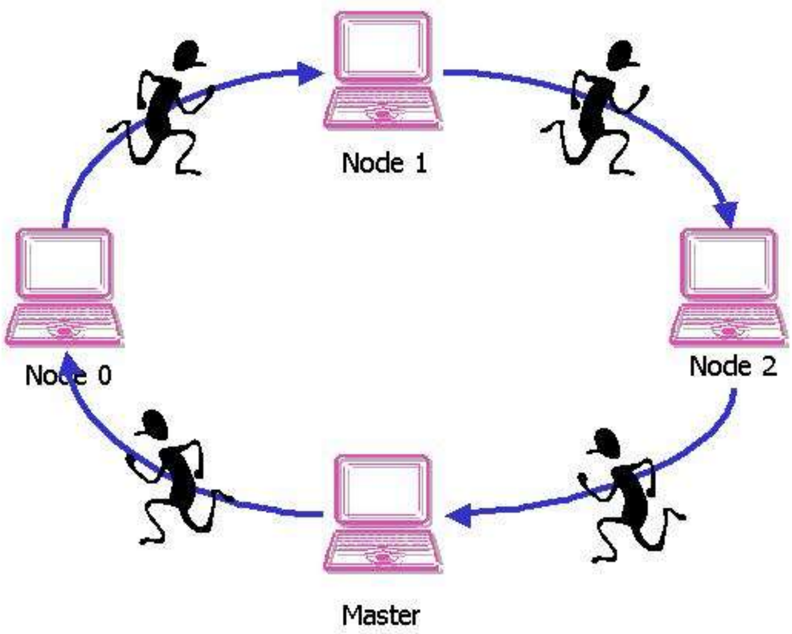
Chapter seventeenth

Mobile Agent and Power Management



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Mobile agent

17.1 Introduction

As the trend towards wide-area open networks like the Internet and intranets grows larger, an increasing number of people are expected to use partially connected mobile devices such as laptops, mobile phones, personal digital assistants(PDA) home and business computers etc. to realize the benefits of having their electronic work available from anywhere and at any time.

However, developing distributed applications that can function in a mobile computing environment is difficult for various reasons. First, mobile devices are not permanently connected to the network and often disconnect from it for long periods of time. Second, even when connected, the connection often has low bandwidth, high latency and prone to sudden network failures. Third, every time the mobile device reconnects, the network address assigned to it may change.

Any distributed application that need to effectively use internet resources from a mobile platform must deal with the environmental changes and intolerant network conditions. Mobile agents because of their features such as autonomy, mobility, asynchronous communication, flexible query processing, intelligence, cooperation, reactivity etc. not only support mobile computers and disconnected operations, but provide a convenient, efficient and robust programming paradigm for implementing distributed applications. This paper will provide a comprehensive overview of mobile agents in mobile computing. In particular, the paper will address what mobile agents are, their usage, advantages, applications, existing technologies, languages, architectures and implementation challenges such as security, portability etc.

17.2 mobile agents

A mobile agent is a program that is autonomous and can move through a heterogeneous network under its own control, migrating from a host to host and interacting with other agents. It decides when and where to migrate. It can execute at any point or suspend its execution, move to another host and continue its execution on that host.

Mobile agents have certain features such as autonomy, mobility, goal driven, temporarily continuous, intelligence, cooperation, learning, reactivity etc. Because of these features, they are well adapted to the domain of mobile computing. For instance, a mobile agent can move from a PDA to Internet to collect interested information for the user. Since it is on the network and does not have to transfer the multiple requests/responses across the low bandwidth connection, it can access necessary resources efficiently. Further, sudden connection losses will not affect the agent since it is not in continuous contact with the mobile device. An agent can perform its tasks even if the mobile device is disconnected from the network. Upon the reconnection of mobile device to the network, agent will return to it with results. Alternatively, a network application can dispatch a mobile agent onto the mobile device. The agent acting on behalf of the application interacts with the user regardless of whether or not mobile device is connected.

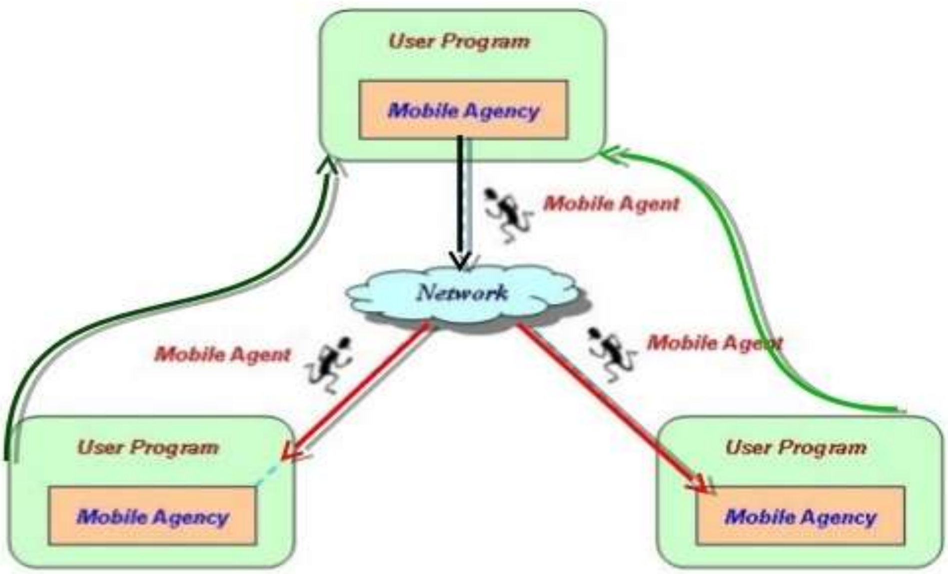

Figure 17.1: life cycle of mobile agents

17.3 Advantages of mobile agent

•***Reduction of network traffic*:** In distributed systems, performing a simple job involves multiple interactions, resulting in increased network traffic. In mobile agent paradigm, the objective is to move the computation to the data rather than the data to the computation, thus consuming fewer network resources and thereby increasing efficiency.

• ***Overcome network latency*:** Management of critical real time systems with substantial size networks creates latencies, which are unacceptable. Deployment of mobile agents will overcome this problem since these agents can execute locally upon the central controller's directions.

• ***Encapsulation of protocols*:** Often, as new communication protocols which improve efficiency and security emerge, businesses need to upgrade their protocols, otherwise they turn into a legacy problem. This whole process is cumbersome. Mobile agents will resolve this problem, as they can migrate to a remote host and establish channels based on proprietary protocols.

•***Asynchronous and autonomous execution*:** For jobs that require a continuous open connection, deployment of mobile agents will result in cost savings. Mobile agents with embedded tasks can be dispatched into the network where they operate independently and asynchronously.

•***Dynamic adoption*:** Mobile agents can perceive the surrounding environment and can act dynamically.

• ***Seamless system integration*:** Both from the perspectives of hardware and software, networking computing are heterogeneous. Mobile agents can provide seamless system integration since they are dependent only on those environments in which they execute.

•***Robust and fault-tolerant*:** Since mobile agents can act and react dynamically in presence of unfavorable conditions, it is easy to build a robust and fault-tolerant distributed system with mobile agents.
Some of the alternative techniques such as RPC, proxy servers etc can also provide many of the above advantages. However, each of these techniques is only suited for certain applications. In contrast, a mobile agent, which has a single unified framework is suitable for a wide range of distributed applications, thus making it an appealing solution for distributed applications.

17.4 Applications of Mobile Agents

- ***Electronic Commerce*****:** Many commercial transactions require access to resources in real time. The ability of a mobile agent to personify their creators intentions and to act and negotiate on behalf of them makes it well suited for electronic commerce.

