International Journal of Innovative Technology and Exploring Engineering (IJITEE)
ISSN: 2278-3075 (Online), Volume-2 Issue-5, April 2013

Reliable Data Delivery in Mobile Adhoc Networks Using Light Weight Verification Algorithm with High Node Mobility

S.M.Nandhagopal, S.N.Sivanandam

Abstract:- ***This paper addresses data aggregation and data packets issues for highly dynamic mobile ad hoc networks and Wireless Sensor Networks thereby leading to a timely and reliable reduction in both communication and energy consumption. But there might be node failures in existing systems and an aggregation framework does not address issues of false sub-aggregate values due to compromised nodes leading to huge errors in base station computed aggregates when data is transferred through mobile sensor nodes. It cannot also transfer data after nodes fail at the intermediate level. This paper proposes a novel lightweight verification algorithm and Position-based Opportunistic Routing (POR) protocol which reduces node failure and data loss issues. Theoretical analysis and simulation prove that POR and the novel lightweight verification algorithm achieve excellent performance under high node mobility with acceptable overhead. Also the new void handling scheme performs efficiently.***

Keywords: Geographic routing, opportunistic forwarding, reliable data delivery, void handling, mobile ad hoc network, Base station, data aggregation, hierarchical aggregation, in-network aggregation, sensor network security, synopsis diffusion

I. INTRODUCTION

Wireless sensor networks (WSNs) and MOBILE ad hoc networks (MANETs) are used increasingly in many applications [1] like wild habitat monitoring, forest fire detection, and military surveillance. After deployment in the field sensor nodes organize themselves into a multihop network, the base station being the central control point. Usually sensor nodes are greatly hampered by due to computation capabilities and energy reserves. A direct sensed information collection method from networks would be to forward each sensor node's reading to the base station, through other intermediate nodes, before the base station processes received data. But its disadvantage is its high cost regarding communication overhead (or energy spent).

Manuscript published on 30 April 2013.
***Correspondence Author(s)**
S.M.Nandhagopal, Research Scholar, Assistant Professor, Department Of Computer Science and Engineering, Easa College of Engineering and Technology, Coimbatore - 641105, Tamil Nadu, India.
Dr.S.N.Sivanandam, Professor Emeritus, Department Of Computer Science and Engineering, Karpagam College of Engineering,Coimbatore-641032, Tamil Nadu, India.

Wireless networks gained interest due to advantages brought about by multihop, infrastructure-less transmission. However, high node mobility remains an issue due to error prone wireless channels and dynamic network topology, affecting even reliable data delivery in MANETs, especially in challenged environments. Conventional topology-based MANET routing protocols (e.g., DSDV, AODV, DSR [1]) are vulnerable to node mobility a reason being predetermination of an end-to-end route before data transmission. Due to constantly and fast changing network topology, deterministic route maintenance is a problem. Discovery and recovery procedures consumer both time and energy. Data packets are either lost or delayed for long once a path breaks, until route reconstruction leading to transmission interruption.

Computing aggregates in-network (combining partial results at intermediate nodes during message routing) in large WSNs significantly lowers the amount of communication and the resultant energy consumed. Data acquisition systems for WSNs [2], [3] construct a spanning tree rooted at the base station to perform aggregation along the tree. Important aggregates considered include Count, and Sum. It is straightforward to generalize aggregates to predicate Count (e.g., sensors with readings higher than 100 units) and Sum. Also, Count and Sum can be used to computer Average. Sum algorithm can also compute Standard Deviation and Statistical Moment of any order. Tree-based aggregation approaches do not accept communication losses due to node and transmission failures, common in WSNs.

