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A novel destination-based routing protocol (DBRP) in DTNs

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Abstract

In Delay Tolerant Networks (DTNs), the aim of any forwarding/routing protocols is to achieve a high delivery ratio of packets/bundles at the lowest possible bandwidth cost, buffer space and energy. Therefore, finding a protocol which uses less resource to achieve high delivery ratio and low latency is an open research question. This paper proposes a quota-based protocol which confines the number of replicas and forwards them based on the meeting history of nodes. The unique aspect of our protocol is to weight any encounter with the final destination to be much higher than any other node encounter. This aspect of the protocol is based on the idea that regardless of how small an encounter rate with the destination, given a highly correlated movement model (i.e., human behaviour) we will end up with a high delivery ratio. The results of our simulation support this hypothesis.

Keywords

destination, novel, routing, dbrp, dtns, protocol

Disciplines

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A Novel Destination-Based Routing Protocol (DBRP) in DTNs

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***Abstract*—In Delay Tolerant Networks (DTNs), the aim of any forwarding/routing protocols is to achieve a high delivery ratio of packets/bundles at the lowest possible bandwidth cost, buffer space and energy. Therefore, finding a protocol which uses less resource to achieve high delivery ratio and low latency is an open research question. This paper proposes a quota-based protocol which confines the number of replicas and forwards them based on the meeting history of nodes. The unique aspect of our protocol is to weight any encounter with the final destination to be much higher than any other node encounter. This aspect of the protocol is based on the idea that regardless of how small an encounter rate with the destination, given a highly correlated movement model (i.e., human behaviour) we will end up with a high delivery ratio. The results of our simulation support this hypothesis.**

Keywords-delay tolerant networks; network resources; quota-based protocols; history-based protocols

I. Introduction

Delay Tolerant Networks (DTNs) are characterized by frequent disconnections, and may have no contemporaneous paths between nodes. Hence, delivering packets/bundles is challenging as any developed routing protocols will have to address problems that arise from frequent network partitions. Moreover, nodes may have resource constraints, such as limited buffer space, energy and transmission rate. There are many DTN applications, such as Inter-Planetary Networks (IPNs) [1], which comprise of robotic spacecrafts and vehicles orbiting planets. Notably, in November 2008, NASA's Jet Propulsion Laboratory used a DTN to transmit images through the EPOXI spacecraft that is located about 20 million miles from Earth. Another DTN application is providing data communications in rural areas [2-4].

In these applications, nodes act as relays whereby they cooperatively help forward bundles from a source to a destination node. A node such as a bus may carry bundles until it meets another node such as pedestrians or other busses, which then forward bundles onward. In Figure 1(a), there is no path between source S and destination D. The challenge then is to exploit the movement and contacts of other nodes in order to route bundles from source S to D. The routing process proceeds as follows. As shown in Figure 1(a), bundles from node S can be delivered to node D by forwarding the bundle to node C at 10:05am. In Figure 1(b), which shows the state of the DTN at 11:30am, node C is able to forward the bundle to node A and finally at 12:15pm, node A forwards the bundle to node D. In this example, the bundle is delivered through a 'path' comprising of two hops whereas other replicas of the bundle are disseminated throughout the network whenever an opportunity of connection is provided by carrier nodes.

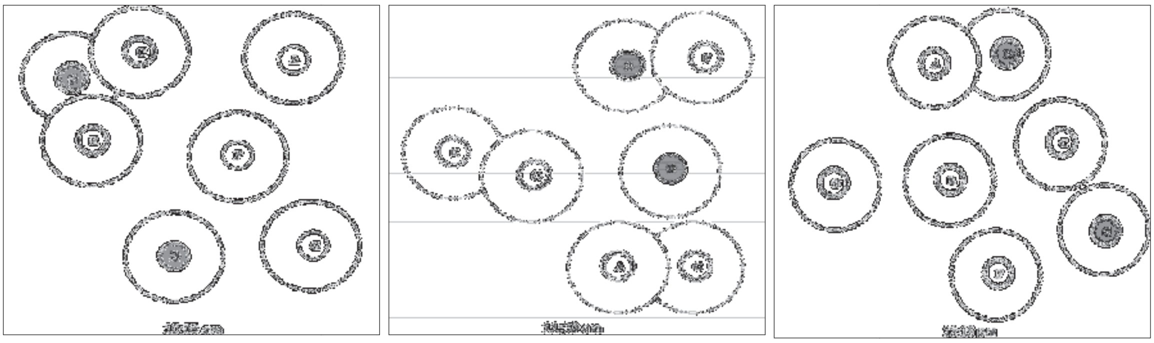
(a) (b) (c)

Figure 1: an evolving network.

