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STOCHASTIC PROBABILITY DISTRIBUTION MECHANISM(SPDM) FOR BUFFER QUEUING DELAY IN MOBILE AD HOC NETWORKS

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Abstract

Buffer queuing latency is one of the primary causes for delayed transmission in mobile ad hoc networks. This paper proposes a stochastic probability distribution mechanism (SPDM) which overcomes the shortcomings of Shannon entropy. Mathematical modeling has been proposed for SPDM which has finite state buffer. Simulations have been carried out using NS2 simulator. The performance metrics such as average end-to-end delay with varied number of nodes, packet delivery ratio with varied number of nodes, average end-to-end delay with varied number of CBR connections, packet delivery ratio with varied number of CBR connections, packet delivery ratio with varied delay-constraint, normalized routing overhead with varied delay-constraint are taken into account. Simulation results projects that the proposed SPDM outperforms the rest of the protocols such as ad hoc on demand distance vector routing (AODV) protocol, energy efficient delay constrained routing (EEDCR) protocol and interference based topology control algorithm for delay constrained (ITCD) protocol.

Keywords:
Delay, MANET, AODV, EEDCR, ITCD, SPDM, Routing, CBR, Overhead.

1. INTRODUCTION

With the rapid growth of wireless communication and technological advancement Mobile Ad hoc Networks (MANETs) has a growing demand for Quality of Service (QoS) provisioning, such as voice over IP (VoIP), multimedia, real-time collaborative work. Various applications over and over again have different QoS requirements in terms of bandwidth, packet loss rate, delay, packet jitter, hop count, path reliability and power consumption *[Zhang., 2008]*. In order to guarantee the QoS requirement in terms of delay, some researchers explored the delay incurred in a forwarding node or a routing path. In *[Draves et al., 2004]*, *[Yang et al., 2005]*, *[Sharma et al., 2007]*, *[Li et al., 2009]*, *[Zhu et al., 2009]*, delay was defined as the transmission delay of a packet. Then, *Xie et al., 2005* found that in many cases the queuing delay takes a significant portion of the total delay over a hop. A path, which contains many packets in queue of the nodes and with short transmission delay on links, could have a larger delay than the one, which has fewer packets in the queue at nodes but longer transmission delay. This research work concerns buffer queuing delay as one of the major research paradigm in MANET protocols. The paper is organized as follows. This section introduces the paper work with the motivation. Section 2 portraits the related works carried out on the concerned research problem. Section 3 discusses on the proposed work. Section 4 portrays simulation environment and settings. Section 5 shows the results and discussions of the proposed work. Section 6 concludes the paper.

2. BACKGROUND STUDY

Xin Ming Zhang et al., 2015 proposed a cross-layer distributed algorithm called interference-based topology control algorithm for delay-constrained (ITCD) MANETs with considering both the interference constraint and the delay constraint, which was different from the previous work A modified Transmission Control Protocol (TCP) which was capable of handling congestion in the network caused by Jelly Fish Attackers was proposed in *Wazid et al., 2013. Prabu and Subramani. 2014* proposed new routing algorithm named Energy Saver Path Routing using Optimized Link State Routing (ESPR-OLSR) protocol because routing in MANET was serious issue since network topology which was changeable due to nodes mobility. *Othmen et al., 2014* proposed a new power and delay aware routing protocol for wireless Ad Hoc networks. It was not only to find more stable paths from a source to a destination node in terms of remaining life time of battery, but also to find multi-paths that satisfy QoS requirements, given in terms of delay and bandwidth. *Desai et al., 2014* proposed a detection scheme to detect the malicious nodes at route discovery as well as at packet transmissions. *Asha and Muniraj. 2013* developed a Network Connectivity based Energy Efficient Topology Control Scheme that focused on both network connectivity and energy consumption. *Maurya et al., 2014* presented performance evaluation and comparison of three different On-Demand routing protocols for Mobile Ad-Hoc Networks i.e. Ad hoc On-Demand Distance Vector (AODV), Dynamic Source Routing (DSR), and Dynamic MANET On-demand (DYMO) protocols in variable pause times. *Mahajan et al., 2014* attempted to find an event based optimum path which created because of the dynamic topology of the Ad-hoc network and its advantages in data transmission in terms of delay and energy efficiency. *Valikannu et al., 2015* proposed a novel energy consumption model using Residual Energy Based Mobile Agent selection scheme (REMA), where mobile agents dynamically choose the appropriate upper layer agents by sharing topology information among nodes for reliable data transmission. *Mahmood* and *Johari.,2014* proposed a new routing approach, a Cluster based approach coined as RIMCA for efficient routing of message from the source to destination, where it consists of mobile wireless nodes which moves randomly within boundary of cluster.