Location information is used by geographic routing (GR) [2] to forward data packets, in hop-by-hop routing fashion. Greedy forwarding selects the next hop forwarder with biggest progress toward destination while void handling mechanism to route around communication voids [3]. There is no need to maintain end-to-end routes, leading to GR's efficiency and scalability, but it is sensitive to location information [4] inaccuracy. In greedy forwarding operations, a relatively far away neighbor is selected as the next hop. When the node goes away from the sender's coverage area, transmission fails. In GPSR [5] (a famous geographic routing protocol), the MAC-layer failure feedback offers packet another reroute chance. But simulation reveals that it is incapable of maintaining performance when node mobility increases. A single packet transmission leads to multiple reception due to the broadcast nature of the wireless medium. When such transmission is the backup, the routing protocol's robustness is greatly enhanced.

Published By:
Blue Eyes Intelligence Engineering and Sciences Publication (BEIESP)

Opportunistic routing [6], [7], [8] demonstrated multicast-like routing strategy.

This paper addresses this problem. The research community proposed using multipath routing techniques to forward sub-aggregates [2]. Aggregates like Min and Max are duplicate-insensitive and so this approach provides a fault-tolerant solution.A novel Position-based Opportunistic Routing (POR) protocol where several forwarding candidates' cache packets using MAC interception was proposed. When the best forwarder fails to forward packets in certain time slots, suboptimal candidates forward them in turns in a locally formed order. So, as long as one candidate successfully receives and forwards packets, data transmission is uninterrupted. Possible multipath is exploited on a per packet basis on the fly, leading to excellent robustness for POR.

The rest of this paper is organized as follows: we present the protocol design of POR and complementary mechanisms in Section 2. VDVH is depicted in Section 3. Section 4 analyses the effect of node mobility on packet delivery and reveals the benefits brought about by the participation of forwarding candidates. Redundancy in POR, including memory consumption and duplicate relaying due to opportunistic forwarding will also be discussed. In Section 5, we evaluate the performance of proposed schemes by simulation and compare them with other routing protocols. Section 6 reviews the related work and conclusions are given in Section 7.

II. POSITION-BASED OPPORTUNISTIC ROUTING

2.1 Overview

POR design is based on geographic routing and opportunistic forwarding. The nodes are thought to be aware of their location and their direct neighbor's positions. Neighborhood location information is exchanged through a one-hop beacon or through riding piggyback in the data packet header. It is thought that location registration and lookup service that map node addresses to locations is available as in [5] for the destination position. This can be realized through use of many types of location service [11], [12]. In this scenario, efficient and reliable ways are also available. Destination location can be transmitted by low bit rate and long range radios, which are implemented as periodic beacons, as well through replies when the source requests it.

When a source node plans to transmit a packet, it gets destination location first after which it is attached to the packet header. Because of the destination node's movement, a multihop path may diverge from the final location's true location with a packet being dropped even if it has been delivered in the destination neighborhood. Additional destination node checks are introduced to handle such issues. The packet forwarding node checks the neighbor list at every hop to see whether destination is within transmission range. If so, the packet is directly forwarded to the destination, similar to destination location prediction scheme described in [4]. Though such identification checks prior to greedy forwarding based on location information, path divergence effect can be alleviated.

For a packet to be received by multiple candidates in conventional opportunistic forwarding either IP broadcast or a routing integration and MAC protocol is adopted. The former is vulnerable to MAC collision due to lack of collision avoidance support for broadcast packet in current 802.11, while for the latter it needs complex coordination whichis not easy to implement. POR uses a scheme similar to the MAC multicast mode described in [13]. The packet is transmitted asunicast (the best forwarder making the largest positive progress towards destination becomes the next hop) in IP layer and multiple reception is through MAC interception. Use of RTS/CTS/DATA/ACK greatly lowers the collision and nodes within the sender's transmission range could eavesdrop on a packet successfully with good probability due to medium reservation.

As data packets are transmitted multicast-like each is identified with a unique tuple (src_ip, seq_no) where src_ip becomes the IP address of source node and seq_no the corresponding sequence number. Each node has a monotonically increasing sequence number, and an ID Cacheto record packets ID (src_ip, seq_no) which were received recently. Receipt of a packet with same ID results in it being discarded. Otherwise, it is forwarded to the receiver to the next hop, orstored in a Packet List if received by a forwarding candidate. It is dropped when the receiver isnot specified. The packet in the Packet List is sent out after awaiting a specific number of time slots or discarded if the same packet is received again during the waiting period (this means a better forwarder has already carried out the task).

