Efficient on Demand Routing Protocol to Optimize Throughput in Manet

Anupama Sharma, Abhay Bansal , Vinay Rishiwal

Abstract Throughput oriented route selection is still a challenging task due to several constraints of ad-hoc networks such as absence of central control, dynamic network topology, selfish nature of nodes, etc. A routing protocol produce optimum results if it prioritizes wireless links on the basis of link quality and consider high quality/ efficient links at the time of path selection. Proposed protocol discovers high quality/ efficient links and connects those links to establish efficient route in mobile ad-hoc network that leads to high Aggregate Network Throughput. This work has been done by estimating every link's ENT (Expected Number of Transmission) value as QoS parameter and considering qualifying high capacity/efficient links to communicate data packets. To estimate ENT value of each link, variability in packet loss rate on that link is observed in simulation experiments. Probability of errors in transmission is estimated at bit level. Results are stochastic and high fluctuations observed in packet loss rate hence σ^2 (i.e. packet loss variance on a wireless link) included in link quality estimation. In proposed protocol EODRP (Efficient On Demand Routing Protocol) link quality based route metric ENT, selects QoS qualified wireless links during route computation and routing information disperse through reactive routing protocol. Simulation results have been analyzed and compared with MXAODV [7] which indicates significant improvement in network efficiency in terms of throughput and other parameters.

Keywords: MANET, AODV, QoS, ENT, mETX, MXAODV.

I. INTRODUCTION

Forte of mobile ad-hoc network is its zero infrastructure transmission, where a host node may directly transmit to another host through radio links within their range. Mobile nodes which are not in the range may be indirectly approached by other mobile nodes known as intermediate nodes. Wireless computing is having a wide range of applications in different fields. mobile packet radio networking technology presents an extremely flexible mechanism for establishing instant communication at various emergency operations like military base station, rescue, fire, or other safety operations, etc.

many other real scenarios require rapid deployable communications with high network capacity (aggregate network throughput) and efficient dynamic behavior. Various route selection metrics has been analyzed in literature for efficient communication in ad-hoc network. Efficient communication requires efficient links with required link quality based on specific application.

Different applications of ad-hoc network have different QoS requirements like delay, congestion, packet loss, throughput, etc. Though, every requirement is interconnected but has application specific priority. Link quality metrics works on one or more application specific parameter and calculates weight of a particular link on that. Selection of a good link quality metric with routing protocol enhances results drastically. It may improve throughput, minimize delay, cut down packet loss, decrease normalized routing load, etc.

We picked this active research area to amend or draft link quality based routing protocol for efficient communication in terms of high throughput. A proposal has been made in this paper to excogitate a routing protocol that produces optimized aggregate network throughput in ad-hoc networks during experiments. To achieve this optimization, quality of every link in ad-hoc network is measured at specific interval to choose or reject links for instant communication. Proposed work considers four major steps for optimization:

1) Find and select efficient links for data transmission in entire mobile ad-hoc network through link quality metric ENT [1] (QoS parameter).
2) Reject inefficient links for further communication hence reduce control overhead.
3) Assign cost to each link through link quality metric mETX [1] which is used as quality indicator for all efficient links.
4) Disperse link quality indicator information with routing information.

Information flow in the paper: after introduction, next is Section 2, about related work. Section 3 provides brief on link quality metric ENT, its definition, calculations and algorithm to compute *log*ENT. Design of EODRP is shown in Section 4. High quality path selection process with an example is detailed in Section 5. Brief of simulation parameters, results and performance analysis is in section 6. Section 7 has some words on possible directions to further research with conclusion of paper.

II. RELATED WORK

Literatures are reviewed to analyze current research on link quality metrics and optimization of network throughput.

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Some of the previously proposed metrics are considered here for discussion during this literature review. Simplest route metric is Hop Count route metric. It finds shortest path for communication. It is used with AODV [2], AOMDV [3] and various other routing protocols. Primary advantage of Hop Count route metric is its simplicity which is an attraction for high mobility networks.

