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Task

On graduate qualification work of student Yodgorov Farrukh Tokhirovich

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8. Schedule of works

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3.	Analysis of wireless sensor network applications	15.04.2013	
4.	Safety of vital activity	15.05.2013	

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« ___ » _____ 2013

Abstract

This work is devoted to wireless sensor networks, their features and applications. Potential benefits of using of WSN in various fields and advantages of WSNs are discussed. Major application-specific challenges of various applications are defined. The four most promising applications were selected for detailed consideration. As a result of the work WSNs' potential for various real-world applications is revealed and proved.

Mazmunnoma

Ushbu ish simsiz sensor tarmoqlariga, ularning hususiyatlari va qo'llanmalariga bag'ishlangan. Turli sohalarda simsiz sensor tarmoqlaridan foydalanish va ularning afzalliklari muxokama qilingan. Turli qo'llanmalarga hos bo'lgan asosiy muammolar aniqlangan. Chuqurroq ko'rib chiqish uchun to'rt turdagi istiqbolli qo'llanmalar tanlab olindi. Natijada simsiz sensor tarmoqlaridan turli real sharoitdagi qo'llanmalarda foydalanish salohiyati yoritib berildi va tasdiqlandi.

Аннотация

Эта работа посвящена беспроводным сенсорным сетям, их особенностям и приложениям. Обсуждены потенциальные выгоды использования беспроводных сенсорных сетей в различных применениях и преимущества беспроводных сенсорных сетей. Определены основные проблемы, свойственные к различным приложениям. Четыре самых многообещающих приложений были выбраны для подробного рассмотрения. В результате, освещен и подтвержден потенциал беспроводных сенсорных сетей для применения в различных реальных приложениях.

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INTRODUCTION

In many applications of our real life it is required to make a communication between sensory devices. In many solutions that are based on the use of sensory devices, communications between these devices serve to advance the performance of the entire solution.

Modern wireless sensor networks (WSNs) are made up of a large number of inexpensive devices that are networked via low power wireless communications.

Sensor network differentiates from a mere collection of sensors due to networking capability, which enable cooperation, coordination, and collaboration among sensor assets.

Advances in microelectronics made it possible to create miniature chips with processing and networking capabilities. Further development of sensing, analog and digital signal processing, wireless communications, and networking, WSN technology is expected to have a significant impact on our lives in the twenty-first century.

WSNs have the potential to be applied in such spheres as environmental monitoring, natural disaster prediction and relief, homeland security, healthcare, manufacturing, transportation, and home appliances and entertainment.

Nowadays Crisis-proof Program is being realized in the Republic of Uzbekistan. The program is based on the "Global financial and economic crisis, ways and measures to overcome in Uzbekistan" book written by the President of the Republic of Uzbekistan Islam Karimov [1].

In the report of the President of the Republic of Uzbekistan at the meeting of the Cabinet of Ministers, devoted to results of social-economic development of the country in 2012 and the most important priority directions of economical program for 2013, great and responsible tasks are indicated for communication and informatization sphere [2].

In particular, the implementation of the modern flexible technologies must be provided in the nearest future. We should provide the application of new, effective and promising technologies in our industry and science in order to achieve competitive positions on national and international scale.

The President outlined that without broad implementation of information and communication technologies (ICTs) in all spheres of economy and our everyday lives it is hardly possible to envisage the future development.

Wireless sensor technologies could be one of the main solutions in achieving ubiquitous existence of ICTs through many spheres of economy and people's lives in our country. WSNs can reduce the cost of traditional wired solutions, easing installation and eliminating connectors. Connected through the network, sensors and so-called motes with small and limited computational resources are able even to handle tasks that ordinary computer system is unable to cope with.

Therefore the research and development of WSNs, their features and application in various fields has a proof significance.

Basing on described above importance of WSNs and their capabilities in improvement of production, automation, management and control processes, this graduate qualification work is devoted to the investigation of features and application fields of WSNs, as well as the study of characteristics of WSNs.

The main task of the work is to reveal the potential of application of WSNs in various fields of industry, research and every-day lives of human-beings.

1. OVERVIEW OF WIRELESS SENSOR NETWORKS

1.1 Introduction to WSNs

Sensors integrated into structures, machinery, and the environment, coupled with the efficient delivery of sensed information, could provide tremendous benefits to society. Potential benefits include:

- fewer catastrophic failures,
- conservation of natural resources,
- improved manufacturing productivity,
- improved emergency response,
- enhanced homeland security [3].

However, barriers to the widespread use of sensors in structures and machines remain. Bundles of lead wires and fiber optic “tails” are subject to breakage and connector failures. Long wire bundles represent a significant installation and long term maintenance cost, limiting the number of sensors that may be deployed, and therefore reducing the overall quality of the data reported.

Wireless sensor networks (WSNs) are the main solution for these problems.

The ideal wireless sensor is networked and scaleable, consumes very little power, is smart and software programmable, capable of fast data acquisition, reliable and accurate over the long term, costs little to purchase and install, and requires no real maintenance.

Sensors may represent temperature probes, pressure meters, luminance, vibrance or other sensors.

Recent advances have resulted in the ability to integrate sensors, radio communications, and digital electronics into a single integrated circuit (IC) package. This capability is enabling networks of very low cost sensors that are able to communicate with each other using low power wireless data routing protocols.

WSNs differ fundamentally from general data networks such as the internet, and as such they require the adoption of a different design paradigm. WSNs are

often application specific - they are designed and deployed for special purposes. Selecting the optimum sensors and wireless communications link requires knowledge of the application and problem definition. Battery life, sensor update rates, and size are all major design considerations. Examples of low data rate sensors include temperature, humidity, and peak strain captured passively. Examples of high data rate sensors include strain, acceleration, and vibration.

For battery-operated sensors, energy conservation is one of the most important design parameters, since replacing batteries may be difficult or impossible in many applications. Thus sensor network designs must be optimized to extend the network lifetime. A general class of approaches - cross-layer designs - has emerged to address the challenges related to efficient resource allocation and sensor management.

1.2 Advantages of WSNs over traditional sensing solutions

WSNs advantages are due to their embedded construction and distributed nature. The most notable feature is the cost. Using low-power and relatively inexpensive microcontrollers and transceivers, the sensor nodes used in WSNs are often less than 100 dollars in cost. This is the major point for many commercial or military applications, as the relatively low cost of nodes allows for not only large numbers of sensors to be deployed, but also for large numbers of sensors to be lost [4]. It allows for some nodes to be damaged or lost without compromising the system, unlike larger, more centralized sensors.

Another advantage wireless sensor networks hold over traditional wireless sensing technology lies in the mesh networking scheme. Due to the nature of RF communication, transmitting data from one point to another using a mesh network takes less energy than transmitting directly between the two points. The overall energy spent in RF communication is lower in a mesh networking scenario than using traditional point to-point communication [5].

Sensor networks can also offer better coverage than more centralized sensing technology. Organizations can deploy more sensors using a WSN than they could using more traditional technology [5].

This decreases the overall signal-to-noise ratio of the system, increasing the amount of usable data. For all these reasons and more, WSNs offer many possibilities previously unavailable with traditional sensor technology .

When application deals with large-scale sensor networks WSNs are notable for scalable and flexible architecture and low installation cost. For example, using 16 digits for address information, 65000 sensor devices could be addressed in a network.

The most attractive feature of WSN is the autonomy. When deployed in the field, the microprocessor automatically initializes communication with every node in range, creating an ad hoc mesh network. In this case there is no need in wiring between nodes. Flexible mesh networking algorithms serve to transport information from node to node. This allows nodes to be deployed in almost any location. Coupled with the almost limitless supply of available sensor modules, the flexibility offered by WSNs offers much potential for application-specific solutions.

1.3 Basic operation principles of WSNs

A WSN generally consists of a basestation (sink and gateway) that can communicate with a number of wireless sensors via a radio link. Data is collected at the wireless sensor node, compressed, and transmitted to the gateway directly or, if required, using other wireless sensor nodes to forward data to the sink. The data is cooperatively passed through the network to the sink. The transmitted data is then presented to the system by the gateway connection.

A sink or base station acts like an interface between users and the network.

One can retrieve required information from the network by injecting queries and gathering results from the sink. Typically a wireless sensor network contains

hundreds of thousands of sensor nodes. The sensor nodes can communicate among themselves using radio signals (Figure 1).

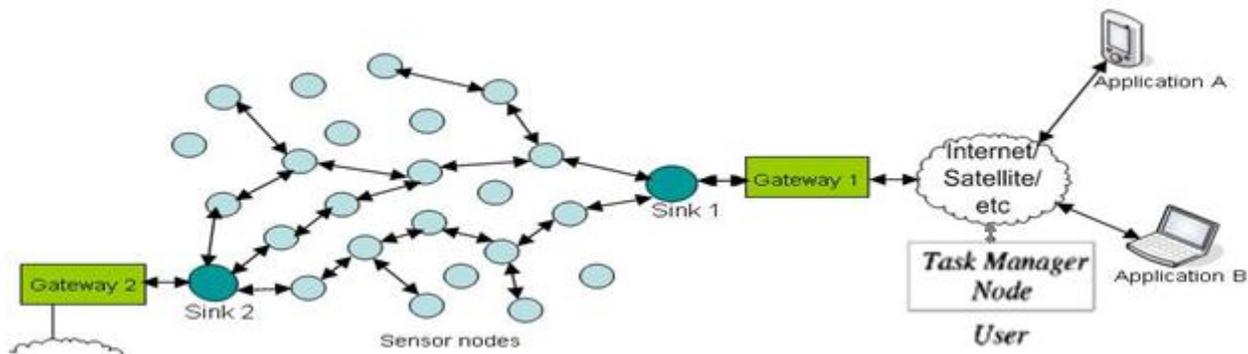


Figure 1 - A typical wireless sensor network.

Each node in a WSN is equipped with one or more sensors in addition to a microcontroller, wireless transceiver, and energy source. The microcontroller manages the operation of electronic sensors and transceiver in order to form an efficient system for relaying small amounts of important data with minimal power consumption.

The individual nodes in a WSN are inherently resource constrained: they have limited processing speed, storage capacity, and communication bandwidth. After the sensor nodes are deployed, they are responsible for self-organizing an appropriate network infrastructure often with multi-hop communication. Then the onboard sensors start collecting information of interest. Wireless sensor devices also respond to queries sent from a “control site” to perform specific instructions or provide sensing samples. The working mode of the sensor nodes may be either continuous or event driven. Global Positioning System (GPS) and local positioning algorithms can be used to obtain location and positioning information.

1.4 Structure of individual wireless sensor node

A sensor node is made up of four basic components such as sensing unit, processing unit, transceiver unit and a power unit which is shown in Figure 2. It also has application dependent additional components such as a location finding

system, a power generator and a mobilizer. Sensing units are usually composed of two subunits: sensors and analogue to digital converters (ADCs). The analogue signals produced by the sensors are converted to digital signals by the ADC, and then fed into the processing unit.

The processing unit is generally associated with a small storage unit and it can manage the procedures that make the sensor node collaborate with the other nodes to carry out the assigned sensing tasks. A transceiver unit connects the node to the network. One of the most important components of a sensor node is the power unit. Power units can be supported by a power scavenging unit such as solar cells. The other subunits of the node are application dependent.

