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In this issue

Wireless Sensor Networks

What are wireless sensor networks?

A Wireless sensor network (WSN) has a large number of small, low powered sensor nodes (also called motes), usually densely located in the target area and one or more remote sinks organised into a cooperative network. These can be connected to other networks through gateways. Each node is equipped with sensing, processing and communication capabilities. These smart disposable micro sensors can be deployed on the ground, in the air, under water, on bodies, in vehicles and inside buildings to collect information from their surroundings, and continuously report back to the remote sinks. They are an envisioned to play an important role in military and civilian applications. Figure 1 shows a general diagram of a wireless sensor network.

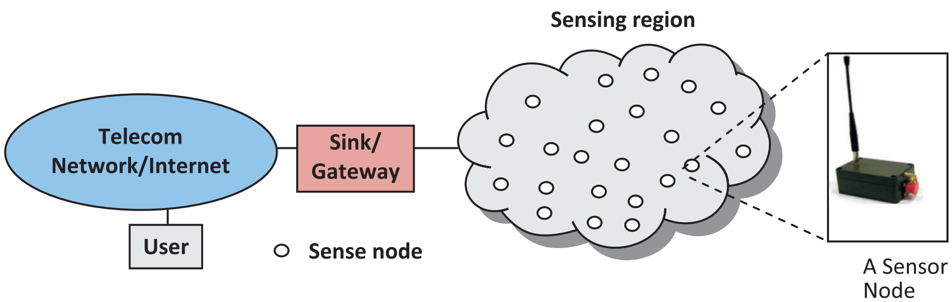
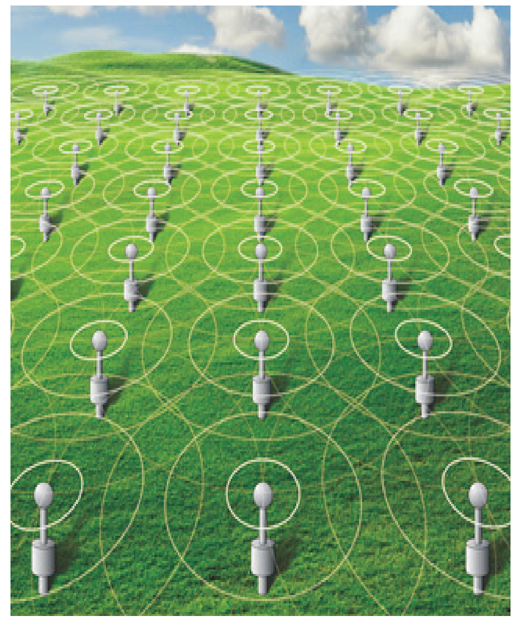


Figure 1 Wireless Sensor Network



WSNs can be static or mobile. A mobile wireless sensor network (MWSN) owes its name to the presence of mobile sink or sensor nodes within the network. The advantages of mobile wireless sensor network over static wireless sensor network are better energy efficiency, improved coverage, enhanced target tracking and superior channel capacity.

In order to support M2M applications mobile cellular networks and wireless sensor networks (WSN) are evolving from heterogeneous networks to converged networks. WSNs and cellular networks have different characteristics. Distinguished from cellular systems, WSNs have denser level of node deployment and higher unreliability of sensor nodes. They have severe energy, computation, and storage constraints. The key disadvantages include less mobility robustness, small coverage, and weak terminals. In contrast, cellular networks have the advantages of mobility robustness, large coverage, and powerful user terminals, but their deployment and management are expensive and complicated. Therefore, it is intuitive to integrate cellular networks and WSN for supporting M2M communications. The convergence of cellular networks and WSN can benefit both types of network. For WSN, the cellular networks can enable higher layer control and optimization to prolong network life time, improve WSN system performance, and provide quality of service (QoS) for WSN services. For Cellular networks, WSN can enable the cognitive and intelligent aspects of the cellular system. It is envisaged that the converged network architecture of cellular networks and WSN could enable better wireless services and more data-centric applications. Figure 2 gives the converged cellular and WSN architecture.

