

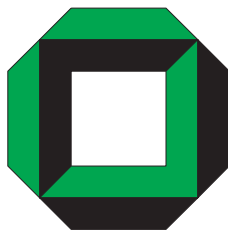
Economic Incentive Patterns and their Application to Ad Hoc Networks

Ralf Anders, Philipp Obreiter

`ralfanders@gmx.de`, `obreiter@ipd.uni-karlsruhe.de`

November 10, 2003

Technical Report Nr. 2003-17



University of Karlsruhe
Faculty of Informatics
Institute for Program Structures and Data Organization
D-76128 Karlsruhe, Germany

Abstract

While research about cooperation incentives for mobile ad hoc networks (MANETs) is done only for a relative short period, there exists tremendous knowledge in the economic and social areas. Based on a new categorization of incentive patterns, we examine the relevant properties of each pattern and demonstrate their respective design alternatives and occurring challenges for the application to ad hoc networks. With a focus on trade based patterns, we found that negotiation about actions proves to be very complex or inefficient in MANETs. Another approach, the introduction of an artificial currency, also implies several problems like how to equip the entities with means of payment and how to secure liquidity. As a novelty, we introduce a new kind of incentive pattern following the concept of company shares. It suits well for MANETs because it can be shown that through the creation of individual currencies the above mentioned problems disappear.

Contents

1	<i>Introduction</i>	1
2	<i>General Considerations</i>	1
2.1	Aspects for Economic Incentives.....	1
2.2	Aspects for the Application to Ad hoc Networks	2
3	<i>Trust Based Incentive Patterns</i>	2
3.1	Collective Pattern	2
3.2	Community Pattern	3
4	<i>Trade Based Incentive Patterns</i>	3
4.3	Barter Trade Pattern	3
4.4	Bearer Bills/Notes Pattern.....	3
4.5	Checks Pattern.....	4
4.6	Banknote Pattern	4
5	<i>The Shares Pattern</i>	4
5.1	Relationship with Trust/Trade Based Patterns.....	4
5.2	Characteristics	5
5.3	Transferring Shares to Ad hoc Networks	5
5.4	Advanced Design Alternatives.....	6
6	<i>The Choice of Appropriate Patterns</i>	6
6.1	The Situation in Economics Environments.....	6
6.2	The Situation in Ad-hoc Network Environments	7
6.3	Example: Cooperation Incentives for a Discovery Overlay	8
7	<i>Conclusion</i>	9
	<i>Bibliography</i>	10
	<i>Glossary</i>	11
	<i>Excluded Aspects of 2.2</i>	12

1 Introduction

Due to the absence of infrastructure in mobile ad hoc networks, communication and service provision depends on the cooperation of the participating devices themselves. In economic and social life, there are multiple possibilities to remunerate someone in exchange for a certain service. Often, it is not possible to gather full information about the execution of a task. To ensure that an agent acts in favor of the principal in spite of this lack of control, their benefit should depend on similar conditions. Hence both profit from better execution. The well examined Principal/Agent-Theory addresses these issues in depth. The aim is to find an optimal balance between positive incentive effects and the costs for the applied incentive measures (Laux 1998).

These principles are also applicable to ad hoc networks, though there exist some specific characteristics which differ from the physical world as well as the conventional client/server networks, e.g. the lack of persistent entities, roles and hierarchies. For instance, the possibility that an agent executes a service well is much higher if she has confidence that she can consume equal resources. Additionally, a principal will not be lavish with someone else's resources if this leads to effective counter-measures or draining of remuneration resources.

A systematic overview of incentive patterns is presented in Obreiter et al (2003a, 2003b). We continue and extend this exposition. I.e., we introduce several new aspects, examine in more depth the applicability of individual incentive patterns and emphasize their challenges and limits. Starting with the general aspects in Chapter 2 we present our results about trust and trade based patterns in the following sections (Chapter 3 and 4 respectively). The introduction of the share pattern in Chapter 5 is another major contribution of this paper. Finally, in the context of a case study (Chapter 6), we demonstrate how to choose an appropriate incentive pattern for a discovery overlay, considering our results and insights.

