

USN-based Architecture for Traffic Management

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Abstract — this paper reviews a general USN (Ubiquitous Sensor Network)-based architecture of traffic management which consists of wireless sensors, wireless APs (access points) and central traffic controller. Since thousands of thousand sensors installed on the roads in a huge physical area send and receive through wireless coordinators and AP traffic data such as vehicle detection, classifications and speed measurements, a central traffic controller is required to produce meaningful information for users. Particularly, it is of paramount importance to relate time-specific, location-specific and contents-specific information one way another. This paper reviews the recent updates of advanced methodologies for vehicle detection and classification sensors, USN network elements such as wireless coordinators (Zigbee) and AP (Wi-Fi or WiMAX(Worldwide Interoperability for Microwave Access)), and RIA (Rich Internet Application)-based user interfaces. This paper also introduces an application of new standards KML (Keyhole Markup Language) to USN-based traffic management systems.

Keywords — USN, Architecture, ITS, Traffic, AP, Zigbee, Wi-Fi, WiMAX, SN(Sensor Node), IP(Internet Protocol), NM (Network Management), RIA.

such as GUI (Graphical User Interface), applications, databases including MIB data, etc. The middle tier IP consists of wireless or wired IP network elements connected each other. It should be noted that road-side gateways (RSGWs) are sink nodes or gateways that connect both SN and IP tiers.

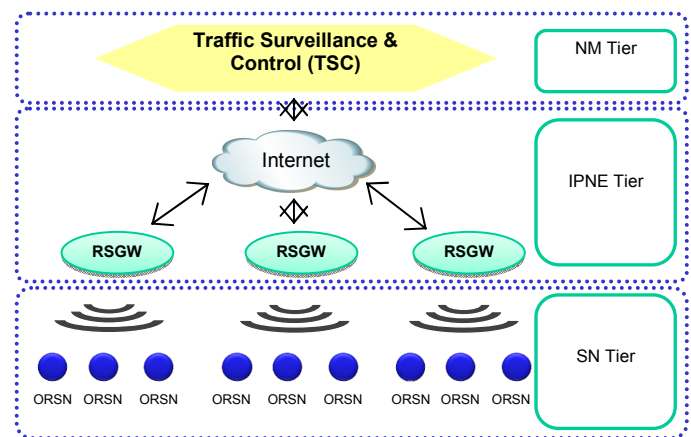


Figure 1. USN-based Architecture

I. INTRODUCTION

Sensor networks are wired or wireless networks for collecting from sensor nodes (SNs) and controlling sensor nodes. Recent advances of wireless technology enabled sensors and actuators to be connected wirelessly, and thus these networks are sometimes called as wireless sensor networks [1]. To include RFID (Radio Frequency Identification) such as wireless passive sensor networks [2], however, we call these networks as USNs for general purpose in this paper.

USNs have been identified as one of the most important technologies for the 21st century [8]. The current and potential applications of sensor networks cover a wide range, including environment monitoring, military sensing, emergency medical care, industrial and manufacturing remote control, mechatronics, automation and traffic management [1][8][19][20]. Such a big diversity of applications poses huge challenges to the application design of USNn.

As Fig.1 illustrates, the USN-based architecture in this paper consists of three tiers: SN, IP and NM. The highest tier NM composes of many management and control components

