Introduction

Motivation towards wireless sensor networks :

Now a days people not only coant to receive the information from the physical coorld but also keen for the processing of the information. Traditional information processing is basecally happened through computing devices such as old fashioned macinframes and modern laptops. Most of the office applications uses computers for information Processing where it centered around a human user system, i.e. the information from large database is accessed by human for further processing

However, some other application areas, where computation exerts control over Physical processes. for example controlling the chemical processes in a factory for correct temperature and Pressure. In this case computation is integrated with the control, i.e. control is embedded into a Physical system. Unlike previous systems, these embedded system are usually not based on human interaction, they are intimately tied to their control task in the context of larger system. Even if the impact of embedded system is growing in everyday life still household work such as control of a washing machine, a videoplayer or a cell phone in these applications embedded Systems meet human interaction based systems. Therefore, the tendency not only to equip larger objects like washing machine with embedded computation and control, but also smaller even dispensable goods like groceries. Eventually, computation will surround us in our daily lives, realizing a version of "Ambient Intelligence', where many different devices will gather and process information from many different sources to both control physical processes and to interact with human users. These technologies need to be unobstructive and be taken for granted.

Hence, by integrating computation and control in our physical environment, the requirements of person-to-person, person to machine and machine to machine are supplemented. Therefore, at the end a person-to Physical world interaction is successfully carried out than mere symbolic data manipulation.

To realize the vision of ambient intelligence a critical aspect is needed along with computation and control is communication. All these sources of information have to be transfered to the actual required place (an actuator or a user), which collaborately provide an accurate picture of real world. In some application the networks of sensors and actuators are built by wired communication however wired communication has shortcomings such as large cost due to wiring of number of devices, wiring causes immobility of entities, wiring leads to maintenance problem, wiring also prevents sensors and actuators from being close to the phenomenon to be controlled. Hence, wireless communication between these devices is essential in many application scenarios.

All the above requirements leads to a new class of networks which is called as Wireless Sensor Network (WSN).

→ These networks consists of individual nodes which are able to interact with their environment by sensing or controlling physical parameters

→ These nodes have to collaborate to fulfil their tasks, a single node is usually not able to do so. In general, the nodes without such network contain at least some computation, wireless communication, and sensing or control functionalities

→ Even if these networks include actuators, the term wireless sensor network has become the commonly accepted name, it is also referred as wireless sensor and actuator networks.

Performance of WSNs

WSNs are powerful mechanism that support a large number of real-world application. Due to its flexibility WSNs are also a challenging research and engineering problem.

Therefore, there is no specific requirements that classifies all WSNs, also deciding a single technical soln. for all WSNs is not possible.

→ In some WSN applications energy efficiency of proposed solution is very important figure of merit for longer operation. In some WSN applications individual nodes in network cannot easily be connected to wired power supply and it rely on onboard batteries.

→ In some WSN applications accuracy of results is more important than power supply requirements. Size and cost of individual node is also important. The capacity of onboard battery. The price is also related to the quality of node's sensors which also influences the accuracy of a single node.

→ considering the operation of WSNs in distributed framework where the number, price & low accuracy of individual sensor nodes is relevant than a centralized version with fewer, more expensive and higher accuracy sensor nodes.

Application examples:

For a suitable WSN design a potential long lasting sensor node is the primary ingradient apart from building a low cost, simple to program and network. Appropriate sensing technology is integrated in a node of WSN.

→ Actuators controlled by a node of WSN is not multifaceted. It basically controls a mechanical device like servo drive, or it is used to switch some electrical appliance by means of electrical relay, like a lamp.

Based on the sensing and/or actuation facilities along with computation and communication abilities, different applications for WSNs are considered.

(1) Disaster relief applications

A typical application scenario is wildfire detection.

→ Here sensor nodes are equipped with thermometers & the nodes can determine their own location.

→ These nodes are deployed over a wildfire. The sensor nodes collaborately produce a "temperature map" of the area to determine the perimeter of areas with high temperature This scenario is also possible for accident control in chemical factories.

→ Another disaster relief operation is military applications, where sensors used to detect enemy troops. In these applications sensors need to be cheap, and large in numbers as lifetime requirement is not high.

(2) Environmental Control & biodiversity mapping

WSNs can also be used to control the environment. From chemical Pollutants - garbage dump sites.

→ surveillance of marine ground floor and understanding of its erosion process which is important for construct". of offshore wind farms.

→ In bio diversity mapping where WSNs are used to find the no. of plant and animal species live in a given habitat.

Here the key point for WSNs are long-term application, unattended & wirefree operation of sensors. As Sensors are small to be unobstructive, they negligibly disturb the animals & Plants.