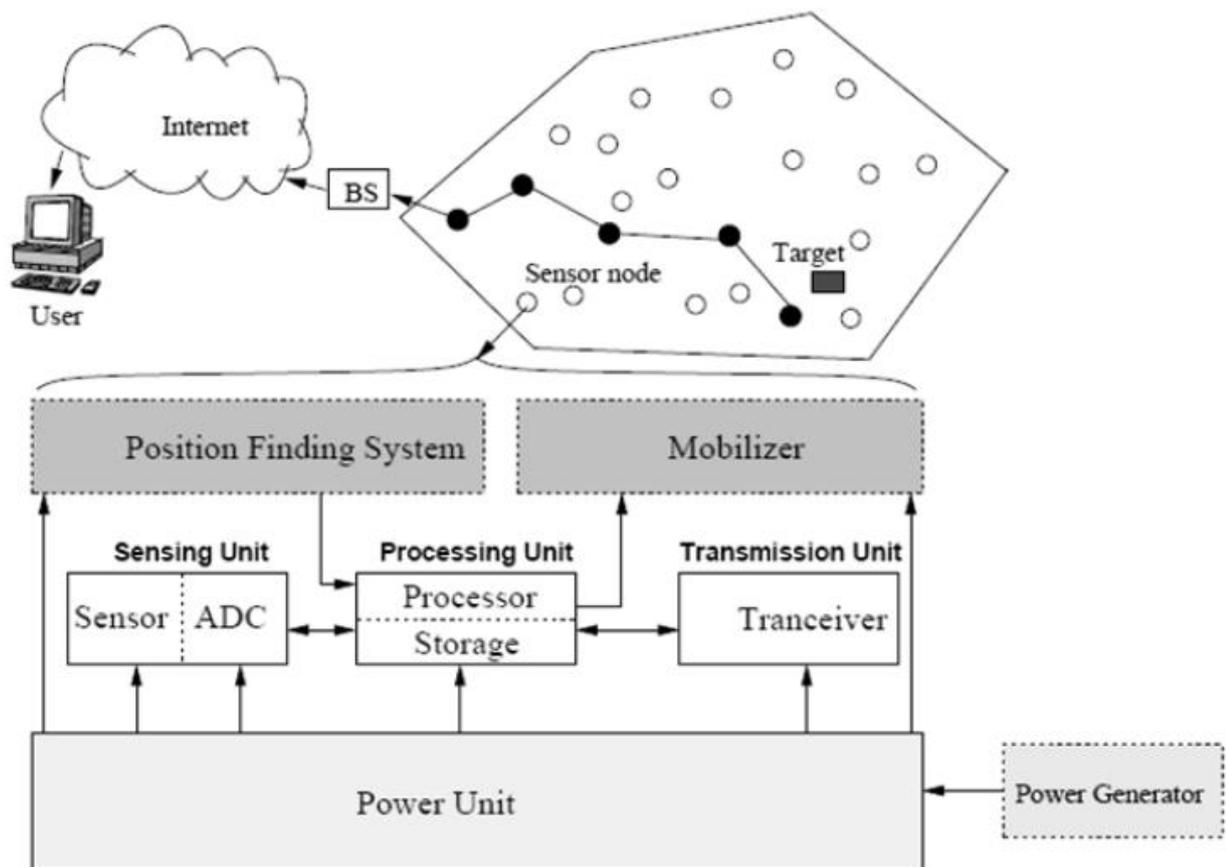


Figure 2 - The components of a sensor node.

A functional block diagram of a versatile wireless sensing node is provided in Figure 3. A modular design approach provides a flexible platform to address the needs of a wide variety of applications. For example, depending on the sensors to

be deployed, the signal conditioning block can be re-programmed or replaced. This allows for a wide variety of different sensors to be used with the wireless sensing node.

The use of flash memory allows the remote nodes to acquire data on command from a base station, or by an event sensed by one or more inputs to the node. Furthermore, the embedded firmware can be upgraded through the wireless network in the field.

The microprocessor has a number of functions including:

- 1) managing data collection from the sensors
- 2) performing power management functions
- 3) interfacing the sensor data to the physical radio layer
- 4) managing the radio network protocol

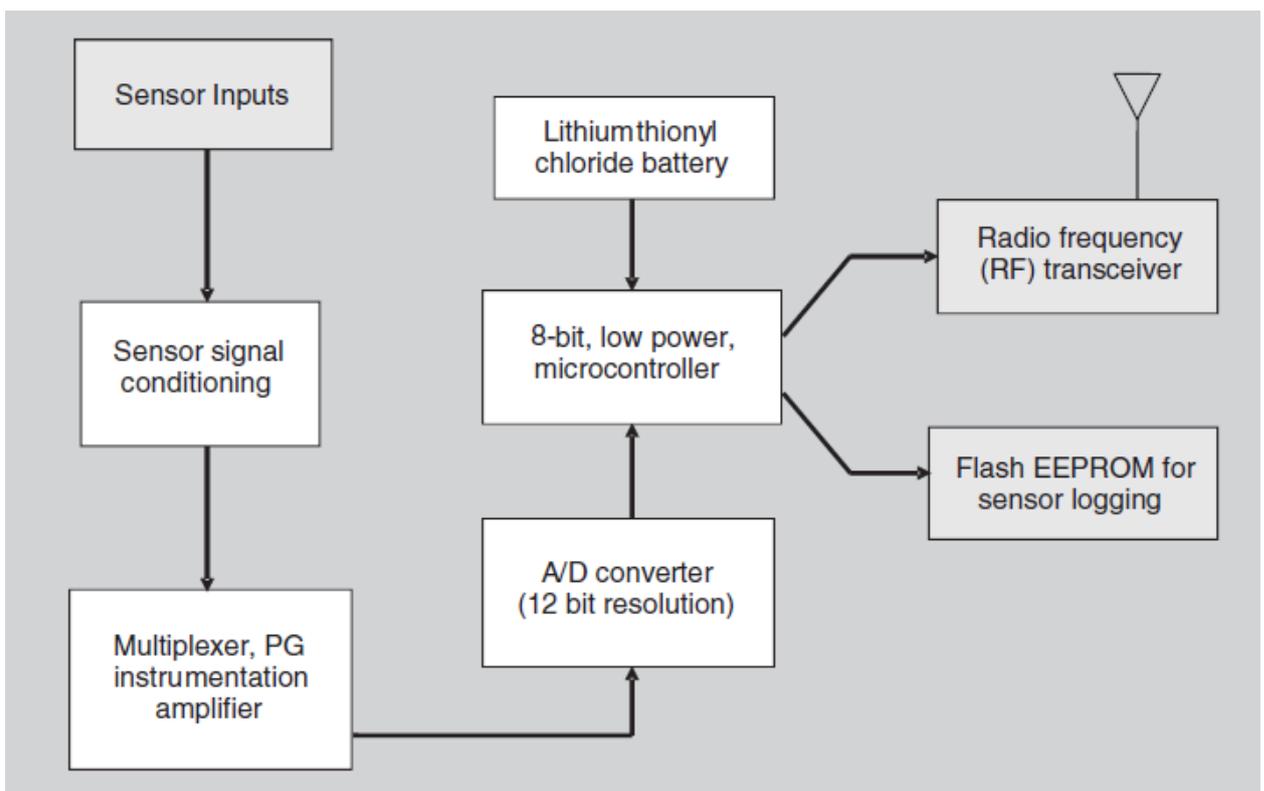


Figure 3 - Wireless sensor node functional block diagram.

A key feature of any wireless sensing node is to minimize the power consumed by the system. Generally, the radio subsystem requires the largest amount of power. Therefore, it is advantageous to send data over the radio network

only when required. This sensor event-driven data collection model requires an algorithm to be loaded into the node to determine when to send data based on the sensed event. Additionally, it is important to minimize the power consumed by the sensor itself. Therefore, the hardware should be designed to allow the microprocessor to judiciously control power to the radio, sensor, and sensor signal conditioner.

1.5 Wireless sensor networks topologies

Let us provide a brief discussion of the network topologies that apply to WSNs.

1.5.1 Star Network (Single Point-to-Multipoint)

A star network (Figure 4) is a communications topology where a single base station can send and/or receive a message to a number of remote nodes. The remote nodes can only send or receive a message from the single base station, they are not permitted to send messages to each other.

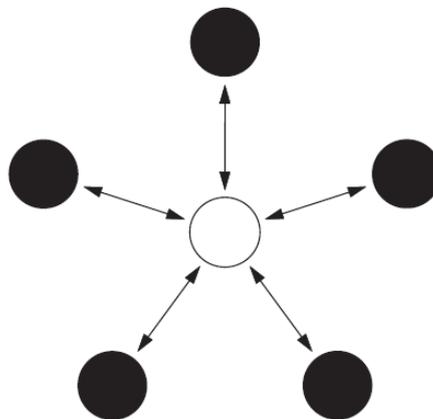


Figure 4 - Star network topology.

This type of network has the advantage of:

- simplicity and the ability to keep the remote node's power consumption to a minimum;

- low latency communications between the remote node and the base station.

Also there are disadvantages:

- the base station must be within radio transmission range of all the individual nodes

- the network is not as robust as other networks due to its dependency on a single node to manage the network.

1.5.2 Mesh Network

A mesh network (Figure 5) allows for any node in the network to transmit to any other node in the network that is within its radio transmission range. This allows for what is known as multihop communications; that is, if a node wants to send a message to another node that is out of radio communications range, it can use an intermediate node to forward the message to the desired node.

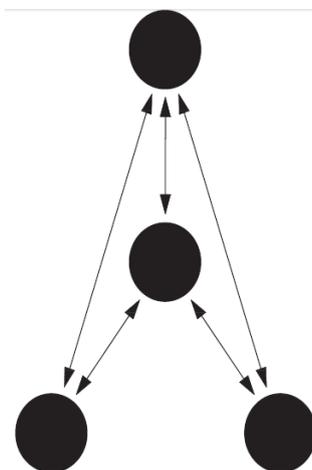


Figure 5 - Mesh network topology.

This network topology has the advantage of:

- redundancy - if an individual node fails, a remote node still can communicate to any other node in its range, which in turn, can forward the message to the desired location;

- scalability - the range of the network is not necessarily limited by the range between single nodes, it can simply be extended by adding more nodes to the system.

The disadvantages of this type of network:

- power consumption for the nodes that implement the multihop communications are generally higher than for the nodes that don't have this capability, often limiting the battery life;

- as the number of communication hops to a destination increases, the time to deliver the message also increases, especially if low power operation of the nodes is a requirement.

1.5.3 Hybrid Star-Mesh Network

A hybrid between the star and mesh network (Figure 6) provides for a robust and versatile communications network, combining advantages of both topologies. This type maintains the ability to keep the wireless sensor nodes power consumption to a minimum.

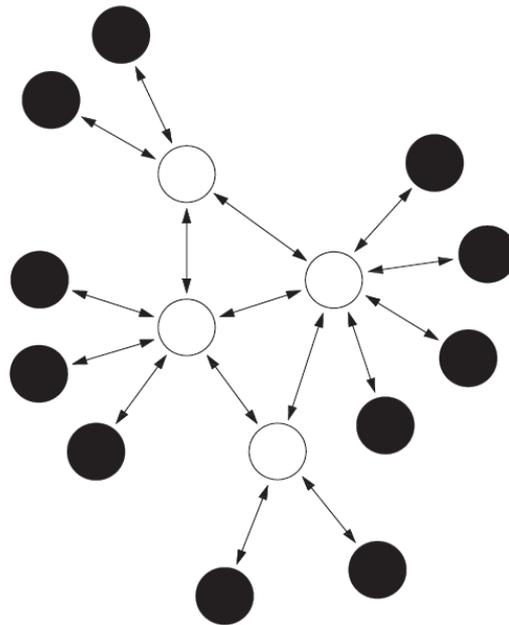


Figure 6 - Hybrid star-mesh network topology.

In this network topology, the lowest power sensor nodes are not enabled with the ability to forward messages. This allows for minimal power consumption to be maintained. However, other nodes on the network are enabled with multihop capability, allowing them to forward messages from the low power nodes to other nodes on the network. Generally, the nodes with the multihop capability are higher power, and if possible, are often plugged into the electrical mains line. This is the topology implemented by the up and coming mesh networking standard known as ZigBee.

1.6 Mesh network routing

Mesh networks are designed such that each node can communicate with each other node in the network without the use of a central control scheme. Figure 7 contains an example of a mesh network. Note there are no any communication between nodes yet.

