Intelligent Self-Organizing Transport

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Intelligent self-organizing transport is transport arranged in an ad-hoc manner between clients (agents with transport demand) and hosts (agents offering transport supply) in a peer-to-peer manner. The absence of any centralized transport management system allows for a fully scalable solution that works in real-time in a transportation network of unpredictable and transient agents. Self-organizing transport also requires no further infrastructure than agents being equipped with positioning sensors and able to communicate locally via radio. This project report demonstrates the feasibility of such a system, presents preliminary results of simulations, and defines future research questions.

1 Motivation

Globally we experience an increasing demand for mobility that provides equitable access in sprawling cities [e.g., 4]. The complexity of modern cities needs smart transport solutions, which may emanate from the observation that urban traffic consist of many under-utilized transport resources, such as buses occupied far below capacity, private cars with low occupancy, and taxis with idle times, as well as some over-utilized resources, such as crammed trains or buses, or lack of resources in the outskirts of cities with no developed transportation system. This observation identifies an assignment problem of transportation clients—agents with transport demand—and hosts—agents offering transport supply.

In this situation, a major shift of paradigm in transportation management is suggested, called *self-organizing transport*. In self-organizing transport, clients and hosts negotiate directly for transportation, giving up any dependency or reliance on a centralized service. Note that for *intelligent transportation systems* (ITS) engaged in travel planning centralized services are still the standard paradigm. Car sharing, ride sharing or dial-a-ride services all rely on a centralized service. Centralized services may have a better overview of the transportation network—the set of vehicles offering transportation, their locations and their directions. But in particular where transportation demand and supply is non-predictable, i.e., non-scheduled, they are overstrained by maintaining a real-time picture of the transportation network and serving and maintaining ad-hoc assignments automatically. Existing services are not capable to do that for large numbers of agents. Self-organizing transport addresses and solves this bottleneck.

Self-organizing transport is a novel approach to design decentralized ITS for travel planning. The approach is based on *mobile sensor networks* (MANETs), which are designed here as networks of social agents: nodes that have individual beliefs, desires and intentions, and are able to collaborate. This design is in contrast to classical mobile sensor network designs where nodes are homogeneous, redundant and of limited intelligence [21]. The paradigm shift towards self-organizing transport enables an ad-hoc transport management that is inherently ubiquitous, real-time, and independent from any external infrastructure. The system design is tested and demonstrated in simulations.

2 Current state in ITS and MANET

Current research in decentralized ITS focuses on the *autonomous vehicle* and *telematics* [2]. Vehicle-to-vehicle communication and vehicle-environment communication to centralized services via roadside equipment are the keys, and form so-called vehicular ad-hoc networks [e.g., 5]. This research is largely led by the automotive industry and governments[1], and in a few multi-disciplinary projects such as MIT's CARTEL [8]. The focus of these projects is on sensor observations and information for local actions, such as traffic flow management, congestion avoidance, and driving safety. Global information needs, such as supporting wayfinding or assigning transport resources, are frequently ignored. Other agents than car drivers, such as people, goods, and non-automobile means of transport, are also largely ignored.

In decentralized ITS, communication has to be wireless because of the mobility of most agents. Current developments of peer-to-peer communication standards are wireless LAN, Bluetooth, WAVE (Wireless Access for the Vehicular Environment), and ZigBee (for wireless personal area networks and sensor networks). Even if these standards are not compatible nowadays, and hence, inhibit the development of comprehensive intelligent transportation systems, they demonstrate already a trend towards peer-to-peer communication, and raise the expectation that in future all agents in an intelligent transportation system can communicate with each other in an ad-hoc manner. Alternatively, wireless communication can be realized in a non-ad-hoc manner. An example for one-way communication of this type is the radio data services [10], and an example for two-way communication of this type is the wireless internet access via cell phones. Both ways, ad-hoc or non-ad-hoc communication, can include immobile agents in the environment, although they are less limited and can also communicate by other means such as wired internet with centralized services.

In contrast to current ITS designs for travel planning and assignment, self-organizing transport should function without centralized control instances. Central control instances are known to be the major obstacle to reliable and ubiquitous management schemes for the incessantly growing transportation networks of modern cities; they form bottlenecks and central points of failure. Imagine traffic as an emerging complex system of non-scheduled and transient

[1] For example, `http://www.car-to-car.org` or `http://www.internetits.org`.

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