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# An Analysis on Animal Tracking System using Wireless Sensors

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***Abstract*— A sensor is a device for detecting and signalling a changing condition. The "changing condition" is simply the presence or absence of an object or material (discrete sensing). It can also be a measurable quantity like a change in distance, size or colour (analog sensing). This information, or the sensor's output, is the basis for the monitoring and control of a manufacturing process. In a wireless sensor network (WSN), event detection and tracking are significant for several applications. Wireless sensor networks (WSNs) have gained worldwide attention in recent years, particularly with the proliferation in Micro-Electro-Mechanical Systems (MEMS) technology which has facilitated the development of smart sensors. These sensors are small, with limited processing and computing resources, and they are inexpensive compared to traditional sensors. WSNs have great potential for many applications in scenarios such as military target tracking and surveillance, natural disaster relief, biomedical health monitoring and hazardous environment exploration and seismic sensing. These sensor nodes can sense, measure, and gather information from the environment and, based on some local decision process, they can transmit the sensed data to the user. The goal of our survey is to present a comprehensive review of the recent literature on sensor networks especially in Animal Tracking.***

***Keywords*— sensor, networks, analog sensing, computing, seismic sensing**

## I. INTRODUCTION

Sensor applications in multiple fields such as smart power grids, smart buildings and smart industrial process control significantly contribute to more efficient use of resources and thus a reduction of greenhouse gas emissions and other sources of pollution. Sensors measure multiple physical properties and include electronic sensors, biosensors, and chemical sensors. Wireless sensor and actuator networks (WSANs) are networks of nodes that sense and potentially also control their environment [1]. They communicate the information through wireless links "enabling interaction between people or computers and the surrounding environment". The data gathered by the different nodes is sent to a sink which either uses the data locally, through for example actuators, or which "is connected to other networks (e.g. the Internet) through a gateway. Sensor nodes are the simplest devices in the network. As their number is usually larger than the number of actuators or sinks, they have to be cheap. The other devices are more complex because of the functionalities they have to provide. Figure 1 illustrates a typical WSAN.

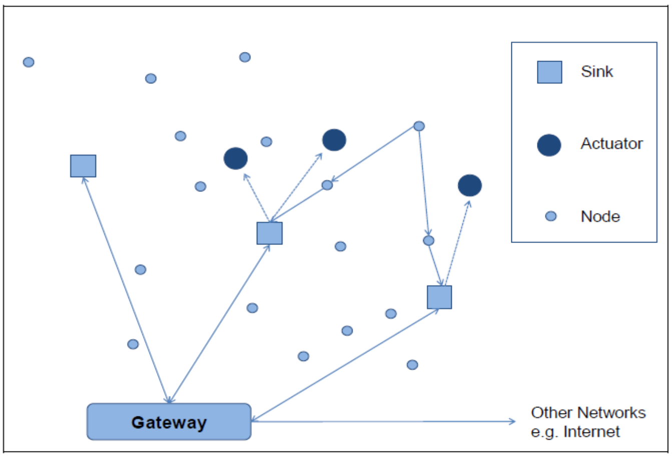


Fig. 1 Typical wireless sensor and actuator network

A sensor node typically consists of five main parts: one or more sensors gather data from the environment. The central unit in the form of a microprocessor manages the tasks. A transceiver communicates with the environment and a memory is used to store temporary data or data generated during processing. The battery supplies all parts with energy (*Figure 2*). To assure a sufficiently long network lifetime, energy efficiency in all parts of the network is crucial. Due to this need, data processing tasks are often spread over the network, i.e. nodes co-operate in transmitting data to the sinks. Although most sensors have a traditional battery there is some early stage research on the production of sensors without batteries, using similar technologies to passive RFID chips without batteries [2].

 

