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A Framework for Efficient Routing in MANET using Index Routing Tables-based Algorithms

Gundala Swathi* and R. Saravanan

Vellore Institute of Technology University, Vellore - 632 014, India
**E-mail: gundalaswathi@vit.ac.in*

ABSTRACT

Conventional network routing protocols rely on predefined numerical network unique node ID or group identifier for packet delivery, independent of semantic applications. This compels incorporation of resource/service discovery approaches in the design itself, at higher layers of network, causing additional overhead. This overhead, though tolerable in high speed wired networks, significantly restricts the performance in the infrastructure-less wireless ad hoc networks expending their limited battery resources, which are already consumed due to assigning unique identifiers to the naturally anonymous and high mobile nodes. This study proposes a single routing approach which facilitates descriptive and semantically-rich identification of network's resources/services. This fusion of the discovery processes of the resources and the path based on their similarity in a single phase significantly reduces traffic load and latency of communication considering the generality too. Further, a framework capable of exploiting application-specific semantics of messages, adaptable to diverse traffic patterns is proposed. Analytical results amply illustrate the scalability and efficacy of the proposed method.

Keywords: Network routing, single routing approach, semantic-rich destination

1. INTRODUCTION

The concentration of the current research is on the design techniques and methods to enable cyber physical systems and ubiquitous service environments, with mobile ad hoc networks in focus, leading to the development of diverse protocols and architectures for MANETs. Wireless networks rely heavily on collaborative operation of the involved nodes due to the communication and computational resource constraints of the individual nodes, making the maintenance and management of network resources expensive in proportion to the number of nodes requiring to be addressed individually. Node non-reliability and absence of infrastructure make routing most challenging in MANETs. Several proposed applications still depend on such applications which provide unique identifiers of nodes. This requires another protocol for resource discovery which enables the sender to establish the destination node identifiers for communication. At present, this is the job of middle-ware. Separation of route and service discoveries enhances network control traffic, draining the nodes' batteries faster. For instance in AODV[19], the same employed broadcast for an on-demand route discovery could also cover the resources using the same control packets. This duplication-avoiding process saves another storm of broadcast on network.

Non-renewable sources of energy are yet another major problem in certain MANET applications requiring longevity. Any attempt by technologies to optimise node's energy efficiency, only delays the issue with no proper solution. MANETs need to tolerate node death and instantly integrate and deploy the progressive nodes compensating the failed nodes. The design of MANET's protocols and architectures need to accommodate alterations in the network's basic resources, mission, connectivity or QoS needs. The structure and behaviour of the network must be adaptable to the corresponding changing run-time environments and requirements, for longevity of such applications encountering alterations in resources and/or mission in their life time. This research study proposes a novel routing approach which exploits destination descriptors profiles of generic node identification to accomplish both path and service/resource discoveries in a single phase with the following advantages:

- Dynamic discovery and addressing
- Optimisation of routing through exploitation of semantics of application layer
- Intrinsic multicast, and
- Maintenance of node anonymity.

Analytical evaluation has established this proposed framework to be highly scalable with minimal overhead of advertisement.

2. RELATED WORK

In spite of the apparent differences between the routing protocols of WSNs and MANETs, their technical requirements

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remain much the same, as a result of the development of multi-purpose shared WSNs. There is a dire need to integrate both the protocols into cyber-physical systems of greater magnitude. Hence, any differentiation between their patterns of communication is invalid. For instance, content-based routing is preferred in MANETs[3] to the address-based routing. Wireless sensor network WSN[4] study secure process of node-to-node communication, while an integrated routing layer is proposed for both[5]. Routing depending on addressing scheme is proposed in this paper.

Data-centric routing: The requested data content is the basis of routing in data-centric routing, also known as content-based routing, with the applications remaining oblivious of terminal points of communication. The layers of network and application are usually inseparable. DataTinyDB[6,7] as well as EnviroTrack[8] can be cited as instances of middleware systems adopting this routing.

Service-centric routing: The routing in network is driven also by the on-request service profile. Applications here, as in data-centric routing remain, oblivious to the end points of communication, with the network and application layers staying usually inseparable. Service oriented architecture (SOA) in WSNs and MANETs enables the functionality of service-centric routing such as the reliable adaptable service-driven efficient routing[9].

