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An efficient energy saving approach for improving lifetime of node in wireless sensor network

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ABSTRACT

Sleep/wake-up scheduling is one of the fundamental problems in wireless sensor networks, since the energy of sensor nodes is limited and they are usually un-rechargeable. The purpose of sleep/wake-up scheduling is to save the energy of each node by keeping nodes in sleep mode as long as possible (without sacrificing packet delivery efficiency) and thereby maximizing their lifetime. In proposed system, a self-adaptive sleep/wake-up scheduling approach is proposed. Unlike most existing studies that use the duty cycling technique, which incurs a tradeoff between packet delivery delay and energy saving, the proposed approach, which does not us duty cycling, avoids such a tradeoff. The proposed approach, based on the reinforcement learning technique, enables each node to autonomously decide its own operation mode (sleep, listen, or transmission) in each time slot in a decentralized manner. Simulation results demonstrate the good performance of the proposed approach in various circumstances.

Keywords: *Energy Efficient, Sleep Awake, Decentralized*

INTRODUCTION

Due to recent technological advances, the manufacturing of small, low power, low cost and highly integrated sensors has become technically and economically feasible. These sensors are generally equipped with sensing, data processing and communication components. Such sensors can be used to measure conditions in the environment surrounding them and then transform these measurements into signals. The signals can be processed further to reveal properties about objects located in the vicinity of the sensors. The sensors then send these data, usually via a radio transmitter, to a command center (also known as a "sink" or a "base station") either directly or via several relaying sensors. A large number of these sensors can be networked in many applications that require unattended operation, hence producing a wireless sensor network (WSN). Currently, there are various applications of WSNs, including target tracking, health care , data collection, security surveillance, and distributed computing . Typically, WSNs contain hundreds or thousands of sensors which have the ability to communicate with each other. The energy of each sensor is limited and they are usually unrechargeable, so energy consumption of each sensor has to be minimized to prolong the life time of WSNs. Major sources of energy waste are idle listening, collision, overhearing and control overhead. Among these, idle listening is a dominant factor in most sensor network applications. There are several ways to prolong the life time of WSNs, e.g., efficient deployment of sensors optimization of WSN coverage and sleep/wake-up scheduling In this paper, we focus on sleep/wake-up scheduling. Sleep/wakeup scheduling, which aims to minimize idle listening time, is one of the fundamental research problems in WSNs]. Specifically, research into sleep/wake-up scheduling studies how to adjust the ratio between sleeping time and awake time of each sensor in each period. When a sensor is awake, it is in an idle listening state and it can receive and transmit packets. However, if no packets are received or transmitted during the idle listening time, the energy used during the idle listening time is wasted. Such waste should certainly be minimized by adjusting the awake time of sensors, which is the aim of sleep/wake-up scheduling. Recently, many sleep/wake-up scheduling approaches have been developed These approaches roughly fall into three categories: 1) on-demand wake-up approaches; 2) synchronous wake-up approaches; and 3) asynchronous wake-up approaches, as categorized in In on-demand wake-up approaches out-of-band signaling is used to wake up sleeping nodes on-demand. For example, with the help of a paging signal, a node listening on a page channel can

