# Routing in Opportunistic Network based on Erasure codes with buffer management

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**Abstract-** Opportunistic Network is one type of challenged network where node contacts are occasional and routes are found dynamically while the message travels through the network. In such a network, there does not occur a complete path from source to destination for maximum time. In order to solve this routing issue many routing protocols such as epidemic routing and quota based routing protocols were employed. Such protocols manage relatively low network overhead but suffer from low delivery ratio. This paper confers erasure coding based routing in Opportunistic network. First our approach exploits buffer management to regulate buffer efficiently because of the lower node capacity. Second we calculate maximum communicable message size to avoid retransmission. This apprehension is exploited to make better forwarding decision. Third we apply erasure coding by adding redundancy to encode the original message and decode in the destination. Simulations demonstrate the benefit of our protocol and exhibit that our strategy provides prominent delivery ratio and inferior network overhead in comparison with a number of well known algorithms.

**Keywords:** Opportunistic network, routing, buffer management, erasure coding.

## 1. Introduction

Opportunistic network is an approach to computer network architecture. That descends into a remarkable category of wireless Ad-hoc network where the accomplished route from source to destination does not prevail. The source node has the destination address but the contact between the nodes is not continuous, hence finding a contact to the destination node is a critical job. Here node conventions where done prudently. It brings out a lot of challenges such as high node mobility, low node density, intermittent power from energy management schemes, environmental interference and hindrance, short radio range and denial-of-service attacks. The application areas of this network are Underwater Sensor Network, Vehicular Ad-hoc Network (VANET), Zebra Net and Military Networks, etc.


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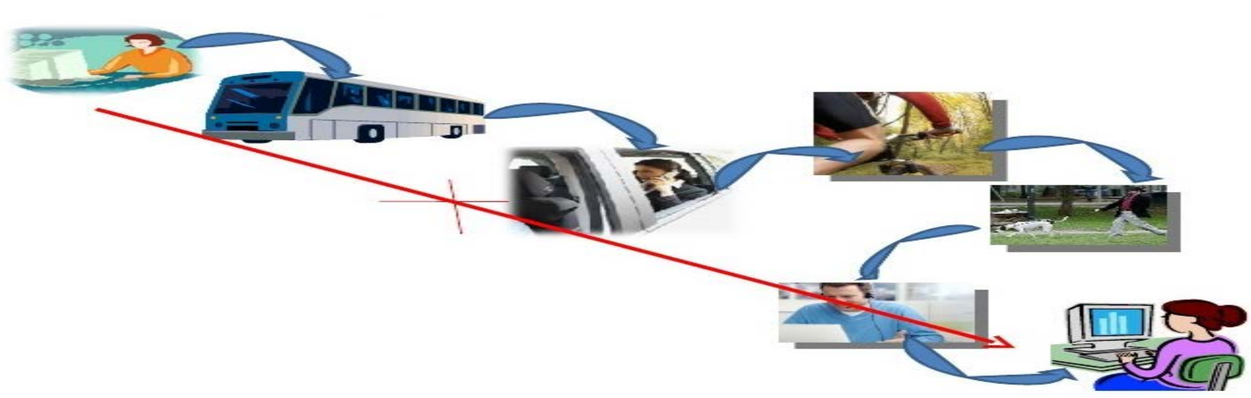
Normally routing algorithms are classified into forwarding based and replication based protocols. Forward based routing protocols use only a single copy of message to direct to the destination based on network dynamics. TRP such as AODV, DSR, etc., are examples of forward based routing protocols. RRP replicate multiple copies of the message as the resource permit into the network to increase the chance of message delivery. But this approach is vulnerable to high network congestion. PROPHET [7], MaxProp [5], PREP [14], etc. are the examples of replication based routing protocols. Basically the capacity of the node buffers is limited. By considering the characteristics of Opportunistic network due to intermittent connection the node has to store messages before forwarding to the next encountered node. For that buffer management is necessary to regulate buffer efficiently. The rest of the paper is arranged as follows. In Section 2, we present related work on other routing protocols for Opportunistic Networks. Section 3 briefly describes our ECBR protocol. Section 4 presents the simulation results. Finally, we concluded in Section 5 with some future research directions.

