Demo Abstract: An Affordable, Long-Lasting, and Autonomous Theft Detection and Tracking System

Somnath Mitra[§] Zizhan Zheng[†] Santanu Guha[§] Animikh Ghosh[§] Prabal Dutta[‡]
Bhagavathy Krishna[§] Kurt Plarre[§] Santosh Kumar[§] Prasun Sinha[†]
[§]CS Department, University of Memphis
[†]CSE Department, The Ohio State University
[‡]CS Division, Univ. of California, Berkeley

Abstract

The AutoWitness project aims to deter, detect, and track theft of everyday objects using a combination of ultra low-power mobile *tags* and a wide-area network of static *anchors*. Key research challenges include dramatically driving down the cost and size of tags and increasing their lifetime, discriminating between normal activities and theft using motion detection and classification algorithms, reconstructing getaway trajectories from sparse anchor rendezvous, and ensuring sufficient coverage and connectivity in a sparse, wide-area network of anchors. The demonstration will show AutoWitness in operation including motion detection, classifying theft signatures, and tracking the trajectories of "stolen" objects near the conference venue.

Categories and Subject Descriptors

B.0 [**Hardware**]: General; B.4 [**Hardware**]: Input Output & Data Communication;; J.4 [**Computer Applications**]: Social and behavioral sciences

General Terms

Design, Experimentation, Performance, Measurement

Keywords

Burglar Tracking, Theft Detection

1 Overview

According to the 2007 FBI Uniform Crime Reporting Program, burglary accounted for an estimated 22.1 % of all property crimes, and burglary losses totaled $4.3 billion [9]. Loss of property aside, a burglary incident is a traumatic experience for victims. Yet, due to the difficulty and expense of investigating such crimes, most go unsolved, and burglary continues to be pervasive. Unfortunately, most traditional home- and office-based security systems attempt to *deter* or *detect* burglary through increased vigilance – security cameras, motion detectors, and alarm systems – but they cannot help *track* or *recover* objects once they are stolen.

Existing asset tracking products like Brickhouse [1] and Liveview [2] can track stolen objects. They use GPS to obtain location fixes and cellular infrastructure to communicate this data but unfortunately, the size, cost, and lifetime of such devices is not suitable for use in tracking everyday objects like televisions and microwaves. The LoJack vehicle tracking system [3] uses a small device hidden inside a vehicle to transmit homing beacons when stolen. When a LoJack-equipped vehicle is reported stolen, a network of high-power wireless transmitters send an activation signal to the device. Once activated, devices transmit periodic beacons that can be tracked using police car-mounted LoJack receivers. Unfortunately, this approach requires a device to be powered continuously to receive the activation signal, and requires frequent, high-power transmissions once activated, making it unsuitable for long-term, battery-powered operation (approximately three days of operation without access to vehicle power). In addition, a $695 price tag makes the cost prohibitive for tracking everyday objects.

In this demonstration, we will show a new burglar tracking system called *AutoWitness* that addresses the drawbacks of earlier systems and better matches the cost, size, and power requirements of everyday theft detection and tracking. The AutoWitness system consists of battery-powered *tag* nodes that are attached to everyday objects and a city-wide network of *anchor* nodes that enable energy-efficient tracking in real-time. Although the goal of this system is to lead to the arrest of burglars, rather than merely deterring them to hit more vulnerable targets, installation of LoJack-style systems are known to have deterrent effects [4].

Figure 1 shows a prototype tag mote based on the Epic Core [7], and its operation. Since we are currently using this platform for evaluating design tradeoffs, it has several additional features that would not be part of the final production design, such as rechargeable Li+ battery, dual linear voltage regulators, a secondary wakeup circuit, and 2 MB external flash memory. The tag node detects theft autonomously using a hierarchical wakeup system of passive and active vibration sensors. The radio is turned off until motion is detected, a theft signature is classified, and the stolen asset is presumably being transported by a vehicle. The vibration sensor serves several other purposes including a novel procedure for arming/disarming the system.

