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Integrated Sensor Networks: Applications and Architecture Design

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***Abstract*—The potential of sensor network applications and architecture is in the capacity to set up big numbers of bit-sized nodes that assemble and arrange on their own. The most direct application of sensor network innovation is to observe remote settings for low frequency information developments. Main technique of finding will be an open sensor network application and architecture that are compatible with a number of easily available sensor network nodes. The methodological findings will be instructions for sensor network application and architecture trends. The produced findings that serve as guidelines will guide users through the dimensioning of communication grids, identifying forms of nodes to deploy for various application domains.**

Keywords*— Application, architecture, management, wireless sensor network.

I. INTRODUCTION

The emergent innovation of sensor networks forms new opportunities for creative applications while creating new procedural problems for building sensor networks architecture [1]. This paper explores both opportunities and problems involved with sensor networks. This exploration will be achieved by repeating synchronized work on a universal sensor network design and its advancement platform, and on particular sensor network applications that assess the fundamental platform and instructions. As sensor networks progress more and more towards heterogeneity, the frequency of connection layers, MAC procedures, and fundamental transportation solutions rise as well. Sensor network developers should adjust to their applications and frameworks to make room for a broad array of fundamental procedures and solutions.

II. SENSOR NETWORK APPLICATION

Sensor networks are a technology that has massive potential as far as meeting some of the challenges that are present in the contemporary society. Wireless sensor networks have the potential of improving the capabilities of the current technologies. This can arise from the promised aura of freedom resonating from the venture. For one, there will be a reduced need to be tethered to a singular spot. An epitome of this is the flexibility of using equipment with minimal interference from cables and hitching. This is especially in the fields of agriculture, medicine, military applications, transportation, industrial processes and environmental awareness. The impacts of this technology have been to a certain degree that there is now better environmental monitoring. As a result of the use of the wireless sensor networks, famers have now realized Precision agriculture. The healthcare sector has also benefitted from the conscious decision of employing this technology in day to day operations. This is principally in reference to the enhancement of home and assisted care. The capabilities of numerous military applications have also been significantly enhanced.

The technologies whose capacities cannot be enhanced by the sensor networks technologies are extremely limited. This is given the multi-faceted benefits of this technology. The wireless sensor network technology is understood to be a combination of a vast amount of minimal capacity sensing devices that have the capability of working in tandem. The functions of these devices are aided by additional computing and communicating devices that are of different types of actuators. The ability of the sensor networks is such that they can be able to monitor otherwise complex phenomenon. In addition to this, sensor networks have been largely successful given their ability to monitor areas that are otherwise inaccessible. Given these capabilities, it comes as no surprise that habitat monitoring, military application, healthcare technologies, industrial applications and environmental monitoring have all been enhanced as a result of using this technology.

A. Habitat monitoring

The technology of sensor networks has become instrumental in the tracking and monitoring of zebras and ducks. The need to monitor the populations and nesting characteristics of burrows has been critical in the goal of understanding birds in general. With this goal in mind, it has been near critical to ensure that the method that has been employed towards the realization is non-invasive. This is so as not to skew the data. The microclimate of birds has been an issue that has elicited scientific concern. Scientists handling this issue need a technology that will be able to provide long-term observation of these birds. This is especially given the need to appreciate the realization that the current methods that are in use are at best described as being intrusive.

Sensor networks have availed a method of long-term monitoring that is also non-invasive. It is via sensor networks that node placement can be employed as the method of choice. Here the nodes are placed in the location where the birds operate [2]. A base station whose capabilities are dependent on the Internet can then be created. A multi-

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hop network will thus be present. The figure 1 below demonstrates how the sensor nodes that locate birds report to the base station and in turn via the internet to the user.

