DELIS

Dynamically Evolving, Large-scale Information Systems

Information Society Technologies

Reliable Broadcasting

Reliable Broadcasting in an Automotive Scenario

Design overview

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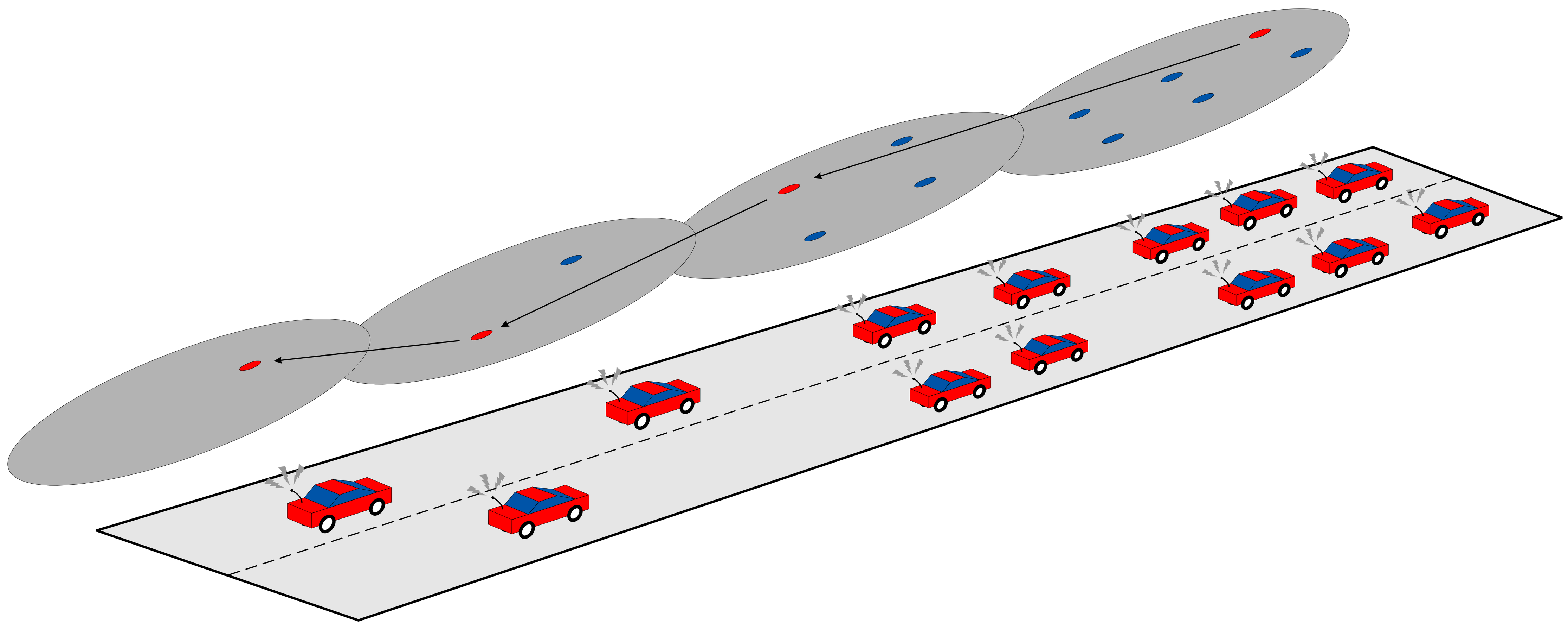
Abstract

