

Energy Behavior in Ad Hoc Network Minimizing the Number of Hops and Maintaining Connectivity of Mobile Terminals Which Move from One to the Others

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Abstract

Wireless ad-hoc network is a special kind of network, where all of the nodes move in time. The topology of the network changes as the nodes are in the proximity of each other. Ad-hoc networks are generally self-configuring no stable infrastructure takes a place. In this network, each node should help relaying packets of neighboring nodes using multi-hop routing mechanism. This mechanism is needed to reach far destination nodes to solve problem of dead communication. This multiple traffic hops within a wireless ad-hoc network caused dilemma. Wireless ad-hoc network that contain multiple hops become increasingly vulnerable to problems such as energy degradation and rapid increasing of overhead packets. This paper provides a generic routing framework that balances energy efficient broadcast schemes in Wireless Ad-Hoc Network and maintaining connectivity of nodes (mobile terminals). Typically, each node's activities will consume energy, either for sending packets, receiving or preparing/processing packets. Number of hops, distance of nodes, and size of packet will determine the consumption of energy. The framework is based on the principle that additional relay nodes with appropriate energy and routing metric between source and final destination significantly reduces the energy consumption necessary to deliver packets in Wireless Ad-Hoc Network while keep the connectivity of dynamic nodes. Using the framework, the average network connectivity is kept 18% higher and the lifetime of network lasting more than 2.38% compared with network with Link State Routing mechanism. The simulation notes that the end-to-end delay may increase rapidly if relay nodes are more than five.

Keywords: Multi-Hops, Energy, Connectivity, Metric

1. INTRODUCTION

A Wireless Ad-Hoc Network consists of mobile nodes platforms which are free to move in the area. Node is referred to a mobile device which equipped with built-in wireless communications devices attached and has capability similar to autonomous router. The nodes can be located in or on airplanes, ships, cars, or on people as part of personal handheld devices, and there may be multiple hosts among them. Each node is autonomous. The system may operate in isolation, or have gateways to a fixed network. In the future operational mode, multiple coverage of the network is expected to operate as global "mobile network" connecting to legacy "fixed network".

At each time and every node's positions, a wireless connectivity in the form of a random, single-hop, and multi-hop paths may exists among nodes. This topology may change as the nodes move or adjust their parameters. Among networks, Wireless Ad-Hoc Network has several characteristics, e.g.:

- 1) Dynamic topologies,
- 2) Bandwidth-constrained,
- 3) Energy-constrained operation, and
- 4) Limited physical security.

These characteristics create a set of underlying assumptions and performance considerations for protocol design which extend beyond static topology of the fixed Internet. All nodes in Wireless Ad-Hoc Network rely on batteries or other exhaustible energy modules for their energy. For this network, the most important system design criterion for optimization is energy conservation. Thus one critical design issue for future Wireless Ad-Hoc Network is the development of efficiently power consumption that suits communication architectures, protocols and services of network enabled wireless devices. Energy conservation means to maximize the operational lifetime of a node, thus, enhancing the overall user experience [12].

In this paper, we provide a framework that balances between energy efficient broadcast schemes in Wireless Ad-Hoc Network and maintaining connectivity. Various formation options of nodes and their potential overheads and impacts on efficiency are evaluated via simulation study. A comparison between similar network of Link State Routing and the generic framework is also conducted. Simulation results show that modified algorithms under different formation conditions are more efficient than the previous one. The remainder of this paper is organized as follows: Section 2 gives preliminaries and our system model. Section 3 discusses the detail design of the simulation model, its notations, and assumptions. Simulation algorithm that suits mobile environment is presented in Section 4. A performance evaluation of generic algorithms and comparison to a broadcast-based link state routing protocol that uses transmission power as the link cost unit are presented in Section 5 and Section 6, respectively. Section 7 concludes the paper.

2. PRELIMINARIES

Wireless network configuration is generally set up with a centralized access point for provide high level of connectivity in certain area. The access point has knowledge of all devices in its area. Routing to nodes is designed in a table driven manner [14][17][18]. The [17] introduced a technical review of wireless network technology products that implemented IEEE802.11 standard through experiments of fixed wireless network nodes. In terms of review the network performance at this stage, it will be represented as the view of use and evaluation of outdoors Muni-WiFi devices in accordance to applying the legacy LAN technology inside the corporate network. Performance of network access layer, e.g. performance of voice and TCP data transmission in terms of throughput, response time between nodes, and communication delay in multi-hop transmission are presented.

However, the [17] were intended to operate in static topology network. With recent performance in computer and wireless communications technologies, advanced mobile wireless is expected to see increasingly widespread use and application. The vision of future mobile ad hoc networking is

to support robust and efficient operation in mobile wireless networks by incorporating routing functionality such that networks are capable to be dynamic, rapidly-changing with random, multi-hop topologies which are likely composed of relatively bandwidth-constrained wireless links. Supporting this form of host mobility requires address management, protocol interoperability enhancements and the like.

In this dynamic network, broadcasting plays a critical role especially in vehicular communication where a large number of nodes are moving and at the same time sending a large size of packet. In wireless network where nodes communicate with each other using broadcast messages, the broadcast environment works as receivers collect information from all transmitting nodes within its coverage pattern's neighborhood, and then allowing receivers to aware of immediate surrounding respond before re-transmitting packet [9][10][4]. Several transmissions may be unnecessary during broadcasting mechanism. These redundant cause the broadcast storm problem [22], in which redundant packets cause contention and collision consume a significant percentage of the available energy resources. Thus, routing protocols should be capable to respond these changes using minimum signaling and taking into account the energy as a parameter distributed in network.