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DTN routing protocols can be divided into two types: *flooding* and *quota*. Flooding-based protocols send a replica of each bundle to any encountered nodes, whereas quota-based protocols restrict the number of replicas. In fact, unlike flooding based routing protocols, the number of replicas in quota-based routing protocols is not dependent on the number of encounters [5]. Flooding based protocols do not require any knowledge of network topology [5-7]. Despite their robust delivery ratio and low delay, flooding-based protocols have higher energy usage, bandwidth and buffer space consumption [7-9]. However, the buffer size of devices may be limited, which may lead to bundle loss. Hence, under high traffic loads, these protocols suffer from high bundle loss, and low bundle delivery ratio [5-6, 10]. On the other hand, quota based protocols employ a limited number of replicas, which improve network resource usage [11].

This paper makes use of the following observation. Consider a person A who goes to work and meets person C every day. This means person A is an ideal bundle carrier for person C. We hypothesize that it is much better to weight this link higher than other links that may have much higher encounter rates with other nodes except the destination. We are proposing to pass on more replicas to nodes that have met the destination although this rate may be low in comparison to other nodes. This simple example illustrates the key idea which our protocol exploits in order to improve bundle delivery ratio whilst reducing overheads and delay. Specifically, we limit the number of replicas transmitted at each contact depending on a node's history of contact with a given destination. Every encountered node is evaluated according to its encounter history, where nodes with a low rate of encounters have a lower chance to receive bundles.

The protocols which Destination Based Routing Protocol (DBRP) is closest to are PROPHET [12] , Spray And Wait [10], EBR [5] and MaxProp [13]. PROPHET is based on the probability of encountering each node with the destination. However, PROPHET still suffers from high overheads as it does not control and limit the number of replicas. Two aspects of DBRP are distinct from PROPHET. First, we consider nodes that have a higher destination contact frequency (contact rate with a given destination) and nodes that have a high contact rate with other nodes. Collectively, these counters indicate the encounters ratio of a node. Secondly, to limit the number of replicas, DBRP is similar to Spray and Wait EBR protocol. In Spray and Wait, bundles are flooded but the number of replicas for each bundle is limited. This thus reduces overheads and improves delivery ratio. However, Spray And Wait suffers from low delivery [5]. In EBR, in each encounter, the protocol considers the rate of both sender's and receiver's encounters. For EBR, the traffic will be directed to parts of the network where the rate of encounters is higher than other parts. Only the nodes with high rate of encounters are able to act as relay nodes. DBRP copes with these issues by always weighting the rate of encounters with the destination as much higher than any other node.

To this end, we like to highlight the following key features of DBRP:

- Up to 57% improvement in network performance including delivery, delay and overhead as compared with EBR [5], Spray and Wait [10] and PROPHET [12] especially when the network is sparse.
- At least 28% lower buffer consumption than EBR and Spray and Wait due to the use of finite number of replicas.

The rest of the paper is organized as follows. Section 2 describes our proposed scheme and in Section 3 the simulation setup is given, and the simulation results can be found in Section 4. Finally Section 5 concludes and discusses some issues and looks into future work.

II. Destination Based Routing Protocol (DBRP)

DBRP is a quota-based routing protocol that limits the number of replicas for each generated bundle in order to achieve low overhead ratio. A sender forwards only a portion of replicas to the receiver. This strategy is based on the rate of encounters that the sender and receiver have had with the destination and other nodes. DBRP gives a higher weight to nodes that have encountered the destination. In the case of high node density areas where nodes have high encounter rates, DBRP ensures all nodes with contact to the destination receive a significantly higher weight.

