Indian Journal of Science and Technology, *Vol 9(33), DOI: 10.17485/ijst/2016/v9i33/99592, September 2016*
ISSN (Print) : 0974-6846
ISSN (Online) : 0974-5645

Dynamic and Secure Joint Routing and Charging Scheme with Mobile Power Back Ferry Nodes in Mobile Adhoc Networks

R. Vallikannu[1*], A. George[2] and S. K. Srivatsa[3]

[1]Hindustan University, Chennai - 603103, Tamil Nadu, India; abiuma2008@gmail.com
[2]Periyar Maniyammai University, Thanjavur - 613403, Tamil Nadu, India; amalanathangeorge@gmail.com
[3]Prathyusha Engineering College, Tiruvallur - 602025, Tamil Nadu, India; profsks@rediffmail.com

Abstract

Recent introduction of hybrid architectures in Mobile Adhoc NETworks (MANETs) made researchers to concentrate on routing techniques to prolong the network lifetime with improved performance and scalability. Major research activity has been carried out to explore and improve constrained lifespan of the network by proposing on - demand power aware routing protocols. However, these protocols try to increase the network life time but doesn't guarantee a network remain operational forever. Charging of premature failure nodes which were frequently used as relying nodes is essential to prolong network lifespan. Therefore, to improve network connectivity and lifespan, it's essential to charge energy drained nodes based on their expected lifetime. Hence, we propose a dynamic and secure routing cum energy recharging scheme using Mobile Power Back Ferry Nodes (MPBF) to recharge energy drained nodes. Consumption of energy from the MPBF nodes affords a most trustworthy energy supply than deriving energy from other sources. This approach retains the node energy to maximum time with improved battery life by selecting a gateway based on link weight age. Secure Source-Based Loose Synchronization (SOBAS) protocol is used for authenticated power transfer. The total number of MPBF nodes required for the optimum energy conservation is determined by the target detection mechanism assigned by the Secured Sink Trail (SST). Using this joint methodology, the network lifetime and percentage of energy consumption of mobile nodes under two different scenarios (a) Variable node velocity and network traffic with fixed node density (b) Variable node density and node velocity with fixed network traffic are analyzed. We evaluate the proposed scheme performance through NS2 simulations. The results show that the proposed scheme can retain the network lifetime for a longer duration. Its performance is compared with power aware and ACO based Dynamic Power Control and load balanced energy efficient routing protocols under different QoS scenarios.

Keywords: Energy Conservation, Joint Routing, Mobile Power Back (MPB), QoS Analysis, SOBAS, Residual Energy, Secure Sink Trial

1. Introduction

Mobile ad-hoc networks (MANETs) have attained quick-tempered interest among the wireless user society in the recent past and have laid remarkable inroads into the mobile communication[1]. Hybrid networks constitute themselves and set up instantaneous connectivity[2]. Energy conservation has been the principal factor for managing such hybrid networks. For connectivity establishment and network life time extension, energy consumption reduction plays a vital role. However it is imperative to minimize the overall transmission power utilization across the network. Various load balancing techniques were adopted for even load distribution which in turn uses more number of relay nodes to communicate rather taking a shortest path. Swarm intelligence based routing with autonomous localization of MANETS was developed with ATPC and balanced load distribution[3]. However network partitioning can't be avoided when any

**Author for correspondence*

of the existing nodes runs out of energy. Transmission phase incurs higher energy cost, hence can be minimized with proper selection of mobile agents for the transmission. Mobile agent is used for carrying the data from the source to sink on demand and acts as messenger based on the route planning[4]. Residual Energy based Mobile agent selection plays an important role in maintaining network connectivity and prolonged network lifetime[5–7]. Therefore finding out an optimal route for the Mobile Agents with secured data transmission, in case of large networks where many neighbor nodes need to be visited, provision of single Mobile Agent leads to several negative aspects such as network delay and the energy depletion. To tackle these issues, multiple mobile agents[8] can be used.