- ***Personal Assistance*****:** An agent can act as a personal assistant to the user and perform tasks for user on a remote host regardless of whether or not user is connected to the network. For instance, to schedule a meeting, a user can dispatch a mobile agent onto the network to interact with agents belonging to other users. The agent can negotiate with other agents the convenient time for all of the users and can schedule a meeting.

- ***Secure brokering*****:** Mobile agent technology is an attractive solution to brokering, particularly in the context of untrustworthy collaborators. In such a situation, the interested parties can let the agents meet and negotiate at a mutually agreed impartial secure host and form alliance.

- ***Distributed information retrieval*****:** Mobile agent technology provides efficient information retrieval. When dealing with large amounts of data, rather than moving all the data to search engine to create search indexes, user can simply dispatch mobile agents to remote sources to create those indexes locally and to ship them back later to its origin.

- ***Telecommunication networks services*****:** Mobile agents provide an effective and flexible solution to the management of advanced telecommunication services by providing dynamic network reconfiguration and user customization.

- ***Workflow applications and groupware*****:** Mobile agents because of their features such as autonomy, mobility etc, provide autonomy to the workflow item and support the information flow between co-workers.

- ***Monitoring and notification*****:** As a local representative for remote services, an agent can perform tasks on behalf a user irrespective of whether or not user is connected to the network. For instance, a user can dispatch a mobile agent to the internet to monitor the stock prices and to notify him/her only when certain thresholds are reached.

17.5 Architectures

The domain's characteristics determine what type of an agent system to be employed. These characteristics include the number of agents needed, the assigned time, communication and failure costs, involvement of the user, uncertainty of the environment and the probability of arriving at the goals dynamically. A system can have single or multiple agents.

17.5.1 Single Agent System

As the name suggests, a single agent system employs only one agent. This type of a system can become more complex than multiple agent systems, if the job assigned to an agent is complex. For instance, in multiple agent systems, control can be distributed and a single agent does not have to complete the given job. On the other hand, in a single agent system, an agent can be unnecessarily burdened if it has to complete all the tasks. Single agent architecture is better suited for those systems whose domain requires centralized control.

17.5.2 Multi-agent systems

Deployment of multi-agent architecture benefits a system in many ways. In these systems, various independent agents handle separate tasks. Provision of parallel processing capabilities and the presence of redundant agents increases system's operations and robustness. Even if one or more agents fail, a system can still work, since agents share responsibilities. Another advantage of multi-agent system is scalability. It is easier to add new agents to a multi-agent system than to single agent system. Programmers can easily decompose a system into multiple tasks and assign these tasks to different agents. Hence from the programmer's perspective, it is relatively easy to program in these systems. Multi-agent system architecture suits those systems such as ecommerce, where criterion changes across agents or over time. Multi-agent systems can be of different forms.

17.6 mobile agent platform

Mobile agent platforms consist of two parts: mobile agents and runtime systems. The former defines the behavior of software agents. The latter are called agent platforms, agent systems, and agent servers, and support their execution and migration. The same architecture exists on all computers at which agents are reachable. That is, each mobile agent runs within a runtime systems on its current computer. When an agent requests the current runtime system to migrate itself, the runtime system can migrate the agent to a runtime system on the destination computer, carrying its state and code with it. Each runtime system itself runs on top of the operating system as a middleware. It provides interpreters or virtual machines for executing agent programs, or the system themselves are provided on top of virtual machines, e.g., the Java virtual machine (JVM).

17.7 Portability and Standardization

Mobile agent technology allows program to migrate freely from one host to another among heterogeneous machines. The code compiled into some sort of platform independent representation, such as java byte codes is either executed inside an interpreter or compiled into native code, when it arrives at the target machine. This code if not, portable across mobile-code systems, will limit the usage of mobile agents. Standardization is required to make this code portable across mobile-code systems. The OMG MASIF standards currently addresses only cross-system communication and administration leading to a state where an agent is forced to migrate to a nearby machine that runs the right agent system rather than to the desired machine. Standards for specific execution environments as well as the format and state of the encoded migrating agent need to be addressed.

17.8 Languages

A number of new and open technologies such as distributed objects, Java and extensible markup language (XML) can be used to implement mobile agents.

One of the popular languages for implementing mobile agents is Java. In fact, Concordia, Odyssey and Voyager are all implemented in Java. Some of the features of Java such as multi-platform support, object serialization, networking support which includes sockets, URL communication, distributed object protocol called remote method invocation (RMI) etc makes it extremely suitable for mobile agent technology. Applets can be used to launch and receive mobile agents. XML documents can be used to publish anything on the internet. It is one of the most popular accepted foundation layer on which to build. It can be used to encode data with meaningful structure and semantics that any agent with proper authorization can easily access, understand and interpret.

Power management

17.9 Introduction

The number of personal portable devices sold each year is increasing rapidly. Cell phones are ubiquitous. The mobile phone industry is currently the largest consumer electronics (CE) segment in the world. The cell phone has replaced the personal computer as the most universal piece of technology in our lives. Industry analysts indicate that cellular phones are outpacing personal computers at the rate of 5 to 1.

Personal mobile devices are increasingly becoming more than just devices for voice communication as they have a multitude of features including connectivity, enterprise, and multimedia capabilities.
Another growing application area for personal portable devices is entertainment. Devices like portable media players (PMP), FM radios, MP3 players, and portable gaming devices are found in every electronics store. Portable music has improved significantly since the days of the cassette tape; a collection with 500 h of music now fit inside a shirt pocket.

In addition**, gaming devices provide portable entertainment**. Portable gaming devices were pioneered by Nintendo with the Game boy. The gaming devices evolved from simple toys into powerful computers with the progress of technology. These gaming devices turn kids into young consumers that think digitally and prepare them for the mobile device market. Figure 17.2 shows the Sony Play Station Portable which is capable of playing games, music, video, and has a Wi-Fi connection.

Figure 17.2: Sony play station portable

17.10 Power Trends

Power consumption is the limiting factor for the functionality offered by portable devices that operate on batteries. This power consumption problem is caused by a number of factors. Users are demanding more functionality, more processing, longer battery lifetimes, and smaller form factor and with reduced costs.

Battery technology is only progressing slowly; the performance improves just a few percent each year. Mobile devices are also getting smaller and smaller, implying that the amount of space for batteries is also decreasing. Decreasing the size of a mobile device results in smaller batteries, and a need for less power consumption. Users do not accept a battery lifetime of less than 1 day; for personal portable devices even lifetimes of several months are expected.

New, more powerful processors appear on the market that can deliver the performance users desire for their new applications. Unfortunately, these powerful processors often have higher power consumption than their predecessors. Figure 17.3 graphically depicts the gap between battery energy density and the overall system performance required by evolving cellular and consumer portable devices.