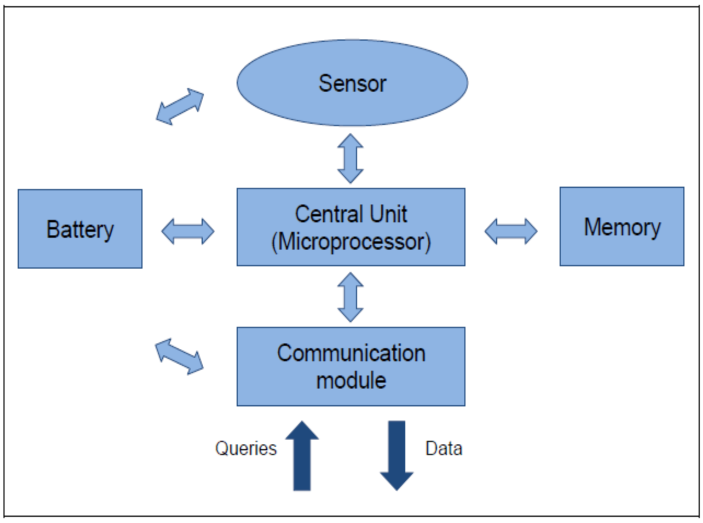


Fig. 2 Architecture of a sensor node

Transportation infrastructures and other linear infrastructures are known to potentially have a significant negative impact on animal wildlife [3]. Their effect is twofold. First, they reduce the size of species populations as a consequence of road kills and the so-called edge effect, i.e., the reduction of the population density in areas close to roads (due to animal aversion to the road system, human activities, traffic noise or visual stimuli among others). Second, the movement of individuals between populations fragmented by roads and other infrastructures may be reduced. This harmful effect, known as barrier effect, may happen as a result of a physical impediment or, in the case of species with a more complex nervous system, of a behavioural aversion. In any case, the generated division may have demographical and genetic implications on the affected population. This is especially important for highly endangered species with a reduced number of individuals, such as the Iberian lynx, where inbreeding prompted by isolation may compromise the survival of the species. In order to preserve wildlife populations, local exchange of animals must be allowed. Sometimes, this could be achieved thanks to the use that some species make of drainage structures and other passages not specifically designed for fauna [4,5] and, less frequently (because of their limited number), of fauna specific passages [6]. This paper presents a survey on the usage of wireless sensor in animal tracking. The types of sensors are portrayed in Section II, Major applications of sensors are depicted in Section III. Reviews of various authors are presented in Section IV. Finally Section V concludes the paper.

## II. TYPES OF SENSOR NETWORKS

Current WSNs are deployed on land, underground, and underwater. Depending on the environment, a sensor network faces different challenges and constraints. There are five types of WSNs: terrestrial WSN, underground WSN, underwater WSN, multi-media WSN, and mobile WSN. Terrestrial WSNs typically consist of hundreds to thousands of inexpensive wireless sensor nodes deployed in a given area, either in an ad hoc or in a pre-planned manner. In ad hoc deployment, sensor nodes can be dropped from a plane and randomly placed into the target area. In pre-planned deployment, there is grid placement, optimal placement, 2-d and 3-d placement models. In a terrestrial WSN [7], reliable communication in a dense environment is very important. Terrestrial sensor nodes must be able to effectively communicate data back to the base station. While battery power is limited and may not be rechargeable, terrestrial sensor nodes however can be equipped with a secondary power source such as solar cells. In any case, it is important for sensor nodes to conserve energy. For a terrestrial WSN, energy can be conserved with multi-hop optimal routing, short transmission range, in-network data aggregation, eliminating data redundancy, minimizing delays, and using low duty-cycle operations.

Underground WSNs [8] consist of a number of sensor nodes buried underground or in a cave or mine used to monitor underground conditions. Additional sink nodes are located above ground to relay information from the sensor nodes to the base station. An underground WSN is more expensive than a terrestrial WSN in terms of equipment, deployment, and maintenance. Underground sensor nodes are expensive because appropriate equipment parts must be selected to ensure reliable communication through soil, rocks, water, and other mineral contents. The underground environment makes wireless communication a challenge due to signal losses and high levels of attenuation. Unlike terrestrial WSNs, the deployment of an underground WSN requires careful planning and energy and cost considerations. Energy is an important concern in underground WSNs. Like terrestrial WSN, underground sensor nodes are equipped with a limited battery power and once deployed into the ground, it is difficult to recharge or replace a sensor node's battery. As before, a key objective is to conserve energy in order to increase the lifetime of network which can be achieved by implementing efficient communication protocol.

Underwater WSNs [9] consist of a number of sensor nodes and vehicles deployed underwater. As opposite to terrestrial WSNs, underwater sensor nodes are more expensive and fewer sensor nodes are deployed. Autonomous underwater vehicles are used for exploration or gathering data from sensor nodes. Compared to a dense deployment of sensor nodes in a terrestrial WSN, a sparse deployment of sensor nodes is placed underwater. Typical underwater wireless communications are established through transmission of acoustic waves. A challenge in underwater acoustic communication is the limited bandwidth, long propagation delay, and signal fading issue. Another challenge is sensor node failure due to environmental conditions. Underwater sensor nodes must be able to self-configure and adapt to harsh ocean environment. Underwater sensor nodes are equipped with a limited battery which cannot be replaced or recharged. The issue of energy conservation for underwater WSNs involves developing efficient underwater communication and networking techniques.

