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ESAHR: Energy Efficient Swarm Adaptive Hybrid Routing Topology for Mobile Ad hoc Networks

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Abstract - Ad hoc networks consist of independent self structured nodes. Nodes use a wireless medium for exchange their message or data, therefore two nodes can converse directly if and only if they are within each other's broadcast range. Swarm intelligence submits to complex behaviors that occur from very effortless individual activities and exchanges, which is frequently experienced in nature, especially amongst social insects such as ants. Although each individual (an ant) has little intelligence and simply follows basic rules using local information gained from the surroundings, for instance ant's pheromone track arranging and following activities, globally optimized activities, such as discovering a shortest route, appear when they work together as a group. In this regard in our earlier work we proposed a biologically inspired metaphor based routing in mobile ad hoc networks that referred as Swarm Adaptive Hybrid Routing (SAHR). . With the motivation gained from SAHR, here in this paper we propose a energy efficient swarm adaptive hybrid routing topology (ESAHR). The goal is to improve transmission performance along with energy conservation that used for packet transmission In this paper we use our earlier proposed algorithm that inspired from Swarm Intelligence to obtain these characteristics. In an extensive set of simulation tests, we evaluate our routing algorithm with state-of-the-art algorithm, and demonstrate that it gets better performance over a wide range of diverse scenarios and for a number of different assessment measures. In particular, we show that it scales better in energy conservation with the number of nodes in the network.

Keywords : Manet, Swarm intelligence, hybrid routing, unicast routing, ACO.

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ESAHR ENERGY EFFICIENT SWARM ADAPTIVE HYBRID ROUTING TOPOLOGY FOR MOBILE AD HOC NETWORKS

Strictly as per the compliance and regulations of:

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B. M. G. Prasad [α] & Dr. P.V.S. Srinivas [σ]

Abstract - Ad hoc networks consist of independent self structured nodes. Nodes use a wireless medium for exchange their message or data, therefore two nodes can converse directly if and only if they are within each other's broadcast range. Swarm intelligence submits to complex behaviors that occur from very effortless individual activities and exchanges, which is frequently experienced in nature, especially amongst social insects such as ants. Although each individual (an ant) has little intelligence and simply follows basic rules using local information gained from the surroundings, for instance ant's pheromone track arranging and following activities, globally optimized activities, such as discovering a shortest route, appear when they work together as a group. In this regard in our earlier work we proposed a biologically inspired metaphor based routing in mobile ad hoc networks that referred as Swarm Adaptive Hybrid Routing (SAHR). . With the motivation gained from SAHR, here in this paper we propose a energy efficient swarm adaptive hybrid routing topology (ESAHR). The goal is to improve transmission performance along with energy conservation that used for packet transmission In this paper we use our earlier proposed algorithm that inspired from Swarm Intelligence to obtain these characteristics. In an extensive set of simulation tests, we evaluate our routing algorithm with state-of-the-art algorithm, and demonstrate that it gets better performance over a wide range of diverse scenarios and for a number of different assessment measures. In particular, we show that it scales better in energy conservation with the number of nodes in the network.

Keywords : Manet, Swarm intelligence, hybrid routing, unicast routing, ACO.

I. Introduction

In disparity to merely establishing accurate and efficient routes among pair of nodes, one significant goal of a routing topology is to remain the network functioning as long as potential. This objective can be consummate by reducing mobile nodes energy not only through active communication but also when they are not participating. Communication energy control and load allocation are two approaches to reduce the energy levels of active communication, and sleep/energy-down mode is used to reduce energy through inactivity.

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Wireless ad hoc networks typically consist of mobile battery functioned computing devices that correspond over the wireless medium. While the dispensation ability and the memory space of computing devices augment at a very rapid speed, the battery method wraps distant behind. Therefore, it is significant to obtain energy preservation schemes to augment the device and network process time.

