ISSN (Online) 2456 -1304

International Journal of Science, Engineering and Management (IJSEM)
Vol 2, Issue 12, December 2017

An Energy Efficient Self-Healing Sleep/Wakeup Scheduling Against Denial Of Service Attacks For Long Life Wireless Sensor Networks

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***Abstract:*-- Wireless sensor network is a network of spatially distributed sensor nodes equipped with sensing, computing, power, and communication modules to monitor a certain phenomenon such as environmental data or object tracking. The nodes in such networks are characterized by limited power, processing, and memory resources. The energy of each sensor is limited and they are usually unrechargeable, so to prolong the life time of WSNs energy consumption of each sensor has to be minimized. The existing system used duty cycling based sleep/wake-up scheduling approaches, in that the time axis is divided into periods, each of which consists of several time slots. In each period, nodes adjust their sleep and wake up time, i.e., adjusting the duty cycle, where each node keeps awake in some time slots while sleeps in other time slots. A long wake-up time may cause energy waste, while a short wake-up time may incur packet delivery delay. However, these duty cycling based approaches in WSNs may incurs tradeoff between both energy saving and packet delivery delay. In order to avoid this, self healing based sleep/wake-up scheduling is proposed to save the energy of each sensor node by keeping nodes in sleep mode as long as possible and thereby maximizing their lifetime. In addition to this denial of Sleep Attack is also considered in this technique which prevents the radio from going into sleep mode and also drain the battery in only a few days. To prevent against denial of sleep attack a cross layer energy efficient security mechanism is additionally added to protect the network from these attacks. The cross layer interaction between network Mac and physical layers is mainly exploited to identify the intruders' nodes and prevent sensor nodes from denial of service. Thus the proposed protocol will reduce the delay and improve the lifetime and QoS of networks.**

I. INTRODUCTION

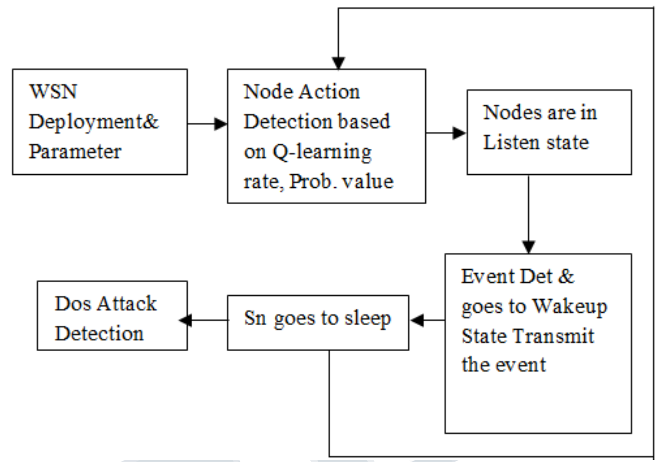
A sensor is a device which detects or measures a physical property and records, indicates, or otherwise responds to it. Memory is the faculty of the mind by which information is encoded, stored, and retrieved. Memory is vital to experiences and related to limbic systems, it is the retention of information over time for the purpose of influencing future action. If we could not remember past events, we could not learn or develop language, relationships, nor personal A wireless sensor network (WSN) is a wireless network consisting of spatially distributed autonomous devices using sensors to monitor physical or environmental conditions. A WSN system incorporates a gateway that provides wireless connectivity back to the wired world and distributed nodes .Good knowledge of the sources of energy consumption in WSNs is the first step to reduce energy consumption. The WSN denial of sleep attack is a subset of the denial of service class of network attacks. The denial-of-sleep attack, in which a sensor node's power supply is targeted. Attacks of this type can reduce the sensor lifetime from years to days and have a devastating impact on a sensor network. The wireless sensor nodes have hundrends and thousands of nodes that help in communication with each other. The energy of each sensor is limited to a certain extent and the nodes are usually not rechargeable and so the energy consumption of the sensor has to be minimized to increase the lifetime of wireless sensor nodes. The energy waste may occur due to idle listening, collision, overhearing and control overhead. And among these idle listening is the most important factor that reduces the lifetime of the wireless sensor nodes. The sleep/wakeup scheduling approach can be used to increase the lifetime of the wireless sensor nodes. Sleep/wakeup scheduling is how to adjust the ratio between sleeping time and awake time of each sensor in each period. A sensor in an awake mode is said to be in idle listening state and it can both send and receive packets. But the energy during the idle listening time is wasted when there are no packets to transmit or receive .The main goal of the sleep/wakeup scheduling is to minimise such waste of energy by adjusting the awake time. There are three categories in sleep/wakeup scheduling (i) on demand wakeup approaches (ii) asynchronous wakeup approaches (iii) synchronous wakeup approaches.

