Performance Analysis of Ad-Hoc Networks using Statistic Mechanics

Anil Kumar, B. I. D. Kumar

***Abstract:** An ad-hoc network is an interconnection of source node and destination node pairs with wireless communication, and it is non-centralized manner, nodes are having self-organizing capabilities. The nodes can move dynamically in such a way that interconnection between nodes vary. The routing mechanism in these networks is in multi-hop manner by taking help of intermediate nodes, these nodes helps in packet flow between source and destination node. Advantage of this type of routing is conservation of energy and efficiently delivers packets. This multi-hop manner of packet transmission introduces blending of various traffic flows, resulting in inter-dependencies between activities of nodes and strong correlations among the nodes. The analysis of ad-hoc networks is complicated task; techniques of the information theory will not yield an accurate analysis. In this work, we use a sub field of statistic mechanics called Totally Asymmetric Simple Exclusion Process and MAC technique for evaluating ad-hoc networks. This helps in evaluating performance parameters such as average delay and throughput of linear ad-hoc network. Finally it has been demonstrated that TASEP can improve the performance parameter such as end to end delay and throughput.*

***Keywords:** Ad-hoc networks, Random Time Division Multiplexing, Totally Asymmetric Simple Exclusion Process.*

I. INTRODUCTION

Ad-hoc networks are suitable for military applications and natural disasters, because these networks can deploy quickly and architectural requirements are less. Traffic flow is transverse across multiple hops; therefore, packet arrival and departure related with each other. Thus, the joint distribution of packet delays is considered to determine delay performance metric. Correlation of throughput of different traffic flows is also very important parameter, sincerely nodes help in multiple packet flows; correlation of throughputs of the multiple traffic flows in the network with each other is essential Since interactions among nodes are very complex in the network, it is difficult to analyze ad-hoc networks using conventional information theoretic methods[6][7]. The focus of this work is to evaluate performance metrics such as delay experienced by packets in linear ad-hoc network with MAC Channel access technique and by considering correlations in the network [8][10] .

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II. AD-HOC NETWORK ROUTING PROTOCOLS

Routing protocol are classified based three strategies.

i> Hierarchical and Flat network architecture.

ii> Pro-active and Re- active routing protocol.

iii> Hybrid routing protocols.

Hierarchical network is a multilayer architecture in which there are nodes clusters and one gate way node for communication between nodes of different clusters. The gateway node is responsible for storing network topology and it is critical node in deterring successful network operation. This uses Zone-based Hierarchical Link State routing protocol. Layering of nodes is done in flat architecture; same routing protocol is used by each node in network.

Routing protocols which are proposed to mitigate counting infinity and looping problems in networks are proactive, In these protocols, every node maintains complete information about network topology and this information is updated periodically.

Routing protocol, maintains active routes information form source to the destination are called reactive protocols. A path finding mechanism is required for every new destination. There is delay in route search but communication over head between nodes is reduced.

Combination of proactive and reactive is called hybrid protocol. These are also called as global reactive and local proactive states. Proactive routing protocols can be simplified as readily available routes in the network that means no need to discover the routes. These are also called as Bandwidth efficient protocols. High response time involved in reactive protocols as route has to found on demand basis, this involves transmission packets to new destination nodes which do not involve in active path [9].

III. METHODOLOGY

The proposed work uses TASEP random channel access scheme. The TASEP link between statistical mechanics and wireless networking. this work showcases the characterizing performance parameters of a linear multi-hop traffic flow [1] [2][3].

We have taken a multiple hop ad-hoc network consists of source nodes destination nodes. The sources nodes deliver packets to destinations over an infinite duration of time. The source node is designated as 0 and induces packets at a constant rate and each packet is of fixed in size. The network contains K intermediate nodes are numbered from 1 to K and destination node is designated as K +1, This work employs two new concepts, one is modified channel access scheme and the other is buffering scheme. Additionally this system can able to consider correlation in system which is very crucial in designing smarter retransmission system and in implementing flow control mechanism.