In wireless networks, the broadcasted signal is assuaged at the speed of $1/d^n$, where d is the distance among sender and receiver and n is the route loss exponent with approximate value between 2 and 6 depending on the equipped environment. As an alternative of using the maximum energy for transmissions all the time, with energy control, a sender can regulate the communication energy according to d. Though, link level energy control cannot make sure that the end-to-end energy utilization from a source to a destination is minimal. To conserve energy, many energy efficient routing topologies have been projected [1, 2, 3, 4, 5, 6, 7, 8, 9]. These topologies can be usually classified into two categories: Minimal Energy usage routing topologies [1, 2, 3, 4, 5, 6] and Utmost Network Lifespan routing topologies [8, 9].

In existing minimal energy routing topologies, signaling packets are often transmitted at the maximum energy to reduce the hidden terminal problem as a result of using asymmetric transmission energy from different adjacent nodes. The signaling packet effects by more collisions, for instance the RTS packet in 802.11, would use noteworthy amount of energy. Without taking into consideration the energy utilized for transmitting, the route exposed could utilize much more energy than a route selected based on a more precise energy utilization model. In addition, the majority of literature works paying attention only on the direction of new hop level transmission cost metric. Once a new hop level transmission cost is resultant, the traditional shortest route routing topologies, for instance AODV (Ad hoc On Demand Distance Vector) and DSR (Dynamic Source Routing) topologies, are customized to search for the minimum cost route. Though, such straightforward customization would lead to numerous problematic issues. Foremost, the routing overhead in route detection phase is excessive, which not only utilizes a significant amount of energy but also shows the way to a long route establishment delay impediment. Second, the route maintenance plan used in conservative shortest route topology is not suitable for maintaining energy efficient route in a mobile environment.

In this paper, we first present a comprehensive argument on the problems in conventional energy efficient routing topologies. We then derive a new hop level transmission cost model to account for energy utilization due to signaling packets at MAC layer, and make available the schemes for approximation the parameters necessary for calculating the hop level transmission cost. Based on the new energy utilization model, we extend our earlier work Swarm Adaptive Hybrid Routing topology [14] as Energy Efficient Swarm Adaptive Hybrid Routing topology for energy conserved data transmission along the route discovered by swarm adaptive hybrid routing topology [14].

This paper discussing the related work in section II that followed by the exploration of the proposed energy efficient swarm adaptive hybrid routing topology in section III. Section IV elaborates the considered basic routing topology SAHR and section V explores simulations and results analysis, which followed by the conclusion of the proposal and experiments.

II. Related Work

There are numerous obtainable routing topologies for wireless ad hoc networks. In general, these topologies can be categorized as proactive, on-demand, and hybrid. In proactive routing topologies, all nodes need to advertise the routing information periodically to keep an up to date view of the network topology. Different from table driven routing topologies, on-demand routing topologies create a transmission route only when required by the source node. Hybrid topologies combine both approaches. For example, in Zone level Routing Topology (ZRP), proactive routing scheme is used for intra-zone level routing and on-demand routing scheme is used for inter-zone level routing. Most of energy efficient schemes proposed in the literature modified on-demand routing topologies such as AODV [16] or DSR [17] to build energy efficient route since the routing overhead is very high in proactive routing topologies [2]. In on-demand routing topologies such as AODV, a node will initiate a route detection process if it needs to find a route to a target node. It transmits the route request packet and waits for the reply from the target node.

The adjacent nodes that receive these route request packet will retransmit it, and so on. To decrease the routing overhead, the intermediary nodes will only retransmit the first conventional route request packet and discard the subsequent duplicate ones. In addition, the target node only replies to the first route request packet. It is obvious that the overhead for these on demand routing topologies is $O(n)$, where 'n' is the number of nodes belongs to the network considered. Route detection in energy efficient routing topologies is however fairly dissimilar. The intermediary nodes could not simply discard the duplicate route request packets now as such packets may come from more energy efficient routes. That is, the intermediate nodes need to process and retransmit the duplicate route request packets if they come from a more energy efficient route. Consequently, the nodes may require transmitting the same route request packet numerous times.

In the context of the routing topology SAHR [14], several successful routing algorithms have been proposed taking inspiration from ant colony behavior and the related framework of Ant Colony Optimization (ACO) [8A]. Examples of ACO routing algorithms are AntNet [6A] and ABC [13].