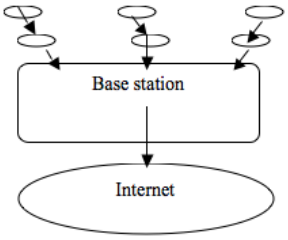

Figure 1: how bird locators communicate to the end user via the internet [2]

The migration patterns of wild animals has been the subject of numerous and wide ranging research. The one pattern that has eluded zoologists happens to be that of zebras. The reason for this has been cited as being the expansive area that zebras use when migrating. Additionally, there is need for long-term observation so as to arrive conclusively at the migration patterns. The advent of sensor networks has made it plausible to monitor and arrive at the migration patterns of zebras.

The process starts with the fitting of a piece of hardware on a small number of zebras within a population of zebras. The characteristics of the hardware are such that the animal can wear them with very minimal discomfort being evident. A battery that last about five days powers this hardware. The technology is fitted with two types of radio, which are the long-range and the short-range radios. The long-range radio is such that it can be able to communicate, effectively, with the base station. The short-range radio has the unique capability of being able to communicate only with the neighbors. In addition to showing the location of the animal, the technology is able to monitor the heart rate, the frequency of feeding and the body temperature of the animal.

B. Environmental monitoring

There have been significant impediments that are inhibiting the full comprehension of the leaf physiology of treat by the environmental field of study. One has to comprehend the verity that the current knowledge is only limited to leaf physiology of single trees. There is need to expand the understanding of this concept when set in an environment of a canopy of trees. This is to analyze whether there are indeed differences. There have been three methodologies that have been employed thus far. It is essential to point out that these technologies are at best described as flawed. This is with regard to the quality of data that is sourced from these three methods.

The first of these has to be the use of satellites. The one key flaw that was immediately apparent in this methodology was the expansive area that was covered, despite the need for wide coverage; satellites provided too wide a scope to generate valid and reliable data. The potential for skewing is significant. In addition, low resolution of the pictures provided by the satellite observations is a critical impediment to the overall effectiveness of this technology. The second method that was employed was the use of single weather stations. The one key flaw was the single point characteristic of the data provided by this method. The third method was that of instrument elevator. This method only yielded data along a vertical transect thus being insufficient for answering research questions.

There was need for an instrument that will be effective despite the dense nature of the trees. It is critical that the sampling of trees not be dependent on the measuring instrument that is being employed. The use of sensor networks was such that it monitored the interior and the exterior of the sampled trees. This is best demonstrated using the figure 2 below which shows how the technology is used in the exterior and interior of trees. This then made it possible to monitor trees in dense vegetation [3]. The instrument is able to sample data after every five minutes. This is for twenty-five days. This provides the much needed data that is both valid and reliable.

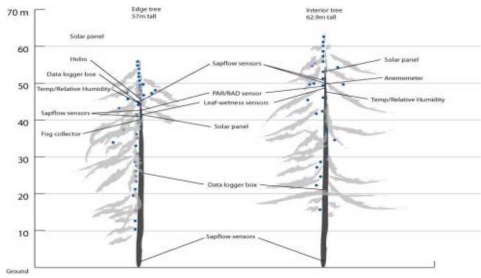

Figure 2: use of sensor nodes in trees [3]

C. Health monitoring

The use of code blue in the health care sector has availed a means via which sensor networks can be able to aid in the enhancement of the quality of care being provided. Code blue was designed to aid in the management of disasters. In addition, it also caters for the safe transfer of patients. Code blue uses sensor nodes to monitor the heart rate of the patient. This is best exemplified in figure 3 where the technology is used for this purpose. In addition to this, this technology aids checking and recording the oxygen and CO_2 levels. It can also measure the serum chemistries. Given these capabilities, the piece of hardware is either placed on the heart or worn around the wrist. This is given that these are the areas easiest to measure the afore-mentioned features.

The sensors work in a multi-faceted manner. First, these technologies monitor state of health of the patient. In the event of registering of vital signs, they send signal to the relevant authorities. These are usually the police. The function of the police is to discover the location of the patient. This goal is made relatively easier given that the technology also serves as a location beacon [4]. This then makes it easier for the ambulance services to reach the patient in time to avert a deterioration of health state.