Communication-centric routing: Network routing depends on destination addresses of terminal points to enable communication between them. Protocols of this routing are the most generic and do not condition communication pattern or application programming paradigm. The network layer is separable from application layer with distinct boundaries. This routing is further classified into two subclasses:

1) Identifier-based routing: Destination identification is on the basis of the unique identifiers of the groups or nodes with direct mapping between the nodes and the identifiers.
2) Identification Static addressing: The node is identified using a global unique address in the network which stays static without change in changing locations. This routing protocol is very common in MANETs as for instance, AODV[1].

Self-motivated addressing: The node identifier and its network address are decoupled with changing network address based on the changing locations with the help of dynamic mapping of node identifiers. The distributed hash tables are DART[11] and its multi-path alternative M-DART, for this purpose.

Associative routing: Descriptive addressing is employed to identify the destination, with no direct mapping of multicast groups or specific nodes.

3. PROPOSED METHOD

The proposed routing method uses semantic-rich destination descriptors in place of semantic-free ones, dynamically binding the nodes at routing. Here, nodes are identified by the services they provide or share, or other application-relevant attributes and not by their unique identities. The identification of the nodes is verifiable against the destination descriptors (who will deliver the packet, we can define as destination descriptors)to determine the path for the packet to travel. With minimal changes in transport layer protocols, routing can be supported to permit the destination descriptors to the protocols of routing. Protocols based on address can be applied through routing framework by inclusion of a numeric field to define destination descriptors. DART[11] presents the concept of employing dynamic addressing to surmount scalability constraints in ad hoc routing protocols, by preserving the identities of the node identifiers and their respective network addresses, while maintaining a distinction between them. This indirection of address in routing increases the scalability considerably. Proposed routing dynamically maps the descriptors based on attribute to physical nodes, devoid of explicit node identifiers, different from DART with direct mapping of the specified data packet destination and the packet-delivered physical nodes. Several diverse destination descriptors could lead to the same node or the same descriptor could lead to diverse nodes or groups of nodes as per the changes in the attributes. For instance, if the level of battery in a node is dropped, it is disqualified for a descriptor, which it used to qualify previously. Thus, proposed routing is an attractive solution for large scale routing of dynamic topologies such as sensor networks.

3.1 Advantages of Proposed Routing Method

Major advantages in the proposed routing:

Efficiency: The proposed routing method enables a combination of route discovery service/resource discovery in the design resulting in reduced traffic overhead and communication latency, and enhanced network lifetime with devices using battery.

Dynamic identification and addressing: Routing addressing increases scalability in larger networks of dynamic topologies and rapid mobility better than the static addressing with serious limitations of scalability. Further, network resilience is enhanced by permitting the fail-over to nodes of equal attributes.

Ability to achievement in application layer semantic to elevate routing: The semantics-rich pattern of route addressing enables the protocols of routing to acclimatise to application semantics.

Intrinsic multicast: Instead of the nodes explicitly joining the multicast groups, the sender could identify a end descriptor capable of matching any quantity of nodes at any particular time, thereby reducing the overheads of forming group.

Privacy: In case of any need for privacy, the designers or routing protocols could hide the node identity as the senders need not be aware of the identifiers of the destination nodes. This proves convenient to manipulate great number of anonymous nodes present in sensor networks. Effective routing should envisage the requirements of service-centric and data-centric networks defining destinations in generic manner. The resultant network design enables maintenance of layer boundaries in the required networks, different from the current all-in-one approaches of design. Our proposed routing framework uses the model of targeted messaging allowing message exchange between the source and target group of nodes. The identification profile and destination descriptor are defined by the routing agent, while the source node produces the destination descriptor object and defines its criteria for targeting. A targeted message can be defined as a network packet transporting application data as its payload and the destination descriptor for the variable length header. The sender side application agent after instantiating a destination descriptor and configuring the same as per its targeting needs passes it to the transport agent, specifying it as the destination address. The transport agent in turn, devises a targeted message to forward it to the routing agent, which decides the procedure for forwarding the packet as per the implemented protocol or/and its maintained routing table. When the routing agent receives the message from the lower layers, it picks up the destination descriptor contained in the message and verifies it with the identification profile of the node. If a match occurs, then the destination descriptor is sent to the local agent of transport for further transmission to the application agent, or else decision for forwarding is made. If multicast functionality is implemented, the routing agent can still transmit the target messages which match the local profile of identification.

