Architecture and Characteristics of Social Network Based Ad Hoc Networking

Satoka Fujii
Ochanomizu University
satoka@ogl.is.ocha.ac.jp

Tutomu Murase
Nagoya University
tom@itc.nagoya-u.ac.jp

Masato Oguchi
Ochanomizu University
oguchi@computer.org

Eng Keong Lua
SingTel Enterprise Security
eklua@computer.org

***Abstract*—An incentive problem of ad hoc networks still remains for relaying frames from other nodes. By utilizing the Social Network System such as Twitter and Facebook, it is possible to estimate the degree of intimacy of friendship links not only to direct friends but also indirect friends such as friends-of-friends. If we provide links of ad-hoc network in relation to direct/indirect friends instead of other incentive mechanisms, ad-hoc network can obtain infinite potentials to connect all nodes efficiently and cover wide areas by short range communication such as IEEE802 wireless LANs. This paper is devoted to discuss social network based (real) ad-hoc network concept and evaluation of its connection probability performance.**

Keywords— Multihop and cooperative communications, wireless LAN, social network, destination selection, throughput

I. INTRODUCTION

In recent years, mobile communication devices such as smartphones, tablets and laptop PC are popular and widely used. They can enjoy with mobile broadband because some of these devices have 3G/LTE communication functions and they are covered with 3G/LTE radio cells. Some others, however, have no 3G/LTE communication functions, nor are covered with 3G/LTE radio cells. Another problem can be that LTE is expensive for many users. This is likely to happen in developing countries rather than developed countries. Thus, Wi-Fi communication functions are becoming important to obtain broadband access opportunity.

Generally, considering fee of the pay-per packet, users would prefer to find public Wi-Fi and offload their traffic to the Wi-Fi, though 3G/LTE has broad coverage compared to Wi-Fi whose coverage is small. An AP of Wi-Fi assumed here is not only fixedly installed as a part of infrastructure but also ad hoc-like APs such as mobile routers and smartphones which are in tethering. Both fixed AP and ad hoc AP would require contract, permission or privileges to use ones. This is one of reasons why mobile users walk around to look for free APs even if many AP radio signals are detected.

In this paper, it is assumed that individual mobile users can connect their contracted APs but cannot directly connect other else. When there is an AP operated by service provider "A", mobile users of "A" can connect the AP and others are denied access. It is desirable that if a node connectable to an AP relays traffic of other nodes, that is, the node configures an ad hoc network and establish links between the node and other nodes, the other nodes which cannot connect directly to the AP can then use Wi-Fi communication. This implies that connection opportunity is improved and Wi-Fi coverage is extended. However, incentive problems still remain for relaying data frames of other people. We propose social-based ad-hoc network in order to solve incentive problems and achieve high connectivity effectively to many users.

In our social-based ad-hoc networking proposal, if two users are friends, then the users have a link of an ad-hoc network. The friendship can be a good incentive to establish wireless links between the friends. Assume that user "A" is connected to an AP and a friend of "A", "B", is not. "B" would ask "A" to have link to "B". "A" may accept the request because they are friends. When "A" and "B" are connected, "B" has a connection to the AP. This can happen vice versa. This concept is a type of "give and take" strategy. One successful example using this strategy is FON [1]. Although one AP can be used by any FON users over the world, ad-hoc network links in the proposed social-based ad-hoc network are only used by the direct friends or the indirect friends who have specific degrees of intimacy to the link owners.

SNS is used for finding degrees of intimacy of users. It is not so easy to know who are friends-of-friends or acquaintances-of-acquaintances. SNS is a very powerful tool to find the relations and to define intimacy between users. How to find the relations and to define intimacy between users is out of scope of this paper, and is for further study.