Figure 3: workings of code blue sensor nodes [4]

D. Military applications

Each day the military is endeavoring to enhance their capabilities so as to surpass the capabilities of the adversaries that threaten the status quo. Machines are getting bigger and the input of technology is growing by each day. Aside from the need to build bigger machines, the military has also gone to great lengths in a bid to protect the soldiers during events of war. Forces that are brought into war by enemies all have the potential of putting the soldier into great risk and reduce the potential for survival. One way in which this heightened risk is realized is via the use of snipers who present one of the greatest challenged during war. This is given that they are normally positioned in locations that favor their need to remain concealed. It is this concealment ability that makes the sniper an unidentifiable killer of many a war soldiers. The figure below illustrates the ability of snipers to camouflage both themselves and their rifles. Snipers have the ability to migrate from one concealed space to another with little or no chance of being spotted by the opposing force. They usually stay for a single location for a very small time. Spotting the sniper optical is a difficult task, thus increasing the efficiency of the sniper.

Figure 4: a concealed sniper [9]

Via the use of the sensor networks, it has become relatively easy to pin point the location of a sniper. Figure 5 shows how the vibrations of a bullet can aid in tracking a sniper. This is via the use of a capability of the sensor networks to both identify and record shockwaves. These are especially the shockwaves culminating from a bullet from a sniper rifle {5] The system records the patterns of these shock waves. These patterns are then used as data by specialized software to reveal the location of the sniper.

E. Industrial applications

The industrial process is one whose success is dependent on the ability to adequately monitor the machines. It is not simply enough to schedule maintenance checks on these machines. The need for monitoring is necessitated by a requirement to ensure continuity in the workflow. Otherwise, there would be a rise a case of an intermittent flow of work. This is especially in regard to industries that are heavily reliant on machines. As such, it is critical for the growth and the success of the business to be assured of the productivity of the machines. The advent of sensor networks has had the impact of availing a means of the continued monitoring of the state of the machine [6]. This emanates from the simplifying the same process. This is in terms of reduced monitoring level and involvement of humans in ensuring their continued work. This is especially with regard to realizing the full capacity of the machines in question.

Furthermore, the sensor network hardware will also provide perpetual data on the overall performance of the machine (s). This will go a long way in realizing an avenue for the continued analysis of the overall performance of the machine. One has to comprehend that devoid of this input from this application, the industries would be relegated to the reliance on the scheduled maintenances modus operandi. Such an archaic means of problem detection makes it cumbersome to ascertain the overall performance of the machines. Additionally, there is a high risk of unexpected breakdowns. This is where the industry then comes to understand that maintenance happens to be cheaper as compared to repairing unexpected machine breakdowns.

It has to be noted that the above-mentioned applications of sensor networks are in no way exhaustive. Rather, they have been chosen in line with the sectors where they have had the most impact. As such, there do exist other applications of sensor networks. There are very few industries that cannot be able to exploit the potential offered by sensor networks. The above-mentioned capabilities have only been realized owing to the superior architecture of sensor network applications. The subsequent section will endeavor to give a wholesome analysis of the hardware architecture that is present in most if not all sensor network applications.

III. SENSOR NETWORKS ARCHITECTURE

Prior to embarking on the analysis of the hardware architecture of the sensor networks, there is need to give some point of note. Sensor network applications are data centered applications. Their existence has been instigated by the need to collect data in otherwise difficult environments. In addition to this, this technology is capable of processing this data in such a way that is eases the burden of analysis. This is best exemplified in the case of the code blue that is so vital in the healthcare sector. It is near critical to comprehend that these capabilities had not been so effectively realized prior to the introduction of this know-how. As such, the contemporary data centered applications such as the new sensor network applications are such that they use and follow different architectures as compared to the earlier data centered applications. The architecture of a sensing node has been illustrated in figure 6.

