Journal of Computer Science 4 (5): 366-371, 2008
ISSN 1549-3636

Power Saving Mechanism in Clustered Ad-Hoc Networks

Arwa Zabian and Ahmed Ibrahim
Department of Computer Information system, Irbid National University Irbid, Jordan
Department of Computer Science, Irbid National University, Irbid, Jordan

Abstract: In wireless Ad-Hoc networks, multihop transmission breaks the single hop path from a mobile node to another, into two or more hops, in a manner that the distances between transmitter and receiver are smaller than that in the direct transmission, which reduces the transmission power significantly. We have proposed the use of graph search algorithms to increase the power remaining at the destination node and to enhance the performance of clustering algorithms in mobile ad-hoc networks. Where we have organized the nodes of a cluster in a tree rooted by the leader in a manner that, instead of making a direct communication between two nodes distant to each other a distance x, we make a communication by multihop with many nodes in the path between the sender and the destination with distance shorter than x. Our simulation results have confirmed the proposed idea, where it was concluded that the power remaining at the destination will increase with the decreasing of the distance. Consecutively, the power consumption was reduced.

Key words: Power management, graph search algorithm, multihop communication, dynamic tree, clustering algorithms, signal strength measurement

INTRODUCTION

Wireless Ad-Hoc network consists of a number of mobile nodes that communicate with each other through multihop wireless links in the absence of fixed infrastructure where each node must work as router in forwarding the packets between any pair of nodes in the network.

When the number of nodes is increased, the size of the routing table to each node is increased. Therefore, clustering algorithms are proposed to address scalability issue.

Clustering algorithms organize the nodes into clusters, where the number of nodes of a cluster is smaller than the number of nodes of the entire network. Certain nodes known as cluster heads are responsible for cluster formation. A cluster head does the resource allocation to all the nodes belonging to its cluster.

Due to mobility, nodes in ad-hoc networks are usually powered by battery with finite capacity. For that, to extend the system life time it is necessary the study of energy management mechanisms.

In wireless ad-hoc networks, the major energy consumption at each node is due to system operation, data processing and wireless transmission and reception.

When two communicating nodes are not in the range of each other in wireless ad hoc networks, they need to rely on multihop transmission and reception. Under such condition packet forwarding or routing becomes necessary. The value of the radio transmission range influences in the network topology and energy consumption considerably. A larger transmission range increases the distance progress of data packets toward their final destinations. This is unfortunately achieved at the expense of higher energy consumption per transmission. On the other hand, a shorter transmission range uses less energy to forward packets to the next hop. Although a larger number of hops is needed for packets to reach their destination[2]. Our goal is to propose a power saving mechanism that reduces the power consumption in sending a packet and distributes the power consumed for the communication between the node of the network. So, we have studied the variation of the power consumption in sending packets with the variation of the distance between two nodes in a clustered ad-hoc network. Our study is based on the work proposed in[6], in which the nodes of ad-hoc networks are organized in a cluster given the transmission range. To each cluster is elected a leader that has the role to coordinate the communication between the nodes of the cluster. We have used the local search beam[7], to organize the node of the cluster in a tree rooted by the head cluster and leveled given the distance to the leader.

Corresponding Author: Arwa Zabian, Department of CIS, Irbid National University Irbid, Jordan

MATERIALS AND METHODS

Algorithm description: The system as any network model is represented by a graph G = (V, E) where V is a set of mobile nodes, |V| = n and E is a set of bidirectional links. The nodes are organized in clusters given the transmission range and to each cluster is elected a leader using DHCEA (Dynamic Head Cluster Election Algorithm) proposed in[6], in which the head cluster is elected given two parameters are the power level and the number of neighbors. The nodes in the same cluster are in the transmission range of the head cluster can hear it and can communicate to it directly. Our algorithm work in phases, where in the first phase is defined the neighbors of the root and then in the successive phases in the same manner each node defines its neighbors.

The number of phases must be equal to the height of the tree, we limit the number of child to each node to k where $2\leq k\leq 5$ insuring that the tree does not become separated due to nodes mobility and the tree will grow by width and not by height.

Our discussion is applied on a single cluster and then our algorithm will be applied for all the network in the same manner. So, the system is composed on a set of nodes S are similar in the transmission range.

