NAVI: Neighbour-Aware Virtual Infrastructure for Information Collection and Dissemination in Vehicular Networks

Pedro M. d'Orey[1], Nitin Maslekar[1], Idoia de la Iglesia[2] and Nikola K.Zahariev[1]

[1]NEC Laboratories Europe, Kurfürsten-Anlage 36, 69115 Heidelberg, Germany
[2]DeustoTech-Mobility, University of Deusto, Av. Universidades 24, 48007 Bilbao, Spain
{pedro.dorey, nitin.maslekar, nikola.zahariev}@neclab.eu, idoia.delaiglesia@deusto.es

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Abstract

To enable a vast number of innovative applications in vehicular network this paper presents a novel mechanism for information collection and dissemination based on virtual infrastructure selected in combination with multiple communication technologies. The system has been evaluated using a simulation framework, involving network simulation in conjugation with realistic vehicular mobility traces. Simulation results show the feasibility of the proposed mechanism to achieve maximum message penetration in a geographical area with reduced overhead. The judicious vehicle selection also enables scalable data collection and leads to improved network utilization through the offload of traffic to the short-range network.

Problem Statement

Vehicular network pose challenges for efficient and reliable data dissemination due to:

- Varying - network topology, vehicle speed, network density
- Limited roadside infrastructure
- Single technology paradigm limiting the solution optimality
- Variable penetration rates for the several communication technologies

To address the above mentioned challenges, in this work , efficient and reliably data dissemination is achieved with the assistance of **virtual infrastructure with multiple communication technologies**.

Virtual infrastructure with multiple technologies can :

- alleviate the requirements for fixed infrastructure
- exploit the advantages of individual technologies (in terms of characteristics and performance) while still considering variable penetration rates

Problem Formulation

The virtual infrastructure selection algorithm is formulated as a **min-max optimization problem** while considering the defined constraints

Mathematically, this problem can be defined as:

$$\min_{SS_t} \quad [\max f(v)]$$
$$\text{s.t.} \quad \sum_{i=1}^{m} c_i \leq C$$
$$SS_t \in VS_t$$

Where,

- f(v) is the function defining the message penetration in the geographic region,
- m is the cardinality of the set SSt,
- ci is the cost associated with node i and C is the total budget.
- V S_t is total number of vehicles
- SS_t is subset of vehicles

Architecture

Figure 1 outlines the general architecture of NAVI, In terms of execution, the multi-technology information system comprises three main phases: **a) Data Collection , b) virtual Infrastructure Selection c) Data Dissemination Strategy**

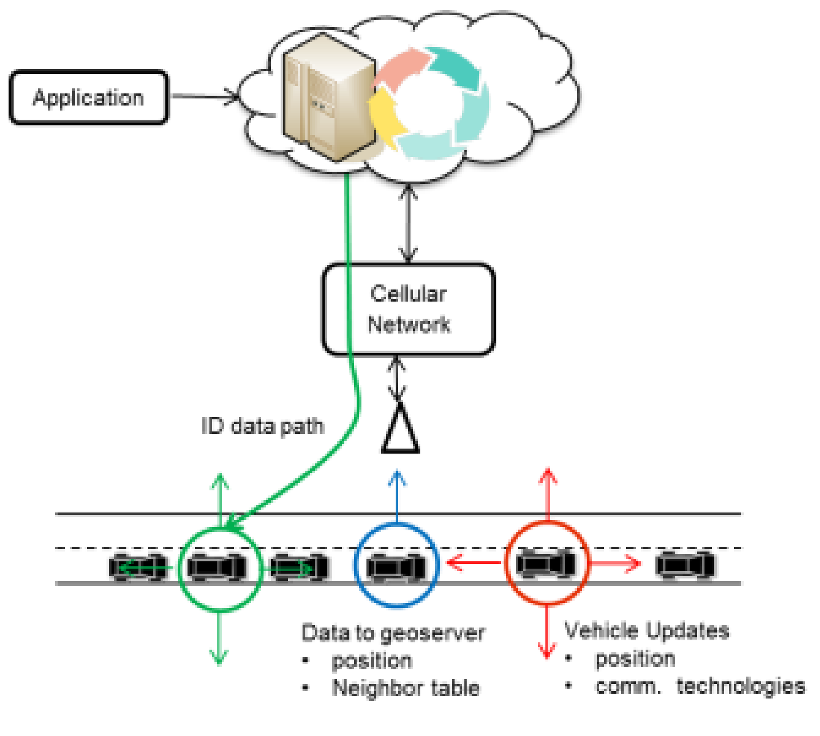

Fig. 1: Multi-technology information collection and dissemination system

Simulation Parameters

- The proposed system is evaluated using discrete-event network simulator **NS- 3**.
- Mobility traces have been generated using SUMO
- The simulated urban scenario is the downtown area of the city of Malaga, Spain.
- The maximum vehicle velocity is 50 km/h.

