The Buddy System
A Distributed Reputation System Based On Social Structure[1]

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Abstract: In ad hoc networks, there are no incentives to cooperate. There is neither a reward for cooperation nor a punishment for non-cooperation. A distributed reputation system could solve this problem, by giving means of managing trust towards other entities and discovering vicious entities. The existing distributed reputation systems are based on plausibility considerations and, thus, have several limitations. Therefore, in this paper, we aim at overcoming these limitations by proposing the Buddy System as a distributed reputation system that is based on social structure. For this purpose, we choose an appropriate social structure for the Buddy System and discuss the ensuing issues for its maintenance. Finally, we show by the means of simulation the robustness and effectiveness of the Buddy System.

1 Introduction

In ad hoc networks, the degree of cooperation relies on voluntary participation and inoffensive behavior. No incentives or punishments are involved to ensure these two crucial necessities. A distributed reputation system establishes social order [CP02] and, thus, solves this problem by giving means to rate other entities and share ratings with others. Hence, entities who try to exploit the network can be identified and ignored for future transactions. With an increasing number of vicious entities, an ad hoc network that lacks a distributed reputation system can easily perish. This is because well behaving entities have no motivation for participation if the degree of cooperation declines too much.

Still, distributed reputation systems are based on plausibility considerations and, thus, have to cope with inherent limitations. For example, self-recommendations are not possible, the impact of recommendation depends on one's own reputation, and only the recommender may disseminate his trust values. Therefore, it is necessary to introduce a paradigm that

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complements the plausibility considerations. For this purpose, we propose the design of a distributed reputation system that is based on social structure. The ensuing Buddy System improves the detection of vicious entities and, thus, increases cooperativeness.

This paper is organized as follows: In Section 2, we provide an introduction to distributed reputation systems and social structures. The key design decisions of the Buddy System are described in Section 3. Finally, we discuss simulation results of the Buddy System in Section 4 and conclude the paper in Section 5.

2 Distributed Reputation Systems and Social Structure

In this section, we provide a brief introduction to distributed reputation systems and social structures. For a more detailed introduction to these fields, the reader is referred to [Ob04] and [OFN04] respectively.

The considered system consists of autonomous entities that may cooperate in the course of transactions. Each entity is autonomous and can therefore exhibit vicious behavior in any cooperation, i.e., it defects by breaking his commitments. Each entity runs an independent instance of the reputation system and reports any observed behavior to it. The instances of different entities may cooperate by exchanging recommendations. The individual trust levels are passed on in order to inform other entities about personal experiences made.

According to Giddens [Gi84], social structure is defined as ”the patterning of interaction, as implying relations between actors or groups, and the continuity of interaction in time”. From this definition, we deduce the following two main aspects: **(1)** The patterning of interaction implies that an entity may establish a relationship with some of the other entities. **(2)** Relationships may be adaptive such that the relationship network is responsive to time-variant cooperation patterns. Hence, there have to be criteria of when a relationship is to be *established* and *cancelled*.

In our previous work [OFN04], we have examined how the existence of social structure influences distributed reputation systems. It shows that such influence is threefold: **(1)** An entity requests recommendations from its socially related entities and pro-actively disseminates recommendations to them. **(2)** An entity perceives a recommendation as more truthful if it has a relationship with the recommender. **(3)** An entity is able to self-recommend by stating which entities have a relationship with it. The more relationships an entity has, the more it appears trustworthy.

Among the existing approaches for distributed reputation systems [KR03, MM02, MR03, BW00], only two approaches make explicit use of social structure. In [OFN04], it is shown that both fall short of exploiting the potential of social structure: **(1)** The friends-and-foes reputation system [MR03] only considers social structure for the formation of trust. Hence, the dissemination and assessment of recommendations does not make use of the social structure. **(2)** Buskens et al. [BW00] analytically examine the impact of social structure on a system in which entities may exchange recommendations. However, the analysis assumes that recommendations are always truthful and, thus, ignores how social structure assists in assessing recommendations and issuing self-recommendations.

3 Design of the Buddy System

The Buddy System is a distributed reputation system that makes use of a social structure. In this section, we present the key design decisions for the Buddy System.

Buddy-relationships. The only type of relationship is a mutual *buddy*-relationship that is established adaptively between a pair of entities (so-called buddies). A *buddy*-relationship necessitates especially high trust levels since the buddies mutually agree to be punished for the misbehavior of their partner buddy. There are two criteria for its establishment[2]. Apart from mutually trusting each other, the entities have to perceive the trustworthiness of other agents likewise. This additional criterion is called similarity of world views. It is set in place in order to reduce the conflict potential between buddies.