For the above-mentioned applications of sensor networks to exist, they first had to go through the design process. This design process presents some very significant hurdles in its own accord. The first hurdle entails the large-scale nature in which the eventual application will have to work [7]. Given this actuality, accommodating for this potential for expansive area of application is essential. The second issue has to do with communication volatility. The dependability of the application with regard to communication just happens to be the corner stone of the applications' viability in the field. The third issue is that of the consumption of power. Given the need for the application of sensor networks to be operational in the field for a considerable amount of time, the usability of the application is thus also dependent on its ability to use power economically [6]. These are features that need to be addressed before an application is ready for use in the field.

Below is a simplified diagram of a sensor node. The subsequent section will endeavor to give an analysis of the different components that make up a typical sensor network application. It has to be understood that the primary creation of a sensor network application has to be characterized with a sensor node.

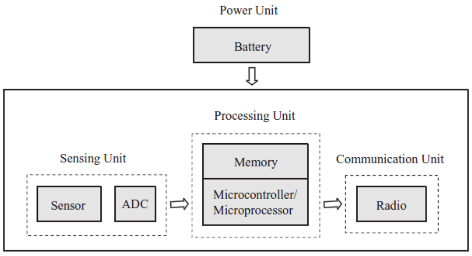

Figure 5: architecture of a sensing node [7]

Sensor networks, and much more specifically wireless sensor networks, are deployed in regions where the use of wires is not a feasible undertaken. This is with reference to productivity. A wireless sensor network comprises a vast number of sensor nodes. These sensor nodes are in turn equipped with sensors that sense data process this data, transmit this data and a power unit for making all these functions plausible. In a wireless network, the role of a sensor node is to essentially monitor the surrounding environment. This is then supplemented by the collection of data that is application dependent. These can be best exemplified by the temperature, location of the element under analysis and other parameters of interest that is being measured by the application.

The sensor nodes work by first sensing the data on the parameter of interest. The nodes then process this data to the neighboring nodes present in the application. The then creates a network of communication. Once the data has been adequately collected, that is according to the frequency timeframe that has been set, it is sent to the sink node. This transmission is a manner best referred to as a hop-by-hop transmission. One of the underlying principles to which the respective applications have to be adhered has to be the need to utilize the lowest amount of power possible. Upon arrival of the data to the sink node, it is routed directly to the user using a pre-existing network connection or via satellite.

It is fundamental to point out that a sink node can adopt the form of a mobile application. As has been asserted earlier on, the sensor network applications have to have the capability to use power economically while still being able to give optimum performance. In the understanding that the transmission of data over long physical distances is power consuming, the most effective approach is the use of multi-hop architecture. The use of intermediate relays replaces the power consuming option of using a single hop communication. Relays act as power savers during the process of transmission of data from the source node to the user node. The components of a sensing unit have been illustrated in figure 7.

A. Sensing Unit

The sensing unit is made up of an A/D converter and a sensor. The A/D converter has the role of converting the digital signal that is being received from an analog signal to a digital signal. After the initial process has been successful, the signal is then transferred to the micro-controller. The second component is the sensor. Sensor networks are comprised of a vast number of sensor nodes. These nodes, then in-turn contain sensors. The specific number of the sensors that are contained in sensor nodes is largely dependent on the application of use.

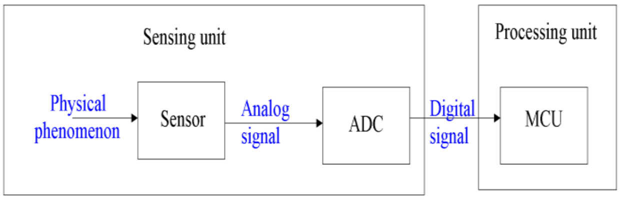

Figure 6 shows the components of a sensing unit as connected to a processing unit [7]

There is need to give this process further analysis in order to offer wholesome comprehension of the same. The sensor senses the parameter of interest, an example of temperature is given. The signal that is culminated from this sensing process is an analog signal. The A/D processes the analog signal and converts it into a digital signal.

