Optimizing the Life Time of Sensor Network Nodes using Scheduling and Routing Algorithm

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Abstract : **Wireless Sensor Networks (WSN) is the key resource of insight and is widely used trends now a days. Sensor nodes are powered by batteries and proper energy conservation is needed to prolong the lifetime of the sensors. The determination of scheduling and routing algorithm is to save the energy of each nodes by keeping nodes in sleep mode as long as possible . Life time of sensor network is increased by reducing the number of times sensor is wake up. This can be done using sleep wakeup scheduling of the sensor nodes. In earlier work, a distributed sleep wakeup scheduling of sensor node is done using reinforcement learning. But the problem in this approach is that nodes proximity is not considered in decision making. If two nodes are close by, then if reinforcement learning has resulted in both nodes we on, then this decision has to overridden to make the sensor node with highest energy to be on and other sensor near its proximity to be switched off. This way energy can be saved better. This work implements the optimization proposed above over reinforcement learning based sleep wakeup scheduling to increase the life time of the sensor network.**

Keywords: WSN, Duty Cycling, Reinforcement learning technique.

I. INTRODUCTION

Wireless Sensor Network (WSN) has some great advantages such as flexible arrangement and communication, low power consumption and low cost. As the world is moving towards digitalization technology, the wireless mode of communication makes the network so updated with the current expectations. WSN are applied in many applications like tsunami detection, ocean-boarding alarming for fisherman. Typical WSN consist of nodes connected through wireless infrastructure. The nodes scattered with the objective to sense some environment parameters and route these parameters to base station to realize application logic. The sensors are battery powered and energy depletes during the operation of nodes. At one point of time sensors fails to operate due to very low or no battery energy. In most cases sensors are deployed in unattended environment and it may be costly or not possible to replace the sensor nodes. This necessitates prudent use of energy in the nodes so that longevity of network increases.

II. RESEARCH METHODOLOGY

Recently, many sleep scheduling approaches have been developed. These approaches roughly fall into three categories: On-demand wake-up approaches, synchronous wake-up approaches and asynchronous wake-up approaches. In on-demand wake-up approaches, out-of-band signalling 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 be woken up. As page radius can operate at lower power consumption, this strategy is very energy efficient. However, it suffers from increased implementation complexity.

The author in the Reference [1] proposes an important technique known as Power management to prolong the lifespan of sensor networks. Many power-management protocols employ wake-up/sleep schedules, which are often complicated and inefficient. Author present power management schemes that eliminate such wake-up periods unless the node indeed needs to wake up. This type of wake-up capability is enabled by a new radio-triggered hardware component. They evaluate the potential power saving in terms of the lifespan of a sensor network application, using experiment data and SPICE circuit simulations. Comparing the result with always-on and rotation-based power management schemes, they find the radio-triggered scheme saves 98% of the energy used in the always-on scheme, and saves over 70% of the energy used in the rotation-based scheme.

The author in the reference [2] proposes a protocol in which energy is conserved by amortizing the energy cost of communication over multiple packets. In addition, they allow sensors to control the amount of buffered packets since storage space is limited. To achieve this, a two-radio architecture is used which allows a sensor to "wakeup" a neighbour with a busy tone and send its packets for that destination. However, this process is expensive because all neighbours must awake and listen to the primary channel to determine who the intended destination is.

The author in the reference [3] proposes a wakeup scheme that helps to achieve the equilibrium between energy saving and end-to-end delay. The scheme uses a wakeup tone channel in addition to the regular data channel. When a node has packets to be sent, it sends a tone to the wakeup channel, which lasts for some duration. Once a node detects the wakeup tone during its duty time, this node will stay active on the data channel. As the wakeup tone does not contain receiver's identity, any node within the transmission range of sender will be awakened.