Section (2) Related works
Section (3) Proposed the ECBR algorithm
Section (4) Evaluation Method
Section (5) Simulation Results
Section (6) Conclusion and Future Work



Fig, 1. Opportunistic Network

## 2. Related works

Due to the intermittent nature of Opportunistic network many routing protocols were summarized in order to maximize delivery ratio. In that Epidemic routing[2], Max Prop[5], RAPID[8], PREP[14] is the flooding based protocols. It is one type of replication based protocols. It generally replicates as many copies of a message as the resource permit.

PROPHET [7] protocol proposes few modifications on epidemic routing instead of blind forwarding. Here each node calculates a delivery probability for all the known destinations. RAPID design Opportunistic routing as a utility-driven resource allocation problem. RAPID [8] protocol introduces three core components: a selection algorithm, an interference algorithm, and a control channel. Selection algorithm is employed to resolve which packets replicate at a transfer opportunity prescribed their efficiencies. The inference algorithm is employed to resolve the efficiency of a packet prescribed the routing metric. PREP[14] assigns priority to a message based on the path cost to the destination and expiration time of the message which is used to find which messages should be deleted or transmitted next. Each node in MaxProp[5] maintaining a list of meeting probabilities for all its known nodes, when two nodes meet each other they first exchange their probabilities and build a network topology graph and also calculates the minimum cost of reaching each known destination using the topology graph. This approach of injecting multiple copies of a message may increase the delivery ratio but the approach is vulnerable to high network congestion.

This drawback led to the new generation of replication based protocols- Quota based routing protocols. Quota based protocols keep the number of replicas of a message independent of the network size. Spray and Wait, Spray and Focus, EBR [15] are the examples of this protocol. Spray and Wait [3] protocol spray multiple copies of the message in the network and wait when the node having a single message to forward to the destination. Spray and Focus [4] is also similar to Spray and Wait where slight modifications were done in focus phase. In a focus phase, where even the single copy messages can be forwarded in order to maximize a utility function. EBR protocol uses the previous contact history to spray the messages in the network but keeps the wait phase similar to that of the Spray and Wait protocol. These protocols succeed by limiting network overhead problem but suffer with lower delivery ratio as a result of reduced flooding. In our approach we use erasure coding, along with buffer management and also calculate maximum communicable message size to maximize delivery ratio.

## 3. Proposed the ECBR algorithm

This section presents the details of Erasure Coding Based Routing (ECBR) protocol.

### 3.1. System Model

In this system, we model network as a set of mobile nodes with Opportunistic contacts. This Opportunistic Network is first introduced for interplanetary communication. Disconnections and reconnections are common in this network. When two nodes are in direct communication range, they are able to transfer data packets to each other. The capacity of the node buffer is limited. We consider each message being transmitted as a whole as well as fragmentation is considered. Here our goal is to maximize delivery ratio in the Opportunistic network with minimum network overhead. First we introduce erasure coding by encoding the original message and decode in the destination. Since the capacity of the node buffer is limited. For that two logically separate lists: Scheduling list and Dropping list is used. Then we calculate maximum communicable message size ($S_{max}$) to measure the size of a meeting window as in ORWAR [12].

### 3.2. ECBR Protocol

After message generation in ECBR each message is tagged with replication count ($L_k$) and $L_k$ denotes the number of copies of the message the node has to shower. Like Spray and Wait [3] $L_k$ is divided by 2 before the message is forwarded to the next hop neighbor. For example: If $L_k$ is 6, then the current node keeps 3 message copies in its buffer and forwards the remaining 3 message copies to the encountered node. When $L_k$ of message becomes 1, erasure coding is applied by encoding the message by adding redundant data and dividing it into equal sized code blocks. Based on speed, direction of movement and radio range maximum communicable message size is calculated before forwarding messages to the next node. Due to limited contact opportunities the node requires a buffer to temporarily store the messages. The capacity of the node buffer is limited. In order to regulate buffer efficiently message scheduling list and message dropping list is introduced.

### 3.3. Erasure coding operation

Whenever a node having a single message to forward to destination erasure coding is applied. The idea behind the erasure coding is to encode a message by adding redundant data and divide it into a larger set of equal sized code blocks such that any enough large section of the code blocks received at the destination can be used to decode the original message. Consider M as the size of the message and r as the redundancy factor. Here the algorithm generates M*r/b identical sized code blocks of size b, then if any (1+c) .M/b erasure coded blocks can be consumed to decode the message.

