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Adaptive Coalition Based Power Aware Routing In Wireless Networks

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Abstract

A group is a set of nodes in sensor networks having a purpose in common. Once the groups of sensor networks have been identified, they form coalition to minimize power consumption to route the packets. Different agencies can deploy their sensors in the same area and use coalition to minimize power consumption within each group. In such situations, resources consumed by a group are more important than those consumed by individual nodes and distributed computation can be performed even when some members in a group fail. Initially the coalition based routing is achieved by forwarding the packets to the nodes with minimum distance towards the destination. Our algorithm selects the shortest path from the source to the destination, group wise. Then, it selects the shortest path excluding the nodes in that particular group whose average power consumption more in previous shortest path calculations. Our approach aims to design an Adaptive Coalition based Power Aware Routing algorithm to maximize network life time and this can be achieved by forwarding the network traffic in different paths by means of selecting different nodes instead of selecting some particular nodes so that the variance of power level of nodes in different groups are minimized. It also consumes minimum power as well as increases the network life time by excluding overused nodes in different groups.

Keywords: Adaptive Coalition based Power Aware Routing, Variance

Introduction

The issue of energy management is addressed in wireless as well as wire-line networks by creating an effective routing (called power- aware routing) that would minimize the power consumption using the schemes such as finding the minimum distance to reach the destination, removing isolated clusters and making coalition among groups. Communication-related operations are a major source of energy consumption in mobile nodes. In particular, consumption is significantly high when there is no wired medium to route packets from source to destination. Many power-aware routing schemes have been developed for wireless networks assuming that the nodes are willing to sacrifice their power reserves in the interest of the network as a whole. In many real time applications, nodes are organized in groups (for example, the nodes belonging to one organization) and as a result, a node is willing to sacrifice in the interest of other nodes in its group but not necessarily for nodes outside its group. If different organizations deploy their sensors in the same area then they can make coalition (route each other's packets) and they can save the energy while routing packets.

The problem of power conservation demands a special attention in wireless sensor network owing to their limited battery power. The nodes in a wireless sensor network lose their residual energy increasingly due to complex computing and communication functionalities. This is significant since they operate at low power levels and limited bandwidth. Researchers have devised schemes to improve hardware to address these needs and much is needed to be done to develop software that uses technique like power-optimizing algorithms. Sharing of resources is one significant step in eliminating power and bandwidth limitation.

Despite the benefits associated with resource sharing, a variety of challenges impede the progress. They are:

- Criteria to determine the sharing of resources,
- Time of sharing resources,
- With whom to share resources.

Resource Sharing in Sensor Networks

Groups of nodes rather than individual nodes are basic entities in the sharing mechanism. Groups are said to form coalitions when they route each other's packets. The benefit incurred by a group due to the coalition operation is the decrease in its power consumption after it joins the coalition. The coalition routing algorithms provide foundations for developing operational protocols.

Coalitions for Power Aware Routing

A group is a set of nodes having a purpose in common where each group is capable of sharing resources among other groups. The critical resource that is under consideration is power. Nodes in wireless networks are powered by battery, and size limitations compel the usage of small and low lifetime batteries. Normally, communication consumes significantly higher power than other operations. Nodes share power by routing each other's packets, and it is well-known that multi hop routing substantially decreases the overall power. The research challenges that arise when nodes decide to route each other's packets with the sole objective of reducing the power consumption of their groups and reducing the variance that mainly arises due to overuse of some particular nodes addressed here.

Related Work

The Research carried out by K. Das & M. Panda [1] is aimed at explaining the load balancing approach which select different paths to take forward the traffic to the destination, as a result of which, the network life time increased. V Kawadia et al. [2] proposed a transmit power control model which affects the physical layer , network layer and transport layer. The research carried out by Yanru Bao [3] explains about the power-aware routing algorithms for wireless ad hoc networks. The research carried out by Radhika Joshi & Priti Rege [4] has explained about the on-demand power aware routing algorithm and proposed DEEAR (Distributed Energy Efficient AODV Routing) protocol.The research carried out by Tomas Johansson and Lenka Carr-Motyckova [5] has explained about the power-aware routing in Bluetooth networks. Ratul K. Guha et al. [6] proposed Fair Coalitions for Power-Aware Routing in Wireless Networks where groups involves in coalition get equal benefits. Sun-Ho Lee et al. [7] proposed Timer-Based Broadcasting for Power-Aware Routing in Power-Controlled Wireless Ad Hoc Networks; this technique used both power aware routing algorithms and MAC layer algorithms for better performance. The research carried out by G. Varaprasad [8] have explained about the Mobile Ad hoc Network (MANET), which minimizes number of control message packets, energy consumption and as a result throughput gets increased.