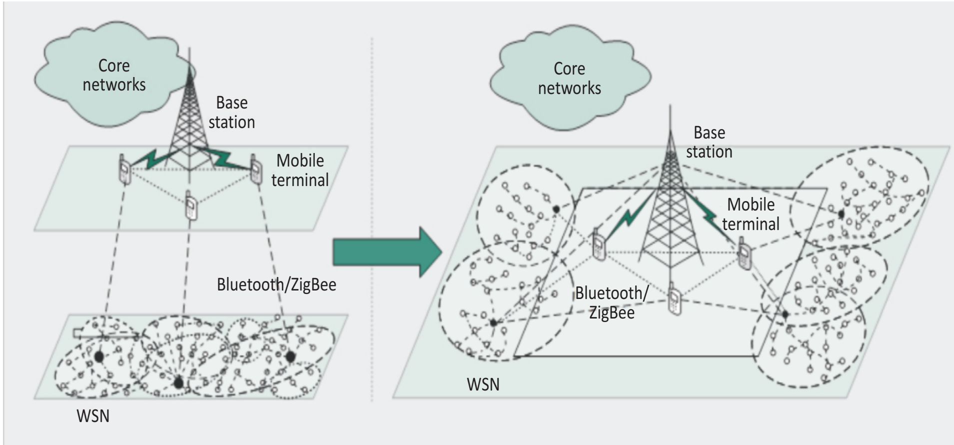


Figure 2 Converged network architecture for MCN and WSN

Architecture of Sensor Networks

The sink sends queries or commands to the sensor nodes in the sensing region while the sensor nodes collaborate to accomplish the sensing task and send the sensed data to the sink(s). The sink may also act as a gateway to other networks, collect data from the sensor nodes, perform simple processing on the collected data, and then send relevant information via the Internet or mobile network to the users who requested it. Figure 3 shows the architecture of WSN in which each node accesses the sink in a single hop.

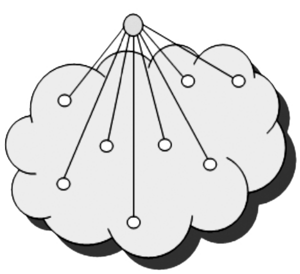


Figure 3 Single hop network architecture

In most applications a large number of sensor nodes are closely deployed and therefore communication between a sink and a node can be though intermediate nodes which are closer to each other. Such multihop communication uses short distance transmission and reduces energy consumption. There are two types of prevailing architecture for multihop sensor networks: flat and hierarchical. In a flat network, each node plays the same role in performing a sensing task and all sensor nodes are peers. Due to the large number of sensor nodes, it is not feasible to assign a global identifier to each node in a sensor network. For this reason, data gathering is usually accomplished by transmitting a query to all nodes in the sensing region via flooding and only the sensor nodes that have the data matching the query will respond to the sink. Each sensor node communicates with the sink via a multihop path and uses its peer nodes as relays. Figure 4 illustrates the typical architecture of a flat network.

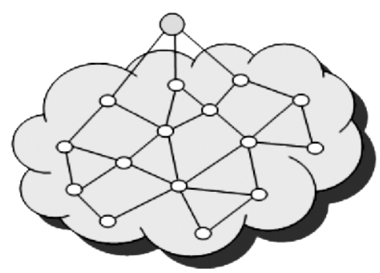


Figure 4 Flat network architecture

In a hierarchical network, sensor nodes are organized into clusters, where the cluster members send their data to the cluster heads while the cluster heads serve as relays for transmitting the data to the sink. A node with lower energy can be used to perform the sensing task and send the sensed data to its cluster head at short distance, while a node with higher energy can be selected as a cluster head to process the data from its cluster members and transmit the processed data to the sink. This process can not only reduce the energy consumption for communication, but also balance traffic load and improve scalability when the network size grows. Figure 5 shows the multihop clustering architecture.

