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Wireless Sensor Network Applications

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Abstract

In this paper we explore some important applications of wireless sensor networks (WSNs). There are 8 Sections. In Section 2 we discuss structural monitoring. We present how WSNs are used in traffic control in Section 3. Section 4 shows the use of WSNs in the field of telemedicine. Pipeline monitoring with WSNs are illustrated in Section 5 and WSN precision agriculture in Section 6. In Section 7 WSNs usage in natural disaster monitoring is explored. Finally, the conclusion is given in Section 8.

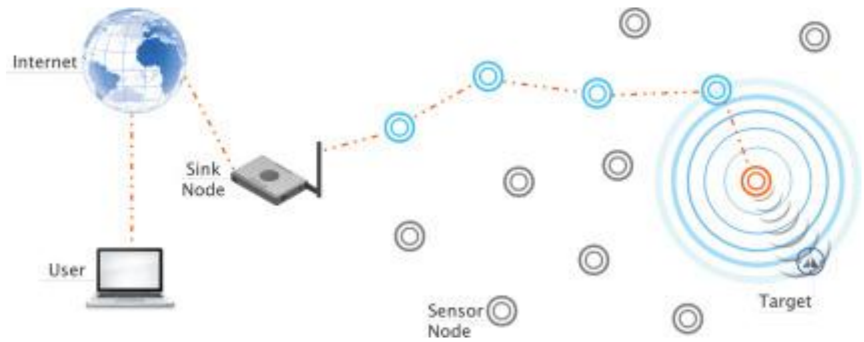
Keywords: Wireless sensor network, WSNs, Structural monitoring, Traffic control, Telemedicine, Pipeline monitoring, Precision agriculture, Disaster monitoring

1. Introduction

What are wireless sensor networks and what are their applications? We're interested in learning more about what wireless sensor networks are, as well as their primary characteristics and components. We would want to see some examples of global applications.First, let's define a wireless sensor network. A wireless sensor network is a collection of independent, standalone nodes that we commonly refer to as sensor nodes [18]. These nodes are connected to one another via wireless links that are typically not well-planned or deployed but rather spontaneous and random. Finally, every sensor network that I am aware of or that has been deployed typically includes a special node called the base station.

The sensor nodes are often connected to one other and eventually to the sink or base station, but they are typically not connected to the internet because they are part of a self-sufficient network that is only connected to the internet or to the outside world through this sink or base station, see Figure 1. This base station is often also slightly more powerful than an ordinary sensor node, although it can also be an extremely ordinary sensor node that is connected to the base station.

Figure 1: Wireless Sensor Network. [24]



What are the main characteristics [15] of wireless sensor networks? First of all, they are very resource limited. Typically, sensor nodes are small, cheap, run on battery power, and have very limited resources. This means that they have little memory, little programming memory, a small battery on board, and a tiny antenna on board—everything that is necessary for a wireless sensor network to function.

Since the 1980s and early 1990s, they have naturally shrunk in size, which is one of the key benefits since we want them to be small so that we can deploy them anywhere, but at the same time, we must work with their constrained resources. The experience demonstrates that the environments in which we deploy them, including those for agricultural activities, volcano monitoring, smart homes, etc., are so complex that you can't actually plan the deployment of the sensor nodes.

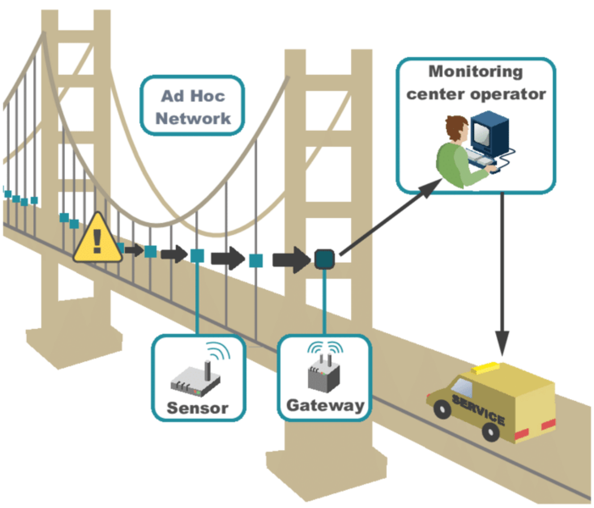
A typical sensor network may be sensing temperature, humidity, acceleration, light intruder detection, and other phenomena [4]; they may be cooperatively pre-processing these events before they send them to the base station. The primary purpose of a sensor network is to transmit some phenomenon and to send this data to the outside world typically through the sink or the base station.Prior to reaching the base station, nodes will forward these data among themselves, and the base station will either forward or store these data on an external database server.

