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# Proposed Fuzzy based Routing for DTN

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## ABSTRACT

This paper introduces a proposed fuzzy-based routing protocol for *DTN* networks, called *FBRP* designed to maximize successful data delivery rate and minimize transmission delay It uses only two parameters namely, probability of delivery and energy value as inputs to fuzzy system in order to compute the delivery predictability value which determine the routing path for packets. Simulation results are used to draw conclusions regarding to the proposed routing algorithm and compared it with well known routing protocols: Epidemic and PRoPHET routing protocols. Conducted experiments showed that our proposed algorithm exhibits superior performance with respect to the well known routing protocols in terms delivery rate and overhead ratio.

## General Terms

DTN Routing Protocol, Opportunistic Routing, Routing Protocol.

## Keywords

DTN Routing; Fuzzy Based Routing Protocol; New Routing Protocol; Priority Routing Protocol.

## 1. INTRODUCTION

*DTN* networks are one of the most interesting evolutions of classic Mobile Ad Hoc Networks (*MANET*). The main assumption of *MANET* environments is that a sender and a destination are connected to the network at the same time. If the destination is not connected when the sender wishes to transmit messages, they get dropped at some point of the network. However, in a pervasive networking environment, nodes will be seldom connectable at the same time through a multi-hop path. For example, devices that users carry with them might be only sporadically attached to the Internet, e.g. when the user moves close to an Access Point. In other words, it is foreseeable a scenario in which a large number of wireless devices and limited-size networks will be *just occasionally* connected to each other. *DTN* networks aim at make users able to exchange data even in such a disconnected environment, by opportunistically exploiting any nearby device to move messages closer to the final destination. To this end, legacy protocols designed for *MANET* should be drastically redesigned [1],[2],[3]. Currently, envisioning routing and forwarding protocols1 for *DTN* networks is one of the most exciting topics [4]. In *DTN* networks, the traditional routing paradigm of Internet and *MANET*, in which routes are computed based exclusively on topological information, is not adequate anymore. A first approach to routing in *DTN* networks is some variation of controlled flooding: Messages are flooded with limited Time-To-Live (*TTL*), and delivered to the destination as soon as it gets in touch with some node that received the message during the flood [5]. Many researchers have proposed new routing protocols such as Epidemic [5], Prophet [6], Spray-and-Wait[7], Spray-and-Focus [8], MaxProp [9] and *ORWAR* [10] to handle this specific problem for *DTN*.

This paper introduces a proposed fuzzy-based routing mechanism, called FBRP in DTN. Our mechanism is simple with low overhead. It uses only two parameters, namely, probability of delivery and energy value as inputs to fuzzy system in order to compute the delivery predictability value which determine the routing path for packets. The remainder of this paper is organized as follows: Section 2 presents the related work. In section 3 our proposed mechanism is described. Simulation and results of our proposed routing protocol can be found in section 4. Section 5 discusses our conclusion.

## 2. RELATED WORK

In this Section, we present an overview of the significant concepts on routing protocols for DTN, namely Epidemic [5], PRoPHET [6], Spray and wait [7], along with their relative pros and cons.

### 2.1 Epidemic

The Epidemic routing [5] protocol is a flooding-based scheme. Each node has two buffers, the first one for storing the messages generated by itself, and the second one for those messages received from other nodes. Each message is tagged with a unique ID. Each node also maintains a list of message IDs that it is currently holding in its buffer called the Summary Vector. When two nodes meet, they exchange their Summary Vectors with each other. By comparing these Summary Vectors, the nodes exchange those messages which they do not have with them. When this operation of message exchange is completed, all nodes have the same messages in their buffers. This creates a large amount of redundancy in the network, which incurs significant demand on both bandwidth and buffer capacity, but at the same time, makes it extremely robust to node and network failure. The simulation results obtained in this work show that for this protocol, the message delivery ratio is very high and the message is delivered in minimum amount of time if sufficient resources are available.

### 2.2 PRoPHET

In PRoPHET (Probabilistic Routing Protocol using History of Encounters and Transitivity) [6], before sending a message, each node estimates a probabilistic metric called

Delivery Predictability for each known destination. It indicates the probability of successful delivery of a message to the destination from the source node. The calculation of the Delivery Predictability is based on the history of encounters between nodes or history of visits to certain locations. This metric is calculated by each node A of the DTN network and for each known destination B and will be used to decide which messages to be exchanged whenever two nodes meet.

The calculation of the probability of delivery is done in three steps [11]:

- When a node A meets another node B: A updates the probability of delivery in accordance with the following equation:

$$P\langle A,B\rangle = P\langle A,B\rangle_{old} + \langle 1 - P\langle A,B\rangle_{old}\rangle * Penc \qquad (1)$$

Where $P_{enc}$ .is calculated in the following way:

$$P_{enc} = P_{enn-\max x}\,(Intvl_B / I_{typ})$$

$$\text{for } Intvl_B \in \left\lfloor 0, I_{typ} \right\rfloor$$

$$= P_{enc-\max} \qquad \text{otherwise} \qquad (2)$$

Where $Penc-\max$ is used as the upper limit of scaling factor that increases the delivery predictability for a destination when the destination node is encountered, $I_{typ}$ is a parameter that is set to the expected typical time interval between connections in the application scenario relevant to the network deployment and $Intvl_B$ is the time since the last encounter with node B.