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be woken up. As page radios can operate at lower power consumption, this strategy is very energy efficient. However, it suffers from increased implementation complexity. In synchronous wake-up approaches sleeping nodes wake up at the same time periodically to communicate with one another. Such approaches have to synchronize neighboring nodes in order to align their awake or sleeping time. Neighboring nodes start exchanging packets only within the common active time, enabling a node to sleep for most of the time within an operational cycle without missing any incoming packets. Synchronous wake-up approaches can reduce idle listening time significantly, but the required synchronization introduces extra overhead and complexity. In addition, a node may need to wake up multiple times during a full sleep/wake-up period, if its neighbors are on different schedules. In asynchronous wake-up approaches each node follows its own wake-up schedule in the idle state. This requires that the wake-up intervals among neighbors are overlapped. To meet this requirement, nodes usually have to wake up more frequently than in synchronous wake-up approaches. The advantages offered by asynchronous wake-up approaches include easiness of implementation, low message overhead for communication, and assurance of network connectivity even in highly dynamic networks. Most current studies use the technique of duty cycling to periodically alternate between awake and sleeping states Here, duty cycle is the ratio between the wake up time length in a predefined period and the total length of that period]. For example, suppose a period is 1 s and a node keeps awake for 0.3 s and keeps asleep for 0.7 s in the period. Then, the duty cycle is 30% (or 0.3). The use of duty cycling incurs a tradeoff between energy saving and packet delivery delay: a long wake-up time may cause energy waste, while a short wake-up time may incur packet delivery delay. However, in WSNs, both energy saving and packet delivery delay are important. Because each node in WSNs is usually equipped with an un-rechargeable battery, energy saving is crucial for prolonging the lifetime of WSNs. Because delay is unacceptable in some applications of WSNs, e.g., fire detection and tsunami alarm, reducing packet delivery delay is crucial for the effectiveness of WSNs. An intuitive solution to this tradeoff is to dynamically determine the length of wake-up time. The solution proposed in can dynamically determine the length of wake-up time by transmitting all messages in bursts of variable length and sleeping between bursts. That solution can save energy but it may exaggerate packet delivery delay, because each node has to spend time to accumulate packets in its queue before each node transmits these packets in bursts. Another solution, proposed in enables senders to predict receivers' wake-up times by using a pseudo-random wake-up scheduling approach. In the future, if senders have packets to transmit, senders can wake up shortly before the predicted wake-up time of receivers, so the energy, which senders use for idle listening, can be saved. In this case, senders do not have to make the tradeoff, because their wake-up times are totally based on receivers' wake-up times. Receivers still face the tradeoff, however, since a receiver's wake-up time relies on a pseudo-random wake-up scheduling function and different selections of parameters in this function will result in different wake-up intervals. In addition, before a sender can make a prediction about a receiver's wake-up time, the sender has to request the parameters in the receiver's wake-up scheduling function. This request incurs extra energy consumption.

1.1 Domain Information

A **wireless sensor network (WSN)** consists of spatially distributed autonomous sensors to *monitor* physical or environmental conditions, such as temperature, sound, pressure, etc. and to cooperatively pass their data through the network to a main location. The more modern networks are bi-directional, also enabling *control* of sensor activity. The development of wireless sensor networks was motivated by military applications such as battlefield surveillance; today such networks are used in many industrial and consumer applications, such as industrial process monitoring and control, machine health monitoring, and so on.

The WSN is built of "nodes" – from a few to several hundreds or even thousands, where each node is connected to one (or sometimes several) sensors. Each such sensor network node has typically several

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parts: a radio transceiver with an internal antenna or connection to an external antenna, a microcontroller, an electronic circuit for interfacing with the sensors and an energy source, usually a battery or an embedded form of energy harvesting. A sensor node might vary in size from that of a shoebox down to the size of a grain of dust, although functioning "motes" of genuine microscopic dimensions have yet to be created. The cost of sensor nodes is similarly variable, ranging from a few to hundreds of dollars, depending on the complexity of the individual sensor nodes. Size and cost constraints on sensor nodes result in corresponding constraints on resources such as energy, memory, computational speed and communications bandwidth. The topology of the WSNs can vary from a simple star network to an advanced multi-hop wireless mesh network. The propagation technique between the hops of the network can be routing or flooding.

1.2 Applications

1.2.1 Area monitoring

Area monitoring is a common application of WSNs. In area monitoring, the WSN is deployed over a region where some phenomenon is to be monitored. A military example is the use of sensors detect enemy intrusion; a civilian example is the geo-fencing of gas or oil pipelines.

1.2.2 Environmental/Earth monitoring

The term Environmental Sensor Networks has evolved to cover many applications of WSNs to earth science research. This includes sensing volcanoes, oceans, glaciers, forests, etc. Some of the major areas are listed below.