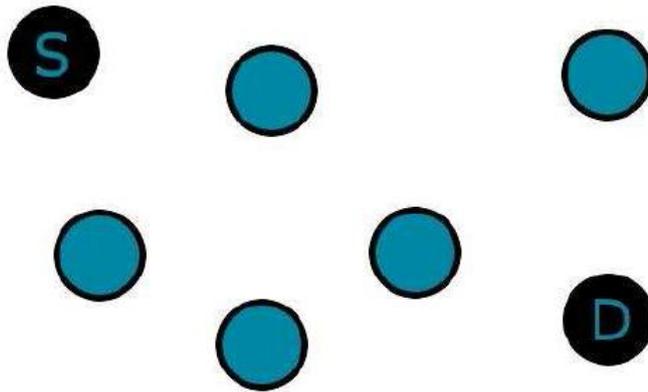


Figure 7: Preliminary mesh network topology.

The routing protocol of the mesh network works as follows: the source node shares its routing information with each node surrounding it. Each node performs this action, until a complete routing table is established, and all topology information is shared between the nodes.

Once the nodes have established their routing table, the source node can send its packets safely to the destination node via the ideal routing path [6]. This is depicted in Figure 8, note that the ideal routing path is highlighted in this Figure.

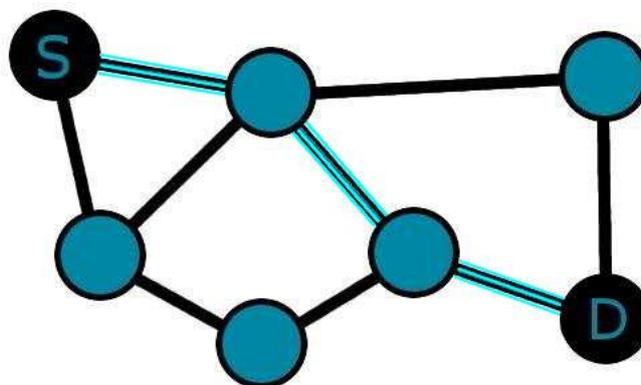


Figure 8 - Mesh network topology with ideal routing path.

Mesh networking allows for ad-hoc networks to operate with an arbitrarily large number of nodes. This protocol allows for a particularly resilient network, as data can take more than one path to its destination, meaning the network rarely has a single point of failure. Ad-hoc mesh networking scales exceedingly well and is reliable.

1.7 Sensor network architecture

The architecture of wireless sensor networks draws upon many sources and much research has been done in the context of self-organizing, mobile ad-hoc networks. The characteristics of self-organizing and low power operation govern the design of the network architecture to fit the different purposes, but they share the need for a decentralized and distributed form of organization. Sensor network architectures can be broadly separated into two categories: “layered architecture” and “clustered architecture” [6, 7,8].

1.7.1. Layered Architecture

In a layered architecture, a network consists of a base station with multiple nodes, as depicted in Figure 9. Network sensors are organized in these “layers” based on their hop count to the base station. Sensors with the same hop count are grouped together in each layer. In this case communication between the farthest nodes to the base station is possible without having to use high power transmission. The main advantage of this is that it allows short distance communication between the nodes with high energy efficiency. It is capable of supporting hundreds of nodes in the network [5, 6].

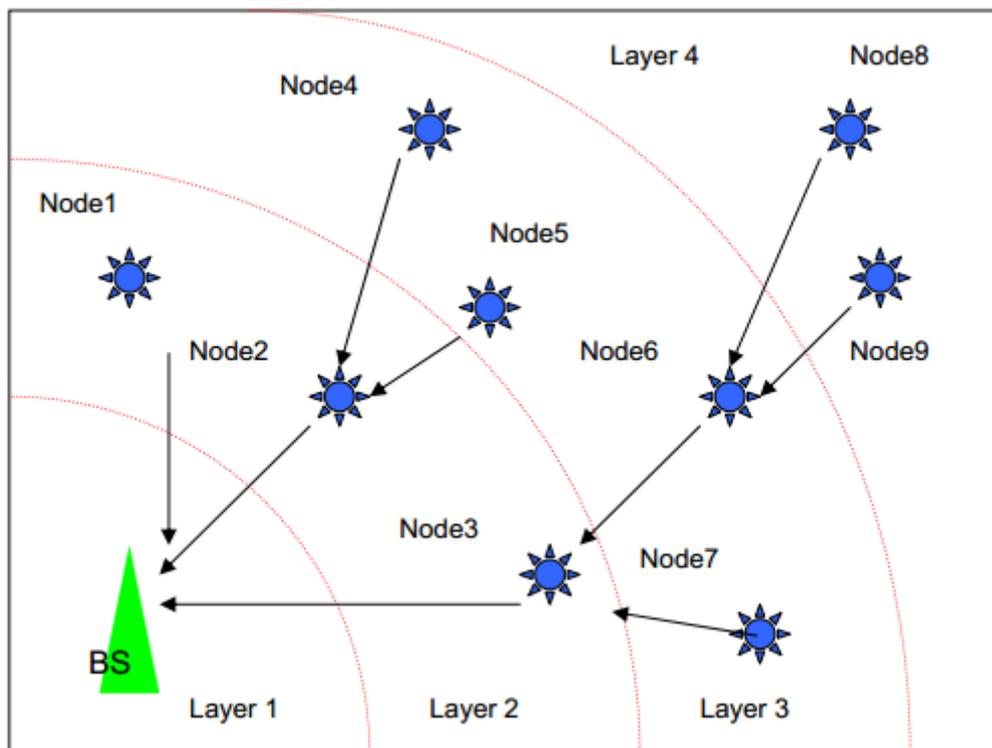


Figure 9. Layered Architecture [6, 7].

1.7.2. Clustered Architecture

In a clustered sensor network architecture, the sensor node will communicate to the base station via the cluster head as depicted in Figure 10.

The cluster head has two main roles: (1) intra-cluster coordination (i.e., coordinating among nodes in within its cluster), and (2) inter-cluster communication (i.e., communicating with other cluster heads and/or the base station). The main advantages of a clustering architecture are to increase scalability and reduce communication delay between the nodes [6, 7].

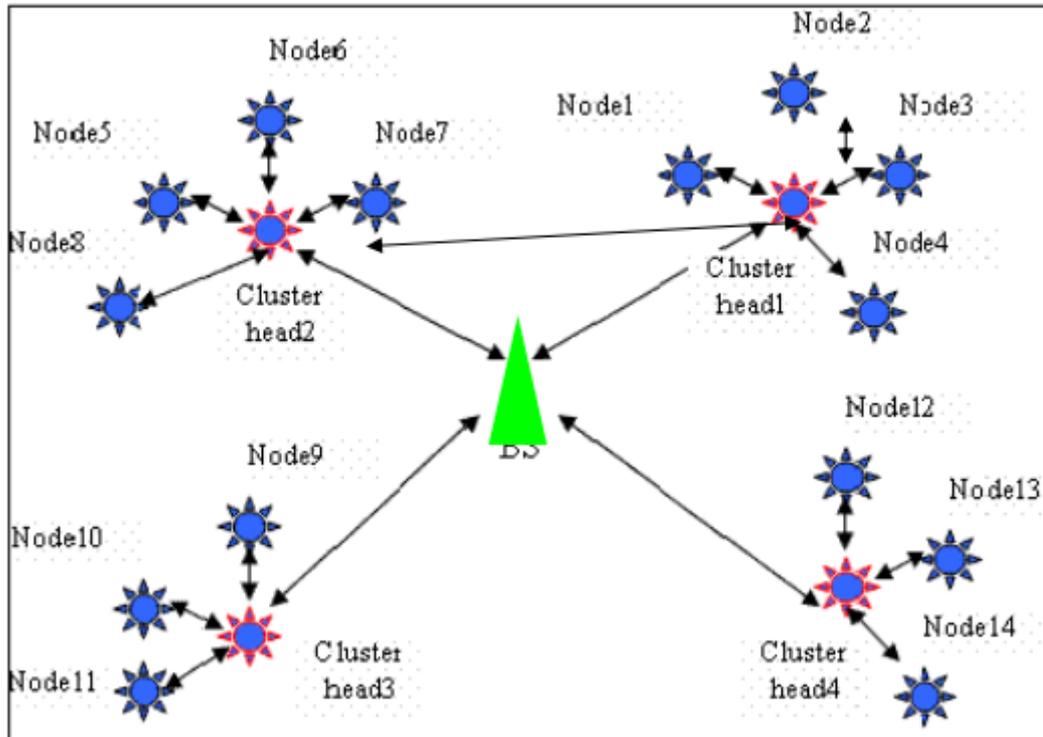


Figure 10. Clustered Architecture [5, 6].

Each of the above architectures has its own merit and suited applications and there is always a dilemma of having to strike a balance between energy efficiency, accuracy, and latency of the sensor network. There is no clear cut solution as to which is better, as the choice is dependent on the application and environment.

Summary to the chapter 1

General introduction and description of WSNs was provided in this chapter. Potential benefits of using of WSN in various real-world applications and Advantages of WSNs over traditional sensing solutions are discussed. The most advantages of WSNs are due to mesh networking features. Mesh networking enables to achieve energy efficiency and robustness in harsh environments, because the message have a number of alternative paths to reach the destination and thus there is no single failure point in the network. Moreover WSNs have the

potential to be designed easily scalable which is a very important point in applications requiring a large amount of sensors.

Also basic operation principles of WSNs were considered which is essential in understanding the working mechanisms of real-world applications.

Network topologies are another important issue in WSN design and they are application specific. However, in most practical implementations the hybrid star-mesh network topology is mainly used. WSN architecture is also turns out to be application specific as different applications pose different operational requirements. Layered Architecture has the advantage of short distance communication between the nodes with high energy efficiency, while clustering architecture increases scalability and reduces communication delay between the nodes.

2. DESIGN ISSUES OF A WIRELESS SENSOR NETWORK

There are a lot of challenges placed by the deployment of sensor networks. As we have seen above WSNs are based on embedded devices equipped with sensors and radio transceivers, which communicate and collaborate to achieve a common goal. Sensor nodes communicate over wireless, lossy lines with no infrastructure.

In a survey on the problems of WSN [9], the lack of installation ease, the concern about the interference, robustness, and reliability were the biggest problems reported by people who developed and deployed sensor networks.

Additional problems reported by researchers were the significant manpower involved in the deployment and the dependance on the individual skills of deployers.

Furthermore, from a general and especially industry perspective, the major barrier to the wide adoption of wireless sensor networks technologies is the lack of easiness in WSN programming.

For surveillance systems, it is also a very important issue to increase the robustness of the applications, especially due to the dynamicity of the environment. For example, autoconfiguration schemes should be provided in order to deal with varying environmental conditions.

The need of an always faster deployment is also very radicated in surveillance and defence systems, as well as in emergency scenarios. The lengthy and tedious deployment phases should be shortened and the number of external assistant devices and tools should be reduced.

Different applications have different features and needs, but they share the same design constraints and limitations. Although different, all WSN applications need to easily access sensor data, to deal with the radio channel interference, to monitor the battery lifetime, as well as to provide easy auto-configuration schemes.

Wireless Sensor Networks design is influenced by several factors: for example depending on the application of sensor networks, it may be indispensable

that sensor network functionalities are not interrupted. For this purpose fault tolerance is an extremely important property, that can be achieved through redundancy. As long as the sensor network grows, scalability problems may arise. Simulations are a very useful tool to predict how efficient is the topology design when deployed in a large scenario with many nodes. The cost of a single node is also very important to justify the overall cost of the network: a sensor node should be very cheap because many nodes are usually deployed to ensure a better coverage and a greater fault tolerance. Among all other possible factors, it must be remarked that the ones that really drive WSN design are power consumption and energy efficiency. Those two properties are related to each other and are driving today's research focus and development.

The next paragraphs describe some of the main common challenges in WSN applications.

2.1 Energy consumption and battery lifetime

The most important challenge is related to the limited, usually non-renewable energy supply of the sensor nodes. Sensing, data processing and communications affect the energy consumption and thus the lifetime of the system.

Lifetime is extremely critical for most applications, and its primary limiting factor is the energy consumption of the nodes, which need to be self-powering. Although it is often assumed that the transmit power associated with packet transmission accounts for the lion's share of power consumption, sensing, signal processing and even hardware operation in standby mode consume a consistent amount of power as well [10, 11].