ISSN: 2348 9510
International Journal Of Core Engineering & Management (IJCEM)
Volume 2, Issue 7, October 2015

3. SPDM FOR BUFFER QUEUING DELAY IN MANET

Consider a single server queue with the finite buffer of size N. We assume that $p(n)$ represents the probability distribution of the queue with size n. The normalization constraint, moment constraint in the form of geometric mean Q of non-zero queue size and the utilization U are specified as follows:

$$\sum_{n=0}^{N} p(n) = 1 \qquad (3.1)$$

$$\sum_{n=1}^{N} \log_2 n \; p(n) = \log_2 Q \qquad (3.2)$$

$$\sum_{n=0}^{N} h(n)p(n) = U = 1 - p(0) \qquad (3.3)$$

where $h(.)$ is defined as

$$h(n) = \begin{cases} 0, & if\ n = 0 \\ 1, & n \neq 0 \end{cases} \qquad (3.4)$$

There may be infinite number of probability distributions which are consistent with the given constraints (3.1), (3.2), and (3.3). Our aim is to propose stochastic probability distribution mechanism which is not only consistent with the given constraints but also maximizes Shannon entropy. Mathematically, the problem is stated as

$$Max\ S = -\sum_{n=0}^{N} p(n) \log_2 p(n) \qquad (3.5)$$

subject to constraints (3.1), (3.2), and (3.3). The Lagrangian is given by

ISSN: 2348 9510
International Journal Of Core Engineering & Management (IJCEM)
Volume 2, Issue 7, October 2015

$$L = -\sum_{n=0}^{N} p(n)\log_2 p(n) - (\alpha_0 - 1)\left(\sum_{n=0}^{N} p(n) - 1\right) - \alpha_1\left(\sum_{n=0}^{N} h(n)p(n) - U\right) - \alpha_2\left(\sum_{n=1}^{N} \log_2 n \; p(n) - \log_2 Q\right) \qquad (3.6)$$

where α_0, α_1 and α_2 are Lagrange multipliers.

The maximum entropy solution is found to be

$$p(n) = \exp\left(-\alpha_0 - \alpha_1 h(n)\right) n^{-\alpha_2}, \qquad n \geq 1 \qquad (3.7)$$

Using (3.1) and (3.3), we get

$$p(n) = \begin{cases} 1 - U = p(0), & n = 0 \\ \dfrac{(1 - p(0))n^{-\alpha_2}}{H_N, \alpha_2}, & 1 \leq n \leq N \end{cases} \qquad (3.8)$$

The Lagrange multiplier α_2 can be obtained by using (3.2). Here H_N, α_2 in (3.8) is generalized harmonic number given by

$$H_N, \alpha_2 = \sum_{n=1}^{N} \frac{1}{n^{\alpha_2}} \qquad (3.9)$$

It is noted that for sufficiently large N, probability distribution $\{p(n), n = 0,1,2, \ldots N\}$ exists for $\alpha_2 > 1$. The rth moment of jobs for the buffer size N in the system is

$$E_N(n^r) = \sum_{n=1}^{N} \frac{(1 - p(0))n^{-\alpha_2 + r}}{\zeta(\alpha_2) - \zeta(\alpha_2, N)} \qquad (3.10)$$

Using (3.8), the loss probability when the finite buffer is full, is given by

$$p_L(N) \equiv p(N) = \frac{\left(1 - p(0)\right)N^{-\alpha_2}}{H_N, \alpha_2} \qquad (3.11)$$

ISSN: 2348 9510

International Journal Of Core Engineering & Management (IJCEM)

Volume 2, Issue 7, October 2015

When $N \to \infty$, the generalized harmonic number H_N, α_2 becomes the Riemann zeta function $\zeta(\alpha_2)$, i.e.,

$$\lim_{N\to\infty} H_N, \alpha_2 = \sum_{n=1}^{\infty} \frac{1}{n^{\alpha_2}} = \zeta(\alpha_2), \quad \alpha_2 > 1 \qquad (3.12)$$

H_N, α_2 can also be written as

$$H_N, \alpha_2 = \zeta(\alpha_2) - \zeta(N, \alpha_2), \quad \alpha_2 > 1 \qquad (3.13)$$

where $\zeta(N, \alpha_2)$ is the Hurwitz zeta function

$$\zeta(N, \alpha_2) = \sum_{n=0}^{\infty} \frac{1}{(n+N)^{\alpha_2}}, \quad \alpha_2 > 1. \qquad (3.14)$$

Using (3.8), the loss probability $p_L(N)$, for asymptotically large buffer size N, follows power law

$$p_L(N) \sim N^{-\alpha_2} \qquad (3.15)$$

and (3.15) is identical to the infinite buffer.