The author in the reference [4] proposes Energy harvesting technologies that are required for autonomous sensor networks for which using a power source from a fixed utility or manual battery recharging is infeasible. An energy harvesting device (e.g., a solar cell) converts different forms of environmental energy into electricity to be supplied to a sensor node. However, since it can produce energy only at a limited rate, energy saving mechanisms play an important role to reduce energy consumption in a sensor node. In this article author present an overview of the different energy harvesting technologies and the energy saving mechanisms for wireless sensor networks. The related research issues on energy efficiency for sensor networks using energy harvesting technology are then discussed. To this end, we present an optimal energy management policy for a solar-powered sensor node that uses a sleep and wakeup strategy for energy conservation. The problem of determining the sleep and wakeup probabilities is formulated as a bargaining game. The Nash equilibrium is used as the solution of this game.

In synchronous wake-up approaches, sleeping nodes wake up at the same time periodically to communicate with one another. Such approaches have to synchronize neighbouring nodes in order to align their awake or sleeping time. Neighbouring 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 neighbours are on different schedules.

The author in the reference [5] proposes S-MAC, a medium access control (MAC) protocol designed for wireless sensor networks. Wireless sensor networks use battery-operated computing and sensing devices. A network of these devices will collaborate for a common application such as environmental monitoring. They expect sensor networks to be deployed in an ad hoc fashion, with nodes remaining largely inactive for long time, but becoming suddenly active when something is detected. These characteristics of sensor networks and applications motivate a MAC that is different from traditional wireless MACs such as IEEE 802.11 in several ways: energy conservation and self-configuration are primary goals, while per-node fairness and latency are less important. S-MAC uses a few novel techniques to reduce energy consumption and support self-configuration. It enables low-duty-cycle operation in a multi-hop network. Nodes form virtual clusters based on common sleep schedules to reduce control overhead and enable traffic-adaptive wake-up. S-MAC uses in-channel signalling to avoid overhearing unnecessary traffic. Finally, S-MAC applies message passing to reduce contention latency for applications that require in-network data processing

The author in the reference [6] proposes a protocol for node sleep scheduling that guarantees a bounded-delay sensing coverage while maximizing network lifetime. Their sleep scheduling ensures that coverage rotates such that each point in the environment is sensed within some finite interval of time, called the detection delay. The framework is optimized for rare event detection and allows favourable compromises to be achieved between event detection delay and lifetime without sacrificing (eventual) coverage for each point.

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 neighbours 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. Asynchronous wakeup has the merits of not requiring global clock synchronization and being resilient to network dynamics.

The author in the reference [7] presents a systematic approach to designing and implementing asynchronous wakeup mechanisms in ad hoc networks. The optimal wakeup schedule design can be formulated as a block design problem in combinatory. They propose a neighbour discovery and schedule bookkeeping protocol that can operate on the optimal wakeup schedule derived. Two power management policies, i.e. slot-based power management and on-demand power management, are studied to overlay desirable communication schedule over the wakeup schedule mandated by the asynchronous wakeup mechanism.

The author in the reference [8] proposes B-MAC, a carrier sense media access protocol for wireless sensor networks that provides a flexible interface to obtain ultra -low power operation, effective collision avoidance, and high channel utilization. To achieve low power operation, B-MAC employs an adaptive preamble sampling scheme to reduce duty cycle and minimize idle listening. B-MAC supports on-the-fly reconfiguration and provides bidirectional interfaces for system services to optimize performance, whether it be for throughput, latency, or power conservation. We build an analytical model of a class of sensor network applications. They use the model to show the effect of changing B-MAC's parameters and predict the behavior of sensor network applications. By comparing B-MAC to conventional 802.11- inspired protocols, specifically S-MAC, we develop an experimental characterization of B-MAC over a wide range of network conditions. We show that B-MAC's flexibility results in better packet delivery rates, throughput, latency, and energy consumption than S-MAC.