(3) Intelligent buildings:

→ Buildings used to waste large amount of energy by inefficient humidity, ventilation, air conditioning. Therefore, a better realtime high resolution monitoring of temperature, airflow, humidity & other physical parameters of building through WSN can easily increase the comfort for inhabitants & also reduce energy consumption.

→ In some applications sensor nodes are used to monitor mechanical stress levels of buildings in earthquake zones. By measuring the bending load of girders, it is easy to know through a WSN whether it is safe for entry after earthquake. This gives an advantage to the rescue personnel. This system can also be applied to bridge.

-) If the power supply is not available, lifetime requirement (3) is high, but the no. of sensor nodes, cost is relatively low considering the cost of entire building.

(4) Facility management

Simple WSN based application is keyless entry applications where people wear badges that allow a WSN to check which person is allowed to enter which areas of larger company site.

-) This can be extended to the detection of intruders, for example checking vehicles that pass a street outside of normal business hours.

-) WSN could be used in chemical plant to scan for leaking chemicals.

In this applications the required no. of sensors is large, they have to collaborate (eg. tracking) and they should be able to operate a long time on batteries.

(5) Machine surveillance and Preventive maintenance

The sensor node need to be fixed to areas which can be used to detect the vibration patterns of difficult to reach areas of machine and provide maintenance. Examples of such machinery could be robotics or the axles of trains.

→ The advantage of WSNs here is cablefree operation, avoiding a maintenance problem in itself.

If wired power supply is not available sensor should last a long time on a finite supply of energy since exchanging batteries is usually impractical & costly. Size of node is not an issue, also the price is not a constraint.

(6) Precision agriculture

WSN application to agriculture allows precise irrigation & fertilizing by placing humidity/soil composition sensors into the fields. About one sensor in 100x100m area required.

→ Pest control can profit from high resolution surveillance of farm land.

→ for checking & control of health status of animal by checking

body temperature, step counting, & raising alarms when given threshold are exceeded is carried out via WSN.

(7) Medicine and health care:

In intensive care, sensors are directly attached to the patients, the advantage of doing without cables is considered here, for long-term surveillance of elderly patients and for automatic drug administration (embeding sensors into drug packaging, raising alarms when applied to wrong patient.

→ Patient & doctor tracking within hospitals can be literally life saving.

(8) Logistics:

→ In different logistic applications several goods are equipped with sensors that allow a simple tracking of these objects during transportation or facilitate inventory tracking in stores or warehouses.

→ In these applications, sensor nodes need not to actively communicate passive data readout is sufficient. for example when a bag is moved around on conveyor belt at airport & pass through certain checkpoint. This passive readout is ~~carried~~ realized by Radio frequency Identification (RFID) tags.

However, RFID cannot support more advanced applications, such as how to locate an item in a warehouse through passive RFID system. Also it cannot easily store information about history of attached object.

Telematics:

In telematics the sensors embedded in the streets or roadsides can gather information about traffic conditions at a fine grained resolution.

→ This 'intelligent roadside' also interact with cars to exchange danger warnings about road conditions or traffic jams ahead.

Apart from all these applications WSNs are used in waste water treatment plants, instrumentation of semiconductor processing chambers and wind tunnels, in smart 'kindergartens' where toys interact with children, flood detection, interactive museums, monitoring bird habitat on remote island, implanting sensor on human body for glucose monitoring.

Types of application:

WSN separate its application around based on many directions. In many applications there is sources (from where actual data is sensed by nodes) and sinks (nodes at which data to be delivered)

→ The sinks are sometimes a part of sensor network, and also sometimes outside the network. In most cases there are more sources than sinks

The interactive pattern bet^n Source & Sink lead to most relevant ones are:

Event detection:

→ Here sensor nodes report to the sinks once the occurance of a specific event is detected.

→ ~~An event can be~~ detected event can be considered as single event or composite event. for example temperature threshold exceed of a single node and an event that requires collaboration of nearby remote sensors to check temperature gradient is too steep or not.

~~Peri~~ Periodic measurements:

Sensors can be used to report measured values periodically when an event is detected.

Function approximation and edge detection:

The way a physical value like temperature changes from one place to another can be regarded as function ~~approximation~~ of location. WSN is used to approximate the unknown function by using a limited number of samples from individual sensor node. This approximate mapping is made available at sink.

→ An example to find isothermal points in forest fire application, detect the border of actual fire. This is generalized to finding 'edges' in such functions or to sending messages along the boundaries of patterns in both space and/or time.

Tracking:

In intruder in surveillance scenarios the source of an event can be mobile. The WSN need to report update about event source position to the sinks, with estimates of speed and direction. TO do this sensor nodes need to cooperate before

updates are reported to the sink.

A wide diversity in sensor node deployment options:

→ The type of deployment ~~of~~ can be a strategic or fixed deployment of nodes or it can be random deployment of sensor nodes by dropping them from aircraft.