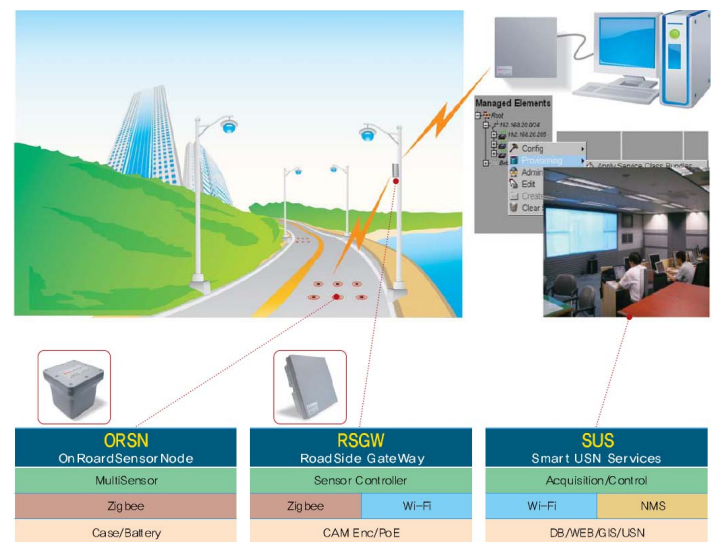


Figure 2. Implementation Example of USN-based Architecture

The lowest tier SN contains on-road sensor nodes (ORSNs)

that consist of multifunctional sensors, power module and wireless modules such as Zigbee for traffic surveillance, detection and monitoring. An implementation example of this USN-based architecture can be seen in Figure 2.

Since SN tier consists of a large number of sensor nodes deployed densely in a huge physical area which return large amount of data. Mostly, the deployment of sensor nodes operating on limited power capacity of their batteries is assumed. IEEE 1451 [3] consists of standards that provide a generic interface between a transducer and external network elements. IEEE 1451.2 handles sensor data format called TEDS (Transducer Electronic Data Sheet) while 1451.3, 4, 5 and 6 specify the multi-drop, mixed mode, wireless, and CANopen-based protocols for communications topology, respectively. A general model for transducer data, control, timing, configuration, and calibration is defined. TEDS provides descriptive information about the sensors in order to enable self-identification and self-description of sensors and actuators, ease sensor system configuration, reduce human error in manual system configuration, simplify field installation, upgrade, and maintenance of sensors by simple “plug and play” of devices to instruments and networks. Since various sensors are characterized by different calibration schemes, it is sometimes difficult to interpret consistently and accurately the data collected from them. In the meantime, SensorML consists of OGC’s GML and SWE (Sensor Web Enablement) based on XML [3].

IP tier consists of IP networks – wireless or wired. Since all wired or wireless networks evolve to the all-IP network, we consider all IP networks for IP tier as an infrastructure for open system distributed architecture. There are many wireless networks such as Wi-Fi and WiMAX, for example. IEEE 1451.1 specifies NCAP (Network Capable Application Processor) information model.

NM tier consists of control units, databases, GUI, and applications. Mostly services are deployed in conjunction with sensor nodes in SN tier and network element in IP tier. For this tier, recent advances of technology such as ontology [6], RIA (Rich Internet Architecture), Web 2.0 and AJAX (Asynchronous JavaScript and XML), to mention a few, can be utilized.

The rest of this paper is organized as follows: Section 2 describes the components of the USN SN tier and Section 3 highlights IP networks of IP tier. Section 4 describes the architecture and services of the NM tier. Section 5 presents the proposed scheme for USN-based architecture, and potential applications. In Section VI, conclusions and recommending directions for future work are discussed.

II. SN TIER

In this section, we provide a general overview of existing works and standards, particularly related to traffic management. Mostly, the sensor node consists of three components: sensing device, communication module and power supply module.

A. Sensing Devices

As shown in Fig. 3, a burial type implementation of ORSN is illustrated. ORSN utilizes multifunctional sensors which consist of three-axis AMR, physical and pressure sensors listed in Tables I and II. The three-axis AMR is used for vehicle detection, classification and speed measurement while other sensors are used for calibration and enhancement of measurements.



