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Fairness of Packet Forwarding Strategy in Opportunistic Mobile Networks

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ABSTRACT

Multicopy utility-based forwarding algorithms are usually popular in opportunistic portable networks. They try to gain high program throughput while keeping the purchase price low. However, many ignore the fairness issue about the successful delivery pace among users. In this paper, we analyze the actual fairness evaluation with the success rate submitting, and we propose a fresh fair packet forwarding strategy according to packet priority. We formulate the actual replication-based packet forwarding algorithms throughout opportunistic networks ignore the fairness issue about the success rate submitting among all players. In this paper we discuss the actual fairness evaluation about success rate, and propose a fresh fair packet forwarding tactic which operates as being a plugin for standard utility-based routing methods. Compare the performance your strategy with a number of well-known routing techniques via both some sort of synthetic contact type and real man mobility traces. We find that our strategy improves the total amount of success prices among users whilst maintaining approximately a similar system throughput. Furthermore, our scheme reduces the price tag on traditional utility-based redirecting protocols.

Keywords:- Fairness, Fair Packet-Forwarding Strategy, Replication based Packet Forwarding, SimBet, Delegation.

I. INTRODUCTION

As a fundamental concept, fairness is significant in many areas of human society such as law, economics, politics, and sociology. In network engineering, it is also an important metric in allocating network resources. In [6], the concept of fairness is investigated, and the significance of considering fairness issues by providing example application scenarios where fairness is essential is emphasized. As a variant of delay-tolerant networks (DTNs) [9], [11], opportunistic mobile networks [2], [8] are unique dynamic wireless networks. Without a fixed network infrastructure, humans utilize contact opportunities to exchange information by short-range wireless connections. The role of a node in an opportunistic mobile network is not only as a packet sender or receiver but as a message forwarder as well. Examples of such networks are wireless mobile sensor networks [10] and inter vehicle ad hoc networks [1]. Due to the unpredictable mobility patterns, end-to-end communications between a source and a destination cannot be guaranteed in opportunistic mobile networks. Each node should independently make forwarding decisions under the store–carry–forward mode.

Our previous work in [4] proposes a fair packet-forwarding strategy depending on packet priority to fix the routing dilemma in opportunistic cellular networks. It could work as plug-in regarding traditional utility-based forwarding algorithms. Simulation outcomes show good efficiency. In this report, we further talk about the evaluation regarding fairness in opportunistic cellular networks, and we build an analytical model with the decision-making mechanism found in our proposed forwarding technique. We formulate your replication-based packet forwarding algorithms inside opportunistic networks overlook the fairness issue about the success rate submission among all members. Here we are generally introducing two algorithms regarding replication-based packet forwarding simbet and also delegation. Simbet will be the algorithm based on forwarding.

Delegation will be the algorithm based on replication. In this particular paper we talk about the fairness assessment on success price, and propose a whole new fair packet forwarding technique which operates being a plugin for conventional utility-based routing standards. We compare the performance your strategy with a number of well-known routing schemes via both any synthetic contact product and real people mobility traces. We realize that our strategy improves the total amount of success rates among users while maintaining approximately exactly the same system throughput. Moreover, our scheme reduces the expense of traditional utility-based direction-finding protocols.

II. RELATED WORK

Many interactions between people count on the establishment with the sense of reasonable treatment. Computer networking communication and more in particular peer-to-peer file discussing applications and services take into consideration the fair cure of users. Fairness is as a result particularly important and challenging since it is considered a significant incentive for fellow to peer assistance usage in today's Internet. These challenges tend to be critical in infrastructure-less cellular networks given deficiency of centralized and dependable mechanisms that manage the fair cure of users. While using the recent shift throughout research interest coming from centralized services to distributed services throughout mobile communication, fairness has become an interesting discipline of investigation in several research topics including resource allocation, blockage control, and multilevel routing. In peer-to-peer mobile networks including mobile ad-hoc communities (MANETs), wireless sensor communities or delay tolerant networks (DTNs) multi-hop cellular communication between customers may fail with all the absence of the particular sense of justness between participating nodes. Throughout DTNs, a device should decide no matter whether to forward data for an intermediate node so it encounters.

