

Optimal Energy Calculation for Cooperative Grid Networks

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The Lifetime of Mobile Ad Hoc Network (MANET) depends on the battery capacity of nodes. IEEE 802.11 supports power saving mode (PSM) in which the station may be kept in awake mode or in a doze state. PSM is energy efficient, which improves the network lifetime and is suitable for MANETs. Node deployment in a network plays a vital role in its topology, routing and network lifetime. Node placement can be categorized into: Deterministic, Semi-deterministic and Non-deterministic types. In grid topology, nodes are placed in a uniform distance and gives better performance over random deployment for MANETs using PSM. Cooperative communication supports higher data rates and provides cooperative diversity. In this paper, the performance of the proposed Cooperative Modified Bellman Ford Algorithm for a grid network with PSM is investigated. In this algorithm, cooperative relays employing Modified Bellman Ford Algorithm (MBFA) are used to improve the performance of the network. The effect of Announcement of a Traffic Indication Message (ATIM) interval on packets received and energy consumption is calculated for different network sizes. Various performance metrics like packets received, energy consumed and delay for cooperative and non-cooperative scenarios are investigated with a different ATIM interval. Simulation results show that an ATIM interval of 16TUs gives better performance and a shorter ATIM interval saves node energy and improves the lifetime of the network.

Keywords: ATIM interval, Cooperative Modified Bellman Ford Algorithm, Modified Bellman Ford Algorithm, power saving mode.

Introduction

Mobile Ad Hoc Networks (MANETs) has dynamic topology, limited bandwidth; nodes rely on battery and therefore require energy conservation for improving the network lifetime. Battery energy conservation can be accomplished by operating nodes in power save mode¹ (PSM). Design of efficient power saving MAC protocol for multi-hop MANETs was explained². In IEEE 802.11 power saving mechanism, time is divided into beacon intervals. Beacon interval has Announcement of a Traffic Indication Message (ATIM) window and all stations awake during the ATIM window to hear an ATIM frame announcement. All stations are synchronized and MAC Service Data Units (MSDUs) that are to be transmitted are announced during the ATIM window. The announcement will be announced by the transmitting station through a transmitting ATIM frame in the ATIM window³. After the ATIM window, all other stations except transmitting and

receiving stations enter into a doze state. Mobile equipment is normally limited by its size, battery and hardware complexity of the antenna. Transmit diversity generally requires more than one antenna at transmitter and cooperative communication provides transmit diversity by using cooperative relays as virtual multiple antenna transmitters. Cooperative communication provides cooperative diversity over spatial diversity to combat frequency selectivity of the wireless channel, supports higher data rates and cost-effective for MANETs. Popularly used cooperative protocols are: Amplify and Forward (AF), Decode-and Forward (DF) Protocols. In this paper, an energy-efficient Cooperative Modified Bellman Ford Algorithm using cooperative relays is proposed. IEEE 802.11 OFDM standards with power saving mode are considered for implementation. The effect of the ATIM interval over received packets and energy consumption is analyzed for different network sizes. Further, the performance of cooperative and non-cooperative routing using PSM is compared for various ATIM intervals. The paper is organized as follows: Section II describes Modified Bellman Ford

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Algorithm (MBFA), and their performances for the grid and random topologies with and without PSM. Section III describes Cooperative Modified Bellman Ford Algorithm. Simulation results were analyzed in Section IV. Finally, conclusions are deduced in Section V.

Modified Bellman Ford Algorithm

In general, routing protocols are classified into: Reactive, Proactive and Hybrid types. Distance Vector routing is a proactive routing protocol in which route tables are updated periodically. Bellman Ford and Dijkstra's algorithms are used to find a shortest path in Distance Vector routing. Loop-free hop-by-hop routing for isotonic and not isotonic routing metric is possible with Bellman Ford Algorithm (BFA) ⁴. In this algorithm, the distance-table is periodically updated with the cost. Information is exchanged among the neighbor nodes. Each node broadcasts the route advertisement until they get a short distance to reach other nodes. In Modified Bellman Ford Algorithm residual energy is considered as a routing metric in addition to the distance and hop count of BFA. The node is deactivated, if the current change in battery capacity is less than the threshold battery capacity. The packet is transmitted through the shortest path using MBFA ⁵. In this Algorithm, nodes communicate with the physical layer and include energy metric in the routing table. Let E_{Tx} , E_{Rx} represents the energy consumed by the node to transmit and receive L bits in a data packets respectively, E_{Idle} indicates energy consumed in idle state, E_{CPU} indicates energy consumed by the processor, E_{Bat} is efficiency loss in the battery and E_{DC} represents energy consumed by DC-DC converter which regulates voltage for different components. During the packet forwarding, a route in MFBA is aware of total energy consumed in z hops and can be written as

$$ET = \sum_{k=0}^{z-1} [E_{Tx}(k) + E_{Rx}(k+1)] + \sum_{k=0}^z [E_{Idle}(k) + E_{CPU}(k) + E_{Bat}(k) + E_{DC}(k)] \dots (1)$$