POR's routing scenario is illustrated in Fig. 1. In a normal situation sans link break, the packet is forwarded by the next hop node (nodes A, E) and forwarding candidates (nodes B, C; nodes F, G) are suppressed (the same packet in Packet List is dropped) by the next hop node's transmission. If node A fails to deliver the packet (node A has moved out and so cannot receive the packet), node B, the forwarding candidate with high priority relays packet and suppresses the lower priority candidate's forwarding (node C) and node S. By using MAC layer feedback, node S removes node A from neighbors list and selects a new next hop node for the subsequent packets. The interface queue packets taking node A as the next hop get a second chance to reroute. A packet pulled back from MAC layer will not be rerouted if node S overhears node B's forwarding.

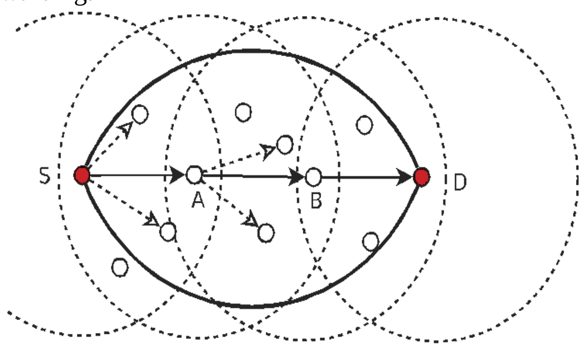

Figure 1: Position-Based Opportunistic Routing

2.2 Selection and Prioritization of ForwardingCandidates

One of POR's main problems is selection and prioritization of forwarding candidates. Only forwarding area nodes [14] would be backup nodes.The sender decides the forwarding area and the next hop node.

A forward area node meets the following two conditions: 1) it makes positive progress toward the destination; and 2) its distance to the next hop node should not be more than a wireless node's half transmission range (i.e., R=2) so that all forwarding candidates can hear from one another. In Fig. 1, the forwarding area is that enclosed by the bold curve.The area nodes beside node A (i.e., nodes B, C), are potential candidates. Of the required number of backup nodes, some will be selected as forwarding candidates. A forwarding candidate's priority is decided by its distance to the destination. The nearer the destination, higher is the priority. When a node sends or forwards a packet, it selects the next hop forwarder and also the forwarding candidates among neighbors. The forwarder list includes next hop and the candidate list. Algorithm 1 provides the method to select/prioritize the forwarder list. Candidate list is attached to the packetheader and updated hop by hop. Only candidates list specified nodes will be forwarding candidates. The lower the node's index in the candidate list, the higher its priority. Before calculating a new forwarder list, it refers to the forwarding table, to see whether a valid item for that destination is still available. The forwarding table built during data packet transmissions is maintained easily than a routing table. It could also be considered a trade-off between efficiency and scalability. As forwarding table establishment is based on local information it is constructed in minimum time. Hence, an expiry time can be set on items maintained to keep the table small. The table records only current active flows, while in traditional protocols, route expiry time decrease would need more resources to reconstruct.

2.3 Limitation on Possible Duplicate Relaying

Due to nodes' movement and collisions, a few forwarding candidates might not receive a packet forwarded by next hop node or a higher priority candidate, resulting in some duplicate relaying. When the forwarding candidate adopts the same scenario as a next hop node, it also calculates a candidate list and in a worst case scenario, a packet's propagation area will include the whole circle with the destination as the center and the radius could be equal to the distance between source and destination. To limit duplicate relaying, only source forwarded packet and the next hop node are transmitted in an opportunistic fashion and cached by multiple candidates. In other words, only source and next hop node calculate the candidate list, while it is empty for the packet relayed by a forwarding candidate. Thus, a packet's propagation area is limited to a certain band between source and destination. Also, with ID cache, duplicate packets are quickly dropped without being propagated further.