In on demand wakeup approach outofband signaling can be used to wake up a node. In synchronous wakeup approach all the nodes that are sleeping wakeup at the same time in a periodic manner to communicate with each other. In such approaches the neighboring nodes have to be synchronized so that their their sleep and wakeup time is aligned. The neighboring nodes start their communication by exchanging the packets only during the common active period, enabling a node to be in sleep mode for a long period of time, without missing any incoming packet.

In asynchronous wakeup approaches each node has it own wakeup scheduling approach in its idle state. The advantage in this is that easy implementation, low message overhead for communication, assurance of network connectivity in dynamic networks.

In this paper the concept of duty cycling is used to overcome the drawbacks of idle listening problem. An important mechanism for reducing energy consumption in sensor networks is duty cycling. The duty cycling technique saves energy by switching nodes between awake and sleeping states [1]. The average duty cycle measures the ratio of the time a node is awake to the total time. Existing duty cycling Energy efficient MAC protocols can be categorized into two types: synchronous and asynchronous.

Synchronous duty-cycling MAC protocols (e.g., S-MAC [13], TRAMA [9], SCP [14], and DW-MAC [10]) reduce sensor energy consumption by synchronizing the sensors' sleep and wakeup times. However, synchronous duty cycling MAC protocols require multihop time synchronization. In addition, using fixed sleeping times and listening times [13] is inefficient in handling traffic with variable rates. In contrast, asynchronous duty-cycling MAC protocols do not require such synchronization. They may be either sender initiated (e.g., B-MAC [8], X-MAC [1], and Wise MAC [3]) or receiver-initiated (e.g., RI-MAC [11]). With the sender initiated approach, a sender transmits a preamble before a packet transmission to notify the receiver of the upcoming packet. Wise MAC pioneered predictive wakeup in sensor network



OVERVIEW OF THE PROPOSED APPROACH

The proposed approach is not designed incorporating a specific packet routing protocol. This is because if the sleep/wake-up scheduling approach is designed incorporation with a specific packet routing protocol, the scheduling approach may work well only with that routing protocol but may work less efficiently with other routing protocols. For example, in sleep/wake-up scheduling approach is designed incorporation with a packet routing protocol. Their scheduling approach uses staggered wake-up schedules to create unidirectional delivery paths for data propagation to significantly reduce the latency of data collection process. Their approach works very well if packets are delivered in the designated direction, but it is not efficient when packets are delivered in other directions.

The contributions of this paper are summarized as follows.

To the best of our knowledge, this approach is the first one which does not use the technique of duty cycling. Thus the tradeoff between energy saving and packet delivery delay, which is incurred by duty cycling, can be avoided. This approach can reduce both energy consumption and packet delivery delay.

This approach can also achieve higher packet delivery ratios in various circumstances compared to the benchmark approaches. Unlike recent prediction-based approaches [29], [30], where nodes have to exchange information between each other, this approach enables nodes to approximate their neighbors' situation without requesting information from these neighbors. Thus, the large amount of energy used for information exchange [14] can be saved

II. APPROACH DESIGN

In this section, we begin with the formulation of the sleep/wake-up scheduling problem. Then, the details of the algorithms, which are involved in the proposed approach, are provided.

A. Formulation of the Problem

As described in Section I, the research of sleep/wake-up scheduling studies how to adjust the ratio between sleeping time and awake time of each sensor in each period as shown in Fig. 2.According to Fig. 2, formally, we have the following definitions.

Definition 1 (Sleep): A sensor cannot receive or transmit any packets when it is sleeping, i.e., in sleep state. A sensor in sleep state consumes very little energy.

Definition 2 (Wake-Up): A sensor can receive and transmit packets when it is awake, i.e., in wake-up state. A sensor in wake-up state consumes much more energy compared to sleep state.

