Context Dependent Messages in Delay/Disruption/Disconnection Tolerant Networks

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***Abstract*—Delay/Disruption/Disconnection Tolerant Networks (DTNs) attract a great deal of attention as the part of the evolution of various telecommunications networks. In DTNs, the desired features of communication are high-speed data-transfer, high rate of transmission, and reduction of terminal resource usage (e.g., network bandwidth or capacity of node storage). These features often conflict with each other. Although balancing conflicting requirements are important, optimum methodology is still not established. In order to address these issues, we propose a new method which propagates information based on the context of messages in the shared network, such as Vehicle-to-Vehicle (V2V) communication. In our method, we use two parameters, namely, rate of dissemination and maximum number of hops, to control the speed of information propagation and total amount of information in the network. We found that rate of dissemination controls the speed of spreading information and an amount of messages needed for spreading, while maximum number of hops controls the speed of spreading information and the information volume sent per time unit.**

Keywords*—*Delay/Disruption/Disconnection Tolerant Networks; Vehicle-to-Vehicle Communication; Context Awareness

I. Introduction

Delay/Disruption/Disconnection Tolerant Networks (DTNs) is a computer network technology which aims to realize a high trust data transmission in the environment where devices are not able to communicate sequentially. DTNs do not assume a fixed wireless infrastructure, where nodes communicate with each other by direct connection or through multi-hop relays. When the terminal cannot connect to the recipient directly, they perform multi-hop relays by using the resources (message storage) of every node encountered on their communication path. DTNs attract a great deal of attention as a network construction technology for a high-speed communication using only mobile devices, in particular, when network infrastructure is damaged by disasters [1].

As an ideal model of DTNs communication, we discuss the approach to construct a network where any message can be delivered with high-speed and high probability. The simplest way to do it is to broadcast every message. It is difficult for the terminal to deliver its message to the recipient directly in DTNs. The terminal expects that somebody delivers the message by passing its copy through other nodes. The more nodes relaying the message exist, the higher are chances that the message is delivered successfully. However, broadcasting a message involves a lot of relaying nodes, so it is not a good policy since the network becomes flooded with messages. Besides, we need to assume that network resources have some restrictions, since DTNs consist of mobile devices only. For example, the broadcast communication leads to the network congestion and, at worst, to the network failure. Hence, communication on DTNs must be performed in a way that reduces the consumption in resources.

Vehicle-to-Vehicle (V2V) networks [2] consist of many moving vehicles which can communicate with each other, so V2V can be regarded as one form of DTNs. For example, Intelligent Transport Systems (ITS) are one of the solutions for road transportation problems [3][4][5]. The most remarkable feature of ITS is that every communication is performed between the unspecified large number of nodes. Every message has no specific recipient, but it is shared by all nodes which could communicate with others. Assuming that ITS aims to share information, we found that according to context, information could be marked either as urgent or important. These two factors affect information propagation.

Based on this analysis, we propose a parameter-based routing method which controls the process of information propagation by using information context. The structure of this paper is as follows: Section II introduces some existing routing techniques in DTNs. Section III shows our proposal. Section IV shows the results of simulation and related considerations. Finally, Section V presents conclusions and future tasks.

II. Related Works

This section introduces some existing routing techniques in DTNs.

Epidemic Routing [6] is the easiest routing technique in DTNs, where copies of messages are sent to adjacent nodes. With a behavior resembling a contagious disease, this method is a simple technique with very high probability of delivering messages. However, most of messages sent by a node do not reach an intended receiver. In order to avoid an overload of network and message storage, more elaborate message propagation methods have been proposed.

Based on the assumption that using historical information estimates future behavior, several methods using historical transmission state have been proposed. PRoPHET [7] uses the delivery predictability calculated from the encounter rate, the encounter time and the delivery success rate. In MaxProp [8], all nodes in the network calculate transmission costs from the number of the past encounters and send own message along the path determined by these costs. However, in a large-scale mobile network, these methods are hard to apply.