The anchor node network provides the communications infrastructure needed to route beacons from tags to first responders. Anchors also task moving tags with wake/sleep information and they communicate with tag nodes using a low-power, short-range 802.15.4 radio interface provided by a Telos B mote [8]. The solar powered anchors associate with nearby 802.11 access points, if available, or they com-

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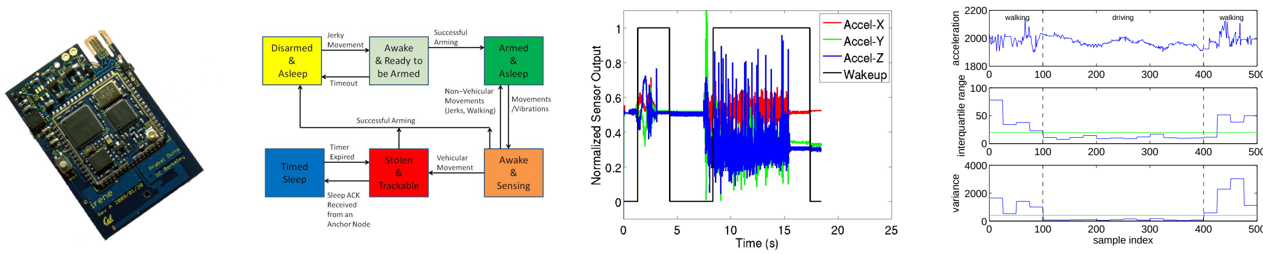

(a) Tag Node (b) Tag State Machine (c) Motion Detection (d) Theft Classification

Figure 1. Prototype tag hardware. (a) The tag mote integrates an Epic Core, dual vibration switches, an accelerometer, and a rechargeable Li+ battery in a 51 mm x 34 mm x 10 mm footprint. (b) The tag node state transition diagram. Tags hibernate in an ultra-low power state ("Armed and Asleep") until they detect motion and then they operate in a low-power beaconing mode. (c) The motion detection circuit in operation. Acceleration bias is removed and the readings are scaled. (d) Acceleration measurements for a walking-driving-walking sequence (top), inter-quartile range (middle) and variance (bottom) of first difference with zeros removed. Horizontal lines show possible classification thresholds.

municate amongst themselves using high-power, long-range proprietary radios that can form a multihop mesh network and are similar in design to DieselNet ThrowBoxes [5]. A tag node that moves an absolute displacement beyond a certain distance (a parameter) along the city road network starting at any location is guaranteed to be captured by at least one anchor node. Such events are forwarded to a gateway node through a multi-hop mesh network of access points. We have designed an approximation algorithm for computing the smallest number of anchor nodes while satisfying such coverage and connectivity constraints.

Each anchor node keeps an estimate of the minimum travel time to its nearest neighbor. Upon receiving a theft report beacon from a tag, the anchor responds with this travel time estimate, allowing the tag to sleep for a substantial fraction of this time. Although not currently implemented, the anchor's travel time estimate should also include a digitally-signed message of the travel time plus a nonce supplied by the tag. Prior work has shown that RSA 1024-bit signature verification is feasible on tag-class nodes [6].

2 Demonstration

We will demonstrate the AutoWitness theft detection and tracking system, including the tag and anchor node hardware, theft signature detection, and real-time tracking. The demonstration will include the following details:

1. **Tags.** Low-power tags running the theft detection algorithms will be available. These nodes will sleep while drawing very low current, until they detect motion that matches a theft action, after which time they will wake up and begin beaconing both their identifiers as well as compressed trajectory information. Several handheld sensors will be available for attendees to play with and "steal." Attendees will also be able to arm and disarm the tags using a special, tag-specific, gesture.
2. **Anchors.** A network of battery or solar or wall-powered anchors will be deployed around the conference venue. These anchors will self-configure into a multi-hop mesh network, listen for tag beacons, transmit sleep time beacons in response, and report tag sightings to a server.
3. **Tracking Portal.** Tag sightings will be reported in real-time to the server and viewable using a browser-based client. The tracking portal will allow attendees to see, in real-time, a history of confirmed tag sightings and estimated tag trajectories.

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