In this paper we explore some important applications of wireless sensor networks (WSNs). There are 8 Sections. In Section 2 we discuss structural monitoring. We present how WSNs are used in traffic control in Section 3. Section 4 shows the use of WSNs in the field of telemedicine. Pipeline monitoring with WSNs are illustrated in Section 5 andWSN precision agriculture in Section 6. In Section 7 WSNs usage in natural disaster monitoring is explored. Finally, the conclusion is given in Section 8.

2. Structural Monitoring

The first application we'll talk about is structural health monitoring [28], [7], [19]. It's a well-established subject in civil engineering and mechanical engineering that deals with inspecting the integrity of complex structures like bridges, buildings, industrial complexes, aeroplanes, and ships, see Figure 2. You may remember years ago, a bridge in Genoa, Italy, collapsed, killing at least 35 people instantly and injuring more than 30 others instantly, according to ABC News. At the time, the bridge was 300 feet above sea level.

Figure 2: WSN deployment for structural health monitoring. [16]



Of course, this issue is not unique to Italy. In 2007, a bridge in downtown Minneapolis, Minnesota, also collapsed, killing nine people instantaneously and damaging more than 20 cars. The interesting thing about this bridge collapse is that it led to a contentious argument between a construction company and the municipality of monopolies. The issue was that at the time the bridge collapsed, there was nearby construction going on, and this construction had blocked four of the bridge's eight lanes leading to this bridge collapse. The municipality claimed that the construction company was to blame for the collapse because they were using shakers to level the ground for the construction. In their claim they stated that the amount of vibration they produced was more than the permissible amount, which led to the bridge collapse. Of course, the construction company rejected his accusation, claiming that we're impaired we're to blame for the collapse of the bridge.

How can they prevent or stop this kind of collapse? The first type of inspection is visual inspection; the municipality or the company in charge of the inspection should send people on a regular basis, probably once a day, to see if the major components of the structure are functioning. There is a well-established guideline to inspect complex structures in civil engineering at this for type of inspections should take place on a regular basis but in different intervals and in different complexity.

The second type of inspection is known as a basic inspection, which occurs at least once a year here you don't send just ordinary people but experts who are familiar with the intricate details of the structure. For instance, if we are inspecting a bridge, civil engineers will typically be the coin the qualified personnel to inspect the integrity of the deck, suspension cables, towers, and other components.

As a result, if the oscillation of the structure, such as a bridge or building, is a bit old or not as it should be, they will recommend detail inspection. In addition, they also observe how the structure reacts to environmental excitation, such as the wind or cars driving on the structure. At least once every five years, a detailed inspection is performed. It is quite expensive and requires bulky equipment, but during this time, the inspection typically calls for or benefits from tools that, for instance, use x-rays, acoustic signals, and infrared signals to monitor the structure's overall health.

As you can see, monitoring a civil structure is quite complex, quite expensive, and most importantly, extremely specialised. If people suspect that there are some microscopic fractures to the structure, they recommend a special inspection. This special inspection does not really focus on the entire structure but localised, so in this case highly sensitive highly accurate instruments will be used and expert in you know stress fracture are involved to examine the integrity of the structure.

In this regard, generally speaking, we can divide inspections into two phases or two major categories. The first one is a local inspection technique that is highly targeted the inspection to identify relatively imperceptible fracture or microscopic fractures in the structure and this requires a significant amount of time as said in the destruction of the normal operation of the bridge or the structure. The other is a global inspection technique. The overall examination picks up on issues that are significant enough to effect how the structure responds to environmental and external forces, such as issues with cables, bearings, or other large structural components when a bridge collapses.