MANET's vibrant topology requires a proficient clustering based on sufficient metrics. But in the real time scenario, pre-deployment arrangements are very hard to implement. Once deployed it is difficult for the MANET nodes to go for energy charging as most of the MANETs underlying applications are catastrophe events, rescue operations, infrastructure monitoring etc. Moreover lack of energy resources available near deployed environment leads to a challenging task of conserving energy of each mobile nodes to make them remain active in the network. Various schemes such as energy conservation, harvesting and battery replacement have been projected to deal with this energy constrained resources. Energy conservation aims at minimum energy usage thereby increasing node's lifetime. Power source servicing has got extensive consideration for extending network life time as battery replacement is difficult for major applications. Energy harvesting with solar powered batteries were studied in energy harvesting technologies[9,10]. But this leads to more energy consumption due to weight of the nodes as the nodes are highly mobile. Battery replacement is difficult since after deployment replacement is quite difficult task. Wireless Power Transfer (WPT) is a new emerging technique[11] where omnidirectional EM radiation based active power transfer method of mobile wireless charger was used to prolong network life time. i.e., allowing the network to stay functional forever.

In the real world applications involving dynamic power requirements, most of the systems are utilizing on-board batteries or super-capacitors. They provide only a limited power resource which makes energy a critical parameter[12]. Various measures are practiced by the research community for replenishing the energy resources, of these, the usage of mobile power charges is reliable and of on-demand nature. In [13] employed a mobile robot with wireless charger (MC) and studied charging schedule of MC so as to extend network life span. In[14] proposed a heuristic algorithm for a static topology and studied simultaneous transfer of data and power in a MIMO broadcasting system using RF signals. By [15] proposed a Mobile Wireless Charging Vehicle (MCV) systematically travelling inside the network and charging each sensor node with a concept of 'Renewable energy cycle". Their experimental results showed that EM radiation can prolong network life span. In [16] designed the same WCV to charge multiple nodes at same time until nodes are within its charging range. They proposed joint optimization of travelling route, flow routing and charging time of WCV. In [17] analyzed the on-demand mobile charging problem using simple Nearest Job Next with Preemption technique for the routing requests placed to Mobile Charger (MC). In [18] studied a charging mechanism for mobile social and sensor networks which consists of human carried devices and investigated the problem of selecting MC set to prolong network lifetime. In [19] illustrate the effectiveness of Wireless Charging to maximize network lifetime using either On-Demand Recharging or Transmission Power Control or both. In [20] formulated the crisis of maximizing the sensor network lifetime via joint routing and charging (ML-JRC) and demonstrated the effectiveness of applying WCT to prolong network life span.

Hence, it is inferred that a heuristic algorithm for on-demand controlled wireless charging and routing is required to ensure the replenishment of energy level of critical nodes in the network. Our work proposes a distributed protocol, namely Residual Energy Based Mobile Agent protocol with Mobile Power Back Ferry (REMA-MPBF), to deal with energy consumption problem at network layer and also help to reduce total energy consumption of network to maximize network lifetime. To guarantee uninterrupted data transmission without any security lapse, REMA-MPBF architecture is proposed to preserve location privacy and ensure target detection. This has a momentous role in the energy conservation.

Hence, the proposed work focuses on introducing special MPBF nodes called multihop ferry node, which moves around MANET environment by shouldering the responsibility of on demand battery charging and also acts as gateway nodes for transmission of network control packets. A co-routing and charging mechanism is implemented with Residual Energy based Mobile

Agent (REMA) and MPBF's. We assume our network to be a heterogeneous network consisting of conventional MANET nodes with restricted energy resources and few MPBF nodes with comparatively copious energy sources. These MPBF's could periodically return to a docking station to recharge their power resources, which is not a part of this work. Once deployed these MPBF's collaboratively monitor the environment and process the request of critical node charging.

The remainder of this paper is organized as follows. In Section 2, presents the energy charging and consumption model. System architecture for a renewable MANET is described in section 3. The performance of the proposed schemes is evaluated in Section 4. We present numerical results to demonstrate the preferred choice of schemes for various scenarios and ultimately prove that the proposed joint routing cum charging is more suitable for MANET environments. Section 5 concludes the work with summary and future research directions in effective on demand recharging.

2. Energy Charging and Consumption Model

We consider a set of N nodes distributed over a 2D area. Each regular node has an initial full charge capacity of E_{full} and all nodes are assumed to have same battery full capacity. Let E_{λ} be the minimum level of energy at a node for it to be operational and W_{full} be the energy budget of MPBF. We investigate with few assumptions such as the wireless band used for charging is different from that of communication and negligible delay in MPBFs.

(i) Calculation of power reception rate of each node (W_i):

Let W_i be the effective amount of power charged by a critical node, where W_i is a distance – dependent parameter. Charging range 'D' is chosen such that the power reception rate W_i of a regular node 'i' is

$$W_i = \eta \, \Delta E_i \tag{1}$$

where, $\eta = \mu(D_i)$ is the efficiency of WPT, a decreasing function of D_i and $0 \le \mu(D_i) \le 1$ and ΔE_i is the amount of energy used by MPBF to charge a node 'i'.