Definitions: we will explain some definitions before describing our algorithm:

- K represents the number of child to each node $2\leq k \leq 5$.
- T_r represents the response time, it is calculated as the time from which the leader sends the request to the time in which it receives a response considering that the attenuation of the signal is ignored for small distance. $T_r = 2d/v$

Where d is the distance between the two communicating nodes and v is the propagation speed that is considered equal for all the nodes. $T_r = T_A - T_S$.

- T_A is the arriving time of the response message
- T_S is the time in which the leader has sent a message
- r is the transmission range
- f is a fitness function given which the nodes is selected by levels:
- f = r*20/100 that represents the selected distance between the two nodes
- P is the power level and takes values from 1 to j where the leader must have power equal to j, given the algorithm proposed in[6]

Dynamic Search Tree Algorithm (DSTA):
Phase 1:

- A node S elected as leader broadcasts a hello message to discover its neighbors and sets a time out is T_r
- Each node hears the hello message and want to join to the leader must send a response message that contains its identity and its power level
- The response messages are inserted in a queue Q given the arriving time T_A
- S visits the nodes in the queue one by one doing the following comparisons:

If $T_r\leq 2f/v$ and $j/2\leq P\leq j$, the visited node is close too the root and has enough power sufficient to carry the communication between the root and the other nodes in the tree. This node will be denoted as discovered. Otherwise, the visited node will be deleted from the queue because it is far from the root or because its power is not enough to connect the tree. And will be connected to more close other nodes in the cluster.

- Step 4 will be repeated until $2\leq k\leq 5$.
- All the nodes with $k> 5$ will be deleted from the Q

Phase 1 will be repeated for each discovered node and so on until all the network will be connected to each other and each node knows who its parent is and who their children are. In this manner, the distance between each node and its child in the tree is fixed and equal to r*20%. That means, the nodes at distance two levels from the root distant physically from the root about r*40% and so on. The nodes with distance more than r*80% from the root will be ignored because if the root needs to communicate directly to it, the transmission will be so weak.

Power management: The goal of our work is to constrain the communication in the single cluster to do by levels to reduce the energy consumption in the communication and to increase the system life time. As knowing in wireless ad-hoc, the power consumption is an important constrain. However, increasing the transmission range increases the power consumption but allows the joining of more nodes. Reducing the transmission range reduces the power consumption but decreases the number of nodes reached. We are interested in studying the power consumed by the leader in sending packets to all the nodes of the cluster.

Feeney in[8], has described the power consumption in sending in point-to-point in a Lucent IEEE 802.11 2Mbps Wave LANPCCARD, 2.4 GHZ Direct

Sequence SPREAD Spectrum in a linear model as follow:

P_T = m*size+b: where P_T refers to the power consumed in sending packets, size is the size of the packet sent and m represents incremental cost. b represents a fixed costs. However, for sending in point -to-point m = 1.9 and b=454. In that, the power consumed in sending a packet of size S is:

$$P_T = 1.9 * S + 454 \quad (1)$$

PT measured by µW.

Feeney shows that sending in broadcast reduces the power consumption to:

P_T =1.9 * S + 266 but still dependent on the packet size.

In[9], is determined the distance between two nodes based on measuring the Received Signal Strength Indicator (RSSI) of the received message in wireless ad- hoc network and based on Frii's transmission equation[10], the remaining power at the receiving node is inverse related to the square of the distance as in the following equation:

$$P_r = P_T (\lambda/4\pi d)^2 \quad (2)$$

Where, Pr is the remaining power at the receiver node, P_T: is the transmission power at the sender, λ is the wave length and d is the distance between the two communicating nodes. So, the remaining power at the receiving node is dependent on the power consumed in the transmission and on the distance. From equations 1,2 we can find that in a network using IEEE 802.11 protocol the remaining power at the receiving node is related to only the size of the packet send and the distance between the two communicating nodes and lightly related to λ given the following equation:

$$P_r = (1.9* S+454(\lambda/4\pi d)^2 \quad (3)$$

In our study we will calculate the power remaining at the receiving node taking in consideration that all the node in the same cluster transmits with equal λ. In that the power consumed in our network will dependent on only the packet size and the distance between the two communicating node. Given that, for a fixed packet size the power remaining is dependent only on the distance d. So, we will try to increase the power saving in a cluster organizing the nodes in a tree, with in a manner that the communication is done by multihop in the tree distributing in that the power consumed between all the nodes of the network to increase the power saving in all the cluster and to increase the system life time.