The size of the nodes limits the size of the battery. The software and hardware design needs to carefully consider the issues of efficient energy use. Many researchers suggest that energy consumption could be reduced by considering the existing interdependencies between individual layers in the network protocol stack. Routing and channel access protocols, for instance, could

greatly benefit from an information exchange with the physical layer. For instance, data compression might reduce the amount of energy used for radio transmission, but uses additional energy for computation and/or filtering. At the physical layer, benefits can be obtained with lower radio duty cycles and dynamic modulation scaling (varying the constellation size to minimize energy expenditure [12]).

The energy policy also depends on the application. Although applications should always use as few energy as possible, they often have to modify their behavior based on the battery status, for example switch off some components or modifying routing schemes, as remarked by Lachenmann et al. [13]. In some applications, it might be acceptable to turn off a subset of nodes in order to conserve energy while other applications require all nodes operating simultaneously. In some applications, extra power is needed for macro-scale actuation.

Using low-power modi for the processor or disabling the radio is generally advantageous, even though periodically turning a subsystem on and off may be more costly than always keeping it on. Techniques aimed at reducing the idle mode leakage current in CMOS-based processors are also noteworthy [14].

Medium Access Control (MAC) solutions have a direct impact on energy consumption, as some of the primary causes of energy waste are found at the MAC layer: collisions, control packet overhead and idle listening. Power saving forward error control techniques are not easy to implement due to the high amount of computing power that they require and the fact that long packets are normally not practical.

Energy-efficient routing should avoid the loss of a node due to battery depletion. Many proposed protocols tend to minimize energy consumption on forwarding paths, but if some nodes happen to be located on most forwarding paths (*e.g.*, close to the base station), their lifetime will be reduced.

A typical example of the benefits brought by a battery lifetime monitoring module is the Sensor Contextaware Adaptive Routing (SCAR) [15, 16, 17]. SCAR is a perfect example of how an application can improve its performance based on

context information like for example the battery lifetime of the system. This routing approach uses prediction techniques over context of the sensor nodes to foresee which of the sensor neighbors are the best carriers for the data messages. Each node evaluates its connectivity rate, battery level and the forecasted values are combined in order to predict the future evolutions of the system.

By monitoring the battery level, it is also possible to predict for how long the data originated by sensors will be meaningful: in fact sensors like the Sensirion SHT11 [18] return wrong values below a certain voltage threshold.

2.2 Fault Tolerance

Sensor nodes are vulnerable and frequently deployed in dangerous environment. Nodes can fail due to hardware problems or physical damage or by exhausting their energy supply. The extremely high variability of the environmental conditions often causes mismatches between the results obtained with emulation and real-world deployments. This can be due not only to the electromagnetic interference, but for example also by moving people, weather effects, and thermal excursion, that can cause different transmission and sensing patterns.

Thus, robustness to dynamic environment is an important issue in. WSNs should be robust, self-configuring, self-healing and adaptive. Application should be able to monitor and answer quickly to environmental changes. Moreover, sensors are often unreliable and sensed values may vary a lot from each other. This implies that decisions based only on snapshot queries are very dangerous, because a single value can give an erroneous information.

We expect the node failures to be much higher than the one normally considered in wired or infrastructure-based wireless networks. The protocols deployed in a sensor network should be able to detect these failures as soon as possible and be robust enough to handle a relatively large number of failures while maintaining the overall functionality of the network. This is especially relevant to

the routing protocol design, which has to ensure that alternate paths are available for rerouting of the packets. Different deployment environments pose different fault tolerance requirements.

2.3 Scalability

Sensor networks vary in scale from several nodes to potentially several hundred thousand. In addition, the deployment density is also variable. For collecting high-resolution data, the node density might reach the level where a node has several thousand neighbours in their transmission range. The protocols deployed in sensor networks need to be scalable to these levels and be able to maintain adequate performance.

Sensor networks should be scalable, and they should be able to dynamically adapt to changes in node density and topology, like in the case of the self-healing minefields. In surveillance applications, most nodes may remain quiescent as long as nothing interesting happens. However, they must be able to respond to special events that the network intends to study with some degree of granularity.

In a self-healing minefield, a number of sensing mines may sleep as long as none of their peers explodes, but need to quickly become operational in the case of an enemy attack. Response time is also very critical in control applications in which the network is to provide a delay-guaranteed service.

Untethered systems need to self-configure and adapt to different conditions. Sensor networks should also be robust to changes in their topology, for instance due to the failure of individual nodes. In particular, connectivity and coverage should always be guaranteed. Connectivity is achieved if the base station can be reached from any node. Coverage can be seen as a measure of quality of service in a sensor network [19], as it defines how well a particular area can be observed by a network and characterizes the probability of detection of geographically constrained phenomena or events. Complete coverage is particularly important for surveillance applications.

2.4 Other considerations

2.4.1 Production Costs

Because many deployment models consider the sensor nodes to be disposable devices, sensor networks can compete with traditional information gathering approaches only if the individual sensor nodes can be produced very cheaply. The target price envisioned for a sensor node should ideally be less than \$1.

2.4.2 Hardware Constraints

At minimum, every sensor node needs to have a sensing unit, a processing unit, a transmission unit, and a power supply. Optionally, the nodes may have several built-in sensors or additional devices such as a localization system to enable location-aware routing. However, every additional functionality comes with additional cost and increases the power consumption and physical size of the node. Thus, additional functionality needs to be always balanced against cost and low-power requirements.

2.4.3 Sensor Network Topology

Although WSNs have evolved in many aspects, they continue to be networks with constrained resources in terms of energy, computing power, memory, and communications capabilities. Of these constraints, energy consumption is of paramount importance, which is demonstrated by the large number of algorithms, techniques, and protocols that have been developed to save energy, and thereby extend the lifetime of the network. Topology Maintenance is one of the most important issues researched to reduce energy consumption in wireless sensor networks.

2.4.4 Transmission Media

The communication between the nodes is normally implemented using radio communication over the popular ISM bands. However, some sensor networks use optical or infrared communication, with the latter having the advantage of being robust and virtually interference free.

2.4.5 Maintenance

The only desired form of maintenance in a sensor network is the complete or partial update of the program code in the sensor nodes over the wireless channel. All sensor nodes should be updated, and the restrictions on the size of the new code should be the same as in the case of wired programming. Packet loss must be accounted for and should not impede correct reprogramming. The portion of code always running in the node to guarantee reprogramming support should have a small footprint, and updating procedures should only cause a brief interruption of the normal operation of the node [20].

The functioning of the network as a whole should not be endangered by unavoidable failures of single nodes, which may occur for a number of reasons, from battery depletion to unpredictable external events, and may either be independent or spatially correlated [21]. Fault tolerance is particularly crucial as ongoing maintenance is rarely an option in sensor network applications.

Self-configuring nodes are necessary to allow the deployment process to run smoothly without human interaction, which should in principle be limited to placing nodes into a given geographical area. It is not desirable to have humans configure nodes for habitat monitoring and destructively interfere with wildlife in the process, or configure nodes for urban warfare monitoring in a hostile environment. The nodes should be able to assess the quality of the network deployment and indicate any problems that may arise, as well as adjust to changing environmental conditions by automatic reconfiguration.

Location awareness is important for selfconfiguration and has definite advantages in terms of routing [22] and security. Time synchronization [23] is advantageous in promoting cooperation among nodes, such as data fusion, channel access, coordination of sleep modi, or security-related interaction.

2.4.6 Data Collection techniques

Data collection is related to network connectivity and coverage. An interesting solution is the use of ubiquitous mobile agents that randomly move around to gather data bridging sensor nodes and access points, whimsically named

data MULEs (Mobile Ubiquitous LAN Extensions) in [24]. The predictable mobility of the data sink can be used to save power [25], as nodes can learn its schedule. A similar concept has been implemented in Intel's Wireless Vineyard.

It is often the case that all data are relayed to a base station, but this form of centralized data collection may shorten network lifetime. Relaying data to a data sink causes non-uniform power consumption patterns that may overburden forwarding nodes [26]. This is particularly harsh on nodes providing end links to base stations, which may end up relaying traffic coming from all other nodes, thus forming a critical bottleneck for network throughput [27], as shown in Figure 11.

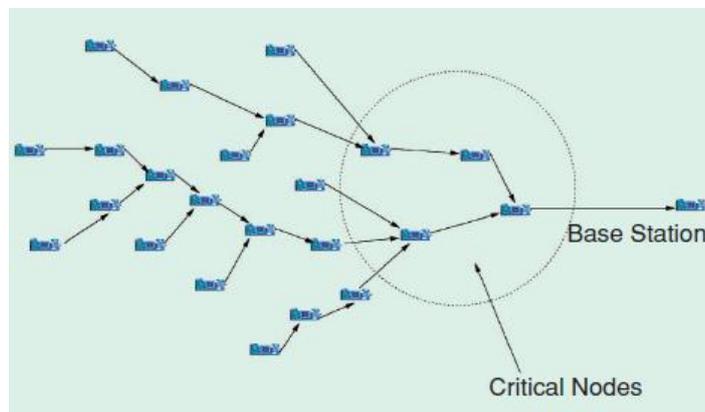


Figure 11 - A uniform energy consumption pattern should avoid the depletion of the resources of nodes located in the vicinities of the base station.

An interesting technique is clustering: nodes team up to form clusters and transmit their information to their cluster heads, which fuse the data and forward it to a sink. Fewer packets are transmitted, and a uniform energy consumption pattern may be achieved by periodic re-clustering. Data redundancy is minimized, as the aggregation process fuses strongly correlated measurements.

Many applications require that queries be sent to sensing nodes. This is true, for example, whenever the goal is gathering data regarding a particular area where various sensors have been deployed. This is the rationale behind looking at a sensor network as a database [28].

A sensor network should be able to protect itself and its data from external attacks, but the severe limitations of lower-end sensor node hardware make

security a true challenge. Typical encryption schemes, for instance, require large amounts of memory that are unavailable in sensor nodes. Data confidentiality should be preserved by encrypting data with a secret key shared with the intended receiver. Data integrity should be ensured to prevent unauthorized data alteration. An authenticated broadcast must allow the verification of the legitimacy of data and their sender. In a number of commercial applications, a serious disservice to the user of a sensor network is compromising data availability (denial of service), which can be achieved by sleep-deprivation torture [29]: batteries may be drained by continuous service requests or demands for legitimate but intensive tasks, preventing the node from entering sleep mode.

2.5 Existing wireless sensor platforms and devices

In recent years there has been growing research in the field of building sensor network platforms, each of these platforms are a point in the design space. Most of the platforms are used to investigate a multitude of research topics ranging from network issues, remote reprogramming, sensing capabilities to software design or scalability. Only a few platforms have been evaluated in large scale application deployments.

The major drawbacks to designing and building sensor nodes, disregarding the cost is: (a) the design process itself is a long and time-consuming and (b) scaling a network to hundreds or thousands of nodes is difficult. To overcome this initial hurdle and to study large scale sensor networks simulation is often employed.

In this section we look at the available sensor nodes. The nodes we describe have been built using commercially available or common off the shelf components (COTS), the next natural move for sensor network platforms is to embed all components on a chip (system on a chip).

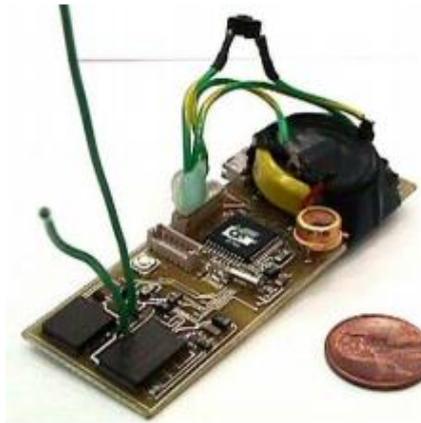
2.5.1 UC Berkeley Motes

The vast majority of research in sensor networks has been centered around the generations of sensor nodes developed at University of California Berkeley: Rene, Mica, Mica2 shown in Figure 12.

Among the first motes to be developed at UC Berkeley were the “RF Mote” and the “weC” motes [30] featuring RF Monolithics TR1000 radio and the Atmel AT90LS8535 at 150 kHz and 4 MHz respectively.

