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Interference aware bandwidth estimation for load balancing in EMHR-energy based with mobility concerns hybrid routing protocol for VANET-WSN communication

Linda F. Mohaisen*, Laurie L. Joiner*

Department of Electrical and Computer Engineering, University of Alabama in Huntsville, United States

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ABSTRACT

The main goal of Vehicular Ad Hoc Networks (VANETs) is to improve driving safety. However, VANETs may not guarantee timely detection of dangerous road conditions or maintain communication connectivity when the network density is low, which may pose a risk to driving safety. Towards addressing this problem, the VANET is integrated with the inexpensive Wireless Sensor Network (WSN). Sensor nodes are deployed along the roadside to sense road conditions, and to buffer and deliver information about dangerous conditions to vehicles regardless of the density or connectivity of the VANET. The most challenging features in VANETs are their dynamic topology and mobility, where vehicles are moving at variable and high speeds and in different trajectories. In contrast, the challenge in the WSN is in managing the limited energy resources of the nodes, since the performance of WSNs strongly depends on their lifetime. Thus, the fundamental design challenge in designing routing protocols for a hybrid network of VANET-WSN is to maximize network lifetime and connectivity, and to minimize delay and energy consumption. To overcome these challenges, this research investigates the effects of different Quality of Service (QoS) parameters on forwarding decisions in an efficient distributed position based routing protocol, and focuses on bandwidth estimation. Bandwidth estimation is of great importance to network Quality of Service assurance, network load balancing, and routing. In this research, a bandwidth estimation strategy based on normalized throughput of a link, taking into account the interference and packet loss ratio in discrete time for every successfully delivered packet is proposed for a hybrid network of VANET-WSN. The simulation results show that the strategy is effective, and can accurately estimate the bandwidth of VANET-WSN. A comprehensive performance analysis in representative urban scenarios is performed that takes into account realistic propagation models and real city scenario traffic.

1. Introduction

The rapid increase in the number of vehicles over the last decades has resulted in growing concerns about adverse environmental impacts and safety issues in land transport systems. Thus, Intelligent Transport Systems (ITS) have emerged as promising solutions for future effective and environmentally friendly transport systems [1]. ITS aim to apply Information and Communication Technologies to improve safety and efficiency as well as passenger experience in modern transport systems.

Currently the major goal of ITS is sensing the environment. Other novel applications may be deployed in future vehicular scenarios. Typically, these systems have relied on different technologies. One group is comprised of intrusive sensors, such as inductive loops, magnetometers and pneumatic road tubes, frequently employed to detect traffic flows. However, the installation and maintenance of these sensors are difficult, since large sections of the road need to be torn up. In addition, non-intrusive sensors can be used, including video cameras, radars, and ultrasonic sensors, which can be placed above the ground. Their major drawbacks are their large size and large power demands. In addition, their performance may be affected by different environmental conditions. Moreover, both intrusive and non-intrusive sensors are expensive and associated with difficult installation, classically requiring wired infrastructures and power lines for energy supply. Thus, these sensors are deployed only at critical locations, which work independently of each other. The information they produce must be transmitted to distant Traffic Management Centers (TMCs) for centralized data processing. Thus, high amounts of data must be transmitted through expensive communication infrastructure, which results

* Corresponding authors.
E-mail addresses: lfm0001@uah.edu (L.F. Mohaisen), joinerl@uah.edu (L.L. Joiner).

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in unacceptable data dissemination delays that limit the utilization of the system for vehicle safety applications requiring quick or near real-time responses.

An alternative to these centralized solutions is the cooperative approach, where data processing is performed in-situ among distributed devices. The distributed network provides faster reaction times, and with the use of wireless communications, some of the inconveniences derived from the placement of nodes because of wired infrastructures are removed. Vehicular Ad Hoc Networks (VANETs) are an example of such distributed networks. VANETs are the most important component of ITS, in which vehicles are equipped with some short-range and medium-range wireless communication. In a VANET, there are On-Board Units (OBUs) for vehicle-to-vehicle (V2V) communications and Road Side Units (RSUs) for vehicle-to-infrastructure (V2I) communications. Moving vehicles become nodes of a highly dynamic mobile network that can disseminate relevant information over long distances, and collaborate to offer drivers and users improved distributed vehicular services. Nevertheless, VANETs only monitor road conditions opportunistically, that is, when a vehicle is nearby, and their proper behavior is conditioned by the number of traveling vehicles, as well as by the diffusion rate of such technology into vehicles. From the definition of VANETs, a salient challenge is obvious. Suppose at midnight in some rural area, a vehicle has a very important data packet (i.e. detection of an accident) which should be forwarded to the following vehicles immediately. The probability of a low density of vehicles in a rural area at midnight is very high. Consequently, in this situation the packet will be lost due to the lack of other vehicles, and arrival of the following vehicles in the accident area is unavoidable. To overcome this serious issue, emerging research focuses on a new hybrid network. Researchers propose to deploy wireless sensors along the roadside using Wireless Sensor Networks (WSNs).