Such forwarding decisions are usually guided by the wish to reduce the quantity of replicas of data items in the network to conserve bandwidth as well as by the wish to reduce end to end delay. Current forwarding approaches in DTN are generally designed to efficiently, and excessively over-use popular nodes to steer and improve forwarding choices. Rank-based forwarding approaches currently represent the most promising methods for addressing the message forwarding challenge. Nodes in these kinds of techniques are ranked according to their social profiles or contact record to identify people with a higher probability of successfully forwarding the message to the destination. While these approaches have demonstrated wonderful efficiency in performance they do not address the climbing concern of justness amongst various nodes in the network. Higher ranked nodes typically carry the biggest burden in providing messages, which creates a higher potential of unhappiness amongst them. Providing fairness is then an important networking goal considering that the unfair treatment of users is regarded as a disincentive to participation in the communication process. It is often shown that ranking-based forwarding algorithms present good performance relying upon identifying and overusing popular nodes in the network. Such well ranked nodes tend to be likely than others to deliver a message to its destination within a shorter delay. Like a direct consequence, a complete fair treatment regarding users causes a tremendous end-to-end delay and also message delivery overall performance degradation. It is then primordial to take into account whether there is a tradeoff relationship in between fairness and proficiency.

Fair sharing of resources has been largely studied in the context of established networks. Previous work has been inspired by the well-known max-min fairness or maybe Jain's fairness index as a way to improve a reasonable allocation/scheduling of resources in the Internet. In the particular context of cellular networks, researchers utilize link quality alternative of access points to improve aggregate throughput. Within the context of DTNs many assumptions are manufactured regarding resource restrictions (storage and bandwidth), and strictly abide by max-min fairness for end-to-end delay minimization. On this paper, we address the above mentioned issue more commonly. We assume unlimited resources in the network and propose an authentic time distributed framework to further improve forwarding decisions to prevent dissatisfaction among popular nodes, and as a result ensure an efficiency-fairness tradeoff applying local information.

III. FAIRNESS EVALUATION

According to equity theory, people evaluate sensible treatment by contrasting the ratios regarding contributions and advantages of each person inside whole system [7]. Below, we take the assumption that men and women make the same contribution to the system. For example, they make the identical payment to make use of the message delivery service inside opportunistic network. Therefore, the major concern of individual user will be the successful message distribution rate. It will be the benefit each user gains from the system. Suppose you will find N nodes inside system. The effective delivery rate regarding node n_i, when i = 1, 2,..., N, is the ratio of successfully delivered messages from all messages created from node national insurance. Here, we select Jain's fairness catalog [5] as each of our metric and it is calculated as follows:

$$\text{Fairness}=\frac{\left(\sum_{i=1}^{N} x_i\right)^2}{N.\sum_{i=1}^{N} x_i^2} \qquad (1)$$

where N is the number of users, and x_i will be the resource or throughput allowance for user my spouse and i. Jain's fairness index ranges from 0 to at least one, where 1 is short for complete fairness, as well as 0 represents particular unfairness. It is without effort understandable to illustrate fairness being a percentage. For instance, a system that has a fairness value regarding 0.3 could be simply accepted as fair to 30% on the users and unfair to the rest. Moreover, this fairness index is continuous because any slight adjust in x_i changes the worthiness of the index. Let random variable X really does the throughput. Equation (1) could possibly be further derived the following:

$$\text{Fairness}=\frac{\left(\frac{\sum_{i=1}^{N} x_i}{N}\right)^2}{\frac{\sum_{i=1}^{N} x_i^2}{N}}=\frac{(E(X))^2}{E(X^2)}=\frac{1}{\frac{D(X)}{(E(X))^2}+1} \quad (2)$$

Where $E(X)$ and $D(X)$ are the expectation and the variance of X, respectively. Here, we can find that increasing the average throughput or decreasing the variance is both helpful in increasing the fairness.

IV. FAIR PACKET FORWARDING STRATEGY

Here, we first introduce the packet priority. It is utilized to offset the unfair success rates. Then, we illustrate the design of our fair packet-forwarding algorithm, detailing two mechanisms to guarantee the fair distribution of successful delivery rates.