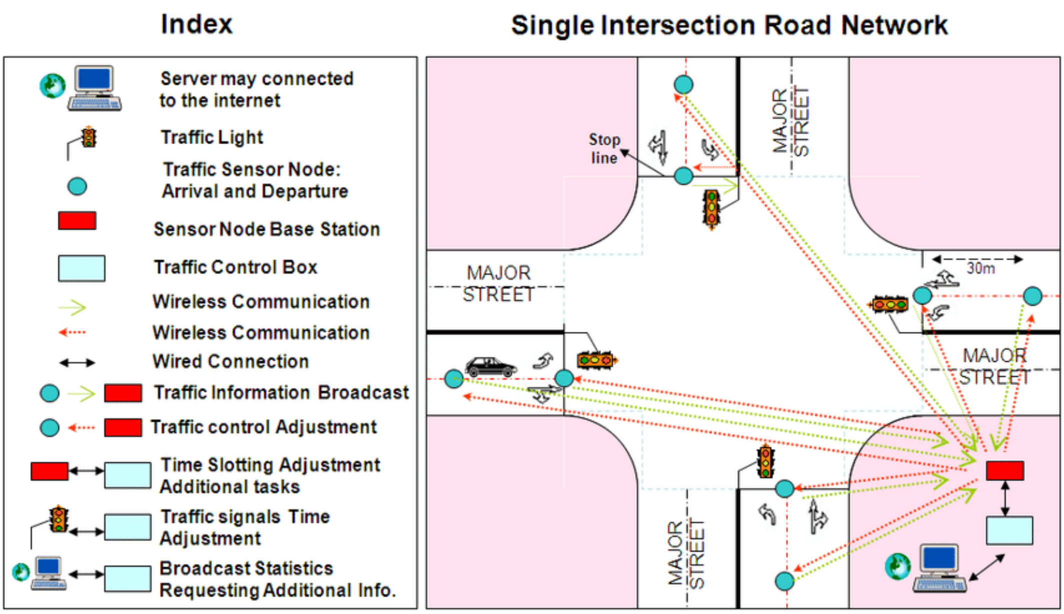
Why are wireless sensor networks interesting? They are interesting in many ways because firstly, because the sensor nodes are quite small, you can easily place them in places that are otherwise excessively inaccessible for quiet sensors, you can easily attach them to the cables, the towers, and the decks. Secondly, because the sensor nodes are small, you can easily place them in places that are otherwise excessively inaccessible.

One of the challenges with local inspection, for example, is locating or determining where exactly these microscopic problems are, but we sense a little because they can be spread out, so you can easily identify where the problem is. We can achieve a high resolution both spatially and temporally, and this also allows you to determine dependency between the various parts of the structure.
Of course, another issue with wireless sensor networks is that they run on exhaustible batteries, which means that you cannot use them for longer than, sometimes, a year. This is one drawback of using exhaustible batteries. Wireless sensor networks are good for global inspections for short to middle term deployment due to the limited resources we have on board, but once local problems are detected, a more rigorous investment should take place utilising more advanced settings complex equipment.
A researcher at Berkeley created a wireless sensor network consisting of 64 sensor nodes [29]. The nodes were installed on the decks, as you can see, along the towers, on the towers, and also on the suspension cables. The nodes were able to self-organize to set up a network. They worked together to transfer data to a remote base station using multi-hop communication. You can see an example [12] of this at the Golden Gate Bridge.

3. Traffic Control

Traffic control is yet another use for wireless sensor networks [25], [2], [22], see Figure 3. Right now, our attention is only on ground transportation. Ground transportation is not only driving a car from home to work; for many nations, it is an essential and complex socio-economic infrastructure that connects many supply-chain networks. Congestion is one of the major issues with traffic management or ground transportation in many nations, and nobody benefits from it. In America, for instance, the urban mobility report in 2017 [8] for example found that in 2009 the time when cars use a lot of fuel to start and brake is also the time when they release unhealthy gases into the environment, making this the worst case scenario for pollution. Additionally, people waste valuable time on the street, which causes stress for employees and employers because they can't get their workers to work on time.