2 General Considerations

2.1 Aspects for Economic Incentives

Motivation: An optimal incentive pattern should provide conditions, such that the individual utility maximization leads to maximal total utility of a community. Therefore it is important that the agent profits directly from putting more effort into his work.

Efficiency: But the costs of an incentive system has to be considered well. Controlling, administration and the remuneration itself have to be balanced with the positive effects. A general rule is that only if additional investment in such a system gains more additional utility it should be enhanced.

Examples: There are very different kinds of incentives, which can easily be found in the social and economic area: Authorities want their people to smoke less or companies to produce safer products. So they tax tobacco or pass a law for extended liabilities concerning new products. People pay for the service of specialists in means of money. In clubs, those who own an honorary post are remunerated with titles and a high reputation. (Tab.1)

Principal	Agent	Aim	Incentive Measure
State	Company	Safety of products	Extended Liability
Company	Manager	Revenue Maximization	Revenue Participation

Table 1 Examples

2.2 *Aspects for the Application to Ad hoc Networks*

In the following, we discuss three aspects for the application to ad hoc networks. In the appendix, more aspects can be found.

Occasionally online networks (OON): There are two extreme models: the pure mobile ad hoc network (MANET) and the infrastructure based network like the internet. The big advantage of the first is their independent applicability and costless usage. The second provides global connection, reliability and trustworthiness. Between them, several hybrid types can be identified. If a MANET gets occasional access to the internet, it can enhance its possibilities considerably. The same counts for nodes logged in the internet. If they can stay in contact after leaving the internet, their utility increases. The more volatile the MANET connections are the more online time is required to preserve persistent data. Therefore, it cannot be said how many online sessions are required for a certain service. We distinct hybrid networks between two basic types: with guaranteed service inside a certain period and without that guarantee.

External Incentives: We refer to incentives that stem from entities which do not participate in MANETs as external incentives. Four types can be distinguished:

- static and positive: the position of some is improved fixedly, e.g. by a prize
- static and negative: the position of some is made worse fixedly, e.g. by excluding from a general remuneration
- dynamic and positive: depending remuneration, e.g. convertibility into money
- dynamic and negative: depending punishment, e.g. under the law

	static	dynamic
positive	Prize	Convertibility
negative	Exclusion from general Remuneration	Law and Punishment

Table 2 *External Incentive Types*

The static types may serve as an additional incentive in some special environments. However, the dynamic ones seem to be more important. Convertibility can transfer price stability into the network and make asymmetric structures possible. Laws can limit the design space for incentive patterns. For instance in Germany, we identified a couple of laws, concerning open mobile communication networks, especially in the areas of privacy and liability.

Duplicates: In the physical world, originals of documents or bonds may be easily distinguished from copies. But in the digital world, a notion of 'original' does not exist. Every string can be copied exactly. In order to cope with this problem, duplicate control could be performed by tamper-resistant hardware or trusted infrastructure. Real MANET approaches have to rely on the power of a reputation system. Additionally, all transactions could be protocolled distributedly. Another inspiring idea is to accept duplicates by automatically dividing the value in half when used. But none of these approaches really serves as a substitute for originals, because all suffer from considerable drawbacks.

3 **Trust Based Incentive Patterns**

3.1 *Collective Pattern*

Collectives are based on membership and static reputation. Total utility has priority over individual interests. In the social-economic area, pure and stable collectives cannot be found. Neither socialist models nor clubs or the military can do without other incentives like reputation, force or bonds in the long term. Therefore, this pattern can only be regarded as a basic incentive.

In MANETs, this pattern can be implemented in a very simple way, as only authentication is required. Hence, it consumes very little additional resources. But it neither provides load balance nor behavior control. This incentive may work in a small closed user group but in open

environments we need a more sophisticated approach.

3.2 *Community Pattern*

Communities can be found in many forms, like special interest groups or clubs. There, the participants do not pay for a service. Rather they trust each other that, in return for a provided service, other services can be consumed on occasion. A positive effect of trust is that it reduces the required amount of control respectively (Shionoya et al 2001). The reputation of those who often provide good services generally increases. Others who do not contribute much to the community are down-valued and avoided. The participants usually exchange their private information among them. The more complex and volatile the relations are, the harder to improve one's reputation. Therefore, the scalability of communities is limited. It helps to spread faster the information about the own reputation in order to create attention. But since reputation is not a possession, its development is out of individual control (Voswinkel 2001). In spite of cooperative behavior, the reputation can change from positive to negative in a second, as the parameters for the valuation of others are unknown. This implies an inhibitive effect.