This metric generally does not check the quality of link such as available bandwidth of link, congestion on link, etc. ETX [4] is a link quality based route metrics which assign ETX value to each link on the basis of forward and reverse packet delivery ratios on that particular link. ETX is designed to overcome the limitation of Hop Count metric regarding link quality estimation. ETX also has some issues [5], therefore ETT [4] route metric is designed to overcome these issues. ETX and ETT computations are based on mean loss ratio, hence works well with relatively static channel conditions. Under wide variety of channel conditions, it may work poorly. To overcome this issue research developed many modifications of ETX and ETT metrics in different literatures. In real network scenario, average channel behavior is totally hypothetical. Short term behavior of channels is observed and found different on different time scale [6] whereas for the same example ETX estimation is approximately same during observed intervals. It shows that packet loss on a link is totally bursty and varies on different time scale. Hence, packet loss variance is an important factor to include in link quality estimation. Mean and variance of packet losses are examined for link quality estimation in mETX [4] hence it better estimate the link quality and also support QoS provisioning. MXAODV [7] protocol uses mETX to estimate quality of links and to provide QoS support. It picks path that maximize the link-layer throughput but optimization of link layer throughput is not enough to get sufficient network capacity; some links having higher packet loss but not noticeable for lower layers may be the part of transmission path. mETX works efficient if protocol's performance evaluated till link layer. An efficient protocol which works well till data link layer may also capitulate after some retransmissions. Hence there is a requirement of route metric which may meet the desired goal to achieve aggregate network throughput.

ENT (Effective Number of Transmission) [1] found as an option to cover this limitation. ENT metric satisfies certain higher layer protocol requirements and it also considers bursty losses at different time scales.

Optimization of network throughput in ad-hoc networks is an area where immense research is going on and researchers are putting lots of efforts to enhance quick and efficient communication. In this array of work Andrews et al. proposed an extended version of basic TC, named *random access transport capacity* (RTC) [8]. RTC estimated consequences of multiple hop communication and re-communication on end to end throughput of mobile ad-hoc network and preconceived productive links for transmission. Vaze et al. [9] assimilated modified TC metric to assess the effect of delay constraints and the number of multiple hops in terms of retransmissions of packets. They obtained the throughput and delay reliability trade off in wireless ad-hoc networks with automatic repeat request (ARQ). Route Assessment Index (RAI) [10] is the hop based approach which finds the smallest path in network. This metric formulate an appropriate data rate and makes precise routing decisions. Number of hops is less with maximum RAI value

holder routes and it provide high throughput and circumvents congestion on link hence reduces the packet drop rate.

One of the reviewed routing protocols in the category of enhancement of network throughput is reward-based routing protocol (RBRP) [11]. This protocol uses the Q-learning route strategy to nominate more stable route which improves effectuation of specific application. All possible routes from the source mobile host to destination mobile host are found during route discovery process. The highest reward value route is selected for transmission. Reward value for every path enumerated on 4 basic parameters: hop count, bandwidth, power of battery, and speed of mobile nodes. To optimize network throughput Deng X. et al, proposed expected path throughput based routing [12] which estimates EPT metric value to consider high throughput path. EPT metric works on available bandwidth, link quality, flow interference with path length to optimum decision. EPTR optimize network throughput by fair distribution of network load during distributed routing decisions. Rath M. et al. proposed PDO-AODV [13] to optimize network performance through load balancing. It estimates neighbor's power, delay and choose path accordingly to balance load in network. Neelagiri P. et al. proposed MObility pattern free Dynamic and Effective Location update (MODEL) [14] protocol which considers beaconing and dynamic location prediction-error measurement to optimize throughput of network.

As discussed above link quality based route metrics help in throughput enhancement of mobile ad-hoc network when used with some efficient routing protocols. ETX is used in many routing protocols for link selection such as ETX-AODV [7], MDART [15], etc. ETT is also used in many protocols as route metric like BAMR [16], etc. Recently in 2019, mETX link quality based route metric incorporated in MXAODV [7] routing protocol and considerably increased throughput of MANET.

This work has been made one more forward step towards optimization of routing protocol. Proposed protocol named EODRP optimize aggregate throughput of mobile ad-hoc network through selection of high quality links. Here we define high quality link in terms of less packet loss variability. At the time of route discovery EODRP eliminate links which seems to have more variability in probe packet loss.

