1. A wireless sensor network (WSN) consists of spatially distributed autonomous sensors to monitor physical or environmental conditions, such as temperature, sound, vibration, pressure, motion or pollutants and to cooperatively pass their data through the network to a main location. The more modern networks are bi-directional, also enabling control of sensor activity. The development of wireless sensor networks was motivated by military applications such as battlefield surveillance; today such networks are used in many industrial and consumer applications, such as industrial process monitoring and control, machine health monitoring, and so on.

2. The WSN is built of "nodes" – from a few to several hundreds or even thousands, where each node is connected to one (or sometimes several) sensors. Each such sensor network node has typically several parts: a radio transceiver with an internal antenna or connection to an external antenna, a microcontroller, an electronic circuit for interfacing with the sensors and an energy source, usually a battery or an embedded form of energy harvesting. A sensor node might vary in size from that of a shoebox down to the size of a grain of dust, although functioning "motes"(demo video) of genuine microscopic dimensions have yet to be created. The cost of sensor nodes is similarly variable, ranging from a few to hundreds of dollars, depending on the complexity of the individual sensor nodes. Size and cost constraints on sensor nodes result in corresponding constraints on resources such as energy, memory, computational speed and communications bandwidth. The topology of the WSNs can vary from a simple star network to an advanced multi-hop wireless mesh network. The propagation technique between the hops of the network can be routing or flooding. In computer science and telecommunications, wireless sensor networks are an active research area with numerous workshops and conferences arranged each year.

Area monitoring

3. Area monitoring is a common application of WSNs. In area monitoring, the WSN is deployed over a region where some phenomenon is to be monitored. A military example is the use of sensors to detect enemy intrusion; a civilian example is the geofencing of gas or oil pipelines.

4. When the sensors detect the event being monitored (heat, pressure), the event is reported to one of the base stations, which then takes appropriate action (e.g., send a
message on the internet or to a satellite). Similarly, wireless sensor networks can use a range of sensors to detect the presence of vehicles ranging from motorcycles to train cars.

**Environmental sensing**

5. The term Environmental Sensor Networks has evolved to cover many applications of WSNs to earth science research. This includes sensing volcanoes, oceans, glaciers, forests, etc. Some other major areas are listed below.

**Air pollution monitoring**

6. Wireless sensor networks have been deployed in several cities (Stockholm, London or Brisbane) to monitor the concentration of dangerous gases for citizens. These can take advantage of the ad-hoc wireless links rather than wired installations, which also make them more mobile for testing readings in different areas.

**Forest fires detection**

7. A network of Sensor Nodes can be installed in a forest to detect when a fire has started. The nodes can be equipped with sensors to measure temperature, humidity and gases which are produced by fires in the trees or vegetation. The early detection is crucial for a successful action of the firefighters; thanks to Wireless Sensor Networks, the fire brigade will be able to know when a fire is started and how it is spreading.

**Greenhouse monitoring**

8. Wireless sensor networks are also used to control the temperature and humidity levels inside commercial greenhouses. When the temperature and humidity drops below specific levels, the greenhouse manager must be notified via e-mail or cell phone text message, or host systems can trigger misting systems, open vents, turn on fans, or control a wide variety of system responses.

**Landslide detection**

9. A landslide detection system, makes use of a wireless sensor network to detect the slight movements of soil and changes in various parameters that may occur before or during a landslide. And through the data gathered it may be possible to know the occurrence of landslides long before it actually happens.

**INDUSTRIAL MONITORING**

**Machine health monitoring**

10. Wireless sensor networks have been developed for machinery condition-based maintenance (CBM) as they offer significant cost savings and enable new functionalities. In wired systems, the installation of enough sensors is often limited by the cost of wiring. Previously inaccessible locations, rotating machinery, hazardous or restricted areas, and mobile assets can now be reached with wireless sensors.
**Water/wastewater monitoring**

11. There are many opportunities for using wireless sensor networks within the water/wastewater industries. Facilities not wired for power or data transmission can be monitored using industrial wireless I/O devices and sensors powered using solar panels or battery packs and also used in pollution control board.

**Agriculture**

12. Using wireless sensor networks within the agricultural industry is increasingly common; using a wireless network frees the farmer from the maintenance of wiring in a difficult environment. Gravity feed water systems can be monitored using pressure transmitters to monitor water tank levels, pumps can be controlled using wireless I/O devices and water use can be measured and wirelessly transmitted back to a central control center for billing. Irrigation automation enables more efficient water use and reduces waste.

**Structural monitoring**

13. Wireless sensors can be used to monitor the movement within buildings and infrastructure such as bridges, flyovers, embankments, tunnels etc... enabling Engineering practices to monitor assets remotely without the need for costly site visits, as well as having the advantage of daily data, whereas traditionally this data was collected weekly or monthly, using physical site visits, involving either road or rail closure in some cases. it is also far more accurate than any visual inspection that would be carried out.

**Characteristics**

14. The main characteristics of a WSN include :

   (a) Power consumption constrains for nodes using batteries or energy harvesting.

   (b) Ability to cope with node failures.

   (c) Mobility of nodes.

   (d) Dynamic network topology.

   (e) Communication failures.

   (f) Heterogeneity of nodes.

   (g) Scalability to large scale of deployment.

   (h) Ability to withstand harsh environmental conditions.

   (j) Ease of use.
15. Sensor nodes can be imagined as small computers, extremely basic in terms of their interfaces and their components. They usually consist of a *processing unit* with limited computational power and limited memory, *sensors* or MEMS (including specific conditioning circuitry), a *communication device* (usually radio transceivers or alternatively optical), and a power source usually in the form of a battery. Other possible inclusions are energy harvesting modules, secondary ASICs, and possibly secondary communication devices (e.g. RS-232 or USB).