In MANETs, the situation is quite similar. With a distributed reputation system, information about the willingness and ability to cooperate can be collected and exchanged. Design questions are which information should be processed, how should this information be diffused and how do we handle the problem of incorrect recommendations. If higher-order reputation (i.e., reputation regarding recommendational behavior) is to be applied, it is advisable to attach roles to the entities and to introduce a certain kind of hierarchy. This makes it easier to cope with coalition misbehavior and evidences because the transparency increases and reputations are more stable.

4 **Trade Based Incentive Patterns**

4.3 *Barter Trade Pattern*

Barter trade has a certain importance in the field of foreign trade with developing countries and for (internet) barter communities (Möhring 1991). However, the use of this incentive pattern cannot be explained by traditional economic explanations (Schulze 1990). Moreover, its ability to conceal trade activities which do not conform to law or treaties, makes it interesting for particular parties. The popularity of barter communities can be explained by their capability to provide fun and contacts. Altogether, it can be emphasized that, in economic terms, this form of bilateral trade is always worse than multilateral trade with prices and markets.

In MANETs, there are no structural differences. But it is not trivial to cope with the complexity of the required negotiations if we want to avoid human intervention. A definition of the tradeable services should be known to all participants. Additionally, a model for the costs and the utility of each service has to be attached on each device. Only then, it is possible to decide about a transaction. To avoid a complicated multistage procedure, a simple negotiation with one request and one offer is to be preferred.

Combined with an adequate transaction protocol, this pattern is very robust, provides full compensation and scalability as the involved entities consume each other's resources simultaneously. But its applicability is limited by the presented constraints, i.e., the inefficiency and complexity.

4.4 *Bearer Bills/Notes Pattern*

These Patterns differ from their physical counterparts: instead of promising a payment in the future, a particular service is promised. Hence, the credit function isn't transferred, too. Hence, it is very similar to barter trade, only with a time shift of the action in return. This implicates the same

problems. Additionally, it has to be emphasized, that these patterns cannot be regarded as secure as in the physical world. If the debtor does not fulfill, she can be punished only by the means of a reputation system. If handing-over of bonds is allowed, we have to cope with duplicates and cannot assert the strict rules for liability.

At the expense of flexibility, bearer notes simplify negotiation compared to bills with three parties to coordinate. Some characteristics fit well to pure MANETs: there is no need for a dedicated bank and the nodes do not have to be equipped with a certain kind of means of payment as they only trade with their own resources. That is why liquidity of the whole network is always guaranteed.

With such incentive patterns, we gain flexibility compared to barter trade at the expense of new problems and complexity.

4.5 *Check Pattern*

This incentive pattern involves a bank and includes such different forms like credit cards, account transactions and checks. They are all very convenient to use and a high level of security can be provided. The credits can be used for arbitrary goods or services. The value depends on the underlying currency, which is controlled by the central bank. Checks can be circulated.

In MANETs, because of the lack of a dedicated bank, other approaches propose tamper-resistant hardware or occasional access to a trusted server (OON). Another problem for MANETs is how to equip the entities with sufficient credits and how to stabilize the value of this artificial settlement currency. A solution could be to introduce convertibility into real money, but then there exists an enhanced incentive to manipulate. Additionally, infrastructure to secure the conversion is required. That is why we call convertibility an external incentive. Without that, inherent agents are able to absorb large amounts of credits such that the means of payment run short. But even in networks with exclusively symmetric entities, prices may suffer from high volatility. The reason for this is that the amount of means of payment and the amount of available resources do not develop synchronously. Therefore, the entities have to cope with a high level of insecurity about the value of their credits. Hence, it becomes virtually impossible to calculate adequate prices. It has to be emphasized that this pattern does not serve well for pure MANETs, MANETs with special hardware or OONs if the amount of available resources is not stable and we do without convertibility. A general application cannot be recommended.