1. ROUTE METRICS USED IN EODRP (EFFICIENT ON DEMAND ROUTING PROTOCOL)

EODRP uses ENT (Effective Number of Transmission) to select efficient links for communication. Selection of such links may improve aggregate network throughput. After selection of efficient links, EODRP uses mETX to estimate link quality. This information about link quality is dispersed with routing information. mETX is discussed with all its detail in our previous proposal i.e. MXAODV [7]. ENT metric details such as definition, formula, calculations and algorithm are as follows:

1.1 ENT (Effective Number of Transmission) formulation

Effective energy required to communicate a packet on a wireless link is represented by ENT.

In other words, we may say that ENT estimates amount of occupied resources in terms of maximum number of transmissions including re transmissions. Thus, before actual loss taken place, it estimates required effective bandwidth.

In the calculation of ENT, channel is formulated as Stochastic Gaussian Process.

*log*ENT [1] formula:

$$\mu_{\Sigma} + 2\delta\sigma_{\Sigma}^2 \le \log M \qquad (1)$$

The *log*ENT should be less than or equal to *log*M to optimize aggregate throughput.

Value of *log*ENT is defined as sum of mean and variance of channel bit error probability. Mean bit error probability is represented by μ_{Σ} and variance of channel bit error probability is represented by σ_{Σ}^2 of $\sum_K$, $k \ge 1$. M is threshold value of the number of retransmissions. Factor 2δ provides extra degree of freedom by multiplying it with variance. ENT may be calibrated through adjustment in δ parameter to achieve desired network performance. If $\delta = 0$, it means higher layer does not specify any loss probability in network. It specifies higher layer's loss estimation ignorance towards transmission and estimations are to observe mean channel behavior same as ETX. In actual conditions higher layers have some packet loss rate, i.e., $\delta > 0$. To work efficient in such actual situations and to provide support QoS, some resources should be reserved so that loss probability may overcome. Experiments show the range of δ varies from 1 to 2.5, where as best results may achieved on $\delta = 2$ in highly moving ad-hoc network.

ENT calculations are carried out at bit level. Calculations of error probabilities at bit level show very random behavior. To accommodate this random behavior of wireless link, ENT calculations get through second order cumulant. This is to subsume different channel conditions at different time in estimation of ENT for a specific link. ENT is perfect to estimate the quality of unpredictable wireless links as it include randomization factor σ^2 i.e. variance of probe packet loss on link.

Once μ_{Σ} and σ_{Σ}^2 are calculated for ENT, mETX value for each link may also be estimated using following formula:

$$mETX = \exp\left(\mu_{\Sigma} + \frac{1}{2}\sigma_{\Sigma}^2\right) \qquad (2)$$

1.2 ENT Computation

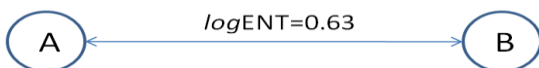Computation of ENT value of a link displayed below by assuming two nodes A and B as shown in figure 1.

Figure 1: ENT value on a dedicated wireless link (For $\delta = 2$, *log*ENT = 0.63).

On this dedicated link shown in figure 1, bit error probabilities $P_{B,T1}$ to $P_{B,T10}$ are noticed through transmission of 10 link layer probe packets periodically. Each probe packet consists of predefined pattern of 10 bits. Values of $P_{B,T1}$ to $P_{B,T10}$ are noted through simulation experiments. One set of observed values is 0.5, 0.6, 0, 0.1, 0.9, 0.8, 0.2, 0.3, 0.7 and 0.1 respectively. These values are noted and all $P_{B,T1}$ to $P_{B,T10}$ values are then passed through EWMA (Exponentially Weighted Moving Average) filter [17].

Moving average filter takes a noisy time series and provides each value with the average value of a neighborhood over noted passed values.

EWMA_$P_{B,T's}$ computations are shown below:

$$EWMA\_P_{B,T1} = \lambda \times P_{B,T1} + (1-\lambda) \times EWMA\_P_{B,T0} \qquad (3)$$

Here EWMA_$P_{B,T0}$ is assumed 0.5 to avoid bias. Experimentally determined perfect value of λ is 0.9, same is used here in computation process. After filtering, obtained EWMA_$P_{B,T1}$ to EWMA_$P_{B,T10}$ values are 0.5, 0.59, 0.059, 0.0959, 0.8196, 0.80196, 0.2602, 0.29602, 0.6596 and 0.15596 respectively.