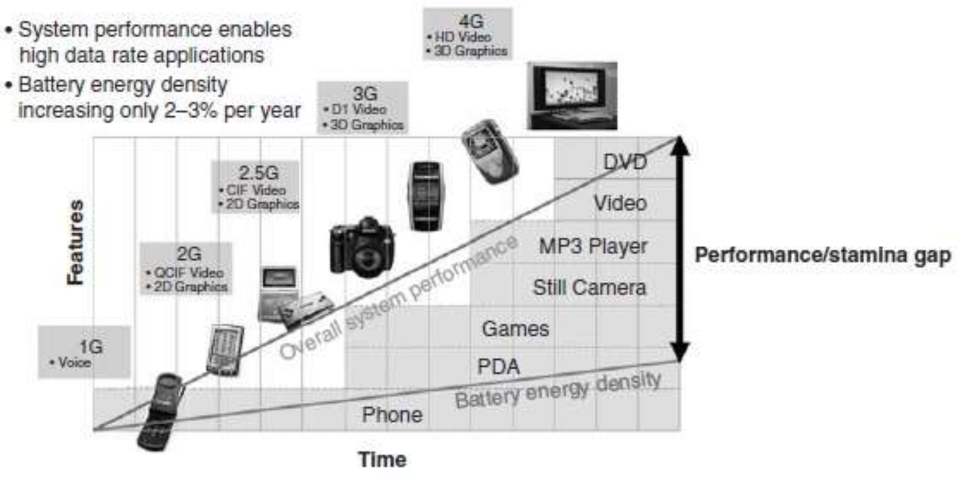

Figure 17.3: The gap between battery energy density and overall system performance

17.11 Cellular Phones

When the first cellular handsets were shipped more than 20 years ago, no one could have imagined all the components and technologies that would be squeezed into a handset 20years later. Back then the DynaTAC 8000X handset from Motorola, fondly called the“ Brick, ” was designed to carry on a voice call, and not much more than that. It weighed2 pounds, offered half an hour talk time and cost almost $4,000.00.

Figure 17.4: Dyna Tac 8000X

Today, there are some ultra low-cost handsets that just handle voice, but that is more an exception than the rule.

Cellular handsets vendors have to produce devices with an ever-increasing number of new technologies. Bluetooth, Wi-Fi, audio, video, cameras, TV, GPS, and others will continue to be blended into handsets in every combination imaginable, and the pressures to make these handsets as cheap as possible, in a “ palm ” size form factor and without sacrificing battery life, will only increase.

17.12 Harvesting Energy from the Environment

The idea of scavenging energy from the environment to feed electronic devices is not new. For example, electronic calculators powered by light sources are sold since long time ago. The new challenge is how to harvest enough energy to sustain the operation of mobile devices. Investigating this direction is very important, for several reasons. Firstly, energy harvested from the environment is pollution free. Secondly, being renewable, it potentially allows devices to run unattended for virtually unlimited time.

Energy harvesting for mobile computing is still in early stages, and is gaining momentum in the research community. A first research direction is collecting energy from electromagnetic fields. The most popular and developed example is getting energy from light sources via solar cells. It is already possible to embed solar cells into thin plastic sheets that, for example, can be laminated onto laptops cases. Unfortunately, current technology allows conversion efficiency just between 10% and 30%, thus requiring too large surfaces to produce reasonable amounts of energy. Should conversion efficiency sufficiently improve, in many cases this technology could replace batteries for devices such as laptops.

It is also possible to harvest energy from RF signals. Actually, this is the way passive RF tags work. This approach can be extended to more complex devices, as well. For example, researchers are trying to feed sensor nodes through the RF signal sent by a reader. While the physical principles is exactly the same as in the RF tags, the power required for feeding a whole sensor device is quite higher, making such a system a challenging one.

Other possible sources of energy harvesting are thermal gradients. The Carnot cycle is the physical principle behind this approach. For example, the Seiko Thermic wristwatch exploits the thermal gradient between the human body and the environment. Also in this case, the conversion efficiency is the main problem, especially when the thermal gradient is small.

Radioactivity has also been proposed as a source of energy for small devices. The typical limited size of the radiating material avoids safety and health problems.

17.13 Energy Characteristics of Mobile Devices

In the past years, several studies have been done to measure the power drained by various components of a laptop. In 1996 Udani and Smith showed that the CPU, wireless network interface, hard disk and display require approximately 21%, 18%, 18% and 36% of the total power, respectively. Other researchers presented later similar results. More recently, several works have confirmed the large impact on the overall system consumption due to the wireless interface, CPU, and hard disks.

The power breakdown of medium-size devices, such as PDAs, is quite different. Usually, such systems do not have hard disks, and use flash memories to store persistent data. Typically the wireless network interface consumes about 50% of the total power, while the display and the CPU contribute for about 30% and 10%, respectively.

Finally, sensor nodes drastically differ from both laptops and PDAs, and hence their power breakdown is completely different. In addition, the power consumption in sensor nodes may greatly depend on the specific task implemented by the sensor network. Typically, the wireless network interface and the sensing subsystem are the most power hungry components of a sensor node. On the contrary, the CPU accounts for a minor percentage of the power consumption.

17.14 Current Work in Power Management

Currently, power management in laptops is performed in a variety of ways, including custom BIOS implementations, unique device configurations for specific operating systems, and various interpretations of the Advanced Power Management standard (APM - a joint proposal from Intel and Microsoft). The APM BIOS is a layer of software that supports power management in computers with "power manageable" hardware. The APM specification defines the hardware independent software interface between system hardware and an operating system power management policy driver. Unfortunately, most manufacturers incorporate only a small subset of the APM features, and few operating systems actually use the features.

Most laptops have simple power management schemes that allow the CPU to be run in "fast" or "slow" mode to conserve power. In addition, the display can be blanked after being idle for a set amount of time, and the hard drive can be powered down when idle for several minutes.

17.15 Hard Disk Power Management

The hard disk is one of the three big consumers in a laptop's power budget. Depending on its state, the disk can use up between one and three Watts-approximately 25% of total system power. Although the Power/M Byte ratio has fallen rapidly in the past few years, the actual power consumed by a typical drive has remained approximately constant. Since some of the other laptop components have reduced their power consumption, the net effect is that a laptop hard drive is taking an increasing percentage of total system power. Drive manufacturers driven by consumer demand shave focused their efforts on increasing drive capacity, rather than decreasing overall power consumption.

17.16 CPU Power Management

The Performance/Power ratio of microprocessors has increased tremendously in the past few years. The key physical changes in the design of microprocessors are reduced feature size (smaller transistor size generally results in lower power consumption) and lower operating voltage. The newer Pentium CPUs also have circuitry that allow the microprocessor to slow down, suspend, or completely shut down various subunits of the processor when they are not in use.

In addition, there are user selectable options to run the CPU at a slower speed to conserve power-this is the most common user choice in most power managed laptops. The problem with user-selectable "slow" or "fast" CPU modes is that the user may actually end up using more power with the "slow" power-saving mode than by not using the power save mode at all.

Chapter eighteenth

Sensor networks and wearable computing

Sensor networks

18.1 Introduction

Wireless sensor networks (WSNs) have gained worldwide attention in recent years, particularly with the proliferation in Micro-Electro-Mechanical Systems (MEMS) technology which has facilitated the development of smart sensors. These sensors are small, with limited processing and computing resources, and they are inexpensive compared to traditional sensors. These sensor nodes can sense, measure, and gather information from the environment and, based on some local decision process, they can transmit the sensed data to the user.

Smart sensor nodes are low power devices equipped with one or more sensors, a processor, memory, a power supply, a radio, and an actuator. A variety of mechanical, thermal, biological, chemical, optical, and magnetic sensors may be attached to the sensor node to measure properties of the environment. Since the sensor nodes have limited memory and are typically deployed in difficult-to-access locations, a radio is implemented for wireless communication to transfer the data to a base station (e.g., a laptop, a personal handheld device, or an access point to a fixed infrastructure).

Battery is the main power source in a sensor node. Secondary power supply that harvests power from the environment such as solar panels may be added to the node depending on the appropriateness of the environment where the sensor will be deployed. Depending on the application and the type of sensors used, actuators may be incorporated in the sensors. A WSN typically has little or no infrastructure. It consists of a number of sensor nodes (few tens to thousands) working together to monitor a region to obtain data about the environment. There are two types of WSNs: structured and unstructured. An unstructured WSN is one that contains a dense collection of sensor nodes. Sensor nodes may be deployed in an ad hoc manner2 into the field.