A. *Algorithm*

In DBRP, every node a establishes a metric called the encounter history, $en\_His_{(a,b)}$, for each destination b. This metric is obtained through the combination of two counters: $en_{(a)}$, for counting the number of times that a encounters other nodes and $en_{(a,b)}$, which counts the number of times a has met b. This encounter history is much more informative than an absolute number of encounters. If we simply rely on the number of encounters, the forwarding strategy can be ineffective because a node with a high encounter frequency, although meets other nodes frequently, may never meet the target destination. Therefore, encounter history as used in DBRP indicates a rough prediction of the future rate of encountering a destination node.

The encounter history, *en_His*, for a node to any other node in a given time interval is calculated as follows:

$$en\_His_{new(a,b)} = \beta \times en_{(a)}^{\gamma \times en_{(a,b)}} + (1-\beta) \times en\_His_{curr(a,b)} \quad (1)$$

where $0<\beta<1$ is a weight of the most recent encounter information. The variable $en_{(a)}$ is the total number of encounters that node a has had over a specific time interval with all nodes. The variable $en_{(a,b)}$ represents only the encounters between nodes a and b. Hence, if this variable is zero then this node has never encountered the destination b in a given time interval. The term time interval is used to consider the network parameters in time slices. For example in a time interval, a node may have 20 encounters with different nodes and in the next interval 10 encounters. Therefore, we can evaluate the rate of encounters in each interval. In our paper time interval is set to 1000 seconds. We used a large interval as compared with EBR because in small time intervals the destination may be encountered only one time in the interval. This cannot be effective as DBRP exponentially weight the encounters rate. On the other hand, in small intervals, destination is not encountered most of the times that causes to work exactly like EBR. The variable $\gamma > 0$ is a weight function. Meanwhile, $en\_His_{curr(a,b)}$ is the value of $en\_His_{(a,b)}$ before an update and $en\_His_{new(a,b)}$ is the new value after the update.

As an example, consider node *A* who has four encounters out of 10 with node *B*, two with node *C*, one with node *D* and three with node *E*. The encounter history for node *A* is computed as follows (assuming β =0.85 and γ=1.4):

$$en\_His_{new(A,B)}=0.85\times10^{1.4\times4} + (1 - 0.85) \times 0 = 338390 \quad (2)$$

$$en\_His_{new(A,C)}= 0.85\times10^{1.4\times2} + (1 - 0.85) \times 0 = 536.3 \quad (3)$$

$$en\_His_{new(A,D)}=0.85\times10^{1.4\times1} + (1 - 0.85) \times 0 = 21.35 \quad (4)$$

$$en\_His_{new(A,E)}=0.85\times10^{1.4\times3} + (1 - 0.85) \times 0 = 13472 \quad (5)$$

This example shows the encounter history of node A with the four destinations. Therefore, a node that mainly encounters *A* gets a higher weight. Here, node *A* has encountered node *B* four times and node *C* two times whereas their encounter history shows that node A has visited node B $\frac{338390}{536.3} = 630$ times more than node *C*.

The number of replicas is dependent on the encounter history of the sender and receiver. Specifically, the number of replicas is proportional to the ratio of the encounter history of the nodes. For two nodes *a* and *b*, for i^{th} bundle M_i, that is headed to destination *d*, node *a* sends

$$m_i \times \frac{en\_His_{(b,d)}}{en\_His_{(b,d)} + \eta \times en\_His_{(a,d)}} \quad (6)$$

replicas of M_i, where m_i is the available number of replicas for the i^{th} bundle at node *a*, and η is a scaling factor. When the sender *a* has encountered the destination *d* frequently, it means the bundle can be delivered through the sender. Therefore, it is better for node *a* to give more opportunities to the receiver *b* to receive more replicas. This means at each contact, when node *a* has a high encounter rate with *d*, there is no need to keep the large number of replicas for itself. This is due to node *a* having a better chance to directly deliver the bundle even with only one copy. As a result, η is used to decrease the effect of the original sender's $en\_His_{(a,d)}$ in forwarding replicas. Here, the values of beta, gamma and eta are determined heuristically. The values were chosen to provide the greatest discrepancy in weight values between the final destination and other nodes.

