Payment Systems for Distributed Transport Schemes

Lars Fischer and Tim Shirley
University Siegen, Research Group IT-Security

Abstract. In a distributed transportation scheme, objects are forwarded without central control by independent agents. This work is on the problem of providing fair payment that pays agents relative to the distance they transported a particular good.

1 Introduction

In this work we discuss different problems to fair payments in participatory transportation of objects. By participatory transportation we denote schemes where objects are forwarded in an opportunistic fashion by piggybacking. Participants are carrying objects if they happen to move in a similar direction. On contact with other participants, information about destinations of participants and objects are exchanged and objects are given to the participant moving closer to the destination of an object.

Our work is related on one side to proof-of-work schemes that provide the foundation for payment-systems based on the Bitcoin-scheme, and on the other side to trust and attestation schemes in distributed networks. In the following we will introduce a few general concepts and ideas for distance measurement in distributed co-presence networks. The general problem has, to the best of our knowledge not been tackled with in this context. This work is to be considered as work in progress to facilitate discussion and innovative ideas at a workshop.

| $s,d$: source and destination of a packet | $a_0,...,a_i,...,a_n$: transporting agents with $a_0=s,a_n=d$ |
| $a_{i-1}a_i = A$: handover event, something is handed from $a_{i-1}$ to $a_i$ |
| $\delta(x,y)$: general distance function |
| $l(a)$: location, e.g., of an event, omitted if it is obvious that location is meant, e.g., in $\delta(l(s),l(a_{i-1}a_i))$ |

Table 1: Notation

2 Advance Payment Scheme

In this scheme every agent $a_{i+1}$ pays the preceding agent $a_i$ a fee relative to the distance the transported object has been forwarded from the source to the
destination \( \delta(s, A_{i+1}) \). At the destination the last agent is paid the amount for the full distance. That way every agent is finally paid an amount relative to his part in forwarding the object.

Prerequisite is that the distance from source to destination is known beforehand as every payment is made relative to this destination. The payment for the whole distance is paid in advance from the source to the destination, so that the destination will pay the objects with the amount transferred by the source. We can calculate the “costs” \( c \) for the participants as follows (negative values mean the agent has lost money, positive mean earnings):

\[
\begin{align*}
  c(s) &= -\delta(s, d) + \delta(s, A_1) = \delta(A_1, d) \\
  c(a_i) &= -\delta(s, A_i) + \delta(s, A_{i+1}) = \delta(A_i, A_{i+1}) \\
  c(d) &= \delta(s, d) - \delta(A_0, A_n) = 0.
\end{align*}
\]

The result obviously is that every agent is paid a sum relative to the distance it has propagated the good. The amount is controlled by the following agent who would have little motivation reducing his own share by increasing the share of the predecessor. The predecessor is the agent controlling the goods in this transaction and may simply refrain from handing over the goods if the payment is insufficient.

2.1 Fair Distance Measures

The crucial problem lies in the selection of a clever distance function. The function must provide a fair share to every participating agent that motivates to propagate the goods towards the destination. It must further be prevented that an agent can increase his share without the following agent consenting. An agent could, for example, take a detour to increase his share, this must be prevented:

We have identified three distinct different functions that differ in the direction in which the distance of transportation is mapped onto the shortest path from \( s \) to \( d \). All methods will, in the end, derive a value for \( \delta(s, A_i) \).

**Orthogonal Propagation Distance** The distance is mapped to the anchor of an orthogonal line that touches the direct line from source to destination \( sd \) and the location of the handover \( loc(A_i) \).

\[
\delta_\perp(s, A_i) :=
\]

**Forward Propagation Distance** The distance is measured from \( s \) to the crossing point of \( sd \) and a circle centred on either \( A_{i-1} \) or \( s \) with the radius being the length of \( A_{i-1}A_i \) or \( sA_i \).

\[
\delta_f(s, A_i) :=
\]
3 Discussion

Even a short glimpse reveals imminent drawbacks of each scheme that will be analysed formally in the full paper.

**Orthogonal** If an agent passes the destination and hands the object over to someone else he is paid the whole amount although the object has not been
delivered.

**Forward** The same problem as *orthogonal* but additionally an agent will be paid although he is moving the object further from the destination.

**Backward** This seems to be the best choice. An agent is paid exactly for the difference he forwarded an object towards the destination.

4 Conclusion

We have introduced the idea of co-operative distance measures to support distance-based payment in participatory transport schemes for co-presence networks. Payment by distance may motivate participation by rewarding work in these transport scheme. It also may be the foundation for general accounting systems in spatially distributed mobile networking.