To address these challenges, we propose framework of energy aware broadcasting technique for wireless ad hoc networks. The framework uses a packet forwarding technique where neighbor nodes can be elected to be relay on behalf of source-destination path with the goal of optimized the overall energy consumption to deliver packets in the network, while maintaining the connectivity among nodes. Transmission to a distant node may consume a higher amount of energy in comparison to transmission to a node in closer range and more energy will be used for sending packets than receiving or processing packets. In addition, transmission of larger packets may consume a higher amount of energy in comparison to transmission of smaller packets. The framework is based on the principle that adding additional relay nodes with appropriate energy and routing metric between source and final destination nodes significantly reduces the energy consumption necessary to deliver packets in Wireless Ad-Hoc Network while maintaining connectivity among nodes.

3. SIMULATION MODEL, NOTATIONS, AND ASSUMPTION

Relays are intermediate nodes between source and final destination which help relaying packets using multi hop connectivity mechanism. The appearance of relays is required to avoid dead communication if the distance is not in the proximity of source node. Multi hop connectivity can extend the mobility and expand the coverage area, but in the same time increase the delay time. In general, the more relay nodes (hop), the longer the delay time. Energy consumption is also affected. Direct transmission is seemed to have more aggregate energy required than indirect communication. Thus the adjustment of relay nodes will influence the balance of delay time and energy consumption.

The simulation is initiated from broadcast mechanism and propagated through node-to-node based routing approach. During propagation, it takes into account both data transmission and route discovery. This model is not only applicable in direct communication (one hop transmission) but it can also work in multi-hop transmission. In this situation, when the source and final destination nodes are located outside the maximum transmission range, source node is capable to discover multiple hop routing efficiently thus maintain the energy level required in comparison to standard flooding based ad hoc routing designs.

The Model

Simulation describes that antenna module installed in each node is capable of dynamically adjusting the transmission energy used to communicate with other nodes. Industrial standard of antenna module that support IEEE 802.11 include a management for controlling this energy consumption. Simulation assumes that the energy consumption required to transmit a packet between nodes A and B is similar to that energy required between nodes B and A if and only if

the distance and the size of packet are same. The coverage distance range of the nodes is a perfect symmetric unit disk (omnidirectional). If $d_{x,y} \leq r_x \rightarrow x$ and y can see each other. This assumption may be acceptable in the condition that interference in both directions is similar in space and time; which is not always the case [7]. Usually interference-free Media Access Control (MAC) protocol such as Channel Sense Multiple Access (CSMA) may exist. In addition, wireless link channel is assumed to have no physical noise; i.e., the errors in packet reception due to fading and other external interferences are not considered as a serious problem. Packets from sender to receiver will be transmitted as long as the bandwidth capacity is sufficient and the received signal to noise ratio (SNR) is above a certain minimum value. Thus every packet successfully received is acknowledged at the link layer and de-encapsulate at the higher layer. Each node is capable of measuring the received SNR by analyzing overheard packet. A constant bit error rate (BER) is defined for the whole network. Whenever a packet is going to be sent, a packet's CRC is generated. At the receiver, packet's CRC will be checked; if the random number generated is greater than the CRC value of received packet, then message is received, otherwise it is lost. The default value for the BER is 0, which means there is no packet loss due to physical link error.

Simulation cover a single area of homogeneous nodes that communicate with each other using the broadcast services of IEEE 802.11. There are nodes with different roles simulated in this simulation, namely initiator node/source node, receiver node, sender node, destination node, and final destination node. Initiator node/source node is node that initiates transmission of packets. Packet can be either route discovery or data transmission. Like other nodes, initiator is always moving with random direction, speed, and distance. At the time it is moving, initiator node is always sensing its neighbor to maintain connectivity. Receiver node is node that can be reached by source/sender node. Nodes are defined as neighbors if it located within its distance radius range. At initial time, node senses its neighbors before packet data is required to be transmitted. Coverage neighbor nodes always receive packets that are broadcasted from sender. Destination node is selected receiver node in multi hop transmission that should relay packets to the next receiver node. Final destination node is node that became the end destination of packets.

The layered concept of networking was developed to accommodate changes in local layer protocol mechanism. Each layer is responsible for different functions of the network. It will pass information up and down to the next subsequent layer as data is processed. Among the seven layers in the OSI reference model, the link layer, network layer, and transport layer are 3 main layers of network. The framework is configured mainly in those layers. Genuine packets are initiated at Protocol layer, and then delivered sequentially to next layer with fragmentation process of selected packets. These fragmented packets are to be randomly distributed. Simulation models at every layer owned with finite buffers. Limited buffer makes packets are queued up according to the drop tail queuing principle. When a node has packets to transmit, they are queued up provide the queue contains less than K elements ($K \geq 1$). To increase the randomization of the simulation process, simulation introduces some delay on some common processes in the network, like message transmission delay, processing delay, time out, etc. This behavior will result that at each instance of a simulation would produce different results. The packets exchanged between sender and receiver is designed at a fixed rate transmission λ based on a Poisson distribution. Nodes that have packet queued are able to transmit it out using in each available bi-directional link channels.

Energy is power kept in each node. [7] was assumed that the radio dissipates $E_{elec} = 50$ nJ/bit to run the transmitter or receiver circuitry and $\epsilon_{amp} = 100$ pJ/bit/m² for the transmit amplifier. The radio model is shown in the Figure 1 below.