This system uses modified media access scheme called randomized TDMA (r-TDMA) instead conventional TDMA scheme [10] [11]. In this r-TDMA source node selected uniformly and in randomized manner from all set of nodes in the flow that have packet in buffer, instead of selecting the source in predetermined fashion even if its buffer is empty, as in the conventional scheme. Since each route has only single transmitter at any instant of time, the interference within each flow is zero, the packet success probabilities are determined by the inter-flow interference

The buffering scheme for each traffic flow employs following strategies.

Strategy1: The queuing is performed at source nodes only it means buffering of packets is performed at source node only, thus source node buffer always contains packets to send, and there is unity buffer size for intermediate node for every flow, therefore these nodes may contain one packet per flow.

Strategy 2: Relay nodes will not be accepting transmitted packets, if their buffer holds packet related to that flow.

From these strategies, it is ensured that the successful transmission occurs if and only if a relay node has a packet to send and else it is empty. This avoids queuing of packets, and, this results in regulation the packets transmission of different traffic flows.in the network. Thus small buffer capacity reduces packet delay [6]. When capacity of buffer is large, many packets may get stored in queue, transmissions of packets are delayed especially in case of poor link quality. These two strategies reveal that the packet delays are effectively controlled if buffer size is small. Finally, decision of packet dropping and replacing a packet with recent one is time spent by a packet in the buffer.

A. TASEP

This section describes proposed architecture, characterizes performance parameters such as delay experienced by packets, and throughput [4] of linear ad hoc network model using the technique called TASEP (Totally Asymmetric Simple Execution Process)[5][12] [13].

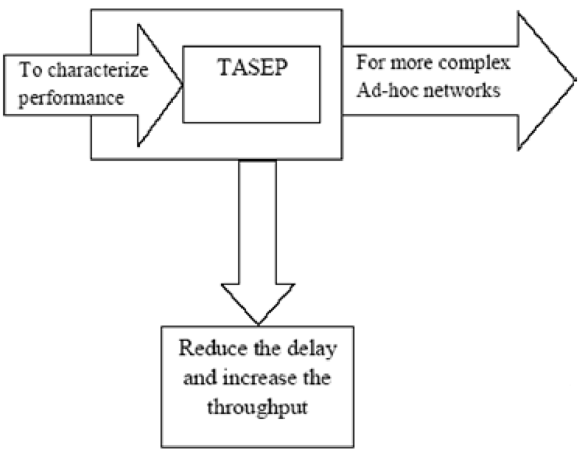

Fig 1: TASEP Process Framework

B. TASEP: Analysis for linear Ad-HOC NETWORKS

The TASEP is simple stochastic process, TASEP technique helps in analyze the dynamics of to describe dynamics of self-driven systems that involves interacting particles. The one dimensional TASEP model is described as follows. A system consists of K + 1 node, numbered from 0 to K. Node 0 is considered as source that introduce molecule into the system. If molecules are introduced into the system from the left endpoint that is at0with probability α and received from the system on the right end point site K with probability β.

The status of node i, at time, i.e., each node is either occupied or empty. The occupied node status is represented as vi [t] = 1. An empty node status is represented as τi [t] = 0. The source node is always occupied, is represented as τO [t] ≡ 1, ∀ t > 0. This system changes with time as per following: At every time step t = t + 1, selection of an integer at random manner 0 ≤ i ≤ K with 1/ (K+ 1) probability. If the integer i has value between1 and K − 1, then the molecule on node i moves to node i + 1, if this node is empty.

$$\tau i\ (t + 1) = \tau\ i(t)\ \tau i{+}1(t)$$

$$\tau i{+}1\ (t + 1) = \tau i{+}1(t) + [1 - \tau i{+}1(t)]\tau\ i(t)]$$

If the selected integers i = 0, then node 1 remains filled at time t + 1 if it was filled at time t, and it gets filled with probability α at time t+1, if it was not occupied at time t. Therefore

$$\tau 1\ (t{+}1) = 1 \text{with probability}$$

$$\tau 1\ (t) + \alpha\ [1 - \tau 1\ (t)]$$

$$\tau 1\ (t{+}1) = 0 \text{ with probability}$$

$$(1 - \alpha)\ [1 - \tau 1\ (t)]$$

Similarly, if selected integer i = K, then node K remains non-occupied at time stamp t + 1. It gets occupied with the β probability at the time stamp t otherwise it will not be filled.