$\eta_{B,T1}$ is defined as $\eta_{B,T1} = - log(1- EWMA\_P_{B,T1})$ it may represented by basic algebra that

$$P_{B,T} \le \eta_{B,T} \le P_{B,T} + \frac{P_{B,T}^2}{1-P_{B,T}^2} \qquad (4)$$

for all Ts.

Hence $\eta_{B,T} \approx P_{B,T}$, for reasonable small values of $P_{B,T}$ so two may be replaceable.

$$\text{Let } \Sigma_k = \sum_{T=1}^{10} \eta_{B,T} \qquad (5)$$

With the values of $\eta_{B,T's}$ in hand, μ and σ^2 can be calculated on it by formulas. Example shown in figure 1 have $\eta_{B,T1}$ to $\eta_{B,T10}$ 0.30103, 0.38723, 0.02641, 0.0438, 0.7437, 0.7033, 0.5847, 0.15244, 0.4680, 0.07364 respectively. Hence, μ of Σ_k is 0.35 and σ^2 of Σ_k is 0.07. Experiments show that $\delta = 2$ [1] gives best result in terms of packet loss rate on a wireless link. Hence, for the value of $\delta = 2$, calculated *log*ENT value is 0.63.

Similarly every wireless link's *log*ENT value is computed in network. Wireless links having *log*ENT less than or equal to *log*M assume to be qualified wireless links for transmission and selected to transmit data packets whereas other wireless links considered as inefficient for data transmission. This calculated value of *log*ENT for every link will be kept as added weighted field in reactive routing protocol to sense link quality during routing process. It improves quality estimations of wireless links hence improve performance of routing protocol in ad-hoc network.

Algorithm to generate *log*ENT values of links

Algorithm 1 : Calculation of *log*ENT
Input : Bit error probability of 10 packets of known sequence of 10 bit – pBt[ ].
Output : *log*ENT of a link.

1. Set λ *to 0.9*
2. Set v, m to 0
3. Set *EWMA_pBt[0] to 0.5*
4. For i=1 to 10
5. *EWMA_pBt[i]=*
   λ*pBt[i]+(1-λ)*EWMA_pBt[i-1]
6. *NBt[i]=-log(1-EWMA_pBt[i])*
7. End for
8. For i=1 to 10
9. *m=m+NBt[i]*
10. End for
11. μ_{Σ} = *m/i-1*
12. For i=1 to 10
13. *v=v+pow((pBt[i]- μ_{Σ}),2)*
14. End for

15. $\sigma_{\Sigma}^2 = v/(i-2)$

16. $log\text{ENT} = \quad \mu_{\Sigma} + 2 * \delta * \sigma_{\Sigma}^2$

Used symbol : λ – smoothing parameter, v – intermediate variable, m – intermediate variable, μ_{Σ} – Average bit error probability , σ_{Σ}^2 – Variance of bit error probability, δ – space parameter.

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2. DESIGN OF PROPOSED ROUTING PROTOCOL EODRP

EODRP (Efficient On Demand Routing Protocol) is a proposal made in this work. Aim of this proposed routing protocol is to find efficient links in MANET and form path to enhance aggregate throughput of network. For the implementation purpose, we are using structure of AODV routing protocol. AODV's route decisions are based on hop count route metric; means it selects the shortest path from source node to destination node. Proposed design makes amendment in this criterion of routing decision. Proposed routing protocol uses ENT route metric to select efficient links and mETX metric (instead of hop count) to select route so that aim of the proposal can be achieved. To maintain the path information in EODRP, we used min-max approach which tells us the quality of path and it helps the routing protocol in path selection process.

We have added one field (WT-field) in AODV routing table, neighbor table, hello packet, route request packet, route reply packet and route error packet which carries quality of wireless link. EODRP has two main functions of routing, these are RD: Route Discovery and RM: Route Maintenance. During route discovery, if source mobile node wants to transmit data packets to destination mobile node and it does not have any active path in its routing table for this particular destination mobile node, then source mobile node initiates route discovery process to find a path from source node to destination node. The role of route maintenance is to maintain the current route, if it fails then send route error packet to source mobile node and if required then re-initiate route discovery process.