1.2.3 Air quality monitoring

The degree of pollution in the air has to be measured frequently in order to safeguard people and the environment from any kind of damages due to air pollution. In dangerous surroundings, real time monitoring of harmful gases is an important process because the weather can change rapidly changing key quality parameters.

1.2.4 Air pollution monitoring

Wireless sensor networks have been deployed in several cities (Stockholm, London and Brisbane) to monitor the concentration of dangerous gases for citizens. These can take advantage of the ad hoc wireless links rather than wired installations, which also make them more mobile for testing readings in different areas. There are various architectures that can be used for such applications as well as different kinds of data analysis and data mining that can be conducted.

1.3 Characteristics

The main characteristics of a WSN include:

- Power consumption constrains for nodes using batteries or energy harvesting
- Ability to cope with node failures
- Mobility of nodes
- Communication failures
- Heterogeneity of nodes

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- Scalability to large scale of deployment
- Ability to withstand harsh environmental conditions
- Ease of use

Sensor nodes can be imagined as small computers, extremely basic in terms of their interfaces and their components. They usually consist of a *processing unit* with limited computational power and limited memory, *sensors* or MEMS (including specific conditioning circuitry), a *communication device* (usually radio transceivers or alternatively optical), and a power source usually in the form of a battery. Other possible inclusions are energy harvesting modules, secondary ASICs, and possibly secondary communication interface (e.g. RS-232 or USB).

The base stations are one or more components of the WSN with much more computational, energy and communication resources. They act as a gateway between sensor nodes and the end user as they typically forward data from the WSN on to a server. Other special components in routing based networks are routers, designed to compute, calculate and distribute the routing tables.

LITERATURE SURVEY

1) Y. Xiao *et al.*, investigates the fundamental performance limits of medium access control (MAC) protocols for particular multihop, RF-based wireless sensor networks and underwater sensor networks. A key aspect of this study is the modeling of a fair-access criterion that requires sensors to have an equal rate of underwater frame delivery to the base station. Tight upper bounds on network utilization and tight lower bounds on the minimum time between samples are derived for fixed linear and grid topologies. The significance of these bounds is two-fold: First, they hold for any MAC protocol under both single-channel and half-duplex radios; second, they are provably tight. For underwater sensor networks, under certain conditions, author derive a tight upper bound on network utilization and demonstrate a significant fact that the utilization in networks with propagation delay is larger than that in networks with no propagation delay. The challenge of this work about underwater sensor networks lies in the fact that the propagation delay impact on underwater sensor networks is difficult to model.

2) S. Zhu, C. Chen, W. Li, B. Yang, and X. Guan concerned with the problem of filter design for target tracking over sensor networks. Different from most existing works on sensor networks, we consider the heterogeneous sensor networks with two types of sensors different on processing abilities (denoted as type-I and type-II sensors, respectively). However, questions of how to deal with the heterogeneity of sensors and how to design a filter for target tracking over such kind of networks remain largely unexplored. We propose in this paper a novel distributed consensus filter to solve the target tracking problem. Two criteria, namely, unbiasedness and optimality, are imposed for the filter design. The so-called sequential design scheme is then presented to tackle the heterogeneity of sensors. The minimum principle of Pontryagin is adopted for type-I sensors to optimize the estimation errors. As for type-II sensors, the Lagrange multiplier method coupled with the generalized inverse of matrices is then used for filter optimization. Furthermore, it is proven that convergence property is guaranteed for the proposed consensus filter in the presence of process and measurement noise. Simulation results have validated the performance of the proposed filter. It is also demonstrated that the heterogeneous sensor networks with the proposed filter outperform the homogenous counterparts in light of reduction in the network cost, with slight degradation of estimation performance.