A. Packet Priority

To order to solve the problem regarding unbalanced delivery success rates, we have to first discuss the reason unfairness happens. Because of the heterogeneity of contact rates in opportunistic cell networks, nodes might have various connections along with others, depending on their mobility patterns in addition to social circles. One example is, a person who's going to be popular may get numerous links along with others; thus, messages generated from him may be easily distributed in addition to transmitted to the majority of destinations. In distinction, one who offers few friends carries a low chance to send packets towards right place. To balance this success rate relating to the strong and weak, we assign important to each packet if it's generated according towards historical information of the source node. The priority regarding message m from source node ni may be calculated as.

$$P_{n_i}(m)=\frac{\left(\frac{SR}{C}\right)max-\left(\frac{SR(n_i)}{C(n_i)}\right)}{\left(\frac{SR}{C}\right)max-\left(\frac{SR}{C}\right)min} \quad (3)$$

where SR(n_i) and $C(n_i)$ represent the delivery success rate and the forwarding cost of node n_i, respectively. Here, the forwarding cost may include power consumption and buffer utilization. Thus, SR(n_i)/$C(n_i)$ is the *throughput/cost* ratio of node n_i. (SR/C)max and (SR/C)min are the maximum and minimum throughput-to-cost ratios, respectively. Here, we assume the same cost for each node. This assumption can be used in the scenarios where power or storage is not critical, such as in vehicular ad hoc networks [7]. We simplify (3) as follows:

$$P_{n_i}(m)=\frac{SR_{max}-SR(n_i)}{SR_{max}-SR_{min}} \quad (4)$$

Equation (4) shows which a message from the node with a low success charge would gain a superior priority, and the main concern value is inversely proportional towards success rate on the source. Right now, we assume the packet priority is solely based on the success rate. It is possible to also consider packet-based priority, such as a higher priority for time-critical packets, by using a weighted priority based on both success rate and packet-based priority.

Note that the success rate data that we mention here are available at a central node. When a new node joins the system, it needs to register through the central node and download all the information required to define its priority. The success rate data may be collected offline, from historical contact information, or online. In the online version, the central node maintains a database that includes the necessary message delivery statistics. Fig. 1 shows the format of a message, which may be used in the system to collect such statistics. It consists of the data payload to be transmitted and the metadata. Here, the metadata include source-node ID, destination-node ID, and all the relay-node IDs on the forwarding path. When a message *m* is forwarded from node *i* to node *j*, *j* is recorded in *m*. The maximum length of the forwarding path is limited by the TTL of each message. When a message is successfully received by the destination node, the destination will send the metadata of the message to the central node. The central node uses the metadata of each successfully received message to calculate the success rate information. The transmission of the metadata is the overhead of this calculation.

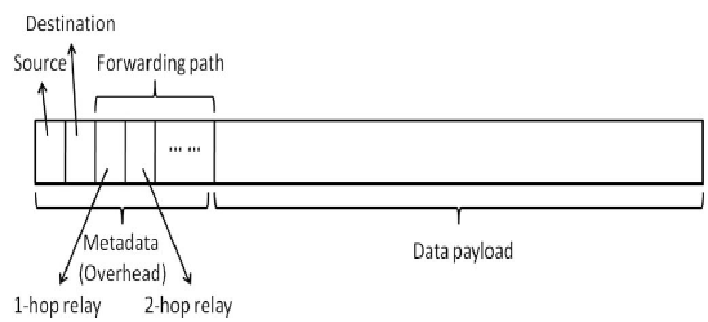


Fig. 1. Format of a message.

Since these metadata are very small compared with the data payload, the transmission overhead imposed by our proposed algorithm may be ignored. For example, if we use 1-B addresses and with a TTL of 5, the overhead is sending seven bytes per successfully received message. With a payload of 1000 B, this overhead is less than 1%. Later on, we will implement packet priority in this protocol design to help offset unfair success rates a result of network topology.