$$\tau\ k(t + 1) = 1$$

With probability $(1 - \beta)\ \tau k(t)$

$$\tau\ k\ (t + 1) = 0$$

With probability $1 - (1 - \beta)\ \tau\ k(t)$

The molecule flow mechanism of TASEP is similar to wireless linear network. The sites are representing relay nodes whereas the molecules are representing the packets. The molecule transverse probability p is similar to reliability of link pc. The principle of simple exclusion shows buffer size of relay nodes is unit. The updating mechanism relates to the channel access technique of the wireless line network. The condition τO [t] = 1, ∀ t this indicates that buffer of source node is always has packets.

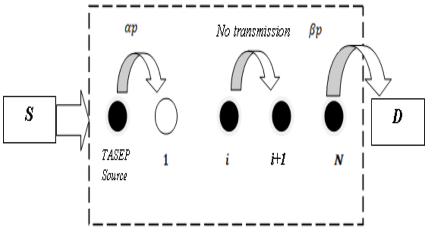

Fig 2: TASEP-equivalent network flows.

The fig 2 depicts linear network, where αp, βp represents hopping probabilities. The source node S, its buffer capacity is large and is connected to the TASEP packet transverse model with K+ 1 nodes, the buffer capacity of each intermediate node is single and there is a destination node represented as D. Darken circles indicate nodes with filled buffer, and the other circles indicate empty buffer nodes. The hopping of packets will not be happen between node Si and i+1 if buffers of both nodes are not empty.

IV. EXPERIMENTAL SETUP

This experiment was setup using NS-2 (Network Simulation Tool over Fedora version 9 Environment with Tcl Scripts & AWK commands to setup the Network and analyses the result. Experiment was empirically run for much number iteration before taking the result.

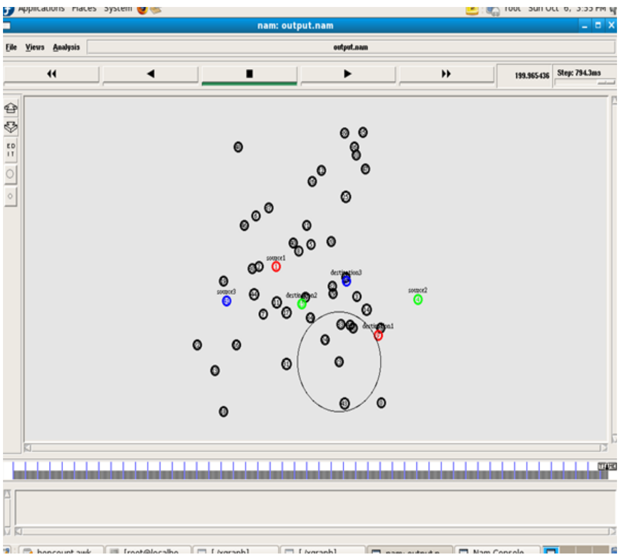

Fig 3: Shows arbitrary wireless network model source and destination nodes with node movement

V. RESULT AND DISCUSSION

In this experiment we are interested in finding the end to end delay with speed factor using the TASEP and without TASEP. The fig 4 graph gives the values for speed and delay comparison. It reveals that, the ad-hoc network employ the concept of TASEP yields reduced end to end delay, when compared to the network without TASEP. Table I summaries Node speed with the Average delay component for TASEP Technique in use.