16. The base stations are one or more components of the WSN with much more computational, energy and communication resources. They act as a gateway between sensor nodes and the end user as they typically forward data from the WSN on to a server. Other special components in routing based networks are routers, designed to compute, calculate and distribute the routing tables. Many techniques are used to connect to the outside world including mobile phone networks, satellite phones, radio modems, long-range Wi-Fi links etc. Many base stations are ARM-based running a form of Embedded Linux.

**PLATEFORMS**

**Standards and specifications**

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

18. Standards are used far less in WSNs than in other computing systems which makes most systems incapable of direct communication between different systems. However predominant standards commonly used in WSN communications include:

(a) Wireless HART.

(b) ISA100

(c) IEEE 1451.

(d) ZigBee / 802.15.4.

**Hardware**
19. One major challenge in a WSN is to produce low cost and tiny sensor nodes. There are an increasing number of small companies producing WSN hardware and the commercial situation can be compared to home computing in the 1970s. Many of the nodes are still in the research and development stage, particularly their software. Also inherent to sensor network adoption is the use very low power methods for data acquisition.

**Software**

20. Energy is the scarcest resource of WSN nodes, and it determines the lifetime of WSNs. WSNs are meant to be deployed in large numbers in various environments, including remote and hostile regions, where ad-hoc communications are a key component. For this reason, algorithms and protocols need to address the following issues:

   (a) Lifetime maximization
   (b) Robustness and fault tolerance
   (c) Self-configuration

21. Some of the important topics in WSN software research are:

   (a) Operating systems.
   (b) Security.
   (c) Mobility.
   (d) Usability – human interface for deployment and management, debugging and end-user control.
   (e) Middleware – the design of middle-level primitives between high level software and the systems.

**Operating systems**

22. Operating systems for wireless sensor network nodes are typically less complex than general-purpose operating systems. They more strongly resemble embedded systems, for two reasons. First, wireless sensor networks are typically deployed with a particular application in mind, rather than as a general platform. Second, a need for low costs and low power leads most wireless sensor nodes to have low-power microcontrollers ensuring that mechanisms such as virtual memory are either unnecessary or too expensive to implement.

23. It is therefore possible to use embedded operating systems such as eCos or uC/OS for sensor networks. However, such operating systems are often designed with real-time properties. Tiny OS is perhaps the first operating system specifically designed for wireless sensor networks. TinyOS is based on an event-driven programming model instead of multithreading. Tiny OS programs are composed of event handlers and tasks
with run-to-completion semantics. When an external event occurs, such as an incoming data packet or a sensor reading, Tiny OS signals the appropriate event handler to handle the event. Event handlers can post tasks that are scheduled by the TinyOS kernel some time later.

24. LiteOS is a newly developed OS for wireless sensor networks, which provides UNIX-like abstraction and support for the C programming language. Contiki is an OS which uses a simpler programming style in C while providing advances such as 6LoWPAN and proto-threads.

Simulation of WSNs

25. In general, there are two ways to develop simulations of WSNs. Either use a custom platform to develop the simulation. And the second option is to develop one's own simulation:

Simulators

26. As such, at present Agent-based Modeling and Simulation is the only paradigm which allows the simulation of even complex behavior in the environments of Wireless sensors (such as flocking). Network Simulators like QualNet, NetSim, and NS2 can be used to simulate Wireless Sensor Network.

Agent-based simulation of WSN

27. Agent-based simulation of wireless sensor and ad-hoc networks is a relatively newer paradigm. Agent-based modeling was originally based on social simulation. A recent article on agent-based simulation published in the IEEE Communications magazine gives examples and tutorials on how to develop custom agent-based simulation models for wireless sensors, mobile robots and P2P networks in a short period of time (few hours). A formal agent-based simulation framework using formal specification using Z notation demonstrating the use of agent-based modeling to represent simulation of complex behavior in the environment of sensors is given in. Agent-based simulation has also been shown to be useful for modeling and simulation for quantifying emergent behavior in the vicinity of WSN nodes.

OTHER CONCEPTS

Distributed sensor network

28. If a centralized architecture is used in a sensor network and the central node fails, then the entire network will collapse, however the reliability of the sensor network can be increased by using distributed control architecture. Distributed control is used in WSNs for the following reasons:

(a) Sensor nodes are prone to failure.

(b) For better collection of data.
To provide nodes with backup in case of failure of the central node.

29. There is also no centralized body to allocate the resources and they have to be self organized.

**Data integration and Sensor Web**

30. The data gathered from wireless sensor networks is usually saved in the form of numerical data in a central base station. Additionally, the Open Geospatial Consortium (OGC) is specifying standards for interoperability interfaces and metadata encodings that enable real time integration of heterogeneous sensor webs into the Internet, allowing any individual to monitor or control Wireless Sensor Networks through a Web Browser.

**In-network processing**

31. To reduce communication costs some algorithms remove or reduce nodes redundant sensor information and avoid forwarding data that is of no use. As nodes can inspect the data they forward they can measure averages or directionality for example of readings from other nodes.

**Information fusion**

32. In wireless sensor networks, information fusion, also called data fusion, has been developed for processing sensor data by filtering, aggregating, and making inferences about the gathered data. Information fusion deals with the combination of multiple sources to obtain improved information: cheaper, greater quality or greater relevance. Within the wireless sensor networks domain, simple aggregation techniques such as maximum, minimum, and average, have been developed for reducing the overall data traffic to save energy.