18.2 Motivation for a Network of Wireless Sensor Nodes

Sensors link the physical with the digital world by capturing and revealing real-world phenomena and converting these into a form that can be processed, stored, and acted upon. Integrated into numerous devices, machines, and environments, sensors provide a tremendous societal benefit. They can help to avoid catastrophic infrastructure failures, conserve precious natural resources, increase productivity, enhance security, and enable new applications such as context-aware systems and smart home technologies.

The phenomenal advances in technologies such as very large scale integration (VLSI), micro electromechanical systems (MEMS), and wireless communications further contribute to the widespread use of distributed sensor systems. For example, the impressive developments in semiconductor technologies continue to produce microprocessors with increasing processing capacities, while at the same time shrinking in size. The miniaturization of computing and sensing technologies enables the development of tiny, low-power, and inexpensive sensors, actuators, and controllers.

Further, embedded computing systems (i.e., systems that typically interact closely with the physical world and are designed to perform only a limited number of dedicated functions) continue to find application in an increasing number of areas. While defense and aerospace systems still dominate the market, there is an increasing focus on systems to monitor and protect civil infrastructure (such as bridges and tunnels), the national power grid, and pipeline infrastructure. Networks of hundreds of sensor nodes are already being used to monitor large geographic areas for modeling and forecasting environmental pollution and flooding, collecting structural health information on bridges using vibration sensors, and controlling usage of water, fertilizers, and pesticides to improve crop health and quantity.

18.3 Sensing and Sensors

Sensing is a technique used to gather information about a physical object or process, including the occurrence of events (i.e., changes in state such as a drop in temperature or pressure). An object performing such a sensing task is called a *sensor*. For example, the human body is equipped with sensors that are able to capture optical information from the environment (eyes), acoustic information such as sounds (ears), and smells (nose). These are examples of *remote sensors*, that is, they do not need to touch the monitored object to gather information.

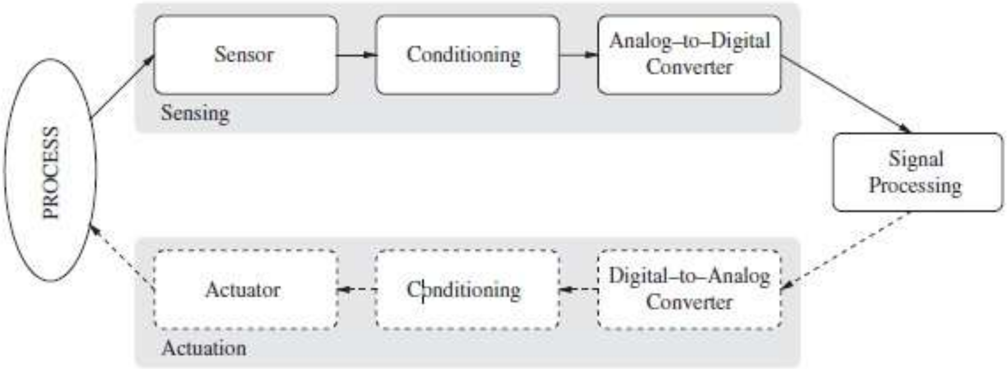

Figure 18.1: step performed in sensing

Many wireless sensor networks also include *actuators* which allow them to directly control the physical world. For example, an actuator can be a valve controlling the flow of hot water, a motor that opens or closes a door or window, or a pump that controls the amount of fuel injected into an engine. Such a *wireless sensor and actuator network* (WSAN) takes commands from the processing device (controller) and transforms these commands into input signals for the actuator, which then interacts with a physical process, thereby forming a closed control loop.

18.4 Sensors

A sensor measures some parameter of a physical, chemical, or biological entity and delivers an electronic signal proportional to the observed characteristic, either in the form of an analog voltage level or a digital signal. In both cases, the sensor output is typically input to a microcontroller or other management element. The left side of Figure 18.2, adapted from a figure in *Middleware Architecture with Patterns and Frameworks* , shows the interface between a sensor and the controller for that sensor. A sensor may take the initiative in sending sensor data to the controller, either periodically or when a defined threshold is crossed; this is the active mode. Alternatively, or in addition, the sensor may operate in the passive mode, providing data when requested by the controller.

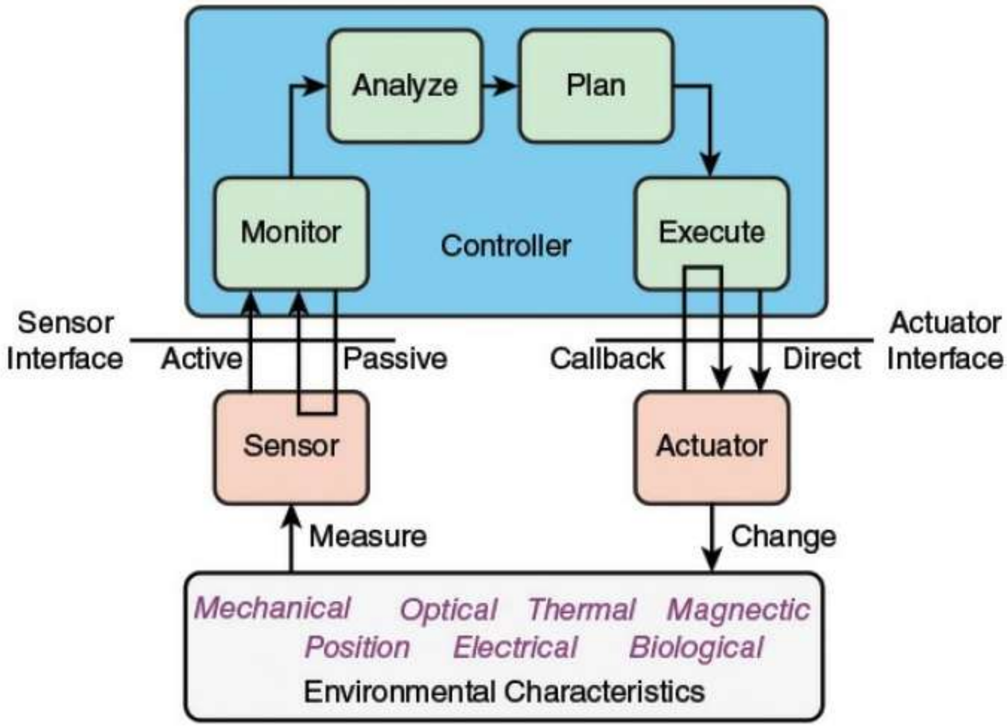

Figure 18.2: The sensor

18.5 Wireless Sensor Networks

While many sensors connect to controllers and processing stations directly (e.g., using local area networks), an increasing number of sensors communicate the collected data wirelessly to a centralized processing station. This is important since many network applications require hundreds or thousands of sensor nodes, often deployed in remote and inaccessible areas. Therefore, a *wireless* sensor has not only a sensing component, but also on-board processing, communication, and storage capabilities. With these enhancements, a sensor node is often not only responsible for data collection, but also for in-network analysis, correlation, and fusion of its own sensor data and data from other sensor nodes.