4.1. EODRP Route Discovery Process

In an ad-hoc network each node periodically calculates mETX and $log\text{ENT}$ (using Algorithm 1) values for every link. mETX stored in neighbor table as link quality and $log\text{ENT}$ is used to select efficient links for transmission. In our simulation, $log\text{ENT}$ values vary from 0.2 to 1. EODRP selects links to formulate path which have $log\text{ENT}$ value

from 0.2 to 0.779. On the basis of experiments, we have considered 6 number of retransmissions i.e. M=6, hence value of $log\text{ENT}$=0.779. mETX values of wireless links used at the time of route selection process. When source node sends RREQ packet to neighbor nodes then it copies mETX value in RREQ link quality field (i. e. WT Field), receiving neighboring node compares this RREQ packet's WT value (link quality) with stored link quality values in neighbor table, maximum value is selected and forwarded with RREQ. When RREQ packet received at destination node then destination node also compares own and received WT values; it select minimum value and forward it with RREP packet to source mobile node. When source mobile node receives the RREP packet, it stores the path in routing table with link quality value and begins the data transfer. Mean while destination node receives another RREQ packet from same source via another neighbor node then destination node compares the link quality value of current path and newly received path, minimum is selected and again RREP packet will be forwarded to source node if necessary. Source node compares the current path link quality with new received route, if it is minimum then source node replace the current path with newly received path and discard the old path.

Further, we are describing proposed algorithm with the help of an example. This example is illustrated in detail with a clear and small network arrangement of 9 nodes in figure 2. In example, node S indicates source node and node D indicates destination node. Nodes A, B, C and E are neighbor nodes of source node S. Every node estimates neighbor's link mETX and $log\text{ENT}$ values. In this example, 6 retransmissions (M) are considered on network layer; i.e. M=6. Thus, calculated value of $log\text{M}$ is 0.779 on minimum six retransmissions. Every link's $log\text{ENT}$ value is compared with $log\text{M}$. If $log\text{ENT}$ is less than $log\text{M}$, node assigns mETX value as cost of communication (WT field) otherwise, assign ∞ to the links whose $log\text{ENT}$ values are greater then $log\text{M}$ ($log\text{ENT}>log\text{M}$). Links having ∞ cost of communication will not be considered for forwarding packets.

In path selection process through EODRP, the first step is the discovery of inefficient links for transmission. In EODRP, the Links S→A, S→C and G→H will not be used for data transfer as their $log\text{ENT}$ values are higher than $log\text{M}$.
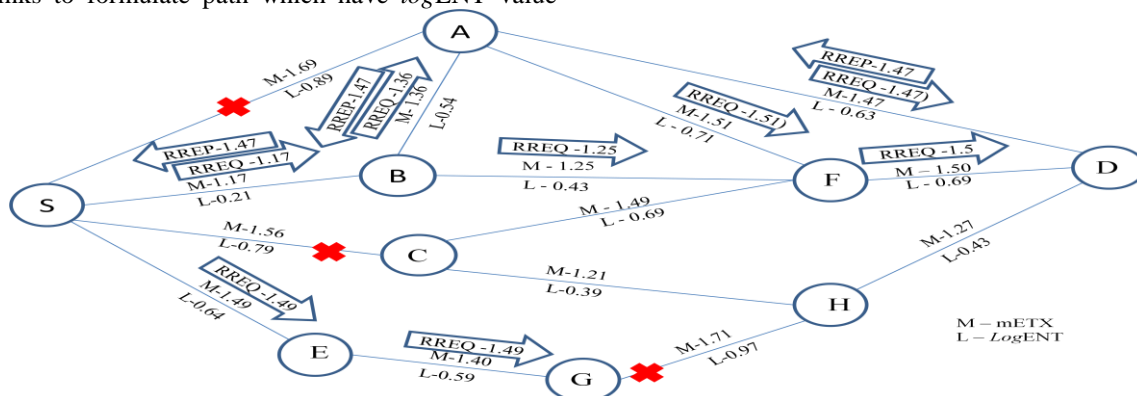
Figure 2: Enhanced aggregate throughput path selection with EODRP