The author in the reference [9] demonstrates a form of preamble sampling to reduce idle listening cost. In Hill's RF wakeup scheme, the analog baseband of the radio is sampled for energy every 4 seconds. By quickly evaluating the channel's energy, they reduced the duty cycle of the radio to below 1%. They demonstrated the use of low power RF wakeup on an 800 node multi-hop network. The ASK radio used by Hill allows very brief radio sampling; we develop a related technique that works on more complex radios.

The author in the reference [10] proposes T-MAC, this work improves on S-MAC's energy usage by using a very short listening window at the beginning of each active period. After the SYNC section of the active period, there is a short window to send or receive RTS and CTS packets. If no activity occurs in that period, the node returns to sleep. By changing the protocol to have an adaptive duty cycle, T-MAC saves power at a cost of reduced throughput and additional latency. T-MAC, in variable workloads, uses one fifth the power of S-MAC. In homogeneous workloads, TMAC and S-MAC perform equally well. T-MAC suffers from the same complexity and scaling problems of S-MAC. Shortening the active window in T-MAC reduces the ability to snoop on surrounding traffic and adapt to changing network conditions

The author in the reference [11] investigate the available energy-efficient Medium Access Control protocols for wireless sensor networks emphasizing on their energy saving methods and present a simple but effective energy efficient MAC protocol named AEEMAC (Adaptive Energy Efficient MAC protocol). Like SMAC, AEEMAC also employs a duty cycling to save energy by avoiding idle listening, but incorporates three additional optimizations to further improve energy efficiency at MAC layer. These optimizations are - (i) adaptive sleeping and reusing of channel, (ii) use of combined `SYNC-RTS' control packet, and (iii) use of combined `ACK-RTS' control packet in bidirectional and multi-hop data transmission.

The author in the reference [12] presents PW-MAC (Predictive-Wakeup MAC), a new energy-efficient MAC protocol based on asynchronous duty cycling. In PW-MAC, nodes each wake up to receive at randomized, asynchronous times. PW-MAC minimizes sensor node energy consumption by enabling senders to predict receiver wakeup times; to enable accurate predictions, PW-MAC introduces an on-demand prediction error correction mechanism that effectively addresses timing challenges such as unpredictable hardware and operating system delays and clock drift. PW-MAC also introduces an efficient prediction-based retransmission mechanism to achieve high energy efficiency even when wireless collisions occur and packets must be retransmitted.

The author in the reference [13] presents the design and evaluation of the EM-MAC (Efficient Multichannel MAC) protocol, which addresses these challenges through the introduction of novel mechanisms for adaptive receiver-initiated multichannel rendezvous and predictive wake-up scheduling. EM-MAC substantially enhances wireless channel utilization and transmission efficiency while resisting wireless interference and jamming by enabling every node to dynamically optimize the selection of wireless channels it utilizes based on the channel conditions it senses, without use of any reserved control channel. EM-MAC achieves high energy efficiency by enabling a sender to predict the receiver's wake-up channel and wake-up time Implemented in TinyOS on MICAz motes, EM-MAC substantially outperformed other MAC protocols studied.

The author in reference [14] presents 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. Through these techniques, the performance of the proposed approach outperforms other related approaches. Most existing previous 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 paper is the first one which does not use the duty cycling technique