The ACO routing algorithms mentioned before were developed for wired networks. They work in a dispersed and restricted way, and are capable to study and adjust to transformations in traffic models. However, changes in MANETs are much more drastic: in addition to disparities in traffic, both topology and number of nodes can change incessantly. Additional complexities are caused by the partial realistic bandwidth of the communal wireless channel, even though the data transmission pace of wireless communication can be fairly high, algorithms in use for MAC, such as IEEE 802.11 DCF [15], create a lot of overhead both in terms of control packets and delay, lessening the effectively available bandwidth. The autonomic control confronts are consequently much bigger, and new designs are essential to assurance even the basic network functions.

III. Energy Efficient Swarm Adaptive Hybrid Routing Topology for Mobile Ad Hoc Networks

1. When a route to a target node D is obligatory, but not known at source node S, S transmits a Rout Trace Swarm Agent RTSA to discover a route to D.
2. When D receives the RTSA from S, it initiates to transmit RTSA as Route Confirmation Swarm Agent RCSA, which transmits in backward manner through the route that traced by parent RTSA. The RCSA updates the routing table and emission table of all the nodes in the route from S to D, allowing for data transfer from S to D. Here emission table is maintained by each node n to store emission attribute value sav_{ni} of its each forwarding neighbor ni. The emission attribute value is similar to pheromone repository of the biological swarm agent.
3. When a route fall shorts at an intermediate node X then SAHR reinitiates route detection process.

4. When a route at D is known to S, SAHR deterministically chooses the route by opting to best forwarding hop level neighbor ni based on their hop level delay and number of hops to reach the destination.

IV. Swarm Adaptive Hybrid Routing Topology [14]

SAHR's style is stimulated by Swarm Agent Optimized routing algorithms for wired networks. It uses swarm agents that follow and update emission tables in an indirect agent interaction for the modification of the surroundings learning method. Knowledge packets are routed stochastically consistent with the learned tables. A vital distinction with alternative Swarm Agent Optimized routing algorithms is that SAHR could be a hybrid algorithm, so as to deal higher with the precise challenges of Manet environments. It's reactive within the sense that nodes solely gather routing info for destinations that they're currently communicating with, whereas it's proactive as a result of nodes try and maintain and improve routing info as long as communication goes on. we tend to build a distinction between the trail setup, that is that the reactive mechanism to get initial routing info a couple of destination at the beginning of a session, and route maintenance and improvement, that is that the traditional mode of operation throughout the course of a session to proactively adapt to network changes. The routing info obtained via indirect agent interaction is unfolded between the nodes of the Manet in hop level neighbor info exchange method to supply secondary steerage for the swarm agents. Within the following we offer a broaden description of the SAHR.

SAHR's design is inspired by swarm agent optimized routing algorithms for wired networks. It uses swarm agents which follow and update emission tables in an indirect agent interaction about the modification of the environment learning process. Data packets are routed orderly in accord to the learned tables. An important difference with other Swarm Agent Optimized routing algorithms is that SAHR is a hybrid algorithm, in the process of dealing better with the specific MANET confronts. It is on-demand in the sense that nodes only collect routing information for targets which they are at present corresponding with, while it is proactive because nodes try to maintain and improve routing information as long as communication is going on. We make a distinction between the route setup, which is the on demand mechanism to acquire initial routing information about a destination at the start of a session, and route maintenance and perfection, which is the usual mode of process through the course of a session to proactively acclimatize to network changes. The routing information obtained via indirect agent interaction learning is spread between the nodes of the MANET in a hop level neighbor information exchange process to provide secondary guidance for the swarm agents. In the following we provide a concise description of each of these components.