Let source node S wish to transmit data packets to destination node D. Source node S is not having any active route to this destination (node D). Now source node S need to broadcasts RREQ packet to its selected efficient neighbour nodes only (i.e. links whose *log*ENT values are less than *log*M). Therefore node S's neighbour nodes B and E receive this RREQ packet. After receiving RREQ packet these nodes (B and E) will check received RREQ packet's WT value and compare it with WT value of the link on which receiving nodes want to forward RREQ packet. Maximum value of WT is selected and added in RREQ for further forwarding and same WT value is stored in routing table for source node S and destination node D pair. In figure 2, the source node S's neighbour nodes A and C are not eligible for receiving the RREQ packet because their links *log*ENT values are greater than *log*M. Destination node D receives two RREQ packets from A and F. In EODRP, destination node selects the RREQ with min value of WT. If destination node D receives RREQ packet via node F then it creates RREP packet with WT value (i.e. mETX=1.50) and send this RREP packet on reverse path to source node. As source node receives RREP packet, it stores this path in routing table and node S begins the data transfer on this discovered route. Further, if node D receives another RREQ packet for the same request (via node A) then node D compares new RREQ WT value with stored current path's WT. In figure 2, new path has minimum WT value (i.e. mETX=1.47) so destination node sends again RREP packet to source node on new reverse path (via node A). When source node S receives this new path then it compares both path's WT value if new path is having minimum one then node S overwrite the current path by new one. Efficient route with required quality is discovered from S to D: S→B→ A→ D. Selected route provides enhanced aggregate throughput.

Figure 2 is a single illustration only, so quick variation of *log*ENT and mETX (WT) for every link is not considered here in this example. To show quick variations in *log*ENT and mETX values for every wireless link, predefined probe packets are used to transmit periodically to note bit error probabilities per 10 packet time scale for every wireless link. Captured bit error probabilities then normalized with exponentially weighted moving average. These normalized values then used to calculate mean packet loss rate of wireless links as well as packet loss variance of wireless links. Bit level calculations of *log*ENT and mETX are illustrated section 3.

Path selected through EODRP is comparatively better quality in terms of packet loss rate hence it enhance aggregate network throughput considerably. Moreover, we visualize that network overhead also minimized with EODRP. Some links are found inefficient for communication in initial phase which may properly visible at higher layer. Here, with EODRP, such inefficient links observed in advance and eliminated from routing process it eventually improves aggregate network throughput.

4.2 EODRP Route Maintenance Process

In EODRP route maintenance, we use the concept of make before break [18]. In this process, source node finds the weak link in a path. To accomplish this process, source node transmits the weak-link-detector packet on the current active path periodically. If any link in a path having more than 0.779 *log*ENT value then route maintenance process initiate the local repair mechanism [18].

III. SIMULATION PARAMETERS AND ASSESSMENT OF PERFORMANCE

Network simulator (NS 2.35) is used to carry out experiments and to measure the performance of EODRP in comparison of MXADOV. Simulation parameters that are used to conduct experiments are stated in table 1. The performance parameters on which performance comparison has been done are below:

(a) Packet Delivery Fraction (PDF) – Proportion of successfully transmitted versus generated data packets by CBR sources.
(b) Throughput- Data volume in bits per sec transferred from communicating host to another host which act a destination host in specific time period is throughput.
(c) Normalized Routing Overhead (NRL) – Amount of control packets communication for single packet delivery. Every hop counted as one communication.
(d) Packet Loss – Packet loss is the failure in transmitted packet hence fails to achieve destination.
(e) End-to-End Delay (EED) – Aggregate delay in communication including route discovery, packet queuing, retransmissions, etc.