4.6 *Banknote Pattern*

Banknotes have similar characteristics like checks, but their nominal value is fixed and they can circulate anonymously because they cannot be counterfeited (almost). This does not hold true for the application to MANETs. The problem with duplicates cannot be solved without considerable constraints. Therefore, this pattern appears to be very unattractive and does not provide any advantage compared to check pattern.

5 **The Share Pattern**

5.1 *Relationship with Trust/Trade Based Patterns*

In this section, we introduce an incentive pattern which has no exact counterpart in the physical world. It is best approximated by company shares which belong to the trade-based group. But as the valuation of shares depends mostly on the expectations of investors about the company's future competitiveness, it also includes a trust component. Due to the versatility of its use, the stress can be mainly on trade or on trust.

5.2 Characteristics

To a company, emitting shares has different aspects besides finance: the market participants on stock exchanges value the shares corresponding to their expectations. Thus, there is an active interaction between the company and its investors. Secondly, the company creates its own currency which it can use to buy others without using its liquidity. Shares are usually negotiable and their value is volatile.

5.3 Transferring Shares to Ad hoc Networks

What we want to transfer to MANETs is a kind of personal currency as a means of payment and the valuation function in order to create transparency. This can be realized by considering each entity as a company which carries 100% of itself when first entering the network. While consuming resources of others, it has to remunerate them with shares. In this way, the entities can build up portfolios. In MANETs, the values of these portfolios cannot be determined by stock exchanges. Moreover, we need a mathematical approach. The resulting interconnection between the entities has the structure of Markov chains. If we can calculate the stationary distribution, the results can be interpreted as the values. To guarantee such a distribution, a dummy entity which exchanges equal shares with each entity has to be added to the calculation.

If the trust component is to be emphasized, each entity collects information about the portfolios of others for itself and tries to approximate their value. Otherwise all reported portfolios are combined to a share matrix on a particular entity (see table 3-6). Then all entities receive uniformly and correctly calculated values.

	A	B	C
A	0.85	0.1	0
B	0.15	0.85	0
C	0	0.05	1

Table 3 Example of a Share matrix with 3 entities

	SI	A	B	C
SI	0.25	0.25	0.25	0.25
A	0.25	0.6	0.1	0
B	0.25	0.15	0.6	0
C	0.25	0	0.05	0.75

Table 4 Example after extending with dummy entity

	SI	A	B	C
SI	0.250	0.250	0.250	0.250
A	0.216	0.216	0.216	0.216
B	0.237	0.237	0.237	0.237
C	0.297	0.297	0.297	0.297

Table 5 Multi-propagated matrix

	SI	A	B	C
Valuation	1.000	0.862	0.948	1.190

Table 6 Results to publish

The latter procedure is accompanied by several problems besides the additional overhead. To avoid manipulation of the messages, adequate cryptographic mechanisms have to be applied. To secure correct calculation and publication, distributed control is required. To double-check the reporting of correct portfolios, all entities should also give proof of their emitted shares. Misbehavior has to be punished by a reputation system.

5.4 *Advanced Design Alternatives*

When we design such a pattern, we have to decide whether we want the emitted shares to exist forever on other devices or whether we prefer to limit their period of validity. The first alternative is a straightforward approach. In the course of time, the number of shareholders increases constantly, although the possibility to trade in one's own shares exists. The portfolio may contain a large number of different shares whose respective entity doesn't exist any more and therefore does not contribute to its value. This problem disappears if we apply time limits. Then, we only have to administrate and to report the valid shares. The length of the period has to be defined generally or negotiated individually. As a prerequisite, the participating devices have to synchronize their local time.

An advanced approach is to implement a standard analysis tool to be able to collect hints about the cooperative behavior of other entities by supervising the development of the respective portfolio valuations. This can accelerate the flow of information and help to identify misbehaving entities. For instance, a declining portfolio value could indicate, that the respective entity behaves lavishly or, even worse, that no other entity wants to consume its resources because of its bad reputation. On the other hand, a constantly rising portfolio value could indicate that the respective entity provides a very competitive service or action which attracts much interest.

