ETOR-Efficient Token based Opportunistic Routing

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Abstract

This paper proposes an Efficient Token based Opportunistic Routing called ETOR, which is an improvement to the token based coordination approach for opportunistic routing proposed by Economy[1]. In Economy, method used for finding the connected candidate order chooses neighbor as the next candidate by considering ETX of that neighbor towards the source but it does not consider the link probability between the relay candidate and neighbor to be selected. ETOR proposes variant methods for finding the connected candidate order in token based opportunistic routing by considering both the ETX of the neighbor towards source as well as ETX of the relay towards sending candidate which avoids weaker links between its intermediate nodes thereby improving the throughput and reducing the AA Ratio. We also propose a solution for reducing the number of hops traversed by the token, which in turn increases the token generation speed. Simulation results show that the proposed ETOR approaches perform better than Economy approach in terms of AA Ratio, number of hops traversed by the token and number of token traversals.

Keywords

Opportunistic Routing, Token based coordination, Connected candidate order, Wireless Networks

1. INTRODUCTION

In Wireless medium every transmission is a broadcast to all its neighbors and this broadcast nature has been taken into advantage in Opportunistic Routing to improve link reliability and system throughput by routing packets through multiple routes dynamically. But OR suffers from duplicate transmissions when lower priority forwarder does not listen to higher priority forwarder, that is, the lower priority forwarder transmits the same packets that are already transmitted by higher priority forwarder. ExOR[2,3] specifies that only those nodes that transmit at least 10% of batch will be considered but it does not specify the connectedness between successive forwarders. In some situations, the forwarders may transmit 10% of batch, but every lower priority forwarder may not be connected to its immediate higher one. For example, if we consider the network shown in figure 1 where node S is the source, D is the destination. The forwarder list of nodes are {F1, F2, F3, ...} ordered from lowest to highest priority, that is, after the transmission of source S, first node with higher priority F3 transmits, then F2 and after that F1. As shown in figure 1, F2 does not listen to F3 and F1 does not listen to F2. F2 transmits the same packets that are already been transmitted by F3. F1 transmits the same packets that are transmitted by both F2 and F3. This causes duplicate transmissions and degrades the performance of OR.

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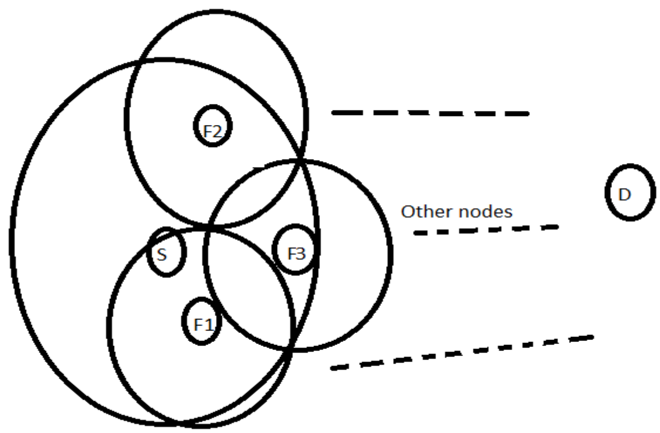


Figure 1. Network showing duplicate transmission in OR

In Token based coordination concept of OR, the duplicate packet transmissions of opportunistic routing protocol are completely avoided by maintaining connectedness between forwarders, that is, each forwarder listens to its immediate preceding forwarder. In this method, Forwarders collect overheard packets and forward them only after getting the acknowledgement information of predecessor candidates from the token as soon as the token arrives. Tokens are generated at the destination and they flow from lower priority forwarder to higher priority forwarder towards the source.

1.1. Motivation

In token based solution proposed by Economy[1], all neighbors whose ETXs (to source) are smaller than that of the relay are considered to be candidates, and it picks the one among those candidates with the highest ETX to source. This does not give importance to the link reliability between immediately connected candidates. If a neighbor has highest ETX to source, then it is not necessary that it is closest or has less ETX to sending relay. As shown in figure 2, the neighbor node B, which has more ETX that is 10 to source S has less packet delivery probability from R, where as the node B which has lower ETX that is 8 to source has more packet delivery probability from the relay node R.

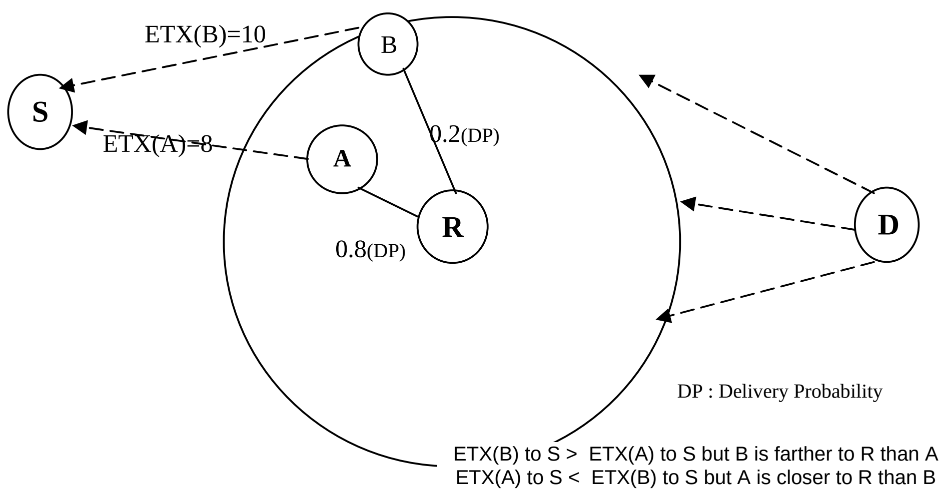


Figure 2. Drawback of candidate order of Economy

The rest of the paper is organized as follows. In section 2, we provide a brief description of some of the previous work in the area of opportunistic routing. In Section 3, we present our proposed approach ETOR – Efficient Token based Opportunity Routing highlighting the factors to be considered while creating connected candidate order. This is followed by a detailed discussion on the proposed approaches for finding connected candidate order ETORM1, ETORM2 and their variants exploiting opportunism OETORM1 and OETORM2 which use two cost metrics considering both Global ETX as well as Local ETX to compute the candidate order. The simulation setup, results and discussion are provided in section 4. The paper finally concludes with a summary and future research directions in this field.