In Encounter-Based Routing [9], the total number of messages is set, and when relaying, sender makes copies of

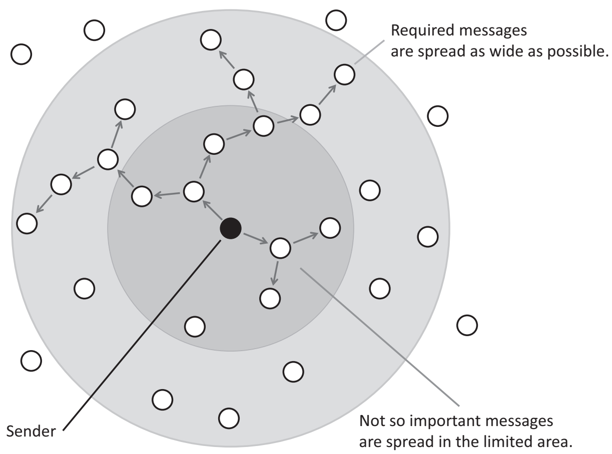

Fig. 1. Spreading messages by priority.

messages according to the number of node encounters. Spray and Wait [10] introduces two propagation phases. In Spray phase, the fixed number of messages is sent to the network. In Wait phase, the node stops sending messages and waits for them to be received. This policy can limit the amount of information transferred in the network. Spray and Focus [11] differs in that Wait phase is replaced with Focus phase. In Focus phase, nodes holding a message do not wait for it to reach the destination, but pass the message to the other node who can deliver it with higher probability. In these methods, however, the number of nodes who receive a message is limited because the number of messages is fixed.

III. Proposed Method

This study does not target networks for communication between specific communication partners. Instead, it is supposed to be used for sharing information scenarios, such as V2V communication. We propose propagating shared information according to the information context. Assuming that every node wants the information shared, the goal is to spread a message to as many nodes in the network as possible.

We understand that urgency and importance of the information shared in V2V communication are defined by information content. By importance in this paper we mean how much profit can be produced. In case of traffic, a profit could mean that the traffic jam is resolved early, traveling time is saved, and the environment is considered by saving fuel. The priority of such message is high because it is beneficial from a viewpoint of V2V network and the vehicles in the network. Urgency means how much information value is lost as time passes. In other words, this shows how important the freshness of information is. One example of such urgent information is the one that prevents driver's life risk. For example, the submergence of roadway underpass or rockfall along the mountain path. Drivers' safety could be ensured by notifying them of such information in the area as wide as possible.

It is hardly possible to balance all requirements in V2V communication (like yielding both speedy delivery and delivery with high probability), similar to how it is done in general DTNs. Instead, balance should be achieved by considering the information context. Therefore, in this paper, we propose changing propagation method according to a propagation media (in this case, a node), considering the information context to attain desired efficiency (Fig. 1).

A. Context-Based Communication

We define context-based communication as follows:

1) Get message context
2) Assign propagation parameters determined by context (importance and urgency) to each message
3) Send information depending on propagation parameters

This paper proposes spreading messages by using parameters (the item 3 above).

During the evaluation (Section IV), we assumed that nodes have functions to get the context and to assign parameters (items 1 and 2 above). Since the number of message types is limited, assigning parameters to each message can be easily performed with the assignment table. It is important to define how the context affects propagation parameters. For example, first, a user sets the level of urgency and importance individually. The level ranges from 0 to 5. Next, the propagation parameters are determined by the level. For example, the level multiplied by 1/5 (20%) is used as rate of dissemination.

B. Communication Parameters

The following parameters are proposed:

1) Rate of dissemination: This is a propagation parameter determining a probability, at which a node sends a message to the other node. It controls the number of messages in the network and the speed of propagation. For instance, a sender sends a message to each receiver with 60% probability when a parameter value is 60. In such case, we expect that this information will reach 60% of possible receivers (Fig. 2). This parameter should be set high when the message owner wants to reach more nodes quickly and wants other nodes to relay (the urgency is high).