Figure 3: Traffic WSN. [36]



What are some of the stages or tasks involved in traffic control for the first information is to the first task is to collect enough information about the type of car, the density of traffic, and of course the destination of driving since this is an increase of 50% from the previous decade so it is reasonable to harness the power of technology to predict congestion to provide drivers with alternative routes on time to alleviate this problem

When discussing wireless sensor networks or any other wired sensor networks, these are used as additional technologies to enrich our knowledge about congestion density so one of the proposed solutions is to very inductive loops every 10 or 50 metres in the streets. This is one of the ways that sensing can help in dealing with congestion. The first one is to use sensors to estimate the number of cars that are on the street. Of course, there are radar systems and camera systems. how the system operates

An inductive loop up is just a simple conductor or sometimes we use coils and if you have a coil in then let a current pass through this coil then there is a magnetic field will be set up around this coil the magnitude of the magnetic field and the direction of the magnetic field are dependent on the amount of current supplied to the conductor now imagine you put a ferromagnetic material near this setup so we have a coil and so this coil cues a magnetic field around it. If this ferromagnetic substance were to move, the magnetic flux distribution would change depending on the speed in the direction of the ferromagnetic substance. Now imagine that this ferromagnetic substance were a car, and of course when cars drive by depending on their speed depending on their size they disturb the structure of the order distribution of the magnetic field. It's a straightforward setup, and because the coil is buried for our children's traffic control under the street, it is not also impacted by weather or rain. However, the only issue is that you must change the design of the street because you have to worry about the coils in the street. This is quite inconvenient and also expensive, and thus only some places around the world use this type of setup.

First off, we don't need to create a magnetic field because the earth already generates one. This magnetic field is not only available, but it is also present everywhere. Secondly, all we need is a very small sensor made of a ferromagnetic material.

Alternately, since the earth has already established a magnetic field, all it takes is for a car to pass by to upset it. Measure the disturbance in this magnetic field. The magnitude and direction of the disturbance of the Earth's magnetic field again depends on the speed, silence, density, and permeability of the car, which is how permissive the substance is to induce magnetic field around it. The same setup can measure the disturbance in the magnetic field, and based on that, we can determine the presence of a car in a street.

You can see that there is a gathering and releasing of the Earth's magnetic field when cars drive [27] by because they contain a large mass of steel in the front, which is the motor, and steel has a much higher permeability than the surrounding air. If we use a magnetometer to measure this disturbance, we can see that this gathering and releasing of the magnetic field occurs when cars drive by.

If enough magnetometer sensors are placed along a street, they can establish a wireless sensor network and communicate with one another. As a result, we are now able to determine not only the distribution of magnetic flux measured by the sensors but also the distance, direction, and change in that distribution, providing us with more precise information about the state of the streets.