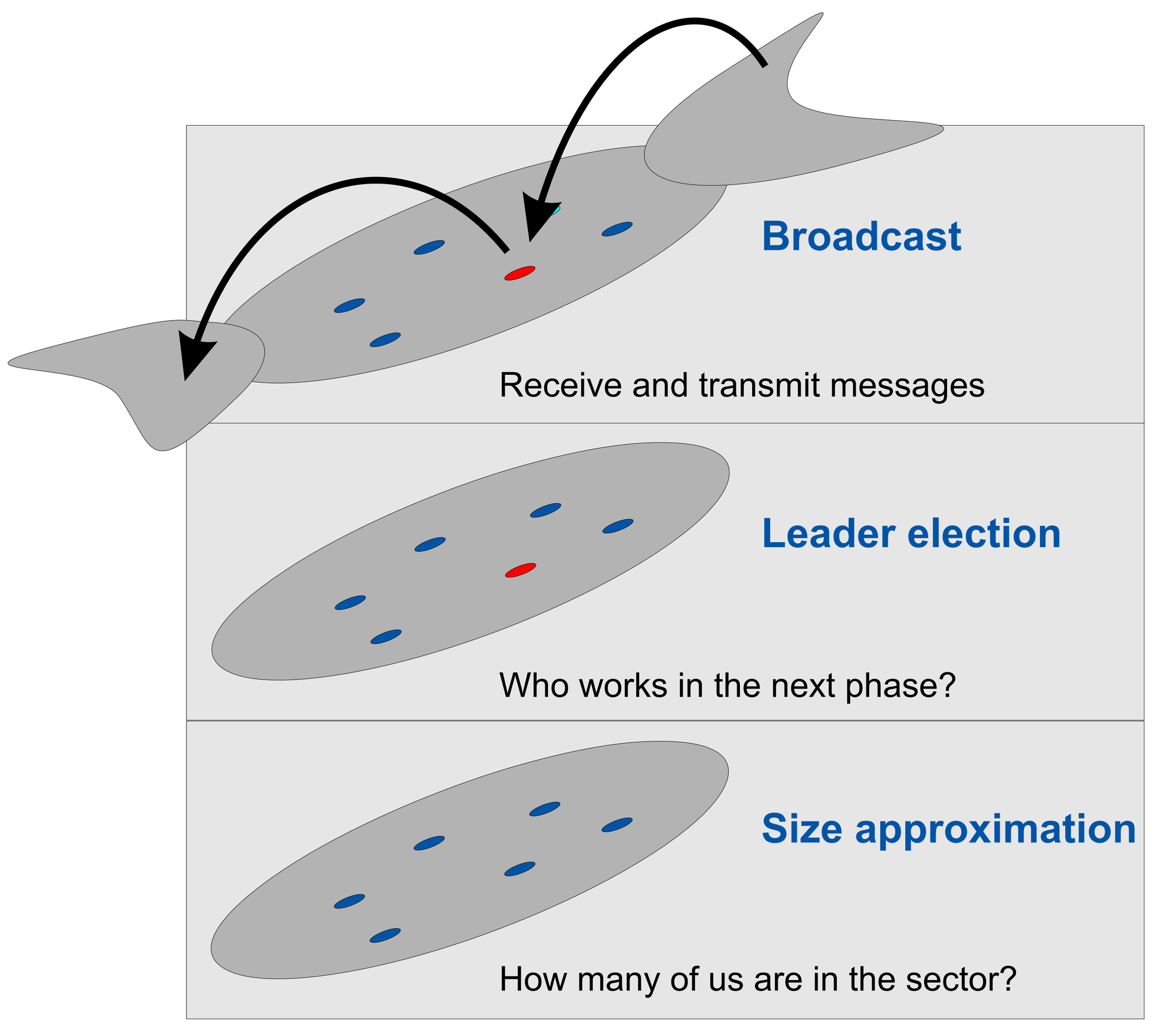
We propose a dynamic, ad-hoc communication network consisting of mobile units that can warn about traffic jams on highways.
Our goal is to provide a practical, low cost solution. Therefore we consider very simple wireless communication hardware, without collision detection, with very small bandwidth and a probabilistic model of link failure.
We provide a complete system architecture, consisting of three fine-tuned algorithms which allow the stations to self-organize and transmit traffic jam warnings.



Architecture

We consider a street conceptually divided into sectors. Whenever a traffic jam is detected, a warning message is issued in the appropriate sector and is sent from sector to sector down the road.

The system operates with the help of three layered algorithms. A broadcast algorithm is responsible for transmitting information about the traffic jams between sectors. Leader election and size approximation algorithms help the nodes to self-organize and provide a framework for the broadcast algorithm.



The wireless transceivers work with one frequency thus a time-division protocol is applied. The time is statically divided between algorithms and sectors, so that nodes in sectors lying within interference range do not transmit at the same time.

The link unreliability model causes every successful (without collision) transmission to fail to reach a node with a constant probability. This event is independent for each station, thus each transmission is heard only by a fraction of nodes within transmission range.

