Challenges of Vehicular Sensor Networks CPS 2008 Position Paper

Ian Downes and Leonidas Guibas*

1 Overview

The future vehicle driver will be aided with greater and more detailed information. In particular, there is great interest in providing information to improve driver safety. Examples include Extended Brake Light (EBL) and Curve Speed Warnings (CSW) where notifications to the driver improve reaction time. These are inherently short range and are on short timescales. We believe that there are many more applications which can improve efficiency and safety but which operate over greater distances and longer timescales. To support such applications we envision the road network and all vehicles as a large dynamic sensor network. The physical world is sensed as and where required and the information is distributed to the areas which depend on it. Information is given in the context of the system and its current state to enable intelligent decisions. To support itself the network learns its dynamics and its capabilities. Robustness and scalability are achieved with a distributed network rather than a centralized scheme.

In this position paper we detail some of the challenges of such a network and how we are approaching them.

2 Challenges

A vehicular sensor network (VSN) is related to the well studied wireless sensor network (WSN) but is different in two key areas—available energy resources and mobility. Rather than rely on a battery or scavenged energy a vehicle node can draw power from the vehicle engine. The removal of the energy limitation eliminates the dominant constraint present in essentially all aspects of WSNs, from communication protocols, to information processing and to hardware design. This relaxation is welcome as the high mobility of vehicular nodes introduces a new set of problems. Rapid topology changes make it difficult to establish and to maintain communication routes. Furthermore, constant motion means that it is difficult to even locate another node. Things

*Department of {Electrical Engineering, Computer Science}, Stanford University, Stanford CA 94305, {downes@stanford.edu, guibas@cs.stanford.edu}

that could be learnt or established in a static network are no longer feasible in a dynamic network.

There is another, more subtle and perhaps more fundamental, difference between the networks. If we consider the measurable variable to be continuous in space then a WSN represents a set of discrete sampling points in this space. The sampling of the space is limited by the distribution of nodes which may be controlled or it may be random. Each node is then capable, energy permitting, of sampling continously in time at its particular sample location. A VSN is precisely the opposite of this, all points in the road network space can (eventually) be sampled but only at discrete time instants corresponding to passing vehicles.

To illustrate the implications of these differences we consider a simple example. We wish to determine the time average value of a measurable variable at some location. In a static network this is simple. A subset of nodes, near the location, can repeatedbly sample during thethe time interval and then share their measurements with an elected aggregation node. The aggregation node calculates and stores the average value and can then be queried as required. In a dynamic network a node passes the location at certain uncontrolled time instants and can obtain a measurement. Each measurement is generally taken by a different node which then proceeds to continue moving. The measurements must be aggregated and the resulting value stored somewhere. However, every measurement node and any possible aggregation node are independently mobile, rendering even this simple problem much more complex.

3 Research directions

In light of these challenges we are exploring three distinct areas of research; high bandwidth sensing, stable substructures for communication/dissemination and large scale simulation.

Eyes-on-cars

With no energy constraint it is feasible to use high bandwidth sensors such as cameras. We are working on a project entitled “Eyes-on-cars” where we consider equipping vehicles with multiple cameras together with processing and communication capabilities. The idea is to provide a driver with a *view* of any part of the road network. The *view* may either be as raw images or in a more concise and refined format providing information such as the level of congestion. By allowing human interpretation of images the scope of applications is greatly broadened. For example, a driver may want to confirm that a particular store is open, a simple recent snapshot of the storefront can establish this. Much of this information can be obtained from either the Internet or from a GPS based database but these sources are inherently inaccurate due to the age of the data.

Stable substructures

Individual vehicles are highly mobile however there is much structure which can be exploited in the global network. Road networks can be classified into a small number of distinct categories in which each exhibits typical behaviour. Residential roads may have low traffic levels where individual vehicle move slowly to a large number of destinations resulting in little structure. In constrast, freeways have higher traffic volumes where each vehicle moves at speed but with a common destination—a structured flow. We are looking at how stable structures can be built and maintained where suitable conditions exist. These structures may be routing or communication backbones or higher level structures used for data dissemination and storage.

Large scale simulation

The vision expressed in the overview requires a network which is both expansive in scale and large in number. Such a network does not exist and is currently not feasible to construct. This necessitates a simulation environment where algorithms and protocols can be tested under real world conditions. We have constructed such a simulator by combining an accurate network simulator with a realistic traffic simulator. The simulator is currently being parallelized to run in a high performance cluster environment. The goal is to support networks of tens to hundreds of thousands of mobile nodes.

4 Biographies

Ian Downes is a Ph.D. student in the Electrical Engineering Department at Stanford University. His interests encompass all aspects of sensor networks from hardware design through to information processing and data dissemination algorithms.

Professor Guibas teaches in the Computer Science Department and has been active in the area of Sensor Networks for the last five years. He is the co-author of a well known textbook in the area (Wireless Sensor Networks, An Information Processing Approach, with F. Zhao) and teaches a course in that area each year. He has also established a camera sensor network lab at Stanford that has been used for a number of experiments, including tracking and counting people, producing video summaries of activities, etc.