II. RELATED WORK

Studies of ad hoc networks have been already done in many literatures [2] [3]. However, in such ad hoc networks, it is an essential issue to solve incentive problems about relaying traffic of others [4]. For the incentive problems, also many researches [5] have been done. For example, in [6], to ensure relay terminals, it proposes a service model to pay a honorarium as compensation

for a relay and show a relationship between a business revenue and user utility. Such a scheme requires big mechanism of save-borrow accounting. More practical and low cost scheme is desired. In [7], instead of the mechanism, it proposes improvement of QoS of the relay node as an incentive. It can work well when all the nodes are cooperative to form a better network. However, it does not discuss about whether people like to connect each other for QoS regardless of user relations such as acquaintances and friends.

There are no researches about social-based ad-hoc network. However, some researches mentioned about social-based network control. In [8], access control mechanism based on a social relation is proposed. Closeness of the user is defined and derived from SNS. The closeness is only defined by one-to-one direct intimacy, and is not defined by one-to-one indirect intimacy, in other words, a relationship to acquaintances of acquaintances is not considered. In the study that information are propagated by communication of acquaintances [9], a communication model similar to Delay Tolerant Network is discussed.

Regarding one-to-one indirect intimacy stated above, research works for trust transitivity suggest inheritance of intimacy from direct to indirect. Reference [10] proposes transitivity model that well describes natural human-to-human relations. This model seems to be applied to one-to-one indirect intimacy.

However, it is difficult to expand it to the model that relay nodes transfer information immediately each other. Thus, this paper is devoted for investigating relations between closeness or intimacy in social networks and QoS performance in ad-hoc networks. Connectivity is here chosen as a QoS measure.

III. SOCNET: SOCIAL NETWORK BASED AD-HOC NETWORK

A. *Relationship Definition by Social Network*

In a social network based ad-hoc network (SOCNET), we assumed that any node pair is connected if the node pair has *N*-hop acquaintance. We define "*N*-hop acquaintance" as the acquaintance reached by connecting to the acquaintances *N* times (the acquaintance of an acquaintance of an acquaintance...). Then, we call the network directly linked to *N*-hop acquaintances "*N*-hop social network (*N*-SN)". Between users who are connected by the *N*-SN, we define that it is possible to relay traffic each other.

N-hop acquaintance is obtainable from SNSs. Relations between users are well defined in SNSs. For example, Facebook has "friend" concept. The friend concept can easily determine if two persons are friend or not friend. There is a privacy problem to see relations of SNSs. However, the privacy problem is out of scope of this paper. This paper assumes that we can easily obtain relations such as acquaintances of acquaintances on a computer.

B. *An Example of SOCNET Construction*

The database that is based on the social network relationship has a lot of nodes including A-E, as shown in Figure 1. Each node that exists on this database has acquaintance relationship directly with other nodes with *r*% probability. For example, when *r*=5, a social network of 101 people, one person is acquainted directly with the five people on average. Nodes connected by a line are direct (one hop) acquaintances. We extract the *S* nodes (in this case, *S*=5) that are within the reach of radio waves of an AP. In Figure 2, when *N*=2, nodes (in A-E) that can be connected each other within two hops are connected by a line. In the figure, 1-hop links and 2-hop links that do not related with the named node are not shown. We call link in Figure 2, logical link (it is a link on the database and does not consider the actual physical layout).

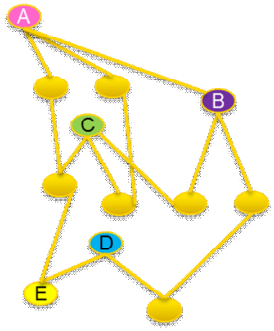

Fig. 1. Direct links based on social network

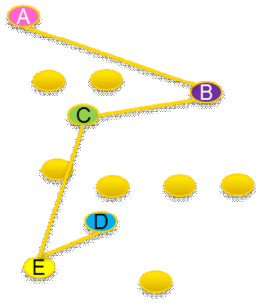

Fig. 2. 2-hop social network structure (links of unnamed node are not shown)