Mathematical Power Model

Power Model

Power consumption of a node Pc is in the form of $Pc = K1+K*r*d^{\alpha}$.Where, $K=1\mu Watt/M\ bit*m^4$ and K1=0 W/Sec, so the power consumption is of the form $Pc =0 + r\ d^{\alpha}$ where α is a constant and the value of α depends on environment, $2 \leq \alpha \leq 6$ and r is the rate of transmission[9][10][11].

Network Model

Our network G^{AB} (V, E) consists of vertices V and edges E for group A and B .To forward the traffic from source to destination, all nodes in a group must obey the flow balanced condition; which is the sum of rate of incoming traffic and rate of originating traffic, equal to rate of outgoing traffic [6].

In our approach we have considered that every node has a limited range to transmit data, beyond which error free transition is not possible. Using shortest path routing, a source node can find the next node to the destination and forward the traffic to the next node. Every node forwards the traffic to its nearby node to the destination. In our simulation we have chosen the value of α=4, so the power consumption is of the form: $Pc= r\ d^4$.

The experimental environment is similar to that employed in Ratul et al. [6].There is one destination to which all nodes forward the traffic. Each node generates 1 Mbps of traffic. Forwarding the traffic to its nearby node towards the destination (minimum coalition). Initially a simple network model with 25 nodes uniformly distributed in a square of side 4 meter is considered. There are two groups namely Group A and Group B. Group A contains nodes {1,4,6,8,10,11,12,15,16,18,21,24} and Group B contains rest of the nodes. Only Group A nodes are distributed in Fig. 1 and routing is carried out using these nodes (Without coalition routing).

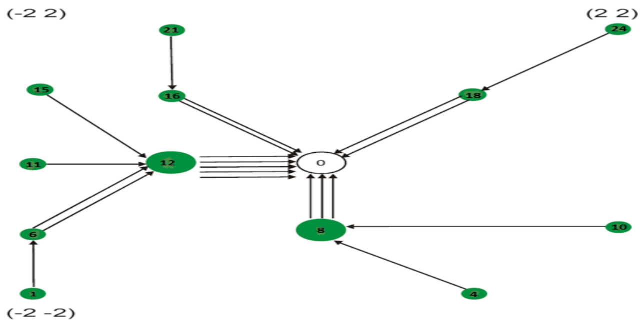

Figure 1: Group A nodes without coalition

`Using only Group A nodes the power spent by node 1 can be computed by the equation K1+K r d^{α} ; Substituting the values for the parameters (as given in the beginning of this section) = 0 + (1µW/Mbit*m^4) *(1 Mbps) * ($1^4 m^4$) =1µ W/Sec (for node 1 using shortest path routing algorithm the next node to the destination is node 6, so d = 1 and rate of outgoing traffic = 1Mbps because there is no incoming traffic and originating traffic=1Mbps). Similarly the power consumption of other nodes is given in Table 1.

Table 1: Power consumption of Group A nodes without coalition

Node No.	Power spent	Node No.	Power spent	Node No.	Power spent
1	1 µ W/Sec	10	16 µ W	16	8 µ W/Sec
4	4 µ W/Sec	11	1 µ W/Sec	18	8 µ W/Sec
6	8µ W/Sec	12	5 µ W/Sec	21	1 µ W/Sec
8	3µ W/Sec	15	4 µ W/Sec	24	4 µ W/Sec

The Group A optimal power expenditure for all nodes is P^a_{opt} =63µ W/Sec.

Only group B nodes are distributed in Fig. 2 and routing is carried out using these nodes (without coalition routing).

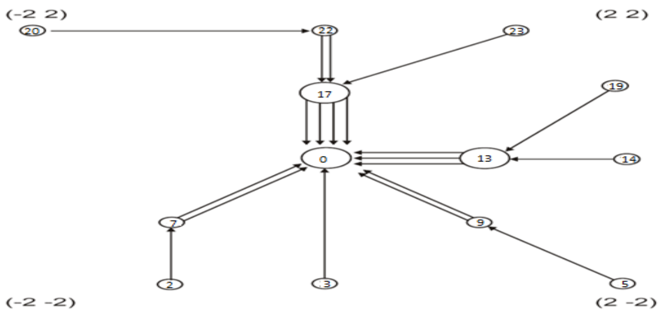

Figure 2: Group B nodes without coalition routing

Using only Group B nodes the power spent by node 1 $=1*10^6$W/Mbit*m^4* $(1)^4$ m^4* 1 Mbps=1µ W/Sec (for node 2 using shortest path routing algorithm next node to the destination is node 7, so d = 1 and rate of outgoing traffic = 1 Mbps because there is no incoming traffic and originating traffic=1Mbps). Similarly the power consumption of others nodes are given in Table 2.