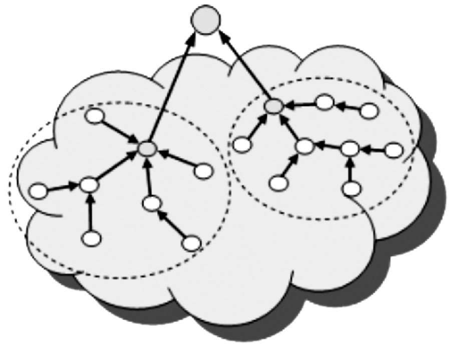


Figure 5 Multihop clustering architecture

According to the number of tiers in the clustering hierarchy, a sensor network can be organized into a single - tier clustering architecture or a multitier clustering architecture. Figure 6 illustrates an example of the multitier.

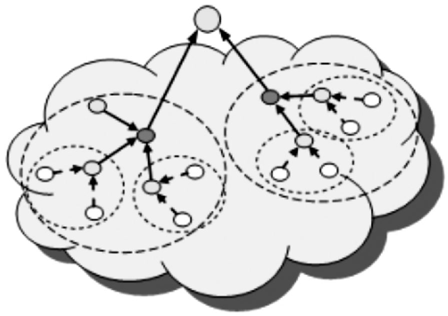


Figure 6 Multitier clustering architectures

Cooperative Wireless Networks

Over the last few years, fundamental research has demonstrated the great potential of cooperative wireless networks in enhancing system capacity and enlarging the coverage area as well as enhancing quality of service(QoS) by taking advantage of cooperative diversity and multiplexing. The key feature of cooperative transmission is to encourage single-antenna devices to share their antennas cooperatively such that a virtual and distributed antenna array can be constructed and, as a result, reception reliability can be improved and power consumption can be reduced significantly. Cooperative diversity has largely been considered by physical layer researchers and various cooperative transmission protocols have been developed at the physical layer to further increase the bandwidth efficiency of cooperative diversity. There have been intensive studies on the physical layer techniques of cooperative communication.

Toward these unique features, many challenges are imposed on cooperative communications for future wireless networks First, physical layer signals are required to be capable of achieving cooperative diversity and multiplexing gain across multiple coexisting multi-hop cooperation links. Second, user cooperation highly depends on the positions of mobile users, which vary frequently and are hard to control by the infrastructure networks. Third, since mobile users serve as both service providers and consumers, wireless resource competition/negotiation strategies among cooperative users and the infrastructure networks become extremely important issues. Fourth, user cooperation at different protocol layers have diverse features and challenges, which motivate cross-layer design to develop optimized cooperation schemes.

Source: IEEE Communication magazine, May 2011

Standards

There are a number of standardization bodies in the field of WSNs and several standards are currently either ratified or under development for wireless sensor networks. The IEEE focuses on the physical and MAC layers; the Internet Engineering Task Force (IETF) works on layers 3 and above. In addition to these, bodies such as the International Society of Automation provide vertical solutions, covering all protocol layers. There are also several non-standard, proprietary mechanisms and specifications. Some of these are discussed below:

IEEE 1451

IEEE 1451 is a set of smart transducer interface standards developed by the IEEE Instrumentation and Measurement Society's Sensor Technology Technical Committee that describe a set of open, common, network-independent communication interfaces for connecting transducers (sensors or actuators) to microprocessors, instrumentation systems, and control/field networks. One of the key elements of these standards is the definition of transducer electronic data sheets (TEDS) for each transducer. The TEDS is a memory device attached to the transducer, which stores transducer identification, calibration, correction data, and manufacturer-related information. The goal of the IEEE 1451 family of standards is to allow the access of transducer data through a common set of interfaces whether the transducers are connected to systems or networks via a wired or wireless means.