(ii) Residual energy calculation of each source node'i':

Let $Sx_{i,j}$ be the total no. of packets transmitted from node 'i' to node 'j' and $e_{i,j}$ is the energy consumed to send one packet over the link from node'i' to node'j'.

$$e_{i,j} = L\gamma D_{i,j}^{n} \tag{2}$$

where, 'L' is no. of bits in a packet, n is the path loss index $2 \le n \le 4$ (3.3) and $\gamma = 0.001$

Then total energy consumed in transmitting Sx packets in a possible (disjoint) path from node'i' to node 'j' is given by

$$\mathbf{E}_{Sx_{i,j}} = \sum_{j \in N_i} Sx_{i,j}\, \mathbf{e}_{i,j} \tag{3}$$

Let E_{Res} be the residual energy at node 'i' and E_{Resr} is the residual energy of node 'i' at the beginning of round 'r'. Length of each round is δr.

Therefore, Remaining energy (E_{rem}) of a node 'i' after transmitting Sx packets after round 'r' is given by

$$E_{Rem} = E_{Resr} - E_{Sx_{i,j}} \tag{4}$$

A cost value $F(E_{Rem})$ is assigned to each node N_i along the possible path between node 'i' to node 'j' based on its remaining energy E_{Rem} is given by

$$[F(E]_{Rem}) = \frac{1}{E_{Rem}} \tag{5}$$

i.e. cost of using the node 'i' is high if E_{Rem} is very less.

Thus the total available battery life time B_{LT} along a path p is the sum of battery capacities of all the nodes along the path 'p' is given by,

$$B_{LT}^{p} = \sum_{N_i \in p} F(E_{Rem}) \tag{6}$$

The proposed algorithm aim at minimizing the overall energy consumption by choosing a path 'p'' with minimum number of nodes with maximum battery capacity $F(E_{Rem})$, given by

$$p' = \frac{min}{p \in P} [\max \mathbf{F}(\square] \, E_{Rem}) \tag{7}$$

The total no. of packets that can be delivered (TPD) by a node 'i' with the residual energy E_{Res} is given by

$$TPD_{cap\ i} = \frac{E_{Resr}}{e_{i,j}} \tag{8}$$

Life time of a node is calculated as

$$N_{LT} = \frac{TPD_{cap\ i}}{R} \tag{9}$$

where, 'R' is the rate of transmission in bps.

3. System Architecture

For hybrid mobile adhoc networks, energy conservation with the extended network connectivity and life time, Residual Energy based Mobile Agents Schemes are found to be appropriate. The network consists of source; destination and Residual Energy based Mobile agent (REMA) and connecting paths between the source and destination through REMA. REMA can transmit data with high power. Nodes cannot reply directly to the Destination due to their low power constraints. This will lead to asymmetric communication. Mobile Power Back Ferries as dynamic chargers, integrated with Residual energy based Mobile agent forms a complicated scheme REMA-MPBF where routing and charging are mutually independent. For improving the security aspects, source based secured authentication protocol SOBAS[21] is incorporated in the data gathering and data forwarding process. The target detection mechanism with Trail reference update is used MPBFs reaching the individual nodes. The system architecture for the Implementation of REMA-MPBF is shown in Figure 1.

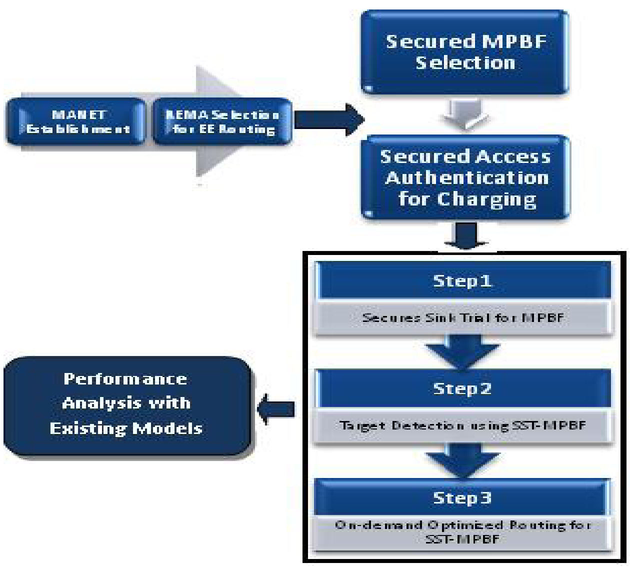


Figure 1. System architecture of REMA with MPBF.