Figure 3. ORSN (On-Road Sensor Node)

TABLE I
SENSOR MEASUREMENT APPROACHES [14]

Property	Specification	
	Measure	Principle
Physical	Pressure Temperature Humidity Flow	Piezoresistive Capacitive Capacitive, resistive Pressure change, thermistor
Motion	Position Velocity Angular velocity Acceleration	E-mag, GPS, contact sensor Doppler, Hall effect, optoelectronic Optical encoder Piezoresistive, piezoelectric, optical fiber
Contact	Strain Force Torque Slip Vibration	Piezoresistive Piezoresistive, piezoelectric Piezoresistive, optoelectronic Dual torque Piezoresistive, piezoelectric, optical fiber, sound, ultrasound
Pressure	Tactile/contact Proximity Distance/range Motion	Contact switch, capacitive Hall effect, capacitive, magnetic, seismic, acoustic, RF E-mag(sonar, radar, lidar), magnetic, tunneling E-mag, IR, acoustic, seismic(vibration)
Vehicle Traffic	Detection Classification Speed	AMR, inductive loop coil AMR, inductive loop coil AMR, inductive loop coil

Magnetic and electromagnetic sensors do not require direct physical contact and are useful for detecting proximity effects [11]. The Hall Effect, discovered by Edwin Hall in 1879, relies on the fact that Lorentz Force deflects flowing charge carriers in a direction perpendicular to both their direction of flow and an applied magnetic field. Magnetoresistive effect is a related phenomenon depending on the fact that the conductivity varies as the square of the applied flux density. Magnetic Field sensors can be used to detect the remote presence of metallic object. Eddy-Current Sensors use magnetic probe coils to detect defects in metallic structures such as pipes. Earth has magnetic force, and the direction and the strength of it depends on the position. We

need the earth magnetic field method to detect vehicles on road. Thus, the ORSN shown in Fig. 3 applied AMR (Anisotropic Magnetoresistive) of which the detectable field range is larger than that of the earth magnetic field. In Table II, the range of magnetic sensor techniques are shown on the unit, gauss and AMR is ranged from 10^6 to 10^1 gauss.

TABLE 2
MAGNETIC SENSOR TECHNOLOGY FIELD RANGES [9]

Magnetic Sensor Technology	Detectable Field Range (gauss) *		Remark
	Min	Max	
Squid	10^{-10}	10^{-5}	
Fiber-Optic	10^{-6}	10^{-1}	
Optically Pumped	10^{-8}	10^0	
Nuclear Procession	10^{-7}	10^2	
Search-Coil	10^{-8}	10^{10}	
Earth's Field	10^{-4}	10^0	
Anisotropic Magnetoresistive	10^{-6}	10^{-1}	ORSN uses this sensor.
Flux-Gate	10^{-6}	10^2	
Magnetotransistor	10^{-1}	10^4	
Magnetodiode	10^{-1}	10^4	
Magneto-Optical Sensor	10^0	10^{10}	
Giant Magnetoresistive	10^{-1}	10^8	
Hall-Effect Sensor	10^2	10^6	

As shown in Table III, ORSN approach offers a very attractive, low-cost alternative to loop detector (inductive loop) for traffic management since it provides ease of installation and flexibility of deployment.

TABLE I
COMPARISON OF TRAFFIC MEASUREMENT METHODS

Method	Pros and Cons	
	Pros	Cons
ORSN	1. Accurate vehicle detection, classification and speed measurement 2. Fast and easy installation (small case for pavement mounting) 3. Robust and configurable detection algorithms 4. Low-power radio	1. Not widely accepted like loop detection method.
Loop Detector	1. Currently the standard: loop coils are buried under roads to detect the change of current. 2. lasts years	1. Closing lane to cut loops in pavement. 2. Requires a large area of installation, resulting in longer installation time and bigger cost.

B. Communication Module

Two way communications for SN tier and IP tier are a highly desirable feature. Most widely used standards can be listed below:

IEEE 802.15.4 LR-WPAN. The IEEE 802.15.4-2003 standard has been superseded by the publication of IEEE 802.15.4-2006. Current version is useful for fast and easy networking of measurement devices in the un-licensed spectrum in 2400-2483.5 MHz (worldwide), 902-928 MHz

(40kbps in North America), 868-868.6 MHz (20kbps in Europe).