A comparison of static and mobile network performance using Modified Bellman Ford Algorithm ⁵ was analyzed by considering the impact of PSM on various performance metrics like the packet delivery ratio, end-to-end delay, and energy consumption. The simulation results show that, the performance of the static network is better using PSM when compared with a mobile network and Grid topology gives better performance over random topology. In grid topology

nodes are placed uniformly and give a better throughput and hence PSM is more suitable when compared to random topology. In mobile networks, there is a packet loss due to mobility of nodes and PSM results in further degradation of performance. Hence, a grid network is considered for the Cooperative MBFA using PSM and is explained in the next section.

Cooperative Modified Bellman Ford Algorithm

The nodes in a network can be categorized into AF or DF relays based on the SNR threshold ⁶. In this paper, grid topology is used for node placement. All the nodes in the network are operating in PSM as per IEEE 802.11 standards. In the proposed Cooperative MBFA, SNR threshold is used as a parameter to categorize nodes into AF or DF relay ⁷. If the received signal SNR at the relay is greater than a threshold SNR, then it acts as DF relay, otherwise it acts as an AF relay. In this model, 700mAh is considered as threshold battery energy and the current battery capacity of the node, which reaches the threshold, will be deactivated. All DF nodes are to be considered as a part of the route. Later it calculates the routing metric, and forwards the packet to a destination through the optimal path selected by MBFA. Any node which is part of the current active route would forward the packet to next hop or destination.

Numerical Results

On QualNet Simulator, nodes are configured in 1000 m^2 area with different node densities of 15, 40 and 60 using Grid topology. The proposed work considered OFDM technique using 802.11a/g standards, 2.4 GHz band, channel bandwidth 20MHz with data packet size 512 bytes for implementation. Source and relay employ equal power allocation scheme of 100mW transmit power, receive power 130 mW, idle power 120 mW with a transmission range of 217-402 m. Pre-defined SNR threshold 20 dB used for Cooperative MBFA implementation. Battery capacity 120 mAh, simulation time 3000 s, initial node energy 6480 J, 1.2 Ahr with 1.5V battery, speed 2 m/s and path loss coefficient 2.3 are used for simulation.

Effect of the ATIM interval on Packets Received and Energy Consumption

Grid topology with a different network size of 15, 40 and 60 nodes are considered for the simulation. The default parameters related to PSM are: Beacon

interval 200 TUs and ATIM interval 20 TUs where $1 \text{ TU} = 1024 \mu\text{s}$. The numbers of packets received with the ATIM interval of 15, 20, 30, 35 and 40 TUs for MBFA using cooperative relays are compared and are shown in Fig. 1. The ATIM interval has a certain limit beyond which, the network throughput drops due to high traffic on the link. From the above graph, it can be observed that, at an ATIM interval (35 TUs) for 60 nodes, the throughput is dropped due to high traffic in that interval which cannot be handled by the node within short a period. So for Optimum throughput the ATIM interval should be configured properly. The default ATIM interval is 20 TUs. According to power saving mode, ATIM interval should be less to reduce energy consumption of all nodes in a network. Simulation results show that a smaller ATIM interval 16TUs gives a satisfactory throughput for different network sizes 15, 40 and 60 nodes.

Effect of the ATIM interval on Energy Consumption

The amounts of energy consumed by the route using Cooperative MBFA by the network for different node densities with different ATIM intervals are shown in Fig.2. As the number of packets received