4. Implementation of REMA - MPBF

The implementation of the proposed system architecture can be done in four steps

1. Selection of REMA
2. Selection of MPBF using SST Protocol
3. Security Access Authentication using SOBAS protocol
4. Target Detection using Secured Sink Trail

4.1 Residual Energy based Mobile Agent Selection Algorithm

The prime focus of implementing Residual Energy Based Mobile Agent Selection Algorithm is choosing the node with highest ranking energy. The sequence of steps involved in the selection is shown in Figure 2 and the concepts are explained:

4.1.1 REMA Selection (REMAS)

Based on the residual energy available at particular instance, all the nodes are observed and the node with maximum residual energy is selected for REMA

4.1.2 Dominator Mobile Agent Set Formation (DMASFM)

Based on the node selected for REMA, the broadcast note message is sent to all other node with location and message identity. All the nodes will select their REMA based on received signal strength, maximum degree of the node, high packet delivery ratio and close proximity. Then, all the nodes will send the acknowledge message to their REMA node. On reception of acknowledge message from the member nodes, REMA node will create the particular time schedule for each member set and will inform the time slot to individual members for their communication.

4.1.3 Data Forwarding (DF)

The data from member nodes will be forwarded to the REMA node on the allocation of time slot for the member set. REMA node, on receiving the data will implement the data aggregation process, compress the data and transfer it to the destination

4.1.4 Route Maintenance (RM)

The optimum route strategy is maintained throughout the data aggregation and forwarding mechanism. Route Maintenance will involve continuous updation of route with the existing routing table and the data forwarding and acknowledgement process.

To obtain optimality, REMA uses the ideal conditions as:

i) Each node work as a REMA or regular mobile node in a round.
ii) Energy consumption of REMA (E_a) and regular mobile node (E_m) are constant during the entire operation, where Ea ≥ Em.

Figure 2. REMA – selection sequences.

4.2 Selection of MPBF

Mobile Charges are used in short distance data communication paths with minimum energy consumption. Lot of researches is focusing on the study of identification of movement patterns of the mobile chargers. The proposed scheme uses Sink Trial mechanism for selection of MPBF which minimizes the node selection path and the target identification time contributing to reduced energy consumption. Using this mechanism, the critical nodes in the deployed MANET environment can send their recharging request through REMA to the MPBFs located in its communication range. Nodes estimate their energy consumption using equation 3, when the residual energy is below E_λ, where $E_\lambda = \theta_e E_{full}$, $0<\theta_e<1$, the mobile node will send a charging request to the MPBF node via REMA.

The mobile charger serves the received requests with NJNP. On selection of MPBF, the service Pool addresses the on-demand Wireless Charging based on Nearest Job Next with Preemption (NJNP) technique followed by target detection through which the MPBF receives the full knowledge about the network, including location of critical nodes and their REMA (Gateway Node). Moreover, Sink Trail mechanism is used to determine optimum numbers of MPBFs. The demonstration of Mobile Power Back based Queuing Model is shown in Figure 3.

4.3 Security Access Authentication using SOBAS Protocol

The implementation of Secure Source-Based Loose Synchronization (SOBAS) protocol in the proposed MANET environment with REMA is basically to synchronize the data flow in a secured manner without the transmission of explicit control messages. In SOBAS, local time value is used as one of the dynamic key values to encrypt the transmitted data. In this way malicious data is filtered by means of en-route filtering mechanism. Basically there are constituents of SOBAS protocol. Flow of SOBAS protocol is explained:

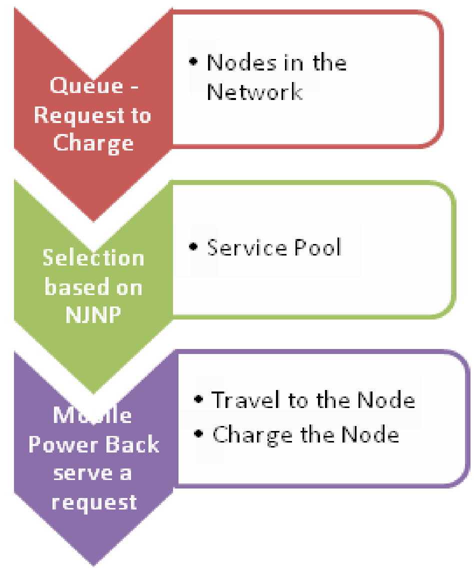


Figure 3. Demonstration of mobile power back based queuing model.