3)G. Acampora, D. J. Cook, P. Rashidi, and A. V. Vasilakos examine the infrastructure and technology required for achieving the vision of AmI, such as smart environments and wearable medical devices. We will summarize the state-of-the-art artificial intelligence (AI) methodologies used for developing AmI system in the healthcare domain, including various learning techniques (for learning from user interaction), reasoning techniques (for reasoning about users' goals and intensions), and planning

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techniques (for planning activities and interactions). Author will also discuss how AmI technology might support people affected by various physical or mental disabilities or chronic disease. Finally, we will point to some of the successful case studies in the area and we will look at the current and future challenges to draw upon the possible future research paths.

4)Y. Yao, Q. Cao, and A. V. Vasilakos work in this paper stems from our insight that recent research efforts on open vehicle routing (OVR) problems, an active area in operations research, are based on similar assumptions and constraints compared to sensor networks. Therefore, it may be feasible that we could adapt these techniques in such a way that they will provide valuable solutions to certain tricky problems in the wireless sensor network (WSN) domain. To demonstrate that this approach is feasible, we develop one data collection protocol called EDAL, which stands for Energy-efficient Delay-aware Lifetime-balancing data collection. The algorithm design of EDAL leverages one result from OVR to prove that the problem formulation is inherently NP-hard. Therefore, we proposed both a centralized heuristic to reduce its computational overhead and a distributed heuristic to make the algorithm scalable for large-scale network operations. We also develop EDAL to be closely integrated with compressive sensing, an emerging technique that promises considerable reduction in total traffic cost for collecting sensor readings under loose delay bounds. Finally, we systematically evaluate EDAL to compare its performance to related protocols in both simulations and a hardware testbed.

4.1 Problem Definition

Sleep/wake-up scheduling is one of the fundamental problems in wireless sensor networks, since the energy of sensor nodes is limited and they are usually un-rechargeable. The purpose of sleep/wake-up scheduling is to save the energy of each node by keeping nodes in sleep mode as long as possible (without sacrificing packet delivery efficiency) and thereby maximizing their lifetime. In proposed system, a self-adaptive sleep/wake-up scheduling approach is proposed. Unlike most existing studies that use the duty cycling technique, which incurs a tradeoff between packet delivery delay and energy saving, the proposed approach, which does not us duty cycling, avoids such a tradeoff.

4.2 Proposed System Methodology

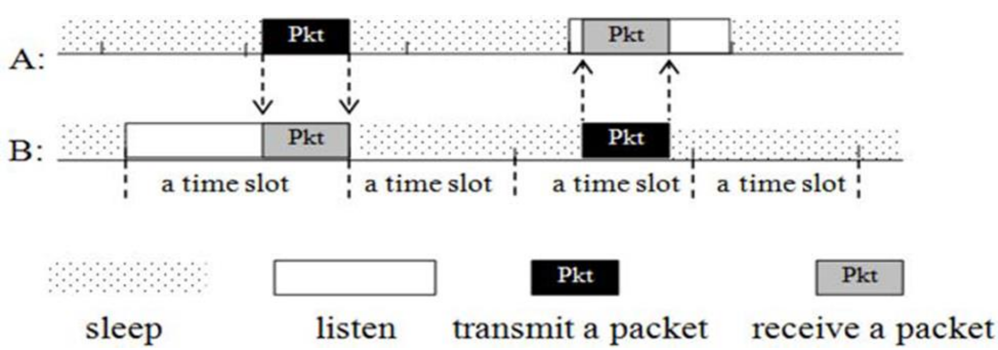

Figure : Proposed System

The simulation is operated in grid types of networks: For each type of networks, there are four different scales. The scale of grid networks fluctuates in 49 nodes, where 49 nodes are structured as a 7 × 7 grid network.In the grid networks, each node is 250 meters from its neighbors and there are 5 sinks which are located at the four corners and the center of the network. 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 selection of each node will be indirectly affected. The expiry time of a packet is based on

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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.

Duty Cycle Scheduling:

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.

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.

Transfer/Active: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.

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 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.

Gossiping:

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 destination or the maximum hop is reached. It should be noted that when the 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.