Broadcast

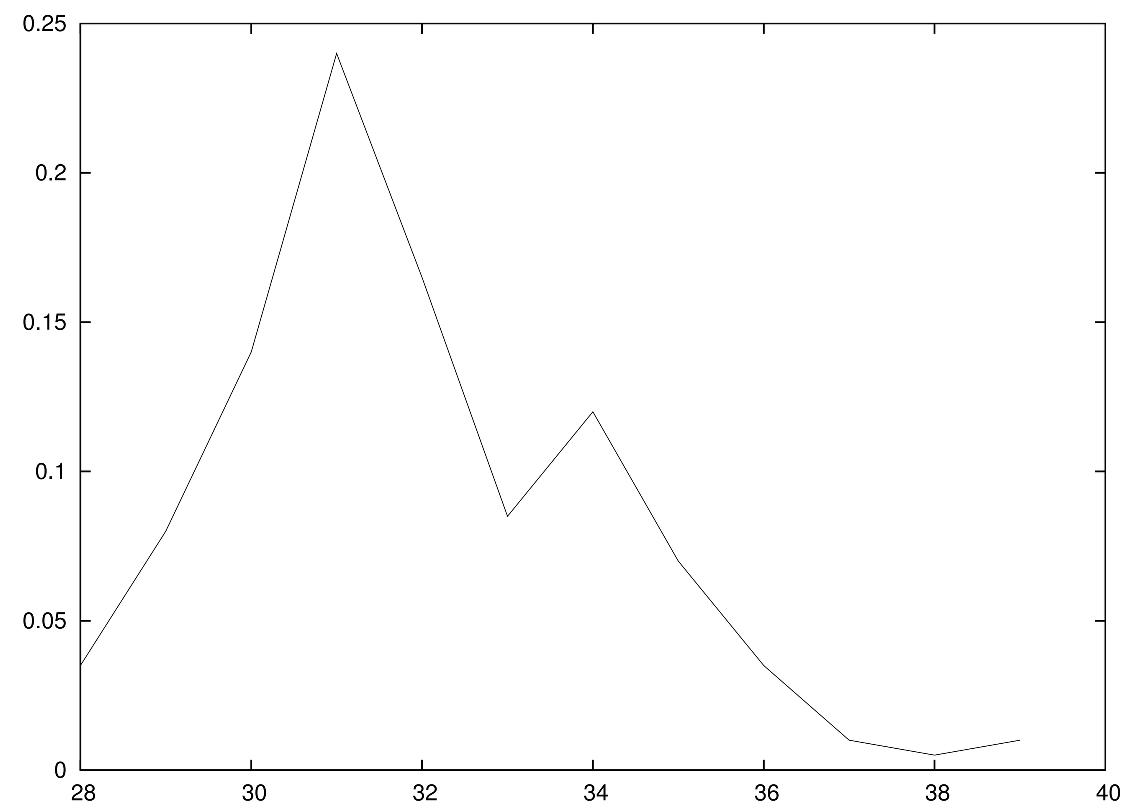
To avoid problems caused by link unreliability, the broadcast algorithm resends each message several times. This way, a message makes its way to the next sector with high probability.

Basing on the analysis of the features of the algorithm it follows that a message will travel some distance within a given time with a constant probability, even with information losses due to link unreliability. The probability for a message to reach distance D within time T is given by

$$c^D\left(\sum_{t=D}^{T}\binom{t-1}{D-1}p_r^D(1-p_r)^t\right) ,$$

with some appropriate constant c (dependent on p_r) and link unreliability given by $(1-p_r)$ (i.e. each station hears a transmission successfully with probability p_r).

Besides the theoretical analysis, the framework has been evaluated within a simulation of a highway with a cellular automaton. The figure shows the probability distribution of the message transmission time on a distance of 27 sectors, corresponding to 6.75 km road distance. The link unreliability has been chosen to be $p_r = 0.9$. The most common transmission time of 31 slots corresponds to 3.1 seconds.



Framework

The size approximation and leader election algorithms are fine-tuned for best operation with small node numbers. According to our experiments, the best known algorithms in terms of asymptotical runtime have much too large constants and thus are not usable in our practical setting.

We have chosen a simple leader election algorithm in which every node transmits in every round with probability $1/n$. For node quantities in the order of 100 it has performed best, using only $log_2\delta^{-1}$ rounds for a successful leader election with probability greater than $1-\delta$.

For size approximation a family of algorithms has been proposed. A common feature of all these algorithms is that they divide they runtime into several phases. In each phase every active node (which has not successfully transmitted yet) chooses one round and transmits in it. The number of successful transmissions in the whole run is counted and, after the last phase, describes the number of nodes in a sector.

The task of choosing the lengths of phases and their number is challenging, when trying to both obtain a small runtime and high probability for exact estimation of the number of nodes. We provide an approach for constructing phase length sequences. This sequence assures that the exact number of nodes will be returned with a given probability. Obtained results show that for practical scenarios a runtime of cn with $c < 10$ can be achieved. This outperforms known algorithms for small n.

When runtime is even more crucial, there exists also the possibility to use only one round of length n and approximate the actual number of stations basing on the number of successful transmissions within this single round.

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DELIS: Integrated European Project founded by the "Complex Systems" Proactive Initiative within the Sixth Framework Programm