# AN IMPROVED DELAY TOLERANT ROUTING PROTOCOL FOR THE OPPORTUNISTIC NETWORKS

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*Abstract*

DTNs are a type of wireless network by which are designed specifically for environments where high latency, frequent disruptions and intermittent connectivity is seen. In this paper we have proposed a variant of Spray and Wait Protocol which gives better results than the Binary SnW protocol.
Real life scenario of cars and pedestrians moving on a map is used to show the working and results of our proposed routing technique.

## INTRODUCTION

Traditional routing protocols (like AODV, DSR, etc.) used in MANETs cannot be used in DTNs[1]. This is because before transmitting the data, these routing protocols try to find at least one complete path from source to destination, but in DTNs such is not the case. When the connection is intermittent[2] we have to use some routing protocols that can deliver the packets to the destination, this type of routing is known as Opportunistic[3] routing and the network is known as Delay Tolerant Network. Some protocols are already defined[6] such as 1. Direct Delivery 2. First Contact[4] 3. Epidemic 4. Spray and Wait have been proposed. But we have not yet got the ideal protocol. So improvements in methods are proposed to make it better day by day. We are also proposing one improvement in Binary Spray and Wait routing protocol: Catalan Spray and Wait Routing protocol. This paper consists II. Existing work III. Proposed Method IV. Performance Evaluation V. Simulation VI. Conclusion and Future Work VII. References

## RELATED WORK

A Significant amount of work has been done in recent years to find a better approach in Delay Tolerant Networks. As we know, a handshake between source and destination is not possible in this type of network, so a routing protocol is necessary that can deliver the message in an appropriate manner to deliver the message like a well-known approach is Spray and wait protocol[1] to get the routing done with two phases as the name suggests.

### *Spray and Wait*

In Spray and Wait, there is restricted flooding, the maximum number of message replicas that are permitted to travel from the source is L, and these replicas are dispersed over the whole network. Based on the number of nodes and the typical amount of time needed to send a message, L can be fixed . There are two steps to this protocol

- Spray Phase: Also referred to as the "Spray" phase, this stage sees the source node transmit L copies of a message to n different encountered nodes.
- Wait Phase: The message accepting n distinct nodes in the first phase will wait until they can directly encounter the destination node before forwarding the message copy if the target node is not located in the "Spray" phase. "Wait" is the name of this stage.

### *Spray Techniques*

1. **Source spraying technique:** This heuristic strategy delivers L copies to the first L relay nodes that do not already have a copy of the message. If during this phase the destination makes contact with the source or relay node, the message is sent to the destination; otherwise, the wait phase begins, and all nodes switch to direct transmission mode, in which case the message is sent directly to the destination whenever any relay node comes into contact with the destination.

2. **Binary spraying technique:** In this heuristic method L number of copies is divided in a binary fashion, i.e, if L is the number of copies then then the first node that comes in contact with the source node will get $\lceil n/2 \rceil$ copies of the message and rest n $- \lceil L/2 \rceil$ will be transmitted to the node and this process continues until every node including source and relay nodes are having at-most one message copy or TTL is achieved. If in this phase destination comes into contact with any node message is delivered to the destination and routing for this message gets terminated.

3. **Pentago Spray Technique:** In this heuristic method L number of copies is divided according to a number series known as pentagonal[7] series where P (i) is the $i^{\text{th}}$ pentagonal number

$$P(i) = (3i^2 - i)/2$$

According to this series number is divided and forwarded to next relay nodes. This protocol gives better efficiency than Binary SnW.

4. **Hexago Spray Technique:**Hexagonal series[7] where X(i) is $i^{\text{th}}$ hexagonal number is:

$$X(i) = 2i^2 - i$$

For an index value i the hexagonal series will look like (for i > 0): 1, 6, 15, 28, 45, 66...

## PROPOSED METHOD

Instead of distributing copies in Binary fashion, here we will divide copies according to Catalan series where the $n^{th}$ Catalan number is

$$C_n = \frac{1}{n+1}\binom{2n}{n}$$

For an index value i the catalan series will look like (for i > 0): 1, 2, 5, 14, 42...

**Catalan SnW** Say a Catalan value is $X_{\mathfrak{num}}$ :

- **Spray Phase:** In this phase source replicates the message and makes L copies of it. The source copies the message and creates L copies of it during this phase. Any node with more than $1(L > 1)$ copies will abide by the following rules:

  1. If a node has L copies of a message, and L is equal to $X_{\mathfrak{num}}$, it will send $\lceil L/2 \rceil$ copies to all nodes within its range while keeping the remaining copies for itself
  2. If a node has L copies, and L is less than $X_{\mathfrak{num}}$, $X_{\mathfrak{prev}}$ will be discovered. The greatest $X_{\mathfrak{num}}$, $X_{\mathfrak{prev}}$, which is less than L, will be passed to the following node while the remainder (L $-$ $X_{\mathfrak{prev}}$ ), will stay with the current node. And until every node in the network has more than one copy, this process will continue.