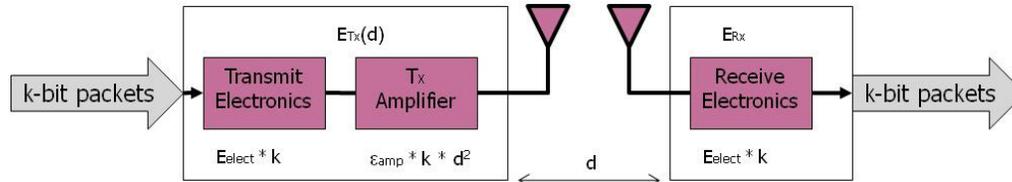


FIGURE 1: The radio model.

Thus, to transmit a k-bit message a distance d using this radio model, the radio expends:

$$E_{TX}(k, d) = E_{TX-elect}(k) + E_{TX-amp}(k, d) \quad (1)$$

$$E_{TX}(k, d) = E_{elect} * k + \epsilon_{amp} * k * d^2$$

and to receive this message, the radio expends:

$$E_{RX}(k) = E_{RX-elect}(k) \quad (2)$$

$$E_{RX}(k) = E_{elect} * k$$

The energy behaviors of node are defined as follow:

- During the idle time, a node does not spend energy. Even though this assumption has been proven untrue because being idle might be as costly as receiving data, this is still an assumption that can be done in most experiments, since the most important factor is the overhead in terms of message exchange and its associated cost.
- The nodes are assumed to have one radio for general communication. The main radio is used in all operations when the node is in active mode, and to send and receive control packets. When this radio is turned off, then no messages will be received and no energy will be used.
- Energy distribution among nodes can either be constant value, normally distributed, Poissonly distributed, or uniformly distributed.

Algorithm

The primary goal of this research is to balance between the energy level required during data transmission in the network and maintaining connectivity to the others. A node keeps its transmitter “on” to transmit one data packet to another node for L/V seconds where L is the size of the transmitted packet in bits (i.e., data plus headers) and V is the raw speed of the wireless node in m/second. Similarly, the receiver node keeps its transmitter “on” to acknowledge a successful data transmission for an associated period of L/V seconds.

As foundation for this mobile environment, the core algorithm is developed from static mode (e.g., sensor networks). The enhancement algorithm for serving mobility then detailed in support of topology development, topology maintenance, and routing maintenance.

Topology development involves transmit and receives of HELLO packets, REPLY packets, and so on; mostly redundant. These packets that successfully received by link layer will update an entry in the table (neighbor table) which cache information about surrounding nodes exist. HELLO packets and corresponding REPLYs have contents of [ID, hop, energy, time, initialTime], where ID is a unique neighbor node (IP address), hop is a number which increment each time packet reach at relay node, energy is current available energy level needed to ensure the communication with the neighbor node, time is current time at which this event is executed, and initialTime is time from which this event was generated.

Let E_{min_j} is the minimum energy ratio of node I at which a node can still receive, process, and transmit packets. Node j finds out the energy level of neighbor node I through analyzing of received reply packet from node I as it responded the previous transmitted Hello packets. Thus

the computation of E_{\min_i} is done through two-step propagations. The use of two-steps propagation model is to simulate interactive propagation in the operation of the protocol in dynamic environment. As a future research, the appropriate propagation model that best matches to this environment should replace the simple two-steps model presented here [9][10][4]. The two-steps propagation model is appropriate for outdoor environments where a line of sight communication existed between the transmitter and receiver nodes and when the antennas are omni-directional. The two-steps propagation model assumes there are two main signal components. The first component is the signal traveling on the line of sight to reached neighbors along with its reply from neighbors and the second component is a confirmation packet transmitted to selected neighbors.

The topology maintenance algorithm is responsible for performing the route optimization operation that leads to respond of routes changes. The route maintenance algorithm performs two basic operations: initiate broadcast maintenance packets, which computes either a route optimization between two nodes is needed and sets up broadcast mechanism; and executes maintenance packets, which determines when to transmit routing maintenance packets.

Because several relay nodes may exist between source and final destination node, multiple packets are sent to only a (selected) single next relay node. The source or sender node will choose the one providing a higher metric value (a combination of energy metric and distance metric). Only one certain node between two communicating nodes can be selected as a relay node at a time. From the simulation, it noted that transmission of multiple route-redirect packets wastes bandwidth and power resources. For sparsely populated networks, this may not be a problem. However, this is an issue in the case of densely populated networks where several potential nodes can be chosen. The framework addresses this issue by giving priority for the execution of an update routing maintenance packet to the potential neighbor node that owned highest route metric energy-distance values first. After receiving an update topology maintenance packet, a node modifies its routing table, putting the source of the received packet as the next hop node for the specific sender-destination route path.

To execute preferential event in sequentially distributed events, we used a simple approach that consists of applying a different time-event execution by means of the triggering event sequences action. The lower and upper bound of the queuing interval are set such that they do not interfere with predefined timers used by the other events for layers and modification events.

Network Convergence

The steps to optimize network topology are iteration of the same procedure of determining relay nodes between source and final destination. At first time, source node transmits packets with TCP type in bursts to neighbor nodes to start the sequence events of topology development. The further the distance the more relay nodes are added.

The framework optimizes routes through sequence of steps to converge to an optimum route. The step refers to the event in which the simulation initiates a source node to transmit a Hello request for the first time. The network will converge as fast as the transmission speed of packets transmitted by node. The more explicit process is explained below.

