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SURVEY ARTICLE

Survey of Geographical Packet Forwarding In Wireless Sensor Networks Using Sleep Wake Pattern

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Abstract: In wireless sensor networks nodes follows sleep- wake cycling policy. If a node wants to forward the packet to another node, it has to select a node from available nodes. Each relay is associated with a reward that gives the benefit of forwarding the packet using that relay. We have to develop a solution to this local problem, if that solution is adopted by every node, it should provide a reasonable heuristic for the end-to-end forwarding problem. Relay selection problem comprises a forwarding node has to select relays which follows asynchronous sleep wake cycling policy. At each relay wake-up instant the forwarder can choose to probe a relay to learn its reward value, based on this it can forward the packet or it can wait for other relays to wake up. The source objective is to select a relay so as to minimize a combination of waiting-delay, reward and probing cost. We formulate this relay selection problem as a Partially Observable Markov Decision Process (POMDP) and obtain some interesting structural results on the optimal policy. We also conduct simulation experiments and gain valuable insights into the performance of our local forwarding-solution. We can formulate this next problem as a Markov decision process (MDP). The exact optimal solution Best Forward can be found, but is not a better solution. Next we consider Simple Forward policy; Simulations show that SF performance is very close to the performance of BF, even for reasonably small node density. We then consider the end-to-end performance of SF in comparison with two external policies: Max Forward (MF) and First Forward (FF), and an end-to-end delay minimizing policy proposed by Kim et al (distributed bellman ford algorithm).

Keywords: Relay, POMDP, Wireless sensor networks, Sleep-wake pattern, Packet, Base station, Source, Destination

1. Introduction

Wireless sensor network used for the detection of a rare events like forest fire, suspect ion activities in border areas, etc. To conserve energy, the nodes in the network sleep-wake cycle whereby they alternate between an ON state and a low power OFF state. Nodes wake up or sleep patterns are independent of each other. In such networks, whenever an event is detected, an alarm packet is generated and has to be forwarded, through multiple hops, to base station where appropriate action could be taken. Since the network is sleep-wake cycling, a forwarding node (i.e., a node with an alarm packet) has to wait for its neighbors to wake-up before it can choose a neighbor for the next hop. Thus, there is a delay incurred, due to the sleep-wake process, at each hop enroute to the sink. The main aim is minimizing the total average end-to-end delay based on hop count, time towards destination etc. Such a global problem can be considered as a stochastic shortest path problem for which a distributed Bellman-Ford algorithm can be used to obtain the optimal solution. A major drawback with such an approach is that a pre-configuration phase is required for such algorithms, which will involve exchange of several control messages. The focus of our research is, instead, towards designing simple forwarding rules using only the local information available at a forwarding node. We can avoid this problem by proposing a local forwarding where we minimize one-hop delay subject to a constraint on the reward offered by the chosen relay, where the reward associated with a relay is a function of the transmission power and the progress, towards sink, made by the packet when forwarded to that relay. Finally simulation results are compared with previous procedure results (distributed Bellman-Ford algorithm). An important application of wireless sensor networks (WSN) is detecting certain infrequently happening events, such as failures in a large systems, or intrusion in a secure region. Such an event can occur anywhere in large wireless sensor networks, once any event is detected, the alarm needs to be rapidly sent to the base station for further action. In such wireless sensor networks, typically the nodes rely on batteries. In order to conserve energy, the nodes operates in sleep-wake cycling when a node wakes up it performs sensing, and also involves in forwarding any alarm packets towards the sink. In this work, we consider the situation in which the sleep-wake cycles of nodes are *not synchronized.* In such condition, stateful routing is not possible. Instead, if the nodes know their own locations and that of the base station, then it is possible to dynamically select forwarding nodes that are nearer to the base station. This is called *geographical routing*, and it is most widely used approach in wireless sensor networks. For the purpose of location determination, low cost GPS devices are now becoming available, and can be used in the nodes. The approximate localization algorithms based on various geometrical principles can also be used. In this work we assume that nodes know their exact locations and also the location of the sink. In geographical forwarding, there arises the problem of optimal relay node selection. One such approach *greedy forwarding*, in this an intermediate node forwards the packet to its neighbor node that makes highest progress towards the base station. This scheme is referred to as Most Forward within Radius (MFR). If the node density is large such that every node has a neighbor that is closer to the sink than itself, then the greedy approach can find routes close to the less hop paths. Following a minimum hop path is useful since it reduces the number of times the network needs to transmit the packet.

