Engineering Incentive Schemes for Ad hoc Networks
A Case Study for the Lanes Overlay

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Abstract. In ad hoc networks, devices have to cooperate in order to compensate for the absence of infrastructure. Yet, autonomous devices tend to abstain from cooperation in order to save their own resources. Incentive schemes have been proposed as a means of fostering cooperation under these circumstances. In order to work effectively, incentive schemes need to be carefully tailored to the characteristics of the cooperation protocol they should support. This is a complex and demanding task. However, up to now, engineers are given virtually no help in designing an incentive scheme. Even worse, there exists no systematic investigation into which characteristics should be taken into account and what they imply. Therefore, in this paper, we propose a systematic approach for the engineering of incentive schemes. The suggested procedure comprises the analysis and adjustment of the cooperation protocol, the choice of appropriate incentives for cooperation, and guidelines for the evaluation of the incentive scheme. Finally, we show how the proposed procedure is successfully applied to a service discovery overlay.

1 Introduction

In ad hoc networks, devices have to cooperate in order to make up for the absence of infrastructure. However, each participating device is under the control of its user and, thus, aims at maximizing its utility. This means that devices will only cooperate if this is profitable for them. Most often, cooperation is not profitable in itself. Therefore, distributed schemes have been proposed which offer incentives for cooperation, thereby making it attractive for devices to cooperate.

Such incentive schemes make use of incentive mechanisms in order to foster cooperation. Yet, the choice and configuration of appropriate incentive mechanisms is highly non-trivial. This is partly due to the dependency on the specifics of the application

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domain. Currently, there is no systematic procedure that supports the developer of an incentive scheme by managing the complexity of his task. As a result, the conception and evaluation of incentive schemes is still more approached as an art than an engineering principle. This situation is especially harmful since each of the various cooperation protocols of ad hoc networks demands for a specific incentive scheme that takes its characteristics into account.

Our approach is to systematically engineer incentive schemes. In Section 2, we discuss the state of the art for the development of incentive schemes. In Section 3, we take a closer look at appropriate models of cooperation. This provides the foundation for presenting and discussing a systematic procedure for engineering incentive schemes in Section 4. We exemplify such engineering for the cooperation protocol *Lanes* in Section 5 and, finally, conclude the paper in Section 6. An extended version of this paper is available as technical report [12].

2 Related Work

In this section, we discuss the state of the art for the development of incentive schemes in ad hoc networks. Furthermore, we discuss incentive engineering as an approach that is used in economics for the conception of appropriate incentives.

*Existing Incentive Schemes in Ad hoc Networks.* In the absence of any systematic procedure for their development, the design of the existing incentive schemes [2, 3, 9, 10, 14] is characterized by the ex ante choice (and configuration) of incentive mechanisms [11]. For the development of further incentive schemes, the usefulness of the existing incentive schemes is limited. (1) They are bound to specific cooperation protocols, often without making this explicit. (2) Their conception is monolithic and, thus, hinders the reuse of their components. (3) Their evaluation is not performed on the basis of comparable criteria.

This means that it is unlikely that a developer can simply reuse one of the existing schemes in order to enhance cooperation in a given situation. On the other hand, he is given little if any help in designing his own incentive scheme. Thus, despite the fact that incentive schemes need to be tailored to the cooperation protocol used, little is known on how to achieve this tailoring.

*Incentive Engineering.* In economics, incentive engineering [4] has been proposed as a means of systematically developing incentive schemes. It assumes an incentive mechanism that is arbitrarily quantifiable and provides full incentive compatibility. For example, the use of money provides such an incentive mechanism. For each action of the cooperation protocol, the engineer determines the quantification of the incentive mechanism that yields a maximization of some utility. This approach has been applied in [8] for an incentive scheme on the link layer.

However, incentive engineering is not suitable for the development of incentive schemes in ad hoc networks. This stems from the following reasons: (1) In [13], we have shown that, in ad hoc networks, it is impossible to conceive an incentive mechanism that it is both arbitrarily quantifiable and fully incentive compatible. (2) The