The Rene and Rene2 were constructed in a modular design as a “sandwich” board, allowing easy and compact connection of additional boards (sensor board, etc.). The Rene2 featured the ATmega163 MCU at 4 MHz increasing the memory from 0.5 KiB to 1 KiB and the program flash from 8 KB to 16 KB.

The successor to these nodes was the Mica [31] and Mica2 motes continuing the modular design but upgrading to a more powerful MCU: the Atmel ATMega 103 at 4 MHz and ATMega 1281 at 7.37 MHz respectively.



(a) RF Mote (1998)



(b) weC (1999)



(c) Mica2 (2002)



(d) Telos (2004)

Figure 12 - Four generations of UC-Berkeley Motes.

Berkeley motes up to the MICA2 generation cannot interface with other wireless-enabled devices. However, the newer generations MICAz and Telos support IEEE 802.15.4, which is part of the 802.15 Wireless Personal Area Network (WPAN) standard being developed by IEEE. At this point, these devices represent a very good solution for generic sensing nodes, even though their unit cost is still relatively high (about \$100–\$200).

Table 1 Sensor node summary. FLASH is used for program memory, Clock is the microcontroller clock, Storage is extra nonvolatile storage.

	MCU	Clock (MHz)	FLASH (KB)	RAM (KB)	Wakeup (μ s)	Storage (KB)	Radio
RF Mote[29]	AT9080515	0.15	8	0.5		32	TR1000
weC[31]	AT90LS8535	4	8	0.5	1000	32	TR1000
Rene[31]	ATMegal63	4	16	1	1000	32	TR1000
Mica[31]	ATMegal03	4	128	4	180	512	TR1000
Mica2[31]	ATMegal281	7	128	4	180	512	CC1000
MicaZ[31]	ATMegal281	7	128	4		512	CC2420
Telos	MSP430	8	60	2	6	512	CC2420

2.5.2 Tmote Sky

Tmote Sky - mote platform for extremely low power, high data-rate, sensor network applications designed with the dual goal of fault tolerance and development ease. It boasts a large on-chip RAM size (10 kB), an IEEE802.15.4 radio and an integrated on-board antenna providing range up to 125 meter.

It also offers a number of integrated peripherals, including a 12-bit ADC and DAC, Timer, I2C, SPI and UART bus protocols, as well as a performance boosting DMA controller. Tmote Sky offers a robust solution with hardware protected external ash (1Mb in size) and applications may be wirelessly programmed to the Tmote Sky module. In the event of a malfunctioning program, the module loads a protected image from ash. Toward development ease, Tmote Sky provides an easy-to-use USB protocol for programming, debugging and data collection.



A Tmote Sky physical sensor device.

2.5.3 Sun SPOT sensor nodes

Sun SPOT [33] (Sun Small Programmable Object Technology) is a WSN mote developed by Sun Microsystems. Project Sun SPOT was to build sensor hardware and to adapt a small, flexible Java Virtual Machine called Project Squawk to the sensor platform.

As illustrated in Figure 13, Sun SPOT motes have three components: (1) a sensor board (2) a processor board and (3) a battery.

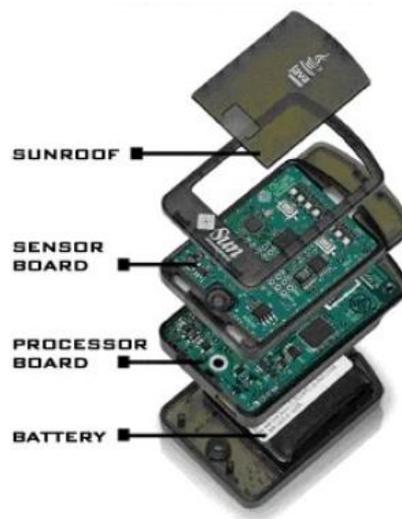


Figure 13 - Sun SPOT produced by Sun Microsystems.

Each Sun SPOT mote comes with a 180 MHz 32-bit ARM920T core, 512K RAM, 4M non-volatile Flash memory, 802.15.4 radio, 8 multi-color LEDs, and a USB interface. The default hardware configuration includes three sensors: accelerometer, temperature and light sensors. The wireless section uses an integrated radio transceiver, the TI CC2420. The CC2420 is IEEE 802.15.4 compliant and operates in the 2.4GHz to 2.4835GHz ISM unlicensed bands. Other features include AES encryption, received signal strength indication (RSSI) with 100 dB sensitivity and transmit output power setting from -24dBm to 0dBm. Receive sensitivity is -90dBm. The antenna is a folded monopole 1/4 wave with reasonable omni directional radiation pattern. The internal battery is a 3.7V 720maH rechargeable lithium-ion prismatic cell. The battery has internal protection circuit to guard against over discharge, under voltage and overcharge

conditions. The Sun SPOT mote drops into a power saving mode (“shallow sleep”) to reduce power consumption.

The Sun SPOT system uses Java technology to up-level programming. Developers can write a program in Java, load it on a wireless sensor device, run it, debug it, as well as access low-level mechanisms with standard Java IDEs. What distinguishes the Sun SPOT mote from comparable devices is that it runs a Java Micro Edition Virtual Machine called Squawk directly on the processor without an operating system.

Summary to the chapter 2

This chapter was focused on design challenges of WSNs and existing hardware platforms.

Sensor nodes communicate over wireless, lossy lines with no infrastructure. As it comes from the analysis, while designing WSN a particular attention is required to energy efficiency, fault tolerance and maintenance issues. However other considerations like production cost, hardware constraints, WSN topology and data collection mechanism are also important.

The major barrier to the wide adoption of WSN technologies is the lack of easiness in WSN programming. In surveillance systems, robustness is also an issue of main importance due to environmental conditions.

Power consumption and energy efficiency are two properties that really drive WSN design. They are related to each other and are driving today’s research focus and development.

The most popular in existing hardware platforms are UC Berkeley motes, Tmote Sky of Sentilla and Sun SPOT of Sun Microsystems. All are commercially available, but Sun SPOT is also an open-source project with all the code and necessary material available in Internet. It based on Java and do not need operating system and therefore in our point this serves to easiness of application. As we’ll see further Mica platform is one of the commonly used one in various real-world

applications of WSN for research purposes and environmental monitoring solutions.

3. ANALYSIS OF WIRELESS SENSOR NETWORK APPLICATIONS

From [34], in the recent past, WSNs have found their way into a wide variety of applications and systems with vastly varying requirements and characteristics. As a consequence, it is becoming increasingly difficult to discuss typical requirements regarding hardware issues and software support. This is particularly problematic in a multidisciplinary research area such as wireless sensor networks, where close collaboration between users, application domain experts, hardware designers, and software developers is needed to implement efficient systems.

Examples of applications of WSNs may include telemetry data acquisition, remote diagnostics and data exchange in various fields beginning with fight against terrorism and finishing with protection of nature and animals.

The most promising implementations involve using the hardware for environmental or security monitoring. The nature of these applications lent themselves well to using large networks of individual nodes. For environmental monitoring, a large WSN could detect climate changes in environments over a large area. Using a WSN for security monitoring would allow for quickly deployed large-scale intrusion detection.

In this chapter we will try to provide a classification of sample applications according to the design requirements, considering deployment, mobility, resources, cost, energy, heterogeneity, modality, infrastructure, topology, coverage, connectivity, size and lifetime.

3.1 Environmental monitoring - Great duck island example

During 2002 researchers from UC Berkeley and The College of the Atlantic deployed a sensor network with 32 nodes on a desolate island off the coast of Maine (Figure 14).



Figure 14 - a) mote with protection package, b) Great Duck island on the map.

The goal was to monitor the habitat of a small sea bird, the Leach's Storm Petrel. The target lifetime was to monitor the birds during their 7 months breeding period. The sensor network monitors how the birds use their burrows and it monitors the micro climate in them. Seabirds are sensitive to disturbance - sensor nodes provide a low invasive alternative to frequent visits.

The deployed sensor nodes were slightly modified Mica motes (see Section 2.5.1) equipped with the Mica weather sensor board. The weather board features temperature, photo-resistor, barometric pressure, humidity, and passive infrared sensors.

The nodes were spread out over a 6 hectar area and results were forwarded to a central database. The wide spread of the sensor nodes demands a sophisticated network infrastructure.

The authors choose a two tiered architecture by grouping sensor nodes close together in a *sensor patch* with a gateway that is part of a *transit network* that transmits the data to a remote data storage unit (see Figure 15).

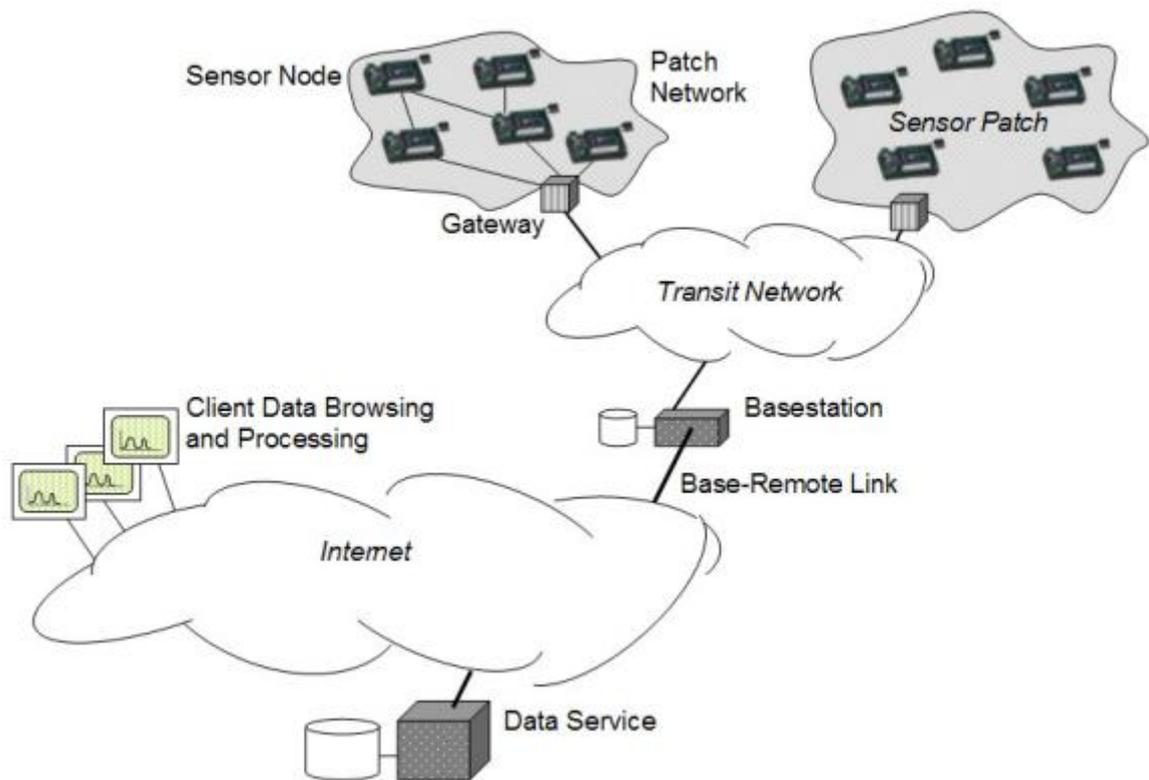


Figure 15 - System architecture for habitat monitoring.

As a simple health sign the nodes regularly included their battery voltage with their sensor reading. This application is representative of a class of sensor network applications described as *habitat and environmental monitoring*, with the following characteristics:

- Immobile nodes that are left unattended for long periods of time.
- On-line data gathering, measurements are forwarded through network infrastructure.

While the experiments were planned for as long as 7 months many of nodes failed much earlier than this. Interestingly only a few died because of depleted batteries, the majority failed to withstand the wear and tear from the outdoors. Based on this fact node failures are shown to be predictable based on their, faulty, sensor readings. An other surprise was the networking performance: the nodes send infrequently and at a low rate, suggesting few or no collisions.

However, in the deployment it turns out that by different types of misfortune

the nodes start dropping a large number of packets for example at certain period the transmission schedule is aligned and packets collide.