Table 2: Power consumption of Group B nodes without coalition.

Node No.	Power spent	Node No.	Power spent	Node No.	Power spent
2	1 µ W/Sec	9	8 µ W/Sec	19	4 µ W/Sec
3	16 µ W	13	3 µ W/Sec	20	16 µ W/Sec
5	4µ W/Sec	14	1 µ W/Sec	22	2 µ W/Sec
7	8µ W/Sec	17	4 µ W/Sec	23	4 µ W/Sec

In Group B optimal power expenditure for all nodes is P^b_{opt} =71µ W/Sec.

Both group A and B nodes are distributed in Fig. 3 and routing is carried out using these nodes (with coalition routing).

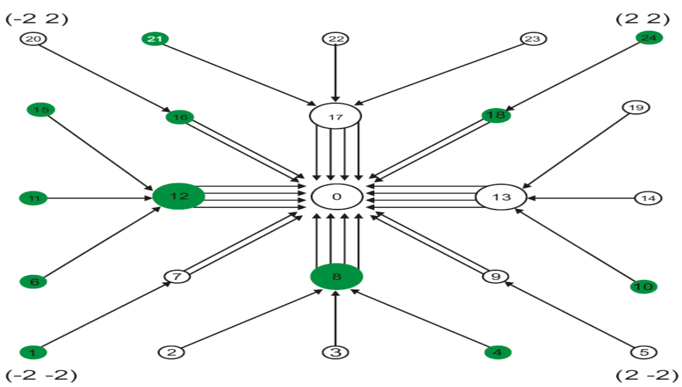

Figure 3: Coalition routing of two Groups A and B.

For the 1^{st} node the power consumption = 0+1μW/ Mbit*m^4* 1 Mbps* $(\sqrt{2})^4$ m^4= 4 μ W/Sec (for node 1 rate of outgoing traffic = 1 Mbps because there is no incoming traffic and originating traffic=1Mbps and using shortest path routing algorithm the next node to the destination is node 7, so d= √ 2 m).

Similarly the power consumption of other nodes is given in Table 3.

Table 3: Power consumption of nodes with minimum coalition routing of Group A and B

Node No.	Power Spent	Node No.	Power Spent	Node No.	Power Spent
1	4 μ W/Sec	9	8 μ W/Sec	17	4 μ W/Sec
2	4 μ W/Sec	10	4 μ W/Sec	18	8 μ W/Sec
3	1μ W/Sec	11	1 μ W/Sec	19	4 μ W/Sec
4	4 μ W/Sec	12	4 μ W/Sec	20	4 μ W/Sec
5	4 μ W/Sec	13	4 μ W/Sec	21	4 μ W/Sec
6	4 μ W/Sec	14	1 μ W/Sec	22	1μ W/Sec
7	8μ W/Sec	15	4 μ W/Sec	23	4 μ W/Sec
8	4μ W/Sec	16	8 μ W/Sec	24	4 μ W/Sec

Using coalition routing for Group A total power consumption is J^a_r = 53μ W/Sec. Similarly for Group B total power consumption is J^b_r = 47μ W/Sec.

Benefit of group A = P^a_{opt} - J^a_r= 63 μ W/Sec -53μ W/Sec =10 μ W/Sec, Similarly benefit of group B = P^b_{opt} – J^b_r = 71μ W/Sec -47μ W/Sec =24μ W/Sec.

Minimum coalition routing gives benefit to every group .In Fig. 3 node 7, node 9, node 16 and node 18 have Pc = 8 units, which is more and if Shortest Path Routing runs for a longer period, these nods would dry out, soon. In this situation, using minimum coalition routing, the variance of power consumption for group A nodes is found to be 3.241 and for group B nodes is 4.9461.

Adaptive Coalition based Power Aware Routing Algorithm

For every node in Group A and Group B

1. For G^{AB}(V,E) For all v€V Run Shortest Path Routing to find the next node to Destination And calculate distance d to the next node.
   Calculate P^{AB}_a = the power consumption of each node by $d^\alpha * r$
   Find Max(P^A_a) for Group A nodes
   Find Max(P^B_a) for Group B nodes
2. Run Shortest Path Algorithm on G^{AB} (V-X, E') where X nodes consumes Max (P^A_a) and Max(P^B_a) .
   Calculate P^{AB}_b = the power consumption of each node by $d^\alpha * r$
   Find P^{AB}_x = Averge (P^{AB}_a, P^{AB}_b)
   Find Max(P^A_x) for Group A nodes
   Find Max(P^B_x) for Group B nodes