For example, assume node *a* has eight replicas of a bundle m_1 with the destination *d* and nine replicas of a bundle m_2 with the destination *z*. Furthermore, assume node *a*, with $en\_His_{(a,d)}$ = 2000 and $en\_His_{(a,z)}$ = 5500 comes in contact with node B, with $en\_His_{(b,d)}$ = 5000 and $en\_His_{(b,z)}$ = 2500. Node a sends $\frac{5000}{5000 + 0.6\times 2000} = \frac{50}{62}$ of the replicas of a bundle m_1 and $\frac{2500}{2500 + 0.6\times 5500} = \frac{25}{58}$ of the replicas of a bundle m_2. Therefore, Node *a* forwards six replicas of a bundle m_1 and three replicas of a bundle m_2.

III. Research Methodology

The Opportunistic Network Environment (ONE) [14] is a Java based simulator that is able to generate node movement using different mobility models. ONE can import mobility data from real-world traces or other mobility generators. Using ONE, we have evaluated the performance of DBRP under the Map-Based model [14]. In this model, nodes have predefined movement in an area of approximately 5×3 km^2 of downtown Helsinki, Finland. In addition, a majority of these nodes are pedestrian. Specifically, we use ONE's default settings, whereby 64% of nodes model pedestrians that follow the shortest path from their current location to a random chosen point with speed between 0.5 and 1.5 m/s. Another 32% of nodes are vehicles that have the same movement but with speed ranging from 2.7 and 13.9 m/s. The remaining nodes are configured to follow pre-defined routes (like tram lines) with speed between 7 and 10 m/s. All nodes have a transmission range of 20m except trams that have a 200m range.

The number of nodes is varied from 50 to 200 in increments of 50 but number of source and destination is fixed to 50. We also vary the offered load by adjusting the time between generated bundles from 10 seconds (high load), to 30 seconds (medium load), to 60 seconds (light load). In all simulations, the bundle size is 25 KB, and each node has one MB buffer space, and all nodes have a transmission speed of 250 kBps. Each simulation lasts for 12 simulated hour and each data point is an average of 10 runs, with 95% confidence intervals.

To illustrate the performance of each protocol we evaluate DBRP against three other popular protocols with respect to node density and load: (1) PROPHET [12], (2) Spray and Wait [10], and (3) EBR [5].

The metrics collected are as follows:

- Delivery ratio is defined as the ratio of the Number of Delivered Bundle (NDB) to the Number of Generated Bundles (NGB),

$$Delivery\ ratio= \frac{NDB}{NGB} \quad (7)$$

- Eq.(8) defines the average delay of all delivered bundles, where t is the delay experienced by bundle i:

$$Average\ latency = \frac{\sum_{i=1}^{NDB} t_i}{NDB} \tag{8}$$

- Eq.(9) defines the ratio of NDB and Number of Relayed Nodes (NRN).

$$Overhead = \frac{NDB\text{-}NRN}{NDB} \tag{9}$$

It is deceptive to view delay and overhead alone since many protocols quickly deliver bundles that take a small number of hops, and do not deliver most bundles that require a high number of hops. To overcome this issue, we define composite metrics that incorporate delivery ratio and other metrics:

- Eq.(10) defines DL based on Delivery Ratio (DR) and Latency Average (LA).

$$DL = DR \times \frac{1}{LA} \tag{10}$$

- Eq.(11) defines DO based on DR and Overhead Ratio (OR).

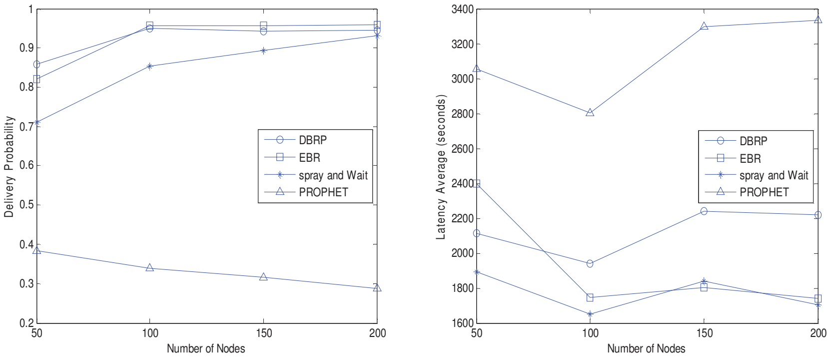
$$DO = DR \times \frac{1}{OR} \tag{11}$$

- Eq.(12) defines DLO based on DR, LA and OR.