Table1 : Simulation Parameters with respective values

|		
1.	Type of traffic	CBR with UDP
2.	Rate of packet	10 Pkts/s
3.	Size of Packet	512 bytes
4.	Mobility Model	*RWM Model
5.	Interface Queue Length	100 packets
6.	Antenna Model	Omni
7.	Number of hosts	200
8.	Topology	Flat Grid
9.	Topology Size	1500X1500
10.	Pause Time	50 Sec
11.	Simulation Time	50-500 Sec
12.	Node Max Speed	10 m/s
13.	Radio Propagation Model	Two Ray Ground Model

*RWM- Randon Way Mobility

Outcomes of experiments for PDF and EED are observed from 50 sec to 500 sec and displayed in table 2 for EODRP and MXAODV both. Each outcome shows some enhancement in performance of EODRP. Figure 3 graphically represent all obtained PDF results for EODRP and MXAODV. In which PDF is shown on different simulation time for EODRP and MXAODV. Both routing protocol follow declining trend of PDF with increment in simulation time. EODRP demonstrates high PDF in comparison of MXAODV. PDF in EODRP is 99.9% for 50s simulation time. It decreases as simulation time increases and that is usual in all routing protocols. In that decreasing trend EODRP performs always comparatively better in every simulation experiment. EODRP eliminate inefficient links from path selection process prior to route a packet hence perform better in terms of PDF. PDF increases on an average 2.59% with EODRP in comparison of MXAODV.

Table 2: Comparison of PDF, EED Versus Simulation Time

Simulation Time (Seconds)	Packet Delivery Fraction (%)		End to End Delay	
	EODRP	MXAODV	EODRP	MXAODV
50	99.89508	98.9508	0.10033	0.11348
100	98.01026	96.41026	0.1128	0.13128
150	97.05938	95.098	0.82041	0.98961
200	95.65718	92.518	0.890584	1.0114
250	93.93192	90.331	1.05669	1.145
300	91.1994	89.1994	1.5078	1.78
350	88.8032	86.1032	1.8386	1.999
400	86.8864	83.8864	2.262	2.452
450	84.05784	81.05784	2.518	2.818
500	80.90344	76.90344	3.032	3.211
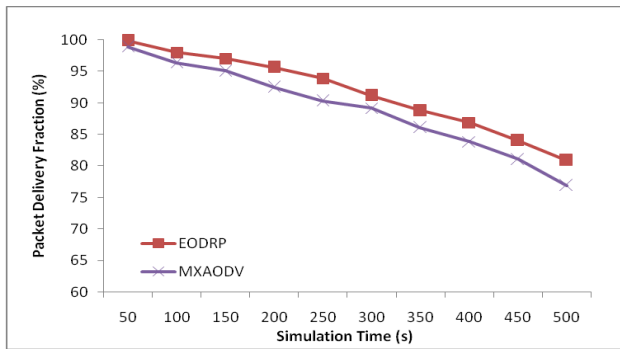
Figure 3: PDF versus Simulation time
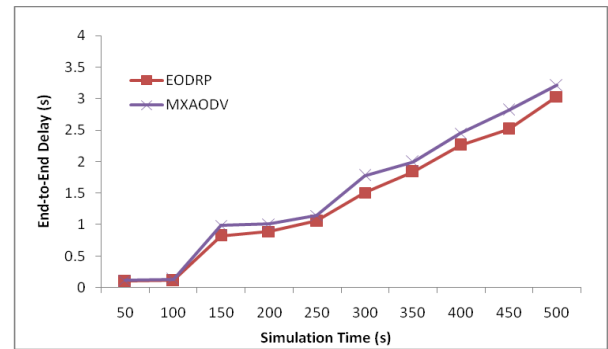
Figure 4: EED versus Simulation time

EED demonstrated in figure 4 at time varying simulation experiments from 50 sec to 500 sec. Experiments show decrement of on an average delay of 0.16s with the use of EODRP in comparison of MXAODV. EODRP uses efficient route metric ENT that discard links that are inefficient in transmission. Usages of more efficient links in transmission of data packets improve EED.

Simulation experiment performed from 50 sec to 500 sec simulation times to observe NRL and aggregate network throughput, and displayed in table 3. These outcomes are found improved as NRL is less in EODRP in comparison of MXAODV. Whereas throughput is improved in each outcome of EODRP compared to MXAODV.