3. Run Shortest Path Algorithm on G^{AB} (V-X', E") where X' nodes consumes Max
   (P^{A}_{x}) and (P^{B}_{x})
   Calculate P^{AB}_{c} = the power consumption of each Node by $d^{\alpha} * r$
   Find P_y = Averge(P^{AB}_{a}, P^{AB}_{b}, P^{AB}_{c})
   Find Max(P^{A}_{y}) for Group A nodes
   Find Max(P^{B}_{y}) for Group B nodes
4. Run Shortest Path Algorithm on G^{A}(V-X", E"') where X" nodes consumes Max (P^{A}_{y}) and (P^{B}_{y})
   Using an Adaptive Coalition based Power Aware Routing; the flow of network traffic is given in Fig. 4 after removing the node 7, node 9, node 16 and node 18, which are overused in previous shortest path calculation.

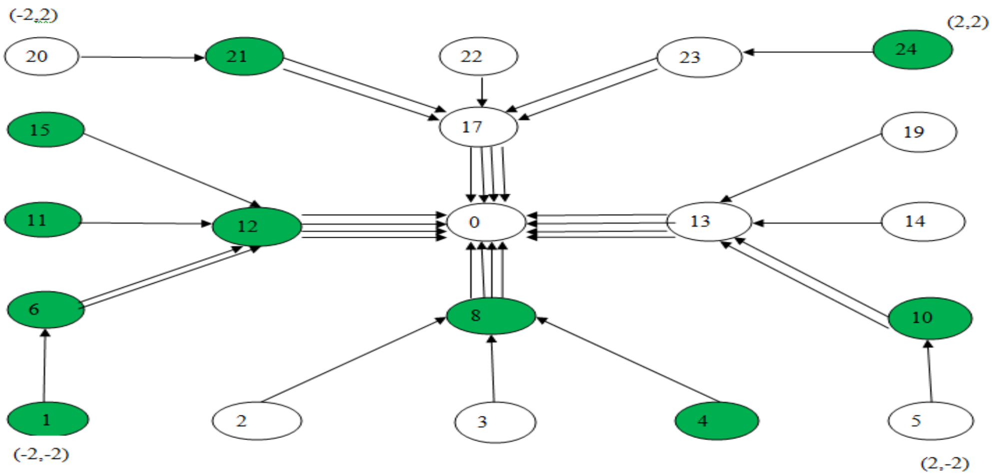

Figure 4: After removing nodes which are overused in previous shortest path calculation.

While running the Shortest Path Routing algorithm for the 2nd time in Adaptive Coalition based Power Aware Routing, the power consumption of all Group A {1,4,6,8,10,11,12,15,16,18,21,24} nodes are 1, 4, 8, 4, 8, 1 , 5 , 4 ,0 ,0 ,8 ,1 and power consumption of all Group B {2,3,5,7,9,13,14,17,19,20,22,23} nodes are 4 ,1 , 1 ,0 ,0 ,5 ,1 ,6 ,4 ,1 ,1 ,8.

After running the Shortest Path Routing for the 1st and 2nd time in Adaptive Coalition based Power Aware Routing, the average power consumption of all Group A {1,4,6,8,10,11,12,15,16,18,21,24} nodes are 2.5 ,4 ,6 ,4 ,6, 1,4.5 ,4 ,4 ,4 ,6 ,2.5 and power consumption of all Group B {2,3,5,7,9,13,14,17,19,20,22,23} nodes are 4, 1, 2.5 ,4 ,4 , 4.5,1 ,5 ,4, 2.5 , 1 , 6.

Using Adaptive Coalition based Power Aware Routing the variance of Power consumption of all nodes in group A is 2.14 and for Group B is 2.56 which is less as compared to minimum coalition power aware routing. As group wise variance is less in Adaptive Coalition based Power Aware Routing when compared with minimum coalition power aware routing, the network life time is more in Adaptive Coalition based Power Aware Routing.

Conclusion and Future Work

Coalition saves power consumption of the groups involved in routing. Initially, group wise forwarding packets to the nodes with minimum distance towards the destination is implemented. But it has been found that in minimum coalition routing, the network traffic is forwarded by only single path from source to destination as result of which only some nodes are overused and hence the network life time is less in all the groups involved.

A new scheme called Adaptive Coalition based Power Aware Routing algorithm is introduced in which variance of power consumption of all nodes is minimized by eliminating the overused nodes. Comparison of performance of the cited schemes via detailed simulations is also carried out and the results shows that the network life time is more in Adaptive Coalition based Power Aware Routing.

The future work can be carried out in the following directions:

- Implementation of security mechanisms while forming coalition.
- Carrying out the simulation for the nodes in the range 50 to 100.

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