Multi-media WSNs [10] have been proposed to enable monitoring and tracking of events in the form of multimedia such as video, audio, and imaging. Multi-media WSNs consist of a number of low cost sensor nodes equipped with cameras and microphones. These sensor nodes interconnect with each other over a wireless connection for data retrieval, process, correlation, and compression. Multi-media sensor nodes are deployed in a pre-planned manner into the environment to guarantee coverage. Challenges in multi-media WSN include high bandwidth demand, high energy consumption, quality of service (QoS) provisioning, data processing and compressing techniques, and cross-layer design. Multi-media content such as a video stream requires high bandwidth in order for the content to be delivered. As a result, high data rate leads to high energy consumption. Transmission techniques that support high bandwidth and low energy consumption have to be developed. QoS provisioning is a challenging task in a multi-media WSN due to the variable delay and variable channel capacity. It is important that a certain level of QoS must be achieved for reliable content delivery. In-network processing, filtering, and compression can significantly improve network performance in terms of filtering and extracting redundant information and merging contents. Similarly, cross-layer interaction among the layers can improve the processing and the delivery process.

Mobile WSNs consist of a collection of sensor nodes that can move on their own and interact with the physical environment [11]. Mobile nodes have the ability sense, compute, and communicate like static nodes. A key difference is mobile nodes have the ability to reposition and organize itself in the network. A mobile WSN can start off with some initial deployment and nodes can then spread out to gather information. Information gathered by a mobile node can be communicated to another mobile node when they are within range of each other. Another key difference is data distribution. In a static WSN, data can be distributed using fixed routing or flooding while dynamic routing is used in a mobile WSN. Challenges in mobile WSN include deployment, localization, self-organization, navigation and control, coverage, energy, maintenance, and data process. Mobile WSN applications include but are not limited to environment monitoring, target tracking, search and rescue, and real-time monitoring of hazardous material. For environmental monitoring in disaster areas, manual deployment might not be possible. With mobile sensor nodes, they can move to areas of events after deployment to provide the required coverage. In military surveillance and tracking, mobile sensor nodes can collaborate and make decisions based on the target. Mobile sensor nodes can achieve a higher degree of coverage and connectivity compared to static sensor nodes. In the presence of obstacles in the field, mobile sensor nodes can plan ahead and move appropriately to obstructed regions to increase target exposure.

## III. APPLICATIONS OF SENSORS

Sensors applications can be classified into two categories: monitoring and tracking. Monitoring applications include indoor/outdoor environmental monitoring, health and wellness monitoring, power monitoring, inventory location monitoring, factory and process automation, and seismic and structural monitoring. Tracking applications include tracking objects, animals, humans, and vehicles. While there are many different applications, below we describe a few example applications that have been deployed and tested in the real environment.

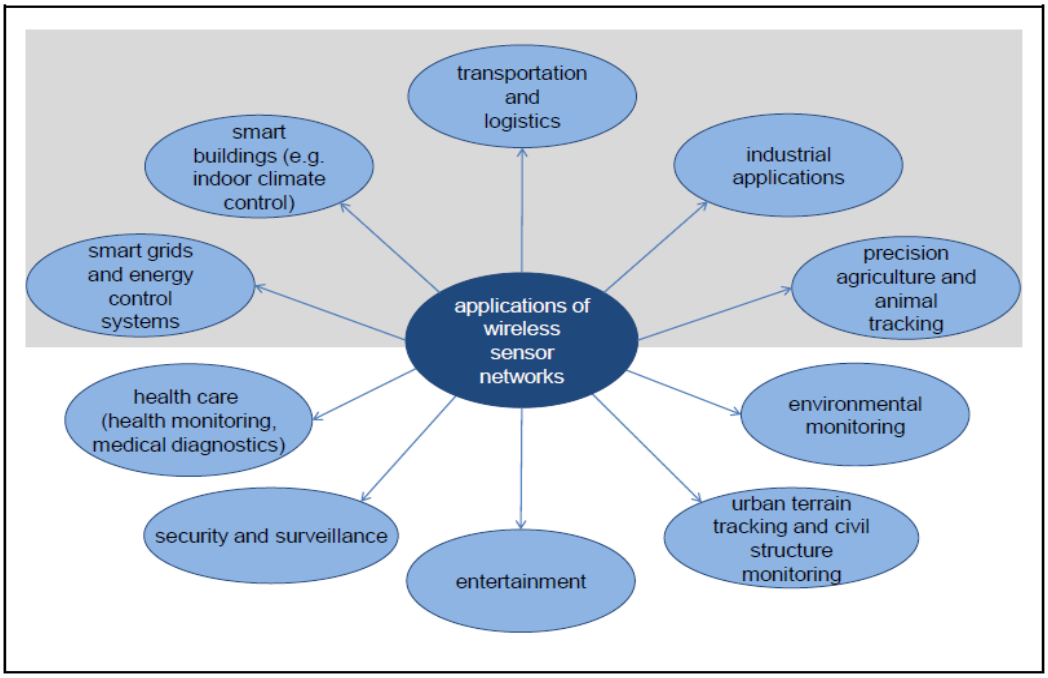


Fig. 3 Fields of application of wireless sensor networks

 

### *A. Smart grids and energy control systems*

The smart grid is an innovation that has the potential to revolutionise the transmission, distribution and conservation of energy. It employs digital technology to improve transparency and to increase reliability as well as efficiency. ICTs and especially sensors and sensor networks play a major role in turning traditional grids into smart grids [2].