4.3.1 Time-based Key Management Module

In this module, key generation takes place for the data transmission from the source to the sink. Local clock value is used as key for encrypting the data. However, the system ensures the key selected is random using the current local time function, initialization vector and previous key value.

4.3.2 Crypto Module

The security part of the SOBAS protocol is taken care by Crypto module. The dynamic key generated from the previous module is obtained by the Crypto module and security services are implemented. The process is repeated until finding the appropriate key or the particular packet is marked as malicious and sent for discarding in Filtering Forwarding Synch Module.

4.3.3 Filtering-forwarding-synch Module

This module filters the packets marked as malicious by the Crypto module. All the other packets are forwarded to the upstream data path. Synchronization between the forwarder node and the source along the data path towards the sink node is also effected in this module.

4.4 Target Detection using Secured Sink Trail (SST)

Sink Trail is a dynamic data gathering and reporting model which is useful in various target detection and energy conservation mechanisms. Secured sink Trail (SST), Sink Trail with suppression of control messages is considered as a suitable mechanism for energy recharging using MPBF[22]. A unique logical coordinate representation is used to identify nodes using SST. For identifying the targets, i.e. critical nodes low complexity dynamic routing protocol is used. To suppress the control messages, Trail reference update with message suppression algorithm is used. The pseudo code for REMA_MPBF algorithm is shown in Table 1.

Table 1. REMA - MPBF

```
// Trail reference update with message suppression
algorithm//
For Data gathered through Unique Logical Coordinate
Representation
Assign Low Complexity Dynamic Routing Protocol
While
Data Gathering not completed
Do
//Receive Trail Message//
Msg Seq No > Most Recent Msg Seq No
Current Assigned Most Recent
If Current element  equal Next Hop Msg
Discard Message
Else
Shift left by one position
Rebroadcast Msg
Compare Current element with Next Hop Msg
If Msg Seq equals Incremented value
Rebroadcast Msg
Else
Discard Message
End While
//Reset variables
```

5. Simulation and Result Analysis

In the laboratory setup, following simulation parameters were taken for consideration for comparing the performance of REMA-MPBF with ALEEP_ with_ ACO and normal REMA. We use RWP mobility model, a widely used mobility model in MANETs. In this model each node chooses speed uniformly distributed over 5 to 20 ms-1. The simulation environment is shown in Table 2.

Table 2. Simulation environment

Simulation Parameter	Simulation Value
IEEE Standard	IEEE 802.11e(MANET)
Number of Nodes	50
Antenna type	Omni directional antenna
Antenna model	Two-ray ground/ Wireless network
Mobility Model	Random Waypoint (RWP)
Simulation Region	1500*1500
Bandwidth	1 - 2 Mbps
Base Protocol	AODV (Adhoc On-Demand Distance Vector)
Purpose	Residual Energy Based Mobile Agent selection scheme (REMA)
Improvisation	Mobile Power Backs using Sink Trail
Optimum Charger Nodes	5
Security	Secure SOurce-BAsed Loose Synchronization (SOBAS) protocol

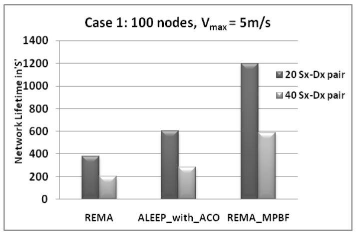
We study the performance of the proposed scheme as the Network traffic, node velocity and network density varies. The performance of the proposed scheme with heuristics is compared with existing protocols without charging (REMA and ALEEP_ with_ ACO).

5.1 Effectiveness of Network Lifetime with Varying Network Traffic and Node Mobility

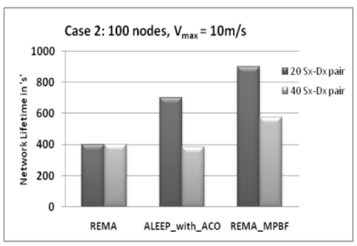
Network lifetime is defined as the time elapsed before the network fails to route a data packet from any of the REMA to destination. Node failure may be due to depleted source node or nonexistence of a route from REMA to destination due to sparse network density.