Zigbee Standard. Since the IEEE 802.15.4 standard only defines two layers: PHY and MAC without specifying the upper layers, the Zigbee standard is developed on top of the IEEE 802.15.4 standard by specifying network and application layers in 2006 [20].

Software power management techniques can greatly decrease the power consumed by RF sensor nodes. TDMA is especially useful for power conservation, since a node can power down or 'sleep' between its assigned time slots, waking up in time to receive and transmit messages. The required transmission power increases as the square of the distance between the source and destination. Therefore, multiple short message transmission hops require less power than one long hop. In fact, if the distance between source and destination is R, the power required for single-hop transmission is proportional to the square of R. leading a strong argument in favor of distributed architecture with multiple nodes.

C. Power Supply Module

Mostly, the deployment of sensor nodes operating on limited power capacity of their batteries is assumed.

A current topic of research is active power control, whereby each node cooperated with all other nodes in selecting its individual transmission power level [1]. This is a decentralized feedback control problem. Congestion is increased if any node uses too much power, but each node must select a large enough transmission range that the network remains connected.

A new architecture for wireless power and data telemetry that recovers power and a system clock from a weak incident RF signal can be found in [15]. A high-efficiency RF-DC converter generates a 3-Vdc supply for the system from a -12.3 dBm incident RF signal, gathered by a commercial 50-ohm antenna.

To ensure long-lasting SNs, the SN must utilize ambient energy. Although several approaches exist [21][22], more efforts for research and development will be required to make them practical and economical.

III. IP TIER

In this section, the IP tier will be discussed in conjunction with USN common features. Even though sensor nodes may not have IP address, IP tier is assumed to consist of IP networks. The communications between two tiers are generally implemented via IP networks. Because of the advantages of hierarchy architecture that is effective for data aggregation (light weighting) and scalability, we consider the USN's management architecture centralized and hierarchical.

A. IEEE 802.11 Wireless Local Area Network(WLAN)

IEEE ratified the IEEE 802.11 specification in 1997 as a standard for WLAN. Current versions of 802.11b and

802.11a/g support transmission up to 11Mbps, and 54 Mbps, respectively. Wi-Fi, as it is known, is useful for fast and easy networking of measurement devices in the unlicensed spectrum in 2.4, 5.4 and 5.8 GHz.

B. IEEE 802.16 Wireless Metropolitan Area Network (WMAN)

IEEE ratified the IEEE 802.16d specification in 2004 as a standard for WMAN, and IEEE 802.16e in 2005. WiMAX, as it is known, is useful for fast and easy networking of measurement devices in both unlicensed spectrum in 2.4, 5.4 and 5.8 GHz; and licensed spectrum from 2 – 11GHz.

C. Other Available Wireless Standards for USN

Others may include WCDMA (Wideband Code Division Multiple Access), HSDPA (High-Speed Downlink Packet Access), and IMT-Advanced (IEEE 802.16m and LTE (Long-Term Evolution)), for example.

D. Network Topology

There are many network topologies: fully connected, mesh, star, ring, and bus [14].

E. Timestamp Reference

The IP tier should provide a common clock for the time stamp that each sensor transmits with every detection event. Since IP connectivity is provided, network elements of this tier can lock their internal reference clock to timing signals generated by the NIST (National Institute of Science and Technology), allowing the timestamps to be absolutely accurate within one millisecond. Data collected from many different IP-connected network elements installed in widely disparate locations can thus all be tied to the same absolute timebase regardless of their location, allowing data from many geographically dispersed sensors to be meaningfully compared. A unified, near-real-time synchronous view of a large transportation network should thus be implemented.

IV. SERVICES OF NM TIER

In this section we discuss the USN services which can be provided in this tier.

A. NM Tier Architecture

Client-server architecture has become popular in the late 1980's with the replacement of large mainframe computers by networks of personal computers. Application programs for distributed computing environments are essentially divided into two parts: the client or front end, and the server or back end. The user's PC is the client and more powerful server machines interface to the network. Fig.4 shows NM tier architecture consisting of important components such as data acquisition, control of sensors, statistics machine, GIS (Geographic Information System), Web and DB (Database) servers.