Sensor nodes may take the form of either active sensors or can be passive sensors. The difference is in the modus operandi of the two forms as far as energy transmission is concerned. With regard to the active sensors, these emit radiation directed at the respective target(s). The radiation that is in turn reflected back is detected. The energy that has been reflected is then measured by the sensor. On the other hand, a passive sensor works by simply detecting and measuring the energy that is naturally occurring.

There are five classifications of sensors that are available for use in the different applications. The first classification is environmental sensors. In this classification, there are six sensors. These are pressure sensors, temperature sensors, contact sensors, non-contact sensors, humidity sensors, pH sensors, wind sensor and soil moisture sensors. The second classification of sensors is physical sensors. This classification has a fair number of sensors. The range of physical sensors is from water sensors, power sensor, flex sensor, presence sensor, accelerometer sensor, ultrasound sensor to sound sensor.

The gas sensor is the third type of sensors. This classification is comprised of CO_2 sensors, O2 sensors, NH3 sensors, CO sensors and CH4 sensors. The fourth classification is optical sensors. These range from color sensors, radiation sensors, infrared sensors, sunlight sensors to ultraviolet sensors. The fifth classification of sensors is that of biological sensors. These sensors are pulse sensors, oximetry sensors, fall sensors and sweat sensors [8].

1) Processing unit

The processing unit is comprised of four key elements that are critical for its effectiveness. The first element is the microcontroller unit, which is commonly referred to as the MCU. This element is in turn a makeup of four parts. These parts are the memory, interfaces, processor and the non-volatile memory. This unit is a general purpose element given that it negates the need for wiring and other traditional hardware. The use of this processor also realizes the goal of effective energy consumption of the sensor network application. This unit has three states that it can adopt. These states are the active state, sleep state and the idle state.

The second component is the memory unit. This unit is used for information storage in the MCU. For the internal memory, this unit uses a RAM. A flash memory serves as a storage location for the storage of the code of the program [9]. The adopted size of the memory is dependent on the application that is being designed. It is, however, crucial to point out that the size of memory is a significant determinant on the power consumption characteristic of the application. As such, significant thought has to be put on deciding on the size of memory to use.

The third component in this unit has to be the time. This component is a special form of a timer that can either be digital, electromechanical, mechanical or electrical. The final component in this unit is the operating system (OS). There are numerous types of OS that are available for the sensor network applications. These are best exemplified by contiki, MANTIS and SOS amongst others [9]. It has to be understood that the sensor network applications use less complex forms of OS as compared to computers. These OS are generated using only a few thousand lines of code [10]. The difference is illustrated by the actuality that the computer OS are generated using millions of lines of code.

B. Transmission/Communication Unit

The role of the transmission unit is to transmit the data it has received from the processor to the other nodes, relays or final user. As such, this unit makes it possible for communication between nodes. This unit is made up of a transmitter and a receiver. The components are designed such that they are able to share one circuit in a single board. The communication between nodes is made possible by the presence of an antenna. The communication types that are available for the communication unit are three. These are RF communication which has a range of 3 KHz to 300 GHz. The second communication is optical communication which has a range of 358 THZ. The third and final communication is infrared communication which has a range of 300G HZ to 120 THZ [11].

The best communication for the wireless sensor network has to be the RF communication. First, it is vital to point out that RF is made-up of electromagnetic waves. Second, the wireless sensor networks use a communication frequency of between 433MHz to 2.4 GHZ. The communication process in a sensor network is via a definite communication channel. There are definite protocol layers that are followed. These layers have been outlined in the figure 8. These are application, transport, network, data link and physical protocols.