2. PREVIOUS WORK

In this section, a brief description of some of the previous work in the area of opportunistic routing is presented. ExOR [2,3] is the first implementation of OR and shows the potential of OR. While data transmission, instead of selecting a single next neighbor, more than one neighbor is selected as forwarder list, this approach makes use of broadcast nature of wireless transmission. Neighbors will be selected based on metric ETX[10] that is expected number of transmissions. The neighbor which has least value of ETX will be given highest priority and this forwarder node transmits the data first and then the chance goes to next priority node. When one forwarder node transmits the data other forwarder nodes updates their list of packets to be sent, by overhearing. When one forwarder node does not listen to its immediate preceding forwarder it transmits the same packets that are already transmitted by its preceding forwarder, this creates duplicate packet transmissions.

Economy[1] has discussed the problem of duplicate transmission in ExOR, it has given a token based solution for avoiding duplicate transmissions. A connected candidate order is created where in every forwarder listens to its immediate preceding forwarder. Tokens are generated at the destination and flows towards the source by collecting acknowledgements of different forwarders, each forwarder transmits only after getting the acknowledgement information from the token as soon as it arrives.

GOR(Geographic Opportunistic Routing) [4, 5, 6] is the OR based on geographical routing[7], where relay selection is done according to the geographical position. In Selection diversity forwarding [8] approach, the source includes list of potential forwarder nodes' addresses in the RTS packet, neighboring nodes which successfully receive the packet respond with CTS packets containing the signal to noise ratio. Source chooses a forwarder by using this information. GeRaf[9] uses an RTS/CTS based receiver contention scheme to select the best of many potential forwarders but prioritizes forwarders based on geographic distance. ETX [10] refers to "expected transmission count", i.e. number of transmissions required to pass a packet from source to destination. It is calculated as the sum of number of transmissions of packets from source to receiver and number of transmissions required to pass acknowledgements from receiver to source. Number of transmissions is calculated as the inverse of delivery probability. MORE [11] is the first protocol that uses network coding [12] as the coordination method. In this approach, the source broadcasts random linear combinations of native packets, and relays forward the linear combinations of received coded packets to the destination. Coded packets are decoded only when the destination has collected enough linearly independent coded packets. In this redundant packets are created, but they are not duplicates and do not contain any additional information.

3. PROPOSED APPROACH – ETOR

In this section, we present our proposed approach named ETOR – **E**fficient **T**oken based **O**pportunity **R**outing. In order to illustrate our approach, we define the following terms:

Relay node (R) is defined as the node in the Forwarder list F selected for forwarding (relaying) the packets.

Global ETX (GTX) is defined with respect to the relay node as the ETX of a neighbouring Node of the relay node R in the Forwarder list F to the source S
Local ETX (LTX) is defined as the ETX of the relay node R to a neighbouring node in the Forwarder list F.

In ETOR approach, to improve the throughput and to reduce the AA Ratio, both Global ETX(GTX) and Local ETX (LTX) are considered to find the connected candidate order. For example, if we consider the simple network shown in figure 3, choosing D as the destination, according to economy the connected candidate order formed is D-3-4-1-S. Where as the connected candidate order D-3-2-1-S performs better in terms of number of transmissions. This connected candidate order D-3-2-1-S is obtained by considering Local ETX in addition to Global ETX. Therefore, selecting a node with highest ETX to source may facilitate that at a time more candidate nodes listen to the particular transmission of a relay but it does not guarantee the link quality between sending relay and its next candidate.

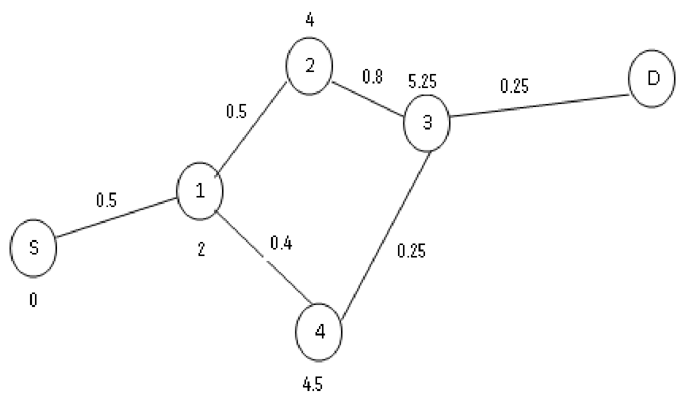


Figure 3. Example network each link is labeled with delivery probability, each node is labeled with ETX to source

3.1 Factors that are considered while creating connected candidate order

- Including more neighbors increases length of the candidate order list, which increases number of nodes the token has to visit at each traversal, that in turn reduces the throughput.
- If a relay transmits the token even when the previous candidates towards source do not have the packets which means that it is unnecessarily blocking the incoming tokens from source during the transmission of its token towards the source.
- Neglecting local ETX may create very weaker links between some intermediate candidates, which cause the token to take more traversals only for transmitting packets of a particular node where as other candidates have no packets to forward. Considering figure 4, source node S has 5 packets and the corresponding link probability is 0.1, it is evident that more number of transmissions are required and each transmission has to wait for a token that has to come from the destination.

