Balanced Load Sharing Protocol for Wireless Sensor Networks

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ABSTRACT

An important factor that controls energy consumption to good extents in Wireless Sensor Networks (WSNs) is the routing protocol used to relay messages between the deployed sensor nodes. The way in which data is routed in the network has a significant effect on the energy consumption, and consequently, on the life-time of the network. In this paper we propose the Balanced Load Sharing Protocol (BLSP), a new routing protocol that optimizes and controls the consumption of the energy to extend the life time of all nodes in Wireless Sensor Networks.

Keywords:
WSNs, Power consumption, Routing

INTRODUCTION 1.0

Wireless Sensor Networks (WSNs) are becoming increasingly popular in civil, environmental and military applications. The network consists of a distributed set of sensor nodes. Nodes sense, compute, and communicate with each other cooperatively. These sensor nodes typically are battery-operated. They carry limited and non-replaceable batteries. Power consumption is one of the most important constraints on WSNs utilization. While traditional networks aim at achieving high quality of service or high bandwidth, WSNs must focus on power saving to achieve a prolonging network lifetime. This is accomplished usually at the cost of lower throughput or higher transmission delay(Akyildiz, Cayirci, Sankarasubramaniam, & Su,2002).

Extending the life of a wireless system has been looked at mostly from a hardware point of view, such as directional antennas and improving battery life (Royer & Toh, 1999) Power-aware routing is a fairly new concept in Wireless Networking. Great amount of power is consumed by the communication between the deployed sensor nodes. Therefore, the way in which data is routed in the network has an effect on the energy consumption, and consequently, on the life-time of the network.

Most routing protocols implemented in WSNs have focused mainly on establishing routes, and maintaining these routes under frequent and unpredictable changes in the network topology. Using routing to minimize power consumption has been found to be reasonably successful. Routing packets in a power-aware method will complement hardware-based methods for extending the network's life time (Akkaya & Younis, 2005).

The metrics that have so far been devised to minimize power consumption can be grouped into two main categories: *power-aware* and *cost-aware* metrics. Power-aware metrics aim at minimizing the total power needed to route a message between two different locations while cost-aware metrics look at extending the nodes' battery lifetime(Akkaya et al. 2005).

The algorithms that have been proposed thus far are *centralized* and *decentralized* distributed algorithms. Centralized algorithms have the advantage of maintaining global information about the network, leading to always getting an optimum path for routing. However, due to the limited power, the large number of nodes in a sensor network, and the change of power available at the nodes, this is not an efficient way (Toh, C.-K, 2002) Because of the high cost of communication compared to the computation cost and the low battery power, decentralized-distributed algorithms are more appropirate for WSNs. Execution of millions of instructions consumes approximately the same energy needed to transmit one average size packet (Akyildiz et al. ,2002). Instead of relaying data to a central location that does all the computations, each node processes information internally. The internal computation of routes is based on local information that is available to the node from its neighbors only. This way there is no messages need to be sent in the network to discover routes or to make a decision for routing except for the ACK at the beginning of transmission, which will be expalined later .

In this paper we propose the Balanced Load Sharing Protocol (BLSP), a new routing protocol. BLSP uses a decentralized alogirthem. It depends on no golobal information of the network. BLSP uses a cost-aware matric while trying to minimize the total power needed to route a message. It compromises both the power-aware and cost-aware matircs. BLSP is based on the following observations of the behaviour of the shortest path protocol:

- Middle nodes die first due to their frequent message relaying.
- Boundary nodes die last due to their infrequent message relaying.
- Boundary nodes with sufficient energy are not doing much good to the network communication due to their locations.
- Packet dropping increases noticibly after a significant number of the middle nodes die.

Integrating boundary nodes in the transmission process more often will reduce the load on the middle nodes. In other words, BLSP works on balancing the load of power consumption among all nodes in the network. By using the boundary nodes to relay messages more often, the middle nodes will live longer.

Simulation Model 3.0

The Simulation is done on an x-y grid. There are 900 nodes, 30 nodes on the x-axix and 30 nodes on the y-axix. Each node will have a fixed position with an address of (x,y) coordinates. Each node has 8 neighbours. Transmision range covers only the 8 neighbours. In other words, any transmsion from any nodes can reach and be sensed by only the 8 neighbours. Nodes setting is shown in figure 1. The direction of the transmission between the Source and Destination will be as direct as possible with minimim number of hops. If the most direct neighbour is not avialable for transmision for any reason, the next most direct neighbour is chosen, and so on.

