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ERASURE-CODING DEPENDENT STORAGE AWARE ROUTING

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ABSTRACT

Delay Tolerant Networks are a newest and promising class of wireless networks with sparse population of heterogeneous mobile nodes. These networks may not have full source to destination path at any particular instant due to intermittent connection between the nodes. There are many environments in which a Delay Tolerant Network can operate namely interplanetary networks, underwater networks, wildlife tracking sensor networks, military networks and remote rural village networks. A new routing approach that employs erasure codes and buffer capacity evaluation before routing messages is proposed. This protocol evaluates the worthiness of a node before handing over the message blocks to other nodes.

Keywords: Delay Tolerant Networks, Routing, Erasure Coding.

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1. INTRODUCTION

Owing to the absence of contemporaneous end to end path, routing in a Delay tolerant Network (DTN) is a highly challenging task. Routing in delay tolerant networks is tough because nodes have very little information about the peer nodes. Also, path from source to destination is non-existent at any particular time due to frequent disconnections. Erasure coding has widely been used in the literature (Wang et al 2014) to achieve lower time delay in DTN. Erasure coding is applied on the original message at the source node, which splits the message into a set of code blocks. These coded message blocks are transmitted across different links. As soon as the required subset of coded blocks arrive at the destination, the original message could be reconstructed. Thus erasure coding provides an alternate way to generate redundancy without full duplication of the message with fixed overhead since only a portion of the coded blocks are needed for rebuilding the message.

2. LITERATURE SURVEY

Chen & Shen (2014) have proposed a lightweight routing using distributed social maps for DTN. Wang et al (2014) have designed a routing scheme which allows nodes to cooperatively distribute information that of interest to each other. Local historical paths travelled and user's information interests have been exploited to make effective transmission. Rao et al (2015) have addressed the problem of timely delivery of content in DTN using a solution framework called Ameba. The content properties are analysed to get the optimal routing hop count along with the evaluation of utility value of a node based on its location and capability before making a routing decision.

Dudukovich et al (2017) have presented Bayesian and reinforcement learning for Contact Graph Routing algorithm. Omidvar & Mohammadi (2014) have suggested a particle swarm optimization strategy to choose the number of message copies for attaining better delivery performance. In the ACRP protocol suggested by Zhang et al (2010) control messages associated with forward ants and backward ants were transmitted through the use of the epidemic protocol. The CGrAnt protocol of Vendramin et al (2012) used the cultural algorithm and the ant colony optimization metaheuristic to explore new paths and route messages to their respective destination.

3. *MP* COMPUTATION

Initially, a node starts without knowing about other nodes in the network. When a node comes into contact with another node for the first time, the node number along with the corresponding MP value are added in the node list table of both nodes. If the MP value between a pair of nodes is larger, then it indicates that both nodes move around in the vicinity of one another. Therefore there is high probability for them to meet again in the near future. The MP value helps in the optimal use of network bandwidth and buffer storage at intermediate nodes by avoiding message transmission to nodes that are less likely to meet the destination.

When two nodes meet for the first time, they create a new MP value between them. For example, after the first meeting between the nodes 'f' and 'g', the MP value of both nodes are updated according to Equation (1).

$$MP(f,g) = \frac{IP}{CD(f,g)} \quad (1)$$

where IP = Initial Prospect ($IP \in [0, 1]$) is a constant

$CD(f,g)$ = Contact Duration between nodes 'f' and 'g'

At the start of every next meeting between the same pair of nodes, their MP value is lessened to compensate for the non-contact duration between them using Equation (2). For example, if the nodes 'f' and 'g' encounter each other after their first meeting, then

$$MP_i(f,g) = MP_{i-1}(f,g) - \frac{MP_{i-1}(f,g)}{NCD(f,g)} \quad (2)$$

where $NCD(f,g) =$ Non-Contact Duration between nodes 'f' and 'g'

If the non contact duration is less or more, the MP value is decremented appropriately through the proposed Equation (2).

At the end of their contact, their MP value is swelled through the execution of Equation (3). For example, at the end of meeting between the nodes 'f' and 'g', then

$$MP_i(f,g) = MP_{i-1}(f,g) + \left(\frac{MP_{i-1}(f,g)}{CD(f,g)} * NOM(f,g)\right) \quad (3)$$

where $NOM(f,g)$ = Number of meetings between nodes 'f' and 'g'

If the contact duration is large or small then there would be a proportional increment in the MP value of the nodes using Equation (3).

3.1. STORAGE CAPABILITY EVALUATION

The Storage Capability (SC) of a node is also taken into account before transferring the message blocks. Only when a node has sufficient buffer area to hold a message, the success of message delivery would increase. Therefore, SC of a node 'f' is evaluated by the formula given in Equation (4).

$$SC(f) = 1 - \frac{OBS(f)}{TBS(f)} \quad (4)$$

where, $OBS(f)$ - Occupied Buffer Space in node 'f'

$TBS(f)$ - Total Buffer Space in node 'f'

3.2. MESSAGE BLOCK DISTRIBUTION

When node 'f' meets another node 'g', the number of erasure coded message blocks transmitted between them differs depending on the MP and SC values. Let node 'f' contain message blocks for the destination node 'k'. Message blocks are sent from node 'f' to node 'g' only if $MP_{(f,k)}$ is lesser than $MP_{(g,k)}$. All message blocks for node 'k' are routed from node 'f' to node 'g' if $MP_{(g,k)}$ is greater than MP_{high} and $SC(g)$ is greater than SC_{high} since node 'g' has very good opportunity to meet the destination and also ample storage space to comfortably carry the coded blocks. If $MP_{(g,k)}$ is greater than MP_{high} and $SC(g)$ is greater than SC_{low} or $MP_{(g,k)}$ is greater than MP_{low} and $SC(g)$ is greater than SC_{high}, then only half of the message blocks in node 'f' are sent to node 'g' as there is lower chance to meet the destination and the buffer storage is also lesser.