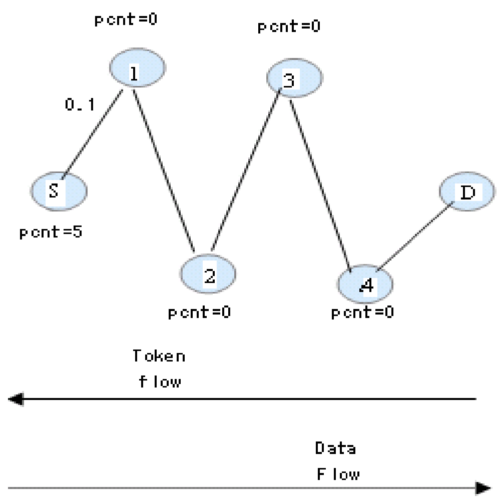
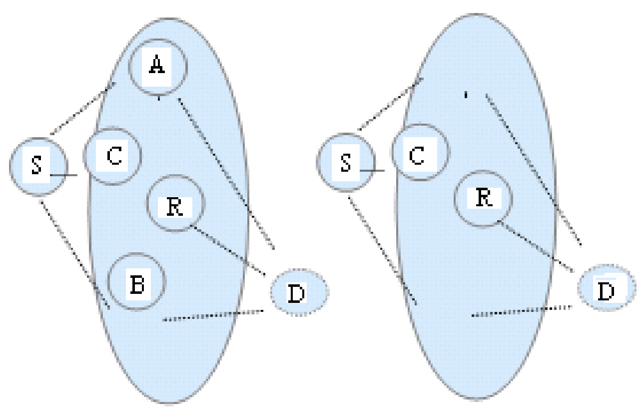


Figure 4. Example network that shows weaker intermediate links

- When a relay has multiple candidate neighbors, that is, multiple candidate nodes are there in its region as shown in Figure 5, then the token will be in the range of that particular relay for more time, which in turn stops other tokens coming from destination towards source. So, if the number of candidate neighbors of a particular relay increases, then the token generation speed at the destination has to decrease. For example, consider the Figure 5a), destination D can send the token only when R and its 3 candidate neighbors(Candidate neighbors are those candidates which are also neighbors of a particular relay) A, B and C are not sending. Where as in Figure 5b), the destination D can send the tokens at faster rate because it has to wait only for 2 nodes R and its candidate neighbor C.



(a) **(b)**

Figure 5. Effect of multiple candidates in the range of a relay candidate**.**

- If we do not consider the local ETX, then due to the weaker intermediate links, token losses may be more which in turn increases token retransmissions.
- If the token always terminates at the source, irrespective of whether source and other candidates have any packets to transmit, the total number of hops to be transmitted by the token increases unnecessarily because if a node does not have any packets then that candidate has no use of the token received.

Hence considering only global ETX will cause an increase in the number of transmissions, number of hops at each round, number of rounds the token has to take which in turn will result in decrease in the token generation speed and increase in the waiting time of each candidate to transmit token. All these factors will cause the throughput to decrease. In order to improve the throughput and to decrease the AA Ratio, both the local ETX and global ETX are taken into account which avoids weaker links between its intermediate nodes, pumps more packets at each transmission, reduces number of traversals and decreases the number of hops at each round. Token generation speed also increases because it does not include more candidate neighbors.

In this approach, we have proposed two methods ETORM1 and ETORM2 for finding connected candidate order suited for networks of higher link probabilities and two variants of these methods OETORM1 and OETORM2 exploiting opportunism suited well for networks of lower link probabilities. These approaches use two cost metrics M1& M2 considering both Global ETX as well as Local ETX for computing the candidate order which will be discussed next.

3.2 ETORM1 for finding connected candidate order

This method proposes that a neighboring node which, if selected, causes minimum ETX from relay candidate towards the source will be chosen as the next candidate. In this case, sending candidate ETX can be defined as the sum of its Global ETX and Local ETX. This is not a new metric but the application of this metric gives better performance than that of economy.

Let N be the set of neighbors of relay node R, N_i be the i^{th} neighbor, GTX_i be the Global ETX, that is, ETX of neighbor node N_i to the source, LTX_i be the Local ETX, that is, ETX of relay node R to the neighbor node N_i , GTX_R be the ETX of the relay node to source node and j be the number of neighbor nodes of relay node R.

Considering both global ETX and local ETX, we propose a metric M1, defined as :

$$M1=\min\{GTX_1+LTX_1, GTX_2+LTX_2, GTX_3+LTX_3,\ldots\ldots, GTX_j+LTX_{j,},\ldots\}$$

where i ranges from 1 to j and $GTX_R > GTXi$

For the selection of next candidate node of relay node R, compute M1 and select N_i^{M1} , i^{th} neighbor node with least cost value M1, as the next candidate node of relay node R.

Considering all neighbors of relay node R, the neighbor with least cost value M1 will be selected as the next candidate. This metric is considered because it gives the candidate order of shortest length as only the nodes with minimum ETX to source and minimum ETX to relay are considered. Both these are favored as the number of candidates that participate in the simultaneous packet transmission decreases and it guarantees the quality of the link between relay and its next neighbor. Further, the shorter candidate order reduces the number hops to be traversed by the token at each traversal.

In fact, this method forms the shortest path from destination to source but for dense networks, this also facilitates multiple candidate neighbors. The advantage of this method is that it completely eliminates the weaker links. For example, if we consider the figure 6, using the metric M1, node A will be selected first since its metric value is 12 and then node B is selected as its metric value is 13 and further, B is also in the range of A as shown in the figure.