Table I details the simulation parameters used in the evaluation.

TABLE I. MAIN SIMULATION PARAMETERS

Type	Parameter	Value
Neighbor Information	CAM Frequency	1 Hz
	Neighbor Table Timeout	5 s
	Server update Frequency	1 Hz
Dissemination Request	Frequency	1 Hz
	Dissemination area	0.44 km^2
Scenario	Type	Urban (Malaga, Spain)
	Number of Vehicles	45
	Simulation Duration	180 s
	Vehicle Speed	10-50 km/h
	Vehicle Density	113 veh/km^2
802.11p Network	Bit Rate	6 Mbps
	Bandwidth	10 Mhz
	Frequency band	5.9 GHz
	Maximum Tx Power	[16, 21, 23] dBm
LTE Network	eNodeB Tx Power	30 dBm
	UE Tx Power	10 dBm
	Propagation Model	Friis

Simulation Results

For evaluation, following metrics are considered:

- **Covered Area (%):** This metric describes the capabilities of the algorithm to maximize data dissemination in a given geographical area
- **Virtual Infrastructure Usage:** This metric allows understanding the ability of the algorithm to minimize resource consumption
- **Gain (%):** the ratio of vehicles that do not need to directly use of the long-range communication network for data transfer to the central entity
- **Delay (ms):** This metric allows understanding the temporal performance of the system