4. DISTRIBUTED ROUTING

A totally distributed routing, based on the previously presented concepts, is presented in this section. Only the designated nodes take part in the routing role and not all the network nodes, such as resource node or router nodes, either in routing or to maintain tables of routing information. The resource nodes need to be in the single hop connectivity range of one router node at least, deciding either to take part in the routing or not. The algorithm of location-aware affinity propagation (LAP)[17] is employed for choosing a completely connected cluster of router nodes and establishing neighbourhood lists. Every resource node registers itself with just one router node at single hop distance. Router packing ratio (RPR) can be understood as the average quantity of resource nodes for each gateway. The proposed routing makes use of the criteria indexes in order to accelerate the process of message routing to groups targeted mostly. The actively employed indexes are contained in the Working Set (WS) of the router nodes. Monitoring performance metrics of runtime accomplishes adaptability and accordingly the WS is automatically modified. The WS changes corresponding to the changes in the network topology and the workload of application, to find indexes of high efficiency for use in the current workload. Such indexes without efficiency gains or performance are dropped, while creating indexes for adoption in the groups targeted most frequently. The routing makes use of a destination descriptor of boolean predicate referred to as target predicate here. The essence of the proposed approach is executed in a unit of message routing. Each individual node involved in the network, based on routing, contains a minimum of one unit of message transmission. The proposed routing is aware of the heterogeneity of the capabilities in nodes and hence, maintains a profile of identification for the node in MANET depending on its location, capabilities and criteria of administration. The summary of the node is an collection of several exact benchmarks with each criterion representing key/value pair. Values could be real numbers, Boolean or text strings. A criterion could represent node capabilities, information of context, application data or administrative configuration. Routing addresses are the criteria of predicate's referencing nodes for the evaluation of target node(s) only. The proposed routing empowers the applications to efficiently integrate the group resources as defined by the application criteria for supporting collaboration oriented jobs.

5. ROUTING TABLES USED IN THE PROPOSED METHOD

Profile Identification table (PIT): All the conditions for source recognition are enclosed in this table, containing the criterion of the last updated value, which is the field, updated last whenever the criterion value changes.

These tables are classified into the following categories:

Definition of index table (DIT): This table contains the name of the index, its properties, sequence number, segment size and time. An index from PIT contains at least one condition or more. A record is included in the index for every individual condition having the same name of index. If the fragment size value is other than zero, then the range of values related to the indexed condition is so segmented as to reduce the size of the table to match that condition which contains greater quantity of single values. The last advertised time of the index to the proximate routers is indicated by the time field. All announcements are duly numbered from due updating and required certifications.

Routing index table: The routing index table (RIT) contains the name of the index, value, criterion, time and Gw. This table can be effectively used during the phase of construction of route for multicasting route construction packets (MRP). All the records contained in the table are auto-terminated, if the time exceeds more than c time units.

Updating index table: Updating index table (UIT) contains the name of the Index, its source, sequence number, cost, time and GW. Information related to the index value advertisement packets (IAPS) received recently, is accumulated for the short term, employing this Index update table. Primarily UTI is used to handle the receipt of replicated copies of packets of advertisement procured from indistinguishable resource, and to determine the best available route to the specific resource from among the various dissimilar paths used by the packets. The node hosting the resource is specified by the source field, while the Gw denotes the neighbouring node forwarding the index updating.

Routing response table : Router response table (RPT) contains the Id of the source, its cost, time, sequence number and Gw. Routing table is employed to route the results of the query back to the source of the query. The table along with the records is circulated during the phase of route construction. The source identifies the source of the query. The field of sequence number holds the progressive number for taking up new paths. The time eliminates the routes, currently not in use.