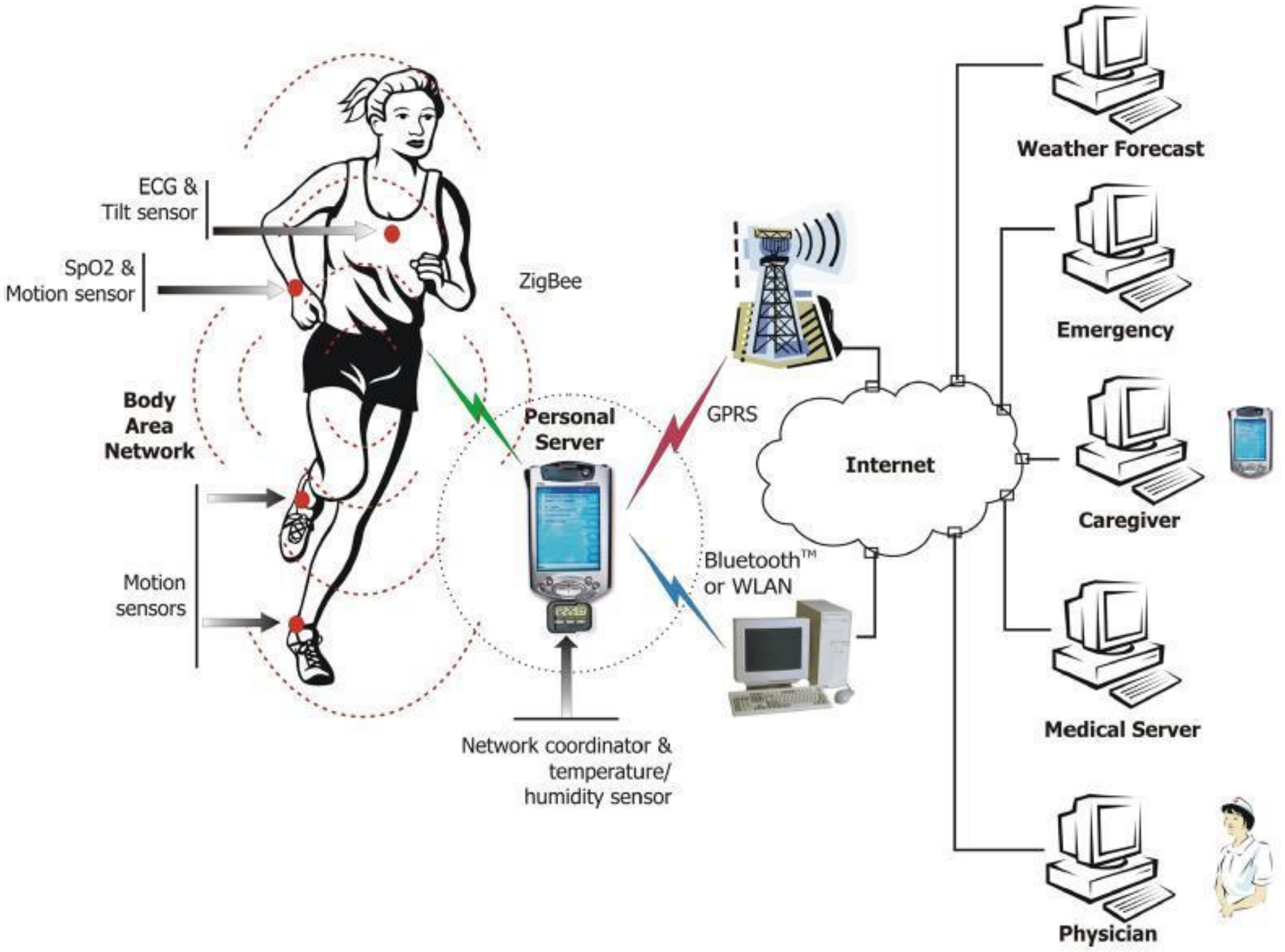
4. Telemedicine

The concept [11], [37], [30] is as follows: Typically, if you have a problem, you must visit a doctor and wait in a controlled setting while they take some measurements. Your electrocardiogram, electromyogram, and blood pressure might all be monitored, which is obviously very inconvenient for many people because they have to take time off of work.

For some elderly people, this also entails additional costs and breaking certain routines, such as going to social events or exercising, but a wireless sensor network can at least make this task simpler because we can deploy sensors on the body of patients, see Figure 4. Because these sensors are wireless and unobtrusive, you can wear a shirt or t-shirt over them or hide some of them behind a jacket.

One of these applications [35] is for Gastroparesis, and I'll briefly explain what Gastroparesis is. Normally, the stomach and intestine drive out digested food from the body, especially the vagus nerve, which contracts the muscles in the stomach and intestine so that food can always be driven into the large intestine, but for whatever reason—either because the vagus nerve is malfunctioning or because they asked a mother—the food is not always driven into the large intestine. Constipation is one of the symptoms, for instance. When people have this kind of issue, doctors often can offer them an array one of the mechanism for gastroparesis, which simply refers to the difficulty of the stomach and intestinal walls to squeeze correctly so that food can leave the body on time.

Figure 4: Wearable vital signs monitoring for Telemedicine. [10]



To address this issue, nuclear medicine in diplomats and doctors with compromised radio actually a very small radioactive material in the foot that releases radiation so that it will be ingested into the body. Because this radioactive material releases radiation, we can use a sensor outside of the body to see the movement, speed, of the radioactive material, and how long it dwells in certain parts of the body.

Another option is to use an electrogastrogram (EGG) [26], which measures the electrical energy produced by the contraction and relaxation of the muscles in the duodenum, stomach, or intestinal region of the body. Typically, the body has three types of cells that produce electrical energy when they are excited: tissue cells, muscle cells, and nerve cells.

Similarly, if the vagus nerve is healthy for instance, it always causes the stomach and intestinal cells to relax and contract. This is similar to how the heart produces an electrocardiogram because there are nerve and muscle cells that are responsible for contracting and relaxing muscles of the heart. If these cells are given some excitation they generate electrical energy and this electrical energy tickles the walls of the heart to produce you know contraction and relaxation.