a) Pheromone Indicator for ESAHR

Routes are implicitly outlined by the emission tables that are kept regionally at every node. An entry g_{ni} of the emission table ST_i at node i that consider as pheromone indicates about the goodness of the routing from node i to via immediate node ni contains a price indicating the estimated goodness of going from i over neighbor ni to reach destination d. This goodness is derived from the combination of route end-to-end delay and range of hops. These are commonly used quality measures in Manets. Combining the number of hops with end-to-end delay between immediate node ni to current node i and destination node d is a way to swish out presumably giant oscillations within the time estimates gathered by the swarm agents. Since SAHR solely maintains info regarding destinations that are active during a communication session, and due to continuous change at neighbor nodes, the filling of the emission tables is dynamic.

b) Route Detection in ESAHR

The source node s determines the route to node d via transmitting Route Trace Swarm Agent $RTSA$. At each neighbor hop that received $RTSA$, transmits the same to their neighbor hops. This process is recursive for each $RTSA$ till it received by destination node d. Upon receiving the $RTSA$, the destination node d initiates to transmit Routing-route Confirmation Swarm Agent $RCSA$ that derived from $RTSA$. $RCSA$ Transmits in backward manner through the route that traced by parent $RTSA$. Upon reaching each node i in the routing route, $RCSA$ updates pheromone indicator value g_{ni} of relay hop node ni of the current node i in the routing route opted by $RCSA$. The process of updating the pheromone indicator value is as follows: During the transmission of swarm-agent $RCSA$, it collects the time $t_{ni\to i}$ taken to reach each node i from relay hop node ni the '$RCSA$' is coming from. The estimated time $t_{i\to d}$ to transmit a data packet from node i to destination node d via $\{ni, ni+1, ni+2 ... ni+n\}$ is measured using equation (1).

$$t^{ni}_{i\to d} = t_{(ni+n)\to d} + \sum_{k=n}^{1} t_{(ni+k-1)\to(ni+k)} \quad (1)$$

And then pheromone indicator value will be measured using equation (2) and (3) that fallows

$$\left(t_{i\to d}^{ni}\right)' = \left[t_{i\to d}^{ni}\right]^{-1} * 100 \qquad (2)$$

$$g_{ni} = \frac{\left(t_{i\to d}^{ni}\right)'}{hc_{i\to d}^{ni}} \qquad (3)$$

Here in equation (3), $hc_{i\to d}^{ni}$ indicates the hop count in route from current node i to destination node d via relay hop node ni.

The inverse value of the estimated time $t_{i\to d}^{ni}$ for a data packet to travel from node i to destination node d indicates the optimality of the route between nodes i to destination node d via relay node ni. Hence the equation (2) is significant.

Upon receiving swarm agent $RCSA$, the source node s also updates its emission table with pheromone indicator value g_{ni} of each neighbor hop ni the $RCSA$ coming from.

c) Energy efficient Data transmission and route maintenance in ESAHR

The routing-route maintenance will be carried out in proactive manner and will be initiated at destination node d. The data transmission and route maintenance strategies explored in fallowing subsections.

i. *Data Transmission with minimal Energy Usage*

In the process of transmitting data, source and hop level node selects the target neighbor relay hop dynamically. Initially source node finds best neighbor ni based on pheromone indicator value of the nodes registered in its emission table. Opting to a neighbor relay hop ni with best pheromone indicator value g_{ni}, transmits data packet to selected neighbor relay hop ni .Upon receiving the data packet the neighbor relay hop registers the sender's information in routing cache. The strategy of selecting neighbor relay hop dynamically and transmitting data packet is recursive at each neighbor hop relay node. This process will be halted once the data packet received the destination node d. And as an extension to this process a energy conservation mechanism introduced to minimize the energy usage in data transmission that described in section ii that follows.

ii. *Minimal Energy Usage for data transmission in ESAHR*

The nodes are having limited energy and storage capacity, Hence the Energy efficient Swarm Adaptive Hybrid Routing topology has been proposed that saves energy resources. Here in this proposed ESAHR model the RTS packet takes the energy used for communication by the source node of that RTS. Then the target node of that RTS finds the state of the signal that used to send out RTS.

$$SS_r = SS_s(\alpha / 4\pi d)^2 S_T S_R$$

Here α is the wavelength of the signal to be carried, d is the distance travelled by RTS between source and target nodes. ST is the single plane uniform radio wave transmission threshold of source node antennas and SR is the single plane uniform radio wave receiving threshold of target node antennas. 'SS_s' is the actual state of the transmission signal energy at the source node s. And SS_r is the state of the signal energy that found at target node r, which used to transmit RTS.