IEEE 802.15.4

IEEE 802.15.4 is a standard which specifies the lower network layers - the physical layer and media access control - for low-rate wireless personal area networks (LR-WPANs). It is maintained by the IEEE 802.15 working group. It is the basis for the ZigBee, ISA100.11a, WirelessHART, and MiWi specifications, each of which further extends the standard by developing the upper layers which are not defined by 802.15.4. Alternatively, it can be used with 6LoWPAN and standard Internet protocols to build a Wireless Embedded Internet. The emphasis is on very low cost communication of nearby devices with little to no underlying infrastructure, intending to exploit this to lower power consumption even more. The basic framework conceives a 10-meter communications range with a transfer rate of 250 kbit/s. Even lower rates can be considered with the resulting effect on power consumption. Important features include real-time suitability by reservation of guaranteed time slots, collision avoidance through CSMA/CA and integrated support for secure communications. Devices also include power management functions such as link quality and energy detection.

ZigBee

ZigBee is a low-cost, low-power, wireless mesh network standard. The name, ZigBee, refers to the waggle dance of honey bees after their return to the beehive. The technology defined by the ZigBee specification is intended to be simpler and less expensive than other WPANs, such as Bluetooth. ZigBee is targeted at radio-frequency (RF) applications that require a low data rate, long battery life, and secure networking. The low cost allows the technology to be widely deployed in wireless control and monitoring applications. Low power-usage allows longer life with smaller batteries. Mesh networking provides high reliability and more extensive range. ZigBee operates in the industrial, scientific and medical (ISM) radio bands; 868 MHz in Europe, 915 MHz in the USA and Australia, and 2.4 GHz in most jurisdictions worldwide. Data transmission rates vary from 20 to 900 kilobits/second. ZigBee builds upon the physical layer and medium access control defined in IEEE standard 802.15.4 (2003 version) for low-rate WPANs. The specification goes on to complete the standard by adding four main components: network layer, application layer, ZigBee device objects (ZDOs) and manufacturer-defined application objects which allow for customization and favor total integration. Because ZigBee nodes can go from sleep to active mode in 30 ms or less, the latency can be low and devices can be responsive, particularly compared to Bluetooth wake-up delays, which are typically around three seconds. Because ZigBee nodes can sleep most of the time, average power consumption can be low, resulting in long battery life.

ISA100.11a

ISA100.11a is an open wireless networking technology standard developed by the International Society of Automation (ISA). ISA 100.11a specifies a standard for wireless industrial networks. The standard specifies how communication between devices is established and how the wireless infrastructure can be used to run industrial control applications. The ISA 100.11a standard specifies different functional roles for the various operations needed to run and manage a wireless industrial network. Each role is a high level description of functionality that need to be implemented on a device. The American National Standards Institute (ANSI) has approved ISA-100.11a-2011, Wireless Systems for Industrial Automation: Process Control and Related Applications, as an American National Standard. ANSI/ISA-100.11a-2011 was developed to provide reliable and secure wireless operation for noncritical monitoring, alerting, supervisory control, open loop control and closed loop control application, as an American National Standard. The standard defines the protocol suite, system management, and gateway and security specifications for low-data-rate wireless connectivity with fixed, portable and moving devices that support very limited power consumption requirements.

WirelessHART

WirelessHART is the first open wireless communication standard specifically designed for process measurement and control applications. At the very bottom, it adopts IEEE 802.15.4-2006 as the physical layer. On top of that, WirelessHART defines its own time-synchronized MAC layer. Some notable features of WirelessHART MAC include strict 10ms time slot, network wide time synchronization, channel hopping, channel blacklisting, and industry standard AES-128 ciphers and keys. The network layer supports self-organizing and self-healing mesh networking techniques. WirelessHART also distinguishes itself from other public standards by maintaining a central network manager. The network manager is responsible for maintaining up-to-date routes and communication schedules for the network, thus guarantee the network performance.