III. Proposed Work

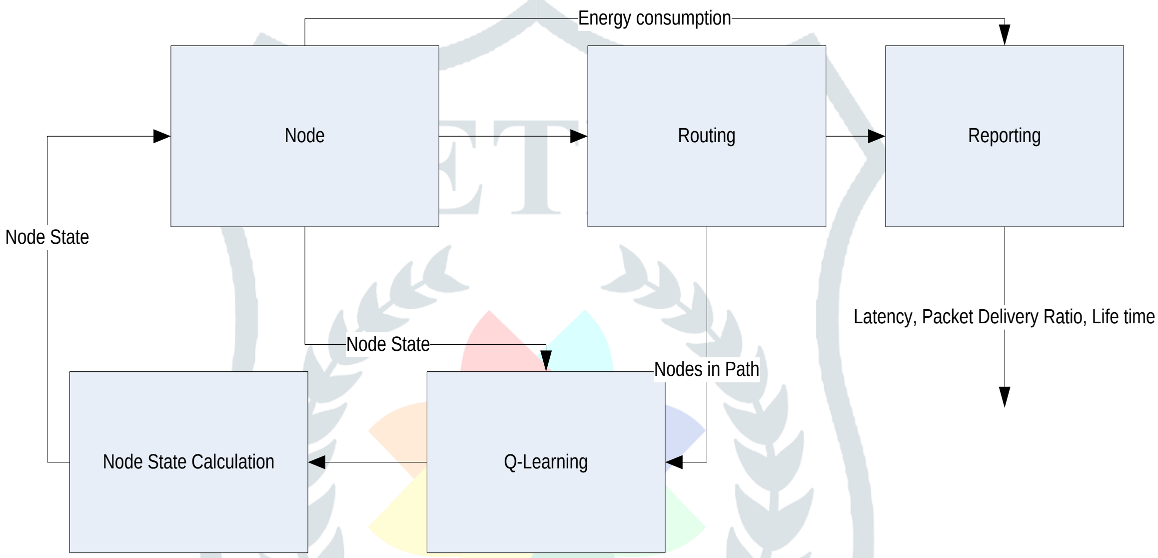


Figure 3.1 System architecture

The System architecture is shown above.Node can be in one of three states – Transmit, List & Sleep. Node states when packet is routed is observed by the Q-Learning module and it calculates the reward or punishment for each state based on node's presence in the routing. From reward or punishment calculated at each state, the probability of nodes state is calculated from it and it is used to decide the node's next state. Reporting module collects performance parameters like energy consumption, routing delay, packet delivery ratio and summarizes it in form of graphs.

Different from sleep wake up scheduling proposed in the another base paper [14], Node state calculation functionality is added. This module after calculating the node state probability based on Q-Learning rewards, does further optimization to node state to save the energy of nodes. The strategy adopted is if two nodes are close than certain distance threshold , then only node whose energy is high can be on and other can sleep. By this way, energy is saved without affecting sensing or routing performance.