Then the loss state of signal SS_l during routing can be found at target node r by using the following equation.

$$SS_l = SS_r - SS_s$$

And then this SS_l can be used to find minimal signal state SS_m required at the source node, the equation is as follows

$$SS_m = mh \times (SS_l + RSS_m)$$

Here in the above equation

The 'SS_m' indicates minimal signal state required at the source node s

The 'mh' is the marginal hike threshold that is used to normalize SS_m to handle the inference issues on the target node side.

The 'RSS_m' indicates the minimal signal state required at receiving node side to detect the appropriate signal.

There are a set of topologies available for energy control in mobile ad-hoc networks based on the common energy approach [10]. These topologies are complex and have been analyzed that the variable range transmission energy is a better approach than the general energy.

The proposed ESAHR is capable to conserve the energy even to transmit RTS/CTS packets, which is based on the received signal condition. When a source node needs to transmit data, it initiates the optimal routing strategy such as AODV and then transmits the $RREQ$ packet to the hop level nodes and the $RREP$ packet is received from the intermediate nodes via the shortest route and then enters it in their routing table about the next hop to which the anon data packets are desired to be advanced.

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For energy preservation, the RREP packet is recognized by an identifier (id) at the MAC layer and its signal state information is attained from the physical layer. Upon receiving the $RREP$ packet by a node 'r' from a node 's', the node 'r' computes loss state of the signal SS_l during the RREP transmission from node 's' to 'r' and minimal signal state SS_m required at node 's'. And then node 'r' stores minimal signal state required for the node 's' in its routing table.

The process of energy conservation during data transmission in proposed ESAHR as follows:

The source node 's', while sending RTS to its next hop level node r of the routing route, also sends the $SS_m(r)$ stored in its routing table. Here $SS_m(r)$ is the minimal signal state required for r, which is measured and stored in the routing table of node s during route detection. The source node s also includes $SS_m(s)$ as an extra field in the RTS packet. Upon receiving the RTS, the target node r tunes its transmission energy and replies back with 'CTS' packet. Upon receiving the CTS the source node s sends the data with the requisite transmission energy informed by the target node r through 'CTS'.

iii. *Routing Route maintenance*

Upon receiving a packet dp_i, the destination node d verifies the time $t(dp_i)$ taken by dp_i to travel from source node s to destination node d and then measures the end to end delay for data packet dp_i. If end to end delay of dp_i is exceeding the delay threshold τ then it initiates a swarm agent $RCSA$ and transmits towards source node that opts to the route accessed by data packet dp_i. Hence the '$RCSA$' performs the process of updating pheromone indicator value g_{ni} at each hop level relay node in the route. This process explored in equations (1), (2) and (3).

iv. *Handling link failures*

The destination node d initiates swarm agents $RCSA$ to each neighbor relay hop nodes in fixed time intervals. Hence the pheromone indicator values in emission table of each node will be updated in fixed time interval ς.

The pheromone indicator value of any neighbor relay hop ni in emission table of any node i is not valid if time since last update of g_{ni} is greater than time interval ς. This indicates the link failure between node i and destination node d.

V. Experimental Results

We have simulated ESAHR, SAHR, as well as basic AODV topologies in NS2. The position per hop transmission distance is 250m. For energy maintenance function, many smaller hop level nodes are taken. Energy management is used in all three topologies, including normal AODV topology, in which a transmitter adjusts the transmission energy based on its actual distance to the next hop level receiver. The network area in the simulation is fixed to 1200(m) X 1200(m) and the nodes are arbitrarily dispersed in the network. The available transmission energy levels are $1; 5; 10; 15; 20; 25; 30; 35$ mW. The Pm is set to 35 mW. The session arrival rate follows Poisson distribution and the session interval follows Exponential allocation. The application topology is CBR (Constant Bit Rate) and the source and target pairs are arbitrarily selected. The mobility follows customized random waypoint model [18] with pause time of thirty seconds. For each CBR session, 50 packets are sent for each second. The rate of route loss and collision are projected using method described in [12]. The detection rate, which can be described as filter memory [11], is fixed to nearly 1. A simulation result was gained by averaging over 25 executions with dissimilar seeds.