Definition 3 (Sleep/Wake-Up Scheduling): Sensors adjust the sleeping time length and the awake time length in each period in order to save energy and meanwhile guarantee the efficient transmission of packets.

Generally, the radio transceiver in a sensor node has three modes of operations (termed actions): 1) transmit; 2) listen; and 3) sleep. In transmit mode, the radio transceiver can transmit and receive packets. In listen mode, the transmitter circuitry is turned off, so the transceiver can only receive packets. In sleep mode, both receiver and transmitter are turned off. Typically, among these actions, the power required to transmit is the highest, the power required to listen is medium and the power required to sleep is much less compared to the other two actions. The example provided in [20] shows these power levels: 81 mW for transmission, 30 mW for listen, and 0.003 mW for sleep.

B. Model Description

Table I describes the meaning of each symbol or term that will be used in this paper. Interaction between two neighboring nodes is modeled as a two-player, three-action game, where two players,1 a row player and a column player, represent two neighboring nodes and three actions mean transmit, listen, and sleep. The three terms, player, node, and sensor, are used interchangeably in this paper. Game theory is a mathematical technique which can be used to deal with multiplayer decision making problems. During the decision-making process, there may be conflict or cooperation among the multiple players. Such conflict or cooperation can be easily modeled by game theory via properly setting the payoff matrices and utility functions. In WSNs, there are conflict and cooperation among sensors during many processes, such as packet routing and sleep/wake-up scheduling.

symbol or term	meaning
a player	a node/sensor
row player and column player	two neighbouring nodes
three actions	action 1: *transmit*, action 2: *listen*, action 3: *sleep*
state of a node	Each node has four states: s_0, s_1, s_2, s_3, where s_0 means the node does not have any packet in its buffer, s_1 means the node has 1 packet in its buffer, s_2 means the node has 2 packets in its buffer, s_3 means the node has 3 packets in its buffer.
R and C	payoff matrices for row player and column player, respectively
r_{ij}	payoff obtained by row player when row player takes action i and column player takes action j
c_{ij}	payoff obtained by column player when row player takes action i and column player takes action j
$\alpha_1, \alpha_2, \alpha_3$	the probability for row player to select actions 1, 2, 3, respectively
$\beta_1, \beta_2, \beta_3$	the probability for column player to select actions 1, 2, 3, respectively
U	Successful packet transmission reward
$\pi(s, a)$	the probability for a node to select action a in state s, where a is one of the three actions and s is one of the four states
$Q(s, a)$	the reinforcement value for a node to take action a in state s. The value is be updated using payoff and then the value is used to update $\pi(s, a)$.
$\xi, \delta, \zeta, \epsilon$	Learning rates
γ	Discount factor
η	Gradient step size
TTL	Time to live

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ALGORITHIM

Sleep/Wake-Up Scheduling of a Node

Let ξ and δ be the learning rates and γ be the discount factor;

For each action, initialise value function Q to 0 and policy π to 1/n, where n is the number of available actions;

repeat

select an action a in current state s based on policy π(s, a);

if the selected action a is transmit **then** the node determines when to transmit the packet in the time slot.For each sub-slot in the current time slot, initialize Q-value to 0 and the probability for selecting each sub-slot is initialised to $x_i = 1/m$, where $1 \leq i \leq m$ and m is the number of sub-slots select a sub-slot in current time slot based on the probability distribution over the sub-slots $\mathbf{x} = (x_1, \ldots, x_m)$;

observe payoff p and update Q-value for each sub-slot, $Q_i \leftarrow Q_i + x_i \cdot \zeta \cdot (p- \Sigma_{1\leq i\leq m} x_i Q_i)$;

update x_i for each sub-slot,

$$x_i = \begin{cases} (1-\epsilon) + (\epsilon/m), \text{if } Q_i \text{ is the highest} \\ \epsilon/m, \text{otherwise} \end{cases}$$

$\mathbf{x} \leftarrow Normalise(\mathbf{x})$;

observe payoff p and next state s`, update Q-value

Q(s, a) ← (1 − ξ)Q(s, a) + ξ(p + γ max$_{a'}$Q(s`, a`));

if the selected action a is not sleep **then** based on the updated Q-value, approximate the policy of the neighbour that interacted with the node in the current time slot based on the approximation, for each action a A, update the node's policy π(s, a);

else

calculate the average payoff

(s) ←a∈A π(s, a)Q(s, a);

for each action a ∈ A **do**

π(s, a) ← π(s, a) + δ(Q(s, a) − $\bar{P}$;