When many sensors cooperatively monitor large physical environments, they form a *wireless sensor network* (WSN). Sensor nodes communicate not only with each other but also with a *base station* (BS) using their wireless radios, allowing them to disseminate their sensor data to remote processing, visualization, analysis, and storage systems. For example, Figure 18.3 shows two *sensor fields* monitoring two different geographic regions and connecting to the Internet using their base stations. The capabilities of sensor nodes in a WSN can vary widely, that is, simple sensor nodes may monitor a single physical phenomenon, while more complex devices may combine many different sensing techniques (e.g., acoustic, optical, magnetic). They can also differ in their communication capabilities, for example, using ultrasound, infrared, or radio frequency technologies with varying data rates and latencies. While simple sensors may only collect and communicate information about the observed environment, more powerful devices (i.e., devices with large processing, energy, and storage capacities) may also perform extensive processing and aggregation functions. Such devices often assume additional responsibilities in a WSN, for example, they may form communication backbones that can be used by other resource-constrained sensor devices to reach the

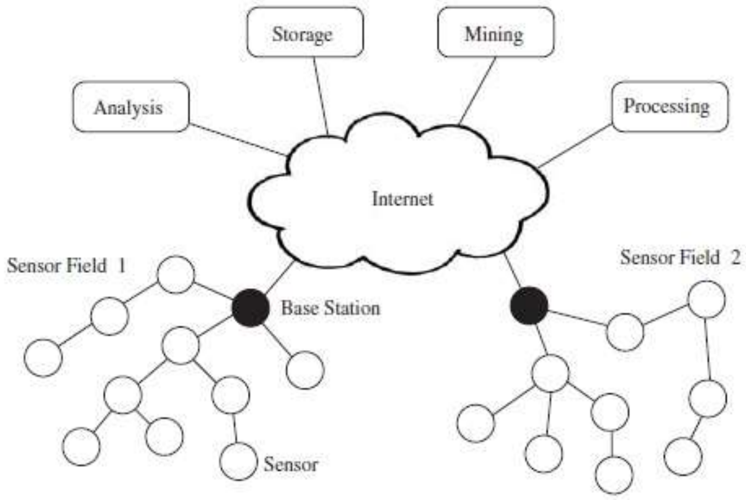

Figure 18.3: wireless sensor networks

18.6 Types of sensor networks

Current WSNs are deployed on land, underground, and underwater. Depending on the environment, a sensor network faces different challenges and constraints. There are five types of WSNs: terrestrial WSN, underground WSN, underwater WSN, multi-media WSN, and mobile WSN.

18.6.1 A terrestrial WSN

reliable communication in a dense environment is very important. Terrestrial sensor nodes must be able to effectively communicate data back to the base station. While battery power is limited and may not be rechargeable, terrestrial sensor nodes however can be equipped with a secondary power source such as solar cells. In any case, it is important for sensor nodes to conserve energy. For a terrestrial WSN, energy can be conserved with multi-hop optimal routing, short transmission range, in-network data aggregation, eliminating data redundancy, minimizing delays, and using low duty-cycle operations.

18.6.2 Underground WSNs

consist of a number of sensor nodes buried underground or in a cave or mine used to monitor underground conditions. Additional sink nodes are located above ground to relay information from the sensor nodes to the base station. An underground WSN is more expensive than a terrestrial WSN in terms of equipment, deployment, and maintenance. Underground sensor nodes are expensive because appropriate equipment parts must be selected to ensure reliable communication through soil, rocks, water, and other mineral contents.

The underground environment makes wireless communication a challenge due to signal losses and high levels of attenuation. Unlike terrestrial WSNs, the deployment of an underground WSN requires careful planning and energy and cost considerations. Energy is an important concern in underground WSNs. Like terrestrial WSN, underground sensor nodes are equipped with a limited battery power and once deployed into the ground, it is difficult to recharge or replace a sensor node's battery. As before, a key objective is to conserve energy in order to increase the lifetime of network which can be achieved by implementing efficient communication protocol.

18.6.3 Underwater WSNs

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

18.6.4 Multi-media WSNs

have been proposed to enable monitoring and tracking of events in the form of multimedia such as video, audio, and imaging. Multi-media WSNs consist of a number of low cost sensor nodes equipped with cameras and microphones. These sensor nodes interconnect with each other over a wireless connection for data retrieval, process, correlation, and compression. Multi-media sensor nodes are deployed in a pre-planned manner into the environment to guarantee coverage. Challenges in multi-media WSN include high bandwidth demand, high energy consumption, quality ofing techniques, and cross-layer design. Multi-media content such as a video stream requires high bandwidth in order for the content to be delivered.

18.6.5 Mobile WSNs

consist of a collection of sensor nodes that can move on their own and interact with the physical environment. Mobile nodes have the ability sense, compute, and communicate like static nodes. A key difference is mobile nodes have the ability to reposition and organize itself in the network. A mobile WSN can start off with some initial deployment and nodes can then spread out to gather information. Information gathered by a mobile node can be communicated to another mobile node when they are within range of each other. Another key difference is data distribution. In a static WSN, data can be distributed using fixed routing or flooding while dynamic routing is used in a mobile WSN. Challenges in mobile WSN include deployment, localization, self-organization, navigation and control, coverage, energy, maintenance, and data process.

18.7 Precision, Accuracy, and Resolution

Two key concepts need to be distinguished in discussing sensors: precision and accuracy. Accuracy refers to how close a measurement comes to the truth, represented as a bull’s eye in Figure 18.4. Precision refers to how close multiple measurements of the same physical quantity are to each other. If a sensor has low accuracy, this produces a systematic error. If a sensor has low precision, it produces a reproducibility error.

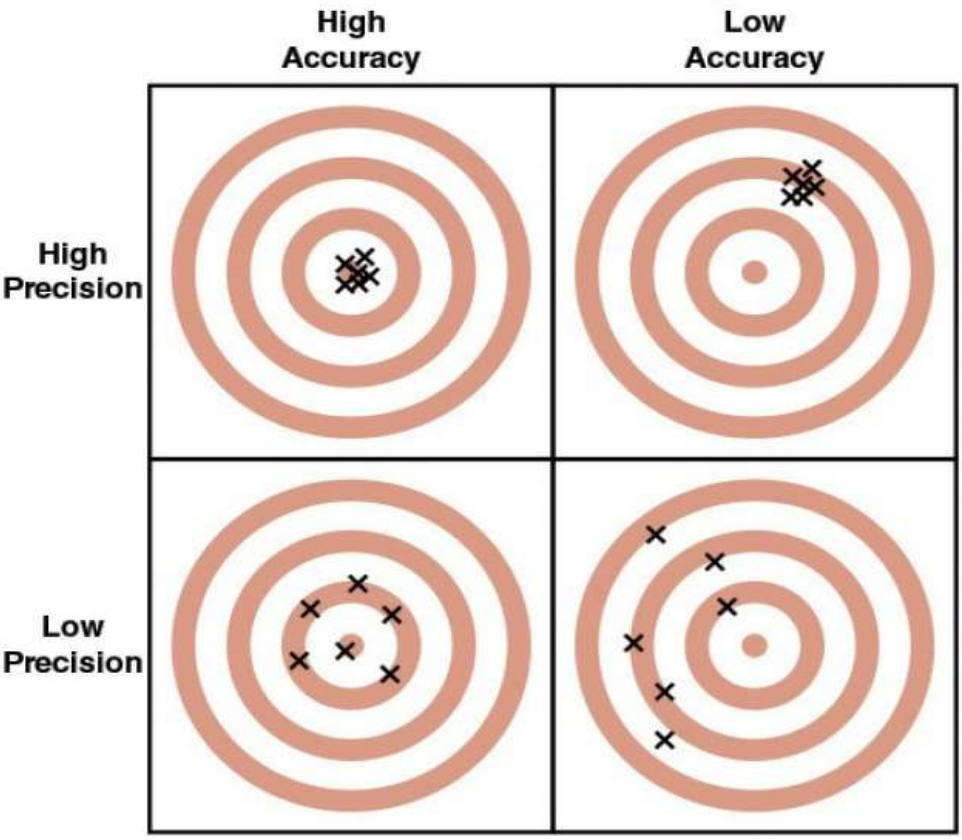

Figure 18.4: precision and accuracy

Related to precision is the concept of resolution. If a sensor has high precision, a very small change in the value of a physical quantity results in a very small change in the value of the sensor measurement. If the sensor output is digital, more bits are needed to represent the measurement to capture these small changes in the underlying physical parameter.