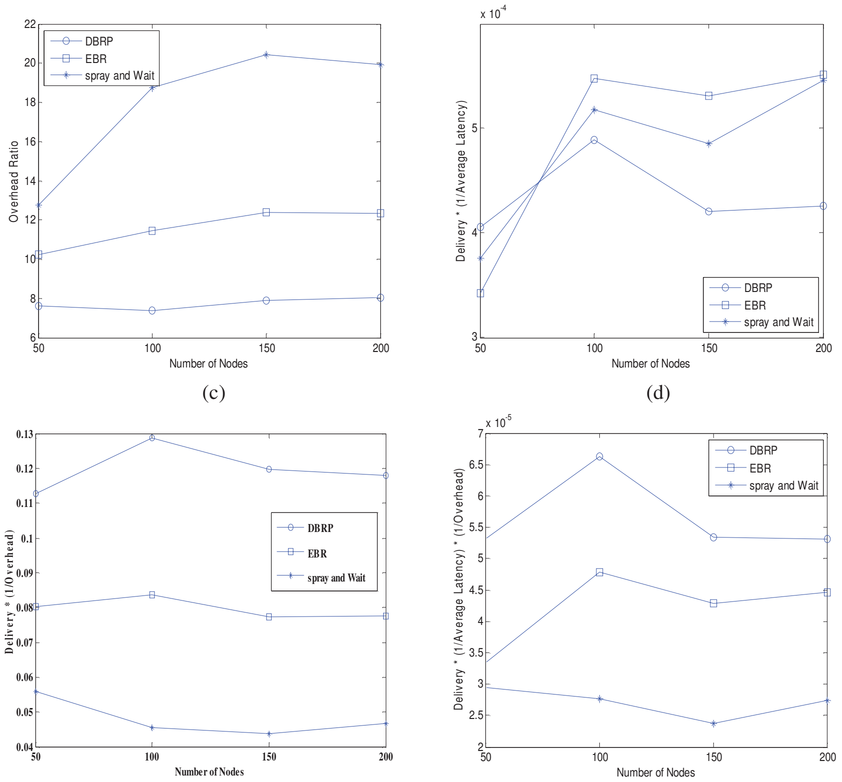
$$DLO = DR \times \frac{1}{LA} \times \frac{1}{OR} \tag{12}$$

IV. Results

Figure 3 shows the impact of node density. As shown in Figure 3(a)(c), DBRP performs very close to EBR in terms of delivery while DBRP use 28% fewer relayed nodes as compared to EBR. Spray and Wait works better than PROPHET in all metrics but it has 45% powerless as compared to DBRP. This is due to two factors. First, this mobility model fits perfectly into our hypothesis that past information on rate of encounters is an estimator for future rate of encounters. Therefore, nodes have higher probability to visit each other in the future if they have met in the past. PROPHET also uses the history of observations in this mobility but its overhead and rate of dropped bundles do not allow it to overcome in any of the metrics against Spray and Wait, EBR and DBRP. Second, network utilization is correlated to delivery ratio, delay and overhead due to constrained buffer space and number of nodes. As Spray-and-Wait floods the n replicas, we can see in Figure 3(c) that in high density scenarios, dissemination rate increases. Consequently, as all replicas have the opportunity of being forwarded, overhead increases. Spray and Wait has approximately 120% higher overhead as compared to DBRP. The overhead of DBRP with the average of eight is, by far, the most resource friendly, as shown in Figure 3(c)(e).