MiWi Protocol

MiWi and MiWi P2P are proprietary wireless protocols designed by Microchip Technology that use small, low-power digital radios based on the IEEE 802.15.4 standard for wireless personal area networks (WPANs). It is designed for low data transmission rates and short distance, cost constrained networks, such as industrial monitoring and control, home and building automation, remote control, low-power wireless sensors, lighting control and automated meter reading. The MiWi protocol is based on the MAC and PHY layers of the IEEE 802.15.4 specification, and is tailored for simple network development in the 2.4 GHz band. The protocol provides the features to find form and join a network, as well as discovering nodes on the network and route to them. It does not cover any application-specific issues, such as how to select which network to join to, how to decided when a link is broken or how often devices should communicate.

6LoWPAN

6LoWPAN is a set of standards defined by the Internet Engineering Task Force (IETF), which creates and maintains all core Internet standards and architecture work. 6LoWPAN standards enable the efficient use of IPv6 over low-power, low-rate wireless networks on simple embedded devices through an adaptation layer and the optimization of related protocols. The first 6LoWPAN specifications were released in 2007, first with an informational RFC [RFC4919] specifying the underlying requirements and goals of the initial standardization and then with a standard track RFC [RFC4944] specifying the 6LoWPAN format and functionality. Through experience with implementations and deployments, the 6LoWPAN working group continued with improvements to header compression, 6LoWPAN Neighbor Discovery, use cases and routing requirements. In 2008 a new IETF working group was formed, Routing over Low-power and Lossy Networks. This working group specifies routing requirements and solutions for low-power, wireless, unreliable networks. Although not restricted to use with 6LoWPAN, that is one main target. Recent activities related to 6LoWPAN include the IP for Smart Objects (IPSO) to promote the use of IP in smart objects and Internet of Things business [IPSO]. In 2009 the European Telecommunication Standards Institute (ETSI) started a working group for standardizing M2M, which includes an end-to-end IP architecture compatible with 6LoWPAN.

ITU standards

Within ITU, Ubiquitous Sensor Networks (USN) standardization is being carried out under the Next- Generation Network Global Standards Initiative (NGN-GSI). A draft Recommendation Draft Y.USN-reqts, “Requirements for support of USN applications and services in NGN environment,” has been developed. A Ubiquitous Sensor Network can either be based on Internet Protocol (IP) or non-IP based protocols. As an example of standardization work on the former, the 6LoWPAN (IPv6 based Low-power Wireless Personal Area Network) standard (more correctly, IPv6 over IEEE 802.15.4) provides for a communications network with limited power requirements suitable for wireless sensors. However, certain other applications may be more suited to a non-IP platform, especially for near-field communications and where speed of response and low power requirements are critical factors.

QoX: What is it really?

Service differentiation and QoS supporting building blocks can be found in several network architectures, techniques, and frameworks, including, but not limited to, the following: IP(DiffServ, IntServ), Next Generation Networks(NGN), Generalized Multiprotocol Label Switching (GMPLS), Automatically Switched Optical Network (ASON), Optical Burst Switch-ing (OBS), Optical Packet Switching (OPS), Bluetooth, Global System for Mobile Communications (GSM), and Universal Mobile Telecommunications System (UMTS). QoS is currently not only a technical issue, it became also a kind of product and marketing subject. Sometimes telecommunications services are advertised as having QoS control, support, and so on, but infact, they have not much in common with a real QoS as meant by standards.

To cover different areas and views on QoS, atleast the following terms should be distinguished: Class of Service (CoS), Grade of Service (GoS), Quality of Resilience (QoR), and Quality of Experience (QoE). All of them are sometimes used inappropriately. So the generic acronym QoX is used when issues adhering at the same time to QoS, GoS, QoR and QoE are discussed. The above set of QoX terms (where X stands for Service, Experience, etc.) is sufficient to describe and distinguish all aspects of service provisioning.