2) Maximum number of hops: This is a propagation parameter determining the number of intermediate nodes. It controls the area of spreading and the speed of propagation. Basic behavior is similar to Time To Live (TTL) parameter of an

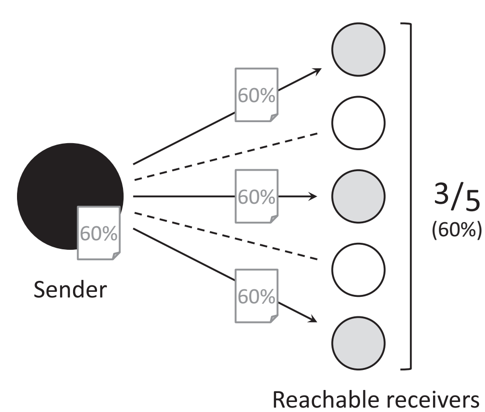

Fig. 2. Example—rate of dissemination (60%).

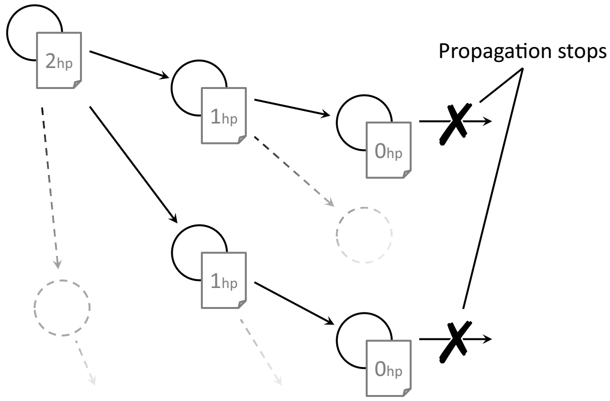

Fig. 3. Example—maximum number of hops (2 hops).

IP packet. Fig. 3 shows an example when the message with maximum number of hops = 2 is propagated. The parameter is decreased by 1 with each hop. The message whose maximum number of hops becomes 0 is not propagated anymore. In case the same information arrives, the message is dismissed. We decided not to overwrite maximum number of hops, since our network aims to spread the information as much as possible. This parameter should be set high when the message owner wants to deliver a message in an area as wide as possible (the importance is high).

IV. Evaluation

Evaluation was done under the assumption that the context of messages (importance and urgency) affects propagation parameters (rate of dissemination and maximum number of hops), which, in turn, influences spreading speed and the amount of information. We use custom DTN simulator written in Java, since none of existing open source software or commercial software met our specific needs for this evaluation. Physical parameters (e.g., communication bandwidth, communication channel or communication delay) were not taken into account.

A. Simulator Design

One cycle of simulation contains the following sequence of actions.

1) Each node moves within the simulation field area.
2) Each node searches other nodes in range.
3) Each node sends messages to nodes found.

All nodes move by 1 unit of length every cycle. The contactable distance of all nodes is 10. The movable field size is 1000 x 1000. To evaluate the effect of our parameters more precisely, nodes and communication relay devices were designed as follows:

- Unlimited storage: prevents deleting messages in the storage.
- Fixed number of nodes: prevents losing messages.
- Communication always succeeds: prevents communication failures affecting successfulness of propagation.

TABLE I. Average Number of Contactable Nodes

Nodes	Upper	Average	Lower
50	0.33	0.02	0.00
100	0.80	0.03	0.00
200	1.18	0.06	0.00

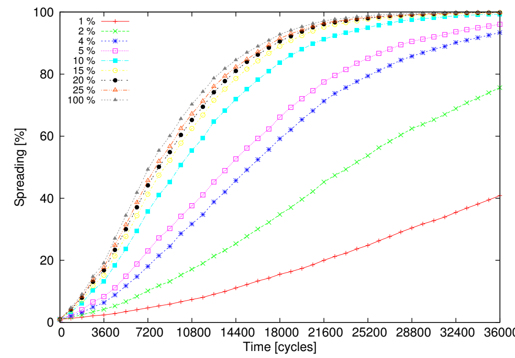

Fig. 4. Spreading (maximum number of hops = 2).

- Free movement: all nodes can either go straight or turn randomly. In an epidemic broadcasting in DTNs, the difference in mobility affects spreading messages [12]. The more freely nodes can move, the more difficult message spreading patterns become.

All shared messages have two propagation parameters and are transmitted according to them. At the beginning of each simulation, the number of messages is the same. The number of messages is affected only by our proposed parameters.