4. SIMULATION ENVIRONMENT AND SETTINGS

NS2 is a discrete event simulator targeted at networking research. NS provides substantial support for simulation of TCP, routing, and multicast protocols over wired and wireless (local and satellite) networks.

In order to evaluate the performance of the SPDM protocol, we compare SPDM with the conventional AODV [*Perkins et al., 2003*] protocol, ICTD protocol [*Xin Ming Zhang et al., 2015]* and the Energy-Efficient and Delay Constrained Routing protocol (EEDCR) [*Lee and Cho. 2004*]. By adjusting the transmission power in data packet transmissions, SPDM can select the optimal path with minimized cost of links (path loss).

The experiments are divided into three parts, and in each part we find the impact of one of the following parameters on the performance of routing protocols *[Xin Ming Zhang et al., 2015]:*

- ✓ **Number of nodes.** We vary the number of nodes from 50 to 300 in a fixed field to research the impact of different network density. In this part, we set the number of CBR connections to 15.
- ✓ **Number of CBR connections.** We vary the number of randomly chosen CBR connections from 10 to 20 with a fixed packet rate to research the impact of different traffic load. In this part, we set the number of nodes to 150.
- ✓ **Delay constraint.** We vary the delay constraint from 40 to 140 ms in a fixed field to research the impact of delay constraint. In this part, we set the number of nodes to 150, the number of CBR connections to 20.

Simulation Parameters

Simulation Environment	NS2 (v2.34)
Simulation Time	200 s
Topology Size	1000 m * 1000 m
Max power	0.8 W
Carrier sense threshold	6.30957e-12
Noise floor	7.96159e-14
SINR of data capture	10
Min speed	1 m/s
Max speed	5 m/s
Pause time	0 s
Traffic Type	CBR
Packet size	512 bytes
Max delay	$\frac{T_{real}}{n}$
Bandwidth	2 Mbps

5. RESULTS AND DISCUSSIONS

Performance of SPDM is made a comparison with AODV *[Perkins et al.,2003]*, EEDCR *[Lee and Cho.,2004]* and ITCD *[Xin Ming Zhang et al.,2015]* in terms of Number of nodes, Number of CBR connections and Delay constraint.

ISSN: 2348 9510
International Journal Of Core Engineering & Management (IJCEM)
Volume 2, Issue 7, October 2015

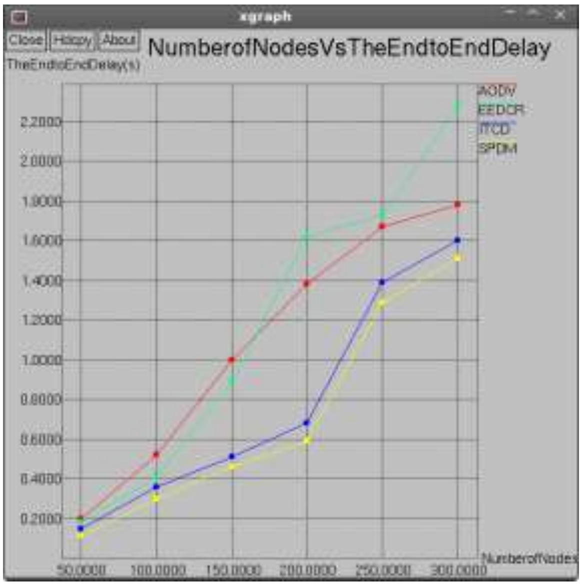

Fig 1: Average end-to-end delay with varied number of nodes

Fig 1 presents the performance of SPDM in the basis of end-to-delay over of number of nodes and the results proved that the proposed SPDM approach delivers significant better performance over other methods namely AODV, EEDCR and ITCD. The performance values are depicted in Table 1.