At the first iteration, the source node communicates directly with the destination node. All destinations in proximity will receive the packets due to the broadcast nature of wireless communication media. Upon receiving a packet, destinations create reply packet which contain its condition (i.e. energy and its position in neighborhood map) and sent it back to sender. Selected destinations also forward the packet to the next neighbors. During this sequence, relay node is determined and confirmed by relevant information gathered at each group of neighborhood nodes. After omitted redundant packets and based on calculation metric value, relay node is set (i.e., a small set of nodes that potentially forward the broadcast packet) to achieve high delivery ratio with energy consideration. The new relays added to a route during iteration are very much dependent on the relay nodes found in the previous iteration. The set can

be selected dynamically (based on both the connectivity and broadcast state information). This relay node set forms a connected dominating set (CDS) and achieves full coverage of connected network. It is possible that the first iteration, which seemed as most optimum value of metric value is not the route achieving the optimum energy-routing path.

We built network simulator to evaluate this performance. The simulator supports physical, link and routing layers for single/multi hop ad-hoc networks. We assume that IEEE 802.11 Distributed Coordination Function (DCF) or MAC protocol which uses Channel Sense Multiple Access with Collision Avoidance (CSMA/CA) already deployed. Successfully received packet by receiver's interface is packet whose SNR is above a certain minimum value otherwise the packets cannot be distinguished from background noise/interference. Packets are transmitting through physical layer in accordance with Poisson distribution. Communication between two nodes in IEEE 802.11 uses TCP signaling before the actual data transmission takes place. Simulation simulates this with random hearing to link's condition. If link allow packets to be sent, then sender executes some packets already queued.

4. CONSIDERATION OPERATION IN MOBILE ENVIRONMENT

Update energy metric and distance metric values in the mobile environment uses a propagation model. The propagation model is based on a flooding approach [10]. Nodes can learn the energy level of neighbor's and required transmission energy from neighboring nodes. The framework maintains routes to other nodes in the network on per on demand node basis. Before execute the sequence of transmitting packet data, a sender node modifies its packets header to request energy level of its receivers. On the other side, if the receiver node determines that its energy level is above a certain threshold, the packets will be successfully received. If the Link layer (of receiver node) receives an error-free packet without any duplication, it passes the packet to the Interface layer and so on. The receiver nodes will respond these packets back to sender. After receiving a respond packet from neighbors, node can then use information contained in the reply packet (i.e. the energy level at which the packet was received) to compute the most capable neighbor whose adequate energy to receive transmitted packets in order to reach the next destination node. Nodes can learn the optimum transmission with sufficient energy metric toward neighboring nodes. In the next step, sender node may invoke a propagation package to transmit data.

The framework comprises core algorithms that support topology development, maintenance and routing, as explained in Section 3. The topology development algorithm creates information about the connectivity tree map of current neighboring nodes. This algorithm also performs route optimization through the relay node that would result in optimum data transmission using combination metric of energy and distance values. If this is the case, the node is adjusted to become a potential relay, and involved in transmission path to the destination nodes and creates/update appropriate entries in its routing table. The packet is then processed by the layering modules with the result that one of the following actions is taken: (i) the packet is passed to the subsequent layers if both MAC and IP addresses match; (ii) the packet is dropped if neither MAC nor IP addresses match; or (iii) the packet is forwarded to another node when only the MAC address matches. In the latter case, nodes search the routing table to find the next route (relay) node with the higher energy and adjust the transmission energy needed to reach next destination node. When receiver receives encapsulated packet data from the higher layers it searches the routing table to see if a route toward the destination node exists. If this is not the case, node searches the neighbor table to see if information regarding the destination node is available. If this is not the case, the packets will be discarded and node transmits the route maintenance packet with energy metric contained to its neighborhood. After the neighbor node replies with a packet of its own then route optimization follows as described previously. When nodes are mobile and no data packets are available for transmission, a source node required to transmit explicit maintenance packets periodically to maintain a topology. The role of the route maintenance algorithm is to ensure that connectivity to neighbors is taken care and a minimum flow of packets is transmitted in order to maintain the route when there are no data packets available to be transmitted.

5. PERFORMANCE EVALUATION

In this section, an evaluation of the framework is discussed and followed by a number of performance issues associated with energy metric and route maintenance.

Energy Performance

As discussed in Section 3, the more densely nodes population in the network the higher the average number of potential relay nodes, the busier communication among nodes, and the more average energy consumed in the network. The simulation topology consists of a 500x500 m² area network with 10 randomly positioned dynamic nodes and different number of source nodes of 1, 3, 5, 7, 9 nodes for each experiment. At initial stage, nodes have energy of 1000 J. Beside existing default overhead packets, simulation conducts source node to transmit packet's which contain data with size of 5000 and 10000 bytes. Source node consecutively transmits packets while moving during simulation. In order to achieve a reasonably high delivery ratio of dynamic network with moving nodes, average speed of network incrementally set at 5 km/h. The simulation trace captured network behavior is executed at each end of source's events in every 100 cycle.

Figure 2 shows the average energy necessary to transmit all data packets versus the average speeds of nodes in the network topology of 10 nodes. When average speed of network increases in Figure 2, average energy remained in each node is similar to its initial level. The speedier the node's move the higher rate of topology change, thus the lesser number of average neighbors and the lower successful transmission, as shown in Figure 3.