→ In certain scenarios the sensor node can be made mobile to handle the shortcomings of deployment process by allowing movement in post deployment phase, in such a way that the new positions of sensor nodes lead to better sensing. In logistics operation the sensor nodes are also mobile as they are attached to other objects. Here the network adapts itself to the location of nodes.

Maintenance requirement options:

The type of WSN applications has influence on avoidable maintenance,

→ If the maintenance of sensors feasible or the maintenance is not required as networks are deployed in adhoc sense for short term basis.

If the sensors have to function without any attention, for long duration with no possibility for maintenance. All these above considerations are possible for WSN application types.

Options for energy supply:

In some applications wired power supply is used. However, for self powered sensor nodes energy supply is important because amount of energy supply depend on time for the task.

→ The most challenging research is to check the sensing life of nodes over the years without ~~need~~ maintenance. ~~The~~ Furthermore, the design of energy supply depend on size per node.

Challenges for WSNs

The different WSNs applications uses certain characteristics such as:

type of service: In conventional communication network bits are moved from one place to another. However, the purpose of WSN is not to move bits from one to other end, rather WSN provide meaningful information and or control action for a given task.

In simple sense WSN doesn't deal with how many bits transferred sucessfully rather it deal with proper information about a task.

Quality of service: (packet/data delivery ratio, delay)

In some WSN applications an occasional packet/data delivery is enough whereas in some other WSN applications require high reliability, i.e data packets need to be accurately delivered.

→ In some WSN applications delay is important where actuators need to be controlled in real-time through the sensor network. Hence, packet delivery ratio is not a sufficient metric for quality of service, rather the relevant thing is the amount and quality of information that is extracted at given sinks about observed area.

→ Therefore, reliable event detection or the function approximation quality like temperature map is important.

Fault tolerance: (node failure, interference betn nodes/signals)

WSN must be capable of tolerating the faults such as sensor node energy run out, interruption of wireless communication between sensor nodes.

→ Hence to tolerate node failure redundant node deployment is essential.

Life time: (must be energy efficient for long operation)

In some WSN applications the sensor nodes need to operate for long mission time and due to limited power supply availability the lifetime of WSN becomes an important figure of merit. Therefore, WSN must operate in energy efficient version.

→ Lifetime of a network has direct tradeoff against quality of service, as providing more energy can improve the quality but may also lead to decrease lifetime.

→ Lifetime of a network can be defined as the time untill the first node of network get failed. It can also be defined as

the time till the network is not disconnected in two or more partitions, or the time until 50% of the nodes get failed.

An alternative for energy supplies, is to provide a limited power sources (like solar cells) need to be available on sensor node. These sources provide some recharging of batteries.

Scalability: The WSN architectures & protocols need to scale the number of sensor nodes in a network. (can be made large)

Wide range of densities: (variation in no. of nodes due to node failures & movements)

So WSN the no. of nodes per unit area i.e density of network varies considerably. The node density changes as per the WSN applications. In some applications density can vary over time and space which occurs due to node failure or node movement.

Programmability: (Need to provide flexibility to changed tasks)

The sensor nodes in WSN need to be programmable because these nodes not only require to process the information, but also need to be flexible to change tasks. Therefore, these programmable nodes allows change in sensor operation when new important tasks are fed. Therefore, the fixed way of information processing is insufficient.

Maintainability:

WSN need to monitor its own health and status to change operational parameters or choose different tradeoffs. WSN may provide low quality when energy resources are scarce. In such scenarios WSN are capable of interacting with external maintenance mechanisms to ensure the operation at desired quality.

Required mechanisms:

To realize the above required challenges, some new mechanisms as well as new architectures and protocols are found.

Some of the mechanisms of WSNs are:

Multihop wireless communication:

Sometimes direct communication betn sender and receiver has some limitations. To communicate over long distance a high transmission power is required so that a direction communication betn transmitter and receiver become successfull. Therefore, to reduce the total required power intermediate nodes can be used as relays. Hence, In many WSN applications multihop communication is necessary.

Energy efficient operation:

To support long operating life of WSN, energy efficient operation is required.

→ Energy efficiency operation of WSN is carried out by including energy-efficient data transfer betn two nodes or energy-efficient determination of requested information.

Auto-configuration:

WSN need to configure itn operational Parameters automatically. For example nodes must be capable of determining their geographical positions i.e they must have self-location ability.

→ The network must also tolerate the failing nodes (due to battery discharge) or to new nodes integration (due to node deployment after failure).

Collaboration and in-network processing:

In most WSN applications single node is not capable of deciding whether the event has occured or not. However, many sensor nodes collaborate to detect the event due to the joint information of many nodes.