B. Routing Algorithms

Here we are using replication based packet forwarding. In replication based packet forwarding we are using SimBet and Delegation. SimBet is a forwarding-based algorithm in which a packet only possesses one replica. A packet is forwarded to a node if of which node has higher metric compared to the current node. Delegation can be a replication-based algorithm in which a packet may have got multiple replicas. When simbet algorithm is used, it decreases the delivery ratio as the volume of malicious nodes will increase. The number of packets employed for forwarding is a smaller amount when simbet is used. When the amount of malicious nodes will increase then more amount of packets are decreased. The number associated with hops traversed with the packet becomes a smaller amount. When the delegation algorithm is used, the packet distribution ratio increases as the volume of malicious node will increase. In this criteria the nodes are replicated so that the communication cost can be reduced. When the duplicated packet is passed to the malicious node then this probability of replicating the packets gets decreased.

When the algorithm delegation is used, the packet distribution ratio increases as the volume of malicious node will increase. In this criteria the nodes are replicated so that the communication cost can be reduced. When the duplicated packet is passed to the malicious node then this probability of replicating the packets gets decreased. The destination node can readily receive the packets as soon as packets are duplicated. The storage cost can be reduced by removing the packets when not necessary. Thus the algorithm improves the performance by reducing the volume of malicious nodes as possible.

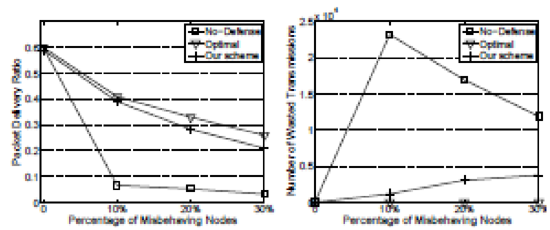
V. EXPERIMENTAL RESULTS

We compare our scheme to two solutions: one is called *No-Defense*, which does not deal with routing misbehavior; the other one is the *optimal* scheme, which assumes that all misbehaving nodes are known and no packet will be forwarded to them.

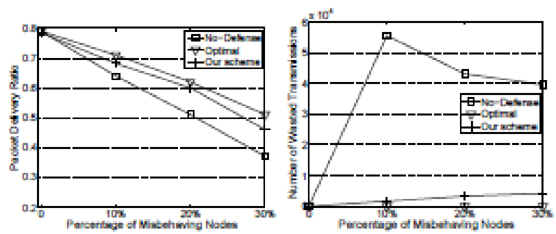
A. Routing Misbehavior Mitigation

We first evaluate the case where misbehaving nodes drop all received packets. Fig. 2 shows the comparison results on the Reality trace. Generally speaking, our scheme performs much better than No-Defense. For SimBet where the routing performance is the major concern, our scheme is close to the optimal in terms of packet delivery ratio; for Delegation where the reduction of wasted transmission is the major concern, our scheme is close to the optimal in terms of wasted transmissions. When SimBet is used as the routing algorithm, as shown in Fig. 2(a), the packet delivery ratio of all three schemes decreases as the percentage of misbehaving nodes increases, because fewer nodes can be used for packet forwarding. However, our scheme still delivers much more packets than No- Defense, since it can effectively limit the number of packets forwarded to misbehaving nodes. For similar reasons, our scheme has a much lower number of wasted transmissions than No-Defense, as shown in Fig. 2(b). In No-Defense, the number of wasted transmissions first increases and then decreases as the percentage of misbehaving nodes increases. This is because with more misbehaving nodes, more packets are dropped but the average number of hops traversed by each dropped packet is smaller.

As a result, the maximum is reached at some middle point. When Delegation is used as the routing algorithm, again, our scheme delivers more packets than No-Defense. As shown in Fig. 2(c), when 30% of nodes are misbehaving, our scheme delivers 46% of packets which are 24% higher than that of No-Defense. No-Defense performs worse due to the following reason. In Delegation, although replicating a packet to a misbehaving node does not decrease the probability of other replicas carried by normal nodes to reach the destination, it can reduce the probability of the packet to be further replicated. As a result, fewer replicas are created and the overall probability of reaching the destination is reduced. For the number of wasted transmissions as shown Fig. 2(d), our scheme performs much better than No-Defense.