We consider that there is no energy saving approach for the nodes, and therefore, a node will use energy in monitoring the channel even if it doesn't receive a packet. A node also utilizes energy when overhearing packet transmissions. Therefore, the receiving energy cannot be dynamically controlled. In the simulations, we thus disregard the receiving energy and focus only on the comparison of transmission energy. We first evaluate the accuracy of the proposed cost model, we then study the performance of route detection for each topology, and finally we consider energy utilization as well as RTS retransmissions in both static and mobile environment.

We compared the energy utilization and the average number of RTS retransmissions of the ESAHR, SAHR and basic AODV topologies by varying the following parameters: node count, average size of the data transmission packets, and advent ratio of the connection. The simulation time for each topology is 5 hours. We monitored the total energy utilization of all the packets delivered at target node, the count of delivered packets at target nodes, and the count of retransmissions RTS required for each execution of the simulation. The couple of evaluation metrics that used to evaluate the topologies are:

Energy Utilization per Packet: It is defined by the total energy utilization divided by the total number of packets delivered. This metric indicates the energy efficiency for each topology.

Average RTS Retransmissions required for each Data Packet: It is defined by the total number of RTS retransmissions divided by the total number of packets delivered. The RTS packet is transmitted at the utmost energy usage level and the packet size is very little. The majority of RTS retransmissions are due to collisions, together with the collisions of both RTS messages and data packets. Hence, this metric can indicate the pace of the collision for each topology. Higher collision rate will cause more energy utilization, higher end-to-end delay, and lower throughput.

The simulation results are shown in Fig. 1 and 2. According to these results, ESAHR topology performs the best in terms of Energy Utilization per Packet as well as Average RTS Retransmission per Data Packet, followed by SAHR topology and AODV.

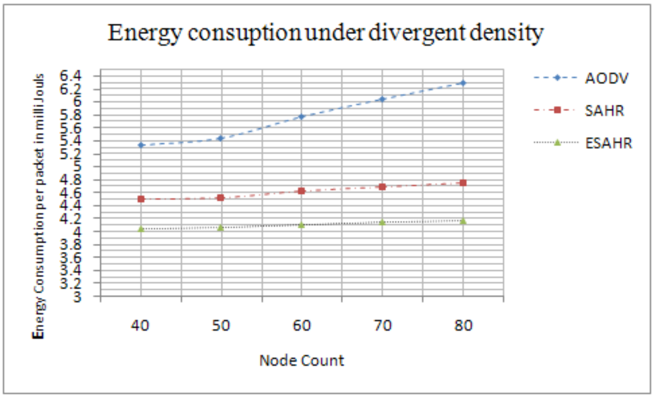

Fig. 1 : Energy Utilization ratio between ESAHR, SAHR and AODV

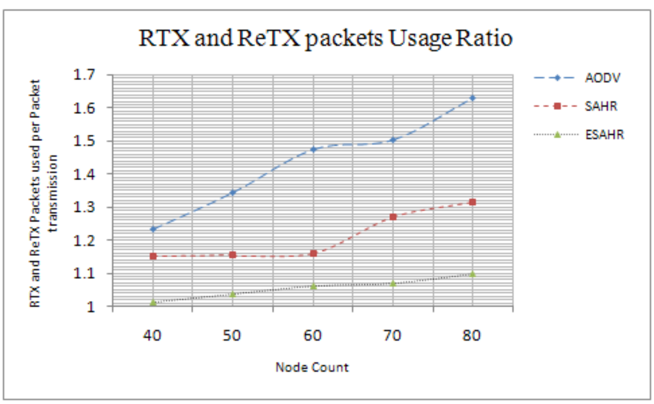

Fig. 2 : RTX and ReTX packets usage Ratio comparison between AODV, SAHR and ESAHR