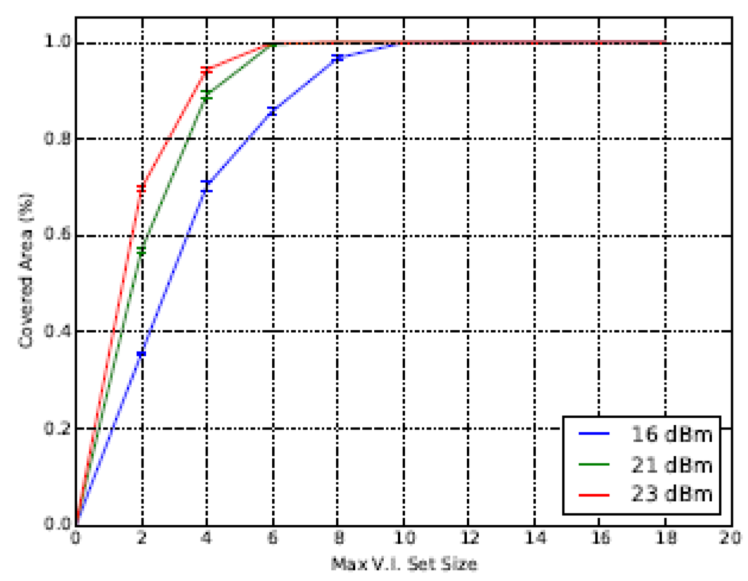

Fig. 2: Covered Area

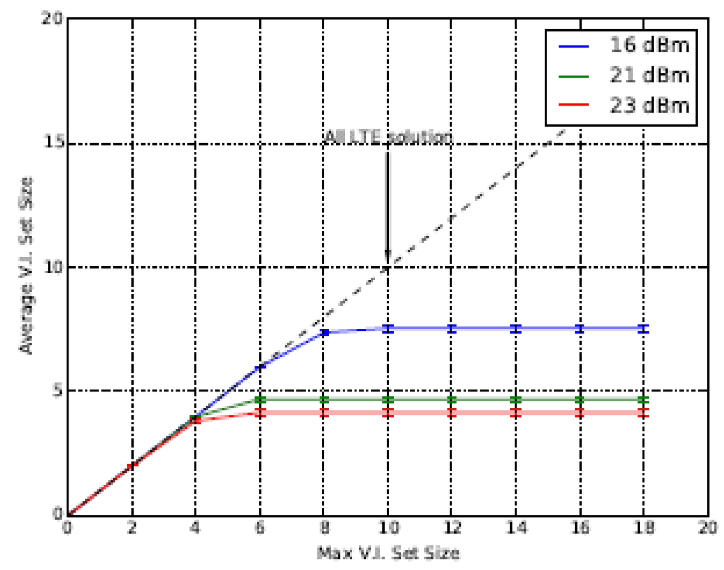

Fig. 3: Mean VI set size

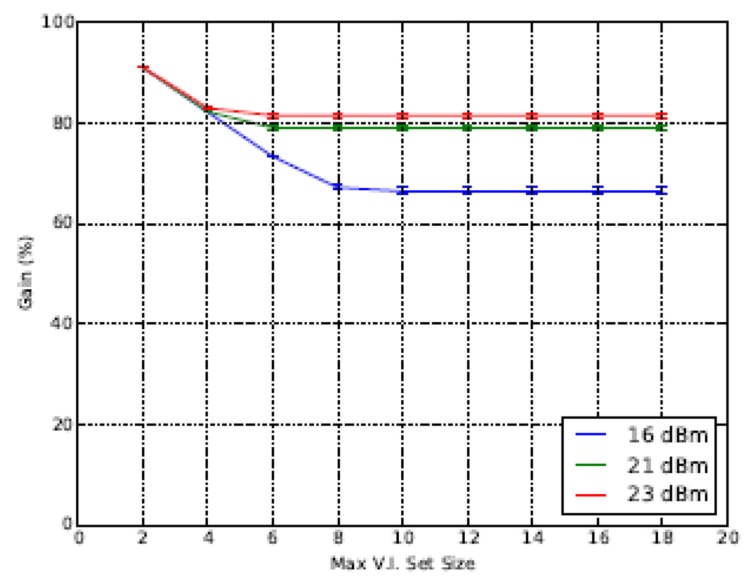

Fig. 4: Gain

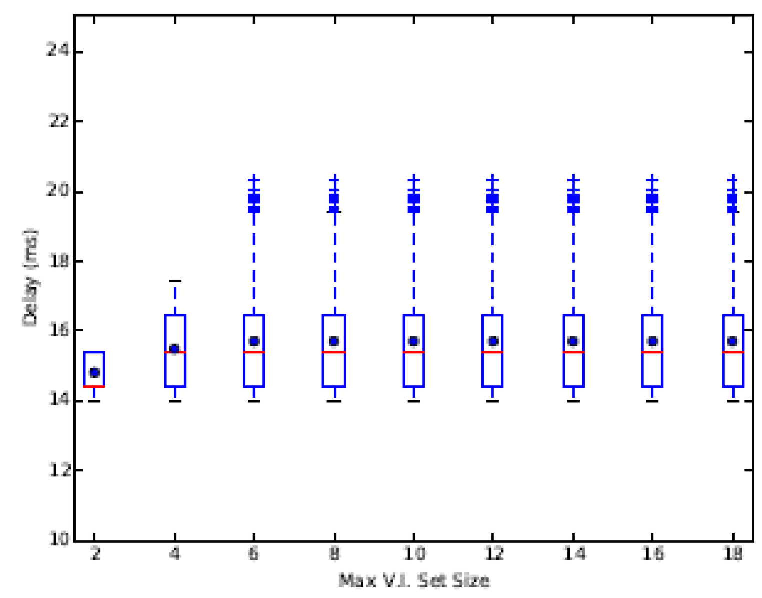

Fig. 5 Delay

Key Observations:

- After a given threshold (variable for different transmit powers) (fig 2.) increasing the maximum number of virtual infrastructure does not provide benefits in terms covered area.
- From Fig. 3, we can also conclude that the size of the virtual infrastructure set remains fairly constant after the threshold is reached.
- the average virtual infrastructure set size is considerably small when comparing with the total number of nodes in the dissemination area (e.g. 10% for a 21 dBm Tx power).
- The system gains are 67%, 79% and 83% for 16, 21 and 23 dBm tx. Power (fig 4), respectively.
- In Fig. 5 results show that the algorithm delivers low latency values that meet the requirements of the majority of applications

Conclusions

A combined system for information collection and dissemination in Vehicular Networks based on virtual infrastructure election in combination with multiple communication technologies:

- **Can achieve maximum message penetration** with reduced overhead.
- Impose **minimal implications in the communication** performance in terms of delay.
- Offloading results in **considerable overhead reductions**.

As future work, we plan to compare the behavior of the system on different scenarios (urban, semi-urban and highway environment) and to analyze the impact of the vehicle density

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