(a) (b)



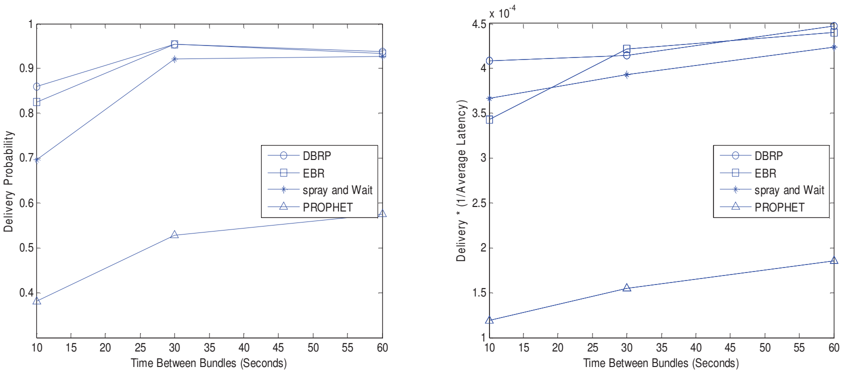
(c) (d)

(e) (f)

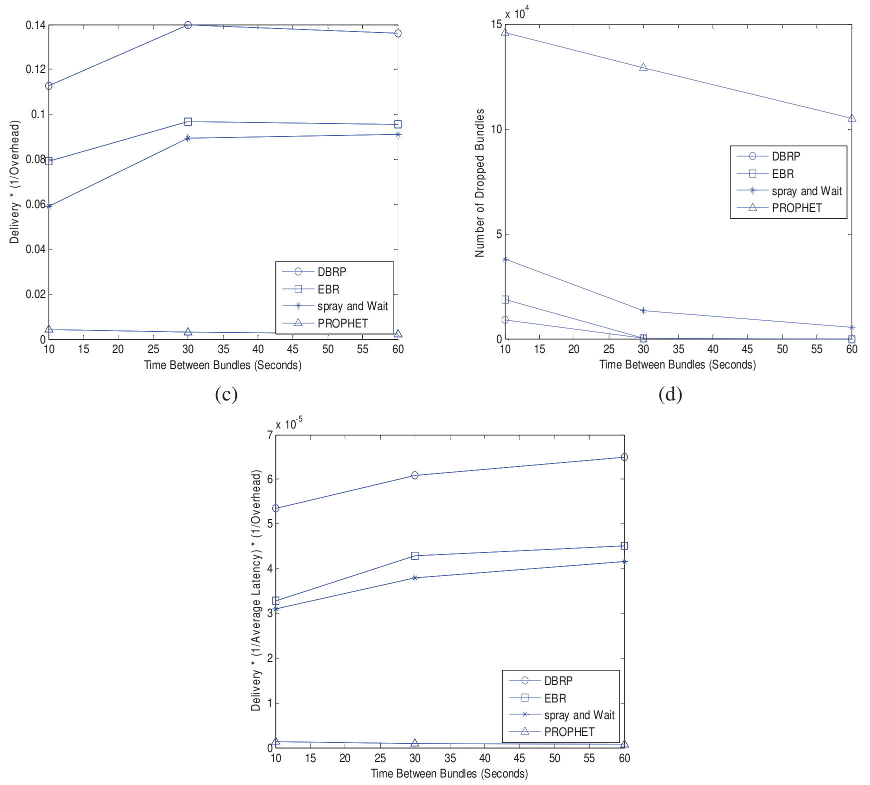
Figure 3: Network performance in different node densities, a) delivery probability, b) Latency average, c) Overhead Ratio, d) Delivery * (1/ Latency average), e) Delivery * (1/ Overhead), f)Delivery * (1/ Latency average)* (1/ Overhead)

Figure 3(d), 3(e) and 3(f) plot the composite metrics DL, DO and DLO. Figure 3(b)(d), DBRP is shown to have large delays. This is in part due to the low dissemination rate of replicas. We observe in Figure 3(f) that for low density scenario, the DLO of DBRP has 57% improvement as compared to EBR.

In the second group of simulations, the offered load is varied from 1, 2 and 6 bundles per minute. There are 50 source and destination nodes. DBRP has the best performance in all categories. All the protocols suffer from low performance as the offered load increases. The average latency, however, shows PROPHET performed much worse than other protocols. This is due to its reliance on a much larger buffer and hence an increase in load results in a higher rate of dropped bundles as compared to other protocols. In terms of delivery, by decreasing the load, the gap between PROPHET and the other protocols becomes smaller. This is due to in light load rate of dropped bundles decreases for PROPHET (see Figure 4(d)). The composite metric in Figure 4(e) shows that DBRP has at least 40% improvement in comparison with the other protocols.