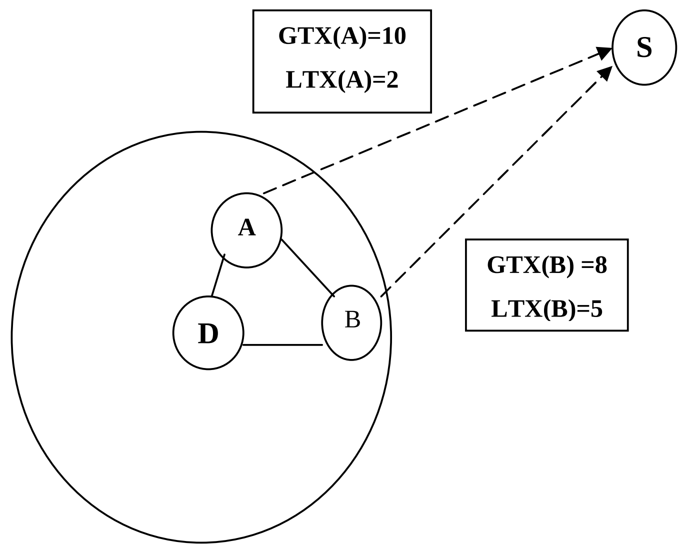


Figure 6. Forming of multiple candidate neighbors using ETORM1

3.3 ETORM2 for finding connected candidate order

To include more nodes in the simultaneous packet transmission while considering intermediate link quality, the ratio of global ETX to the local ETX can be considered as the metric for choosing next candidate. Based on this, we propose a metric M2 which is defined as :

$M2 = \max\{GTX_1/LTX_1, GTX_2/LTX_2, GTX_3/LTX_3, \ldots\ldots. , \ldots\ldots\ldots\ldots., GTX_j/LTX_j, \ldots\ldots\ldots\ldots\}$

where i ranges from 1 to j and $GTX_R > GTXi$

For the selection of next candidate node of relay node R, compute M2 and select N_i^{M2}, i^{th} neighbor node with least cost value M2, as the next candidate node of relay node R.
This metric is chosen because when the global ETX of a neighbor node increases, numerator in the ratio figure increases which causes more number of neighbors to be included in the range of a particular relay. If local ETX increases (which causes weaker intermediate links), the total ratio value decreases which in turn reduces the chances of selecting a particular neighbor node with weaker link probability as the next candidate relay .

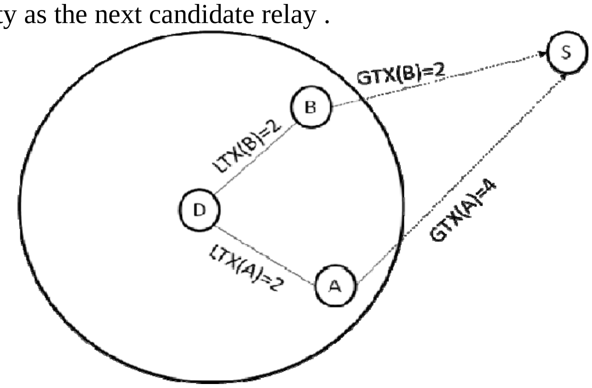


Figure 7. Creation of bad links by ETORM2

The disadvantage of this method is that the candidate which provides bad link will also be selected some times as next candidate. For example in figure 7, both the candidates A and B have the same LTX and A has more GTX. ETORM2 chooses A rather than B which has better connection to S than A. This drawback can be compensated as it causes multiple candidates to be in the range of relay candidate. For example consider the figure 8, neighbors A and B are in the range of relay node D. GTX(A) is more than GTX(B). Common coverage region of A and D is greater than that of B and D. There will be more common neighbors of A and D than B and D. That means selection of A gives more opportunism than selection of B. In many cases, there is more probability that next candidate of A will be in the range of D than the next candidate of B. Even though A is a bad connection to D than B but it gives better performance with opportunism.

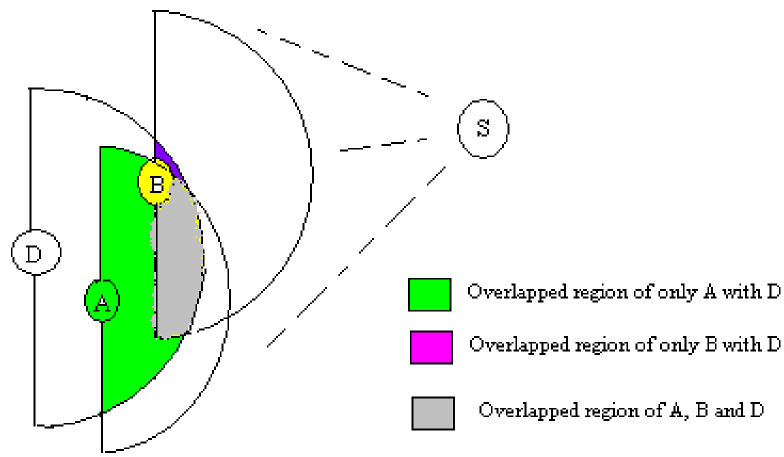


Figure 8. Bad links are compensated by opportunism in ETORM2

3.4 Exploiting Opportunism - OETORM1 and OETORM2

Economy, ETORM1 and ETORM2 approaches do not guarantee that every candidate listens to multiple candidate neighbors. Opportunistic versions OETORM1 & OETORM2 add one more condition to the metric given by ETORM1 and ETORM2. For selecting the next candidate, common neighbors of relay candidate and its previous candidate are considered. If there is no common neighbor that has less GTX than relay candidate then only neighbors of relay candidate are considered and the corresponding metric is applied. For destination node, there are no previous candidates, hence only the neighbors of destination node are considered.
For example considering the figure 9, the next candidate of D is selected from neighbors of D and it is J. Next candidate of J, that is K, is calculated from the common neighbors of J and its previous candidate D. Next candidate of K, that is L, is calculated from common neighbors of K and J and this process continues for every candidate up to the source. Finding the next candidate in this way facilitates that next candidate receives the packets from relay candidate and previous candidate of relay candidate. It gives more opportunistic nature in OETORM1 than ETORM1 and more opportunistic nature in OETORM2 than ETORM2. Opportunism gives more advantage to low probability networks than high probability networks.