18.8 Challenges and Constraints

While sensor networks share many similarities with other distributed systems, they are subject to a variety of unique challenges and constraints. These constraints impact the design of a WSN, leading to protocols and algorithms that differ from their counterparts in other distributed systems. This section describes the most important design constraints of a WSN.

18.8.1 Energy

The constraint most often associated with sensor network design is that sensor nodes operate with limited energy budgets. Typically, they are powered through batteries, which must be either replaced or recharged (e.g., using solar power) when depleted. For some nodes, neither option is appropriate, that is, they will simply be discarded once their energy source is depleted. Whether the battery can be recharged or not significantly affects the strategy applied to energy consumption. For non rechargeable batteries, a sensor node should be able to operate until either its *mission time* has passed or the battery can be replaced. The length of the mission time depends on the type of application, for example, scientists monitoring glacial movements may need sensors that can operate for several years while a sensor in a battlefield scenario may only be needed for a few hours or days.

18.8.2 Self-Management

It is the nature of many sensor network applications that they must operate in remote areas and harsh environments, without infrastructure support or the possibility for maintenance and repair. Therefore, sensor nodes must be *self-managing* in that they configure themselves, operate and collaborate with other nodes, and adapt to failures, changes in the environment, and changes in the environmental stimuli without human intervention.

18.8.3 Security

Many wireless sensor networks collect sensitive information. The remote and unattended operation of sensor nodes increases their exposure to malicious intrusions and attacks. Further, wireless communications make it easy for an adversary to eavesdrop on sensor transmissions. For example, one of the most challenging security threats is a *denial-of-service* attack, whose goal is to disrupt the correct operation of a sensor network. This can be achieved using a variety of attacks, including a *jamming attack* , where high-powered wireless signals are used to prevent successful sensor communications.

The consequences can be severe and depend on the type of sensor network application. While there are numerous techniques and solutions for distributed systems that prevent attacks or contain the extent and damage of such attacks, many of these incur significant computational, communication, and storage requirements, which often cannot be satisfied by resource-constrained sensor nodes. As a consequence, sensor networks require new solutions for key establishment and distribution, node authentication, and secrecy.

Wearable computing

18.9 Introduction

The betterment in the field of medical science has its adverse effect on the abhorrent increase in population in the last five decades. As per the ongoing trend, the current population is likely to reach 10 billion by next three decades. This massive growth also tends to increase the people above the age of 65 double its present value. To have a better treatment facility other than hospitable conditions, elderly people are looking for better options with certain prominent protocols.

The smart homes, since its development, have always been a better choice for the monitoring of people of all ages. The research goes on ways to give a better life for the people who are incapable of doing day-to-day activities of the irown. The smart homes are being used for monitoring the behavioral pattern and activities people for more than ten years. But there are some clauses that are followed by the people operating these automated homes, like 1. Use of video cameras intrude the privacy of the people living in these homes are avoided. 2.Minimum use of technological hardware to decrease the complexity of the overall system. 3. Maximizing the security of data regarding any individual. Different types of sensors are used in these homes to monitoring various activities in these homes.

Wearable sensors are one of the externally close fitted sensors to an individual monitoring the activities of the connected person. The wearable sensors are operated in both wired and wireless manner. A single wearable sensor is used to measure more than one physiological parameter, for example, the wrist watch measures the heart rate, blood pressure, body temperature of the individual wearing it. Research works have also been done on the individualistic measurements of parameters of gait analysis, blood pressure, respiration rate at different intervals, heart beat, human posture, cigarette smoking, etc.

One of the primary objectives of using these wearable sensors is to minimize the disturbance faced by the person being operated on. Some of the sensors are used in proximity like for measuring sweat , and some are worn on the hands or other body parts of the user. Human activity recognition is another aspect on which considerable work is done. Different wireless technologies are acquired to work along with these sensors for the real-time data collection.

18.10 Motivation

The amount of population in New Zealand grew from around 800,000 to 4,000,000 in the last century. The number of people above the age of 65 is likely to increase to 230,000 in the next decade. So the need of smart homes is likely to increase in the future. The elderly people have a tendency to live independently or in their homes. They do not prefer to be monitored in every step or visualized doing any activity. Therefore, the smart homes are built on the residing home of the people so that they do not face a change in ambiance. The smart homes designed for the elderly people are customized to make sure that the caregiver is in a continuous touch with the people living in these homes so that any abnormality in the house can be notified.

Different kind of alarm systems is installed in the smart homes to take immediate action. The sensors used in the smart homes can be categorized into wearable and non-wearable. The non-wearable sensors are the ones mainly used for the detection of usage of different electrical objects or the position of the individuals residing in the house . They are also used to keep a note of the ambient conditions of the people living in. The wearable sensors are attached to the clothes, accessories or bare body of the individual for the measurement of individualistic parameters.

Wearable sensors are in more need in future because they have a few distinct advantages over the non-wearable ones like 1.They can be placed dynamically and moved according to the need. 2. They can be turned on only when the measurement is to be taken. 3. They can be designed according to different parameters to be measured. 4. They are designed to be smaller in size in order to fit comfortably causing minimum disturbance to the person under consideration. So the increase in wearable sensors would help to detect number of measured parameters, as well as the actual physiological conditions of the person being monitored on real-time.

18.11 Physiological Conditions That Are Measured by Wearable Sensors

With the current lifestyle, a person tends to face from number of problems in his/her body which needs attention. It is tough to experience the hospital conditions every time a person suffers from a minor or major disease. So, it is recommended to scrutinize every physiological parameter possible as soon as possible. Some of the typical physiological parameters need to be monitored on a regular basis are:

1. Body temperature – The temperature of a human body is one of the vital parameters to know the condition of a person. Any aberration from this range indicates the abnormality of the person. In many cases, high rise of temperature causes death. Analogue or digital thermometers are used for the measurement of temperature. But they are only used when the patient is in need. Any deflection from the ideal temperature of a human body proves the person is already affected. In older persons, the temperature of the body tends to decrease with the typically defined temperature. This is due to the incapability of the body to control the temperature.

   This may increase (hyperthermia) or may decrease (hypothermia) the temperature of the body from a normalized temperature. So, in order to avoid any critical condition, it is better to use a temperature sensor to keep a note of the temperature at regular intervals. Now, there are various types of temperature sensors with different ranges. Many of them have been used for the temperature monitoring of the rooms the elderly people reside in. The temperature sensors to be used for body temperature measurement need not be higher range

2. Heart rate- The heart rate (HR) is unarguably the most pivotal variable that matters in a human body. This needs to be working in perfect condition every time for the well-being of a person. The heart is responsible for pumping blood to all the parts of the body, so any change in the HR will also change the blood pressure and other parameters of the body. In earlier days, the HR is calculated by the auscultation process by a stethoscope, but that is manual which makes it prone to error and takes a long of time for the calculation of healthy number of patients.

3. Respiration rate- The respiration rate of a human being is the foremost external sign to verify if a person is healthy or not. However, the elderly people sometimes find it difficult to breathe normally. Internal structures of lungs and breathing system changes in as the age progresses, causing it difficult for an elderly person to breathe. The rate of extraction and contraction of the lungs decreases that leads to forcible breathing of the individual.