### 3.4 Buffer Management

Node buffer is used to temporarily store the messages. For efficient buffer management Message Scheduling list and Message dropping list are introduced. The message Scheduling list priority ( $P_{k_s}$ ) is calculated by using the formula.

$$P_{k_s} = \frac{1}{H_k \times TTL_k \times S_k}$$

(1)

Where,

- $TTL_k$ – message time to live
- $H_k$ — message hop count
- $S_k$ – message size

Larger messages with lower hop count and lower TTL are given priority for forward. Likewise the message dropping list priority ( $P_{k_s}$ ) is calculated by using the formula

$$P_{k_d} = \frac{L_k}{S_k}$$

(2)

A node will delete the copy of a message in the buffer if the message is timed out (TTL expires) or the node is notified of the message delivery through acknowledgement or when the node receives a higher priority message when the buffer is full.

### 3.5. Maximum communicable message size calculation

The maximum communicable message size is calculated before forwarding messages to the next node. The maximum communicable message size is calculated based on speed, direction of movement and radio range between the communicating nodes. This helps to protect the loss of messages and also save the system resources. This approach maximizes the delivery ratio and also optimizes the utilization of system energy unnecessarily. When two nodes progress at a vectorial speed of $\vec{v_i}$ and $\vec{v_j}$ and radio range $r_i$ and $r_j$ respectively, then the meeting window time $t_{mw}$ is calculated using

$$t_{mw} = \frac{2 * \min(r_i, r_j) * \cos\alpha}{\left|\vec{v_i} - \vec{v_j}\right|}$$

(3)

where $\alpha$ is the angle between the relative speed of the nodes. Then the maximum communicable message $S_{max}$ is calculated as

$$S_{max} = b * t_{mw}$$

(4)

Where b is the data rate of the communication link.

### 3.6. ECBR ALGORITHM

// node p, q and destination node (d)
//message $m_k$
//replication count $L_k$
//$H_k$→ message hop count
//$TTL_k$→ message time to live
//$S_k$→ message size
//$S_{max}$→ maximum communicable message size
//$M_E$→ encoding message

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//$M_D$→ decoding message
//M→ message size
//r→ redundancy factor
//b→ code block size
//c→ constant
// $P_{k_s}$ →message scheduling priority
// $P_{k_d}$ →message dropping priority
//$ack_p$→ acknowledgement list at node p
When node p contacts node q
Exchange $ack_p$ and $ack_q$
$ack_p$, $ack_q$ ← $ack_p$U $ack_q$
for each message $m_k$ Є Buffer at node p do
if $L_k$>1 then
//maximum communicable message size is calculated
$S_{max}$←Compute_$S_{max}$(p,q)
//buffer management is carried out based on scheduling priority and dropping priority

$$P_{k_s} \leftarrow \frac{1}{H_k \times TTL_k \times S_k} \text{ (Scheduling priority)}$$

$$P_{k_d} = \frac{L_k}{S_k} \text{ (Dropping priority)}$$

else if $L_k$=1 then
//node with single message is encoded with redundant data
$M_E$← M* $\frac{r}{b}$
destination node (d) ← (1+c) . $\frac{r}{b}$
//Destination node decode the received code blocks and reconstruct the original message
$M_D$← (1+c) . $\frac{M}{b}$ Є (d)
return $m_k$

## 4. Evaluation Method

ECBR protocol is estimated based on the following three metrics

**Delivery ratio:**

Delivery ratio is defined by the ratio of the total number of messages delivered ($m_{del}$) to the total number of messages created ($m_{cre}$).

**Overhead:**

Overhead is defined as the ratio of the total number of messages relayed ($m_{rel}$) to the total number of messages delivered.

**Delivery Latency:**

Delivery Latency is the median of the time required for a message to reach its destination:

### 4.1. Simulation setup

To compare the performance of ECBR with that of the other popular dominant Opportunistic Network routing protocols, we setup a simulation environment using ONE (Opportunistic Network Environment). ONE is a powerful tool for generating different movement models, running simulation with various routing protocols, visualizing simulations in real time and generating results.