Table 1: Number of Nodes Vs End-to-End Delay

Protocols / Nodes	AODV	EEDCR	ITCD	SPDM
50	0.20	0.18	0.15	0.11
100	0.52	0.41	0.36	0.30
150	1.00	0.89	0.51	0.46
200	1.38	1.62	0.68	0.59
250	1.67	1.73	1.39	1.29
300	1.78	2.28	1.60	1.51

ISSN: 2348 9510

International Journal Of Core Engineering & Management (IJCEM)

Volume 2, Issue 7, October 2015

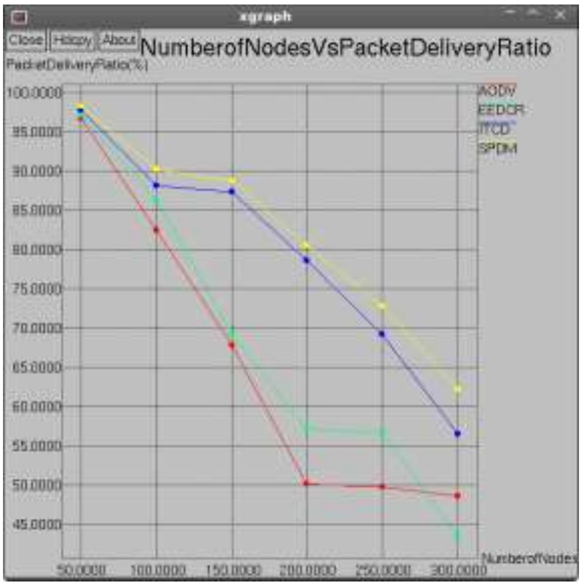

Fig 2: Packet delivery ratio with varied number of nodes.

Fig 2 presents the performance of SPDM in the basis of packet delivery ratio over number of nodes and the results proved that the proposed SPDM approach delivers significant better performance over other methods namely AODV, EEDCR and ITCD. The performance values are depicted in Table 2.

Table 2: Number of Nodes Vs Packet Delivery Ratio

Nodes \ Protocol	AODV	EEDCR	ITCD	SPDM
50	96.7	97.1	97.8	98.3
100	82.4	86.3	88.1	90.2
150	67.8	69.2	87.3	88.7
200	50.2	57.2	78.6	80.6
250	49.8	56.7	69.2	72.8
300	48.6	43.5	56.6	62.3

ISSN: 2348 9510

International Journal Of Core Engineering & Management (IJCEM)

Volume 2, Issue 7, October 2015

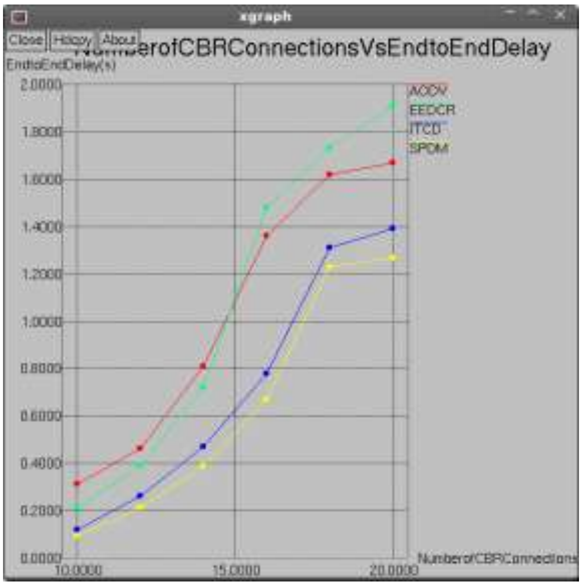

Fig 3: Average end-to-end delay with varied number of CBR connections.

Fig 3 presents the performance of SPDM in the basis of end-to-end delay over number of CBR connections and the results proved that the proposed SPDM approach delivers significant better performance over other methods namely AODV, EEDCR and ITCD. The performance values are depicted in Table 3.

Table 3: Number of CBR connections Vs End-to-End Delay

Protocols / CBR Connections	AODV	EEDCR	ITCD	SPDM
10	0.31	0.21	0.12	0.09
12	0.46	0.39	0.26	0.21
14	0.81	0.72	0.47	0.39
16	1.36	1.48	0.78	0.67
18	1.62	1.73	1.31	1.23
20	1.67	1.91	1.39	1.27

ISSN: 2348 9510
International Journal Of Core Engineering & Management (IJCEM)
Volume 2, Issue 7, October 2015

Fig 4: Packet delivery ratio with varied number of CBR connections.