6 **The Choice of Appropriate Patterns**

6.1 *The Situation in Economics Environments*

Due to the rising importance of attention and reputation, large communities are proliferating in many areas. Where people come together regularly to share ideas, this kind of incentive may be sufficient. Since neither physical prerequisites nor explicit negotiations are required, it can be used always and everywhere. But it suffers from limited scalability and effectiveness.

Although barter trade is both, scalable and effective, its use cannot be recommended under normal conditions since transaction costs are very high. Only in the absence of a stable currency, the use of this pattern can be justified.

All other trade-based incentive patterns depend on a stable currency underlying them.

Bearer bills and notes are only used between companies with commercial relations. Trust in the financial strength of the debtor is a prerequisite. Their most important task is to save liquidity. An important property of these bonds is that they can be generated without any physical requirements.

Checks, however, depend on the availability of banks, which in commercial environments normally can be taken for granted. The convenient use of checks boosts their popularity but transactions are usually accompanied by fees.

The handling of banknotes often causes higher transaction costs compared to checks, as their values are fixed and they have to be taken around with one. Nonetheless, they have unique characteristics which justify their use. They can be exchanged by everyone anonymously and, for small amounts, they are still the best choice.

Company shares serve for many purposes. But usually, they are not used as a means of payment. Moreover they help the emitting company to finance its risks. The shares can also be used, to buy other companies. It has to be considered that their value is generally very volatile.

A quick overview of these incentive patterns is given in table 7.

	Community	Barter Trade	Bearer Bonds	Checks	Banknotes	Shares
Areas for Application	mutuality and trust based relations internet platforms	substitute for stable currency barter communities concealment	means of credit between companies intl. trade	means of cashless payment	means of payment with bias to smaller amounts	investment in /financing of companies acquisitions
Today's Importance	ubiquitous	proliferating internet barter communities defense industry	minor	major and increasing	major but decreasing	major, but not in everyday trade
Advantages	no physical requirements no negotiations	security due to instant exchange of services	high level of security facilitates cheap credits negotiable	cashless arbitrary granularity high security partially negotiable	anonymous spontaneously and locally independently usable negotiable	makes private financing possible creates currency for acquisitions
Disadvantages	effects of own action not controllable limited incentive	high trans-action cost limits rights of disposal	formal requirements cause high costs	transaction fees limited anonymity	fixed granularity risk of transport	investment risk generally not suitable for payments

Table 7 Overview of the presented economic incentive patterns

6.2 The Situation in Ad-hoc Networks

Due to its minimal consumption of resources, the use of the collective pattern can be justified, although its competitiveness is very limited. In some situations, no stronger incentive is necessary, e.g., if the activity in the network is very low or the participants know each other well.

Another basic incentive is the community pattern. Its main goal is to avoid misbehavior. To a certain extent it also remunerates very cooperative behavior. Since the valuation is done by the other entities, there is no control over one's reputation.

Full remuneration is guaranteed by barter trade. But the typically very complex negotiations cannot be transferred well to MANETs. This further contributes to the high transaction costs of this pattern. In special volatile environments with symmetric relations and few well-defined actions, its usage could be considered.

Bearer bills and notes make it easier to find a transaction partner, but the negotiations are even more complex, since more parameters are involved. Additionally, a Public Key Infrastructure (PKI) is required and the fulfillment of the promise is not guaranteed. In environments with low volatility, this pattern could be the better choice compared to barter.

Banknotes and checks depend on the stability of the underlying currency which cannot be guaranteed without central bank control. As the advantages of banknotes cannot be transferred to MANETs, their usage cannot be justified. Checks serve as a standard means of payment if the participants trust in their value. In environments with inherent agents, the amount of means of payment in the network can run short. Therefore, this pattern can only be used in symmetric environments. A still unsolved problem is how to equip the entities with adequate amounts of credits.

If we apply shares, this problem does not exist since every entity owns 100% of its own. Thus, this type of means of payment guarantees network liquidity. The value of single shares will often be rather volatile but, within a mixed portfolio, relative stability should be achieved. This is a versatile approach with many applications. But it does not work well with volatile relations and needs adequate cryptographic mechanisms.