Application of social structure to the distributed reputation system. By the quite simple buddy structure, several limitations of distributed reputation systems can be overcome. Self-recommendations are possible by stating the number of buddies the recommender has. Obviously the more buddies one entity has, the trustworthier it appears since it has already proven to be trustworthy to those entities. With an increasing number of buddies, the impact of an entity's recommendation is increased as well because this entity has proven trustworthy in the past.

Recommendations are preferable circulated among buddies. The assessment of the truthfulness of a recommendation is based on the trustworthiness of the recommender and recommendee which, in turn, is evinced by the respective number of their buddies. In this respect, the buddy structure influences the distributed reputation system in all of the three categories that we have identified in Section 2.

The presence of buddy-relationships also has an impact on trust formation. Whenever an entity defects, its transaction peer re-evaluates the trustworthiness of the defector's buddies by downgrading them.

Dynamics of the buddy-relationships. As a prerequisite of the proposed social structure, the dynamics of its relationships has to be taken into account. More specifically, we have to devise a mechanism that supports the establishment and cancellation of buddy-relationships in a comprehensible manner. In the Buddy System, the establishment and cancellation of relationships is consensual and implicit. This yields two implications: **(1)** The assessor of a self-recommendation has to contact the alleged buddies in order to ensure that have agreed on the establishment of a buddy-relationship with the self-recommender. The overhead of such an action is reduced by probabilistically contacting a subset of the alleged buddies and making a projection of the actual number of buddies. **(2)** Problems can arise if a buddy unilaterally cancels a buddy-relationship. In such a case, the assessor of a self-recommendation has to decide whether the alleged buddy-relationship is still valid or not. For this purpose, a conflict resolution mechanism is required. In the Buddy

[2]The algorithm for establishing *buddy*-relationships is described in [FO04].

System, we make use of a lazy conflict resolution policy. Whenever an alleged buddy fails to acknowledge the buddy-relationship, the assessor assumes that the buddy-relationship has been cancelled unilaterally and informs the self-recommender about the cancellation.

4 Evaluation of the Buddy System

In this section, we take a closer look at the evaluation of the Buddy System. Due to space limitations, we focus on the interpretation of the most important simulation results[3].

Colluding entities are uncooperative entities that make active use of the Buddy System by mutually forming buddy-relationships. In order to test the robustness of the Buddy System against such an attack, we have compared the performance of colluding entities and simple uncooperative entities that refrain from participating in buddy-relationships. The simulation results show that colluding entities are less efficient in exploiting the network than regular uncooperative ones. This finding has to be explained in more detail since it represents a crucial advantage of the Buddy System. When a new entity enters the network, the colluders can self-recommend and therefore seem trustworthy for the newcomer. Nevertheless, this is an acceptable tradeoff since after one colluder defects the whole group of colluders is downgraded. Therefore, colluders can be efficiently discovered.

According to [OKRP04], the *fairness* of the system is measured as the correlation between the individual costs and benefits of the respective entities. The higher the correlation the more effective is the distributed reputation system. It is clear that individual costs and benefits are uncorrelated if the system lacks a distributed reputation system. The simulation results show that the fairness of the Buddy System is superior to the one of conventional distributed reputation systems that are solely based on plausibility considerations. The coefficients of correlation for the Buddy System and conventional systems are about 95% and 85% respectively.

The success of *newcomers* is another very important aspect of how efficient a reputation system is. In the initial phase where no entity knows any other, it is easier for vicious entities to exploit cooperative users. After transactions occurred among most of the entities, newcomers are warned efficiently. Our simulation results show that the rate of betrayed newcomers decreases with the maturity of the social structure from 74% to 40%.

5 Conclusion

In ad hoc networks, there are no incentives or punishments that enforce cooperation. A distributed reputation system combined with a social structure improves the ad hoc network and assures its mere existence. In this paper, we have pointed out the advantages of social structures and discussed the design of the Buddy System as a distributed reputation system

[3] A detailed description of the benchmarks, the simulation setting and the simulation results is found in [FO04].

that is based on social structure. We showed how it overcomes the limitations of conventional distributed reputation systems. By the means of simulation, we have shown that the Buddy System improves the degree of cooperation and therefore the overall quality of a ad hoc network. Furthermore, the robustness of the Buddy System has been shown.

In the future, we will examine the impact of non-repudiable tokens [Ob04] on the Buddy System. By this means, the effectiveness of the Buddy System could be further improved. Furthermore, we aim at developing more complex strategies for the maintenance and evaluation of social structure.

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