- For a node C known by a node B: A updates the probability of delivery in accordance with the following equation:

$$P\langle A,C\rangle = \max\langle P\langle A,C\rangle_{old}, P\langle A,B\rangle * P\langle B,C\rangle + *\beta\rangle \qquad (3)$$

Where $\beta \in [0,1]$ determines the impact of transitivity on the delivery predictability.

- For nodes infrequently met by A: A updates the probability of delivery in accordance with the following equation:

$$P\langle A,B\rangle = P\langle A,B\rangle_{old} * \gamma^{K} \qquad (4)$$

Where $\gamma$ is an aging constant and $k$ is the number time units that have elapsed since the last time the metric was aged.

Each node maintains in its cache the information of all the nodes it has contacted recently i.e. the frequency of encounters with each node and thus a probability of delivery value will be associated

# 3. PROPOSED ROUTING

Our approach to routing is based on the frequency of contacts between network nodes [6]. Therefore, each network node calculates the probability of delivery (As it is mentioned above, from equation 1 to equation 5). The measured probability of delivery and energy value are used as input to the fuzzy system in order to compute the delivery predictability value which determine the routing path for packets. In this regards the defined inputs and output sets have been defined for *FBRP* protocol

## 3.1 Probability of Delivery (PD):

The most important problem of fuzzy logic is to define the appropriate ranges for each fuzzy input. On the bases of recommended parameter values (see Table 1) [11], we can define the range for probability of delivery. The membership function of *PD* is divided into 3 sections, low, medium and high, with linear symmetric shape. Figure 1 illustrates the degree of membership function of *PD*.

**Table 1. Default parameter settings**

| Parameter | Recommended value |
|---|---|
| P_encounter_max | 0.7 |
| P_encounter_first | 0.5 |
| P_first_threshold | 0.1 |

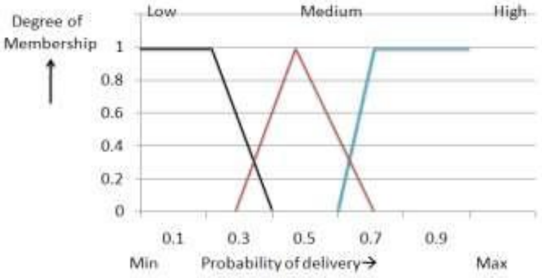

**Fig.1: Memberships function of probability of delivery.**

## 3.2 Energy Value (EV):

We defined that every node is in high level which means it has full capacity (100%).The node will not be a good router to forward the packets if the energy of it falls below 50%.[6] For energy capacity between 50 % to 100% of

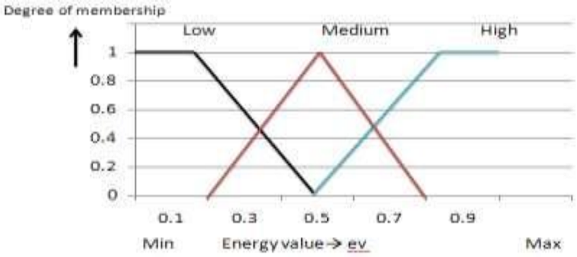

Fig.2: Memberships function of energy value.

total capacity, we define high fuzzy set, for 20% to 80% we define medium fuzzy set and for 0% to 50% we define low fuzzy set

### 3.3 Delivery Predictability (DP) Evaluation:

Fig. 3 shows the membership function of delivery predictability. It takes a different values based on 9 rules that dependent upon varied input metric values i.e. *PD* and *EV*. A fuzzy system decides for each two input values which values appear in output.

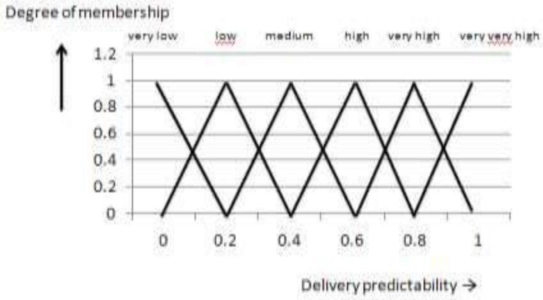

**Fig.3: Memberships function of delivery predictability.**

The fuzzy system with product inference engine , singleton fuzzifier and center average defuzzifier is of the following form:

$$f(x) = \frac{\sum_{i=1}^{6} y_o^{\,i} \left( \prod_{k=1}^{2} \mu_{A_{ik}} \{x_k\} \right)}{\sum_{i=1}^{6} \left( \prod_{k=1}^{2} \mu_{A_{ki}} (x_k) \right)} \qquad (5)$$

where $y_0^{\,i}$ is the center average of output fuzzy set, $x_i$ represents crisp value of $i^{th}$ input (probability of delivery or energy value and $\mu_{A_{ik}}(x_k)$ represents fuzzy membership function for $i^{th}$ input.