The smart grid is characterised by:

- More efficient energy routing and thus an optimised energy usage, a reduction of the need for excess capacity and increased power quality and security
- Better monitoring and control of energy and grid components
- Improved data capture and thus an improved outage management
- Two-way flow of electricity and real-time information allowing for the incorporation of green energy sources, demand-side management and real-time market transactions
- Highly automated, responsive and self-healing energy network with seamless interfaces between all parts of the grid.

New and advanced grid components allow for a more efficient energy supply, better reliability and availability of power. Components include, for example, advanced conductors and superconductors, improved electric storage components, new materials, advanced power electronics as well as distributed energy generation. Superconductors are used in multiple devices along the grid such as cables, storage devices, motors and transformers. Smart devices and smart metering include sensors and sensor networks [12]. Sensors are used at multiple places along the grid, e.g. at transformers and substations or at customers' homes. They play an outstanding role in the area of remote monitoring and they enable demand-side management and thus new business processes such as real-time pricing. Information provided by smart sensors and smart meters needs to be transmitted via a communication backbone. This backbone is characterized by a high-speed and two-way flow of information. Different communication applications and technologies form the communication backbone.

### *B. Programmes for decision support and human interfaces*

Another key component area of the smart grids comprises programmes for decision support and human interfaces. The data volume in smart grids will increase tremendously compared to traditional grids. Tools and applications include systems based on artificial intelligence and semi-autonomous agent software, visualisation technologies, alerting tools, advanced control and performance review applications [13] as well as data and simulation applications and geospatial information systems (GIS). Artificial intelligence methods as well as semi-autonomous agent software, for example, contribute to minimise data volume "and to create a format most effective for user comprehension" whereby the software has features that learn from input and adapts [2]. New methods of visualisation enable integration of data from different sources, providing information on the status of the grid and power quality and rapid information on instabilities and outages. Finally, geographic information systems provide geographic, spatial and location information and tailor this information to the specific requirements for decision support systems along the smart grid.

### *C. Smart buildings*

Smart buildings rely on a set of technologies that enhance energy-efficiency and user comfort as well as the monitoring and safety of the buildings. Technologies include new, efficient building materials as well as information and communication technologies (ICTs). ICTs [14] are used in: i) building management systems which monitor heating, lighting and ventilation, ii) software packages which automatically switch off devices such as computers and monitors when offices are empty and iii) security and access systems. These ICT systems can be both found at household and office level. Sensors and sensor networks are used in multiple smart building applications [2]. These include:

- Heating, ventilation, and air conditioning systems (HVAC)
- Lightning
- Shading
- Air quality and window control
- Systems switching off devices
- Metering (covered in the section on smart grids)
- Standard household applications (e.g. televisions, washing machines)
- Security and safety (access control).

### *D. Transport and logistics*

An intelligent transportation system (ITS) can be defined as "the application of advanced and emerging technologies (computers, sensors, control, communications, and electronic devices) in transportation to save lives, time, money, energy and the environment". The ITS can be categorised into intelligent infrastructure and intelligent vehicles. Figure 4 gives an overview of different ITS applications for both intelligent infrastructure and intelligent vehicles as well as some examples for each application [2] . Many of these applications are based on sensors and sensor networks. In the field of intelligent infrastructure sensors in pavements are used for road traffic monitoring systems [15] to measure the intensity and fluidity of traffic (vehicle count sensors) and to provide information for traffic lights which are then controlled.

 