Table I: Delay compution for with and Withou TASEP

Without TASEP			With TASEP	
SL. No	Node Speed in 5.0 mtr/Sec	Average Delay in ms	Node Speed in 5.0 mtr/Sec	Average Delay in ms
1	5	87.35 ms	5	20.00ms
2	10	120.00ms	10	40.00ms
3	15	163.96ms	15	159.90ms
4	20	240.00ms	20	110.00ms
5	25	184.29ms	25	164.29 ms
6	30	220.00ms	30	119.01 ms

The Table I shows the node speed and average end to end delay parameters of ad hoc network that employ concept of TASEP an without the TASEP. From above Table I, it is observed that ad-hoc network that employs the concept of TASEP yields reduced average end to end delay when compared to Ad hoc network that does not employ concept of TASEP and it reveals that use concept of TASEP in Ad hoc network will enhance the performance of ad-hoc network.

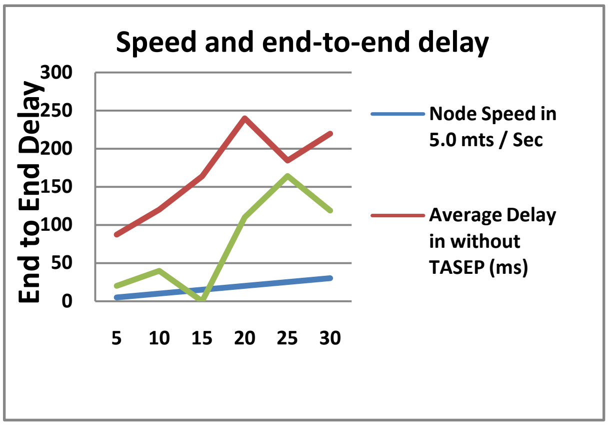

Fig 4: shows speed and delay graph for existing system

Throughput: The fig 4 shows speed and throughput graph, it reveals that, the ad-hoc network employs the concept of TASEP yields reduced greater throughputs compared to the network, which does not use TASEP.

Table II: Throughput computation for with and Without TASEP

Without TASEP			With TASEP	
Sl. No	Node Speed in 5.0mtr/Sec	Throughput In Kbps	Node Speed in 5.0mtr /Sec	Throughput In Kbps
1	5	21.65Kbps	5	32.64kbps
2	10	32.97kbps	10	38.25 kbps

3	15	21.98kbps	15	131.32kbps
4	20	77.92kbps	20	60.00kbps
5	25	66.95 Kbps	25	90.00kbps
6	30	52.31kbps	30	87.22kbps

The Table II above shows the speed of nodes and throughput parameters of ad-hoc network that employ concept of TASEP and without the TASEP. From above Table II, it is observed that ad-hoc network that employs the concept of TASEP yields greater average throughput when compared to Ad hoc network that does not employ concept of TASEP and we can conclude that the concept of TASEP can improve the performance by increasing throughput of network.

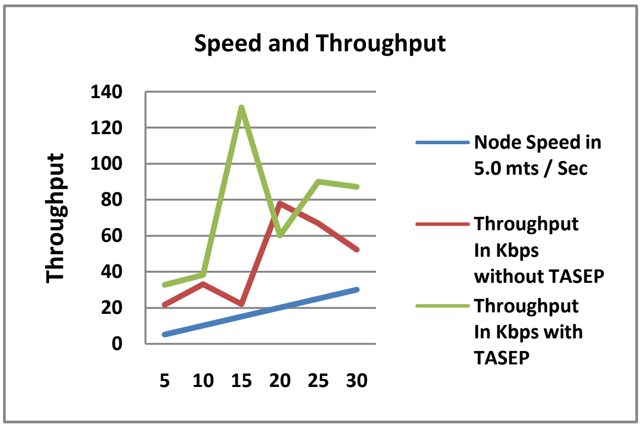

Fig 5: shows Speed versus throughput graph of existing system.