Performance Evaluation

Performance is measured by three quantitative metrics:

- Average packet delivery latency
- Packet delivery ratio
- Average energy consumption.

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 percentage of packets that are successfully delivered from the source to the destination. Average energy consumption is calculated by using the total energy consumption to divide the number of nodes in the network during a simulation run.

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Proposed System Flow

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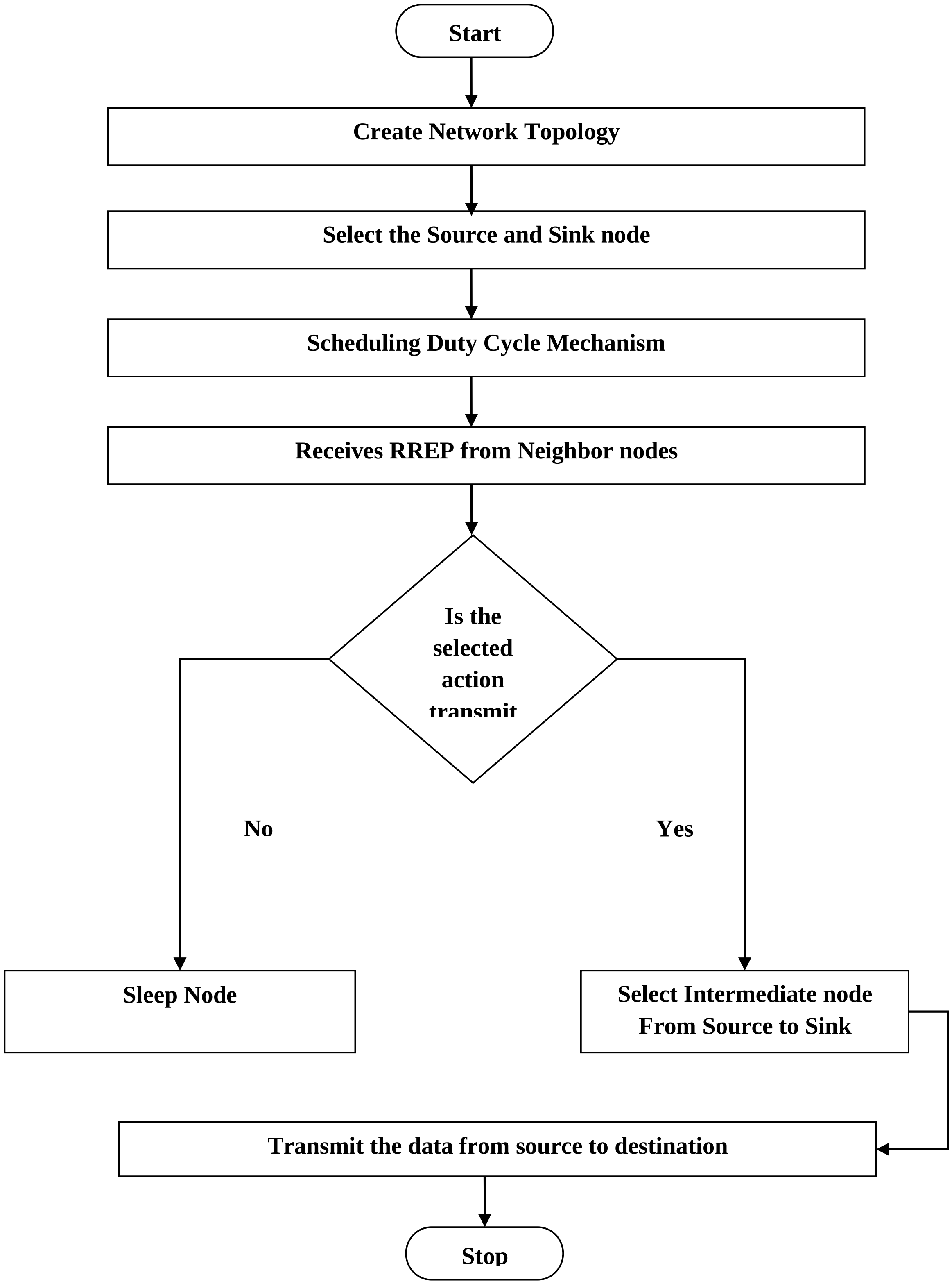