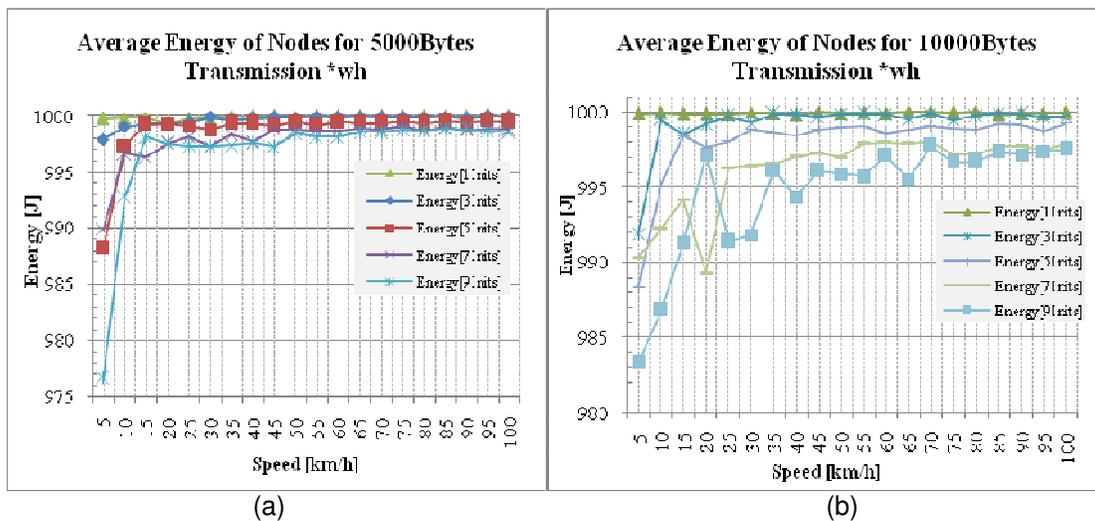


FIGURE 2: The average energy needed to transmit all data packets versus the average speed of nodes in the network with 10 nodes.

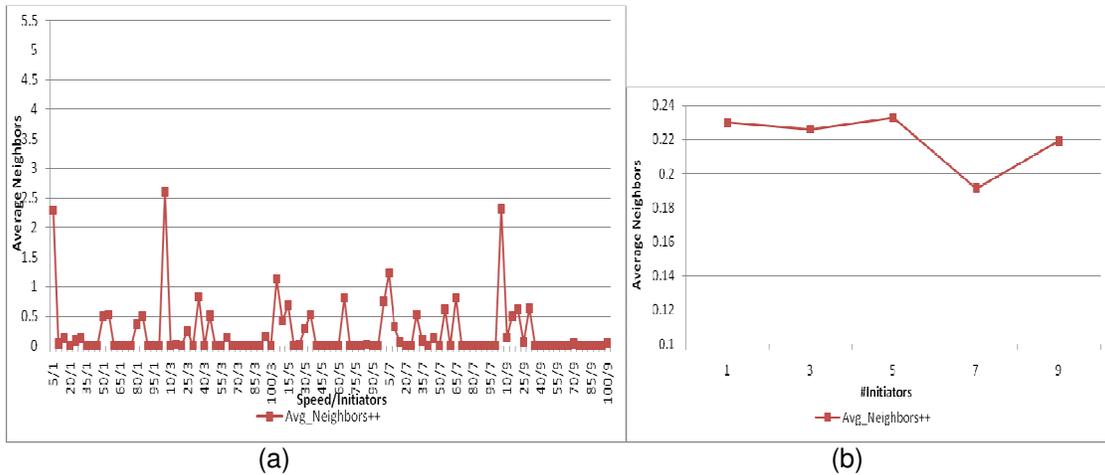


FIGURE 3: Average neighbors at different speed and different number of Initiators.

Figure 4 shows the average time necessary to transmit all data packets versus the average speeds of nodes in the network topology of 10 nodes. Figure 4 also indicates the average number of times packets are forwarded before reaching its destination node, i.e., average number of relay route (hop). This number of relays is dependent on the number of nodes and nodes density. The more nodes in the network then the higher the probability of having more relay nodes between source and final destination nodes. We observe that the aggregate transmission energy increases as the number of relay nodes increases. At first the aggregate transmission energy decreases rapidly when there are between an average of 3 and 4 relay nodes present.

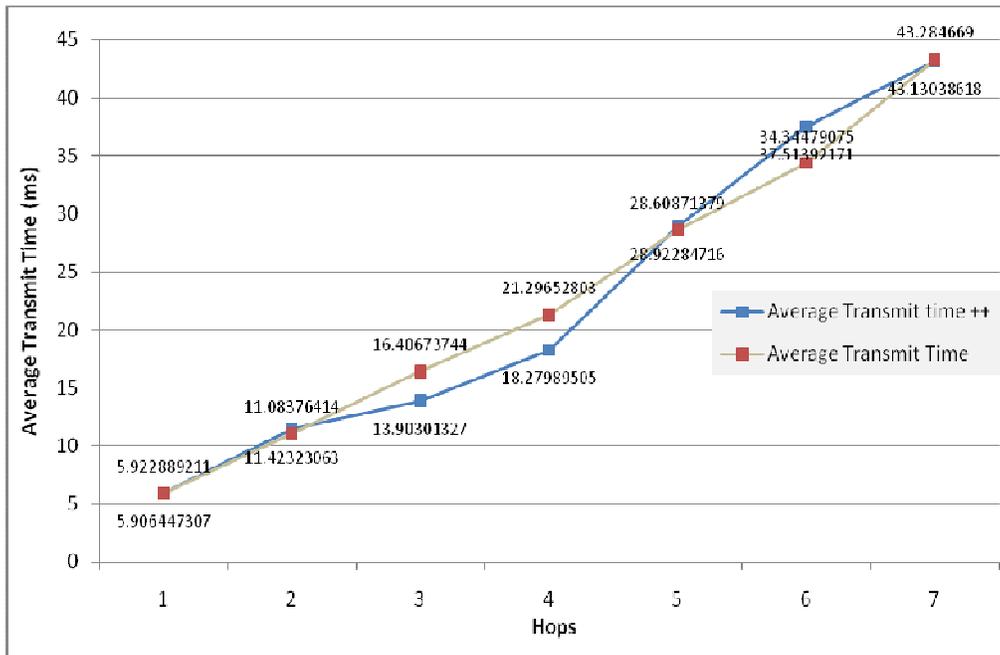


FIGURE 4: The average time needed to transmit all data packets in the network with 10 nodes with 10000bytes packet data.