In our simulation we compare the performance of ECBR protocol with the performance of TBR, SNW and MaxProp. We used a replication factor L=6 for all the quota based protocols.

In our simulation, we evaluated the impact of the message size and the network size on different metrics to compare the performance of different protocols. Here, the total number of nodes in a network denotes its size. To evaluate the impact of message on the metrics, we start our simulation in a city environment of 100 nodes with 1500 messages. The message size (S) is normally distributed with an average size of 2MB. Then, we gradually decrease the message size and proportionately increase the number of messages in order to maintain a constant load in the network.

In order to assess the impact of node density on the network, we vary the number of nodes in the network keeping the number of messages fixed at 10000 and the message size (S) normally distributed with average 500kB. We start with 50 nodes and at each iteration, increase the number of nodes by 25 until it reaches 200.

### 4.2. Mobility model

As Opportunistic Network can operate in many different environments, we used a Map-driven vehicle based movement model to analyze the effectiveness of various protocols in a city environment.

### 4.3. Map- based vehicular model

Map-based vehicular model restricts the movements of the network nodes to actual streets in an imported map. In our simulation, we used the map of 4500m × 3400m. We used three types of nodes in our simulation- cars, trams and pedestrians. For pedestrians, cars, and trams transmission ranges are assumed to be 10m, 20m, and 20m, respectfully. Transmission speed for all the nodes is assumed 250 KBps (2 Mbps). We also assume a buffer of 100 MB for trams, 20 MB for cars, and 10 MB for pedestrians. Cars and pedestrians move with a speed within [2.7 , 13.9] m/s and [0.5, 1.5] m/s, respectively with random pause. Speed of the trams vary within [7,10] m/s. In each of the iteration we keep the node distribution as- 12% trams, 28% cars and 60% pedestrians.

## 5. Simulation Results

Figure 2 and 3 demonstrate that our simulation results 10% higher delivery for varying message size and varying number of nodes compared with existing TBR, SNW and

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MaxProp routing protocols.

Figure 4 and 5 compares the overhead ratio of different protocols. Where ECBR protocol achieves significantly lower overhead by 10-15% compared to that of TBR, SNW and MaxProp routing protocols.

As for as latency is concerned, our protocol, ECBR achieves 15% lower latency on average than that of MaxProp and TBR. However, ECBR's latency seems higher compared to that of SNW. The latency is generally computed considering the messages that have been delivered to the destination. SNW only deliver the messages having small number of hops. But ECBR successfully delivers many messages having both small and large number of hops.

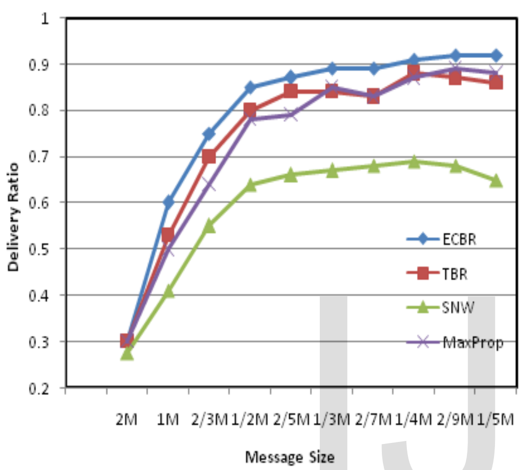



Fig 2. Map based vehicular movement model-delivery ratio: varying message size

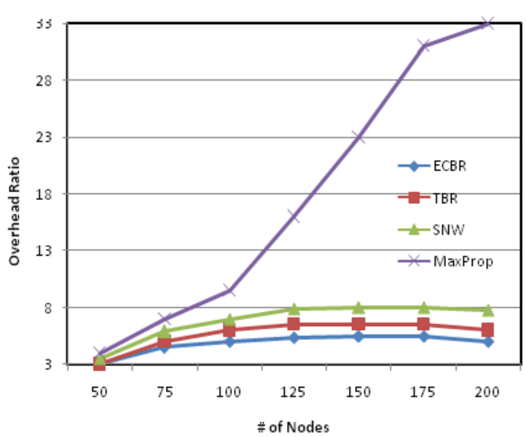



Fig 5. Map based vehicular movement model- Overhead ratio: varying number of nodes