VI. Conclusion

In this paper we have described ESAHR that is an extension to our earlier routing topology SAHR[14], an Energy efficient Swarm Adaptive hybrid routing (ESAHR) topology for MANETs. The algorithm combines reactive and proactive behavior with swarm intelligence adaptation to deal with the routing challenges of MANETs in an efficient way. This also concern about energy conservation during packet transmission. An efficient hop level transmission cost model to more accurately track the energy utilization due to various factors was explored for packet transmission through the route discovered and maintained under SAHR topology. Our performance studies show that ESAHR topology reduces about 40% usage of energy used during packet transmission, and is highly adaptive to the environment change. In future this topology can be equipped with route overhead endurance mechanism.

References Références Referencias

1. K. Scott and N. Bambos, "Routing and Channel Assignment for Low Energy Transmission in PCS", ICUPC '96 , Oct. 1996
2. S. Doshi, S. Bhandare, and T. X Brown, "An Ondemand Minimal energy routing Topology for a Wireless Ad Hoc Network", ACM Mobile Computing and Communications Review, vol. 6, no. 3 , July 2002
3. V. Rodoplu and T. Meng, "Minimum Energy Mobile Wireless Networks", IEEE Journal on Selected Areas on Communications, vol. 17, Aug. 1999.
4. S. Banerjee and A. Misra, "Minimum Energy Routes for Reliable Communication in Multi-hop Wireless Networks", MOBIHOC'02, June. 2002
5. J. Gomez, A. T. Campbell, M. Naghshineh, and C. Bisdikian, "Conserving Transmission Energy in Wireless Ad Hoc Networks", IEEE Conference on Network Topologies, Nov. 2001
6. J. Zhu, C. Qiao and X. Wang, "A Comprehensive Minimal energy routing Topology for Wireless Ad Hoc Networks", INFOCOM'04 , Mar. 2004
7. C. K. Toh, H. Cobb and D. Scott, "Performance Evaluation of Battery-Life-Aware Routing Schemes for Wireless Ad Hoc Networks", ICC'01, June 2001
8. A. Misra and S. Banerjee, "MRPC: Maximizing Network Lifetime for Reliable Routing in Wireless Environments", WCNC'02, Mar. 2002
9. ANSI/IEEE Std 802.11, 1999 Edition.
10. Outay, F.; Vèque, V.; Bouallègue, R.; Inst. of Fundamental Electron., Univ. Paris-Sud 11, Orsay, France This paper appears in: 2010 IEEE 29th International Performance Computing and Communications Conference (IPCCC)
11. G. Bianchi and I. Tinnirello, "Kalman Filter Estimation of the Number of Competing Terminals in an IEEE 802.11 network", INFOCOM'03, 2003
12. C-K Toh, "Ad Hoc Mobile Wireless Networks Protocols and Systems", Prentice Hall, 2002
13. R. Schoonderwoerd, O. Holland, J. Bruten, and L. Rothkrantz. Ant-based load balancing in telecommunications networks; Adaptive Behavior, 5(2):169– 207, 1996
14. B.M.G.Prasad and P.V.S. Srinivas; IJCSI International Journal of Computer Science Issues, Vol. 9, Issue 5, No 1, September 2012; ISSN (Online): 1694-0814

15. M. Heissenbttel and T. Braun, "Ants-Based Routing in Large Scale Mobile Ad-Hoc Networks," University of Bern, Tech. Rep., 2003
16. D. B. Johnson and D. A. Maltz, "Dynamic Source Routing in Ad Hoc Wireless Networks", Mobile Computing, Kluwer Academic Publishers, 1996
17. DS. PalChaudhuri and D. B. Johnson, "Power Mode Scheduling for Ad Hoc Networks", ICNP, 2002.
18. J. Zhu and X. Wang, "PEER: A Progressive Energy Efficient Routing Protocol for Wireless Ad Hoc Networks", INFOCOM'05 , Mar. 2005.

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