→ For example if the highest or average temperature within an area need to be determined and is sent to sink node

To efficiently acheive this all the sensor nodes reading are aggregated when they are transmitted through the network. This reduces the amount of data transmitted by restricting every node to transmit all data and thereby improving the energy efficiency.

Data centric.

The traditional communication networks deals with transfer of data betn two devices with one network address which leads to address centric operation. However, in WSN nodes are placed randomly to prevent node failure. Here the important part is what values are obtained rather which node has provided. Therefore, WSN switches from address centric to data centric paradigm in designing architecture and communication protocols.

→ Example of data centric interaction is if we wish to determine the average temp. in a given area instead of finding temperature readings of individual sensor nodes. The data centric paradigm can be used to provide alert signal if temperature exceeds a threshold. Data centric paradigm also combines well with collaboration, in-network processing and aggregation.

Locality:

Locality principle in WSN ensures scalability. Nodes that have limited resources such as memory, try to gather the information about their neighbours to during protocol processing. In this process the WSN allows a large sensor nodes without a powerful processing unit at each node. This uses concept of distributed processing. However, combining locality principle with efficient protocol design is one open research problem.

Exploit trade-offs.

WSN also relies on exploiting the trade off between contradictory goals, during system/protocol design at runtime. Trade off such as higher energy expenditure allows higher accuracy results, depending on application, deployment scenario and node failure at runtime node density changes considerably.

Why sensor networks are different?

Based on the application examples and major challenges, WSN has close relationship with Mobile AdHoc Networks (MANETs) and fieldbuses.

MANETS and WSNs:

Adhoc networks are the networks used for specific purpose and needs quick communication requirement. A basic example is one in which a set of computers are connected to each other via cables to build a small network. This network is expected to work without manual management or configuration.

→ MANET is basically associated with wireless communication in particular multihop communication. The term mobile in MANET indicates the nodes are mobile in nature. Some typical examples are disaster relief: firefighters communication with eachother. In these networks individual nodes together form a network that relays packets bet^n nodes to increase the reach of single node allows the network to cover large geographical area.

→ The major challanges in MANET are to recognize a network when the nodes are moving and to handle the limited reach of wireless communication.

However, there are some differences bet^n MANETS & WSNs and hence requires separate research efforts for each of them.

Applications and equipment:

MANET is used typically for voice communication between two distant peers or used to access a remote web server. Therefore, their equipment need to be powerful to support these applications. It requires powerful laptop with a large battery.

Application specific: It is difficult for WSNs to provide 'one-size-fits-all' solution as WSNs consists of different network densities which can vary from sparse to very dense scenarios. These scenarios require different or adaptive protocols. This diversity is not quite as large in MANETs.

Environment interaction:

In WSNs the data traffic characteristics are different in different applications. Therefore, WSNs exhibit very low data rates over a large time scale, but also have bursty traffic when certain event happens (i.e when event showers or alarm storms). MANETs on the otherhand supports more conventional applications such as web, voice etc, where the traffic characteristics is well defined.

Scale:

WSNs has to scale in large numbers of entities which requires different and more scalable solutions. Therefore, endowing sensor node with unique identifier ~~is~~ might be an overhead and need to be avoided. Therefore, protocols without such identifier is important in WSNs. However, it is assumed that such identifiers exist in MANET nodes.

Energy:

WSNs have tighter requirements on network lifetime, recharging & replacing WSN node batteries are difficult option than MANETs.

Self configurability: ~~respect~~

WSN need to self configure into connected network with new solutions. In this respect both MANETs & WSNs are most similar.

Dependability and QOS:

In MANET, individual node is fairly reliable. However in WSN, single node is not much relevant. Similarly, the QOS in MANET are specific like low jitter for voice applications, whereas for WSN, entirely new QOS concepts are required that also considers energy aspect.

Data centric

In WSNs redundant deployment make data centric protocols attractive. However, except file sharing applications in MANETs, data-centric protocols are irrelevant in MANETs.

Simplicity and resource scarceness:

Since sensor nodes are simple & energy supply is less, the operating and networking software is kept orders of magnitude simpler compared to today's desktop computers. This simplicity may require breaking with conventional layering rules for networking software, as layering typically cost time & space.

→ Resources like memory is relevant for heavy-weight routing protocols as those used in MANETs is not available in arbitary quantities, requiring new, scalable, resource efficient solutions. Therefor, MANETs, require resource efficient solutions.

Mobility:

In both MANET and WSNs mobility can be correlated - a group of nodes moving in a related, similar fashion. This correlation in a MANET can be caused by the correlation to a group of people travelling together. In a WSN movement of nodes is correlated because nodes are jointly carried by a storm, river or some other flood.

In general WSNs have to support different applications as they have to interact with physical environment, they have to carefully adjudicate different trade-offs justifying WSNs as a system concept is different from MANETs.