Every relay candidate and previous candidate may not have common neighbors with less GTX to Source than relay candidate. With this approach, some next candidates that are only in the range of a relay candidate are formed. As shown in figure 10, nodes M and K are such candidates. Candidate M listens only to its relay candidate N, candidate K listens only to its relay candidate L.

Formation of connected candidate order by OETORM1 and OETROM2 has a combination of common candidates, that is, candidates which are in the range of their previous two candidates and candidates which are in the range of only their relay candidate (M and K as shown in figure 10). This approach uses every possibility of forming common candidates where as in Economy, ETORM1 and ETORM2 common candidates are formed by chance. More common candidates are formed with this approach where as less common candidates are formed in Economy, ETORM1 and ETORM2.

To implement this approach, token has to include one more field called neighbor list, NL. Whenever a token is transmitted from previous candidate to the relay candidate, the previous candidate updates the neighbor list of the token with its neighbors. After receiving the token, relay candidate checks the neighbor list and picks those candidates that are also neighbors of itself. Among those common neighbors, the neighbors which have less GTX to source than relay candidate will be considered for applying the metric. If no node that meets these 2 conditions was found then only the neighbors of relay candidate that have less GTX to Source than relay candidate will be considered for applying the metric.

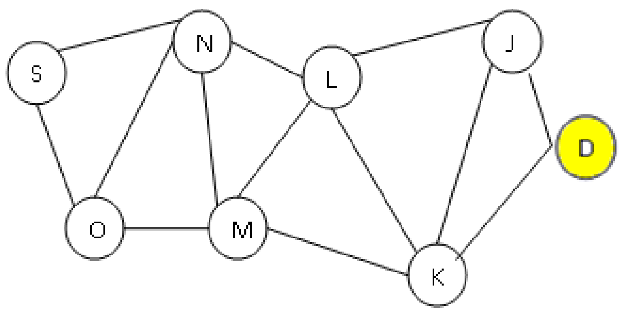


Figure 9. Selecting a candidate which is in the range of previous 2 candidates

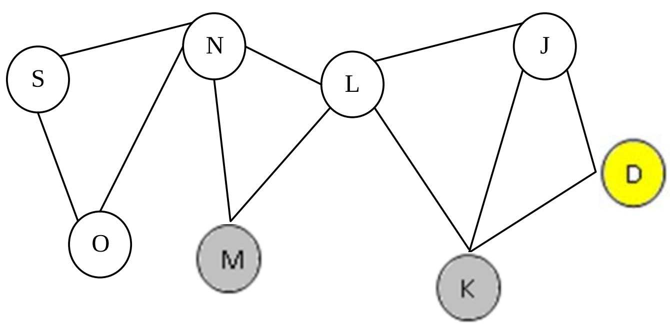


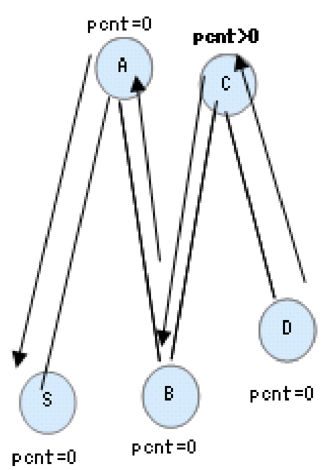
Figure 10. All candidates may not be in the range of previous 2 candidates

3.5 Reducing the Total Hops traversed by a token

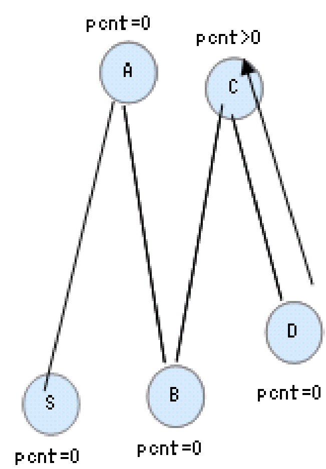
For every traversal, it is not required that the token has to reach the source because at some point of transmission the source and all candidates towards the source after a particular candidate may not have any packets to forward. Even then the source and the other candidates get the token and they simply drop it. The main purpose of the token is to know the status of predecessor candidates of a particular relay candidate and that can be source also and by knowing this status, a

particular candidate decides the set of packets that are to be transmitted. But when a node does not have any packets to forward, it doesn't need to know the status of predecessor candidates.
By restricting the token to the last candidate which has packet count of greater than zero, we can reduce the total number of hops to be traversed by the token and thereby increasing the token generation speed. Figure 11a), represents the situation where the token has to traverse up to the source even when the source and other 2 candidate nodes A and B do not have the packets, but the token is required to reach only up to node C, so if we restrict the token traversal only up to C, 3 hop traversals can be reduced at each token traversal as shown in figure 11b).

