Poster Abstract: Measuring Traffic in Short-Term Construction Work Zones

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ABSTRACT

We describe the design of sensornet systems to measure traffic in short-term work zones in urban areas.

1. INTRODUCTION

Construction work zones on roads are hazardous areas. Motorists are typically exposed to unfamiliar situations in an otherwise familiar environment, often causing them to behave in unexpected ways, resulting in unsafe operating environments both for motorists as well as workers. In order to monitor driver behavior, highway work zones are instrumented with a number of sensors (loop detectors, video cameras, etc.) to monitor traffic. In fact, Intelligent Transportation Systems (ITS) are a major priority for the US Department of Transportation. These sensors produce a wealth of information that can be presented to different consumers in a variety of ways: to transportation engineers for traffic monitoring, to drivers through services such as Google Maps.

A large number of work zones are of a second kind: short-term work zones set up in urban streets for minor maintenance work (cable, telephone, etc.). These work zones are typically active for a few hours at best. The sensors that are used in the longer-term highway work zones are not applicable in this context: the cost of the equipment and the time for deployment make them infeasible. Because of these reasons, there is almost no data collected and maintained to document traffic behavior in these work zones that we encounter everyday in our neighborhoods. In this poster, we describe the design and prototype implementation of an inexpensive sensornet solution for this problem.

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Figure 1: Our sensornet system deployed in a work zone to measure traffic. The motes are mounted on top of construction safety cones. The placement of the cones is as required by the work zone itself as per the MUTCD [1].

2. DESIGN REQUIREMENTS

2.1 Deployment Requirements

Short-term work zones present some design requirements that are distinct from typical sensornet deployments:

1. *Rapid deployment.* Short-term work zones are only active for a few hours . The network only has a few minutes to organize itself and begin producing useful data.
2. *Inexpensive.* The cost of sensornet hardware in a work zone must be kept to a minimum.
3. *No skilled maintenance.* The nodes in these systems must not require any skilled maintenance from sensornet experts. Any regular maintenance activity (*e.g.,* keeping the batteries charged) must be such that it can be performed by the construction personnel themselves.
4. *Self-organization.* Sensornet deployments in short-term work zones are not guaranteed to be "highly-engineered": the placement of nodes in the network cannot be predetermined. However, the deployment is not totally random; simple assumptions can be made (*e.g.,* distance between nodes will be uniform). The sensornet can use these assumptions to aid in self-organization.

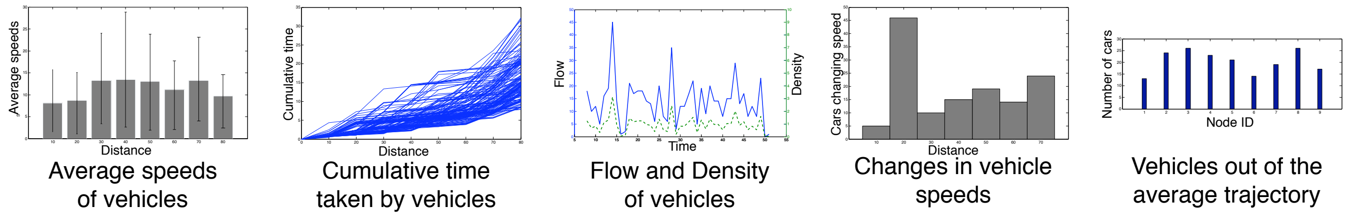

Figure 2: Some examples of traffic statistics that we can measure using our sensornet infrastructure deployed in work zones.

2.2 Data Requirements

Based on our discussions with the researchers at the CSU University Transportation Center (UTC), the most important kinds of information that needed to be collected were:

- Traffic statistics such as *flow* (number of vehicles per hour), *density* (average vehicles per mile), and *average speed* of vehicles traveling through the work zone.
- Trajectories of vehicles as they travel through the work zone. When cars deviate from the expected uniform trajectory, there is potential for crash incidents since they may come close to construction equipment or workers. Such near-crashes need to be recorded.
- Aberrant behavior of vehicles.The design of work zones is intended in such a way that vehicles will still be able to maintain uniform speed. Again, cases where vehicles suddenly brake, for example, may be indicators of unsafe situations in the work zone.

3. DESIGN AND IMPLEMENTATION

We have designed both hardware and software components to meet the requirements laid out above. A photograph of a sensor node's internals is shown in Figure 3. The node is self-contained, and includes a mote that is connected to sensors to detect and count vehicles driving past the sensornet. The node is powered by a battery that can be recharged using TelosB mote itself. The mote is augmented with a charger board that can charge the battery when connected to a USB power source. The USB connector is exposed outside the box for easy charging.

The software for the system is implemented in TinyOS 2.1. The system is self-organizing; once the nodes are deployed and powered on, they exchange messages to establish neighborhoods, and the routing structure is created. The routing protocol we use is a simple tree rooted at the base station.

In addition to forming the routing structure, the nodes needs to perform another task in self-organization. In order to accurately map the work zone to the statistics, it is important for each node in the line to know where it is relative to the other nodes. For this task, the nodes involve the central base-station. As traffic begins to move past the array, each node immediately records each passing vehicle and uploads that information to the base station via multi-hop routing. The base-station uses the first few cars as a sample set to order the nodes, and then transmits the order information back to the network. From this point on, the nodes transmit information including node ordering information, and spatial multiplexing (similar to [3]) — only one node uploads data at a time. This also reduces network traffic since collisions reduce.

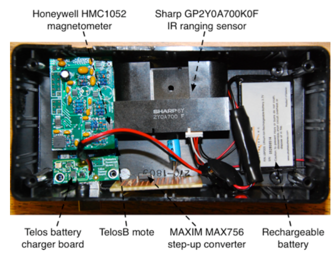

Figure 3: The sensor node that we deploy in the work zones. The node include a TelosB mote, with a Telos charger board connected to rechargeable batteries. The mote is connected to the Sharp IR ranging sensor, and an EasySen sensor board which includes the Honeywell HMC1052 magnetometer.

Once the network has organized itself, each node sends data about each vehicle it "sees." In addition to a time stamp and vehicle count, each node also reports the distance (from the sensor, and hence, the side of the road) at which the vehicle is traveling:

Timestamp (4bytes)	Distance (1byte)	Vehicle count (2bytes)

On receiving data from the network, the base station can assemble trajectories of vehicles moving past the sensor array, and compute other traffic statistics to aid in measurements (Figure 2). We use a particle filter [2] when computing trajectories in order to eliminate any sensor error.

So far, we have deployed our network to measure traffic in a number of work zones commissioned by Area Wide Protective Inc., a local flagging company in Northeast Ohio. We continue to deploy such smart work zones, and these experiences are helping with refining our prototype for wider use.

4. REFERENCES

[1] Federal Highway Administration. *Manual on Uniform Traffic Control Devices*. U.S. Department of Transportation, Washington D.C., 2003 edition with revisions 1 and 2 edition, December 2007.

[2] A. Doucet, S. Godsill, and C. Andrieu. On sequential monte carlo sampling methods for bayesian filtering. *Statistics and Computing*, 10(3):197–208, 2000.

[3] S. Kim, R. Fonseca, P. Dutta, A. Tavakoli, D. Culler, P. Levis, S. Shenker, and I. Stoica. Flush: a reliable bulk transport protocol for multihop wireless networks. In *SenSys '07*, pages 351–365, 2007.