π(s) ← Normalise(π(s));

Suppose that in state s, there are m available actions, i.e., a_1, $a_2, \ldots, a_m$;

Let d = $min1\leq k\leq m\pi(s, ak)$, mapping center $c0$ = 0.5 and mapping lower bound _ = 0.001;

if d < _ **then**

$\rho \leftarrow c0-\_ \; c0-d$;

for k = 1 *to m* **do**

$\pi(s, ak) \leftarrow c0 - \rho \cdot (c0 - \pi(s, ak))$;

for k = 1 *to m* **do**

$r \leftarrow 1\leq k\leq m \; \pi(s, ak)$;

$\pi(s, ak) \leftarrow \pi(s,ak)$

r ;

return $\pi(s)$;

ξ ← k/k+1· ξ ;

s ← s_;

until the process is term

Each node generates a packet at the beginning of each time slot based on a predefined probability: the packet generation probability. As the state of a node is determined by the number of packets in its buffer, the packet generation probability directly affects the state of each node. Then, the action selec-tion of each node will be indirectly affected. The expiry time of a packet is based on exponential distribution. The average size of a packet is 100 bytes, and the actual size of a packet is based on normal distribution with variance equal to 10. In this simulation, four packet generation probabilities are used: 0.2, 0.4, 0.6, and 0.8. This setting is to evaluate the performance of these approaches in a network with different number of transmitted packets. For packet routing, we use a basic rout-ing approach, gossiping [51]. Gossiping is a slightly enhanced version of flooding where the receiving node sends the packet to a randomly selected neighbour, which picks another random neighbour to forward the packet to and so on, until the desti-nation or the maximum hop is reached. It should be noted that when the

ISSN (Online) 2456 -1304

International Journal of Science, Engineering and Management (IJSEM)
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destination and some other nodes are all in the signal range of the source, based on the routing protocol, the source still relays a packet to one of neighbors and this process continues until the destination or the maximum hop is reached. The routing process is not optimized in the simulation, as this paper focuses on sleep/wake-up scheduling only. This routing protocol is not energy-efficient but it is easy to implement. Because all of the sleep/wake-up scheduling approaches use the same routing protocol in the simulation, the comparison among them is still fair.

Performance is measured by three quantitative metrics:
1) average packet delivery latency;
2) packet delivery ratio; and
3) average energy consumption. The minimum time needed by nodes to transmit or receive a packet is about 2 ms , e.g., using the radio chip Chipcon CC2420.
The three metrics are described as follows.

Packet delivery latency is measured by the average time taken by each delivered packet to be transmitted from the source to the destination. Note that those packets, which do not reach the destination successfully, have also been taken into account. Their delivery latency is the time interval, during which they exist in the network.

Packet delivery ratio is measured by using the percent-age of packets that are successfully delivered from the source to the destination. Each packet comes with a parameter, time-to-live (TTL), which is a positive integer. Once a packet is transmitted from a sender to a receiver (no matter whether successfully or unsuccessfully), the TTL of this packet subtracts 1. If the TTL of this packet becomes 0 and it has not reached the destination, the delivery of this packet is a failure.

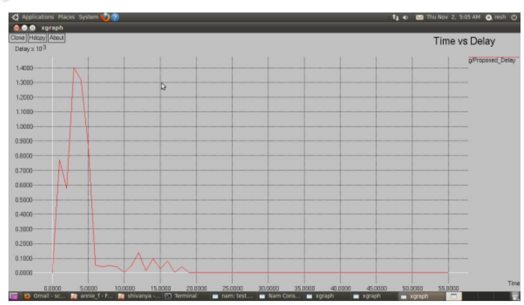
Average energy consumption is calculated by using the total energy consumption to divide the number of nodes in the network during a simulation run.

In this simulation, we set up the evaluation cases ourselves. The approaches used for comparison in the simulation are from four different references which use different evaluation cases. Thus, there are no common evaluation cases among these references. Because all the evaluated approaches are tested in the same cases, the comparison is still fair and the results are convincing.