RESULTS AND DISCUSSION

To study the total power saving in sending packets in multihops in a cluster of wireless networks we have used the Delphi program to model our cluster as graph of connected nodes, where we have been prepared a script that simulate a set of nodes organized in a set of clusters each node in the system is described by two variables are P and d. P is the power level and d is the distance to the leader. Then we have examined the variation of power remaining at the receiver node and the variation of power consumption in transmitting packet with the variation of the distance between two communicating nodes and the number of hops needed to a packet to arrive at destination. Taking in consideration that the power consumed in transmission defined in Eq. 1 is related only to the packet size.

The variation of power remaining with the distance: In our simulation, the distance varies from 20-120 considering that the important values are only those related to the level of the tree. That means 2i where i = 1,2,3…then we have studied the variation of power remaining with the distance in a cluster of 20 nodes in sending a packet of 400 bytes and considering that the packet travel only one hop. Considering that P_T = 1214 (µW). From Table 1 and Fig. 1, we can see that the power remaining is decreased with the increasing in the distance between the two communicating node. That means, if the leader must communicate directly to any node, the power remaining at the receiver node will be decreased with the distance. From figure.1, it is clear that the power remaining is close to zero for a distance of 120m.

Table.1: The variation of power remaining/consumption with the distance

Distance(m)	P_r (µW)	P_c (µW)
20	3.035	1210.965
40	0.758	1213.24
60	0.337	1213.662
80	0.189	1213.810
100	0.121	1213.8786
120	0.084	1213.91

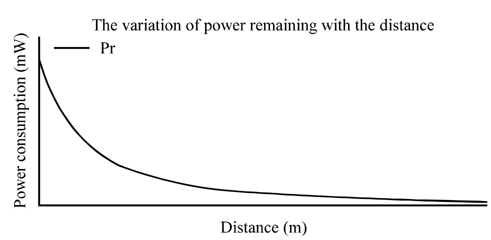

Fig. 1: The variation of power remaining with the distance

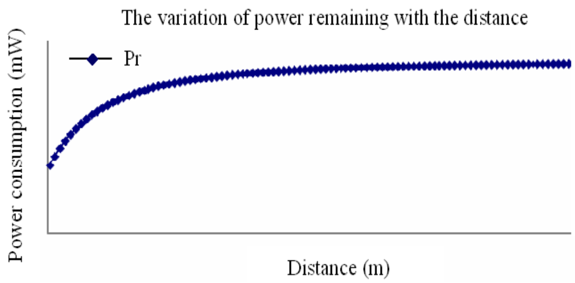

Fig. 2: The variation of power consumption with the distance

Table 2: The variation of power remaining with the number of hops

No. of hops	Power remaining or 400 bytes	Power remaining for 600 bytes
1	0.084	0.110
2	0.674	0.885
3	2.274	2.988
4	18.21	23.748

Which justifies our idea that if a node must send a packet to a node with distance 120m from it in one hop, the signal near the receiver will be very low.

From Fig. 2, we can see that the power consumption is increased with the distance but it is almost fixed for a distance more than 80m. However, the power remaining is decreased continously for a distance from 80-120 m because some of the power of the signal is loss by dissiption. For that more distance travell the signal more is the power losing.

The variation of power consumption with the packet size: To study the effect of packet size variation in the power consumption we have been varied the packet size from 270-1024 bytes fixing the distance traveled by the packet to 60m in only one hop. From Fig. 3, we can see that the power consumption is increased with the packet size.

The variation of power consumption with the number of hops: In our simulation, we have varied the packet size from 400-600 bytes for a distance 120m between the communicating nodes that mean the packet can travel in one hop or multihops. Our simulation results are presented in Table 2 Fig. 4, shows that the power remaining is increased linearly with the number of hops. That means, from Table 2, if the packet travel a distance 120m in only one hop the power remaining will be smaller than that if the packet travel the same distance in two hops. That approves our proposed idea, that consists on dividing the path between any two node by multihops to reduce the power consumption in the network and to increase the cluster life time.