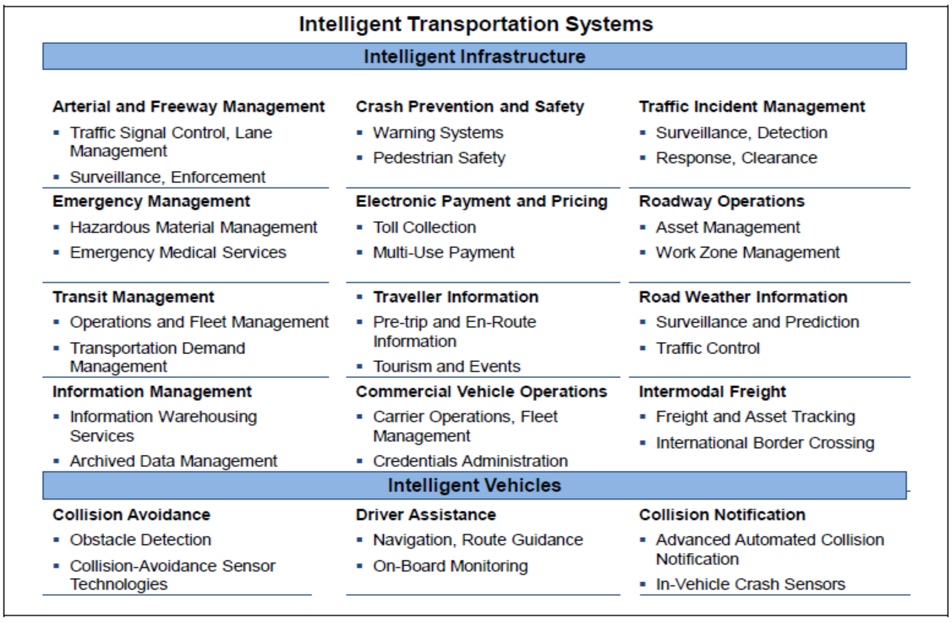


Fig. 4 Overview of ITS applications and examples

### *E. Industrial applications*

As the variety of different sensor applications is immense across industry sectors, this section describes three examples of industrial fields of application of sensors for: i) process control, ii) control of (physical) properties during the production process, and iii) equipment management and control. In the field of process control, sensor and sensor networks deliver real-time data on the production process and are able to detect in situ variations in the process. Control can thus be moved from the finished product after the completed production run to the production process itself. Faults can be minimised reducing the percentage of deficient and reprocessed goods [2]. In the field of the control of physical properties during production processes, sensors and sensor networks measure different properties as well as the amount of available resources during production. This allows them to be employed in an efficient and thus precise manner resulting in energy savings and the reduction of pollutants. In the third field, equipment management and control, sensors monitor the “health of machines” as well as their usage. Sensors installed on different machines measure physical properties such as temperature, pressure, humidity or vibrations [16]. The sensor nodes are able to communicate between each other and send data to the network where the data is processed. This intelligent maintenance monitors the functionality of parts and ensures that they are replaced based on a degradation assessment rather than on replacement rules.

### *F. Precision agriculture*

In precision agriculture, sensor networks can be used for: i) plant/crop monitoring, ii) soil monitoring, iii) climate monitoring and iv) insect-disease-weed monitoring. Overall, sensors and sensor networks significantly contribute to a more sustainable use of natural resources. However, development of sensors and sensor networks for precision agriculture is in an early stage and sensor applications tend to be expensive [17]. To date, farmers only take economic benefits into consideration when deciding on whether they should rely on precision agriculture. Governments can help farmers to recognise the environmental dimension by pointing out the economic benefits of improved soil and pasture quality as well as reduced applications of fertilisers and pesticides. Further, precision agriculture can be encouraged through technical assistance and conservation programmes.

## IV. DISCUSSIONS AND REVIEW

This section elaborates the review and discussions made by various authors on animal tracking using sensors. The discussions are presented below.

H. Yang and B. Sikdar proposed a feasible solution for distributed tracking of mobile targets using sensor networks: the Distributed Predictive Tracking algorithm [18]. DPT’s essential idea is to predict the target’s future location based on known previous locations. Since it is totally distributed, it scales well without having any central point of failure and can be easily extended to tracking in 3-dimension. While a simple first order linear predictor is used for the prediction, our simulation result show that the tracking performance is satisfactory overall, with particularly good performance at higher tracking resolutions. In addition, this algorithm is specifically aimed at minimizing the energy consumption of the network, a very important consideration for sensor networks. They are currently working on more complicated prediction algorithms in order to achieve lower miss rates for a given tracking resolution. Additional work can also be conducted on interpolation mechanisms at cluster heads when a sensor reports multiple targets simultaneously. The relationship between energy consumed and prediction accuracy also remains an open issue. Another possible direction of work is to accommodate mobile sensors. With mobile sensors the scenario complicates considerably and significantly different approaches to the solution may be necessary.

 

Vladimir Dyo, et al., discussed that, the increasing adoption of wireless sensor network technology [19] in a variety of applications, from agricultural to volcanic monitoring, has demonstrated their ability to gather data with unprecedented sensing capabilities and deliver it to a remote user. However, a key issue remains how to maintain these sensor network deployments over increasingly prolonged deployments. They presented the challenges that were faced in maintaining continual operation of an automated wildlife monitoring system over a one year period. This system analyzed the social co-location patterns of European badgers (Meles meles) residing in a dense woodland environment using a hybrid RFID-WSN approach. We describe the stages of the evolutionary development, from implementation, deployment and testing, to various iterations of software optimization, followed by hardware enhancements, which in turn triggered the need for further software optimization. They highlighted the main lessons learned: the need to factor in the maintenance costs while designing the system; to consider carefully software and hardware interactions; the importance of rapid prototyping for initial deployment and the need for continuous interaction with domain scientists which allows for unexpected optimizations.