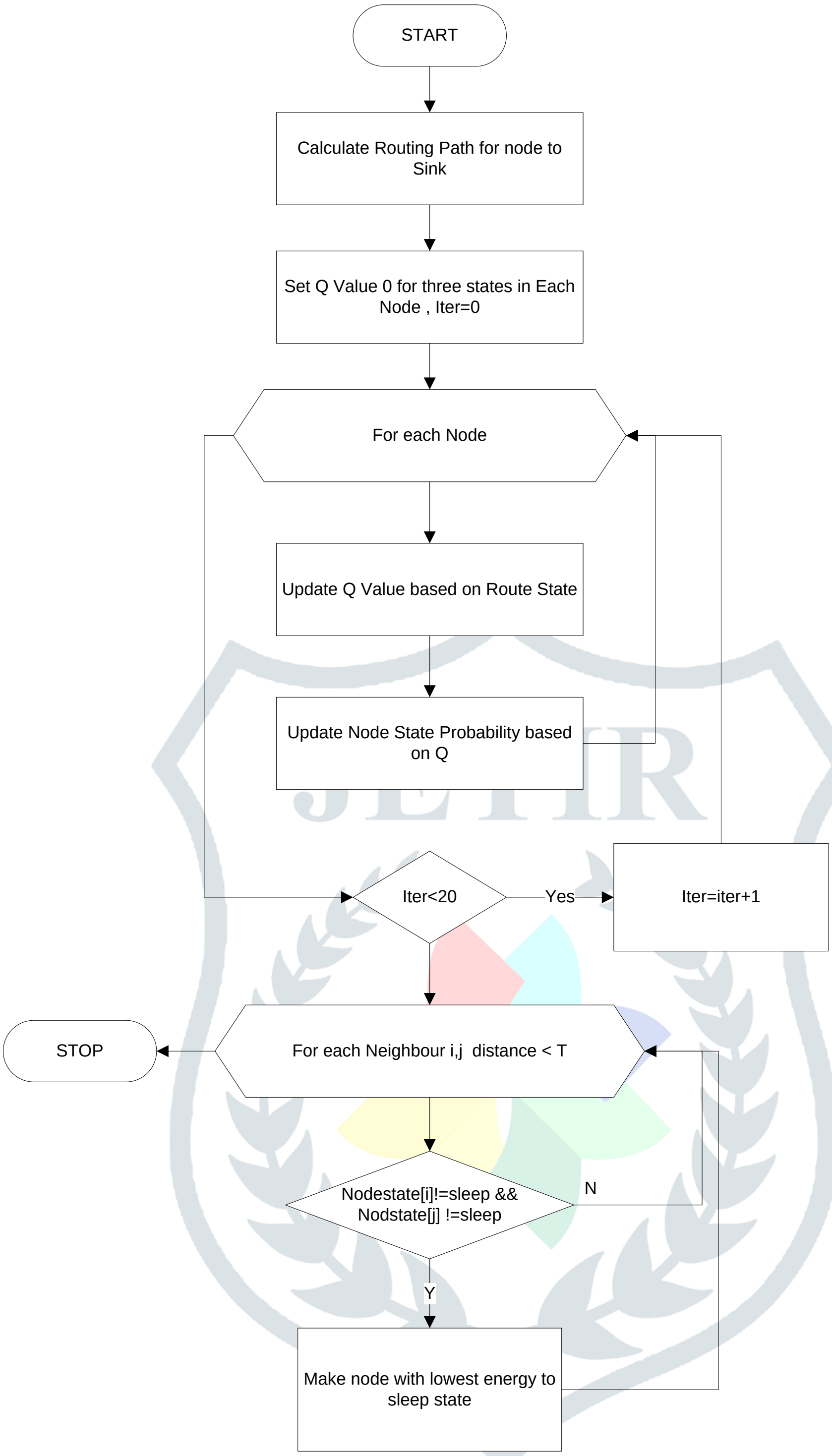
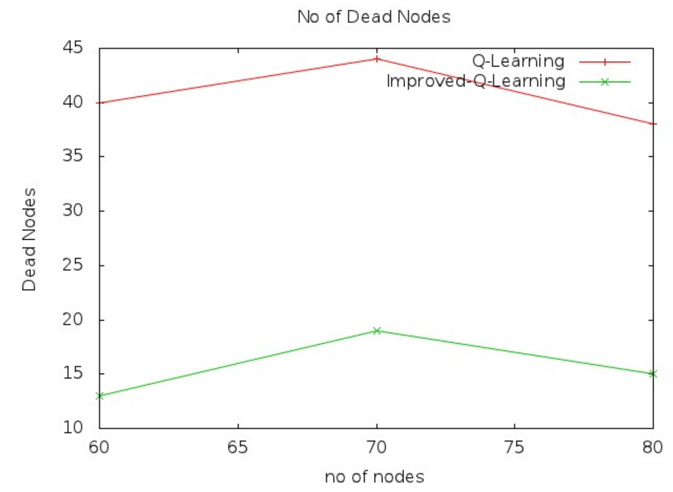