Case 1: Fixed node density with varying network traffic and velocity

The network life time is found to be reduced by half of the value observed with 20s-d pairs when the offered traffic load is increased to 40 s-d pairs for REMA and ALEEP_ with_ ACO, whereas it is constant irrespective of offered traffic in REMA-MPBF. This is because all critical nodes get recharged as they run out of energy and hence none of the nodes fail and since 100 nodes were considered, probability of nonexistence of single route is assumed to be zero. Irrespective of variable traffic load, in all three schemes the rate of improvement in network lifetime remains the same. Figures 4(a) and (b) shows the effectiveness of all three algorithms in a scenario of 100 nodes with node velocity of $5ms^{-1}$ / $10ms^{-1}$ and offered traffic 20 s-d pairs / 40 s-d pairs.



(a)

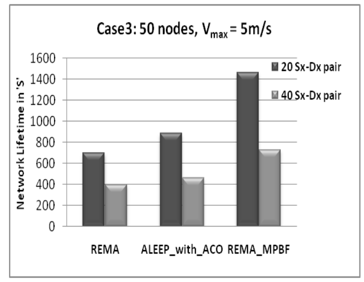


(b)

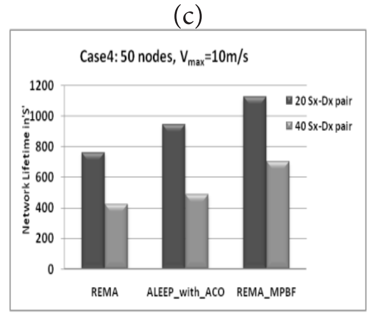
Figure 4. (a) and (b) Network Lifetime of three algorithms for variable node velocity and network traffic with fixed node density.

Case 2: Fixed Network density, offered traffic with varying node velocity

Figures 4(c) and (d) narrates that under lower mobility i.e. $5ms^{-1}$ the two no charging energy efficient routing protocols REMA and ALEEP_WITH_ACO yields lower network lifetime than high mobility conditions as high mobility achieves better fairness of node usage. But, REMA_MPBF yields higher network lifetime under low mobility, than high mobility. Under low mobility conditions, energy consumed for route discovery is relatively low and heavily used nodes were replenished with more energy.



(c)

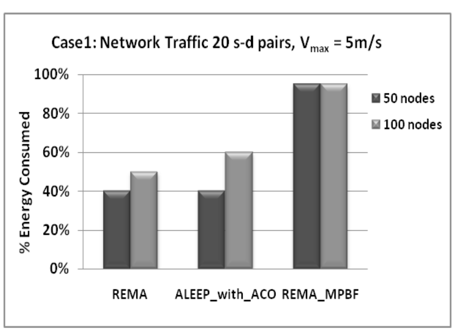


(d)

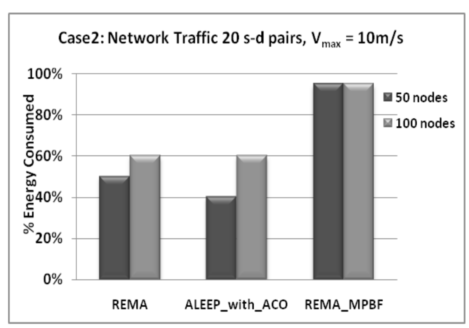
Figure 4. (c) and (d) Network Lifetime of three algorithms for variable node velocity and network traffic with fixed node density.

5.2 Energy Consumption with Varying Node Density

We conducted simulation with fixed number of sources with varying node density. Increased node density



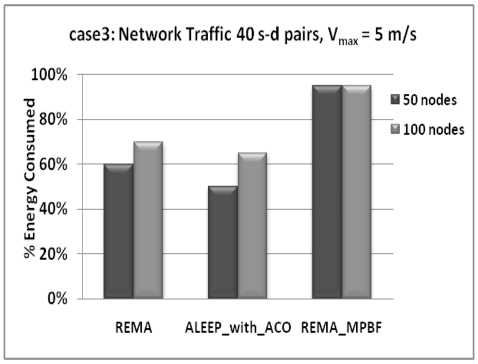
(a)



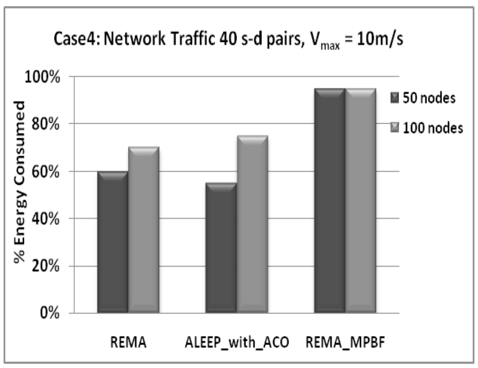
(b)

Figure 5. (a) and (b) % Energy consumption of three algorithms for variable node density and node velocity with fixed network traffic.

provides better option for multi routes with dynamic changing costs and distributed workload. Figure 5 shows that REMA_MPBF outperforms than other 2 schemes because routing and charging strategies are scheduled jointly.