Routing message table : Routing message table (RMT) contains the source, the predicated ID (PID), time, cost, sequence number, MID5 and Gw. RMT is adopted for routing of the messages in the direction of their targeted groups. The table along with the records is circulated during the phase of route construction.

5.1 Index Propagation

Every individual node verifies its DIT intermittently for indexes, containing the condition with newly changed values in the last 1 unit. The resource node publicises the matching values in the index rate announcement packets (IAP) to their respective gateways, which have a pair of condition values belonging to the selected indexes for announcement, collected on the basis of the index name. In the event of a segmented index value, the value of the condition is rounded to the nearest segment value. Every individual IAP index holds the latest sequence number. Besides, it contains the source node identifier, initialized route cost to the current identifier of the node and zero respectively. The following is the order in which a router node updates its records of RIT whenever an IAP is accepted from the neighbour. If the records are already in existence for that specific index from that node, then those record values and updating time take place. If the records fail to match with the combination of the index, then the table is furnished with additional records. Consider $r(q)$ as a forwarding neighbour node of routing; then a new record is added to its UIT for every individual index in the IAPS matching those records. Then, it fixes the neighbour value of the records in UIT to $r(q)$ and finally, updates the route cost by adding the link cost between $r(p)$ and $r(q)$. Every individual node builds joint IAPs for every single neighbour and circulates those packets asynchronously every t time units. The replicas are eliminated through advertisement aggregation by selecting the updates with minimal cost and decreases the quantity of IAP passed through limiting advertisement overhead.

5.2 Route Construction

In the instance of a node $n\ (z)$ intends to forward a directed message, the particular MRU communicates a multicast route creation packet (MCP) to every one of its neighbours having the directing establish and a advanced classification number. Similarly, when an MCP packet is received at node $r(p)$, it constructs an evaluation tree for the predicate from the predicate expression of the destination descriptor and verifies, if there is a match between the predicate and its own IPT. If the predicate evaluation proves true, then the matching node returns a unicast route set-up packet (USP) in the direction of the source node by means of $r(q)$. The Source node is fixed at $r(p)$ after copying the predicate from MCP to the respective USP packet. Further, the RSP packet contains a Resource hash, a value of an integer, assisting in resource ranking. The node computes the Resource hash as per an application-furnished hash function, which tries to compute each resource's unique value. The provided function reflects the ranking criteria pertaining to resources. Incorporation of data such as resource location, helps to achieve the uniqueness of the Resource hash. In our case fully connected resource node and establish neighbour lists are the input parameters for construction of reverse path. Algorithm used to construct the reverse path:

Algorithm 1. Construction of reverse path**:**

1. if n(p) is a reserve node **then**
2. if establish(n(p)) = true **then**
usp ←←new USP packet
Reserve hash ← ← estimate MD5 hash
Direct usp to n(t) over n(q)
end if
3. else if n(p) is a router node **then**
mcp.Cost ←←mcp.Cost + link_cost(n(p),n(q))
4. for all n(r) ∈∈ neighbors of (n(p)) and n(r) ≠≠ n(q) do
5. if establish(n(r)) = true { **then**
{update reverse path (rp_1}
6. for all rp_1 ∈ ∈ RPT and rp_1.Source = mcp.Source do
7. if rp_1.Cost > mcp.Cost or rp_1.time ≤≤ (now ()-e) **then**
remove rp_1 from RPT undermine remaining record
else
8. carry on to next neighbor
end if
end for
9. rp_1←← different record in RPT
10. rp_1.Source ←← mcp.Source
rp_1.Cost←← Cost
11. rp_1.Interval ←←now()
12. advancing mcp packet to n(r)
if end
for end
if end

5.2.1 Forward path

Forward path is established in the event of a node n(x) receiving an USP packet, usp from another node n(y). In forwarding path calculation usp packet cost and link cost are the input parameters.