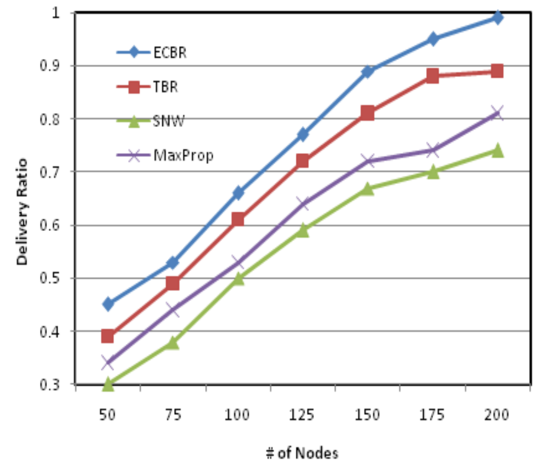



Fig 3. Map based vehicular movement model-delivery ratio: varying number of nodes

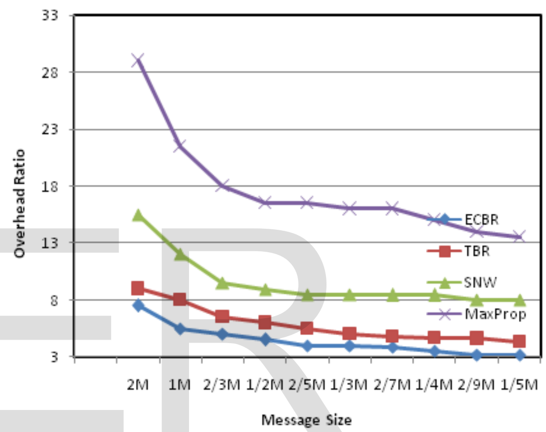
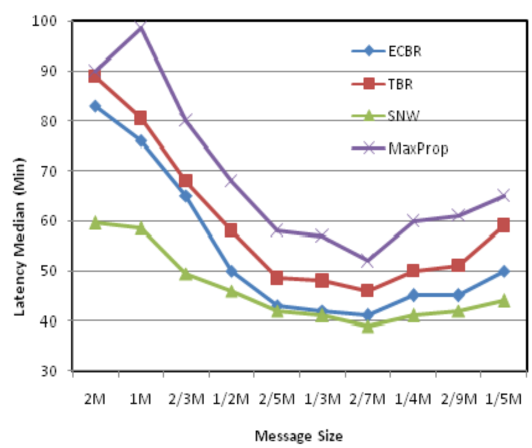



Fig 4. Map based vehicular movement model- Overhead ratio: varying message size




Fi
g. 6 Map based vehicular movement model- Delivery latency: varying message size

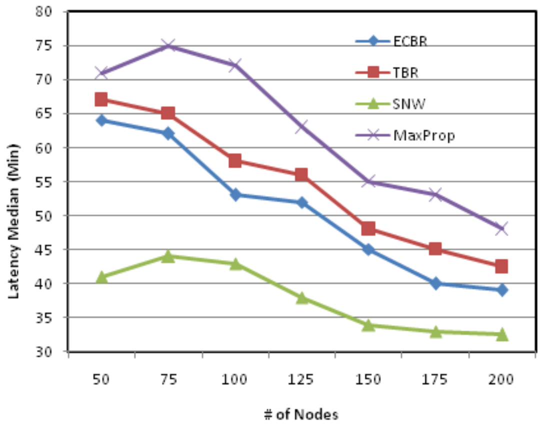



Fig 7. Map based vehicular movement model- Delivery latency: varying number of node

## 6. Conclusion and Future Work

Due to the intermittent connection nature of Opportunistic Network routing is considered to be a one of the major issues for delivering messages to the destination for considering certain specific applications. Opportunistic network was first developed for interplanetary communication. In this paper erasure coding is applied to maximize delivery ratio by adding redundant data to encode the original message and decode in the destination. The maximum communicable message size is calculated to avoid retransmission and also buffer management is carried out to utilize buffer efficiently because of the node buffer capacity is limited. Our simulation reveals the supremacy of ECBR by estimating its performance based on the metrics of delivery ratio, overhead and delivery latency with that of many popular Opportunistic routing protocols.

For future work, our work can be prolonged in various directions. Accordingly we are going to evaluate our approach on a real time network with physical nodes.

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