Source: IEEE Communication Magazine, April 2011

Current and potential applications

Current and potential applications of sensor networks include: military sensing, physical security, air traffic control, traffic surveillance, video surveillance, industrial and manufacturing automation, distributed robotics, environment monitoring and building and structures monitoring. The sensors in these applications may be small or large, and the networks may be wired or wireless. Since, mobile wireless sensor networks are a relatively new concept; its specific, unique application areas are yet to be clearly defined. Most of its application scenarios are the same as that of traditional wireless sensor networks, with the only difference of mobility of mobile sink, preferably in the form of mobile phones. The following are some of the important applications:

- Smart Transport System : A network of sensors set up all over a vehicle can interact with its surroundings to provide valuable feedback on local roads, weather and traffic conditions to the car driver, enabling adaptive drive systems to respond accordingly. A broad city-wide distributed sensor network could be accessed to indicate traffic congestion, administer toll tax or provide continually updated destination routing feedback to individual vehicles. Condition and event detection sensors can activate systems to maintain driver and passenger comfort and safety through the use of airbags and seatbelt pre-tensioning. Sensors for fatigue and mood monitoring based on driving conditions, driver behaviour and facial indicators can interact to ensure safe driving by activating warning systems or directly controlling the vehicle.
- Security : Sensors can be used to implement security system in daily life. On an individual basis, a mobile phone of a person can enter into a "session" with the already present sensors in the area. In this way, it can keep a track of his belongings, car and even kids. Mobile enabled wireless sensor networks can help to monitor the environment, both external and internal.
- Social Interaction : With the possible integration of RFID tags and WSN, mobile phones can act as sinks to have a "social interaction" among peers who share common interest. Similarly, this combination of RFID tags and WSN can help mobile phones users in using their mobile phones as "single" tool to carry out all their tasks like shopping, billing, information gathering, guidance, social interaction, etc.
- Health : A network of advanced bio-sensors can be developed using nanotechnology to conduct point-of-care testing and diagnosis for a broad variety of conditions. This technology will reduce delays in obtaining test results, thus having a direct bearing on patient recovery rates or even survival rates. On the basis of the sensed data, physicians can make a more rapid and accurate diagnosis and recommend appropriate treatment. In recent years, one area of increasing interest is the adaptation of "micro grid" technology to operate in and around the human body, connected via a wireless body area network (WBAN). There are many potential applications that will be based on WBAN technology, including medical sensing and control, wearable computing, location awareness and identification. Such devices are being and will be used to monitor and control medical conditions such as coronary care, diabetes, optical aids, bladder control, muscle stimulants etc.

WIRELESS DATA CENTER NETWORKING

Data centers play a key role in the expansion of cloud computing. However, the efficiency of data center networks (DCN) is limited by over subscription. The typical unbalanced traffic distributions of a DCN further aggravate the problem. Wireless networking, as a complementary technology to Ethernet, has the flexibility and capability to provide feasible approaches to handle the problem. Wireless data center networking, based on the state-of-the-art wireless technologies, provides a promising solution. In constructing data centers, wireless has unique advantages over Ethernet. First, it brings convenience to the deployment and maintenance of a DCN. For a large-scale data center, it usually takes a great amount of manual effort to wire the huge number of servers, which is inherently hard and error-prone. This problem is especially severe for those improved DCN solutions as they introduce more wires than conventional DCN architectures do. By using wireless, these difficulties can be considerably reduced. Secondly, wireless can enhance the flexibility of a DCN. Since wireless links can be dynamically established, it is possible to perform adaptive topology adjustment. Furthermore, since wireless connections no longer rely on switches, they are free of the problems caused by these centralized devices, such as single-point failures, limited bisection bandwidth, etc.

Source : IEEE Wireless Communication Magazine, December 2011

Personal Cloud Computing : The Next Paradigm Shift

Cloud computing is an evolving term these days. It describes the advance of many existing IT technologies and separates application and information resources from underlying infrastructure. Personal Cloud is the hybrid deployment model that is combined private cloud and public cloud. The Personal Cloud describes a user-centric model of Cloud computing where an individual's personal content and services are available anytime and anywhere, from whatever device they choose to access it.