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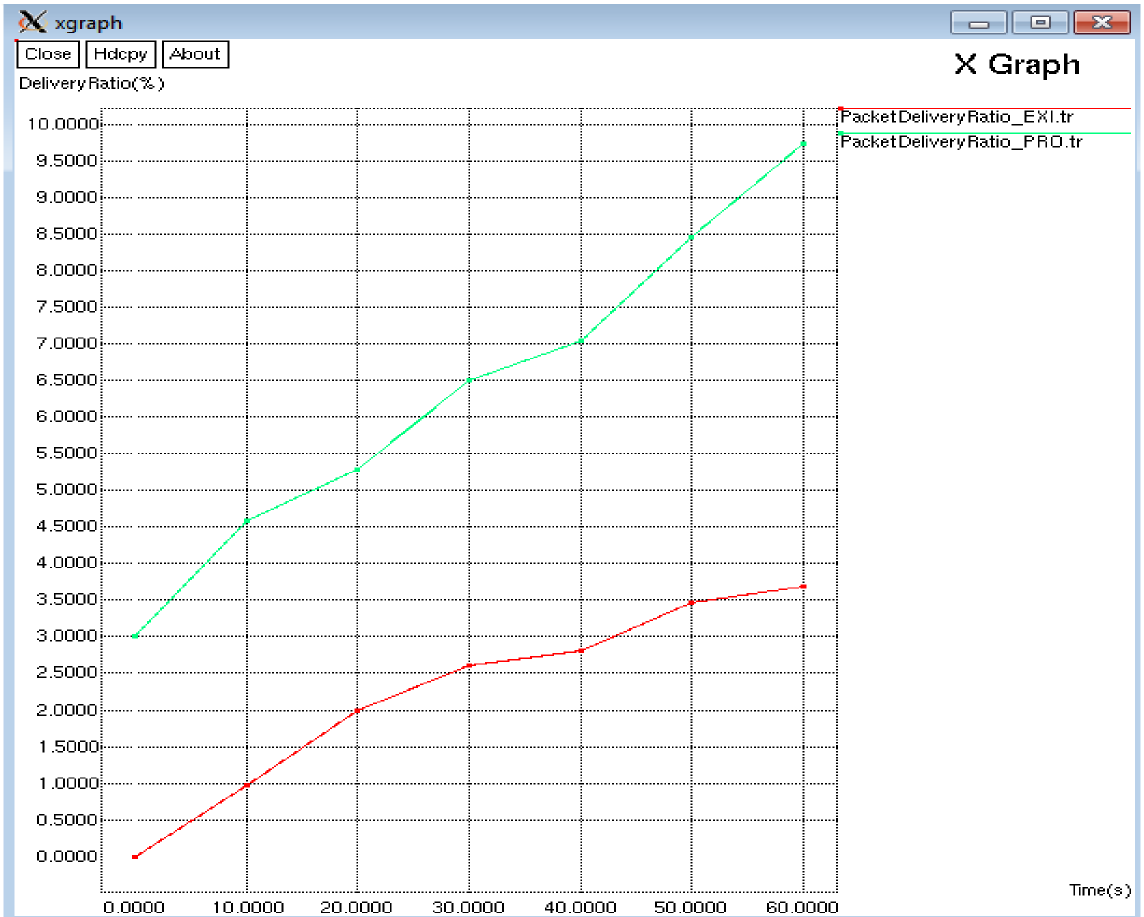
RESULT ANALYSIS