Algorithm 2: Forward path
1. usp.Cost ←←usp.Cost + link_cost(n(x),n(y))
2. record_initiate←← false
3. for all mr ∈∈ MRT and mr.PID = usp.PID and mr.ResHash = usp.ResHash **do**
4. if usp.Cost < mr.Cost then
mr.Gw ←← n(y);qr.Time now();mr.rate←← usp.rate
end if
5. record_initiate true
end for
6. if record_initiate = false **then**
mr ←←original record in MRT
mr.Source ←←usp.Source;mr.PID ←←usp.PID;
mr.ResHash←← usp.ResHash;
mr.rate ←←usp.rate
mr.Gw ←←n(x)
mr.Interval←← now()
end if
7. if n(x) ≠≠ rsp.targetnode **then**
8. for all n(r) ∈∈ neighbours(n(x)) and n(r) ≠≠n(y)**do**
9. if rpt ∈∈ RPT where n(r) = rpt.Gw and rpt.Source = usp.targetnode
then
Forward usp to n(r)
end if
end for
else if Establish limit occurs then

10. Cut off value ← ←Edge cut off value

The cut-off value is evaluated by sorting the USP responses in the descending order of MD5. Before calculating the edge cut off value the target nodes wait for specific time units to permit any delayed responses to extent the target. Resources redundancy and paths is accomplished by deciding on the top level routes.

6. SIMULATION PARAMETER

6.1 Performance Evaluation

The performance efficacy of the proposed routing is evaluated using NS-2 simulation under diverse criteria of quantity of indexes and update rates. Routing envisages seamless on-demand path construction between a sender and a destination node matching specific criteria. The oracle process with its acquaintance with all the node profiles and the generated destination descriptors is adopted for computation of perfect destination groups. Then, perfect group and real group are compared to count false negatives, using different data sets for diverse index levels varying between 'no indexing' and 'full indexing'. Figures 1-3 illustrate the results of the initial set of experiments computing the efficacy of the proposed method by considering the false negatives in the best, average and worst instances of criteria update rates. The occurrence of false negatives is primarily consequent to a node updating an indexed criteria value at a specific time, but with incomplete advertisement of new value. As a result, addition of subsequent indexes enhances the corresponding number of false negatives. It is preferable to avoid random indexing for such criteria which have high update rates.

Table 1. Simulation parameter

parameter	**Symbol** (units)
Number of nodes	200 nodes
Density of nodes	0.0008/m^2
Route request rate	0.05/s
Criteria update rate	0.05
Transmission range	250 m
Advertising period	150 s
Experimental length	3500 s
Advertising packet size	50
Final number of criteria	6 criterion
List of targeted criteria	4
Total of index criteria	1-6
Average size of destination group	5
Criteria value range	2000
Number of Router nodes	5

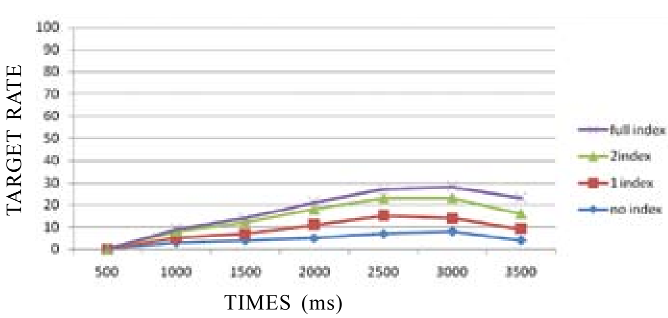

Figure 1. Average case scenario for false negative.

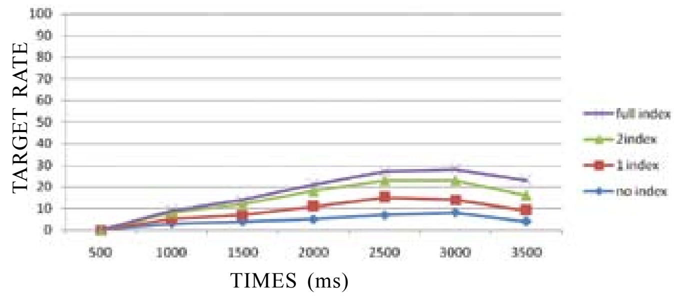

Figure 2. Best case scenario for false negative.