The PetTracker system [20] discussed by Zhengming Tang, *et al.*, allows pet owners to log and track their pets throughout an indoor environment such as a house or apartment. Their current system uses motes with environment sensor boards attached to them. One of these motes is attached to the pet and used to track its location, activity and surrounding environment. The other motes are stationary and installed in different areas of the apartment. These stationary motes act as tracking nodes as well as report their own environmental conditions. One of the stationary motes is attached to a serial programming board so that it can forward all the sensor data coming in from the motes to a PC for analysis and visualization. The application can be networked and accessed from anywhere with an Internet connection.

Andrew Markham proposed Adaptive Social Hierarchy (ASH) [21] was designed that ranks nodes according to their resources, such as energy or connectivity. ASH provides a scalable and adaptable method for nodes to discover the role within the network, inspired by the way animals form linear dominance hierarchies through dyadic (pairwise) interactions. Three different methods of forming the social hierarchy are presented. In the first method, pairwise ASH, pairs of nodes exchange their attributes and their estimates of rank in a two-way exchange. Although this is a simple method of forming the hierarchy, it does not take advantage of the broadcast nature of the radio channel. In light of this, a one-way method of updating ranks is proposed and shown to be able to estimate the node ranks faster than pairwise ASH, due to multiple nodes receiving the same beacon. However, both methods are unable to form an accurate social hierarchy in a stationary network, due to a limited visibility horizon. Thus, this work has the potential to greatly enhance the understanding of animal behaviour, by providing large amounts of inter-related sensor data with minimal human input.

Ragnar S and Erlend T discussed that the location data can be made more useful by analyzing it to determine the future position of animals and optimize farming. Other sensors such as temperature and RFID [22] could be added to increase benefit for both farmers and scientists. Adding more sensors is not trivial and major challenges include energy consumption, cost, size and establishing a market. However these obstacles can be dealt with and the possibility of having mobile sensor platforms available to the public is intriguing.

Antonio-Javier G S, et al., proposed and studied a WSN based system for generic target (animal) tracking in the surrounding area of wildlife passages built to establish safe ways for animals to cross transportation infrastructures. In addition, it allows target identification through the use of video sensors connected to strategically deployed nodes. This deployment is designed on the basis of the IEEE 802.15.4 standard, but it increases the lifetime of the nodes through an appropriate scheduling. The system has been evaluated for the particular scenario of wildlife monitoring in passages across roads. For this purpose, different schemes have been simulated in order to find the most appropriate network operational parameters [23]. Moreover, a novel prototype, provided with motion detector sensors, has also been developed and its design feasibility demonstrated. Original software modules providing new functionalities have been implemented and included in this prototype. Finally, main performance evaluation results of the whole system are presented and discussed in depth.

E.S. Nadimi, et al., elaborated the problem of online monitoring of cows' presence and pasture time in an extended area covered by a strip of new grass using wireless sensor networks has been addressed. The total pasture time in the extended area was estimated by measuring the pasture time in a specific part of that area called the gateway connectivity area where sensor nodes mounted on the cows could communicate directly with a gateway [24]. Packet loss causes a node that was present in the connectivity range of the gateway frequently to be classified as an absent node. Applying a moving average window with optimal window length and optimal threshold could successfully compensate for packet loss between sensor nodes and gateway and thereby improve the result of classification as being within or outside communication range of the gateway.

Mac Schwager, et al., described an application of the K-means classification algorithm to categorize animal tracking data into various classes of behavior [25]. It was found that, even without explicit consideration of biological factors, the clustering algorithm repeatable resolved tracking data from cows into two groups corresponding to active and inactive periods. Furthermore, it is shown that this classification is robust to a large range of data sampling intervals. An adaptive data sampling algorithm is suggested for improving the efficiency of both energy and memory usage in animal tracking equipment.

Tim Wark, et al., designed and implemented an animal state estimation algorithm based on a state-machine mechanism for each animal. Autonomous actuation is performed based on the estimated states of an animal relative to other animals [26]. A simple, yet effective, wireless communication model has been proposed and implemented to achieve high delivery rates in mobile environments. We evaluated the performance of our design by both simulations and field experiments, which demonstrated the effectiveness of our autonomous animal control system.

Francine Lalooses, et al., analyze related work being done and describe how to track mobile sensor nodes. We then present an optimized recovery algorithm to track animals when they cannot be found [27]. Using simulations we show that our proposed algorithm is effective in extending the network lifetime and performing a quick recovery.