- **Wait Phase**
  Every node that has 1 copy of the message enters direct transmission mode and sends the message whenever the destination comes within range.

Consider a network with L = 16 number of copies.

1. **Binary SnW:** In Binary SnW 16 number of copies will be divided in binary fashion like first node with no copies will get $\lceil L/2 \rceil$ means $\lceil 16/2 \rceil$ = 8 copies and 8 copies will be left. and next 8 will be divided as 4 and 4 and process will keep going till every node has only copy of message.

2. **Catalan SnW:** In Catalan SnW, 16 is not a catalan number so we will find X prev that is 14 so next node will get 14 copies and it is left with only one copy and comes into wait phase that is direct transmission phase. Node with 14 copies will now go for binary division because 14 is a hexago number (X num ) and $\lceil L/2 \rceil$ that is $\lceil 14/2 \rceil$ = 7 will go to next node and 14  7 = 7 will be left to it. Now this process will keep going until wait phase. As we can analyse with the help of Fig. 1 and Fig. 2 that wait phase is achieved early(level 2) in Catalan compared to Binary(Level 4). So Catalan is giving better efficiency than Binary Spray.

A table has been shown below to show the wait phase level in binary and Catalan SnW and we can see clearly that in

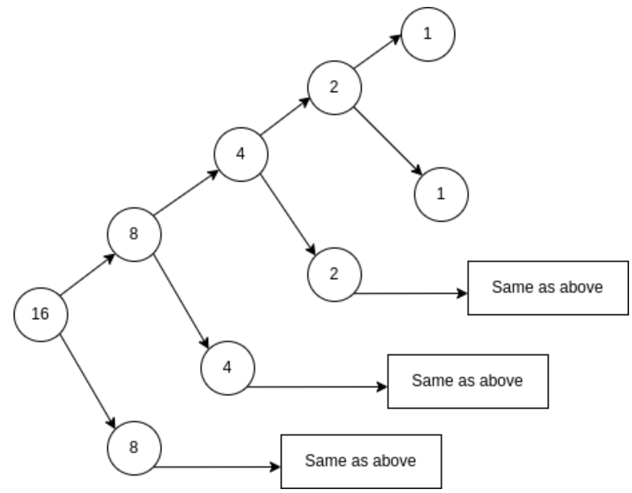


Figure 1: Binary Spray phase(Number of message copies = 16)

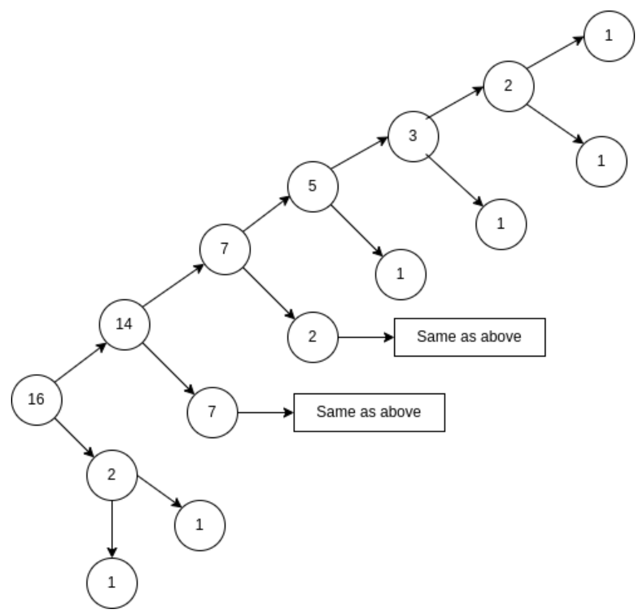


Figure 2: Catalan Spray phase(Number of message copies = 16)

most of the cases wait phase is early in hexago SnW protocol.