From our point of view the most interesting lessons learned from this experience are:

- The differences in conducting lab and field experiments
- More effective approach would be to account for environmental conditions and specific sensors when designing hardware and software.

3.2 Monitoring of structural health of constructions

Another application is structural health monitoring of large civil structures, such as the Ben Franklin Bridge in Philadelphia (Figure 16) [35]. The bridge carries automobile, train and pedestrian traffic. Bridge officials wanted to monitor the strains on the structure as high-speed commuter trains crossed over the bridge.



Figure 16 - Ben Franklin Bridge health monitoring solution.

A star network of ten strain sensors were deployed on the tracks of the commuter rail train. The wireless sensing nodes were packaged in environmentally sealed enclosures. The strain gauges were also suitably sealed from the environment and were spot welded to the surface of the bridge steel support

structure. Transmission range of the sensors on this star network was approximately 100 meters.

The sensors operate in a low-power sampling mode where they check for presence of a train by sampling the strain sensors at a low sampling rate of approximately 6 Hz. When a train is present the strain increases on the rail, which is detected by the sensors. Once detected, the system starts sampling at a much higher sample rate. The strain waveform is logged into local Flash memory on the wireless sensor nodes. Periodically, the waveforms are downloaded from the wireless sensors to the base station. The base station has a cell phone attached to it which allows for the collected data to be transferred via the cell network to the engineers' office for data analysis.

This low-power event-driven data collection method reduces the power required for continuous operation from 30 mA if the sensors were on all the time to less than 1 mA continuous. This enables a lithium battery to provide more than a year of continuous operation.

Resolution of the collected strain data was typically less than 1 microstrain. A typical waveform downloaded from the node is shown in Figure 17.

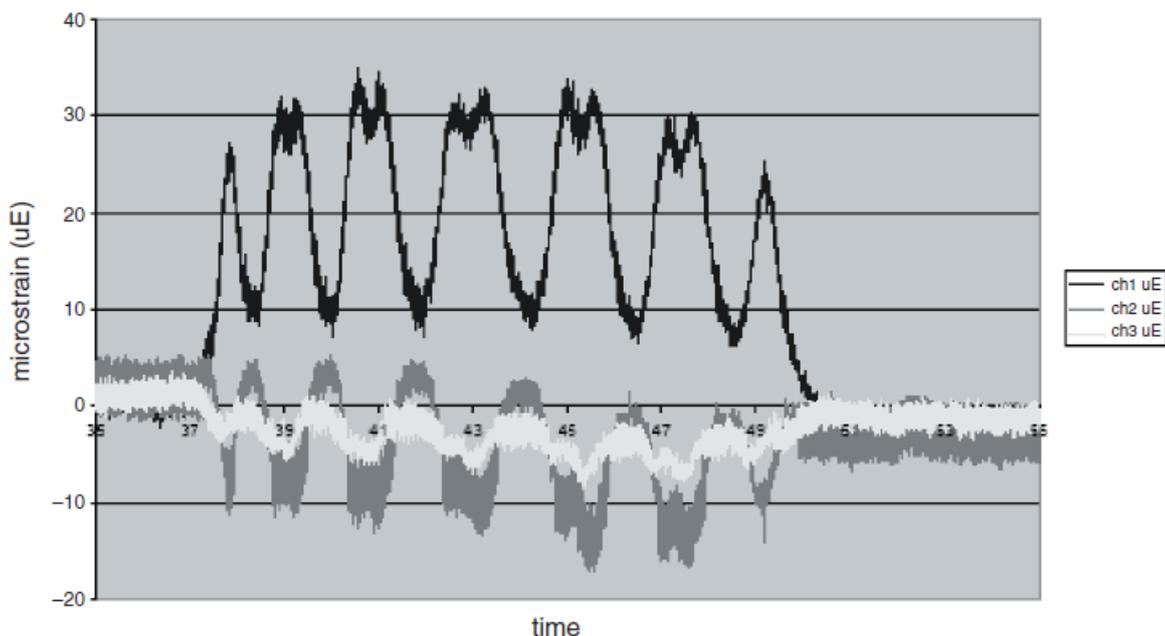


Figure 17 - Bridge strain data.

3.3 WSNs in agriculture

One of the active research areas of WSN application is a precision agriculture deployment. Hundreds of nodes scattered throughout a field assemble together, establish a routing topology, and transmit data back to a collection point. The application demands for robust, scalable, low-cost and easy to deploy networks are perfectly met by a wireless sensor network. If one of the nodes should fail, a new topology would be selected and the overall network would continue to deliver data. If more nodes are placed in the field, they only create more potential routing opportunities.

The idea of possible deployment of ac-hoc wireless embedded network for precision agriculture is described in Figure 18.



Figure 18 - WSN schematics for precision agriculture application.

Sensors detect temperature, light levels and soil moisture at hundreds of points across a field and communicate their data over a multi-hop network for analysis. Motes in agriculture are to enhance the efficiency and growth of cultivations.

3.3.1 Vineyard computing

Intel Corporation in cooperation with Intel Research Berkeley Labs have studied the case of deploying a sensor network in a vineyard [36]. The original idea was that a survey of microclimates would improve productivity and would be useful for farmers. The sensor network can be a component of a system that could be useful for every participant in the wine making process, from the time of growing the grapes to wine production and marketing. We can gain information about temperature, lighting levels, humidity, the movement and presence of people, and many other aspects of the environment.

For example, during the winter, there's a risk of frost damage to vines, so the vineyard needs a system to gather frequent temperature readings at night and alert the manager when the temperature is low.

In a production environment raw data have to be thoroughly interpreted in order to enable the workers to define their course of action. This approach can be achieved via proactive systems, which remove the user from direct interaction with the system.

Proactive systems based on WSNs could provide the following enabling features. The first was a map of powdery mildew risk that could be calculated from temperature data readings gathered throughout the vineyard over a period of time. A map generated in this way could easily demonstrate what areas of the vineyard were at the highest risk for powdery mildew and would let the vineyard manager spray pesticides on the specific at-risk area to avoid problems.

Another vineyard processes that could benefit from proactive system based on WSN is an irrigation. An ideal proactive system would optimize water needs in different areas of the vineyard with available water - particularly because water is a limited, shared resource. Being able to water plants more selectively and precisely on the basis of individual plant needs and available water would save water. This type of precision would be time-consuming for a vineyard manager or worker itself.

Sensor-net equipment will also play a role in domain-specific research by enabling researchers to gather new data that could lead to new knowledge about growing grapes and other types of crops.

It is discovered that vineyard managers are interested in ways that technology can help them with business management tasks, which often involve a lot of time-consuming data entry. A sensor network could support management needs by tracking activities, personnel, and equipment through the vineyard and incorporating this data automatically into budgets and time cards.

The manager's need to track activities in the vineyard also suggests that focusing attention on developing localization algorithms for sensor networks - specifically tracking the location of tagged objects moving through a sensor network - is a research direction potentially useful for agricultural applications.

Other system architectures could be employed in vineyards because they are neither remote nor inaccessible. For example, one architecture used *data mules* to collect and transport data from sensor network motes distributed throughout the vineyard (see Figure 19).

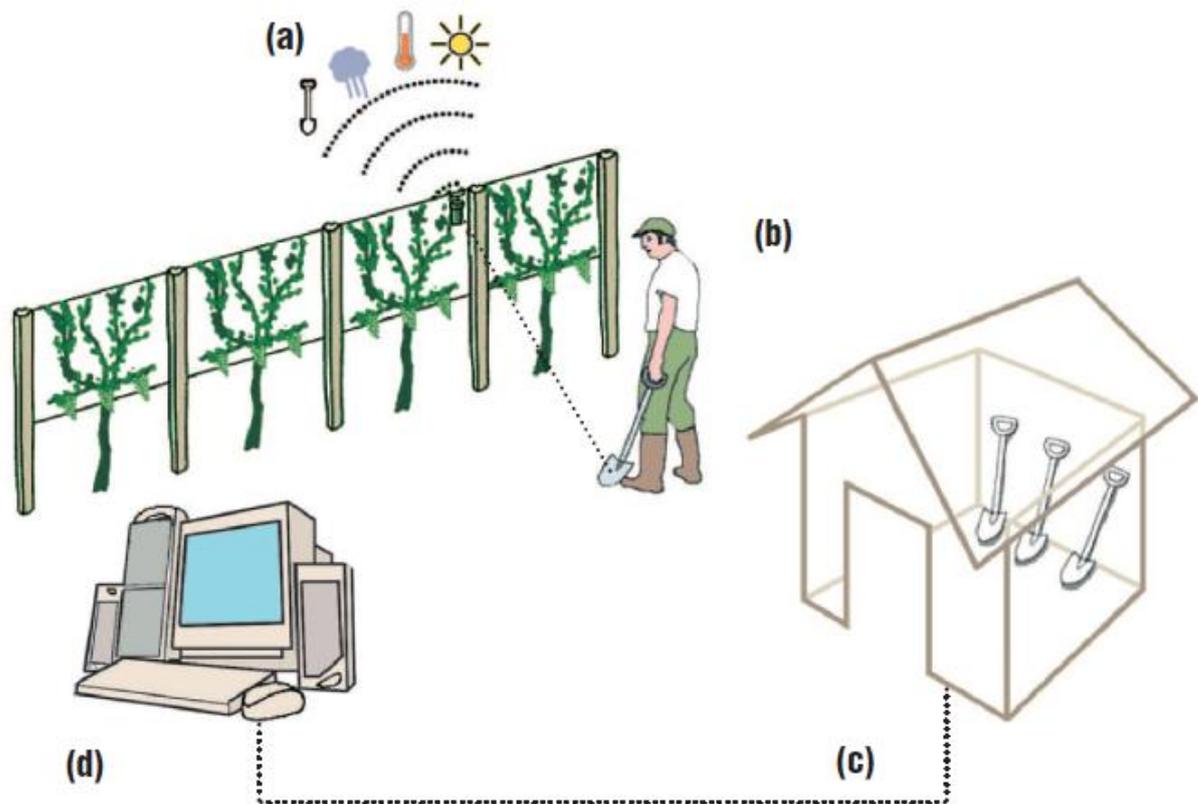


Figure 19 - Data mule system architecture in the vineyard.

This architecture operates as follows:

(a) The motes record environmental data and vineyard activities. (b) In the course of daily activities, the worker collects more data onto the shovel. (c) The worker takes the tool back to the shed. (d) Back in the tool shed, the shovels upload their data to the central database.

During the growing season, workers move up and down the rows a lot. In one vineyard, two family dogs also spent a lot of time going up and down the rows. Any of these moving bodies (even the dogs) could serve as a “data mule” by carrying a small device that simply and invisibly gathers data wirelessly from the static, distributed motes.

The data would be transmitted from the static mote to the data mule mote whenever the two motes are in physical proximity and there’s new data to transmit. This configuration does not represent a distinct advantage in terms of power

savings because static motes must remain in RF listening mode in order to communicate with the data mule mote.

However, it does save on equipment costs because we can distribute motes sparsely throughout the vineyard, as they don't need to communicate with neighboring motes. Several applications in the vineyard lend themselves to in-network data storage and processing.

Generally, crop management, lowering costs and increasing quality is in the scope of applying sensors network technology to agriculture.

3.4 Smart energy metering

WSN can be designed and implemented for smart energy meter applications. For example, the system consists of a digital energy meter, a ZigBee coordinator and a management program. The designed system is capable of automatically reading the unit and sending a terminal and a cover alarm to the management program. The experimental results and real applications show that the such WSNs are feasible to implemented in practical applications for automatic meter reading.

Solution based on WSN implementation may belong to the classes of mobile or fixed systems of automated commercial gas metering and accounting. The general idea of a mobile system is described in Figure 20.