M. Basille, et al., looked into the spatiotemporal dimension of both animal tracking data sets and the dynamic environmental data that can be associated with them. Typically, these geographic layers derive from remote sensing measurements, commonly those collected by sensors deployed on earth-orbiting satellites, which can be updated on a monthly, weekly or even daily basis. The modeling potential for integrating these two levels of ecological complexity (animal movement and environmental variability) is huge and comes from the possibility to investigate processes as they build up, i.e. in a full dynamic framework. They also described how to integrate dynamic environmental data in the spatial database and join to animal locations one of the most used indices for ecological productivity and phenology, the normalised difference vegetation index (NDVI).

Pavan Sikka, et al., described some new wireless sensor hardware developed for pastoral and environmental applications. From their early experiments with Mote hardware, they were inspired to develop our devices with improved radio range, solar power capability, mechanical and electrical robustness, and with unique combinations of sensors. Here they described the design and evolution of a small family of devices: radio/processor board, a soil moisture sensor interface, and a single board multi-sensor unit for animal tracking experiments.

Ruwini Edirisinghe, et al., presented a comprehensive study of alternative solutions with deliberate consideration of the practical constraints. Wi-Alert [30] is a wireless sensor network based intrusion detection system proposed as the best alternative solution. This article reports the outcomes of the first two phases of ongoing developments of Wi-Alert. The first phase of experiments was conducted to investigate the multi-path effect reduction techniques at one site. In the next phase, experiments were conducted to verify the ability to detect elephants. The results obtained via the candidate techniques are compared. Both experiments confirm the feasibility of the prototype as a non-invasive method to detect elephants.

H. T. Kung and D. Vlah, applied sensor networks to the problem of tracking moving objects. They described a publish-and-subscribe tracking method, called Scalable Tracking Using Networked Sensors (STUN) [31], scales well to large numbers of sensors and moving objects by using hierarchy. We also describe a method, called drain-and-balance (DAB), for building efficient tracking hierarchies, computed from expected characteristics of the objects' movement patterns. DAB is shown to perform well by running it on 1D and 2D sensor network topologies, and comparing it to schemes which do not utilize movement information.

Jennifer Yick, Biswanath Mukherjee, Dipak Ghosal, has given the important applications such as remote environmental monitoring and target tracking. This has been enabled by the availability, particularly in recent years, of sensors that are smaller, cheaper, and intelligent. These sensors are equipped with wireless interfaces with which they can communicate with one another to form a network [11]. The design of a WSN depends significantly on the application, and it must consider factors such as the environment, the application's design objectives, cost, hardware, and system constraints. An overview of several new applications and then review the literature on various aspects of WSNs. The problems are classified into three different categories: (1) internal platform and underlying operating system, (2) communication protocol stack, and (3) network services, provisioning, and deployment. The major development in these three categories and outline new challenges are reviewed.

## V. CONCLUSIONS

Unlike other networks, WSNs are designed for specific applications. Applications include, but are not limited to, environmental monitoring, industrial machine monitoring, surveillance systems, and military target tracking. Each application differs in features and requirements. To support this diversity of applications, the development of new communication protocols, algorithms, designs, and services are needed. In a wireless sensor network (WSN), animal detection and tracking are significant for several applications. Typically, a sensor needs to continuously sense the attribute of the event of interest. An attribute is regarded as a user specified predicate on sensor data, which satisfies some properties (e.g., temperature greater than fifty). The majority of existing works primarily utilize sensors, equipped with the same sensing units to track the single event formed by only one attribute. However, animal detection and tracking are unlikely to be achieved if the event is formed by multiple attributes, any one of which is unable to be detected by the same kind of sensors (i.e., sensors with the same sensing units). Thus, sensors with various kinds of sensing units are necessary for such application. In this paper we have presented some of the specific applications of sensors and also with an overview of sensors in animal tracking given by many authors. Sensors have wide range of applications. Animal tracking is one of the major one. Several techniques proposed by various authors can be incorporated to develop an efficient animal tracking system.

## REFERENCES

[1] Verdone, R., D. Dardari, G. Mazzini and A. Conti, *Wireless Sensor and Actuator Networks*, Academic Press/Elsevier, London, 2008.

[2] Verena Weber, *Smart Sensor Networks: Technologies and Applications for Green Growth,* report presented by Organisation for Economic Co-Operation and Development (OECD), December 2009.

[3] Forman, R.; Alexander, L, *Roads and their major ecological effects*, Annu. Rev. Ecol. Syst. 1998, 29, 207-231.

[4] Yanes, M.; Velasco, J.M.; Suárez, F, *Permeability of roads and railways to vertebrates: The importance of culverts,* Biol. Conserv. 1995, 71, 217-222.

[5] Clevenger, A.P.; Chruszcz, B.; Gunson, K, *Drainage culverts as habitat linkages and factors affecting passage by mammals*, J Appl. Ecol. 2001, 38, 1340-1349.

[6] Antonio-Javier Garcia-Sanchez, et al., *Wireless Sensor Network Deployment for Monitoring Wildlife Passages*, Sensors, 10, 7236-7262; doi:10.3390/s100807236, ISSN 1424-8220, 2010.