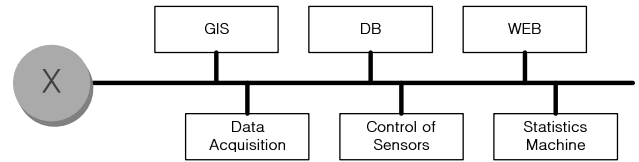


Figure 4. NM Tier Architecture

B. Data Acquisition, Control of Sensors and Statistics Machine

Vehicle event data processing capability provide per-vehicle data that offers considerable flexibility in its usage. Basically, the events detected by the sensor node reflect the presence or absence of a vehicle as a function of time resulting in:

- The presence or absence of a vehicle as a function of time
- A time record of vehicle detection which can be then processed to yield values for the vehicle volume (the number of vehicles observed per unit time).
- Lane occupancy: the fraction of time that vehicles are present over the sensor over a specific averaging time.
- Headway: the time between the front edge of successive vehicles
- Gap: the time between the rear and front edges of successive vehicles.

1) *Historical Data:* NM tier should provide an archive database to store and deliver vehicle event data, whether it is raw detection event data for later processing by network users or status and performance data of the components and overall network. Archived historical data allows various analyses and processing algorithms to be performed to generate detailed reports without each user independently maintaining the data. Raw vehicle event data can be archived into a daily flat file database that can be accessed over the Web, allowing Java scripting to generate customized reports. Similarly, application software should collect detailed data concerning the status of components over a range of selectable time interval (15 minutes, 1 hour, 1 day, 1 week, 1 month or 1 year) that can be archived by and accessed via the NMS (Network Management System). In this paper, we propose one measurement interval of 15 minutes, dividing one day into 96 intervals.

2) *Statistical Analysis of Archived Data:* An application should either archive and host vehicle detection statistics as deployed in SN tier or IP tier, shown in Table IV. As with archived event data, the statistics should be allowed to be accessed over the Web with Java scripting for customized data.

TABLE 4
Vehicle Measurements by Quarter Hour

Dir.	Lane	Type	Current Hour				...	23th Hour				Total
			0	1	3	4		92	93	94	95	
Up	1	Moto	1	1	1	1	...	1	1	1	1	96
		Car	48	48	48	49	...	48	48	48	49	4,632
		SUV	13	13	13	14	...	13	13	13	14	1,272
		Truck	4	4	5	5	...	4	4	5	5	432
		Bus	1	1	1	2	...	1	1	1	2	144
		Others	1	2	4	5	...	1	2	4	5	1,424
		Total	68	70	72	77	...	68	70	72	77	8,000
	2	Moto	1	1	1	1	...	1	1	1	1	96
		Car	48	48	48	49	...	48	48	48	49	4,632
		SUV	13	13	13	14	...	13	13	13	14	1,272
		Truck	4	4	5	5	...	4	4	5	5	432
		Bus	1	1	1	2	...	1	1	1	2	144
		Others	1	2	4	5	...	1	2	4	5	1,424
		Total	68	70	72	77	...	68	70	72	77	8,000
Down	1	Moto	1	1	1	1	...	1	1	1	1	96
		Car	48	48	48	49	...	48	48	48	49	4,632
		SUV	13	13	13	14	...	13	13	13	14	1,272
		Truck	4	4	5	5	...	4	4	5	5	432
		Bus	1	1	1	2	...	1	1	1	2	144
		Others	1	2	4	5	...	1	2	4	5	1,424
		Total	68	70	72	77	...	68	70	72	77	8,000
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		Truck	4	4	5	5	...	4	4	5	5	432
		Bus	1	1	1	2	...	1	1	1	2	144
		Others	1	2	4	5	...	1	2	4	5	1,424
		Total	68	70	72	77	...	68	70	72	77	8,000

All vehicles are counted and classified into Moto (motorcycle), car (passenger), SUV (Wagon+SUV+Van), Truck (pick-up+Truck) and bus. One interval of 15 minutes is used to divide one day into 96 intervals.