(c)



(d)

Figure 5. (c) and (d) % Energy consumption of three algorithms for variable node density and node velocity with fixed network traffic.

Another important performance metric is to measure the overall network life time. We observe that REMA_MPBF incurred the maximum improvement in lifetime of about 60% compared to ALEEP_WITH_ACO with uneven transmission range and no charging. It shows 80% improvement compared to REMA, as it recharges the critical nodes lying on the DASFM path as long as the available energy budget is positive. Major advantage of ALEEP_WITH_ACO technique is consistent energy consumption. It consumes less energy as only one node REMA in the path has to transmit with more power. Therefore network lifetime is comparatively greater than REMA but less than REMA_MPBF. Figure 5 shows the performance of all schemes with changing node density. REMA utilizes minimum of maximum residual energy nodes with increased node density, as more nodes are available within transmission range. REMA's energy consumption is comparatively lesser than non-power aware routing protocols but significantly greater than ALEEP_WITH_ACO. (Figures 5(a), (b), (c) and (d)).

5.4 Transmission Delay with Varying Node Density

Transmission delay varies for each scheme with varying node density. In Figure 6, REMA shows lesser delay than other two schemes as it doesn't consider security and wireless charging mechanisms. This is mainly due to lesser no. of hops used by REMA for packet destiny. In ALEEP_WITH_ACO, though security mechanisms are considered, during packet delivery from REMA to destination fewer no. of gateway nodes are utilized as REMAs transmission range is greater than regular mobile nodes. Hence delay is lesser than compared to REMA –MPBF.

In REMA_MPBF, the delay is considerable but remains constant invariably, as it charges critical nodes and also act as gateway node for transmission of network control packets to prolong network lifetime. It's more suitable for Sparse and Delay Tolerant Networks (DTN). As node density increases, shortest path emerges making routing easier with increased timeslot for charging, causing increased delay beyond 100% increase in node density.

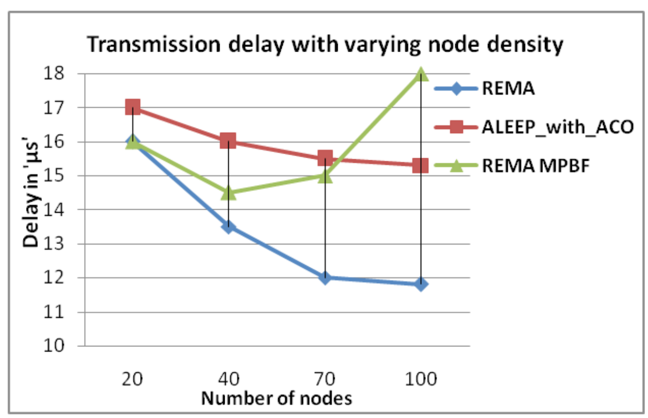


Figure 6. Transmission Delay of three algorithms with varying node density.

6. Conclusion

In the hierarchical MANETs, with use of mobile power back ferry nodes, the residual energy of the system has increased considerably which leads to increased network life time. The energy efficiency of the system is increased to the maximum by using secured sink trail with target detection mechanism. It is capable of tracking multiple nodes at simultaneous point of time through multiple logical coordinates. The security access authentication is added to the system by using secured source based authentication protocol. The Secure Sink Trail with SOBAS act as hybrid model for the mobile power backs. The simulation results highlight the improvement in network lifetime obtained with REMA-MPBF compared with no charging power aware routing protocols. Lightly used nodes have more energy left during network partitioning than heavily used nodes which contribute much to network failure whereas REMA_MPBF exploits this unfairness by charging maximum utilized nodes with more energy and with less energy for minimum utilized nodes, thereby helping to make the network alive forever. Results showed that REMA_MPBF outperforms than other 2 schemes because routing and charging strategies are scheduled jointly. Therefore, network lifetime is maximized in addition to improvisation of energy metrics such as energy conservation and residual energy by implementing REMA with mobile power back. As future work, we plan to study MPBFs coverage limitations and charging capability with moving cost of MPBFs for a system of IoTs.