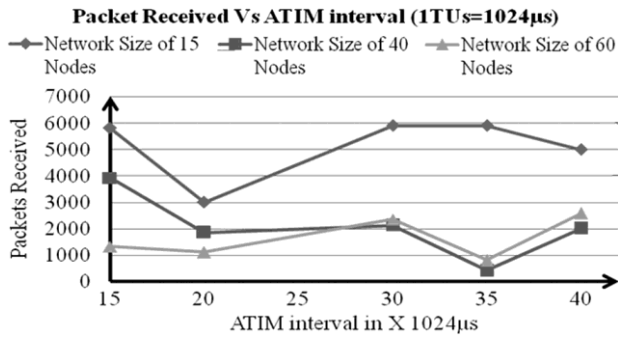


Fig. 1—Packets Received verses ATIM Interval using Cooperative MBFA

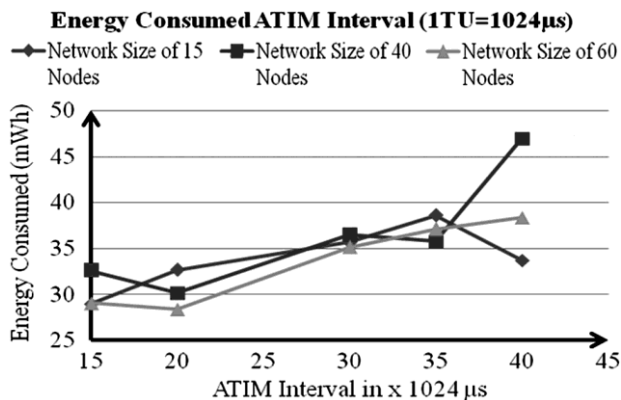


Fig. 2—Energy Consumed verses ATIM Interval using Cooperative MBFA

increases; each node in the route has to spend more energy. Energy consumption is reduced with increasing node density. This is because of the nodes cooperating among themselves by finding the best route to deliver the packets to the destination. In this proposed work, energy consumption of a network can be reduced by using nodes in PSM and a smaller ATIM interval of 16 TUs improves network lifetime further by reducing awake time of nodes during the ATIM interval.

Performance of Cooperative and non-cooperative MFBA using PSM

The performances of cooperative and non-cooperative MFBA using PSM for different ATIM intervals are compared. The number of packets received at different ATIM intervals for cooperative, and non-cooperative MFBA is shown in Fig. 3. The graph is drawn for a node density of 45. The packets received are more in a cooperative network compared to a non-cooperative network because of optimal route selection between the source and destination. In both the cases, the packets received are dropping as the ATIM interval increases because of heavy traffic on the link. Simulation results show that the cooperative scheme gives better performance over non-cooperative scheme. From Fig. 4, a cooperative network has less delay compared to a non-cooperative network due to the shortest path selection. A cooperative network has minimum link failure

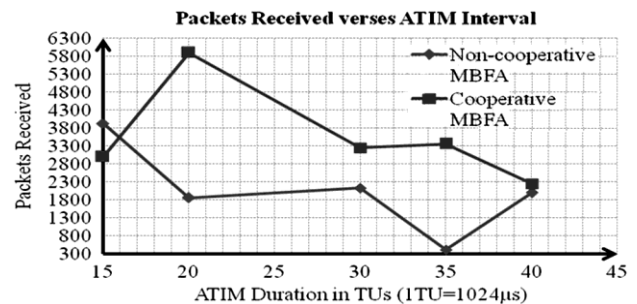


Fig. 3—Packets Received verses ATIM Interval

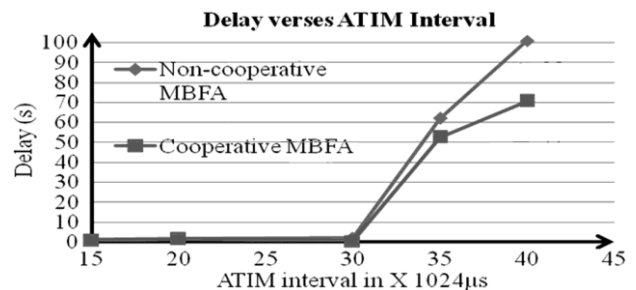


Fig. 4—Average End-to-End Delay verses ATIM interval

and minimum overhead when compared to a non-cooperative network.

Conclusion

Battery power limits the lifetime of Mobile Ad Hoc Networks. The battery power of a node can be saved by using power save mode. In this paper, energy efficient Cooperative Modified Bellman Ford Algorithm for MANETs using power save mode is proposed. In this algorithm, the packet is forwarded by the shortest path as selected by Modified Bellman Ford Algorithm through the selected decode and forward cooperative relays. The effect of ATIM interval using power save mode is investigated using Cooperative Modified Bellman Ford Algorithm. Further, the performance of Cooperative and non-cooperative Modified Bellman Ford Algorithm is compared with different ATIM intervals. In power save mode, during an ATIM interval, all nodes awake and listen to an announcement via ATIM frame. The default ATIM interval available in QualNet is 20TUs. Different ATIM intervals are considered with different network sizes, and simulation results show that the proposed system using Cooperative Modified Bellman Ford Algorithm has better performance at an ATIM interval of 16TUs when compared to the non-cooperative scenario. This smaller ATIM interval

with power saving mode further reduces the awake time of nodes during the ATIM window, save node energy and improves the network lifetime. With the ATIM interval of 16TUs, the nodes awake period during ATIM announcement will decrease and 20% of power will be saved when compared to the default ATIM interval of 20TUs. Simulation results show that the cooperative scenario gives better results compared with non-cooperation one.

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