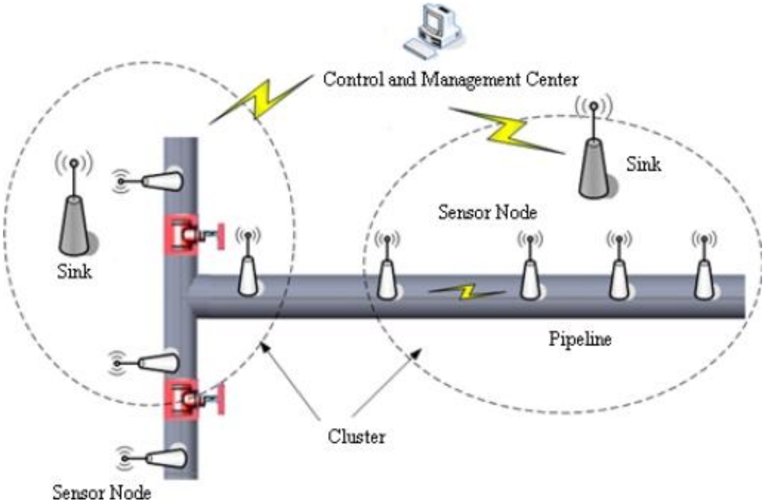
Since this wireless sensor node has pressure, pH, and temperature sensors as well as a recent production that includes a micro-camera, it is possible for scientists to use it to localise problems. Since it can transmit data wirelessly and can be ingested into the body without causing any harm, what happens is that someone outside can set up a receiver to communicate with this device.

For instance, if food is not removed from the body promptly, it turns acidic, and it is possible to determine how long it has been there thanks to the wireless sensor node's ability to send data starting from the moment the food enters the body. This allows us to get more precise information about the location of the modulated sensor and why it is there, as opposed to where we can only detect its presence.

5. Pipeline Monitoring

Another use for wireless sensor networks is pipeline monitoring [20], [34], see Figure 5. Although we may not see them every day, pipelines are a necessary part of modern society's infrastructure because they carry our waste, oil, gas, and water, among other things. As a result, maintaining the integrity of this infrastructure is crucial due to its length and complexity.

Figure 5: Pipeline monitoring sensor networks. [32]



Fortunately, we have simple sensors that we can embed in pipelines to measure pressure, temperature, and major caustic, all of which are essential to understanding the flow of the fluid inside the pipeline. Since the pressure that the pipeline experiences is a result of using the fluid, we can sense the temperature to detect and locate leakage points. Knowing what kind of chemical a pipeline transports is essential for calculating pressure and leakage, for instance in fluid pipelines.

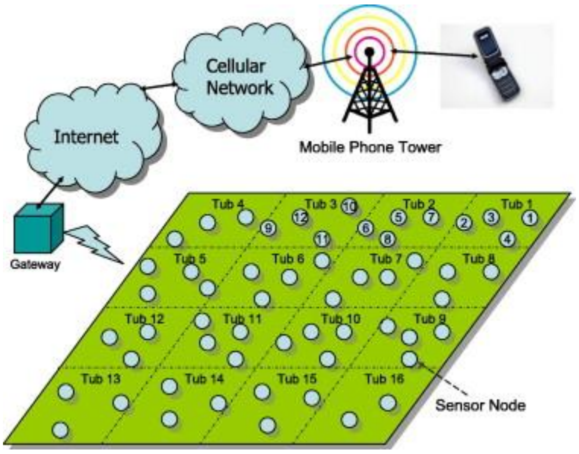
It is crucial to understand that when a pipeline is carrying gas. This is because when a leak occurs between the joints of a pipeline, they will be hotspots at that point, which can be detected by using a temperature sensor. We use acoustic sensors, pressure sensors, temperature sensors, and sometimes infrared sensors to detect problems in complex pipelines because leakage always creates an imbalance that affects temperature and also back propagation, which means that is a caustic yield is produced inside this pipeline in the direction of propagation also important.

A project in the US, where researchers use wireless sensor networks to monitor waste products, is one example of pipe make a pipeline monitoring [31]. The issue with domestic sewage is that traditionally, the pipelines are set up so that the waste water leaves the house or town and travels to a river nearby before being released. Of course, in some cases, not only domestic sewage but also rainwater runoff and industrial waste waters can mix together and are also sometimes released together. Since swearing can sometimes mix with underground water and affect the water we can drink, this has a significant impact on both the environment and our daily lives. For this reason, the researcher in this project used pH sensors, pressure sensors, and acoustic sensors to measure not only the distribution of water in pipelines but also the quality of the water in those pipelines. They used a silver chloride electrode to send the pH quality and this was also sampled every 10 seconds at 100 Hertz rate in this husband was repeated every 5 minutes. The installation was quite seamless and a large amount of data could be collected to ensure that the water we drink is safe.