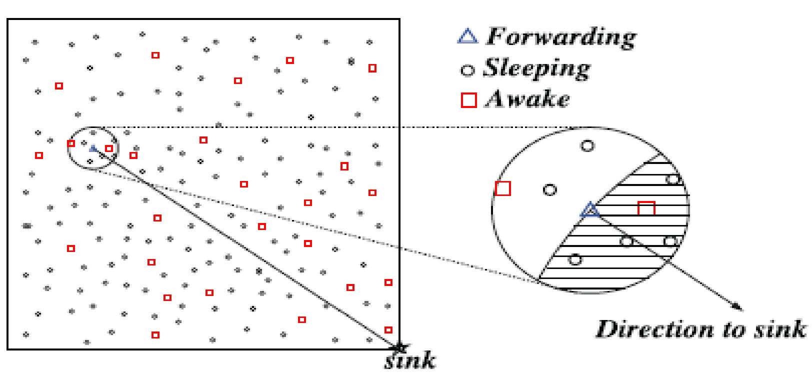

Figure 1. Selecting relay for packet forwarding

2. Back Ground

In Geographical routing each node is aware of its own location, relays location and distance towards the base station through that relay. The nature of geographic routing reduces the overhead brought by route establishment and maintenance, signifying the advantages of modest memory requirement at each node and highly scalability in large network applications. In the conventional routing schemes, each node is required to maintain position information of all its neighbors and the position of a node is made available to its direct neighbors by broadcasting beacons. In wireless sensor networks with invariant network topology, maintaining neighborhood information can greatly improve the performance, because of the reusability of the maintained information and minimal maintenance cost. However, in highly dynamic scenarios, network topology may change frequently due to node mobility, sleeping, link faults etc. In dynamic nature, maintaining neighbor information suffers from three factors. First, communication overhead caused by periodic beacons. Second, the collected information can get outdated soon, which, in turn leads to packet loss. Third, the maintenance of neighbor information consumes the scarce memory. To overcome the drawbacks of conventional geographic routing schemes in scenarios with dynamic topology, beaconless geographic routing protocols have been proposed. Beaconless routing schemes forward packets without the maintenance of neighbor information. When a node has a packet to forward, it broadcasts the packet to its neighbors. Whichever the node in wake up state it receives the packet and forwards that packet another node that is in wake up state. This process will continue until the packet reaches the destination. Because of this sleep wake pattern nodes the energy will be saved. Wireless sensor network has been considered as one of the most important technology. Tiny, cheap, and smart sensors are deployed in a physical area and networked through wireless links to perform some operation, like environmental monitoring, battlefield surveillance and industry process control. In a wireless sensor network sensor nodes are deployed in a required area, due to short transmission ranges large numbers of nodes are deployed, these nodes are equipped with sensors, microprocessor and radio transceiver. These nodes not only has sensing capability but also has data processing and communication capability, these nodes will collect the data and route the data to sink. In wireless sensor network, sensor nodes has dual functionality ie data originator and data router. There are some issues that have to be considered in a WSN, Sensor nodes are powered by battery and in most situations it is very difficult to change or recharge the batteries so power conservation is important in wireless sensor networks. Sensor nodes have limited processing and storage capacities and therefore nodes performed with limited computation functionalities. Routing play an important role in power conservation, the main task of wireless sensor nodes is to sense and collect data from a target domain, process the data, and transmit the information back to required area where the underlying application resides. To achieve this task, it is required to develop an energy-efficient routing protocol to set up paths between sensor nodes and the sink. For this purpose mainly used forwarding technique is Geographical routing. Geographical routing also called as location based or position based routing. In this there are two conditions, first, it is assumed that every node know its own and its neighbor location. Second, the source node knows the destination position where the message has to deliver. This has an advantage that topology can be changes independently and whenever node want to transmit the data it simply addresses the message with the position of destination.