To implement this scheme, each candidate starting from the destination will be assigned an increasing index. For example in figure 11a) and 11b), C will be assigned index 1, B with 2, A with 3 and S with 4. These indexes will be assigned during connected candidate order formation. The process is as follows. When destination sends a token to a next candidate it gives the index as 1. Every candidate gives the index to the next candidate that is equal to one more than its index. After source knows its index , that means every candidate knows its index, source creates a special packet. The number of bits in the special packet is equal to the index of the source that is number of candidates including source and excluding destination. For example in figure 11a) it is equal to 4. Each bit corresponds to each candidate. As shown in figure 11c) and 11d), starting from the left first bit corresponds to source, second bit corresponds to next candidate towards the destination D and so on. Initially all bits are set to 1. When ever source has 0 packets to send, it sets left most bit to 0 and sends that packet to the next candidate(in the figure it is A) in a unicast way. When ever that candidate receives this packet it stops the token transmission. If the next candidate of source also has 0 packets it sets the second bit from left, to 0 and transmits it to next candidate towards destination in a unicast way. All candidates follow the same procedure. This approach involves creation of new packets (of very less size), but the overhead associated with this is very less as it gives significant reduction in the total hops transmitted by the token.



(a)



(b)

a) & b) Reducing number of hops traversed by token

S	A	B	C
1	1	1	1

c) Initial special packet at source(all bits set to 1)

S	A	B	C
0	0	0	1

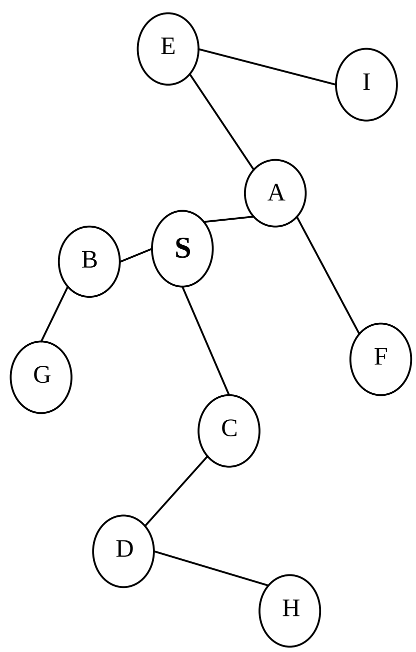
d) special packet at candidate C (token stops at C)

Figure 11. Restricting the token up to the last non zero packet candidate

4. Simulation Setup, Results & Discussion

For simulation, we have developed an enhanced simulator based on the open source simulator from [13] using the same code of the simulator for generation of network and calculation of global ETX, and all remaining required code for the simulation have been added. Topology of the network is random, that is, nodes are randomly distributed depending on the probability. Density of the network is 5. All nodes of the network are static. The probabilities are assigned distance wise. More distant nodes have less probability and less distant nodes have more probability. It is assumed that all proposed methods use the same data rate. Simulation is performed on low probability networks (with maximum probability of 0.45 i.e., nearest neighbor to the sending relay is assigned 0.45), high probability networks (with maximum probability of 0.9) and the minimum probability of any link in the network is considered to be 0.1(probabilities less than this value are considered as 0).

Route length wise simulation is performed on hundred 100-node networks and the average of results are considered in route length wise For comparing the results in route length wise, i.e., for each route length, set of nodes have been taken and average of all the parameters of Economy, ETORM1, ETORM2, OETORM1 and OETORM2 are calculated and compared for all 100 networks. Route length 0 node is only the source node S, route length 1 nodes are all the nodes that are neighbors of S, route length 2 nodes are all the nodes that are in the range of route length1 nodes but not in the range of source, route length 3 nodes means all the nodes that are in the range of route length 2 nodes but not in the range of route length 1 nodes and source node and so on. In this way, different route length node sets have been calculated as shown in below figure 12.



Route Length 1 nodes are: A, B, C
Route Length 2 nodes are: D, E, F, G
Route Length 3 nodes are: H, I

Figure 12. Calculation of route length wise nodes

Considering the 100 packets transmission, AA Ratio, number of total hops and number of hops after restricting the token up to the last non zero packet candidate are calculated.

AARatio (Attempts to Arrived Ratio) can be defined as number of transmission attempts required to transmit a packet from source to the destination. Less AA Ratio is preferable as it indicates less transmission attempts to transmit a packet.

AA Ratio=Total Number of transmissions/Total number of received packets (without duplicates)
Figures 13 and 14 indicate that all the four proposed methods perform better than Economy in terms of AA Ratio. OETORM1 performs better than ETORM1 and OETORM2 performs better than ETORM2 due to their opportunistic nature. AA Ratio improvement of ETORM1, ETORM2, OETORM1 and OETORM2 is given in tables 1 and 2. For low probability networks, all proposed methods give less improvement than high probability networks,. The difference between the improvements of ETORM1 and OETORM1, ETORM2 and OETORM2 for lower probability networks is significantly higher than that of high probability networks. Economy performs better for lower probability networks than higher probability networks. Finally, OETORM2 gives less AA Ratio than all for both low and high probability networks.

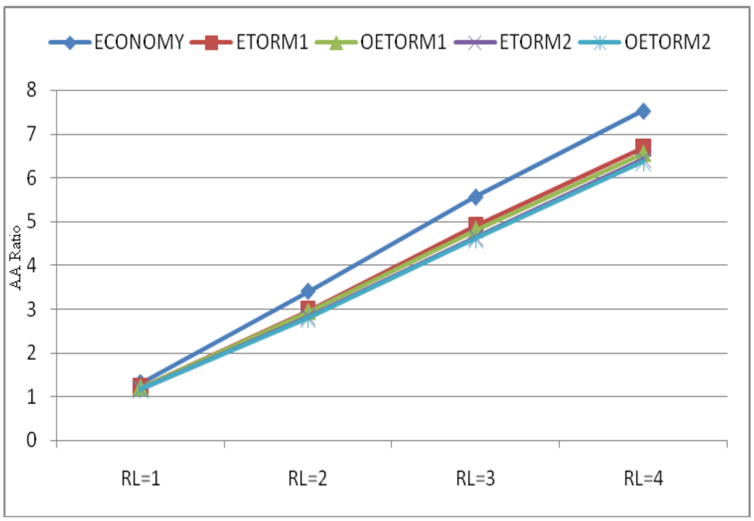


Figure 13. Route length wise simulation of AA Ratio(0.1<=p<=0.9).