   The extensive research works have been done. for continuous monitoring of the respiration rate of a person. Miniaturized battery-operated devices are used for the detection of rate of respiration. This is because the connection of the wearable sensor wired into the monitoring system will cause uneasiness to the person and, as a result, change the rate of respiration.

4. Blood pressure- The blood pressure (BP) of a person signifies what the arterial pressure of the blood at which it is circulating in the body. The increase (hypertension) or decrease (hypotension) of BP in the body malfunction the system of the body. The real reason for the change in BP is still under research, but some of the causes might be stress, and overweight.

   Increase in BP leads to other problems especially in the heart. The change in BP is not very detrimental till the age of 45 for both men and women and then gradually tends to become more prominent. The BP of a healthy person is said to be 120/80 where, the systole is 120, and the diastole is 80. Anything above 140/90 or below 120/80 is a matter of concern and should be checked. A number of work has been done on the monitoring of BP of a person. The wearable sensors are used; similar to the measurement of HR are connected to the body of the individual being monitored.

5. Gait Analysis- Gait analysis, even though is not ancient research has come up to the limelight in the past fifteen years . The gait and proper balance of an elderly person is one of the main consequences of being healthy. The problems are associated with a decreased speed of walking, abnormal walking stances leading to strokes and falls. Abnormality in gait is the primary reason for falls.

   The elderly person wearing wearable sensor and walking might lead to the person walking in a slower pace but will decrease the chances of falling. The person would be under continuous monitoring while walking or standing.

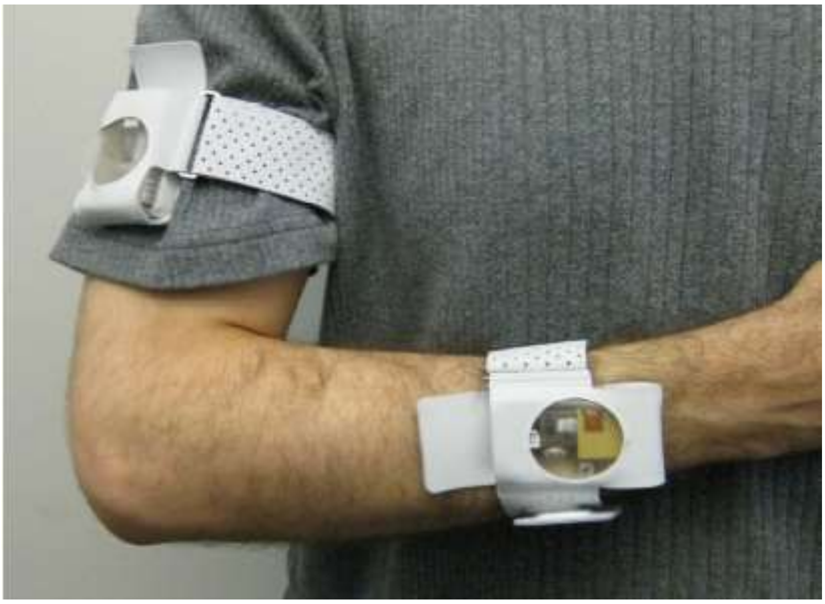

Figure 18.4: Use of wrist sensors to detect its motion

18.12 Sensors for Physiological Parameters Monitoring

Different types of sensors are being developed and used for the monitoring of physiological parameters in and out of smart homes. Some of the sensors are available in the market and used for the monitoring by improvising an algorithm to operate the sensor. A few of the sensors are:

1. **Sweat rate sensor:** Sweat is the form of an energy that goes out from the body. The main constituent of sweat is glucose. The glucose in the body is broken down into simpler constituents to provide energy. Any physical activity will lead to perspiration called sweat. The monitoring of sweat can help to detect the amount of body glucose that comes out. Fick's law of diffusion can be applied for the measurement of sweat. The sweat rate sensor can also be used as a wearable sensor by integrating it with the garment to measure both pH and sweat during any physical activity .

2. **Shoe monitor sensor:** These sensors are used for monitoring of locomotion of individuals in smart homes. The shoe sensor is laboratory made shoes fitted with pressure sensors and accelerometers. The sensor can also be used in in smart homes where the motion is monitored by the wireless communication protocol from the sensor attached to the shoe. The shoe sensor is an important parameter to be monitored in an elderly smart home as the older people face frequent falls.

Figure 18.5: Shoe sensors used for monitoring sports

3. **Light sensor:** The light sensors are the ones that show a change in their properties on exposure to light. They are used in a wide range of applications like navigation, medical, military, home monitoring. They are used for generation of electricity from light energy. The range of light sensors can be divided roughly into four categories namely photo-emissive, photo-voltaic, photo-junction and photoconductive sensors.

Figure 18.6: Light sensors used for security

18.13 Types of Activities

As the impact of wearable sensor increases, the types of activities to be monitored are also increasing. The wearable sensor, depending upon its size, shape, durability, can be used in a lot of applications in today's world. Some of them can be categorized as:

18.13.1 Physical activities

Normally, the use of wearable sensors is much associated with the activities performed inside the smart homes. Even though some of the activities like human navigation, monitoring of physical activities of the elderly at home can be performed with the wearable sensor, most of the physical activities are to be performed outside the smart homes. Some of them can be categorized as:

a. **Jogging/running:** This is one of the common uses of wearable sensor where it is normally seen that a sensor is strapped around the arm of the runner to monitor different attributes like number of steps, breathing rate, body temperature. The size of the wearable sensor used in this activity is compact and is self-operated. The sensor can also be used to collect the data wirelessly to monitor the running or walking of patients with asthma or dementia. Even the sensor can be integrated into the clothing of the elderly people, and monitoring can be done for their movements. The wearable sensors to be used in the smart homes are needed to be operated wirelessly as the use of this sensor will reduce the use of passive infrared sensors that is normally used for movement monitoring.

b. **Driving:** In today's fast pacing world, driving is an everyday activity. People drive cars every day to go to different places like work, home, parties. Professional people drive buses, trucks and other bigger automobiles. To have a better view and understanding of the position and condition of a person driving a vehicle, wearable sensors can be used with that person. It might be difficult for a person to use a wearable sensor on his arm while driving, especially that of professional vehicle, but the wearable sensor can be attached to other parts of the body for its monitoring.

Figure 18.7: Sensors attached to shoes to monitor the activity

c. **Playing any sport/athlete:** Wearable sensors can be a big advantage for any sport played. The sensor can be connected to the athlete or player performing any activity, and the level of emotion, anxiety, excitement can be monitored. Sometimes, it happens that the player is undergoing through an emotional turmoil before or during a match, the wearable sensor connected to the player can detect the exact emotional state of the player. The physical injuries among players can also be reduced by the use of the sensors as the connected sensors can continuously monitor the change in physical state of the person. Monitoring of a lot of characteristics of the human body like body temperature, heart rate, sweat rate can be done during the sports activity with the wearable sensor.

d. **Writing/Reading:** Even though performing these activities is not so strenuous compared to playing sports or driving, but it can still be considered one of the physical activities, especially when a high degree of performance is required in this field for a long period. Writing or reading may be considered as a physical activity that is done sitting or lying. But performing these activities also creates pressure in the brain causing nervous fluctuations. In today’s competitive world, every student has to remain at his/her peak in terms of performance. The students taking exams on a regular basis are under pressure to perform well. This happens with the research scholars and people working the administration section as well.