(a) SimBet (b) SimBet



(c) Delegation (d) Delegation

Fig. 2. Comparison results when misbehaving nodes are selectively deployed to high-connectivity nodes which drop all received packets. The Reality trace is used.

Then we evaluate the case where misbehaving nodes only drop part of the received packets. Figure 3 shows the comparison results when SimBet is used as the routing algorithm on the Reality trace. When misbehaving nodes only drop part of the received packets, *optimal* does not necessarily perform the best since some packets can be delivered by misbehaving nodes. Thus, *optimal* is not compared here. As shown in Figure 3(a), the packet delivery ratio of No-Defense decreases from 59% to 22% as the percentage of received packets that a misbehaving node drops increases from 0% to 100%, because more packets are dropped. The packet delivery ratio of our scheme is much higher than that of No-Defense. For example, when misbehaving nodes drop 60% of the received packets, our scheme delivers 50% of the generated packets, and it outperforms No-Defense by 80%. This shows that our scheme can still effectively limit the number of packets forwarded to misbehaving nodes. For the number of wasted transmissions as shown in Figure 3(b), our scheme performs much better than No-Defense.

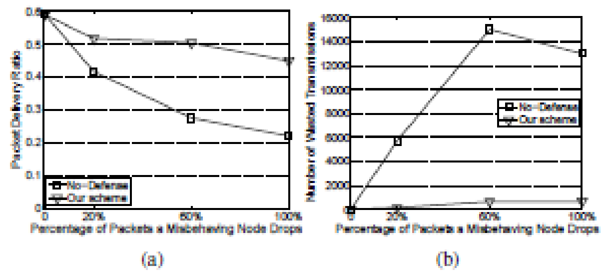
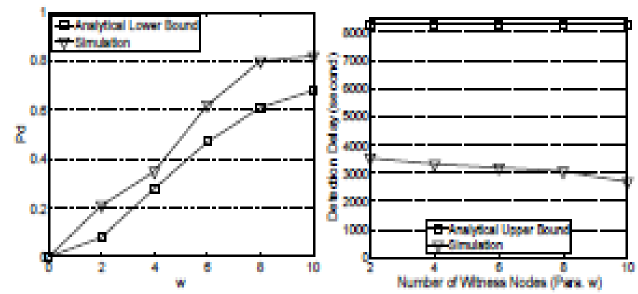


Fig. 3. Comparison results when misbehaving nodes are randomly deployed and they only drop part of the received packets. The Reality trace is used, and the fraction of misbehaving nodes is fixed at 30%.

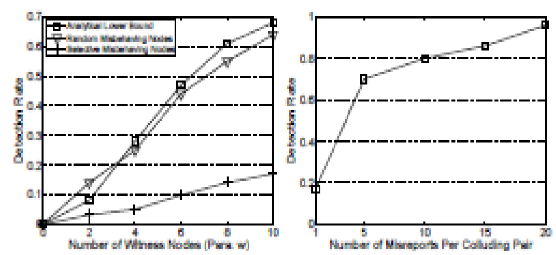
B. Misreporting Detection

In this group of simulations 10 pairs of misbehaving nodes (i.e., 20 in total) launch forge transaction independently. First of all, we verify our analysis results on the detection probability and detection delay of a single misreporting instance. The synthetic trace is used since it is accordant to the mobility assumption. In each run, 200 misreporting events are generated and detected independently. As shown in Fig. 4, the detection probability in the simulations is higher than the analytical lower bound, but the difference is small which means the analytical result is a good approximation. The detection delay in the simulations is lower than the analytical upper bound3. Then we evaluate the detection rate of our scheme on the Reality trace. As shown in Fig. 5(a), the detection rate increases as the number of witness nodes for each record summary increases. When misbehaving nodes are randomly deployed, the detection rate is close to the analytical result, which implies that the set of witness nodes randomly selected from a node's local view can be roughly seen as a random subset of the global node set. However, when misbehaving nodes are selectively deployed, the detection rate is much lower since misbehaving nodes contact normal nodes less frequently and a forged record has less chance to be disseminated by a normal node. Despite this, our scheme can still effectively detect the selectively deployed misbehaving nodes when they launch more misreporting instances. As shown in Fig. 5 (b), when each colluding pair misreports 20 times, 96% of them are detected. Next we evaluate the detection delay of our scheme on the Reality trace. To better evaluate the delay caused by node mobility, we set T_{delete} as infinity in this group of simulations. Fig. 6 shows the CDF of detection delay compared with packet delivery delay when Delegation is used in the Reality trace. It shows that 80% of misreporting instances are detected within 20 days, but it needs 40 days to deliver 80% of the packets. Thus, the detection delay is much shorter than the packet delivery delay.