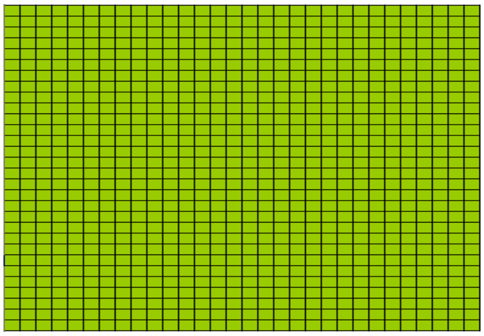

Figure 1: Nodes positions, each node has 8 neighours

A node can only transmit and receive from its neighbours on the grid. All nodes transmit at random, random S and random D. Since computation is significantly less costy than communication, BLSP minimizes communication and maximizes computation to save power. Each node will compute the most direct next hop to the destination. Later, our simulation results will be compared to the shortest path potocol results. The simulation is implemented in Java using NetBean6.

BLSP is a new routing algorithm for WSNs that aims at reducing the amount of energy consumed due to transmission by dividing the energy consumption among as many nodes as possible, on the cost of a reasonably longer delay. There will be two simulations. The first simulation is using the shortest path protocol with minimum number of hops. The second simulation is BLSP. The simulations' results are analysed in terms of the energy consumption of the middle and boundary nodes, and the average power of .the overall network

BLSP 3.0

Each node takes an off-duty time which is an amount of time that is inversely proportional to the its remaining amount of energy. The off-duty time changes as the energy of a node changes. Particularly, the off-duty time increases as the power decreases. The off-duty time is chosen in a way that a node does not stay off duty for too long. In other words, a node should not be considered a live when it is effectively dead. This point will be clear later.

Neighbors do not share any data. The sending node will wait for an ACK for its first packet from the destination node before it starts the transmission. The ACK is only sent at the start of the transmision, and not for every packet. If it does not receive it, it assumes that the other node is off-duty or dead. Then another node is chosen for the relay in the most direct direction to the destination. The sending node keeps track of the number of times a transmission fails for a neighbour. If a number of *n* transmissions fail for a certain neighbour, then it is assumed to be dead, and no more .atempts will be made

The BLSP algorithm is shown in figure 2. The idea simply is whenever there is a transmission or a phenomenon sensed by a node, it checks if it is off duty. If it is off duty, it ignores the signal and goes back to sleep. If it is not off duty, it means it should handle the transmision relay or process any sensed phenomenon as it is required. Then the node reads the remaining energy value and sets the off-:duty flag to true, and stay off duty for

$$(K* 1/RemaingEnergy \qquad (1$$

which is the new time value for the node to take a break or stay off duty once more. Once the off duty time expires, the node sets its off-duty flag to false and becomes ready to process any sensed phenomenon or respond to a required transmission relay. A node does not take the next off-duty time untill it performs an operation that allows it to execute the off duty part of the code. K is a scaling factor to adjust to the most suitable off duty time. As the middle nodes become off duty, transmissions are directed to the next most direct nodes. Eventually they will reach boundary nodes, which have shorter off duty time and ready for participation in the relaying operation. This way boundary .nodes become invloved in the relay more often

```
OffDuty:=false


}(While(true
Sense tranmission
 (If(OffDuty:=false
  }
Open packet and process the associated  operation
Read RemaingEnergy
OffDuty:=true
                    (TakeBreak(K* 1/RemaingEnergy
 OffDuty:= false
{
{
```

Figue2: BLSP Algorithm

RESULTS 4.0

The simulations are done on sensors with maximum energy of 2500 mW. During the simulations, the remaining energy of all nodes was evaluated. For the shortest path :protocol (minimum number of hops), the results are

Average energy of all nodes: 694mW
Average energy of boundary nodes: 786 mW
Average energy of middle nodes: 606 mW

The closest 5 nodes to each of the four sides of the network in figure 1 are considered boundary nodes. The middle 20X20 nodes are the middle nodes. For BLSP, the results :found for the remaining energy are