VI. CONCLUSION

This work incorporates ideas from TASEP to analyze multi-hop networks with random access scheme(r-TDMA); it considers correlations between the nodes of the ad-hoc networks and buffer occupancies. The TASEP technique connects gap between wireless networking and statistical mechanics. This can evaluate delay and throughput of multi-hop networks and has advantage of eliminating cumbersome analysis based on queuing theories and analysis using information theoretic techniques. The results this work show that TASEP concept yields improved results with number of nodes and also reduces end to end delay and maximize throughput of ad-hoc network. Hence, this work can instigates interest in solving problems in wireless networking using TASEP by adopting ideas from statistical mechanics. In future along with the concept of TASEP, we can employ mean field approximation to quantify the performance of complex networks with intersecting nodes.

REFERENCES

1. S. Goldstein∗, J. L. Lebowitz∗, † and E. R. Speer∗Department of Mathematics, Rutgers University, New Brunswick, NJ 08903. †Also Department of Physics, Rutgers. Exact Solution of the F-TASEP April 16, 2019
2. Takahiro Tannai, Katsuhiro Nishinarit "Theoretical Approach To Congestion Relaxation And Saturated Congestion In TASEP (Totally Asymmetric Simple Exclusion Process) Network With Multi-Chain Section With Flow/Density-Dependent Rules Of Junctions" A Physics Letters – Elsevier- 21November 2017
3. Khanh Dao Duc Computer Science Division, University of California, Berkeley, CA 94720, USA Zain H. Saleem Department of Mathematics, University of Pennsylvania, PA 19104, USA Yun S. Song∗ Computer Science Division and Department of Statis "Theoretical analysis of the distribution of isolated particles in the TASEP: Application to mRNA translation rate estimation" Dated: October 21, 2017,doi: http://dx.doi.org/10.1101/147017.
4. Yoram Zarai, Oz Mendel, and Michael Margaliot Aviv University,Israel69978.Homepage:www.eng.tau.ac.il/˜michaelm.Email :michaelm@eng.tau.ac.i "Analyzing Linear Communication Networks using the Ribosome Flow Model " arXiv:1508.06038v1 [cs.NI] 25 Aug 2015
5. Gideon Amir, Omer Angel and Benedek Valk´o Bar Ilan University, University of British Columbia and University of WisconsinTHE TASEP SPEED PROCESS 2011, Vol. 39, No. 4, 1205–1242 DOI: 10.1214/10-AOP561
6. J. Andrews, N. Jindal, M. Haenggi, R. Berry, D. Guo, M. Neely, S. Weber, S. Jafar, and A. Yener; "Rethinking Information Theory for Mobile Ad Hoc Networks," IEEE Comm. Magazine, vol. 46, no. 2Dec. 2008, pp. 94-101
7. K. Takeuchi, T. Tanaka, "Statistical-Mechanics-Based Analysis of Multiuser MIMO Channels with Linear Dispersion Codes," J. Physics: Conf. Series, vol. 95, no. 1, Jan. 2008, pp. 012008-11.
8. M. Xie, M. Haenggi;"A Study of the Correlations between Channel and Traffic Statistics in Multi-hop Networks," IEEE Trans. Vehicular Technology, vol. 56, no. 6, Nov. 2007, pp. 3550-3562.
9. S.S. Tyagi, R K Chauan; "Performance Analysis of Proactive and Reactive Routing Protocols for Ad hoc Networks," International Journal of Computer Applications Volume 1 – No. 14, 2010, pp. 0975 – 8887
10. R. Nelson, L. Kleinrock, "Spatial TDMA: A collision-free multi-hop channel access protocol,"IEEE Trans. Commun., vol. COM-33, no. 9, Sep. 1985, pp. 934–944
11. N. Abramson; "The ALOHA system-Another alternative for computer communications,"in Proc. Fall Joint Comput. Conf., AFIPS, 1970, vol. 37, pp. 281–285
12. M. Xie,M. Haenggi; "Towards an End-to-End Delay Analysis of Wireless Multihop Networks," Elsevier Ad Hoc Networks, vol. 7, July 2009, pp. 849-861.
13. B. Derrida, E. Domany, and D. Mukamel, "An Exact Solution of a One-Dimensional Asymmetric Exclusion Model with Open Boundaries," J. Statistical Physics, vol. 69, nos. 3/4, , Nov. 1992pp. 667-687.