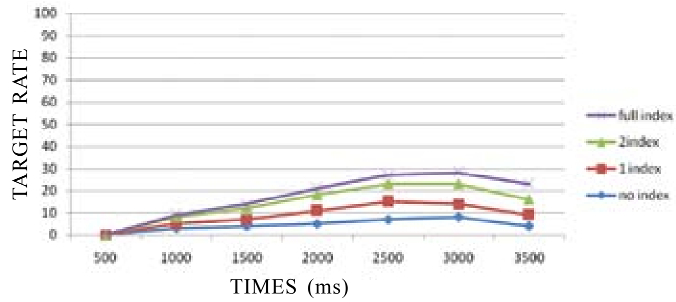

Figure 3. Worst case scenario for false negative.

7. CONCLUSIONS

The proposed novel routing exploits the possibilities in the generic identification profiles of the nodes and the destination descriptors to simplify the path discovery process for both service and resource in single phase. Evolution of scalable efficient routing in view of the large magnitude but with limited potentiality of the MANETs, is motivation enough to propose a novel protocol of routing in this paper,. The protocol explores the possibility of generic identification profiles of the nodes and the destination descriptors in order to enable both service/resource and route discovery in just a single phase. There are several advantages of the routing such as

- identification and addressing dynamically
- capability to exploit the semantics of application layer for the purpose of routing optimisation
- intrinsic multicast, and
- preservation of the anonymity of the nodes.

The proposed routing, designed and executed by employing the proposed framework supports optimisation of multiple applications, while still being generic, exploring the further possibilities of constructing future multi-purpose MANETs of greater magnitude and longevity. Analytical assessments illustrate the high scalability of the protocol with minimal overhead of advertisement. This paper is expected to be a catalyst for further explorations into the broader applicability of the routing as a general framework for a wide range of networks.

REFERENCES

1. Perkins, C.; Belding-Royer, E. & Das, S. Ad hoc on-demand distance vector (AODV) routing. RFC Editor, 2003
2. Pietro, Roberto Di; Mancini, Luigi V. & Mei, Alessandro. Energy efficient node-to-node authentication and communication confidentiality in wireless sensor

networks. *Wireless Networks*, 2006, **12**(6), 709-721. doi: 10.1007/s11276-006-6530-5