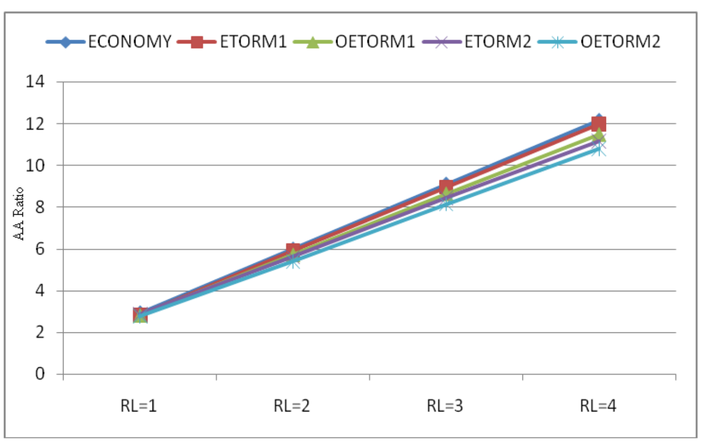


Figure 14. Route length wise simulation of AA Ratio(0.1<=p<=0.45).

Table 1. AA Ratio improvement (0.1<p<=0.9)

Route Length (RL)	ETORM1 over Economy	OETORM1 over Economy	ETORM2 over Economy	OETORM 2 over Economy
1	7.7	7.7	10.1	10.4
2	12.8	13.6	16.7	18.0
3	11.9	13.4	16.3	17.3
4	11.2	12.8	14.5	15.4

Table 2. AA Ratio improvement (0.1<=p<=0.45)

Route Length (RL)	ETORM1 over Economy	OETORM1 over Economy	ETORM2 over Economy	OETORM 2 over Economy
1	3.9	3.9	2.6	5.3
2	1.5	4.4	6.4	9.6
3	1.5	5.0	7.2	10.4
4	1.3	5.4	8.0	11.0

Total number of hops traversed by token: For each connected candidate order, number of hops is one less than number candidates in the candidate order. For each traversal the token has to go through connected candidate order, hence total number of hops is nothing but the product of number of traversals and number of hops for each traversal. Lesser the total number of hops more will be the throughput. Figures 15 and 16 show that the total number of hops traversed by Economy is very high as compared to all the four proposed methods both for low probability and high probability networks. ETORM1 performs better than ETORM2 because it decreases number of candidate neighbors. OETORM2 slightly has less number of hops than ETORM2. OETORM1 has slightly more number of hops over ETORM1. ETORM1 has less number of total hops than all other methods. Improvement of ETORM1, ETORM2, OETORM1 and OETORM2 over economy is given in the tables 3 and 4.

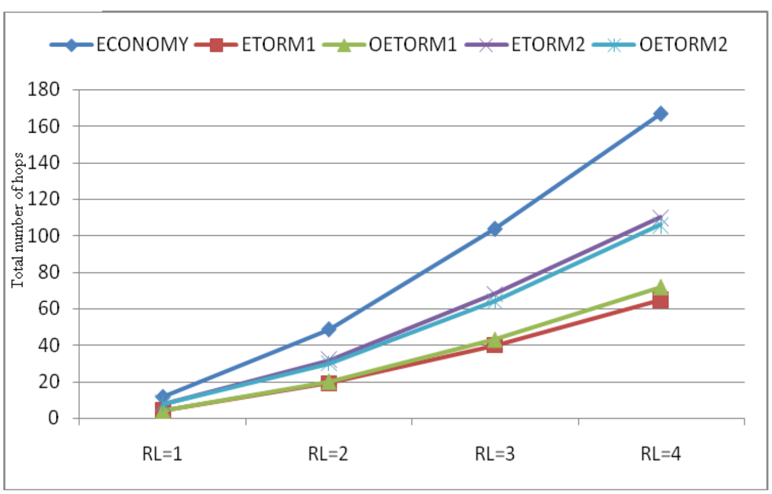


Figure 15. Total number of hops traversed by token (0.1<=p<=0.9)

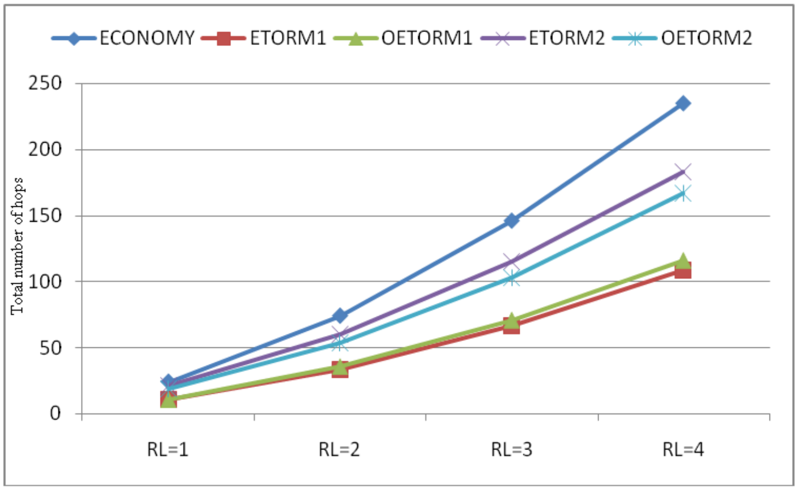


Figure 16. Total number of hops traversed by token (0.1<=p<=0.45)

Table 3. Total Hops improvement (0.1<=p<=0.9)