**for** *each message M having K copies at a node* **do**
  **while** *TTL >0* **do**
    **if** *K == 1* **then**
      node goes into direct transmission mode
    **end**
    **if** *K is NOT a Catalan number* **then**
      forward t(where t<=K) copies of M to the node in contact;
      keep K - t copies to itself;
    **end**
    **if** *K is a Catalan number* **then**
      forward $\lceil K/2 \rceil$ copies of M to the node in contact;
      keep $\lfloor K/2 \rfloor$ copies to itself;
    **end**
  **end**
**end**

| Number of copies | Wait phase level | |
|---|---|---|
| | Binary SnW | Catalan SnW |
| 6 | 2 | 1 |
| 8 | 3 | 2 |
| 10 | 3 | 3 |
| 12 | 3 | 3 |
| 14 | 3 | 3 |
| 16 | 4 | 2 |
| 32 | 5 | 4 |

Table 1: Wait Phase Level Comparison

## PERFORMANCE EVALUATION METRICS

Lets suppose a network in which $M_{\mathfrak{gen}}$ is total number of messages generated and $M_{\mathfrak{del}}$ is the number of messages delivered and T is the time of message generation and $T^{`}$ is the time when messages delivered So there are some metrics to evaluate the performance. They are as follows :

### *Delivery Ratio*

Determine the total number of delivered messages. and the total number of generated messages. Divide the total number of delivered messages by the total number of generated messages. Multiply the result by 100 to express it as a percentage. :

$$DeliveryRatio = M_{\mathfrak{gen}}/M_{\mathfrak{del}}$$

### *Overhead Ratio*

Number of replicas of an original message created.Let $M_{\mathfrak{rel}}$ be the set of total relayed message then the overhead ratio can be defined as :

$$OverheadRatio = M_{\mathfrak{rel}} - M_{\mathfrak{del}}/M_{\mathfrak{del}}$$

### *Mean message delivery latency or relay*

The mean message delivery latency, also known as relay latency, refers to the average time required for a message to reach its destination from the source in a network. It is a measure of the overall delay experienced by messages during the transmission process. And can be defined as :

$$Delay = \sum_{n=1}^{M_{\mathfrak{del}}} (T - T^1)/M_{\mathfrak{del}}$$

### *Average Hop Count*

The average hop count in a network is a measure of the average number of hops or intermediate nodes traversed by messages to reach their destinations. It indicates the average distance or number of network nodes that messages pass through during transmission.

A approach will be called better if it is giving better Delivery Ratio, less Overhead Ratio and low hop count.

| PARAMETER | VALUE |
|---|---|
| World Size | 4500 * 3400 meters |
| Scenario end time | 43200 seconds |
| Scenario update interval | 0.2 seconds |
| Number of nodes | p-1400,c-500,w-100<br>p-60,c-30,w-10 |
| Speed of nodes | Pedestrians-[0.5,1.5]m/s,<br>Cars-[2.7,13.9]m/s |
| Interface | Bluetooth |
| Transmission Speed | 250kBps |
| Transmission Range | 10 meters |
| Message TTL | 300 minutes |
| Common Buffer Size | 5 MB |
| Message Size | [500kB,1 MB] |
| Message Interval | 25,35 |
| nrofCopies | [6;8;10;12;14;16;32] |
| Routing Protocol | Binary,Catalan |

Table 2: PARAMETERS USED IN SIMULATOR

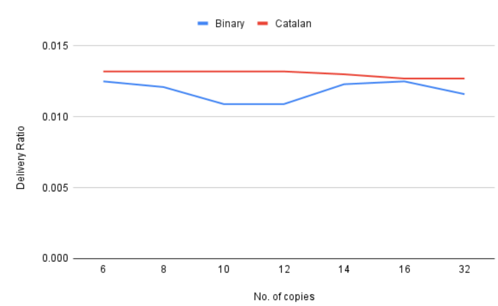


Figure 3: Delivery Ratio Vs Number of copies(100 nodes)

## SIMULATION

### *Simulation Setup*

There are a lot of simulators available to simulate delay tolerant network. We used One simulator to simulate the real world scenarios because simulations give better results and understanding of what we are doing. Parameters can be seen in Table 1. These parameters has been set in simulator configurations and then result is calculated by taking their averages.

### *Simulation Analysis*

1. **Performance analysis on the basis of number of copies** We have taken 60 nodes for pedestrians ,40nodes for cars,10 tram groups. Speed has been set different for both group and there is a tram group also with two interfaces and two nodes and other parameters are defined in Table 2.
   We simulated the scenario using One simulator and result in terms of graph can be seen in Fig. 3. We can compare the performance via the graphs below.

   In Figure 4, we have taken 600 nodes for pedestrians ,300nodes for cars,100 tram groups.