6. Precision Agriculture

In this article, the focus is on a very large agricultural field where we might plant, for example, orange trees, mango trees, or apple trees. In this very large field, it is important to administer all resources efficiently and it is also very important to monitor the quality of the product because these products are typically to be sold. Precision agriculture is one application for wireless sensor networks [12], [13], [5], see Figure 6.

Figure 6: The WSN for the potatoes field. [1]



Because we are now dealing with a vast area, setting up wireless sensor networks is a great idea to monitor both the overall climate of the field and its microclimates in order to accurately determine how much resources should be allocated to each task. This will ensure that we have the right amount of manpower for different tasks, that the yield we produce meets the requirements of the market, that it is available on the market on time, and so on.

We could also measure the quality of the soil and the moisture of the soil not only at the macro scale but also at the micro scale so for all these types of tasks. We have to predict the resources we need to fight climate change, fight weeds and pests or we have to administer fertilisers, water, pesticides, or herbicides plus any other additional resources. In contrast to traditional methods, deploying wireless sensor networks is a good idea in part because the sensors can self-organize, can achieve very high spatial and temporal resolutions, sensors are very small, and so on.

Precision agriculture involves lots of highly detailed in mechanized tasks and it useful as the following presents itself: application of fertiliser is not uniform, what type of product do I get where with what grade, and other highly complex and automated activities. The weather is somewhat diverse, thus variable research should be used here along with mapping, calculating how much weed we must contend with, and other tasks for all of these goals.

In Europe, especially in southern Europe [17], you know that the wine industry is a very important industry. Therefore, it is important to understand the microclimate. By microclimate, I mean the distribution of temperature. One example of how people used wireless sensor networks to monitor the quality of products is a wine vineyard. The other example deals with a potato field in the Netherlands [6].

If I were to ask you, for instance, what the temperature is in your city, you would respond, "Tell me the city where I am living right now," and you would say, "Dresden for example has a temperature of 27 degree Fahrenheit." We won't argue about this number because we believe it to be a reasonable estimate for winter, but Dresden is a big city and the temperature varies from area to area. It is also a city where we have industry in some areas,

Similar to this, when working with a vineyard, the micro-climate is crucial to predicting the quality of yield and all other climate-related aspects. In this case, the deployment's goal was to monitor the temperature distribution and the difference in temperature, whether it be between the peak and trough during times of the day because it appears that the vineyard cares about more than how much heat is produced at any given time.

The grid structure of a vineyard made it very simple to deploy the sensor, researchers in Italy noted. The sensor could self-organize, support mobile communication and do in network processing to aggregate the temperature differences. The researchers used the wireless sensor network to monitor and characterise the temperature distribution in vineyards. They used 65 sensor nodes at a 10 to 20 metre distance to monitor micro-climate.

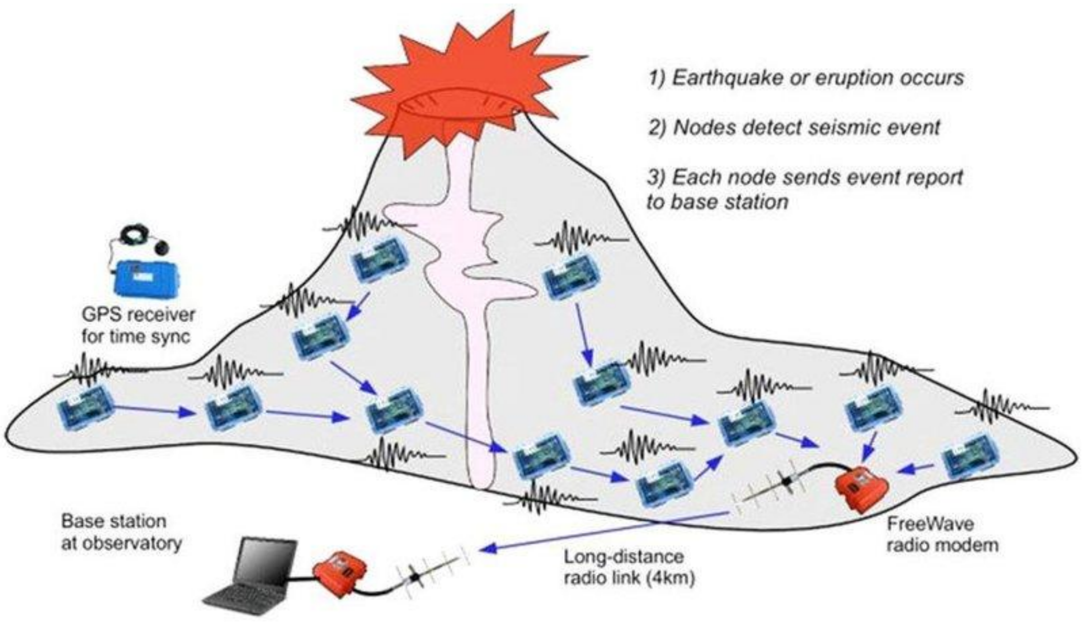
They also looked into growing degree day difference and the difference in temperature so they could estimate first damage, which occurs when the temperature drops below 10 degrees Celsius. According to the author's report, the extent of variation in this vineyard there was a major difference of over having a certified person doing this summation. Thus, it is important to see how the microclimate behaves (consistently or not) in order to predict yield and uniformity of a yield.