2.4 MAC Modification and Complementary Techniques

2.4.1 MAC Interception

The broadcast nature of 802.11 MACis leveraged: nodes within sender range receive the signal. But its RTS/CTS/DATA/ACK mechanism is only fit for unicast. It sends data to all broadcast packets with CSMA. Hence, collision based packet loss dominates multicast-like routing protocols performance. Here, packet transmission scenario was altered. A packet is sent via unicast in a network layer, to the best node elected by greedy forwarding as the next hop. This ensures full utilization of the collision avoidance supported by 802.11 MAC. On the receiver side, MAC-layer address filter is modified, even when data packet's next hop is not the receiver. It is delivered to the upper layer with a hint in the packet header proving this packet was overheard. POR further processes it. So, benefits of broadcast and unicast (MAC support) can be achieved.

III. RELATED WORKS

Castelluccia et al [13] proposed a simple and provably secure encryption allowing encrypted data to be efficiently and additively aggregated. Only a modular addition is needed for cipher-text aggregation. Scheme security is based on the in distinguish ability property of a pseudorandom function (PRF), a standard cryptographic primitive. It was proved that aggregation based on this can efficiently compute statistical values, like mean, variance, and sensed data's standard deviation, while achieving great bandwidth savings. To protect aggregated data's integrity, an end-to-end aggregate authentication scheme was constructed which was secure against outsider-only attacks. Su et al [14] suggested a method to achieve optimal rate allocation for data aggregation in wireless sensor networks. First, a rate allocation problem was formulated as a network utility maximization problem., A couple of variable substitutions on the original problem was made due to its non-convexity and transformed it into an approximate problem, which is convex. Then duality theory was applied to decompose the approximate problem into a rate control sub-problem and a scheduling sub-problem. Based on this, a distributed algorithm for joint rate control and scheduling is designed, and was proved to approach arbitrarily close to the optimum of the approximate problem. Theoretical analysis/simulations prove that approximate solution can achieve near-optimal performance. Boppana et al [15] evaluated two representative SDA schemes realistically using TOSSIM simulator for analyses. To validate data aggregation techniques implementation of data was through use of an analytical model. Results reveal that it is important to reduce transmitted packets number than the overall number of bits transmitted. With low duty cycles and low sensor data generation probability, even simple concatenation of sensor data, which lowered the number of packets transmitted, was as effective as the more sophisticated SDA schemes; when sensor data are generated more frequently, SDA schemes that do not require intermediate nodes decrypt sensor data to give 10% higher network lifetime. Daabaj et al [16] developed a reliable load-balancing routing (RLBR) protocol for network lifetime maximization based on reliability-oriented protocols and traditional energy-aware routing protocols. RLBR uses Channel State Information (CSI) e.g., RSSI and LQI, link estimation based on packet transmissions e.g., success reception ratio (PRR) and packet error ratio (PER), and residual energy capacity including other parameters, e.g., source id, CRC, hop count, aggregation load, and latency to form a cost function for selecting the most reliable and energy efficient route towards the base station. In other words, RLBR lowered energy consumed for packet transmissions by embedding routing information in overheard packets and lowering control traffic. Hence, it maintains low packet error ratio and improves packet delivery while minimizing redundant packet transmission and/or retransmissions throughout the network..

Published By:
Blue Eyes Intelligence Engineering
and Sciences Publication (BEIESP)

It allows adaptation of amount of traffic to network fluctuations connectivity and energy expenditure.

Virmani et al [17] proposed DLMT and CLMT algorithms to extend node life. Decentralized lifetime maximizing tree (DLMT) is part of nodes with increased energy to be chosen as data aggregating parents while Centralized Lifetime Maximizing Tree (CLMT) showcases features with bottleneck node identification to collect data centrally among a given set of nodes. Simulation results reveal that functional lifetime is enhanced by 147% when data is aggregated via DLMT and by 139% when data is aggregated via CLMT. Proposed DLMT algorithm revealed 13% additional lifetime saving without increasing delay. In Figure 2, Packet delivery ratio shows remarkable increase when the tree depth is considered in these tree structures.