Average energy of all nodes: 910mW
Average energy of boundary nodes: 809 mW
Average energy of middle nodes: 1092 mW

If the average energy of all nodes is considered to be 100%, then for the shortest path, the relative energy percentages of :the boundary and middle nodes are

Boundary Nodes: 114%
Middle Nodes: 87%

:For BLSP, the relative percentages are

Boundary Nodes: 88%
Middle Nodes: 120%

These are the values of one simulation for the two protocols. The simulations were run many times and similar relative values were obtained for all runs. From the shortest path simulation results, boundary nodes always hold more energy than the average ones, and significantly more than the middle nodes. This prove the initial assumption that boundary nodes participate less than middle nodes in relaying messages, and therfore, they often have higher .energy

From BLSP simulation results, BLSP actually reverses the action of the nodes of the shortest path. BLSP shows that middle nodes hold more energy than the average ones, and significantly more energy than the boundary nodes. This might not be the state in which we always want the network to be in. However, this shows that BLSP enables us to balance the energy load sharing, and most importantly, BLSP enables us to control the energy consumption among a large set of nodes. Furthermore, the average energy of all .nodes is significantly higher than that of the shortest path

Note that for controling of the behaviour of the nodes and consequently the energy consumption, the scalling factor K, see formula 1, can be used to adjust the amount of off-duty time. Different values of K give different results. A small value of K would not make a significant change on the behaviour of the nodes, and they would behave very much like those of the shortest path. Moreover, a very large value of K would not be very useful since it eventually makes the off-duty time huge, where the nodes would behave as if they are dead, but they are actually not. Therefore, . manipulating the K value is necessary

Graphical analysis of the above simulations results is shown in figure 3. In this analysis, the average power of all nodes is considered as the reference point. Nodes that have 10% or more power above that of the average power of all nodes are coloured grean. Where nodes that have 10% or more power less than that of the average power of all nodes are coloured red. Other nodes (nodes that are 10% or less higher or lower than the average power of all nodes) are coloured black. This analysis is done for both the BLSP .and shortest path simulations

Figure 3a shows the remaining power in the network during the simulation of the shortest path protocol. It can be seen clearly that the vast majority of the middle nodes are more than 10% below the average, along with some nodes containing average power scattered in the middle. On the other hand, boundary nodes enjoy plenty of power, which is .10% or more above the average power

Figure 3b shows the remaining power in the network during the simulation of BLSP. It can be seen clearly that the middle nodes enjoy 10% or more higher power than that of the average nodes. Furthermore, most of the middle nodes have 20% or more higher power than that of boundary nodes. The graph shows clearly the boundary line between middle nodes and boundary nodes. As mentioned above, the middle nodes are the 20X20 middle rectangle. The boundary nodes have less power than the .average and middle nodes

CONCLUSION

The simulation results shows that BLSP optimizes the use of the energy of all nodes in large network. BLSP can balance energy among nodes. Furthermore, it can control the behaviour of the nodes and the distribution of energy. Eventually BLSP improves the average power amoung all .nodes, which leads to a longer life time of the network

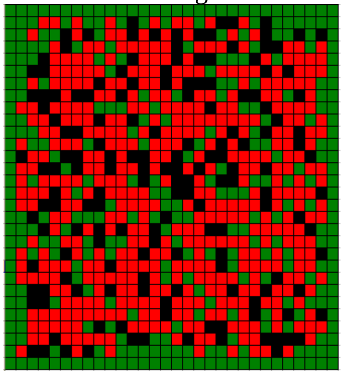

Figure 3a: Analysis of the shortest path simulation results

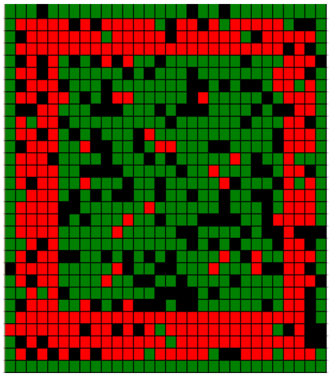

Figure 3b: Analysis of BLSP results

Figure 3: Graphical analysis of the results of shortest path and BLSP simulations

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