3. Bechkit, Walid; Challal, Yacine & Bouabdallah, Abdelmadjid. A new class of Hash-Chain based key pre-distribution schemes for WSN Université de Technologie de Compiègne. Laboratoire HeuDiaSyc, UMR CNRS 7253, Compiègne, France in 2012. doi:10.1016/j.comcom.2012.09.015.
4. Kush, Ashwani; Gupta, Phalguni & Kumar, Ram. Performance evaluation of associative based routing in Adhoc networks. Department of computer Science and Engineering, Indian Institute of Technology, India. *J. Interdisciplinary Mathematics*, 2006, **9**(2), 347-361. doi: 10.1080/09720502.2006.10700448.
5. Sadagopan, N.; Bai, F.; Krishnamachari, B. & Helmy, A. PATHS: analysis of path duration statistics and the impact on reactive MANET routing protocols. *In* ACM MobiHoc, Annapolis, MD, 2003. pp.245-256. doi:10.1145/778415.778444.
6. Zhu, S.; Setia, S. & Jajodia, S. Leap: efficient security mechanisms for large-scale distributed sensor networks. *In* ACM CCS, 2003, pp. 62–72. doi:10.1145/948109.948120
7. Carzaniga, A.; Wolf, A.L.; Carzaniga, C.A.; Rutherford, M.J. & Wolf, E.L. A routing scheme for content-based networking. *In* Proceedings of *IEEE INFOCOM* 2004, Hong Kong, 2003, **2,** pp. 918 - 928 doi:10.1109/INFCOM.2004.1356979
8. Liu, D. & Ning, P. Establishing pair wise keys in distributed sensor networks. In ACM CCS, 2003, pp. 52–61. doi: 10.1145/948109.948119
9. Rezgui, A. & Eltoweissy, M. Textmu racer: A reliable adaptive service-driven efficient routing protocol suite for sensor-actuator networks. *IEEE Trans. Parallel Distributed Syst.,* 2008, **20**(5). 607-622. doi: 10.1109/TPDS.2008.94
10. Samar, P. & Wicker, S.B. Link dynamics and protocol design in a multi hop mobile environment. *IEEE Trans. Mobile Computing,* 2006, **5**, 1156 - 1172. doi: 10.1109/TMC.2006.131
11. Eriksson, Jakob; Faloutsos, Michalis & Krishnamurthy, Srikanth. Scalable ad hoc routing: The case for dynamic addressing. *In I*EEE InfoCom, 2004. pp.1108 - 1119. doi: 10.1109/INFCOM.2004.1356997.
12. Panichpapiboon, S. & Pattara-Atikom, W. Connectivity requirements for a self-organizing vehicular network. *In* IEEE Intelligent Vehicles Symposium, Eindhoven, The Netherlands, 2008. pp.968-972. doi:10.1109/IVS.2008.4621219
13. Intanagonwiwat, C.; Govindan, R. & Estrin, D. Directed diffusion: A scalable and robust communication paradigm for sensor networks. *In* Proceedings of the 6th annual international conference on Mobile, ACM Press, New York, NY, USA, 2000, pp. 56–67. doi:10.1145/345910.345920
14. Lee, Hyo-Jin; Kim, Myung-Sup; W. Hong, James & Lee, Gil-Haeng. QoS parameters to network performance metrics mapping for SLA monitoring. Network Technology Research Lab., ETRI, Daejeon Korea in 2008.
15. Carofiglio, G.; Chiasserini, C.; Garetto, M. & Leonardi, E. Analysis of route stability in MANETs. *In* 2nd EuroNGI Workshop on New Trends in Modelling, Quantitative Methods and Measurements, Aveiro, Portugal, 2005, **13**(3), pp.36-38 doi:10.1145/1215956.1215971
16. Carofiglio, G.; Chiasserini, C.; Garetto, M. & Leonardi, E. Route stability in MANETs under the random direction mobility model. *IEEE Trans. Mobile Computing,* 2009, **2**, pp.1167-1179. doi: 10.1109/TMC.2009.20
17. Bettstetter, C.; Resta, G. & Santi, P. The node distribution of the random waypoint mobility model for wireless ad hoc networks. *IEEE Trans. Mobile Computing*, 2003, 257–269. doi: 10.1109/TMC.2003.1233531.
18. Ross, S.M. Introduction to probability models. Academic Press Inc., 1985.
19. Perkins, C.E. & Royer, E.M. Ad-hoc on-demand distance vector (AODV) routing. *In* IEEE Workshop on Mobile Computing Systems and Applications (WMCSA 1999), 1999, pp. 90–100. doi:10.1109/MCSA.1999.749281
20. Han, Y.; La, R.J.; Makowski, A.M. & Lee, S. Distribution of path durations in mobile ad-hoc networks—Palm's theorem to the rescue. *Computer Networks*, 2006, **50**(12), 1887-1900. doi:10.1016/j.comnet.2005.10.005
21. Tseng, Y.-C.; Li, Y.-F. & Chang, Y.-C. On route lifetime in multi hop mobile ad hoc networks. *IEEE Trans. Mobile Computing,* 2003, **2**(2), 366 - 376. doi: 10.1109/TMC.2003.1255651.
22. Wu, X.; Sadjadpour, H.R. & Garcia-Luna-Aceves, J.J. From link dynamics to path lifetime and packet-length optimization in MANETs. *Wireless Networks,* 2009, **15**(5) 637–650. doi: 10.1007/s11276-007-0086-x

CONTRIBUTORS

Dr Gundala Swathi received the MTech and PhD in computer science from VIT University, Vellore. She also received a Master of computer application from university of Madras in 2004. Currently, he is an associate professor at the School of Information Technology and Engineering,VIT University. His main research interest is the application of combinatorial algorithms in cloud computing, information security system, distributed processing system and secure routing in Mobile Adhoc network.

Dr R. Saravanan is serving as a Senior Professor at School of Information Technology and Engineering in VIT University, Vellore, India. He has research experience in areas of wireless networks and security and published several research papers in the peer reviewed international journals and numerous research papers in national journals. He has two decades of teaching and research experience. He is a life member of Computer society of India, Cryptology Research Society of India and Ramanujan Mathematical Society and also he is a member of ACM.