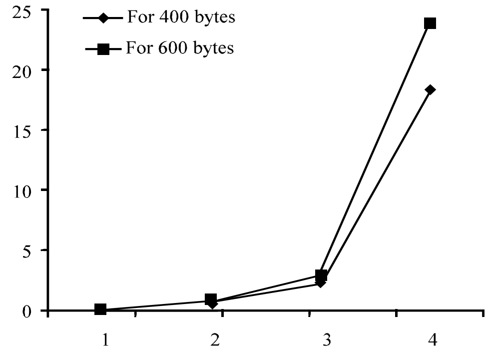

Fig. 3: The variation of power consumption with packet size

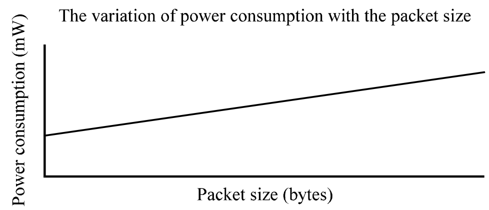

Fig. 4: The variation of power consumption with the number of hops

CONCLUSION

The transmission range that achieves the most economical use of energy in wireless ad- hoc networks is studied under homogeneous node distribution. By assuming the knowledge of the node location. In[3], is studied the optimal transmission range that gives the maximum efficiency of energy consumption. The value of the radio transmission affects network topology and energy consumption considerably. In[4], the optimal transmission radio is studied where it is expressed in terms of the number of terminals in the range. It was found that the optimal transmission radius for slotted Aloha with capture covers eight nearest neighbors in the direction of packets to final destination.

In[5], it was found that higher throughput and progress could be obtained by transmitting packets to the nearest neighbors in the forward direction and using the lowest possible transmission power for each transmission. In wireless networks, a number of different techniques to determine the distance between two nodes are proposed can be classified in three categories: neighboring nodes signal processing and multihop estimation[1].

Neighboring nodes technique works as follow: The location of the observed node is defined given the location of known neighboring nodes are located close to the local node. However, a precise information about the distance to the remote node is not possible[11].

Signal measuring: In this technique the distance between two nodes are determined given the signal strength received. Considering that the power remaining at the receiver is quadratically increased with the distance. This measurement is acceptable for distance of 20m, however many improvement has been done to have an acceptable error ratio for distance up to 160 m. In[12], is proposed an ad-hoc localization system (Calamari). Calamari has no infrastructure to provide known distances or position. The system relay on using small time and low power components. Calamari aims to consume as few resources as possible, including energy, computational power. Calamari estimates the distance between nodes using the Received Signal Strength Information (RSSI) and acoustic Time of Flight (TOF). In RSSI ranging, one node transmits a clean RF carrier frequency of 916.5 MHZ and other node samples the received signal strength. This method does not require any additional hardware or any computational cost. TOF uses more energy and requires a special hardware but yields more accurate distance than RSSI. The transmitter sends short simultaneous R and acoustic pulses while the receiver compares the time of arrival of both pulses. Since light and sound travel at different speeds, the difference in arrival time reveals the distance between the transmitter and the receiver. Calamari use a completely analog solution, where analog components are cheap with low power solution but introduce high variability between nodes. This requires a sophisticated calibration in order to obtain reasonable results. That means, given an input/output for a device we need a calibration function that force the device to adjust its output to conform with a standard output. The calibration function used in Calamari does three functions are: the parameterize of each device and system response, collect data from the system as a whole and choose the parameters such that the behavior of the entire system is optimize. Calamari reduce the average of error from 74.6% without calibration to 10.1%

Multihop estimation: In this technique a flooding is initiated by a sensor node i to other nodes and each sensor node knowing its own position replay the request with hop count 0. Sensor node i collect all hop counts from remote sensor nodes with known position and store the minimal hop count to these sensor nodes that represents the distance. In[13], is proposed ad-hoc positioning system APS that is similar to distance vector algorithm. In APS the network is considered as graph sufficiently connected. At least three nodes called landmarks are known their position have to be presented in the connected graph. For collision reasons and power saving it is necessary that landmarks have a large power to cover the entire network. In this case, it is used hop by hop propagation capability of the network to forward distances to landmark. The immediate neighbors of the landmarks can estimate the distance to the landmark by direct signal strength measurement. The second hop neighbor then are able to infer their distance to the landmark and the rest of the network follows in a controlled flood manner, initiated at the landmark complexity of signaling is therefore driven by the total number of landmarks and by the average degree of each node.

