

## Sensor Networks for Smart Environments

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### Background

The efficient designs of Wireless Sensor Network (WSN) protocols and intelligent Machine Learning algorithms, together have led to the advancements of various systems and applications for Smart Environments. By definition, the Smart Environments are the typical physical worlds used in human daily life, those are seamlessly embedded with smart tiny devices equipped with sensors, actuators and computational elements. The Smart Environments typically include: Smart Home, Smart Building, Smart Office, Smart Farm, Smart Hospital etc. In this article we have discussed the significant works in the literature of Sensor Networks for Smart Environments.

### Sensor Networks

Wireless Sensor Networks (termed as WSN) or simply Sensor Networks consist of spatially distributed devices communicating through wireless radio and cooperatively sensing spatial-temporal states of physical or environmental situations. They provide a high degree of visibility into the environmental physical processes. Wireless Sensor Networks have been used in pervasive domains of applications such as in scientific exploration [1], infrastructure monitoring [2], Smart Environments, military, and many more. Sensor networks are also notably useful in catastrophic or emergency scenarios, such as in flood, fire, volcano, battlefield, where human participation is too dangerous and infrastructure networks are either impossible or too expensive to deploy. However, there are significant challenges to the design for sustainability and reliability for real-world applications. Those challenges come in all forms: software, hardware, protocol designs, and application specific designs.

### Smart Environments

One of the most emerging application domains for Sensor Networks is the Smart Environments. The formal definition of Smart Environments can be as follows. Smart Environments are varied physical worlds typically used in human daily life; those are seamlessly embedded with tiny devices capable of pervasive sensing, actuating and computing. These physically embedded tiny devices are all connected through a continuous network for data collection, in order to enable various pervasive applications and services. The Smart Environments include Smart Home, Smart Building, Smart Office, Smart Farm, Smart Hospital, and Smart Meeting Room etc.

There is considerable amount of work done on development and deployment of sensor network systems for Smart Environments. BScope [3] presents a sensor network architecture design for activity recognition and analysis. Intelligent and networked sensors enabled in-house monitoring of elders is very much in demand due to considerable increase in aging population. Such service has the great potential of increasing autonomy and independence for the elderly people, while minimizing their risks of living alone. ALARM-NET [4] presents the implementation of a wireless sensor network for assisted living and residential monitoring in Smart Home. The goal is to improve the quality of healthcare and the prospects of aging in place using sensor network technology. This project has attempted solving challenging problems in scalability, energy management, data access, security, and privacy. There also are works done on security and safety in Smart Environments. The work in [5] uses data from a deployed

system to show the vulnerability of daily in home activity information from a wireless snooping attack, called FATS attack. This work has demonstrated and evaluated the FATS attack on eight different homes containing wireless sensors. Based on the analysis it has proposed and evaluated a set of privacy preserving design guidelines for sensor network systems in Smart Homes.

Besides typical sensor nodes, RFID based sensor network [6] is also being used for daily activity recognition. This work uses Intel Wisp RFID sensors emplaced on objects of daily use, for capturing daily activity patterns. Gator Tech Smart House [7] deploys Atlas sensor-actuator platform for behavioural monitoring and alteration for diabetic and obese Individuals. The Atlas platform consists a modular architecture for scalable use of sensors and actuators. The work in CASAS [8] and MavHome [9] uses motion and other kinds of sensors for tracking and monitoring the Activities of Daily Living (ADL) for assisted living.

### Activity-Aware Sensor Networks for Smart Environments

Now we discuss some unique research problem and system design challenge specific for Sensor Networks for Smart Environments. Sensor networks have enabled many important social and scientific applications and its protocol design has received considerable research interest. But many existing works mostly did not realize an important difference between sensor networks and traditional networks. Unlike a traditional communication network, a sensor network is deeply embedded in physical environments and its operation is majorly driven by the sensing event activities in the environment.

The Smart Environments in majority are the physical environments used in human daily life. Therefore human motion activity (spatial and temporal) patterns and behaviours are important factors for both sensor network system design and application or service. In Smart Environments, the regular event activities (daily motion activities of the users) show certain repeating patterns in long run. For example in a Smart Home environment, one type of activity is the motion activity of the residents across the rooms. Most of the sensor network designs till date have under-utilized these activity patterns for performance improvement of the network. So there remains a missing link in sensor network design: the feedback from sensed and analysed activity pattern, back to the network operation for resource usage.

The activity pattern information, if utilized in an intelligent manner, can improve the sensor network's application performance (data delivery latency, throughput etc.) while at the same time reducing

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sensor network's resource (bandwidth, network lifetime, energy balance etc.) usages. Therefore sensing event activity context-aware (or simply activity-aware) networking for sensor networks in Smart Environments is essential. In this regard, some of the related works in the literature are as follows. ActSee [10] is an activity-aware radio duty cycling protocol, given the sensor network can use any routing protocol of its choice. Then EAR [11] is an activity-aware and energy-balanced routing protocol, given the sensor network can use any radio duty cycling protocol. Finally the complete ActiSen [12] system is a complete sensor networking solution with activity-awareness integrated in all of: sensing, radio duty cycling and routing.

The goal is to imbue wireless sensor networks with cognitive capabilities and activity context awareness, in order to make them act in a more intelligent manner. The proposed and designed protocols in these works use behavioural pattern information from an available probabilistic activity transition graph (inferred from activity patterns in the Smart Environment). This knowledge is used to efficiently optimize two seemingly conflicting performance goals (application performance and constrained resource usage performance) of the sensor network through: activity-aware sensing, activity-aware radio duty-cycling and activity-aware routing.

## Conclusion

In conclusion, the first decade of research in Wireless Sensor Network has mostly solved and resulted in practically applicable general protocols and system. But the next challenges for sensor networks are in the domain of application specific environments. For Sensor Networks in Smart Environments, some of the important open and future research challenges (in both system and application) are: "pervasive integration of networked sensors and actuators into our connected world" [13], multi-sensor data fusion, automated energy perpetuation for sensor networks (both through energy harvesting and wireless energy transfer), application of Machine Learning on pervasive sensor data, self-autonomous networks for robustness and scalability etc.

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