3. Related Work

Analysis of Problem

In this work, we consider asynchronous sleep-wake cycling, where the sleep wake cycling process of each node is statistically independent of the sleep-wake process of any other node in the network. Due to the asynchronous sleep-wake cycling behavior of the nodes, an alarm packet has to wait a random delay at each hop that is rerouted to the sink. The final performance metrics we are interested in are the average total delay and an average total cost. To optimize the performance metrics one could use a distributed Bellman-Ford algorithm proposed by Kim et al. However such efficient solution requires a pre-configuration phase during which a globally optimal forwarding policy is used, and involves packets exchange. The focus of our work is designing simple forwarding rules based only on the local information available at a forwarding node. Toward this end the approach of geographical forwarding will be useful. In geographical forwarding nodes know their own locations and location of the sink, and forward packets to neighbors that are closer to base station.

Proposed Work and Objectives

In the current work, we have generalized our earlier model by allowing the number of relays to be not known to the source. Also, here we use a general reward structure. There has been other work in the context of geographical forwarding and anycast routing, where the problem of choosing one among several neighboring nodes arises. We applied a distributed relaying algorithm called Geographical Random Forwarding (GeRaF) whose objective is to carry a packet to its destination in as few hops as possible, by making maximum progress as possible at each relaying stage. The Random Asynchronous Wakeup (RAW) protocol also considers transmitting to the first node to wake-up that makes a progress of greater than a threshold. With the number of relays being unknown, we formulate the problem as a partially observed Markov decision process (POMDP). A POMDP is a generalization of an MDP, where at each stage the actual internal state of the system is not available to the controller. The controller can observe a value from an observation space. The observation results depend on the current actual state and the previous action. In some cases, a POMDP can be converted to an equivalent MDP by regarding a belief on the state space as the state of the equivalent MDP. First Forward (FF), it forward to the first node that wakes up within the forwarding region irrespective Of the progress it makes toward the sink. Max Forward (MF), wait for the entire duration T and then choose a neighbor with the maximum progress. The Random Asynchronous Wakeup (RAW) protocol also considers transmitting to the first node to wake up that makes a progress greater than a threshold. This is also the structure of the optimal policy provided by one of our Markov decision process formulations. In Simple Forward (SF), once the node receives the beacon signal it replies with its location information. Based on that replied information source decides whether to forward the packet or not. Wireless sensor network, in which the traffic model and sleep-wake cycling are used. An occasional alarm packet needs to be to the sink, whenever something happens in the network. The nodes follows asynchronous sleep wake cycling policy. The need to use an optimal anycast scheme to minimize average end-to-end delay from any node to the sink. In anycasting, where each sensor node forwards the packet to the first node that wakes up among a set of candidate next-hop nodes.

4. Conclusion

The work is motivated by the problem of geographical forwarding of packets in a wireless sensor networks whose function is to detect certain infrequent events and forward these alarms to a base station, where nodes are sleep-wake cycling to conserve energy. This end-to-end problem motivated the local problem faced by a packet forwarding node, i.e., that of choosing one among a set of available relays. For this relay selection reward metric is taken into consideration. Further the source does not know the number of available relays. We formulated the problem as a finite horizon POMDP and characterized the optimal policy in terms of optimum stopping sets. We proved inner and outer bounds for this set. We also obtained a simple threshold rule by formulating an alternate simplified model. We performed one-hop simulations and observed the good performance of the simple policy. Finally, we applied the simple policy to route an alarm packet in a large network and observed that its performance, over some range of target hop count. That is comparable to with distributed Bellman- Ford algorithm proposed. The problem of optimal relay selection for geographical forwarding was formulated as one of minimizing the forwarding delay subject to a constraint on progress. The simple policy (SF) of transmitting to the first node that wakes up and makes a progress of more than a threshold was found to be close in performance to the optimal policy. We then compared the end-to-end of using Simple Forward at each relay node enroute to the sink with that of the policy proposed by Kim et al(distributed bell man Ford algorithm), which is designed to achieve minimum average end-to-end delay. Simple Forward policy does require any pre-configuration phase like Distributed Bellman Ford algorithm. Simple Forward policy follows self-configuring, where each node takes decisions based only on local information. The end-to-end performance obtained can be observed by the use of a single parameter. For small distance there will be less delay and for large distance it takes more time. In this work we have assumed that each node knows the number of neighbors in its forwarding set. We had given a heuristic policy (Simple Forward) when the actual number of forwarding neighbors is not known. In future work we aim to optimal forwarding policies by using this assumption. The use of a one-hop optimal policy for end-to-end forwarding is a heuristic. In future work we propose to directly formulate the end-to-end problem.

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