3) *Representative Reports – Network Statistics and Diagnostics*: An HTML page, comma-separated value (CSV) file, Excel file or as graph in PNG format should be presented for users. For a given time period and summarized over the specified time interval, per-lane values include volume (count), occupancy (as a percentage), median and average speed (kilometers per hour). Per-vehicle data should also be presented, providing time-stamped values of the measured speed (in kilometers per hour), length (in meters), and gaps (in seconds) accompanied by a lane identifier.

4) Measurement Parameters

Measurement parameters can be summarized as follows:

- *Count*: the total number of vehicles counted over the interval in terms of Moto (motorcycle), car (passenger), SUV (Wagon+SUV+Van), Truck (pick-up+Truck) and bus.
- *RSSI Average and Standard Deviation*: the average, in dBm, and the standard deviation of the received signal strength indicator calculated for any RF links.

- *Speed Average and Median*: The average and median, in kilometers per hour, of the speed as calculated for the trailing sensor of a sensor pair installed in a traffic lane.

V. PROPOSED KEY ELEMENTS AND APPLICATION AREAS

In this section we propose key elements for each tier in conjunction with our USN-based architecture: centralized and hierarchical, and specific application areas for ITS (Intelligent Transportation System) and U-City.

A. Key Elements at Each Tier

Since our proposed USN-based architecture is central and hierarchical, key elements for each tier are identified as listed in Table V.

TABLE 5
KEY ELEMENTS AT EACH LAYER

Key Elements	Specification		
	SN	IP	NM
ID	MAC/IP address	IP address	IP address
Location	GPS coordinates (KML)	GPS coordinates (KML)	GPS coordinates (KML)
Timestamp	64 bits	64 bits	64 bits
Measures	measurements obtained from sensors	Raw and processed data	Raw and processed data
Configuration	Configuration data	Configuration data	Configuration data
Calibration	Calibration data		Calibration data
Messages	Response Unsolicited	Command Response	Command Response
Timestamp reference		NIST	NIST

Each network element must be identified uniquely since our architecture is central and hierarchical. The unique identification (ID) for each sensor node must be used as ISO Layer 2 MAC address controlled by Zigbee Alliance. The unique ID for each network element in IP tier must be used MAC addressed controlled by IEEE and/or IP address (IPv4 or IPv6).

Location information can be easily represented using GPS (Global Positioning System), and thus GPS coordinates should be represented in terms of KML (Keyhole Markup Language) [17]. Timestamp is proposed to have two 32-bit words: the first 32 bits for seconds and the second one for microseconds to represent the time for a specific event. Measures represent either raw data collected directly from sensors or computed information listed in Section IV.B.

Configuration data and calibration data are to be stored both in SN and NM tiers to assure the consistent measurement. Messages include command and response, and unsolicited message from SNs. Since all network elements in IP and NM are connected to Internet, the timestamp reference is to be based on the one that NIST provides.

B. ITS and U-City Application Areas

- Incident surveillance and detection for arterial, freeway, and incident management systems enabled by traffic

surveillance and detection technologies, such as sensors or cameras monitoring traffic flow.

- Accurate and timely road weather information such as icing helps maintenance managers react proactively before problems arise, improving safety while reducing costs, by facilitating the sharing of information about hazardous road conditions.
- Ramp Metering uses traffic signals at on-ramps to control the rate of vehicles entering the freeway to optimize freeway flow and minimize congestion.
- Parking Management most commonly deployed in urban centers or at modal transfer points such as airports and outlying transit stations to monitor the availability of parking and disseminate the information to drivers, reducing traveler frustration and traffic congestion associated with searching for parking spaces.
- Traveler Information and Dynamic Message Signs (DMS) are traffic control devices used for traffic warning, regulation, routing and management, and are intended to affect the behavior of drivers by providing real-time, traffic-related information such as traffic conditions, incidents, weather, construction, safety, and special events.
- Traffic signal optimization and retiming ranks as one of the most cost-effective urban transportation improvement actions, increasing mobility, reducing fuel consumption, and improving environmental quality [13].