Peng et al [18] suggested a reliable data aggregation/ dissemination framework with regard to tactical networks. The framework combines disruption tolerant networking advantages and an adaptive sensor data aggregation method to ensure reliable data delivery. Experimental prototype system architecture was developed and implemented to demonstrate capabilities of the suggested data aggregation and dissemination framework. A relevant demonstration scenario based on a data aggregation map was developed for system evaluation. In Figure 3, test results showed that the proposed framework inferred meaningful messages from raw sensor data accurately and reliably delivered messages to correct destinations. This proposed framework could be lasting solution benefitting current and future system-level design of tactical network architectures.

IV. ANALYSIS

Theoretical analysis on POR's robustness and overhead inclusive of memory consumption and duplicate relaying will also be discussed in this section. As the focus is on node mobility, an ideal wireless channel is assumed and unit disc graph model used by default: a link between two nodes exists if the distance between them is less than a specific threshold. When two nodes are located within each other's' coverage range (R), failure proof bidirectional data transmission between them is achieved.

POR's main concern is its overhead because of opportunistic forwarding, as several packet copies need to be cached in forwarding candidates resulting in more memory consumption, and duplicate relaying. This becomes possible if the suppression scheme fails due to node mobility. But it will be presented later as a not serious problem.

Only node mobility forwarding failure is considered and the effect of unreliable wireless links is not taken into account. It is felt that in light traffic case with MAC layer implemented scheme, node mobility is thought to be the main factor that leads to packet forwarding failure.

V. PERFORMANCE EVALUATION

To evaluate POR performance, the algorithm was simulated in various mobile network topologies in NS-2. It was compared with AOMDV (a multipath routing protocol) and GPSR (a representative geographic routing protocol). Common parameters were utilized in the simulations.

Improved random way point without pausing is used to model nodes' mobility with minimum node speed being set to 1 m/s. The maximum speed is varied to change network mobility degree. The following metrics compare performance:

- Packet delivery ratio: The ratio of data packets number received at the destination(s) to the data packet number sent by source(s).
- End-to-end delay: The average and median end-to-end delay are evaluated, along with cumulative delay distribution function.
- Path length: Average end-to-end path length (number of hops) for successful packet delivery.
- Packet forwarding times per hop (FTH): Average times a packet is forwarded from routing layer perspective to deliver data packet over each hop.
- Packet forwarding times per packet (FTP): The times a packet is forwarded from routing layer perspective to deliver data packet from source to destination.

Among metrics, FTH and FTP evaluate the amount of duplicate forwarding. For unicast style routing protocols, packet reroute caused by path break accounts for FTH being greater than 1. But for packets which are not delivered to destination(s), efforts already made in forwarding packets is still considered in FTH calculations.