Figure 7 Personal Cloud Computing

Today, most people have to juggle multiple devices to access all their services. What the personal Cloud could provide is a single and portable access-point to multiple Clouds. And in emerging economies, where people often share mobile devices, each individual would be able to log into their own Cloud from the shared device.

Source : Gartner

- Smart Home/Smart Office : Smart home environments can provide custom behaviors for a given individual. Sensors can control appliances at home. They provide for better lighting and air conditioning in offices.

- Water catchment and eco-system monitoring : A network of sensors can be utilized to monitor water flows into catchment areas and areas where access is difficult or expensive. This information can be combined with other sensor networks providing information on water quality and soil condition, together with long term weather forecasting to assist with the equitable and efficient distribution of water for irrigation and environmental purposes. Similar technology can be utilized to provide an early warning system for flood prone regions, particularly flash flooding.

- Remote Sensing in Disaster Management : Remote sensing systems have proven to be invaluable sources of information that enable the disaster management community to make critical decisions based on information obtained from study of satellite imagery for better preparedness and initial assessments of the nature and magnitude of damage and destruction. Information derived from satellites can be combined with on-the-ground data from a USN. High resolution remote sensing data is especially useful for documenting certain hazards, for determining where to locate response facilities and supplies, and for planning related facilities for reconstruction and relocation activities. Data availability and its timely delivery are crucial to saving lives and property during disasters, and technological developments are making positive contributions in this area.

- Military : New and emerging technologies, such as networks, support military operations by delivering critical information rapidly and dependably to the right individual or organization at the right time. This improves the efficiency of combat operations.

- Industrial & Commercial : Successful use of wireless sensors in systems such as supervisory control and data acquisition has proved that these devices could effectively address the needs of industrial applications. The critical process applications of WSNs in industry are monitoring temperature, flow level, and pressure parameters.

- Agriculture : Agriculture can also be benefited by the deployment of WSN to get the information regarding soil degradation and water scarcity. With help of WSNs we can check the clean water consumed in irrigation and manage it.

Future trends

The future developments in sensor networks would produce very powerful and cost effective devices, so that they may be used in applications like underwater acoustic sensor systems, sensing based cyber physical systems, time critical applications, cognitive sensing and spectrum management, and security and privacy management.

- Cognitive Sensing:

  Cognitive sensor networks are used for acquiring localized and situated information of the sensing environment by deploying a large number of sensors intelligently and autonomically. Managing a large number of wireless sensors is a complex task. Two well known examples of cognitive sensing are swarm intelligence and quorum sensing:

  - Swarm intelligence is developed in artificial intelligence for studying the collective behavior of decentralized, self organized systems.
  - Quorum sensing is an example of bio inspired sensing and networking. Quorum sensing is the ability of bacteria to communicate and coordinate behavior via signaling molecules.

- Spectrum Management:

  One can envision a future in which wireless devices, such as wireless keyboards, powerpoint presenters, cell phone headsets and health monitoring sensors will be ubiquitous. Pervasiveness of these devices leads to increased interference and congestion within as well as between networks, because of overlapping physical frequencies. A generic solution is provided is SAS: a Self Adaptive Spectrum Management middleware for WSNs, which can be easily integrated with an existing single frequency.

- Underwater Acoustic Sensor System:

  Underwater sensor networks are designed to enable applications for oceanographic data collection, pollution monitoring, offshore exploration, disaster prevention, assisted navigation and tactical surveillance applications. Underwater sensors are also being in use for exploration of natural undersea resources and gathering of scientific data.

- Coordination in Heterogeneous Networks

  The main obstacle in the coordination with other networks is limited energy of sensor nodes. To monitor the WSN, the data produced by sensor nodes should be accessible. This can be done by connecting the WSN with existing network infrastructure such as global Internet, a local area network or private internet. Two type of interconnection techniques have been described: gateway based interconnection technique and overlay based interconnection technique.

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