The purpose of this wireless sensor network was to monitor the potato field [6] because of a fungal disease affecting the potato. Climate understanding or more so the microclimate in this field was important for researchers to once again predict their presence and the magnitude of blight. In Netherlands potatoes can easily be affected by fungus and the climates where the blight can easily strive depend on the temperature, humidity, temperature, and humidity of the place. They deployed 150 wireless sensor nodes at intervals of 20 centimeters, 40 centimeters, and 60 centimeters. They then used additional sensors to ensure that the network is connected from one corner to the other and data can be gathered from any area of the sensor network. The nodes sample temperature and humidity at a rate of one sample per minute, so the results are temporary, and then the data are collected from all the nodes through a remote base station to another application.

7. Natural Disaster Monitoring

Natural disaster monitoring [21], [33], [14] is a very important use case for WSNs. Active volcanoes typically occur when broken slabs of the Earth's outer shell, which is the small sphere, collide. If everything is in order, the slabs usually float smoothly, but because the earth rotates somewhat irregularly and as a result of this regular rotation, the slabs collide together. These slabs are very hot slabs, and in fact, as a result of this collision, volcanoes typically occur.
As more and more events are known to occur on the ocean's surface, we currently have a variety of extremely sophisticated and expensive tools to detect active volcanoes. When volcanic slabs collide, they not only release a lot of heat but also acoustic signals and, in some cases, earthquakes. Therefore, active volcanoes can be detected using extremely sensitive acoustic sensors or microphones.
The issue with an active volcano is that they spray over a large area, so using stand-alone wired and bulky devices may not give you the right resolution in sensing. However, if we use a wireless sensor network, you can deploy a large amount of wireless sensors over a large area, and because the sensors now work together to do local processing, it is possible to detect both the presence of an active volcano and the presence of a major earthquake.

Figure 7: Volcano monitored by WSN. [3]



There are hence two deployments. Researchers from Harvard University set up a wireless sensor network in two locations in Ecuador, one in 2004 and the other in 2005 [9]. Initially, they only used three different types of sensors, primarily high-sensitivity microphones, but in their second deployment, they increased the number of sensors to sixteen nodes and integrated additional seismic sensors for precise sensing the deformation.
Under the Earth the slabs collide, and this may result in a chain event. To record this, researchers in Senegal used a linear college wireless, and their report was quite impressive. They should have been able to record all three interesting events, namely temperature and acoustic vibration, so they noted that it is crucial to detect discrete events due to this event point.
With wireless sensor nodes, we don't have all these issues; all you need are highly accurate, highly sensitive sensors; if the amount of data produced at their precise location is significant, you can even store the data locally.

8. Conclusion

A distributed sensor network containing sensors that can perceive and examine the outside environment is a wireless sensor network. Since WSN sensors communicate wirelessly, network configurations are adaptable, device placements are changeable at any moment, and wired or wireless Internet connections are all feasible. In this paper we talked about several wireless applications. Some of the applications we discussed were traffic control and pipeline monitoring, telemedicine, precision agriculture, and active volcano monitoring. The usage of WSNs are becoming more important daily and coupled with recent advances in technology the field will continue to grow.

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