Figure 5 shows the chart in terms of energy level alone. The figure draws out the result that it should not pay to have more than four relay nodes per source-destination pair for network with 10 nodes. Having more than four relay nodes may increase energy consumption and end-to-end delay. Figure 5 also indicates that the higher successful transmission was obtained for condition

with lesser relay nodes were added between source-destination pairs. Comparing the two scenarios in Figure 5, we clearly observe the benefit of adding relay nodes. However, even if no relay nodes are found between source-destination pairs, by default node will keep the closest relay node to maintain adequate energy level to communicate with a destination node.

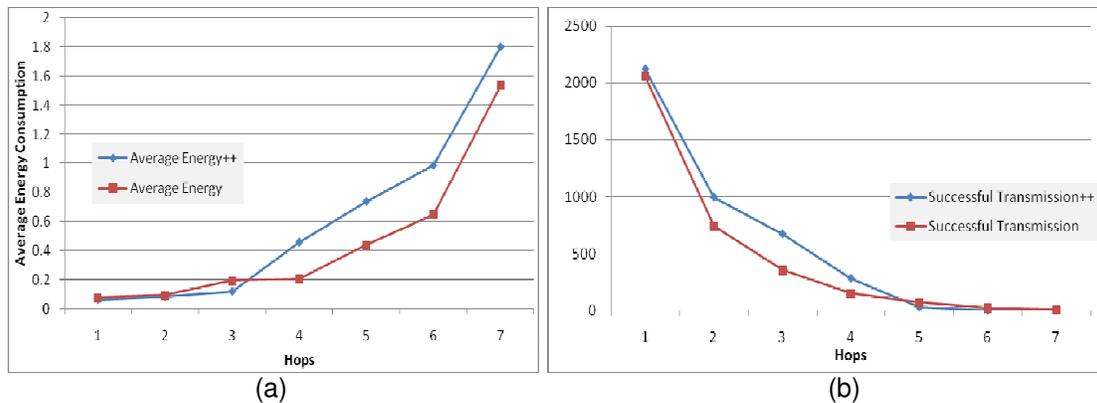


FIGURE 5: (a) The average energy required to transmit all data packets and (b) the successful transmission in the network with 10 nodes with 10000bytes packet data, with the framework (SuccessfulTransmission++) and without the framework (SuccessfulTransmission).

Connectivity Maintenance

In this section, we analyze the performance of the framework in support of maintaining connectivity of mobile nodes using the charts previously shown and Figure 6. Figure 6 shows the total successful transmission per hop, while Figure 5 shows the transmission success ratio versus the number of hops and Figure 4 shows the corresponding average transmission time for each hop. We define the “transmission success ratio” as the number of fragmented packets that are fully received by the corresponding final destination nodes. The simulation includes 10 nodes in a 500x500 m² area network. Source node is chosen semi randomly and incrementally starting from one, three, five, and nine nodes to transmit a TCP packets flow to randomly chosen final destination nodes. Each iteration cycle consists of 10000 bytes packets which transmitted using different time intervals. From Figure 4, Figure 5, and Figure 6, we highlight concluded facts as follows. Fact (I): Nodes operating in low speed mode below 30 km/h. As a result, relay nodes remain in the path of a route for longer periods which translates into low route change updates. This condition results in a high transmission success ratio, even in the case of transmission of big packets size between source and final destination pairs. Fact (II): Nodes operating in faster mode, between 30 km/h and 60 km/h. The relay node changes frequently to a different location and being adjusted to take appropriate measures. As a result, the transmission success ratio is still high even for the case where nodes move faster. Fact (III): Nodes operating in high speed mode. Because of high mobility, most of the routes change and some nodes are outside of coverage distance. However, packets are not transmitted at a high successful rate to maintain routes in the network due to the long silence-intervals between packets. Data packets that are transmitted by nodes located in such situation are likely to be lost. This is because sender nodes may not have accurate information concerning the next hop route. As a result, the transmission success ratio is low.

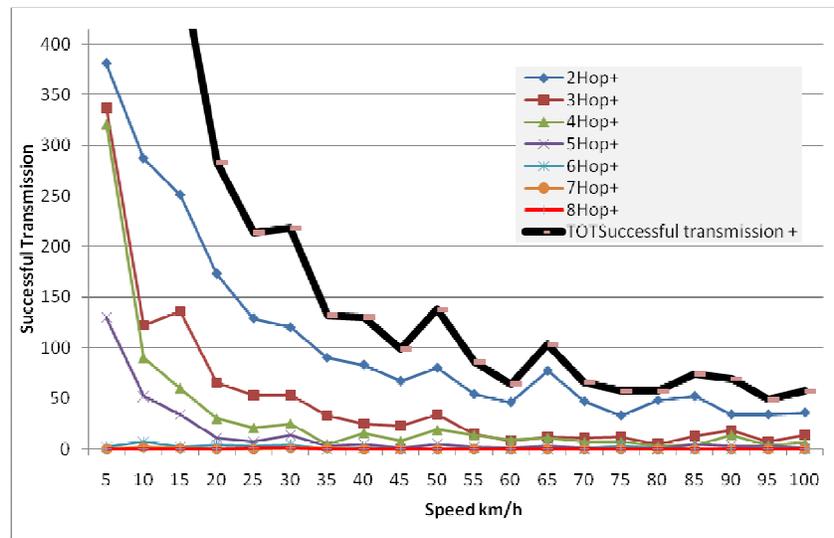


FIGURE 6: The relationship among successful transmission, speed, and average transmission time for network with 10 nodes with 10000bytes packet data.