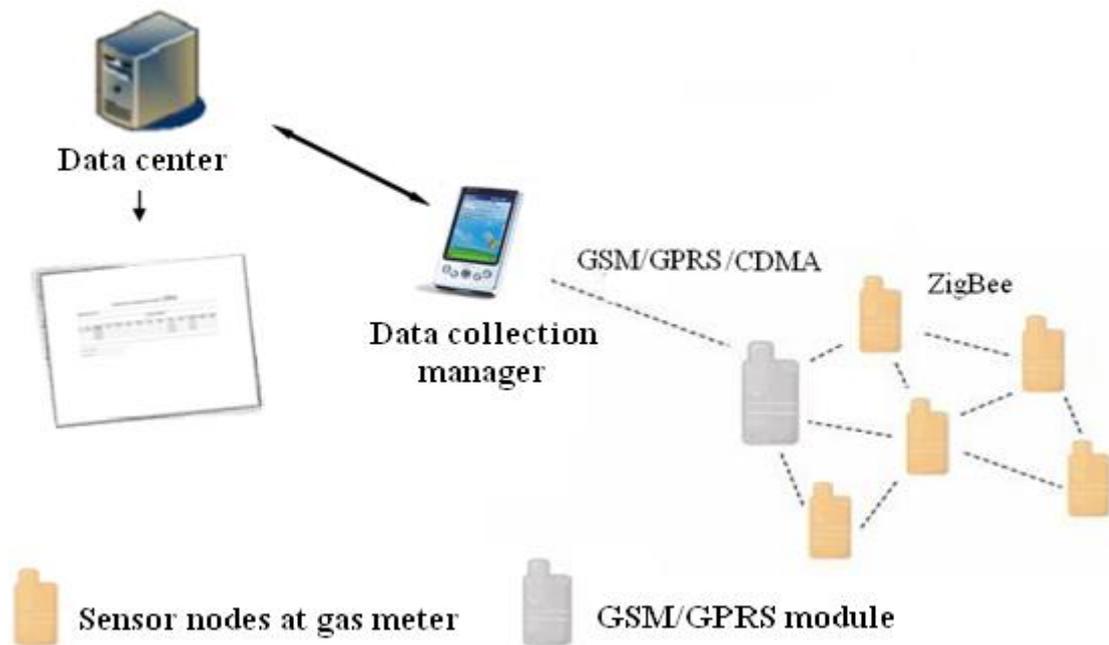


Figure 20 - WSN for smart metering application.

Here the «mobility» means that data collection manager performs a round along houses in order to remotely collect the data from wireless sensor nodes to his pocket PC or another mobile device. After such a collection manager comes back to the data center and uploads the data to the system.

Such a solution can be very useful to automate the management and control process of billing information and gas consumption. Moreover the implementation of such a system will stimulate consumers to approach the gas consumption more economically. On the other hand the domestic sector traditionally involves substantial manpower for maintenance. Automating of data collection process of gas consumption may provide clear productivity in this field.

Obviously such system may involve thousands of sensor nodes throughout a system as a gas meter will be installed in every house. So the main issues are scalability of the network. Also cost issues arise for the same reason of big quantity of sensors needed. Battery lifetime is also an issue but this time there is an alternative of using the mains network for this purpose in addition to batteries. Anyway, the use of mains network will raise the installation cost.

3.5 Other potential application areas and their classification.

Some applications for different areas are shown in table 2.

Table 2 - Some applications for different areas.

Area	Applications
Industrial	Monitoring and control of industrial equipment (LRWPAN [37]). Factory process control and industrial automation [38]. Manufacturing monitoring [39].
Military	Military situation awareness [38]. Sensing intruders on bases, detection of enemy units movements on land/sea, chemical/biological threats and offering logistics in urban warfare [40]. Battlefield surveillance [39]. Command, control, communications, computing, intelligence, surveillance, reconnaissance, and targeting systems [41].
Location	Location awareness (LR-WPAN and Bluetooth [37]). Person locator [39].
Mobile wireless low rate networks for precision location	Tracking of assets, people, or anything that can move in various environments, including industrial, retail, hospital, residential, and office environments, while maintaining low-rate data communications for monitoring, messaging, and control [37]. Physical world Monitor and control the physical world: deployment of densely distributed sensor/actuator networks for wide range of biological and environmental monitoring applications, from marine to soil and atmospheric contexts; observation of biological, environmental, and artificial systems; environmental monitoring of water and soil, tagging small animals unobtrusively, and tagging small and lightweight objects in a factory or hospital setting [42].
Public safety	Sensing and location determination at disaster sites[37].
Automotive	Tire pressure monitoring [37].Active mobility [34]. Coordinated vehicle tracking [38].
Airports	Smart badges and tags [37].Wireless luggage tags [37]. Passive mobility (e.g., attached to a moving object not under the control of the sensor node) [34].
Agriculture	Sensing of soil moisture, pesticide, herbicide, pH levels [37].

The continuation of table 2

Area	Applications
Seismic	Warning systems [40].
Emergency situations	Hazardous chemical levels and fires (petroleum sector) [37]. Fire/water detectors [40]. Monitoring disaster areas [41].
Rotating machinery	Monitoring and maintenance (electric sector) [37].
Medical / Health	Monitoring people's locations and health conditions [39]. Sensors for: blood flow, respiratory rate, ECG (Electrocardiogram), pulse xymeter, blood pressure, and oxygen measurement [43]. Monitor patients and assist disabled patients [41].
Ocean	Monitoring fish [39].

Technological progress in wireless networks, low-power circuit design, and micro electro-mechanical systems (MEMS) has led to the production of tiny sensor devices about a cubic inch in size, bringing us closer to connecting the physical world with pervasive networks. These sensor devices do not only have the ability to communicate information across the sensor network, but also to cooperate in performing more complex tasks, like signal processing, data aggregation and compression. In Chapter 2 we have considered motes as one example of these tiny sensor devices. With their small physical size, sensing and computing capabilities, motes are highly practical and currently used for various purposes ranging from habitat and environmental monitoring to different data collection applications. Some applications with Motes, Smart Dust Sensors and Wireless Sensor Networks are shown in table 3.

Customers benefit by:

- Reducing the costs of hard wiring and maintaining sensor deployments;
- Clearing safety and regulatory obstacles to running cables in constricted or dangerous areas, and;
- Improving operational visibility thereby catching problems before they occur and before they create millions of dollars in down-time losses.

Table 3 - Some applications with Motes, Smart Dust Sensors and Wireless Sensor Networks

Applications	Motes, Smart Dust Sensors and Wireless Sensor Networks
In general	Indoor/Outdoor Environmental Monitoring, Security and Tracking, Health and Wellness
For Industrial and Vibration Monitoring	Plant-wide telemetry, Compliance and quality measurements, Overlay monitoring, SCADA
For Test and Measurement	Vibration and Machine Health Measurement, product test/qualification, and scientific research.
For advanced wireless	Small size, low cost, unobtrusive, unattended, wireless, onboard processing
Available sensor boards	Light and Temperature, Acceleration/Vibration

Summary to the chapter 3

This chapter was devoted provide analysis of various potential applications of WSNs in real-world cases, that could be quite beneficial in solution of application-specific tasks. As the main purpose of the qualification work was to prove the wide applicability and practicality of WSNs in various fields, this chapter is intended to be the major part of our work.

We described and analyzed some of applications that we find having potential also in Uzbekistan conditions. Analysis enable us to make the following application-specific conclusions.

As it found in Great duck island example, the main issues that WSN for environmental monitoring have to address are:

- robustness to environmental changes in outdoor conditions;
- battery lifetime and energy consumption issues;
- minimal maintenance involving human operations (in order not to interrupt natural process under monitoring).

As from bridge health monitoring sensors again the most important issue is battery lifetime and energy consumption. A solution implemented to address this based on change of sensors' sampling mode according to external event that monitoring to be focused on.

WSN application for agriculture found to be more complex as it involves many aspects of human activity in crop fields and not all data is useful in real applications, especially in raw form. So, as it has been shown, in many cases proactive system approach is required (precise irrigation, temperature monitoring in winter). There also may be implemented various data collection approaches like involving mules or traditionally via gateways. The challenges are: effective localisation schemes, battery lifetime and energy consumption, making measurement data actionable for workers and managers, ...

In automated data collection for smart gas metering system, analysis have

shown that the main challenge is a scalability of the WSN and cost of sensor nodes while energy consumption issue may be solved using mains supply. On the contrary such use of mains supply will raise the installation cost.

Also classification of other existing applications was provided based on the analysis of existing solutions and their features.

4. SAFETY OF VITAL ACTIVITY

4.1. Rational organization of a workplace

The complexity of production processes and equipment changed the functions of the person in modern industry: increased responsibility of tasks; increased volume of information perceived by the working and the performance of the equipment. A person's work has become more difficult, increased load on the nervous system and increased physical load. In some cases, the man has become the least reliable link of the system «man-machine». There is a task of providing reliability and safety of persons at work. Solves this task ergonomics and engineering psychology.

Ergonomics (from the Greek «ergon» - work and «nomos» - law) is the scientific discipline that studies the human in terms of its activities related to the use of machines. The goal of ergonomics - optimization of conditions of work in the system "man-machine". Ergonomics defines the requirements of the person to technology and to the conditions of its functioning. The ergonomics of the equipment is the most generalized index of properties and other characteristics of equipment.

The connection of the man with the environment and the parameters of the workplace. Working place, this is the area in which the committed work of the performer or group of performers. Jobs may be individual and collective, universal, specialized and special.

General requirements, which must be observed when designing jobs, the following:

- adequate working space for the person;
- optimum position of the body of the worker;
- sufficient physical, visual and auditory communication between man and machine;
- optimal allocation of working space in the room;

- the permissible level of action of factors of production conditions;
- the optimal placement of the information and the motor field;
- availability of means of protection from hazards.

Design should provide the zone of optimum and easy reach of the motor field of the workplace and the optimal area of the information field of the workplace. Angle of view in relation to the horizontal should be 30-40 degrees. The choice of working arrangements should take into account the efforts expended by the man, the magnitude of the movements, the need for movement, the pace of operations. The choice of working postures should take into account the physiology of man and parameters of working places determined by the choice of the position of the body at work (standing, sitting, a variable). Jobs for work «sitting» are organized in an easy job and middle severity, and the severe - working posture - "standing".

In the design of equipment and organization of a job it is necessary to foresee the possibility of regulating the individual elements, in order to ensure the optimum position of the operator.

The design of the equipment must ensure that it meets the anthropometric and bio mechanical characteristics of the individual on the basis of accounting change dynamics of the amount of heat when you move, the range of motion in joints.

For the account in the design of equipment anthropometric data should:

- determine the contingent of people for whom is designed equipment;
 - select a group of anthropometric characteristics;
 - install the percentage of working, which must meet the equipment;
- determine the boundaries of the interval size (efforts), which should be implemented in the hardware.

When designing the use anthropometric dimensions of the body, and take into account the differences in the sizes of the body of men and women, nationality, age, professional. To determine the boundaries of the intervals, which take account of the percentage of the population, the system is used pertseteley.

Design of the equipment should provide the ability to use at least for 90% of consumers.

To work in a position "sitting" are used by various operating seats. Distinguish workers seat for long and short term use. General requirements for the seat of long use of the following: the seat should ensure position, minimizing the statistical work of muscles; create conditions the possibility of changes in working postures; not to obstruct the activities of the systems of the body; to ensure the free movement relative to the working surface, have adjustable parameters; have the floor upholstery. For short-term use is recommended hard chairs and a different type of stools.

In the conditions of growing mechanization and automation of production processes is of special significance means of display of the information about the object of management. Widespread use of the received information model, that is organized according to certain rules information about the status of the object of control.

The information models of the following requirements:

- the content of the information model should adequately display the object of management;
- information model should provide the best information balance;
- the shape and composition of the information of the model must be consistent with the labor process and possibilities of man for the reception of the information.

Practice makes it possible to outline the sequence of the development of an information model: definition of the objectives of the system, the sequence of their decisions and sources of information; drawing up a list of control objects and their characteristics; the distribution of objects on the degree of importance; the distribution of functions between automation and man; the choice of coding of objects and drawing up of the overall composition models; determination of Executive actions of man.