B. Results and Considerations

During the pre-experimentation stage, we measured the average number of contactable nodes using our simulator (Table I). Most nodes did not have communication partner. The more nodes in the simulation field are, the more communication partners for each node appear, since node density increases.

In case of 50 and 200 nodes, an increase in the number of nodes advanced the termination of spreading messages. The simulation produced the same results in case of 100 nodes as to the effect of rate of dissemination and maximum number of hops. Therefore, we considered only the case of 100 nodes. When maximum number of hops is “Unlimited” or rate of dissemination is 100%, given parameter does not have any effect.

Figs. 4 and 5 indicate how long does it take for the message to spread within the field by changing rate of dissemination. The horizontal axis shows the time, and the vertical shows the spreading. By spreading in this evaluation we mean how many nodes receive the message. As nodes in the field receive a message, spreading approaches 100%. Each line corresponds to messages with different values of rate of dissemination. As rate of dissemination increases, the message is spread faster. In other words, rate of dissemination controls the spreading speed. Besides, by comparing two figures, we can see that changing maximum number of hops also affects message spreading speed.

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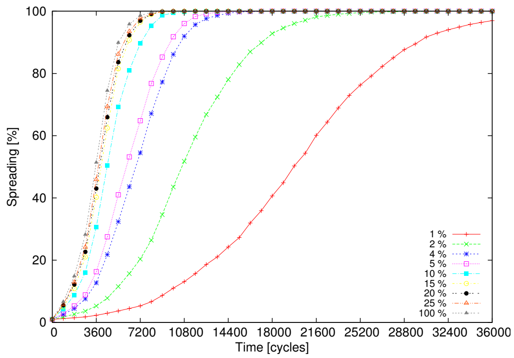

Fig. 5. Spreading (maximum number of hops = 16).

Fig. 6 indicates the number of transmissions for each value of rate of dissemination. The horizontal axis shows the number of cycles. We calculated the average every 600 cycles. Regardless of rate of dissemination, at first the number of transmissions increases with the number of cycles. After that, it stabilizes. The lower rate of dissemination is, the lower is the upper limit of measured value. Fig. 7 indicates the number of transmissions for each value of maximum number of hops. The axes are same as in Fig. 6. As the parameter increases, the number of transmissions increases as well. However, further increase in parameter did not make a substantial change in the number of transmissions. There was a small variation in case of 200 nodes, which we believe is because a small number of nodes restricts the number of hops.

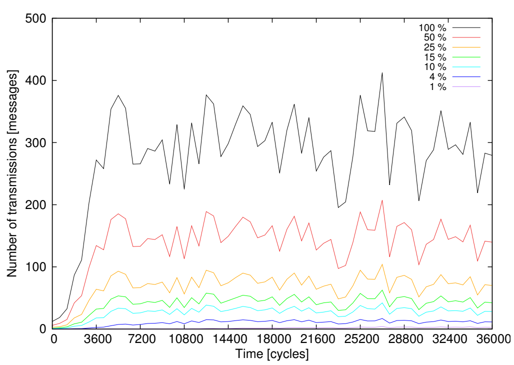

Fig. 6. The number of transmissions (maximum number of hops is fixed).

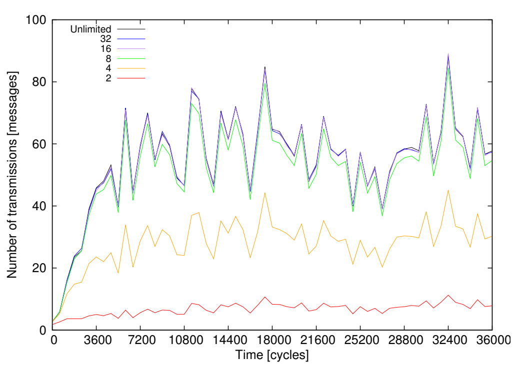

Fig. 7. The number of transmissions (rate of dissemination is fixed).