Figure 3.2 flowchart

IV. Experiments And Results

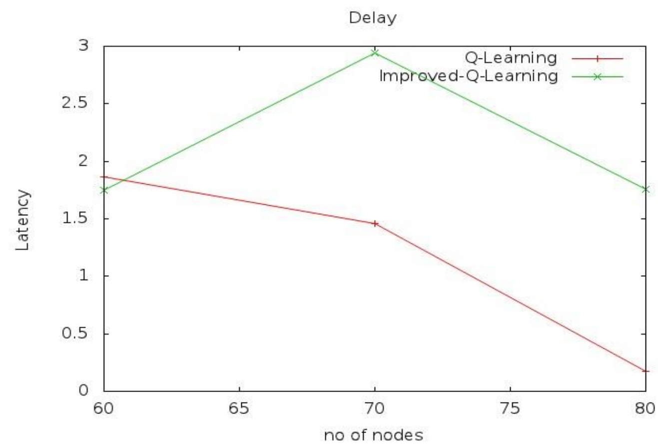
The simulation is operated in random networks. For this type of networks, there are three different scales. This setting is to evaluate the performance of these approaches in different scales. The three scales of random networks are 60 nodes, 70 nodes, and 80 nodes which are randomly located in a 1000×1000 m area. In the three random networks, there are sinks which are also randomly located in the area. The communication radius of each node is set to 200 m.

Performance is measured by four metrics: 1) average packet delivery latency; 2) packet delivery ratio; and 3) average energy consumption 4) no of dead nodes. The minimum time needed by nodes to transmit or receive a packet is about 2 ms.

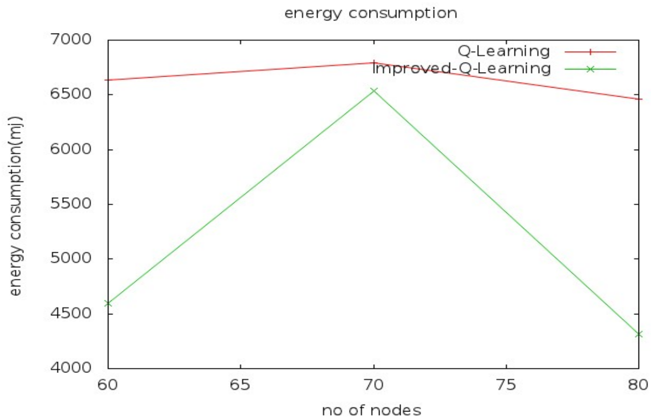


The number of dead nodes is less in the improved Q-Learning when compared to Q-Learning due to node state post processing added.

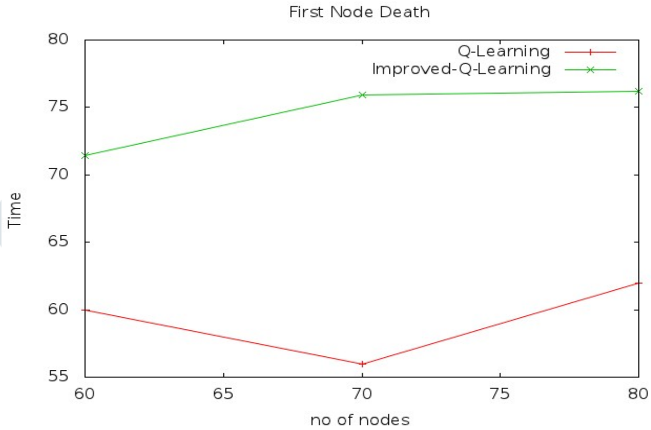
The average delivery ratio is better in the improved Q-Learning when compared to Q-Learning due to node state post processing added.



The delay is little high in enhanced solution due to time taken for node state post processing.



The energy consumption is less in the proposed solution compared to existing solution.



The Life time measured as first node death is high in the improved Q-Learning when compared to Q-Learning due to node state post processing added.

V. Conclusion And Future Work

This work implemented scheduling and routing 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. Through these techniques, the performance of the proposed approach outperforms other related approaches. As an enhancement, energy consideration is made in deciding the node state when two nodes are located very close. By this approach, life time of the network can be increased without affecting the routing and latency performance. Simulation results proved that due to this enhancement, the life time network is increased in the scheduling and routing approach.

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