(a) (b)



(c) (d)

(e)

Figure 4: Network performance in different loads, a) delivery probability, b) Delivery * (1/ Latency average), c) Delivery * (1/ Overhead), d) number of dropped bundles, e) Delivery * (1/ Latency average)* (1/ Overhead)

V. Conclusion

The ability to efficiently and effectively route data through intermittently connected networks is of critical importance to DTNs. Many current routing protocols utilize flooding-based techniques to obtain relatively high bundle delivery ratios. This, however, comes at the expense of overwhelming network resources such as bandwidth and storage.

In this paper, we show that basing routing decisions on the destination encounter rate of a node can increase network performance. As shown in Section 4, DBRP provides comparable or better trade-off between bundle delivery, overhead and latency than the flooding-based and quota-based protocols.

REFERENCES

[1] S. Burleigh, *A. Hooke, and L. Torgerson, K. Fall, V. Cerf, B. Durst, K. Scott, and H. Weiss*, "Delay-tolerant networking: an approach to interplanetary Internet," *IEEE Communications Magazine,*vol. 41, pp. 128-136, 2003.

[2] *Wizzy Digital Courier - leveraging locality*. Available: http://www.wizzy.org.za/

[3] *TIER Project*. Available: http://tier.cs.berkeley.edu/

[4] A. Pentland, R. Fletcher, and A. Hasson, "DakNet: rethinking connectivity in developing nations," *IEEE Computer,* vol. 37, pp. 78-83, January 2004.

[5] S. C. Nelson,*M. Bakh, and R.Kravets*, "Encounter-Based Routing in DTNs," ACM SIGMOBILE MC2R, Vol. 13, Issue 1, pp. 56-59, January 2009.

[6] S.-Y. Ni, Y.-C. Tseng, Y.-S. Chen, and J.-P. Sheu, "The broadcast storm problem in a mobile ad hoc network," presented at the Proceedings of the 5th annual ACM MOBICOM, Seattle, Washington, United States, 1999.

[7] E. P. C. Jones, L. Li, and P. A. S. Ward, "Practical Routing in Delay-Tolerant Networks," *IEEE Transactions on Mobile Computing,* vol. 6, pp. 943-959, 2007.

[8] V. Erramilli and M. Crovella, "Forwarding in opportunistic networks with resource constraints," presented at the Proceedings of the third ACM workshop on Challenged networks, San Francisco, California, USA, 2008.

[9] P. Juang, H. Oki, Y. Wang, M. Martonosi, L. S. Peh, and D. Rubenstein, "Energy-efficient computing for wildlife tracking: design tradeoffs and early experiences with ZebraNet," *SIGARCH Comput. Archit. News,* vol. 30, pp. 96-107, 2002.

[10] T. Spyropoulos, K. Psounis, and C. S. Raghavendra, "Spray and wait: an efficient routing scheme for intermittently connected mobile networks," *Proceedings of the 2005 ACM SIGCOMM workshop on Delay-Tolerant Networking*, Philadelphia, Pennsylvania, USA, 2005.

[11] S. Kapadia, B. Krishnamachari, and L. Zhang, "Data Delivery in Delay Tolerant Networks: A Survey," *Mobile Ad-hoc Networks: Protocol Design,* pp. 565 - 578, 2011.

[12] A. Lindgren, A. Doria, and O. Schelen, "Probabilistic routing in intermittently connected networks," *SIGMOBILE Mobile Computing and Communications Review,* vol. 7, pp. 19-20, 2003.

[13] J. Burgess, B. Gallagher, D. Jensen, and B. N. Levine., "MaxProp: Routing for Vehicle-Based Disruption-Tolerant Networks," i presented at the Proceedings of *IEEE INFOCOM 2006*, Barcelona, Catalunya, Spain, 2006, pp. 1-11.

[14] A. Keränen, J. Ott, and T. Kärkkäinen, "The ONE simulator for DTN protocol evaluation," presented at the Proceedings of the 2nd International Conference on Simulation Tools and Techniques, Rome, Italy, 2009.