Fig 4 presents the performance of SPDM in the basis of packet delivery ratio over number of CBR connections and the results proved that the proposed SPDM approach delivers significant better performance over other methods namely AODV, EEDCR and ITCD. The performance values are depicted in Table 4.

Table 4: Number of CBR Connections Vs Packet Delivery Ratio

CBR Connections \ Protocols	AODV	EEDCR	ITCD	SPDM
10	96.1	96.7	97.1	98.3
12	82.9	84.4	93.2	92.4
14	72.6	76.8	89.6	87.6
16	57.8	59.2	79.8	78.9
18	53.7	55.6	67.4	64.8
20	45.5	47.9	64.8	63.2

ISSN: 2348 9510

International Journal Of Core Engineering & Management (IJCEM)

Volume 2, Issue 7, October 2015

Fig 5: Packet delivery ratio with varied delay-constraint.

Fig 5 presents the performance of SPDM in the basis of packet delivery ratio over delay constraint and the results proved that the proposed SPDM approach delivers significant better performance over other methods namely AODV, EEDCR and ITCD. The performance values are depicted in Table 5.

Table 5: Delay Constraint Vs Packet Delivery Ratio

Protocol / Delay Constraint	**AODV**	**EEDCR**	**ITCD**	**SPDM**
100	33.2	35.2	59.1	70.8
120	34.6	36.3	60.7	72.5
140	35.9	37.2	62.5	73.6
160	37.1	40.4	62.9	74.9
180	38.4	42.6	68.7	76.2
200	39.2	43.8	69.2	78.6

ISSN: 2348 9510

International Journal Of Core Engineering & Management (IJCEM)

Volume 2, Issue 7, October 2015

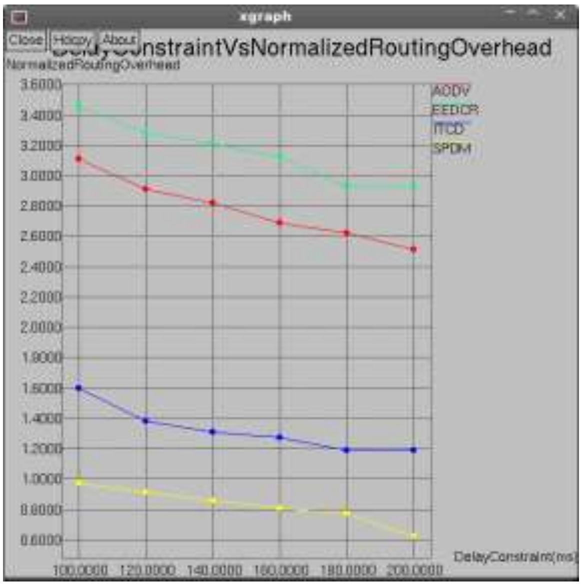

Fig 6: Normalized routing overhead with varied delay-constraint

Fig 6 presents the performance of SPDM in the basis of delay constraint over normalized routing overhead and the results proved that the proposed SPDM approach delivers significant better performance over other methods namely AODV, EEDCR and ITCD. The performance values are depicted in Table 6.

Table 6: Delay Constraint Vs Normalized Routing Overhead

Protocol / Overhead	AODV	EEDCR	ITCD	SPDM
100	3.11	3.46	1.60	0.97
120	2.91	3.28	1.38	0.91
140	2.82	3.21	1.31	0.86
160	2.69	3.12	1.27	0.81
180	2.62	2.93	1.19	0.77
200	2.51	2.93	1.19	0.62

6. CONCLUSION

The emergence of technology and wireless communication has laid a strong foundation for research in mobile ad hoc networks. Quality of Service (QoS) is one of the primary paradigms of proposing routing protocol for MANETs. This paper presents a stochastic probability distribution mechanism (SPDM) which overcomes the shortcomings of Shannon entropy. Simulations have been carried out using NS2 simulator. The performance metrics such as average end-to-end delay with varied number of nodes, packet delivery ratio with varied number of nodes, average end-to-end delay with varied number of CBR connections, packet delivery ratio with varied number of CBR connections, packet delivery ratio with varied delay-constraint, normalized routing overhead with varied delay-constraint are taken into account. Simulation results projects that the proposed SPDM mechanism outperforms the rest of the protocols such as ad hoc on demand distance vector routing (AODV) protocol, energy efficient delay constrained routing (EEDCR) protocol and interference based topology control algorithm for delay constrained (ITCD) protocol.

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ISSN: 2348 9510

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Volume 2, Issue 7, October 2015

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