Determining the optimum value of the blank route path appearance to overcome high speed mobility nodes (in order to guarantee a certain success ratio) is a complex issue. This value is dependent on the size of the network and the node density as well as mobility and data packet inter-arrival rate. Maintaining a route with fewer relays will require less signaling packets both in terms of topology maintenance and routing-maintenance packets. On the contrary, larger areas with high density nodes will likely support routes and maintain connectivity with several relays.

6. DISCUSSION

The proposed framework assumes that nodes are capable of dynamically adjusting their relay nodes on per move step base. It attempts to minimize the number of relay nodes between source and final destination pairs and at the same time maintain the node's energy level required. This behavior is almost similar to MANET routing protocols (e.g., AODV, DSR and TORA). One common property of these routing protocols is that they discover routes using a variety of broadcast flooding protocols by transmitting at maximum power in order to minimize the number of relay nodes between any source and final destination pair. MANET routing protocols do not provide a suitable mechanism for discovering optimum energy aware routes in wireless ad hoc networks and at the same time keep moderate the number of hops. Delivering data packets in wireless ad hoc networks using minimum-hop routes, however, requires more transmission power to reach destinations.

The framework discovers a balance between energy and routes on-demand on a propagation node-to-node basis. A different approach would generate full routing tables in advance where, all nodes in the network would be aware of energy level and distance routes to all other nodes in the network. Such protocol behavior is similar to Link State Routing (LSR) using energy level metric as the link cost unit. The basic LSR operation requires that each node in the network to broadcast a routing packet. The broadcast packet contains information about the combination of energy metric and distance metric of all known destinations. After collecting packets from all parts of the network, any node should be capable of computing optimum routes to other nodes.

We compare the proposed framework and similar Link State Routing network to best understand the various tradeoffs and limitations of design. We consider a network composed of N nodes located within transmission range of each other. Similar Link State Routing network can compute the optimum energy metric with higher energy level ratio and shortest distance to a next relay node by listening to a reply topology development and topology maintenance packets transmitted by the neighbors. These packets include the energy level available and other information to

transmit the packet. The received packet may require to be forwarded by other nodes and then propagate them again to the entire network. Each node computes routes to any other node in the network using a standard link-state Dijkstra algorithm. The iteration of propagation events to be entirely flooded mainly depends on the density of nodes in the network.

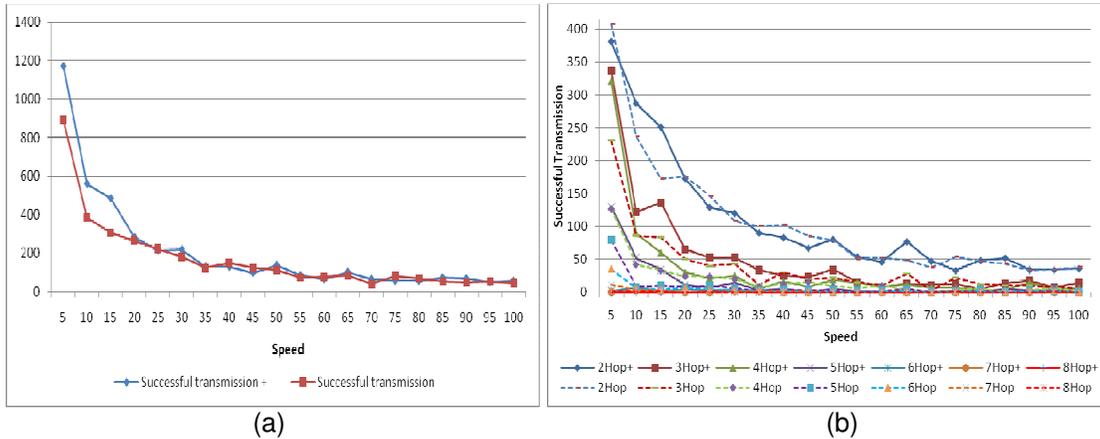


FIGURE 7: Comparison of successful data transmission between The Framework (Successful transmission+; Hop+) and Link State Routing (Successful transmission; Hop).
 (a). There is about 18% differences.
 (b) Successful data transmission each hops at different speed.