[7] I.F. Akyildiz, W. Su, Y. Sankarasubramaniam, E. Cayirci, *A survey on sensor networks*, IEEE Communications Magazine 40 (8), 104–112, 2002.

[8] M. Li, Y. Liu, *Underground structure monitoring with wireless sensor networks*, in: Proceedings of the IPSN, Cambridge, MA, 2007.

[9] J. Heidemann, Y. Li, A. Syed, J. Wills, W. Ye, *Underwater sensor networking: research challenges and potential applications*, in: Proceedings of the Technical Report ISI-TR-2005-603, USC/ Information Sciences Institute, 2005.

[10] I.F. Akyildiz, T. Melodia, K.R. Chowdhury, *A survey on wireless multimedia sensor networks*, Computer Networks Elsevier 51, 921–960, 2007.

[11] Jennifer Yick, Biswanath Mukherjee, Dipak Ghosal, *Wireless sensor network survey*, Elsevier, Computer Networks 52, 2292–2330, 2008.

[12] Shargal, M. and D. Houseman, *The Big Picture of Your Coming Smart Grid*, Smart Grid News, 5 March, 2009.

[13] Science Applications International Corporation (SAIC), *San Diego Smart Grid Study Final Report*, San Diego, 2006.

[14] Atkinson, R. and D. Castro, *Digital Quality of Life – Understanding the Personal & Social Benefits of the Information Technology Revolution*, October, The Information Technology and Innovation Foundation, Washington DC, 2008.

[15] Alberta Transportation, *Intelligent Transportation Systems*, www.transportation.alberta. ca/606.htm, .2009

[16] Verdone, R., D. Dardari, G. Mazzini and A. Conti, Wireless Sensor and Actuator Networks, Academic Press/Elsevier, London, 2009.

[17] Wang, N., N. Zhang and M. Wang, *Wireless Sensors in Agriculture and Food Industry – Recent Development and Future Perspective*, *Computers and Electronics in Agriculture*, 50, 1-14, 2006.

[18] H. Yang and B. Sikdar, *A Protocol for Tracking Mobile Targets using Sensor Networks*, Rensselaer Polytechnic Institute Troy, NY 12180

[19] Vladimir Dyo, et al., *WILDSENSING: Design and Deployment of a Sustainable Sensor Network for Wildlife Monitoring*, ACM Transactions on Embedded Computing Systems, Vol. 9, No. 4, Article 39, Publication date: March 2010.

[20] Zhengming Tang, et al., *PetTracker – Pet Tracking System Using Motes*, University of California, Irvine.

[21] Andrew Markham, *On a Wildlife Tracking and Telemetry System: A Wireless Network Approach*, A thesis submitted to the Department of Electrical Engineering, University of Cape Town, August 2008.

[22] Ragnar S and Erlend T, *Possible Uses for Animal Tracking and Sensor Data*, Institute of Electrical Engineering and Computer Science, University of Stavanger, Norway.

[23] Antonio-Javier G S, et al., *Wireless Sensor Network Deployment for Monitoring Wildlife Passages*, Sensors, 10, 7236-7262; doi:10.3390/s100807236, ISSN 1424-8220, 2010.

[24] E.S. Nadimi, et al., *ZigBee-based wireless sensor networks for monitoring animal presence and pasture time in a strip of new grass*, Elsevier, computers and electronics in agriculture 61,79–87, 2008.

[25] Mac Schwager, et al., *Robust classification of animal tracking data*, Elsevier, Computers and Electronics in Agriculture 56, 46–59, 2007.

[26] Tim Wark, et al., The Design and Evaluation of a Mobile Sensor/Actuator Network for Autonomous Animal Control, CSIRO, Australia, ACM 978-1-59593-638-7/07/0004, 2007.

[27] Francine Lalooses, et al., Recovery Target Tracking in Wildlife, Tufts University, Medford, MA, 2005.

[28] M. Basille, et al., *Tracking Animals in a Dynamic Environment: Remote Sensing Image Time Series Spatial Database for GPS Wildlife Tracking Data*, DOI: 10.1007/978-3-319-03743-1_7, Springer International Publishing Switzerland, 2014.

[29] Pavan Sikka, et al., *Wireless sensor devices for animal tracking and control*, Proceedings of the 29th Annual IEEE International Conference on Local Computer Networks, Australia, 2004.

[30] Ruwini Edirisinghe, et al., *WI-ALERT: A Wireless Sensor Network Based Intrusion Alert Prototype for HEC*, International Journal of Distributed and Parallel Systems, Vol.4, No.4, July 2013.

[31] H. T. Kung and D. Vlah, *Efficient Location Tracking Using Sensor Networks*, Proceedings of IEEE Wireless Communications and Networking Conference, 2003.

 