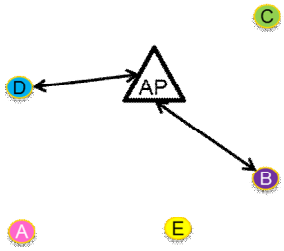

Fig. 3. Physical layout without using SOCNET

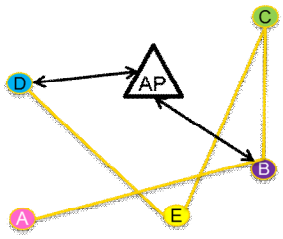

Fig. 4. Physical layout with two hop link of SOCNET

In Figure 3, we present the actual physical layout. This is a full mesh radio basis (All nodes are in the communication range of IEEE802.11 WLAN), but number of nodes that can be connected to the AP is limited. The reason could be; Not available on contract, or don't want to connect if possible, etc. In a case of numbers of nodes directly connected to the AP *T*=2 (in this case, B and D only are able to be connected to the AP), the mapping of 2-SN in Figure 2 to the physical network are shown in figure 4. We call links in Figure 4, as physical links (path that packets are able to be forwarded in the network actually). For example, C could not be connected directly to the AP. Furthermore, C could not connect indirectly because there was no direct logical link between B and C or D and C, but C and B

became two hops acquaintance by a mutual acquaintance, so a logical link is generated within them and they become possible to connect each other physically. Furthermore, to minimize the number of hops of physical connection and to identify the path to the AP, the connection tree is finally formed. In the figure, all nodes of the A-E are connected to the AP; A: A→B→AP, B: B→AP, C: C→B→AP, D: D→AP, E: E→D→AP. A, C, E who has originally no access to the AP can connect to the AP by social relations in SOCNET.

IV. CONNECTION ESTABLISHMENT PROBABILITY

We evaluated the connection establishment probability (simply denoted as connection probability) in SOCNET with models described in the previous section. Connection probability is defined as a ratio of numbers of successfully connected nodes to an AP over numbers of all nodes. There are 100 nodes on the database. S=10 nodes that are extracted randomly from the SN database are randomly placed around the AP.

Figure 5 shows connection probability in case of r=5. When T is one and two, connection probability is remarkably improved and approaches 100% for even very small N such as two or three. In other words, even just by "can be connected to an acquaintance of an acquaintance", connection probability is greatly improved as compared with the case where only direct social link is used.

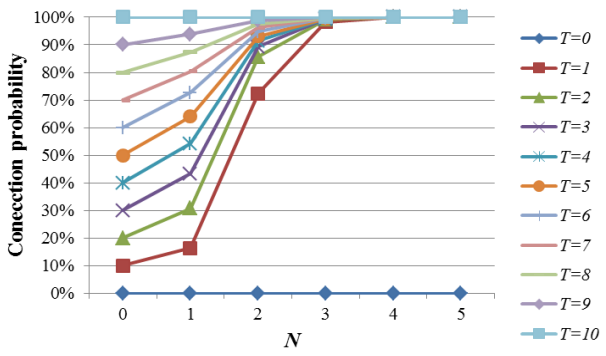

Fig. 5. Connection probability to N

V. CONCLUSION

In order to solve the problems of the relay incentives and service connection probability in ad hoc networking, we proposed social network based ad hoc networking (SOCNET). Our idea is that relationship of acquaintances can be an incentive to relay traffic intuitively. This type of network makes possible communication with relay network between nodes that would not have connectivity to AP directly.

In this paper, we evaluated a connection establishment probability of the user in the social network based ad hoc network. In a case that a number of nodes that connect to AP directly is little (about one or two out of ten), connection probability is remarkably improved when N is even one or two and it approaches 100%. In other words, even just a principle where "users who have relationships of an acquaintance of an acquaintance shall be connected each other" greatly contributes to improve connection establishment probability in an ad hoc network to reach a target AP.

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