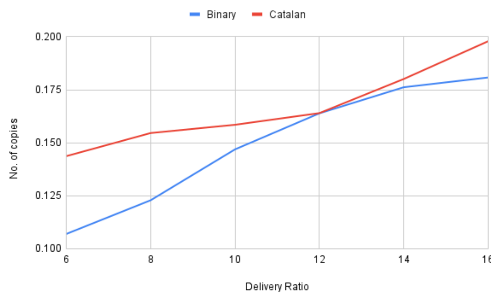


Figure 4: Delivery Ratio Vs Number of copies(1000 nodes)

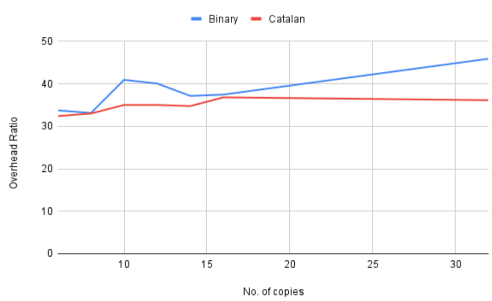


Figure 5: Overhead Ratio Vs Number of copies(100 nodes)

In Fig. 5 it can be seen that overhead Ratio has been decreased when average is taken for Catalan routing compared to others.Overhead Ratio is increasing with number of copies. Sudden decrease at 16 is because it is a power of two so for binary wait phase will come early for all branches. Number of copies used are 6,8,10,12,14,16 and 32.

The impact on overhead ratio while varying the number of copies has been shown in figure.5. For each value of L the overhead ratio is less in case of Catalan SnW. The overhead ratio is increasing because the number of copies in the network is increasing.

Fig. 7 is a graph between the buffer average and number of copies. Buffer average is the average of the times a message spends in buffer, either on source node or on relay nodes. It is clearly seen in the graph that the average message buffer time of Catalan is comparatively less than that of binary SnW. The graph is in decreasing side because an increasing number of copies will make the delivery probability high, terminating the routing early.

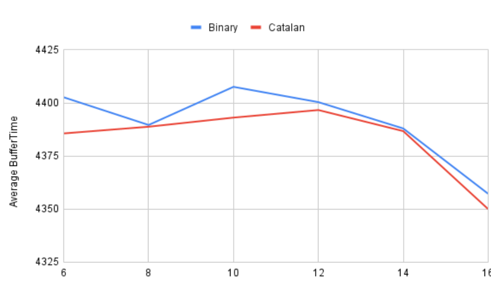


Figure 6: Buffer average Vs Number of copies(100 nodes)

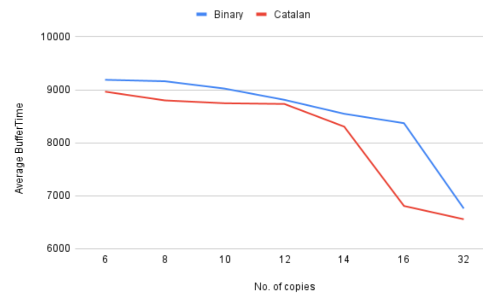


Figure 7: Buffer average Vs Number of copies(500 nodes)

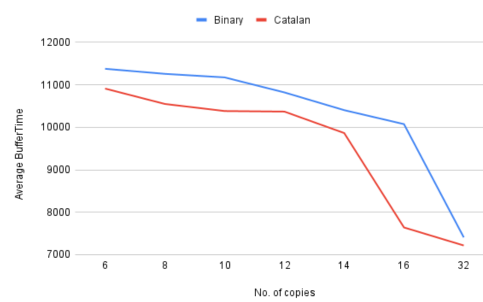


Figure 8: Buffer average Vs Number of copies(1000 nodes)

## CONCLUSION

Routing in Delay Tolerant network is a NP-Hard problem. Many routing approaches have been suggested, yet making the routing for DTN better. This Catalan protocol is also an effort in this direction. With real life scenarios simulated on ONE simulator and collecting results on various parameters and taking the average of those results. We compared it with the existing Binary SnW and found that catalan is better efficiency in every aspect. Future work can be done in the field of security[9] because this algorithm is not effective against faulty nodes[10] and also routing can be improved by simulating other heuristics.

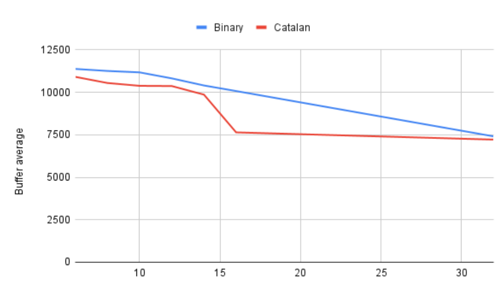


Figure 9: Buffer average Vs Number of copies(2000 nodes)

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