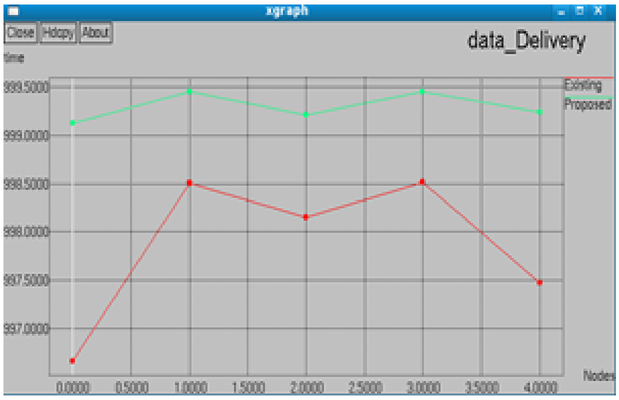

Figure 2. Analytical delivery time ratio versus node ability

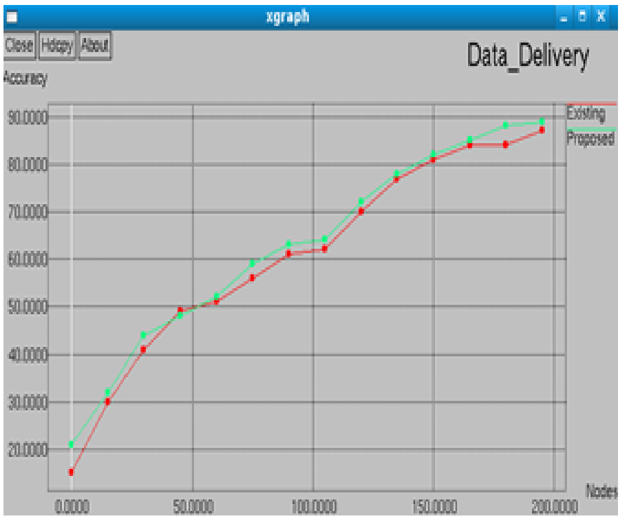

Figure 3. Analytical delivery Accuracy ratio versus node ability

Published By:
Blue Eyes Intelligence Engineering and Sciences Publication (BEIESP)

VI. CONCLUSION

This paper addresses the problem of reliable data delivery in highly dynamic MANETs. Constantly changing network topology makes conventional ad hoc routing protocols incapable of satisfactory performance. In case of constant link breaks due to node mobility, substantial data packets will be lost or undergo long latency before connectivity is restored. Inspired by opportunistic routing, a novel MANET routing protocol POR which takes advantage of geographic routing's stateless property and the broadcast nature of wireless medium is proposed In addition to selecting next hop, several forwarding candidates are specified in case of link break. Leveraging on natural backup in the air, broken routes are recovered in time. The involvement of forwarding candidates against node mobility and overhead due to opportunistic forwarding is analyzed. Simulation further confirms POR's effectiveness: high packet delivery ratio is achieved with low delay and duplication.

VII. ACKNOWLEDGMENTS

This work was supported by the Agency for Science, Technology, and Research (A*STAR) of Singapore (Grant number: 0721010028 - M47020034).