A quick overview about these incentive patterns gives table 8.

	Community	Barter Trade	Bearer Bonds	Checks	Banknotes	Shares
--	------------------	---------------------	---------------------	---------------	------------------	---------------

	Community	Barter Trade	Bearer Bonds	Checks	Banknotes	Shares
Cooperation Incentive	intention of other entities to provide resources increases	action in return of equal value	promised action in return of equal value	arbitrarily usable credits of equal value	arbitrarily usable means of payment of equal value	enhancement of portfolio allows for equal consume of resources
Requirements	relatively low volatility	suitable objects for barter combination of two utilities symmetry	suitable objects to promise combination of two utilities trust in debtor and drawer	availability of a bank (dedicated or distributed) trust in acceptance and stability	availability of a legitimated entity for emission trust in acceptance and stability	relatively low volatility
Cryptography	individual identification	not necessary	authentication and signature of evidences	signature of evidences, secure communication with bank	very complex mechanisms	authentication and signature of evidences
Areas of Application	full settlement not required main goal is to avoid misbehavior	missing of PKI high volatility	if more flexibility is required compared to barter	asymmetry convertibility into money desired OON	application generally not advisable	pre-equipment with means of payment not desired
Effects	limited incentive compatibility insecurity due to lack of control low transaction costs	complete settlement of resources, but high transaction costs limit activity incentive	complete settlement, but insecurity about action in return may limit activity	complete incentive compatibility without convertibility: instability, with c.: high manipulation incentive	theoretically like checks	partially limited incentive compatibility as accuracy of valuation insecure

Table 8 Overview about the presented MANET Incentive Patterns

6.3 Example: Cooperation Incentives for a Discovery Overlay

In this chapter, we examine which incentive patterns suit best for the discovery layer with service ring overlay in a MANET (Ponz 2002, Klein et al 2003) in the context of the DIANE project (Klein 2003). There are several characteristic properties:

- roles/hierarchies: Service Access Points (SAP) and Ring Members (RM)
- a stable logical structure with predominantly unidirectional communication
- no physical infrastructure
- no special hardware
- initial public key equipment of devices

A special property of the discovery layer is the possibility to misbehave by blocking advertisements or service requests of competitors. Based on these prerequisites, inferior pattern types are

- collective, because it provides too little incentive
- barter trade, because of the unidirectional communication
- checks and banknotes, because they depend on unavailable banks

The remaining patterns have to be compared:

Certainly, a competitive community pattern would provide protection against misbehavior and motivate cooperation to a certain extend. But the lack of transparency appears to be a disadvantage. Bearer Bills and Notes are explicit remunerations. They are MANET compatible and fit well to the stable structures. The available actions are well-defined, which makes negotiations simpler. However, it cannot be expected that an entity always can offer an action which the requesting entity will need in the near future. Since the actions on this layer are crucial for the whole network, this drawback hardly can be accepted.

Shares provide a basic incentive to support each other through its connection capabilities. The value calculation provides transparency. Finally, the SAPs suit very well for the task of calculating and broadcasting the portfolio values. The overhead hasn't too bad effects, since there are relatively few transactions on this layer. Thus, the Shares Pattern appears to be superior. We prefer the personal

currency alternative in this case.

7 Conclusion

We showed, that it is important to classify convertibility into money as an external incentive. Real MANET approaches have to do without this feature. Since in MANETs, neither infrastructure, nor fixed hierarchies, nor special hardware exists, not all aspects of physical world incentives can be transferred. Duplicates and volatility are two main items with which we had to cope.

The Community pattern motivates activity well but suffers from the lack of control about one's remuneration. For barter trade, it is hard, to find a suitable environment for its application, as it normally is very inefficient. We could prove that checks do not work well in MANETs because the artificial currency is not controlled and the adequate equipment of entities with credits is non-trivial. Therefore, stable prizes and liquidity are not guaranteed. Even worse are banknotes. Their unique properties in the physical world are not transferable.

A new approach are shares. They remind us of the community pattern, because the values are similar to reputations. But they are also similar to checks, with the difference, that every entity carries its own currency. Because only own shares are traded, there is no need for bank entities. Finally, the arising interconnection between the nodes serves as a basic incentive for mutual support.