Figure 18.8: Wrist worn sensor used for hand motion

18.13.2 Non-physical activities

Maximum of the activities that takes place in an elderly smart home is non-physical. Due to the lack of many movements of the older people, they perform most of their activities from one position. Some of the non-physical activities that can be considered within and outside the smart homes for the use of wearable and non-wearable sensors are:

a. **Sleeping:** One of the most common activities, especially for older people is sleeping. A normal person, before the age of 60, requires at least 8 hours of sleep a day. The older people need at least 10 hours sleep a day. An elderly person might face a lot of problems during the sleep of which he/she might be unaware of. Some of these problems might be breathing problems, heart related problems. In order to monitor any anomaly during the sleeping periods, sensor can be connected to the bed, or the person being operated. In some of the works, a piezoresistive sensor is used beneath the legs of the bed or the mattress to determine the sleeping position and the timings of the sleep.

b. **Talking:** This is one of the important characteristics that drastically reduce in old age. The older people tend to talk less due to some reason. They stay quick most of their time. This might be normal in maximum circumstances, but in certain cases, they might be going through an emotional turmoil that they are unable to share with anybody and as a result of which their health deteriorates more. Both wearable and non wearable sensors can be used for monitoring the emotional condition of the elderly person while talking about different subjects.

c. **Watching television/ playing computer games:** It is seen that a person is highly entertained while watching television or playing computer games. The children normally remain excited to watch their favorite programmers on television or play computer games at particular stipulated times. It would be useful to use a sensor to determine the excitement level of a person while performing these activities. The elderly people in smart homes can also be monitored when they watch television determine the tiredness they face or sleepiness that feel. It may also be useful to use a wearable sensor to determine the effect in eyes of watching television or playing computer games for people of every age.

d. **Different activities in a smart home:** We have been running a continuous system for more than one year dealing with the different activities and issues encountered in a smart home. Daily activities that include both physical and non-physical are monitored in a continuous manner. Different types of sensors that include passive infrared (PIR), electrical sensors, force sensors and temperature sensors, are connected at different locations of the house and electrical objects to parameterize the readings at different intervals of time. Solar temperature sensors are connected outside the house to keep a note of the ambiance temperature.

18.14 Wireless Technologies

Wireless technology has recently gained a lot of popularity in electronics and electrical sector. The use of wireless communication has increased the degree of interaction between two or more nodes. The wireless technology has led the formation of networks involving the transmission of data between nodes simultaneously. The sensors used in smart homes can be conveniently operated via wireless technology. Some of them which are commonly used are:

1. **Wi-Fi:** This is the most common technology in recent days in almost every institute, company and home. The Wi-Fi is a serial standard if IEEE 802.11. The applications with Wi-Fi are continuously growing and are making the use of internet in an efficient way. Wi0fi makes the use of broadband access. Some of the advantages of using Wi-Fi are marked by its speed, coverage of transmission of data and security. The Wi-Fi is also gaining its popularity in local area network and private area network.

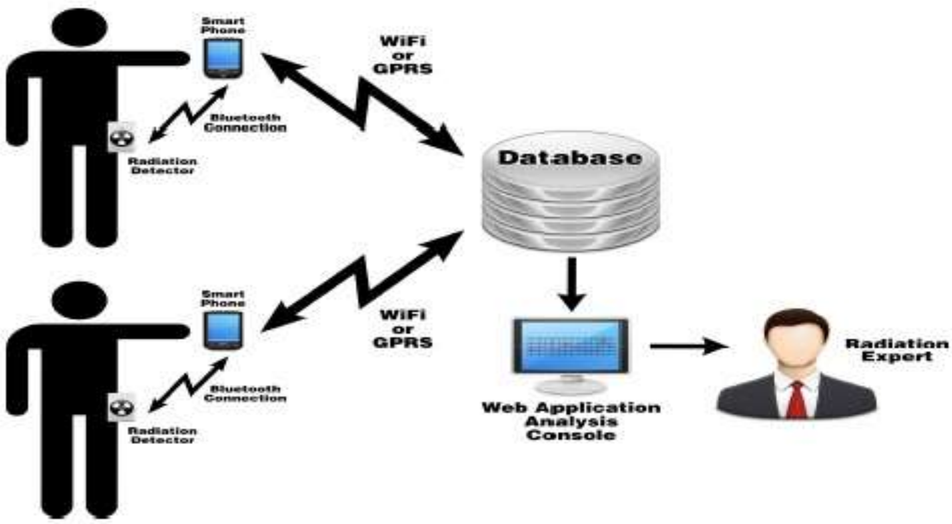

Figure 18.8: Wi-Fi and Bluetooth used for data transfer

2. **Bluetooth:** This is similar wireless technology to Wi-Fi specially used for low range communications. The security issue of Bluetooth is better as compared to Wi-Fi. A security key has to be provided by both the users in order to transfer any data. The authentication key is scripted so that any intruder injected virus will not be able to hack it. The variation of types of data send through Bluetooth is very much similar as compared to Wi-Fi through which text, multimedia messages could be exchanged.

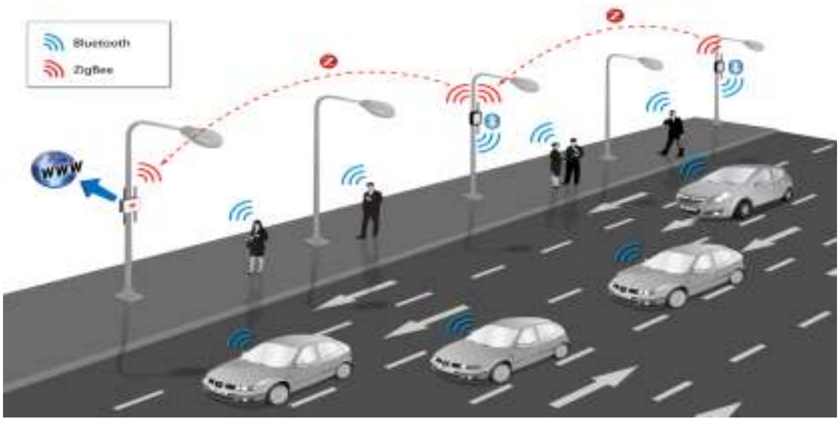

Figure 18.9: Bluetooth and Zigbee functioned in

3. **Zigbee:** This is a very popular technology for low power application. It is based on the IEEE standard 802.15.4. It also works on short range, almost up to 30 metres . The working principle of Zigbee is very simple making it one of the best choices for the transmission of data in smart homes. The Zigbee works ideally between 2.8V to 3.9V. It is also highly secured like Bluetooth as the transfer of data takes place after the matching of identification number between the end devices connected to the sensor and the receiving node.

4. **NFC:** Near-field communication (NFC) is similar to Zigbee protocol with the exception that the communication range decreases to 10cms. It uses 13.56MHz frequency bands with the speed ranging from 106 to 424 Kbits/second. RFID is used for communication by this technology.

Active or passive modes are used in this phenomenon for transmission. The rate of transmission is chosen by the main device providing the RF field while the receiving node uses load modulation technique to receive the data from the transmitting node. Three modes named target, initiator and peer to peer are available to work with this technology. A lot of medical applications are using NFC as their communication protocol for monitoring of blood pressure, heart rate. Alzheimer patients, as well as other medication monitoring, are well monitored with NFC technology. Smart phones, security gaming and other common applications are the reasons of popularity NFC. The communication between smart phones takes place with tags attached to it. One other advantage of using NFC is the availability of sending and receiving the data simultaneously, apart from the fact that the power required for exchange of data is the least in this protocol compared to Bluetooth, Zigbee and Wi-Fi. There is a major disadvantage of using NFC than Bluetooth and Wi-Fi other than the range of communication is the security. Since, no pairing between devices is required for this technology; malware can be introduced in the data transmitted between two nodes.