7. References

1. Chellappan CS, Balaji S. Optimised energy efficient routing protocols and their performance comparison for MANETs. European Journal of Scientific Research. 2012; 90(1):136–42.
2. Hong X, Xu K, Gerla M. Scalable routing protocols for mobile adhoc networks. Journal of Networks. 2002; 16(4):11–21.
3. Vallikannu R, George A, Srivatsa SK. Autonomous localization based energy saving mechanism in indoor MANETs using ACO. Journal of Discrete Algorithms. 2015; 33:19–30.
4. Lingaraj K, Aradhana D. A survey on mobile agent itinerary planning in wireless sensor networks. International Journal of Computer and Communication Technology. 2012; 3(6):7–8.
5. Valikannu R, George A, Srivatsa SK. A novel energy consumption model using Residual Energy Based Mobile Agent selection scheme (REMA) in MANETs. Proceedings of 2nd IEEE International Conference on Signal Processing and Integrated Networks (SPIN); 2015. p. 334– 9.
6. Dyabi M, Hajami A, Allali H. A new MANETs clustering algorithm based on nodes performances. Proceedings of 5th IEEE International Conference on Next Generation Networks and Services (NGNS); 2014. p. 22–9.
7. Zhang S, He Z, Yang H. Mobile agent routing algorithm in wireless sensor networks. Journal of Advances in Computer Science and Information Engineering. 2012; 2:105–13.
8. Bendjima M, Feham M. Multi mobile agent itinerary for wireless sensor networks. International Journal of Emerging Trends & Technology in Computer Science. 2012 May–Jun; 1(1):6–11.
9. Shashank P, Daniel IJ. Energy harvesting technologies. Springer: New York, 1st Edition; 2009.
10. Ajmal T, Jazani D, Allen B. Design of a compact RF energy harvester for wireless sensor networks. Proceedings of IET Conference on Wireless Sensor Systems (WSS); 2012. p.1–5.
11. Kurs A, Karalis A, Moffatt R, Joannopoulos JD, Fisher P, Soljacic M. Wireless power transfer via strongly coupled magnetic resonances. Journal of Science. 2007 Jul; 317(5834):83–6.
12. Conti M, Giordano S. Multihop ad hoc networking: The reality. IEEE Communications Magazine. 2007 Apr; 45(4):88–95.
13. Peng Y, Li Z, Zhang W, Qiao D. Prolonging sensor network lifetime through wireless charging. Proceedings of 31st IEEE Real Time Systems Symposium; 2010. p. 129–39.
14. MIMO Broadcasting for simultaneous wireless information and power transfer [Internet]. [Cited 2013 Feb 15]. Available from: http://arxiv.org/abs/1105.4999.
15. Xie L, Shi Y, Hou YT, Sherali HD. Making sensor networks immortal: An energy-renewal approach with wireless power transfer. IEEE ACM Transactions on Networking. 2012 Dec; 20(6):1748–61.
16. Xie L, Shi Y, Hou YT, Lou W, Sherali HD, Midkiff SF. On renewable sensor networks with wireless energy transfer: The multi-node case. Proceedings of the 9th Annual IEEE Communications Society Conference on Sensor, Mesh and Ad Hoc Communications and Networks; 2012 Jun. p.10–18.
17. He L, Gu Y, Pan J, Zhu T. On-demand charging in wireless sensor networks: Theories and applications. Proceedings of IEEE 10th International Conference on Mobile Ad-Hoc and Sensor Systems; 2013. p. 28–36.
18. Bulut E, Ahsen ME, Szymanski BK. Opportunistic wireless charging for mobile social and sensor networks. Proceedings of IEEE Globecom Workshops, 6th IEEE International Workshop on Management of Emerging Networks and Services; 2014. p.12–14.
19. Meghanathan N, Judon LP. Improvement in network lifetime for on-demand routing in mobile adhoc networks using either on-demand recharging or transmission power

control or both. Journal of Computer and Information Science. 2010 Feb; 3(1):3–11.

20. Li Z, Peng Y, Zhang W, Qiao D. Study of joint routing and wireless charging strategies in sensor networks. Proceedings of 5th Wireless Algorithms, Systems, and Applications (WASA); 2010 Aug. p. 125–35.
21. Uluagac AS, Beyah RA, Copeland JA. Secure Source Based Loose Synchronization (SOBAS) for wireless sensor networks. IEEE Transactions on Parallel and Distributed Systems. 2013 Apr; 24(4):803–13.
22. Liu X, Zhao H, Yang X, Li X. SinkTrail: A proactive data reporting protocol for wireless sensor networks. IEEE Transactions on Computers. 2013 Jan; 62(1):151–62.