VI. Conclusions and Future work

USN is an exciting area of research and development for traffic management requiring automatic search, archiving, retrieval and processing of sensor data. For USN, this paper attempted to describe the concept and relationship of USN tiers each other. We plan to publish specific implementations for each tier in the near future. As for the future work, we are considering the inclusion of energy harvesting technology. Moreover, we plan to test the effectiveness of this approach by quantitatively measuring the improvement in traffic measurement. Our effort will be directed towards enabling USN services to automatically access and process sensing and sensor data.

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REFERENCES

- [1] I.F. Akyildiz et al., "A Survey on Sensor Networks," *IEEE Com. Mag.*, vol. 40, no. 8, August 2002, pp. 102-114.
- [2] O. B. Akab et al., "Wireless Passive Sensor Networks," *IEEE Com. Mag.*, pp. 92-99, 2009.
- [3] IEEE P1451 Project official website, <http://ieee1451.nist.gov>, 2009.
- [4] M. Botts, A. Robin, "OpenGIS Sensor Model Language (sensorML) Implementation Specification," <http://www.opengeospatial.org>, 2009.
- [5] Josie Wernecke, *The KML Handbook*, Addison-Wesley, 2009.
- [6] J.H. Kim et al., "Building a Service-Oriented Ontology for Wireless Sensor Networks," *Seventh IEEE/ACIS International Conferences on Computer and Information Science*, pp. 649654, 2008.
- [7] F. Kocer et al., "Wireless, Remotely Powered Telemetry in 0.25μm CMOS," *Proc. IEEE RFIC*, pp. 339-42, 2004.
- [8] C. Chong, S. P. Kumar, *Sensor Networks: Evolution, Opportunities, and Challenges*, *Proceedings of the IEEE*, 91(8):1247-1256, Aug. 2003.
- [9] M.J. Caruso, et al., "Vehicle Detection and Compass Applications using AMR Magnetic Sensors," Honeywell, www.ssec.honeywell.com.
- [10] J.E. Lenz, "A Review of Magnetic Sensors," *Proceedings of the IEEE*, vol. 78, no. 6, pp. 973-989, June 1990.
- [11] G.T.A. Kovacs, *Micromachined Transducers Sourcebook*, McGraw-Hill, Boston, 1998.
- [12] <http://www.path.berkeley.edu/PATH/Research/currentsafety.html>.
- [13] <http://www.its.dot.gov/cicas>
- [14] F.L. Lewis, "Wireless Sensor Networks," To appear in *Smart Environments: Technologies, Protocols, and Applications* ed. D.J. Cook et al (John Wiley), University of Texas, 2004.
- [15] F. Kocer et al., "A New Transponder Architecture With On-Chip ADC for Long-Range Telemetry Application," *IEEE J. of Solid-State Circuits*, vol. 41, No. 5, pp. 1142-1148, May 2006.
- [16] C. Eklund, et al., *WirelessMAN*, IEEE Press, 2006.
- [17] J. Wernecke, *The KML Handbook*, Addison-Wiley, 2009.
- [18] H. Karl and A. Willing, *Protocols and Architectures for Wireless Sensor Networks*, John Wiley & Sons, 2007.
- [19] J. Zheng and A. Jamalipour, *Wireless Sensor Networks: A Networking Perspective*, IEEE, 2009.
- [20] Zigbee Alliance, "Zigbee Specifications," December 2006.
- [21] J.M. Rabaey, et. al., "PicoRadio Supports Ad Hoc Ultra-Low Power Wireless Networking," *IEEE Computer*, 33(7):4248, 2000.
- [22] S. Roundy, *Energy Scavenging for Wireless Sensor Networks*, Kluwer Academic Publishers, 2003.