Parameters	Values	Explanations
	$81mW$	Energy used for transmission
	$30mW$	Energy used for listen
	$0.003mW$	Energy used for sleep
$\mathcal{U}$	98	Successful packet transmission reward
$\xi, \delta, \zeta, \epsilon$	0.8, 0.4, 0.2, 0.2	Learning rates
γ	0.65	Discount factor
η	0.0001	Gradient step size
TTL	8, 15	Time to live

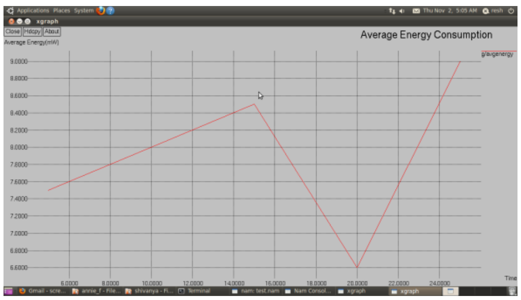
The values and meanings of the parameters used in the simulation are listed in Table II, where the value of the TTL is set to 8 in grid networks and is set to 15 in random networks. The values of the parameters were experimentally chosen to provide the best performance of the proposed approach.7 The values for energy consumption are from .

For the compared approaches, the duty cycle is set to 5%. A full sleep/wake-up interval is set to 1 s. As our approach does not use the duty cycle, the time length of a time slot in our approach is set to 8 ms. As described in Section II-C, learning rates are used to update the learned knowledge. Because the compared approaches do not use reinforcement learning, they do not need update and thus do not need learning rates. In each simulation case, each of these approaches has 200 repeats and each repeat consists of 5000 s. The detailed simulation result data are given in the supplementary material.



Delay

The delay graph represents the time taken for data transmission between two nodes. The graph is plotted between time vs delay. Each time the time taken for data transmission is plotted as a graph. The time increases as the delay increases. Delay occurs when the transmission between the nodes take place even in the sleep mode.The transmission between the nodes take place only when the two nodes in communication are in awake mode.Delay may also cause loss of energy. Dealy may also give rise to packet loss.The delay is unacceptable in some applications of wireless sensor network and a solution to this is to determine the length of the wakeup time.



Average energy

The graph is plotted between time vs average energy consumption. The average energy consumed for each data transmission is represented in the above graph. The maximum average energy consumed is 9mJ.Average energy consumption is calculated by using the total energy consumption to divide the number of nodes in the network during a simulation run. During this simulation run the user can set up the cases themselves. The approaches used for comparison in the simulation are from four different references which use different evaluation cases.

Delivery ratio

The graph is plotted between time vs packet delivery ratio. The maximum Packet delivery ratio is 92%.The packet delivery ratio is measured by using the percentage of packets that are successfully delivered from the source to the destination. Each packet comes with a parameter time to live which is positive integer. Once a packet is transmitted from the source to the destination the time to live of this packet subtracts . If the time to live of this packet becomes 0 and it has not reached the destination, the delivery of this packet is a failure.

CONCLUSION

This project provides a Sleep-wake up scheduling using reinforcement based q-learning algorithm with AODV protocol and also detect the denial of sleep attack based on cross layer MAC design.The AODV protocol stands for Ad-hoc on Demand Distance Vector Routing protocol.This protocol is a routing protocol for mobile adhoc networks (MANETS).AODV is the routing protocol used in ZigBee a low power, low data rate wireless adhoc network. There are various implementations of AODV such as MAD-HOC, Kernel-AODV, AODV-USCB and AODV-UIUC. The reinforcement based q learning algorithm can be specifically used to find an optimal action-selection policy for any given (finite) Markov decision process(MDP).To prevent against the denial of sleep attack a cross layer energy efficient security mechanism is used to protect the network from these attacks. The cross layer interaction between network MAC and physical layers is mainly exploited to identify the intruders nodes and prevent the sensor nodes from the denial of sleep.

ACKNOWLEDGEMENTS

We would like to express our deepest appreciation to all those who provided us the possibility to complete this research paper.We would like to thank all the authors of different research papers referred during writing this paper. It was very knowledge gaining and helpful for the further research to be done in future Also, I would like to extend our sincere esteems to all staff for their timely support.

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