In this study, we have applied the local search algorithms on clustering ad- hoc networks to construct a network represented by a tree in which, the communication between any two nodes in the network is done given the levels of the tree. Our goal was reducing the total power consumption for the transmission in the single cluster, considering that the nodes that are in the same cluster are in the transmission range of the leader but with different distances. For that, we have organized those nodes in a tree with fixed distance between levels to reduce the power needed for the communication. For example, we want to replace the communication between two node distant to each other x to a communication between different nodes distant to each other a fraction of x. Motivated that the power remaining at the destination for sending a packet a distance x/2 is bigger than that remaining in sending the same packet a distance x. Our results show that, the main factor that influences in increasing the power remaining is the number o hops where the power remaining is increased if the packet travel two hops instead one due to signal dissipation will be small. However, the size of the packet influences directly in the power consumption, where is increased linearly with the packet size. In addition, for a single hop communication the power remaining is decreased with the distance where the variation of power consumption with the distance is constant for a certain variation of distance.

REFERENCES

1. D.Kotz, C. Newport, R.S. Gray, J. Liu, Y. Yuan, C. Elliott. 2004. Experimental evaluation of wireless simulation assumptions. International Workshop on Modeling Analysis and Simulation of Wireless and Mobile System (MSWIM’04). Venice-Italy 4-6 October. 78-82

2. Rappaport, T.S., 2002. Wireless Communications, Principles and Practice. 2nd Edn., Prentice Hall Communications Engineering and Emerging Technology. Prentice Hall PTR; 2 edition (January 10, 2002)
3. J.Deng Y.S. Han, P.N. Chen and P.K. Varshney, 2004. Optimum transmission range for wireless Ad-Hoc networks. IEEE /Wireless Communications and Networking Conference. WCNC'04. March, 21-25. pp: 1024-1029. Atlanta-Georgia. USA
4. Takagi, H. and Kleinrock, 1984. Optimal transmission range for randomly distributed packet radio terminals. IEEE Trans. Commun., 32: 246-257.
5. Hou, T.C. and V.O. Li, 1986. Transmission range control in mulihop packet radio networks. IEEE Trans. Commun., 34: 38-44.
6. A. Zabian, A. Ibrahim and F. Al Kalani, 2008. Dynamic Head Cluster Election Algorithm for Clustered Ad-Hoc Networks. Journal of Computer Science 4(1): 42-50, 2008.ISSN 1549-3636.2008 Science Publications.
7. Russel, S. and P. Norvig, 2003. Artificial Intelligence A Modern Approach. 2nd Edn., Prentice Hall, pp: 94-129. ISBN:0-13-080302-2
8. Feeney, L.M. and M. Nillson, 2001. Investigating the energy consumption of a wireless network interfaces in Ad-Hoc networking environment. IEEE Infocom., 3: 1548-1557.
9. Blumenthal, J., F. Reichenbach and D. Timmermann, 2006. Minimal transmission power vs. signal strength as distance estimation for localization in wireless sensor networks. Annual IEEE Communications Society on Sensor and Ad-Hoc Communications and Networks. SECON'06. 3: 761-766.
10. Liu, C.H., D.J. Fang. Y.T. Lo and S.W. Lee, 1988. Antenna Handbook: Theory, Applications and Design. Van Nostrand Reinhold. New York. 1est Edition
11. Blumenthal, J., F. Reichenbach, M. Handy and D. Timmermann, 2004. Optimal adjustment of the coarse grained localization algorithm for wireless sensor networks. Proceedings of the 1st international Workshop on Positioning Navigation and Communication WPNC. Handover, Germany, March, 2004. pp: 137-146.
12. House, W. and K. Ciuller, 2002. Calibration as parameter estimation in sensors networks. In: WSNA'02. Proceedings of the 1st ACM International Workshop on Wireless Sensor Networks and Application.atlanta, Georgia USA. Sep. 28. pp: 59-67.
13. Niculescu, D. and B. Nath, 2001. Ad-Hoc Positioning System (APS). In Proceedings of GLOBECOM. San Antonio, November 2001. pp: 2926-2931.