4. EVALUATION

The ESR protocol has been evaluated with the ONE simulator and SPSS has been used to statistically analyze the simulation results using paired t-test. A t-test is a statistical hypothesis test in which the test statistic follows a student's t distribution if the null hypothesis is supported. It can be used to determine if two sets of data are significantly different from each other, and is most commonly applied when the test statistic would follow a normal distribution. A paired t-test compares two samples in cases where each value in one sample has a natural partner in the other. A paired t-test looks at the difference between paired values in two samples, takes into account the variation of values within each sample, and produces a single number known as a t-value. The formula for t-value is given in Equation (5).

$$t\text{-value} = \frac{\text{Difference of two means}}{\text{Standard error of difference between two means}} \quad (5)$$

The results of the map based movement model in terms of the delivery ratio for the three protocols are presented in Figures 1 and 2 for varying buffer size and varying transmission range respectively. These Figures show that ESR achieves about 1.19 to 1.72 times increase in delivery ratio than other protocols. ESR has accomplished a higher delivery ratio through the use of an efficient erasure coding based routing mechanism so that message blocks are sent through nodes that would meet the destination and deliver messages speedily.

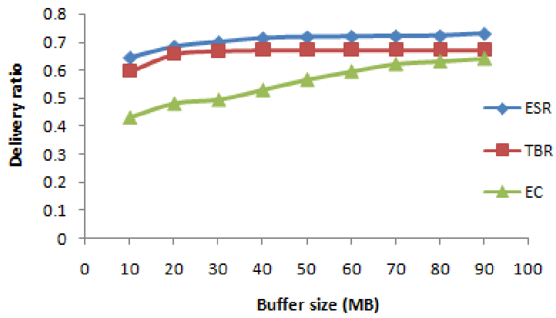

Figure 1 Map based movement model - Varying buffer size –Delivery ratio

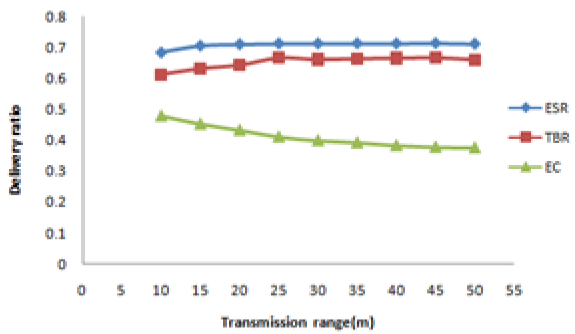

Figure 2 Map based movement model - Varying transmission range – Delivery ratio

Paired *t*-tests were conducted to compare the delivery ratio and delivery delay of ESR with TBR and EC. The paired *t*-test finds the difference in mean between the tested protocols at 95% Confidence Interval (CI) and establishes the result to be statistically significant when the probability (*p*) value is found to be less than 0.05. A statistically significant result proves the supremacy of the protocol.

Table 1 presents the results of the paired *t*-test between the delivery ratio of ESR with TBR and delivery ratio of ESR with EC for varying buffer size and transmission range. There was a significant difference in the mean values for the pair ESR (Mean (M) = 0.70621, Standard Deviation (SD) = 0.027453), TBR (M = 0.66261, SD = 0.024965); t at $df_8 = 12.918$, $p = 0.0001$ and also for the pair ESR, EC (M = 0.55490, SD = 0.074430); t at $df_8 = 8.878$, $p = 0.0001$.

For varying transmission range, the mean scores of the paired *t*-test for delivery ratio between the pairs ESR (M = 0.70948, SD = 0.009764) with TBR (M = 0.65361, SD = 0.019477); *t* at df_8 = 14.613, p = 0.0001 and ESR with EC (M = 0.41169, SD = 0.036533); *t* at df_8 = 19.858, p = 0.0001 also showed significant difference.

These results suggest that the delivery ratio obtained through ESR is statistically significant than TBR and EC for varying buffer size and varying transmission range at $p < 0.05$ level.

Table 1 Results of paired *t*-test between delivery ratio of ESR and other protocols - Map based movement model

Protocol	Mean	SD	Mean difference	Std. Error	95% CI		t_8	Sig. (p)
					Lower Bound	Upper Bound		
Varying buffer size (n = 9)								
ESR	0.70621	0.027453	-	-	-	-	-	-
TBR	0.66261	0.024965	0.043595	0.003375	0.035813	0.051377	12.918	0.0001*
EC	0.55490	0.074430	0.151305	0.017042	0.112006	0.190604	8.878	0.0001*
Varying transmission range (n = 9)								
ESR	0.70948	0.009764	-	-	-	-	-	-
TBR	0.65361	0.019477	0.055873	0.003824	0.047056	0.064690	14.613	0.0001*
EC	0.41169	0.036533	0.297793	0.014996	0.263212	0.332373	19.858	0.0001*
* - Statistically significant								

Thus, the efficiency of ESR has been demonstrated by comparing it with other DTN protocols namely TBR and EC both graphically and statistically.

5. CONCLUSION

In the ESR approach, fragmented erasure coded blocks of the original message were transmitted through nodes with higher meeting prospect to the destination and enough buffer space. The application of erasure coding increased system resilience by improving load balancing among multiple paths taken by each fragment. This approach yielded a higher delivery ratio, lesser delivery delay and overhead than the EC and TBR protocols.

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