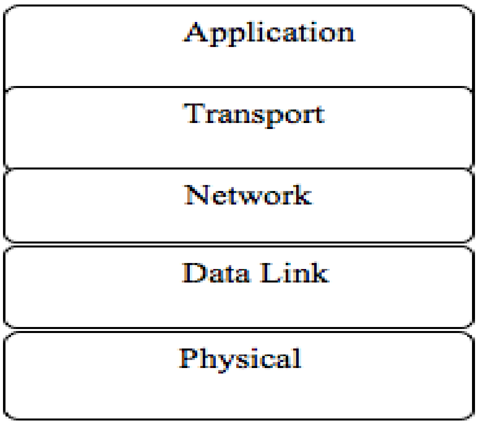

Figure 7: outline of the five protocol layers [14]

C. Power Unit

The only available source of energy in a wireless sensor network application has to be its battery. As such, there is need to ensure that there is efficient power management. It is the role of the power unit to act as a regulator for the power of the battery. It is vital to point out that the role of the power unit is manifest in two ways. The first is the storage of energy and the second is the provision of energy in the required form. The second is the regulation of energy.

There are two components that make-up the architecture of the power unit. These components are the battery and the DC-DC converter. The battery assumes the traditional role of the battery, which is to store power. As such, the battery acts as the primary, if not sole, source of power for the sensor node. The battery that is in use might either be a primary battery, which is not rechargeable or a rechargeable battery. A new form of battery, which is the electro-chemical battery, might also be used. The second component, the DC-DC converter, works as a regulator of the voltage that the node receives. This converter ensures that there is stable supply of power [12]. This is especially critical in the event that the voltage of the battery was to drop.

At this juncture, there is need to provide a mention of the characteristics of sensor nodes. This is all in the endeavor to enhance the overall understanding of sensor networks. One characteristic is that the nodes have to be deployed closely. This is with reference to neighboring nodes or relays. Sensor nodes have not been equipped with identification components. This decision has been informed by the appreciation of the vast numbers of sensor nodes that are in existence. Most, if not all, energy sources for wireless sensor networks are limited and otherwise non-renewable. In addition to this, sensor networks have limited capabilities as far as storage is concerned. This is closely linked also to its limited computational capabilities. All this factors culminate to limit the overall capabilities for communication [13].

There are five primary types of sensor networks that are in existent. The first has to be mobile wireless sensor network. This is characterized by a movement of signals between mobile nodes. The other sensor network is multimedia sensor networks. This is characterized with audio, video and images. The third type is that of underground sensor network. These are the nodes that work best in mines and caves. The fourth type of sensor network is that of underground sensor networks. There are nodes that have been preconditioned to work effectively in deep oceans. The final type of sensor network is that of terrestrial sensor networks. These are nodes that have been especially built to work best in land applications [14].

CONCLUSION

The advent of wireless sensor networks has had profound impact on the interaction between man and society. In a way, these technologies have enhanced man's capacities to inhibit the potency of otherwise inhibitory factors that seem to de-motivate additional understanding of the society and its features. This is especially in reference to the above-mentioned applications of wireless sensing networks. The vast range of benefits of sensing networks architecture has made the technology essential a critical component in a vast range of sectors. An epitome of this is the flexibility of using equipment with minimal interference from cables and hitching. This is especially in the fields of agriculture, medicine, military applications, transportation, industrial processes and environmental awareness. Sensor networks have been largely successful given their ability to monitor areas that are otherwise inaccessible.

Prior to the creation of sensor network applications, the design process has to be embraced. This entails a building of the network architecture of the needed application. The different components that make up a sensor network application network are somewhat the same. This is in reference to the basic elements that have to be present. It is the tweaking of the capabilities of these basic elements that ensure that a specific network application meets the tasks with it was endeavored to meet. The working of the sensor network is largely dependent on the quality of operation of the sensor node. The workings of the networks start as soon as the sensor node detects energy signals. These signals are then converted to digital signals and sent to other sensor nodes or intermediate relays until the collected data reached the user. The use of intermediate relays replaces the power consuming option of using a single hop communication.

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