception l bit data according to energy model LEACH can be described in this way that if transmitter to receiver distance (d) is more than d0, multi rout model (with rout waste coefficient 4) is used ; otherwise, open space model (with rout waste coefficient 2) is used. Eq.(8) shows this model:

$$E_{Tx}(l,d) = E_{Tx-elec}(l) + E_{Tx-amp}(l,d)$$
$$= \begin{cases} lE_{elec} + l\varepsilon_{fs}d^2 & d < d_0 \\ lE_{elec} + l\varepsilon_{mp}d^4 & d \geq d_0 \end{cases} \quad (8)$$

Where E_{elect} is energy needed for activating electronic circuits and εmp and εfs are power reinforcement activating energy for both modes of multi rout and open space. A more general schema of this relation can be stated with constant coefficients p and q in Eq.(9) shows:

$$E_{Tx}(l,d) = p + qd^{\alpha} \quad (9)$$

In direction of receiver, used energy for receiving l bit data is as Eq.(10).

$$E_{Rx}(l) = E_{Rx-elec}(l) = lE_{elec} = p \quad (10)$$

VIII. EVALUTION OF ALGORITHM

In this part we will evaluate the proposed algorithm using computer simulations. For this purpose, we compare it with smac and compromising smac. Parameters involved in this comparison are lifetime, the number of active nodes, remaining energy, and delay. For simulation of proposed algorithm as well as efficiency comparison, MATLAB software was used. In these diagrams the proposed algorithm uses DPM. In this simulation a network with ad-hoc topology having a number of desirable nodes and districts is developed. For simulating and evaluation of algorithm function, N number sensor nodes in a square district with dimensions of 600 by 600 meter are located randomly. N has been taken 300. The primary energy of nodes has been taken 0.01 jule. the number of reiterations considered for simulation has been taken 700. Communicational range of nodes is 60 m, i.e. 2 nodes located with a distance of less than 60 meter are recognized as neighbors capable of communicating with each other. Finally a range within which a node can sense an event is 30 m. events are sensed periodically and within each period one event occurs. Location of sink in simulation is in 300 and 300. Fig.5 shows a comparison of proposed algorithm lifetime with that of smac and compromising smac. Fig.6 examines the comparison of remaining energy in these 3 algorithms. Fig.7 presents a comparison of number of active nodes and Fig.8 presents number of paced hops for the 3 algorithms. Table 1 shows these properties.

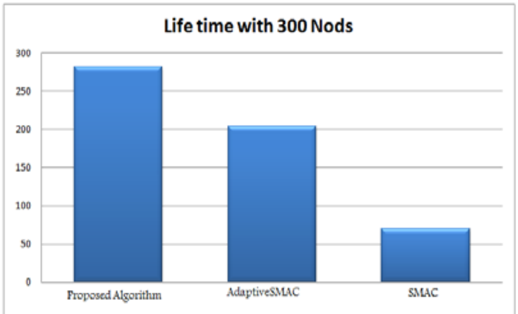

Fig 5. Comparison of lifetime

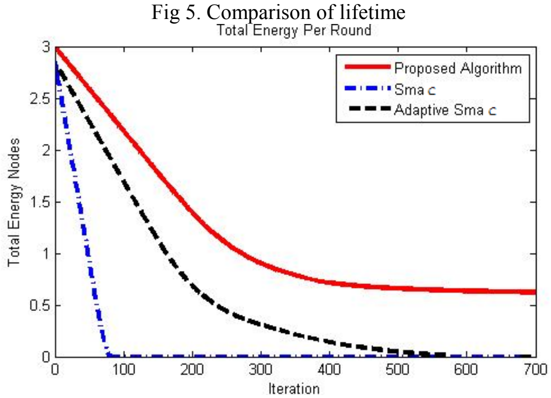

Fig 6. Comparison of remaining energy in the 3 algorithms

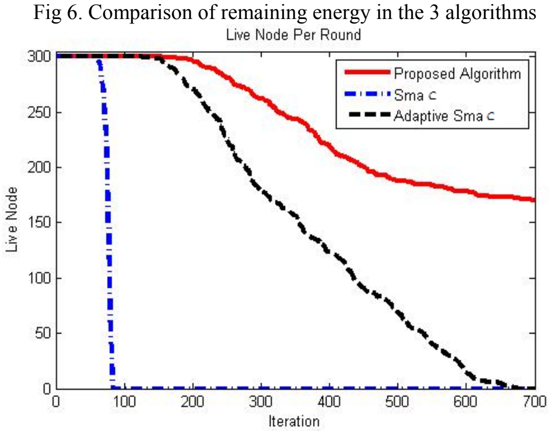

Fig 7. Comparison of number of active nodes in the 3 algorithms

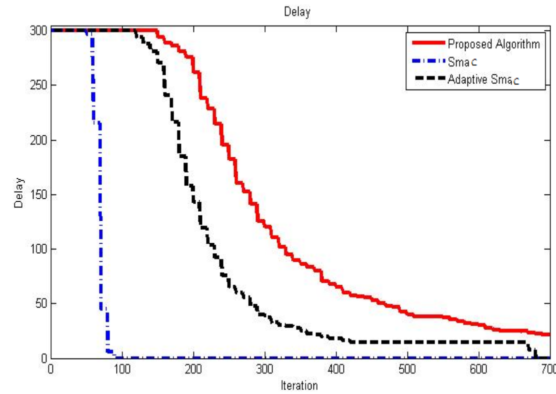

Fig 8. Comparison of number of paced hops to sink for the 3 algorithms

Table 1. Property of simulation

Square border	600*600
N	300
Initial energy	0.01
frequency	700
Connective range	60
Sensing range	30
sink	(300,300)

IX. CONCLUSION AND FUTURE WORKS

A main restriction in wsn networks is energy. Periodic sleep and wake algorithms play a key role in energy use reduction. In this paper network lifetime and the number of active nodes in the network can be increased using compromising smac algorithm and applying a dynamic power management that takes into account the remaining energy of nodes in addition to idle time. Moreover, knowing the next hop node, early wake of all sending and receiving neighbor nodes is avoided that can in turn result in energy use improvement. Results of simulation confirm this claim and compares efficiency of the algorithm with other algorithms. As future works and following research it is suggested to work on improving other fields of energy use and also rover nodes should be used in these algorithms. Furthermore, for programs that need low delay, the amount of this energy use needs to be reduced.

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