Wireless Sensor Networks (WSNs) are a maturing technology for the future Internet of Things. They are being applied ubiquitously, including in ITS. WSNs are medium to large networks of inexpensive wireless sensor nodes capable of sensing, processing, and distributing information acquired from the environment through the collaborative effort of nodes. WSNs provide significant advantages both in cost as well as in distributed intelligence. Installation and maintenance expenses are reduced because of the use of cheap devices that do not require wiring. Distributed intelligence enables the development of diverse real-time traffic safety applications not feasible with centralized solutions.

WSNs can be considered in the ITS context as additional components of a heterogeneous system, where they cooperate with other technologies such as VANETs. This proposed system is called a hybrid network of Vehicular Ad Hoc and Wireless Sensor Networks or, in short, VANET-WSN. There are two types of sensor nodes in the suggested VANET-WSN, those embedded in the vehicles, known as vehicular nodes (VN) and those deployed at predetermined distances on the roads, known as Roadside Sensor Nodes (SN). The VNs collect real data, such as vehicle position, velocity, etc., and forward the data towards the destination via other VNs and SNs.

In the VANET-WSN environment, where heterogeneous access technologies are available, the major issue is data dissemination. The aim of data dissemination is to transport information to the destination while meeting a number of constraints. The information saturation, lifetime of data, and reliability of its transportation are some major considerations. Motivated by this demand, this research investigates the effects of different parameters on forwarding decisions and proposes an efficient distributed position based routing protocol for VANET-WSNs.

The contributions of this study can be summarized as a novel and effective position based routing protocol that takes into account all the major network and environmental parameters from the PHY, MAC, and network layers for node reliability, and balances the highly dynamic mobility of VANET and the energy consumption of WSN by:

- Developing energy-based routing for WSN with mobility concerns for VANET.
- Estimating the bandwidth as a maximum throughput and taking into account the interference influence on the sender and the receiver side, and the transmission time that indicates CSMA-CA MAC layer overhead.
- Applying network performance measures including packet delivery ratio (PDR), total throughput, normalized routing overhead (NRO), end-to-end delay, and energy consumption to evaluate routing decisions in the highly dynamic and energy constrained VANET-WSNs.

List of symbols

α_i	Weighting factor for each parameter that indicates the relative importance of the parameter in making forwarding decisions
β	SINR threshold
Δt	Elapsed time between the present time and the time of the last received beacon
$\hat{d}$	Future position vector
A	Total current (in Amperes) drawn from the sensor device
BR_{ch}	Channel's bit-rate
$BwEst_l$	Bandwidth estimation of a link l
d	Current position vector
$D(a, b)$	Curve-metric distance between node a and b
E_{init}	Initial energy stored in the energy source
E_{rem}	Remaining energy
ETX_l	Expected transmission count of a link l
I	Interference signal power
IR_l	Interference ratio in a link l
LTP	Link throughput
N	Background noise power
$NLTP_l$	Normalized link throughput of a link l
P	Signal power
p_f	Forward packet delivery rates
p_r	Reverse packet delivery rates
$P_r(s)$	Transmitting power from node s to node r
RER	Residual energy ratio
S	Size of the packet in bits
$S1$	Actual data packet size
$S2$	Predefined standard packet size
$SINR_l$	Signal to interference and noise ratio in a link l
SN	Sensor node
SNR_l	Signal to noise ratio in a link l
T_d	Actual time for the channel to transmit the data packet
$T_r - T_s$	Transmission time which includes the channel busy and contention time
T_r	Time-stamp of the received packet
T_s	Time-stamp of the packet that is ready for transmitting at the MAC layer
Tp	Time that is taken to transmit or receive the packet (in seconds)
V	Supply voltage (in Volts)
v	Velocity vector
VN	Vehicle node