(a) Detection Probability (b) Detection Delay

Fig. 4. Comparison of analysis and simulation results on the detection probability and detection delay of a single misreporting instance. The synthetic trace is used.



(a) Each collusion pair misreports once (b) Parameter $w = 10$

Fig. 5. The detection rate of our scheme in the Reality trace.

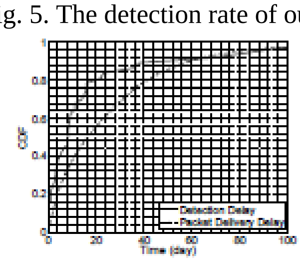


Fig. 6. The detection delay compared with the packet delivery delay.

C. Cost

The size of record and summary is set as follows: node ID, sequence number and timestamp has 4B each; a hash has 16B; a signature has 40B. In default $w = 4$ and $T_{delete} = 30$ days. Delegation is used and all nodes are normal. The communication cost of our scheme is given in Table I. We can see that the communication overhead increases with the parameter *w*, but very slowly. This is because *w* only affects how many times a record summary is transmitted. Since only one record summary is generated per contact, the transmission of summaries is only a minor source of communication. On the contrast, the major source of communication overhead comes from the reporting of contact records which include the vector of buffered packets. For this reason, when the packet generation rate increases, the communication overhead increases significantly as shown in Table I. However, the overall communication overhead is still low, *e.g.*, less than 30KB when each node generates 10 packets per day. The storage cost of our scheme is shown in Table II. The storage overhead increases significantly with the parameter *w* and T_{delete} since record summaries are stored at more nodes and for a longer time. However, the storage overhead only increases slowly with the packet generation rate. This is because the major source of storage overhead is record summaries which are stored for a relatively long time, not contact records which are deleted soon, and the number of generated record summaries only depends on the number of contacts, not on the traffic load. Generally, the storage overhead of our scheme is low, less than 200KB at each node.

TABLE I
THE AVERAGE COMMUNICATION OVERHEAD PER CONTACT

W	2	4	6	8	10
Communication (KB)	10.3	10.5	10.8	11.3	11.5
Pkt. Generation Rate (pkt/node/day)	0.5	1	2	4	8
Communication (KB)	6.7	10.5	14.7	20.6	27.5

TABLE II
THE AVERAGE STORAGE OVERHEAD PER NODE

w	2	4	6	8	10
Storage (KB)	47	71	89	108	127
T_{delete} (days)	20	30	40	50	60
Storage (KB)	45	71	92	126	170
Pkt. Generation Rate (pkt/node/day)	0.5	1	2	4	8
Storage (KB)	70	71	72	74	79

VI. CONCLUSION

This paper has provided an analysis on fairness of routing in opportunistic mobile networks. We formulate the opportunistic routing process as a discrete-time Markov chain and prove that a stationary probability distribution vector could be deduced under the unique lower utility tolerance mechanism. Combining the message-duplication restricting mechanism, here we propose the fair packet-forwarding strategy to improve the imbalance of success rate distribution among users based on replication based packed forwarding. Here we are using SimBet which is a forwarding-based algorithm where a packet only offers one replica. A packet is forwarded with a node if which node has higher metric versus current node. Delegation is a replication-based algorithm where a packet may have multiple replicas. The packet is replicated in line with the usage of the neighbor node. The communication cost can be reduced. Such routing misbehavior can improve the packet delivery ratio and doesn't waste system resources such as power and bandwidth.

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