Table 3: Comparison of Normalized Routing Load , Throughput Versus Simulation Time

Simulation Time (Seconds)	Normalized Routing Load		Throughput	
	EODRP	MXAODV	EODRP	MXAODV
50	7.076	8.076	993.65	873.65
100	10.606	12.9	1199.833	1049.833
150	12.49	15.91	1398.017	1288.017
200	16.086	18.6	1567.318	1467.318
250	20.278	22.71	1612.815	1512.815
300	22.1	25.2	1716.368	1596.368
350	23.4982	26.2	1790.369	1620.369
400	28.46	30.33	1855.145	1685.145
450	32.83	35.3	1916.791	1816.791
500	38.52	42.11	2199.23	1902.283

Figure 5 represents normalized routing load against different simulation time from 50s to 500s.

This parameter is an indicator of protocol efficiency and a   relative measure of routing

overhead. As simulation experiment time increases normalized routing load also increases that shows control as well as data packets increases in network due to packet loss and retransmissions. Figure 5 show that normalized routing load is minimized with EODRP in every experiment. EODRP results got an average decrease of 2.54 % with respect to MXAODV.
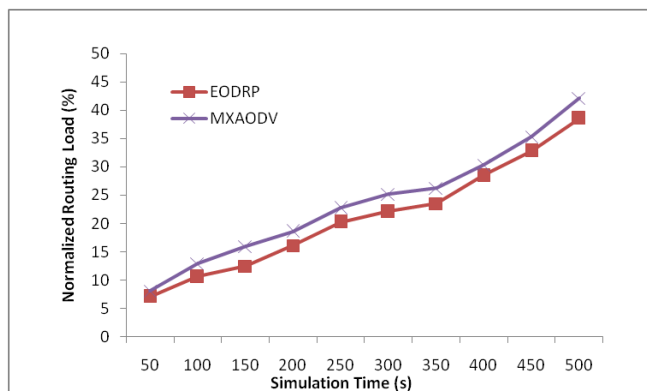

Figure 5: Normalized Routing Load %

EODRP is designed to get enhanced throughput, figure 6 represents success of EODRP in every simulation experiment. We get an increment of 143.69 kbps through EODRP in comparison of MXAODV.
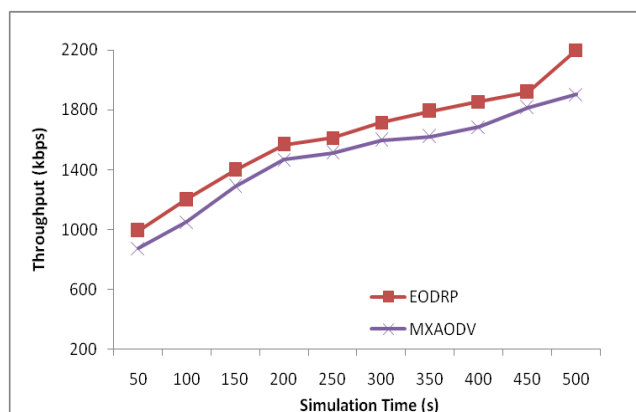

Figure 6: Throughput

Enhance throughput shows efficiency of EODRP in each simulation. EODRP works on ENT routing metric which controls number of retransmissions on higher network layer hence throughput increases. EODRP shows good performance in variable channel conditions as ENT considers variance

IV. CONCLUSION

This work has been done to improve aggregate network throughout of mobile ad-hoc network during transmission of data packets. Proposed protocol EODRP is analyzed and compared with our previously proposed protocol MXAODV. MXAODV is already an enhancement over similar kind of protocols. EODRP maintains link quality QoS threshold in route selection process. Data packet transmission held on permissible efficient links only. Offline calculation of path set up also has been done with an example to show high throughput route selection process. Simulation experiments in NS-2 are conducted to show significant improvement in results of EODRP. EODRP

performance analysis shows improvements in every obtained outcome of simulation with every considered parameter.

We are working further to enhance this proposal and observe the performance on VBR traffic and on different packet sizes. These results will help to decide more future directions. One of the future directions is to implement multi criteria link quality metric which may consider available bandwidth, residual energy, node's idle time and queue length, etc to estimate link quality in routing protocols. Routing protocols may be optimized by using such multi criteria link quality metric to select transmission route.

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