1) Packet delivery ratio

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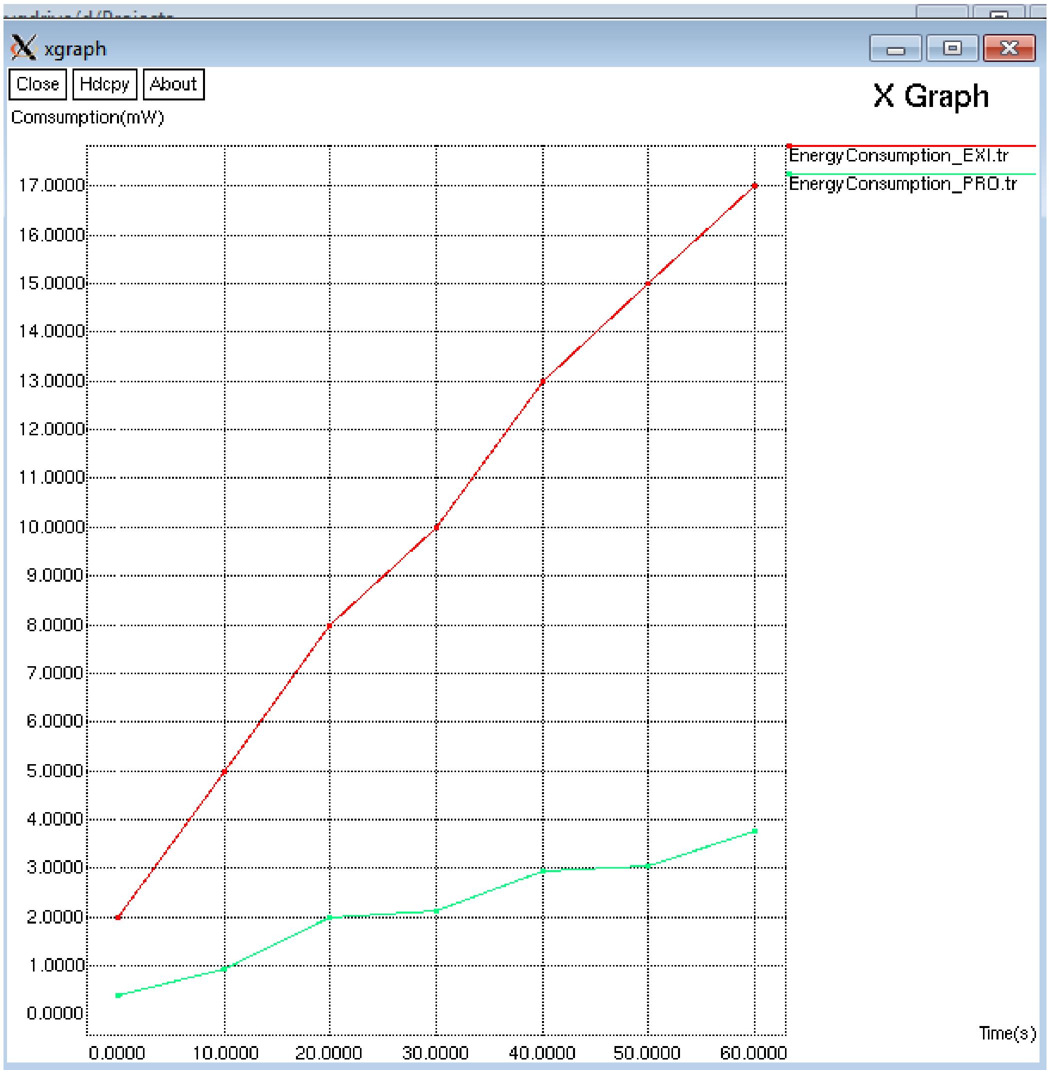