Fig. 8 shows the number of cycles needed for 100% spreading and the total amount of sent messages. The horizontal axis shows rate of dissemination. The left vertical axis corresponds to the line graph and shows the number of cycles needed for 100% spreading. The right vertical axis corresponds to the bar graph and shows the number of sent messages by the spreading termination. As rate of dissemination increases, cycles until termination amount decreases at first, and then stabilizes. In contrast, the total number of messages increases. Increasing the parameter not only do not expedite the termination, but also generates excessive messages, which, in turn, increase the network load. In Fig. 9, we replaced the horizontal axis to show maximum number of hops. Increasing the parameter decreases cycles until termination amount, similar to rate of dissemination. However, maximum number of hops do not affect cycles until termination amount. Considering Figs. 7 and 9 together, we see that this parameter does not change the sum of messages by spreading termination. From another point of view, it can save network bandwidth by delaying the consumption of network resources at the cost of reducing spreading speed.

According to the experiments above, we assume that proposed parameters (rate of dissemination and maximum number of hops) control the amount of messages in the network and the speed of the message spreading. When rate of dissemination is 50%, the number of messages is reduced by half while the termination time remains almost the same compared to broadcasting. By decreasing the rate to 15%, the number of

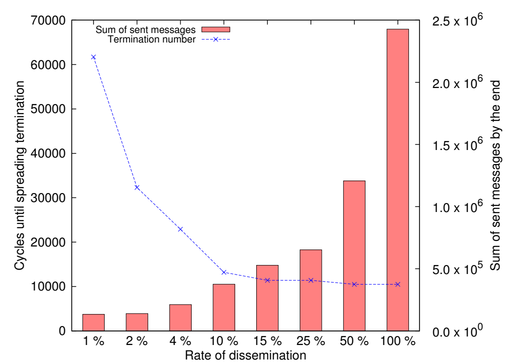

Fig. 8. Cycles until spreading termination and sum of sent messages by the end of the simulation (maximum number of hops is fixed).

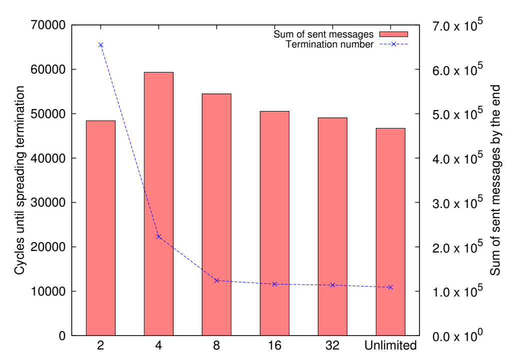

Fig. 9. Cycles until spreading termination and sum of sent messages by the end of the simulation (rate of dissemination is fixed).

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messages becomes one fifth and the time becomes about one tenth compared to broadcasting.

V. Conclusion and Future Work

In this paper, we proposed an efficient means of communication in information sharing DTNs by using the context of information. We suggested that two parameters, namely, rate of dissemination and maximum number of hops, can serve as a way of controlling information propagation and help establish the process of context-based communication. We found that rate of dissemination controls the speed of spreading information and an amount of messages needed for spreading, while maximum number of hops controls the speed of spreading information and the information volume sent per time unit.

By performing the simulation, we established the effect propagation parametes (rate of dissemination and maximum number of hops) have on spreading messages, therefore making the usage of message context feasible.

The future tasks for constructing context-aware communication in DTNs are as follows.

- Making the system context-aware: All nodes in DTNs should take the context from their own messages and assign the propagation parameters according to the context (the items 1 and 2 in Section III-A). Also, in order to deal with different kinds of information, the system must be generalized.
- Realistic simulation: We should perform simulation on the various mobile models and consider various channel models and protocols (e.g., CSMA/CA) by using the ns (network simulator) [13][14].
- Using the network state: Each node should take into account the network state when propagating own messages. This allows to build network-aware system.
- Summarization of the similar information: Each node should summarize similar information shared in the network. In the case of V2V, several vehicles may generate the information containing the similar message (e.g., traffic jam occurred at almost the same location). By summarizing such information, we could reduce the total number of messages in the network.
- Applying game theory to DTNs for sharing information: DTNs would become simple and intelligent if each node acts for oneself. The goal of this task is to make the function of each node simple and reduce their load.

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