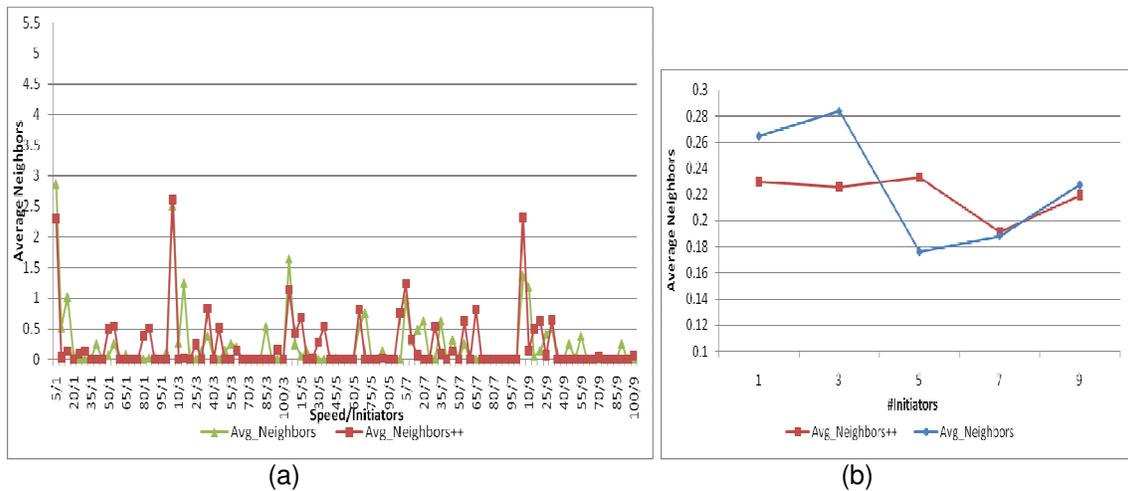


FIGURE 8: Average neighbors at different speed and different number of Initiators for comparison between the framework (Avg_Neighbors++) and similar LSR (Avg_Neighbors).

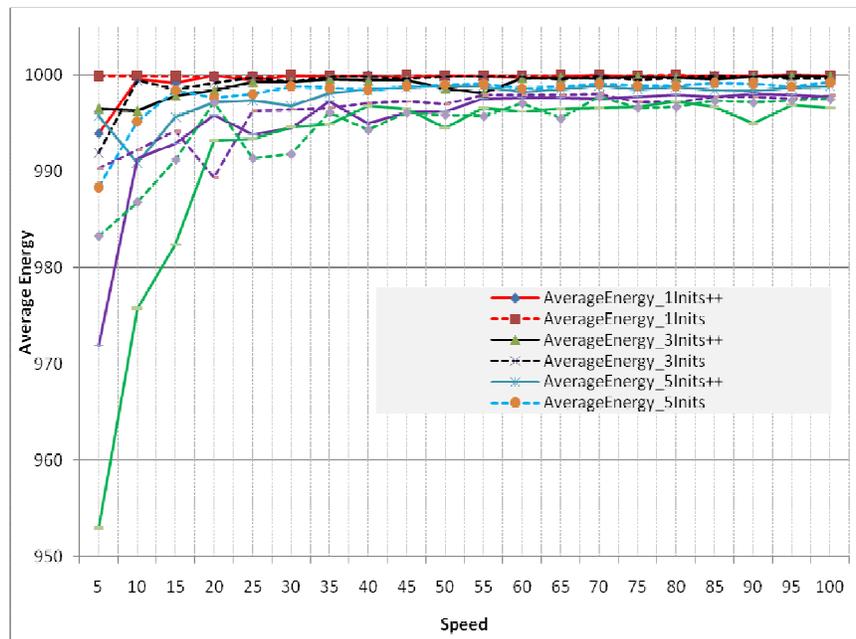


FIGURE 9: Aggregated Energy Level Ratio Consumed by Data and Signaling for The Framework (AverageEnergy++) and Link State Routing (AverageEnergy).

Figure 9 shows a simulation trace of the aggregate energy level ratio consumed by both overhead and data packets for both the framework and Link State Routing. The network simulation consists of 10 static nodes a 500x500 in size with TCP flows transmitting a 5000, and 10000-byte packet. In the case of Link State Routing, topology construction packets are first transmitted to generate full routing tables. Once routing information is available, in Link State Routing, packets data are transmitted. In the case of the proposed framework, packets data are first transmitted at high power because destination nodes is unknown to source nodes and several neighbor nodes are potentially to be selected as relay nodes. Figure 9 shows the remained energy offset to converge to optimum routes for both the framework and Link State Routing. It can be observed from Figure 9 that relative to the remained energy level consumed by signaling packets and the packet contain data, the contribution of data transmission to the overall energy level/consumption is about 2.38%. This result implies an important design principle for future energy-connectivity aware routing protocols is important in data transmissions at mobile environment.

Many researchers have proposed protocols to manage energy consumption in MANET. Among existing protocols, we can group as two categories: topology control oriented and broadcast oriented. The proposed framework could be included in broadcast oriented part. The first category (topology control oriented) assigns the transmission power for each node such that the network is connected independently of broadcast utilization. That means that all nodes can be a source of a broadcast and are able to reach all nodes of the network. The second category (broadcast oriented) considers the broadcast process from a given source node by means of the minimum-energy broadcast tree. It has condition that the source can reach every node of the network. Research e.g. [4] describes a localized protocol where each node requires only the knowledge of its distance to all neighboring nodes and distances between its neighboring nodes (or, alternatively, geographic position of itself and its neighboring nodes), while our proposed framework optimized the broadcast mechanism by means of energy level and distance metrics. Several types of broadcast are introduced to develop the topology, to maintain the connectivity, and to adjust the energy level required for transmission in the network.

7. CONCLUSION & FUTURE WORK

In this paper, we have presented the generic framework of an energy level and distance aware routing optimization for wireless ad hoc networks. We evaluated this framework and compared its performance to similar Link State Routing network. We found that the framework is able to balance of both remained energy level ratio and distance metric routes to maintain connectivity compared to similar Link State Routing with its point to point on-demand design.

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