The fuzzy rules are as follows:

1. if *PD* is low and *EV* is low then *DP* is very low
2. if *PD* is medium and *EV* is low then *DP* is very low
3. if *PD* is high and *EV* is low then *DP* is very low
4. if *PD* is low and *EV* is medium then *DP* is low
5. if *PD* is medium and *EV* is medium then *DP* is medium
6. if *PD* is high and *EV* is medium then *DP* is high
7. if *PD* is low and *EV* is high then *DP* is very low
8. if *PD* is medium and *EV* is high then *DP* is very high
9. if *PD* is high and *EV* is high then *DP* is very very high

## 4. SIMULATION AND RESULTS

## Simulation Setup

To validate behavior and evaluate the performance of *FBRP*, we use ONE (Opportunistic Network Environment) simulator [12] to implement it and other DTN routing protocols, including Epidemic and PRoPHET.

In our simulation, we used the real-world connectivity and traffic traces, collected during a N4C deployment in 2010 [13]. The traces come from one week when the mobility conditions resembled the ones in the N4C summer test of 2009. During that period (July 27-August 3, 2010) only one data mule carrier was used and the network had high usage. The total number of DTN nodes was 18 and the number of bundles sent was 1407. The lifetime of these bundles was set to three days. Only one helicopter flight with data mules was scheduled per day and some of the bundles that were sent in the last days had to be dropped at the end of simulations. As seen in Figure 4, PRoPHET could deliver the same number of bundles as Epidemic Routing with a lower overhead. Moreover, *FBRP* (The proposed routing) could deliver a higher number of bundles with minimum overhead rather than PRoPHET and Epidemic Routing.

In the second evaluation we used the Working Day Model (WDM) [14] with the default settings for WDM in the ONE simulator. The simulation time was set to one week and the expiry time for the bundles was set to 1430 minutes. The number of nodes was 500, and a total of 17000 bundles were sent. In this set up, the buffer space was limited to 100MB per node and the available bandwidth was 100 kbit/s. As seen in Figure 5, despite limited resources (buffer and band- width) *FBRP* (The proposed routing) performed better performance than PRoPHET and Epidemic Routing in this scenario in terms of . delivery rate and overhead ratio. The fact that the proposed routing outperformed PRoPHET and Epidemic Routing shows that the protocol makes wise decisions on what bundles to forward and how to use the limited resources

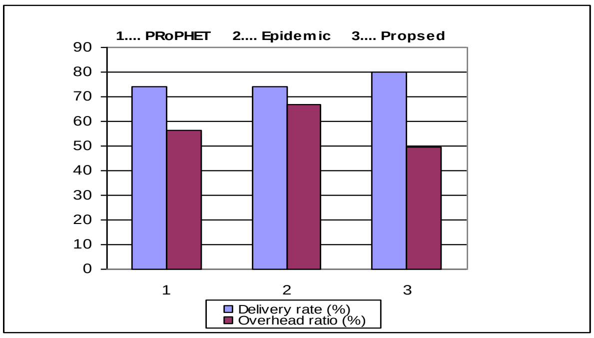

**Fig. 4: Results from simulations using N4C traces.**

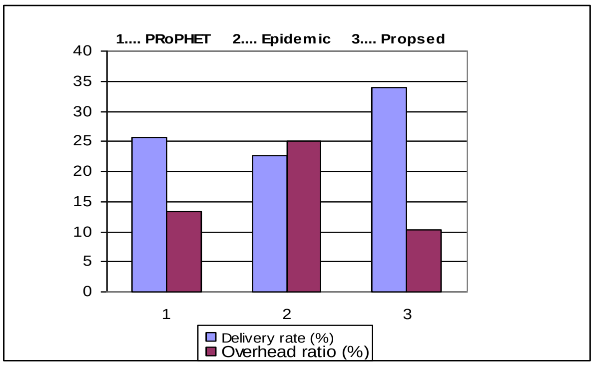

**Fig. 5: Results from simulations using WDM mobility**

## 5. CONCLUSION

This paper introduces a proposed fuzzy-based routing protocol, called *FBRP*. It uses only two parameters namely, probability of delivery and energy value as input to fuzzy system in order to compute the delivery predictability value which determine the routing path for packets. During transmission it is needed only to pass delivery probability along with the actual message to the peer. The fuzzy membership functions can be adaptively constructed based on known network parameters. The fuzzy decision mechanism is very simple compared to complex prediction mechanisms used in many other *DTN* protocols. In spite of that, we have shown that *FBRP* is the best performing protocol, in terms of delivery rate and overhead ratio.

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