REFERENCES

1. Madden, S., Franklin, M. J., Hellerstein, J. M., & Hong, W. (2002). TAG: A tiny aggregation service for ad-hoc sensor networks. ACM SIGOPS Operating Systems Review, 36(SI), 131-146.
2. Law, Y. W., Palaniswami, M., &Phan, R. C. W. (2009). Secure Data Aggregation in Wireless Sensor Networks. Guide to Wireless Sensor Networks, 533-559.
3. Considine, J., Li, F., Kollios, G., & Byers, J. (2004, March). Approximate aggregation techniques for sensor databases. In Data Engineering, 2004. Proceedings. 20th International Conference on (pp. 449-460). IEEE.
4. Garofalakis, M., Hellerstein, J. M., &Maniatis, P. (2007, April). Proof sketches: Verifiable in-network aggregation. In Data Engineering, 2007. ICDE 2007. IEEE 23rd International Conference on (pp. 996-1005). IEEE.
5. Yu, H. (2011). Secure and highly-available aggregation queries in large-scale sensor networks via set sampling. Distributed Computing, 23(5), 373-394.
6. Frikken, K. B., & Dougherty IV, J. A. (2008, March). An efficient integrity-preserving scheme for hierarchical sensor aggregation. In Proceedings of the first ACM conference on Wireless network security (pp. 68-76). ACM.
7. Broch, J., Maltz, D. A., Johnson, D. B., Hu, Y. C., &Jetcheva, J. (1998, October). A performance comparison of multi-hop wireless ad hoc network routing protocols. In Proceedings of the 4th annual ACM/IEEE international conference on Mobile computing and networking (pp. 85-97). ACM.
8. Karp, B., & Kung, H. T. (2000, August). GPSR: Greedy perimeter stateless routing for wireless networks. In Proceedings of the 6th annual international conference on Mobile computing and networking (pp. 243-254). ACM.
9. Arad, N., &Shavitt, Y. (2009). Minimizing recovery state in geographic ad hoc routing. Mobile Computing, IEEE Transactions on, 8(2), 203-217.
10. Ganesan, D., Govindan, R., Shenker, S., &Estrin, D. (2001). Highly-resilient, energy-efficient multipath routing in wireless sensor networks. ACM SIGMOBILE Mobile Computing and Communications Review, 5(4), 11-25.
11. Ye, Z., Krishnamurthy, S. V., &Tripathi, S. K. (2003, March). A framework for reliable routing in mobile ad hoc networks. In INFOCOM 2003. Twenty-Second Annual Joint Conference of the IEEE Computer and Communications. IEEE Societies (Vol. 1, pp. 270-280). IEEE.
12. Rozner, E., Seshadri, J., Mehta, Y., &Qiu, L. (2009). SOAR: Simple opportunistic adaptive routing protocol for wireless mesh networks. Mobile Computing, IEEE Transactions on, 8(12), 1622-1635.
13. Castelluccia, C., Chan, A. C., Mykletun, E., &Tsudik, G. (2009). Efficient and provably secure aggregation of encrypted data in wireless sensor networks. ACM Transactions on Sensor Networks (TOSN), 5(3), 20.
14. Su, L., Gao, Y., Yang, Y., & Cao, G. (2011, May). Towards optimal rate allocation for data aggregation in wireless sensor networks. In Proceedings of the Twelfth ACM International Symposium on Mobile Ad Hoc Networking and Computing (p. 19). ACM.
15. Boppana, R. V., &Panp, P. (2009, December). A comparison of secure data aggregation schemes for wireless sensor networks. In High Performance Computing (HiPC), 2009 International Conference on (pp. 179-188). IEEE.
16. Daabaj, K., Dixon, M., Koziniec, T., & Murray, D. (2010, October). Reliable data delivery in low energy ad hoc sensor networks. In Communications (APCC), 2010 16th Asia-Pacific Conference on (pp. 188-193). IEEE.
17. Virmani, D., & Jain, S. (2013). Performance Comparison of Proposed Lifetime Maximizing Trees for Data Aggregation in Wireless Sensor Networks. arXiv preprint arXiv:1301.3997.
18. Peng, A. S., Moen, D. M., Spinks, J. A., Meredith, L. M., He, T., &Lilja, D. J. (2010, October). Reliable data aggregation and dissemination framework in tactical network architecture. In MILITARY COMMUNICATIONS CONFERENCE, 2010-MILCOM 2010 (pp. 569-574). IEEE.

AUTHOR PROFILE

Mr.S.M.Nandhagopal completed his B.E. (Computer Science and Engineering) in 2004 from Dr.Pauls Engineering College under Madras University and M.E. (Computer Science and Engineering) in 2009 from Vellalar College of Engineering & Technology under Anna University, Coimbatore. Currently he is pursuing PhD degree from CMJ University, Meghalaya. He is working as an Assistant Professor, Department of Computer Science and Engineering at Easa College of Engineering & Technology, Coimbatore. He is a member of various professional bodies like ISTE, IEEE and IAENG. His research areas include ADOC networks, and Wireless Sensor Networks and having 7 years of teaching experience in Engineering Colleges.

Dr. S. N. Sivanandam completed his B.E. (Electrical Engineering) in 1964 from Government College of Technology, Coimbatore, and MSc (Engineering) in Power Systems in the year 1966 from PSG College of Technology, Coimbatore. He acquired PhD in control systems in 1982 from Madras University. He received best teacher award in the year 2001 and Dhakshina Murthy Award for teaching excellence from PSG College of technology. He received the citation for best teaching and technical contribution in the year 2002, Government College of Technology, Coimbatore. His research areas include Modelling and Simulation, Neural Networks, Fuzzy Systems and Genetic Algorithm, Pattern Recognition, Multidimensional system analysis, Linear and Non linear control system, Signal and Image processing, Control System, Power System, Numerical methods, Parallel Computing, Data Mining and Database Security. He is a member of various professional bodies like IE (India), ISTE, CSI, ACS and SSI. He is a technical advisor for various reputed industries and engineering institutions.