Route Length (RL)	ETORM1 over Economy	OETORM1 over Economy	ETORM2 over Economy	OETORM2 over Economy
1	66.6	66.6	33.3	33.3
2	61.2	59.1	34.6	38.7
3	61.5	58.6	34.6	38.4
4	61.0	56.8	34.1	36.5

Table 4. Total Hops improvement (0.1<=p<=0.45)

Route Length (RL)	ETORM1 over Economy	OETORM1 over Economy	ETORM2 over Economy	OETORM2 over Economy
1	54.1	54.1	12.5	20.8
2	54.0	51.3	18.9	27.0
3	54.1	51.3	21.2	29.4
4	53.6	50.6	22.1	28.9

Restricting the token up to last non zero packet candidate : As shown in figures 17 and 18, the number of hops traversed by a token in all the five schemes can be significantly decreased by restricting it to last candidate that contains packets which means that after that candidate up to the source no other candidate contains packets. The improvement in number of hops traversed by token after reduction by ETORM1, ETORM2, OETORM1 and OETORM2 over economy is shown in tables 5 and 6 for both low probability and high probability networks.

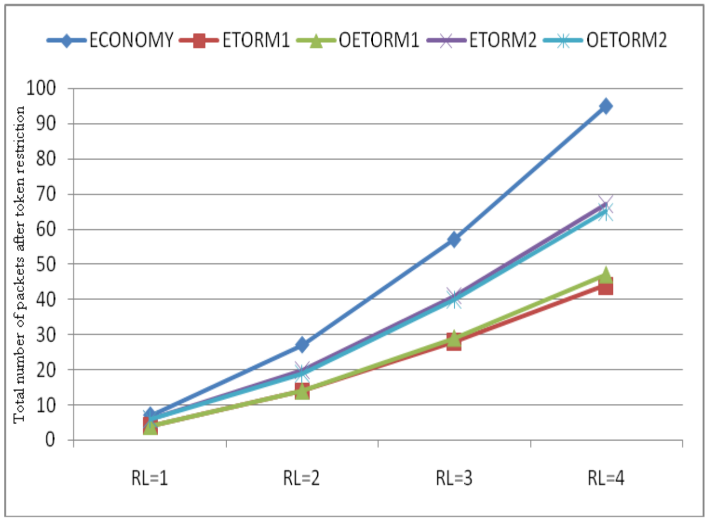


Figure 17. Total number of hops traversed by token after token restriction (0.1<=p<=0.9)

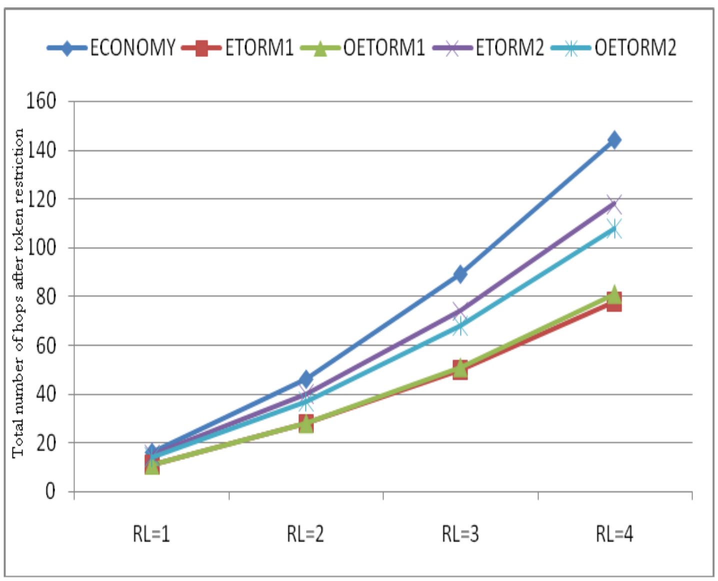


Figure 18. Total number of hops traversed by token after token restriction (0.1<=p<=0.45)

Table 5. Improvement in decreasing of total hops after restricting the token upto last non zero candidate(0.1<=p<=0.9).

Route Length (RL)	ETORM1 over Economy	OETORM1 over Economy	ETORM2 over Economy	OETORM2 over Economy
1	75.0	75.0	14.2	14.2
2	48.1	48.1	25.9	29.6
3	50.8	49.1	28.0	29.8
4	53.6	50.5	29.4	31.5

Table 6. Improvement of total hops after restricting the token upto last non zero candidate(0.1<=p<=0.45).

Route Length (RL)	ETORM1 over Economy	OETORM1 over Economy	ETORM2 over Economy	OETORM2 over Economy
1	31.2	31.2	6.2	14.2
2	39.1	39.1	15.0	19.5
3	43.8	42.6	16.8	23.5
4	45.8	43.7	18.0	25

5. CONCLUSION AND FUTURE WORK

An efficient token based coordination approach for opportunity routing called ETOR is presented in this paper. This work explored different factors that influence the selection of candidates while forming a connected candidate order in token based opportunistic routing and proposed two methods ETORM1, ETORM2 considering both Global ETX as well as Local ETX and their variants exploiting opportunism - OETORM1, OETORM2 for finding connected candidate order. Extensive simulations were carried out considering hundred 100-node networks to study the significance of our proposed methods in determining the connected candidates order and improvements over Economy in terms of AA Ratio, number of hops traversed by the token and reduction in the number of hops traversed by token. Our simulation results have shown that the proposed ETOR approaches perform better than Economy approach in terms of AA Ratio, number of hops traversed by the token and also that all the proposed connected candidate orders perform better than that of economy for both high probability and low probability networks. It is evident from the results that the improvement obtained in case of high probability networks is much greater than that for low probability networks. Further, opportunistic versions perform much better for low probability networks than high probability networks. Our future work includes selection of multiple connected candidate orders for multi flow scenario in ad hoc networks.

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