In the process of constructing information model are determined by the location of the media in the workplace, are selected dimensions of marks and the layout of. Displaying means are placed in the field of view of an observer with the account of optimum corners and observation areas. Dimensions signs monitoring are determined taking into account maximum accuracy and speed of perception of the information, as well as the brightness of the character, magnitude contrast, the use of color. Optimum brightness are considered to be the value at which the maximum contrast sensitivity. The value of it will be greater, the smaller the size of the object of discrimination. Optimal area size contrast is 60-90%. In the work of the eyes is a place of a certain inertia, which requires taking into account the time of exposure of the optic signal and the time intervals for the sense of separate signals the following one after the other. In most cases, the exposure time of the signal should be no less than 50 MS. Each variety of indicators has its area of use: indicators backlit used for the display of high-quality information that requires an immediate response of the operator; gauges are used for the reading of the measured parameters; integral indicators for combining information immediately on several parameters.

The structure and dynamics of the controlled object are usually with the help of a chip. In some cases the scoreboard used to display information and perception of the team of operators.

In the design of the workplace should take into account the rules of the economy's movements: when using two hands of their motion should be simultaneous and balanced; movement should be smooth and rounded, rhythmic and customary for working. The design of the equipment shall take into account the rules relating to the speed and accuracy of workers' struggles. For example, the most rapid movement to itself; in the horizontal plane of the hand speed more than in the vertical; the accuracy of movements better in a sitting position, than standing, etc. Controls, used in the workplace must comply with the General requirements of ergonomics: and direction of the management bodies must comply with the movement associated with him indicator; the compliance of the location

of the management bodies of the sequence of work of the operator; ease of use; the creation of the bodies of the Board of mechanical resistance and etc. In addition, for each type of bodies of pressure corresponds to a specific area of use and the special requirements of the size, form, effort, etc.

The automated workplace of the operator-Communicator (the operator in the control room) in the General case are used:

- means of mapping the information of individual use (imaging units, signaling devices, and so on);
- means of control and input of information (remote the display, keyboard control, separate controls, and so on);
- devices of communication and transmission of information (modems, telegraphic and telephone sets):
- the device documentation and storage of information (printing devices, magnetic recording and so on);
- auxiliary equipment (means of office equipment, the storage media, the device of local lighting).

At the automated working place should be provided with information and constructive compatibility used by technical means, of anthropometric and physiological characteristics of the person.

At optimization of the procedures of interaction between operators of telecommunications workers with technical means in the conditions of automation ergonomic factors act as the main determining the probability-time characteristics and the intensity of the work. These factors are sensitive to variations of individual properties of the operator.

Working the furniture should be comfortable for the execution of planned operations. The design of the working furniture: table, chairs is of great importance for the creation of healthy environments and highly productive work. Working the furniture is designed with consideration of anthropometric data of a human, technical, aesthetic and economic factors.

In the complete set of the working furniture of great importance is the design of the production of a chair, as it depends on the attitude of the employee and, therefore, energy consumption and the degree of its strain. Operating the seat must have the required dimensions, the relevant anthropometric data of the person and be flexible. The most comfortable chairs and seats with adjustable back tilt and height of seat. Changing the height of the seat from the floor and back angle, you can find the most appropriate labour process and the individual characteristics of the employee.

As a rule, all the surface of the written and desktops should be at the level of the elbow in the position of a person. When choosing the height of the table should be considered a man sits during work or stands.

The inconvenient of the table height reduces the efficiency of work and causes rapid fatigue. The lack of sufficient space for the knees and feet cause constant irritation of the employee. Minimum operating table height should be not less than 725 mm. As practice shows, for the working medium height the height of the desktop is accepted 800 mm. For the employee of another growth you can change the height of the working chair, or the position of the boards so that the distance from the object processing before the eyes of the working height is equal to approximately 450 mm.

Accommodation of the technical means and the chair of the operator in the working zone should provide easy access to the main functional nodes and units of equipment for conducting technical diagnostics, preventive inspection and repair; the ability to quickly occupy and to leave the work area; the exception of accidental actuation means of control and input of information; comfortable working posture and position of rest. In addition, the scheme of accommodation should meet the requirements of integrity, compactness and technical and aesthetic expressiveness of the working postures.

The display must be placed on a table or stand so that the distance of observation on the screen does not exceed 700 mm (optimal distance of 450 - 500 mm). Display screen height must be located so that the angle between the centre of

the screen and horizontal line of sight was 200. Horizontal viewing angle of the screen should not exceed 600. The remote display to be placed on a desktop or stand so that the height of the keypad in relation to sex was 650 - 720 mm. When placing the remote control on a standard desktop height of 750 mm it is necessary to use the seat with height adjustable seat (450 - 380 mm) and the footrests. Document (form) for entry operator data it is recommended to have at a distance of 450 - 500 mm from the eyes of the operator, predominantly on the left, with the angle between display screen and the document in the horizontal plane shall be 30 40 degrees. The tilt angle of the keyboard should be equal to 15 degrees.

Display screen, documents and keypad display should be located so that the difference of brightness surfaces, depending on their location relative to the source of light, not more than 1:10 (the recommended value 1:3). At nominal values of brightness of the image on the screen 50 - 100 CD/m² illumination of the document should be 300 - 500 Lux.

Working place should be equipped in such a way that the movement of an employee would be the most efficient, least tedious.

The device documentation and other, rarely used by technical means, it is recommended to concentrate on the right from the operator in the zone of maximum reach and means of communication to the left, to free the right hand for the entries.

4.2. Emergencies

In theory Safety Emergencies - is a set of events, the result of the onset of which is characterized by one or more of the following signso

- a) danger to life and health of a significant number of people;
- b) the material violation of the ecological balance in the area of the emergency;
- c) the failure of the life support systems and control, full or partial cessation of economic activities;

d) significant material and economic damage;

e) the need to involve large as the usually external to the area of emergency forces and means for the salvation of men and the elimination of consequences;

e) psychological discomfort for large groups of people.

It is characteristic that emergency arises outwardly suddenly, suddenly. Specification of definition of the emergency is achieved by introduction of quantitative measures of the dangers.

The classification of emergencies.

For reasons of emergencies are of natural, man-made, man-made, environmental, and social.

To the natural (natural) emergency situations are dangerous natural phenomena or processes that have extraordinary in nature and lead to a breach of everyday life more or less significant groups of the population, loss of life destruction of material values. These include earthquakes, floods, tsunamis, volcanic eruptions, mudflows, landslides, avalanches, hurricanes and Smer-Chi, massive forest and peat fires, snow and avalanches. The number of natural disasters are also droughts, long-term heavy rains, strong stable frosts, epidemics, epizootics, epidemics, mass distribution of pests of agriculture and forestry. Natural disasters can happen: as a result of rapid movement of the substance (earthquakes, landslides); in the release of within the earth's energy (volcanic activity earthquakes) at increasing the overall level of rivers lakes and seas (floods tsunamis) under the influence of an unusually strong wind (hurricanes cyclones). Some natural disasters (fires avalanches landslides, etc..) may arise as a result of the actions of the people themselves but their consequences are always the result of the action of the forces of nature. For each natural disaster characterized by the presence of intrinsic in the affecting factors, adversely affecting human health.

Natural disasters are a tragedy of the entire state and especially for those areas where they occur. As a result of natural disasters are affecting the economy of the country since the collapse of production of the enterprise the destruction of material values and most importantly there are losses among the people killed

their housing and property. In addition, natural disasters pose extremely adverse conditions of life for the population, which may be the cause of outbreaks of infectious diseases. The number of people affected by natural disasters can be considerable and the nature of the lesions is very diverse. Most people suffer from floods (40% of the total damage), hurricanes (20%), earthquakes and droughts (15%). About 10% of the total damage is on the other types of disasters.

A number of Soviet and foreign experts, citing data on the losses in major disasters assume that in the future in connection with the growth and concentration of population similar in the force of the disaster will be accompanied by an increase in the number of casualties in the tens of times.

Man-made emergency situations is considered a sudden failure of machines, mechanisms and units during their operation accompanied by serious violations of the production process the explosions the formation of fire radioactive chemical or biological infections of large territories a group of damage destruction of people. To technogenic emergencies are accidents at industrial facilities construction as well as on rail air road pipeline and water transport as a result of which the fire the destruction of civil and industrial buildings there was a danger of radioactive contamination chemical and bacterial contamination there was the spreading of the oil products and aggressive poisonous liquid on the surface of earth and water and there are other consequences endangering human health and the environment.

The nature of the consequences of technogenic catastrophes depends on the type of accident, its scale and characteristics of the enterprise, where the crash occurred (on the means of transport and the circumstances in which the accident occurred).

Anthropogenic emergency situations are the consequence of the erroneous actions of the personnel. This class of emergency can occur at the same objects that and man-made emergency situations. The difference consists only in the fact that man-made emergency situations is not connected with the human factor directly.

The emergency ecological character may include: intensive degradation of the soil and its pollution by heavy metals (cadmium, lead, mercury, chromium, etc.) and other harmful substances, polluting the atmosphere of harmful chemical substances noise electromagnetic fields acid rain the destruction of the ozone layer, etc.

To the social emergency relate the events taking place in the society (robbery violence) ethnic conflicts accompanied by the use of force contradictions between the States with the use of weapons.

CONCLUSIONS

Based on provided analysis of various application directions in the world and of real conditions of Uzbekistan economy we have chosen the following fields as the most promising fields for WSN applications in our country:

- environmental monitoring;
- precision agriculture;
- constructions structural health monitoring;
- human health monitoring, and
- smart gas metering.

A list prepared after classification of number of existing applications let us conclude that due to features intrinsic to WSNs, a various applications based on WSNs are developing and being applied in many industrial, research and everyday-life areas. Different applications have different features and needs, but they share the same design constraints and limitations. The most common issue is energy efficiency and lifetime of sensor nodes as for battery life limitaions and for environmental impacts. After that comes robustness and scalability of the network. But anyway design approaches and different routing and operational algorithms and concepts used are application-specific. This is also proved by the fact that among all available platforms developed there is no universal one and there are many constrains in standardizing such platforms. Thus, the major barrier to the wide adoption of WSN technologies is the lack of standardisation and of easiness in WSN programming. On the other hand these issues reveal the area for future research and development.

At the same time, some of existing platforms already have the potential to be applied as powerful solution to the real-world problems as we discussed in our qualification work.

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REVIEW

On graduate qualification work of student Yodgorov Farrukh Tokhirovich
on theme “Features and application of wireless sensor networks”

The research and development of wireless sensor networks is one of the most promising and challenging areas in modern telecommunications. Many intellectual resources and talented minds in the world have focused in this direction recently which fact is a proof of importance of this research area.

The graduate qualification work of F.T. Yodgorov is devoted to the investigation of features and characteristics of wireless sensor network technology and analysis of various applications of wireless sensor networks. The main purpose of the work was to reveal the potential of application of WSNs in various fields taking into account real needs. In the work it is made an attempt to define the major application-specific challenges of a number of applications and classification of sample applications is provided.

The main shortcoming of the work in my opinion is that no example of medical applications is considered and therefore is not included in the analysis while the author says that health care applications are of great importance and that they have a potential in Uzbekistan.

In general the graduate qualification work of F.T. Yodgorov deserves an excellent mark and graduating student is worthy of acquiring the bachelor’s degree on the specialty 5522000 – Radiotechnics.

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SUPERVISOR'S TESTIMONIAL

On graduate qualification work of student Yodgorov Farrukh Tokhirovich
on theme "Features and application of wireless sensor networks"

Wireless sensor technologies could be one of the main solutions in achieving ubiquitous existence of ICTs through many spheres of economy and people's lives in our country. WSNs can reduce the cost of traditional wired solutions, easing installation and eliminating connectors. The research and development of WSNs is dynamically evolving fields of modern technologies.

The graduate qualification work of F.T. Yodgorov is devoted to the investigation of features and characteristics of wireless sensor network technology and analysis of sample applications. The main purpose of the work was to reveal the potential of WSNs in various real-world applications.

During the work on this project student F.T. Yodgorov showed his creative abilities at finding solutions and working with literature, feeling of responsibility and discipline.

The graduate qualification work of F.T. Yodgorov deserves an excellent mark and graduating student is worthy of acquiring the bachelor's degree on the specialty 5522000 – Radiotechnics.

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