To further gain insights about MANET incentive patterns, mainly community, bearer bond and share incentive schemes have to be designed and tested in different environments. They all have specific advantages, thus a universal pattern cannot be expected.

Bibliography

Klein, M. (2003): DIANEmu - A Java Based Generic Simulation Environment for Distributed Protocols. Technical Report 2003-7, ISSN 1432-7864

Klein, M.; König-Ries, B.; Obreiter, P. (2003): Service Rings - A Semantic Overlay for Service Discovery in Ad hoc Networks. The Sixth International Workshop on Network-Based Information Systems (NBIS2003), in the framework of the 14th International Conference on Database and Expert Systems Applications DEXA 2003, Prague, Czechia, September 1-5, 2003

Laux, H. (1998); Risikoteilung, Anreiz und Kapitalmarkt. Berlin, Heidelberg, New York: Springer-Verlag

Möhring, W. (1991): Gegengeschäfte: Analyse einer Handelsform. Frankfurt a.M., Berne, New York, Paris: Lang

Obreiter, P.; Nimis, J. (2003a): A Taxonomy of Incentive Patterns - The Design Space of Incentives for Cooperation. Second International Workshop on Agents and Peer-to-Peer Computing (AP2PC'03), Melbourne, Australia, July 14, 2003

Obreiter, P.; König-Ries, B.; Klein, M. (2003b): Stimulating Cooperative Behavior of Autonomous Devices - An Analysis of Requirements and Existing Approaches. Second International Workshop on Wireless Information Systems (WIS2003), Angers, France, April 23-26, 2003

Ponz., E. (2002): An Approach to Support Service Discovery in Mobile Ad-hoc Networks – Concept and Simulation. Master Thesis, July 2002

Schulze, G. (1990): Reasons Behind Barter Reconsidered. University of Konstanz: Diskussionsbeiträge (Contributions to the discussion)

Shionoya, Y.; Yagi, K. (2001): Competition, Trust, and Cooperation: A Comparative Study. Berlin, Heidelberg, et al.: Springer

Voswinkel, S. (2001): Anerkennung und Reputation: Die Dramaturgie industrieller Beziehungen. Mit einer Fallstudie zum „Bündnis für Arbeit“. Konstanz: UVK Verl.Ges.

Glossary

Advertisement	a program language neutral (XML-)document, that represents a network resource (data, service, device). Required for service discovery in ad hoc networks
Convertibility	the ability of a (settlement) currency to be exchanged into another outside the system
Volatility	a measure of the dynamic instability of network structures, characterized by the movement in space and their log-in and log-out behavior.

Excluded Aspects in 2.2

Roles: Every node in ad hoc networks can change arbitrarily between the principal and agent roles as they are all with equal rights. In contrast in the physical world we mostly find hierarchies or organizational structures with defined roles.

Absence of Infrastructure: While in the physical world, there are lots of different trustworthy institutions like banks, judges or notaries, MANETs lack of such dedicated entities. Thus, they can only be realized distributedly. This implicates less reliability and information persistency.

Efficiency: As resources are scarce in MANETs the focus while designing an incentive scheme has to be on efficiency. The additional utility through motivated cooperation must be bigger than the cost for the needed resources for deploying the scheme. Means to keep schemes lean are to avoid as many parameters for negotiations as possible. Secondly, based on the surrounding, should be estimated, which type of resource is most expensive, because often can be chosen between a trade-off for example between more calculation or more communication.

Authentication: Because of the absence of authorities new approaches to be able to identify each other are definitely required. Besides tamper-resistant hardware, devices could be equipped once with a public key pair before entering an ad hoc network. The creation of keys inside a network carries several problems, although this would be a real MANET approach.

Coalition Misbehavior: The most severe danger to the effectiveness of an incentive scheme are coordinated attacks by a coalition. As MANETs are mostly relatively small and without supervision, a malicious coalition often can easily apply profitable misbehavior as long as they are undiscovered. Hence, individual entities should prefer not to trust too much in others and evidences have to be very trustworthy to avoid the communication of faked ones.