2) Energy Consumption

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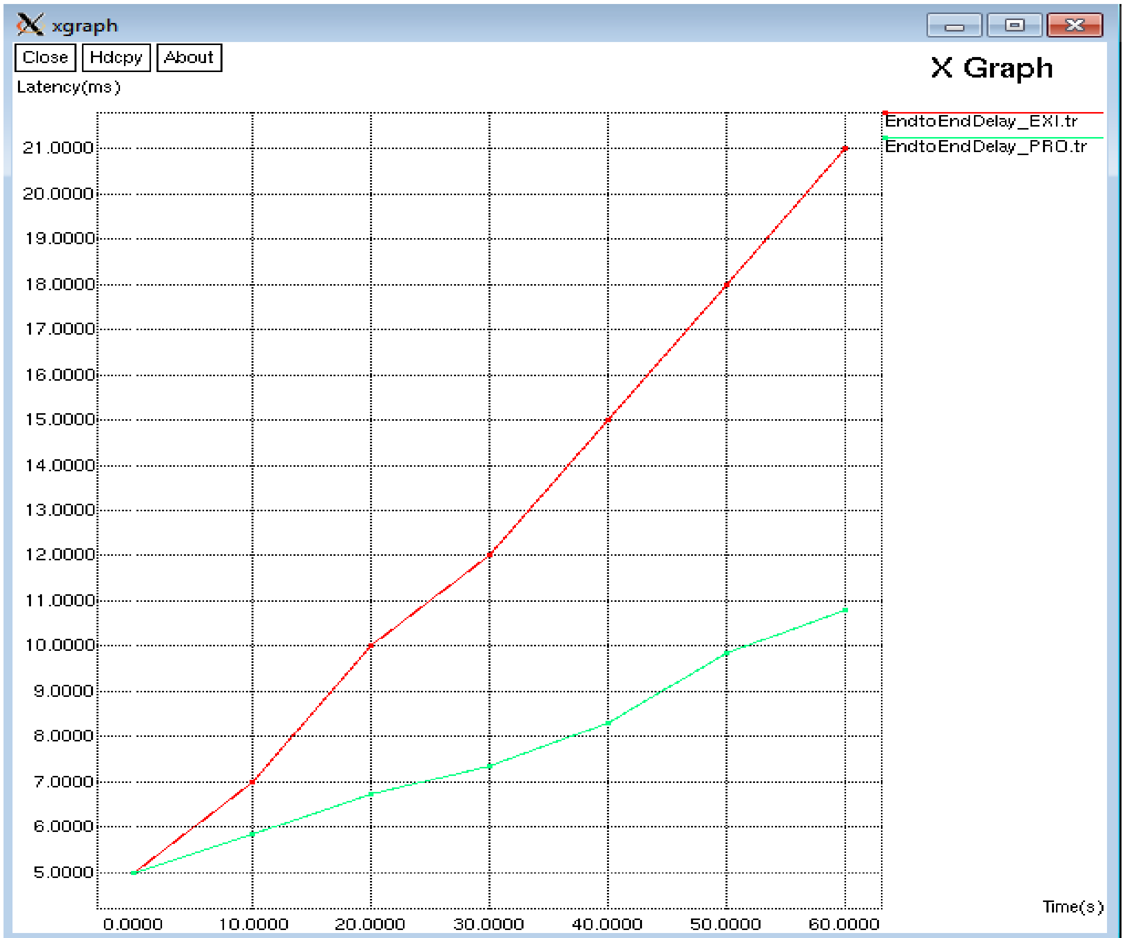

3) End to end delay

CONCLUSION AND FUTURE SCOPE

This paper introduced a self-adaptive sleep/wake-up scheduling approach. This approach does not use the technique of duty cycling. Instead, it divides the time axis into a number of time slots and lets each node autonomously decide to sleep, listen or transmit in a time slot. Each node makes a decision based on its current situation and an approximation of its neighbors' situations, where such approximation does not need communication with neighbors.

Most existing approaches are based on the duty cycling technique and these researchers have taken much effort to improve the performance of their approaches. Thus, duty cycling is a mature and efficient technique for sleep/wakeup scheduling. This proposed approach is the first one which does not use the duty cycling technique. The performance improvement of the proposed approach, compared with existing approaches.

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