**Real World Applications of Wireless Sensor Networks: A Comprehensive Overview**

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***Abstract: Wireless Sensor Network (WSN) has gained worldwide attention due to the invention of Micro – Electro - Mechanical System (MEMS) technology. The sensors are connected with wireless interface and communicate with one another. This paper is basically divided into two parts. First part covers the introduction and structure of WSN (based on environmental conditions).Second part covers the real world applications based on WSN and open research areas of real world applications. We review the WSN, real world applications, and sensor cloud applications.***

***Keywords: WSN, industrial WSN, Digital oil and gas field WSN, Smart lighting based on WSN, Smart home based WSN, wearable sensor: Health and Wellness, Smart metering WSN, Sensor cloud.***

1. ***INTRODUCTION:***

*Wireless Sensor Network (WSN) have gained worldwide attention in some previous years. The sensors are small in size, low processing power and computable resources, and inexpensive in cost. The invention of MEMS (Micro- Electro- Mechanical system)**technology**increase development of smart sensor [1]. The sensor nodes sense, measure and gather information based on some pre-defined decision process and transmit data to base station.**A wireless sensor network is a combined group of sensor nodes, a processing unit, memory, battery for continues power supply, a radio communication and an actuator (used to control different components of WSN system).At the other side, the wired systems require expensive communication cables, regularly maintenance and costly sensors. But, with the recent advances in wireless sensor network (small in size, limited computing resources and battery operated nature etc.) many industries and organization adopted this (WSN) technology. A variety of mechanical, thermal, biological, chemical, optical and magnetic sensors are implemented. These variety are implemented with the base station (on some decision based process) to perform the desired computing and measuring tasks. The sensor node has limited memory and easy to implement in difficult to Access areas such as mountains, mines, under the ocean, under the ground etc. The WSN are mainly divided into two parts (structure based). i.e.*

* 1. ***Structured WSN and Unstructured WSN (ad hoc network):***

*In structured WSN nodes are placed in a pre-planned manner. The main advantages of a structured WSN are that we have a complete knowledge about every sensor nodes, easy to maintain and low cost to cover a region.**In unstructured WSN sensor nodes are placed randomly and work as an ad hoc network to perform desired action. Unstructured WSN based on ad hoc network and in some cases can also have uncovered region [1]. Available sensor nodes in the market are Generic sensor and Gateway sensor nodes. The below fig. 1 gives an overview of market available sensors .i.e.* ***GENERIC SENSOR*** *and* ***GATEWAY SENSOR****. A Multi-purpose****(GENERIC****) sensor node take physical measurements from the monitored environments such as light, temperature, humidity, barometric pressure, velocity, acceleration, magnetic field etc. A Gateway* ***(bridge nodes)*** *node receives data from*

***Fig 1. Market available sensor nodes.***

*Generic nodes and then transmits sensed data to base station. A base station can be a mobile based interface, a personal computer, a web interface, or some time an access point name etc.*

***1.2 Environmental based structure of WSN:***

*Due to the above discussed inherited feature and self-organize nature many real world applications are adopted the WSN technology. The below fig. 2 gives a structure overview of different types of Wireless sensor network based on the environment and location of implementation. WSN can be divided into five parts i.e.*

* *Terrestrial WSN-(e.g. Industrial WSN)*
* *Underground WSN- (e.g. Oil and Gas monitoring)*
* *Underwater WSN-(e.g. Military and Navy equipment’s)*
* *Mobile WSN-(e.g. Health monitoring and Target tracking)*
* *Multimedia WSN-(e.g. Smart lightning and Smart home WSN)*

***Fig. 2 Structure of WSN.***

***1.2.1 Terrestrial WSN:***

*Terrestrial WSN are implemented on flat surface areas or sometime in the air. A terrestrial WSN is a combination of hundreds of sensor (inexpensive and wireless) and implemented in a chosen area in a structured or unstructured manner. As sensor nodes are battery operated so power source is limited. But in terrestrial WSN we can used a secondary source of power i.e. solar panel’s cell* ***[1].***

***1.2.2 Underground WSN:***

*As the name suggest, underground WSN are implemented under the ground surface that can be a mine, an oil and gas pipeline etc. underground WSN are more expansive as compare to terrestrial WSN because some extra sensor nodes are placed under the ground as well as above the surface. Power is the main problem in underground WSN (battery can be discharged) and there is no other source to power. Changing battery is not possible under the ground* ***[1]****.*

***1.2.3 Underwater WSN:***

*As opposite side of underground WSN, in under water WSN sensor nodes are placed under the water and above surface of water. These types of networks are mainly used in underwater vehicles, military and navy equipment’s. Underwater communications are possible through acoustic waves. The underwater sensor nodes must be able to self-configured and adapt to water environments. Under water sensors nodes are more expansive as compare to other sensor nodes. Limited bandwidth, energy conservations, self-configurations of sensors node, low signal fading’s are the some open research issues* ***[1].***

***1.2.4 Multimedia WSN:***

*These types of wireless sensor network are mainly introduce to monitoring and tracking of environment in the form of audio and video and imaging formats. A multimedia WSN consists of high definitions cameras and microphones with low implementations cost. These types of networks are mainly used in vehicle tracking and detecting systems, traffic lighting and signal control, image detections etc. systems. Audio and video transmission required high bandwidth connections. So high bandwidth demand, and quality of services are some open research issues* ***[1]****.*

***1.2.5 Mobile WSN:***

*Mobile WSN consists of moveable sensor nodes that communicates each other at specific distance and can self-repositioning at the demand. Information gathered by a mobile node can be transmitted to another node when they meet at a specific range. Mobile WSN involve in environmental monitoring system, target tracking, search and reuse data, and real time monitoring .Higher degree of coverage, decisions based target tracking, and increasing distance of target expose* ***[1]****.*

***2. REAL WORLD APPLICATIONS ON WSN:***

***2.1 Industrial WSN:***

*The increasing size of many industrial system and manufacturing unit, smart and intelligent system are required to increase productivity, monitoring and controlling systems are required. The industrial system comes with WSN have several advantages over previously used wired system. The wired automation system requires expansive cabling and high maintenance are required. As the size of production unit increase, requirements of large length cabling required, that much more expansive as compare to wireless sensor network.*

*In industrial WSN , tiny wireless sensor are installed on the industrial equipment’s to monitor the power supply, checking temperature level, pressure measurement, sometime alarm systems etc. [2]. After collecting all the required data from each sensor node, data is transmitted to central control unit (sink node- collect data from each sensor node timely). The industrial WSN have a wide range of applications including building automation, industry process automation, electricity meter reading and inventory management. An advanced alarm system is also a part of industrial WSN used to notify any potential problem to plant personal. The plant personal repair or replace the sensor equipment’s before equipment’s fails to perform desired action. For developing an industrial WSN, a combination of expertise are required.*

*Industrial expertise has knowledge about production process and information about required specific applications. To understand the fully functionality and issues relate to sensor, sensor technology expertise is required. Designer expertise is required for designing and implementing an industrial WSN (routing algorithms, sensor configuration etc.) At last network expertise is required, to perform the communication topology and ensure a flexible and scalable network [2].*

***2.1.1 Quality of services:***

*The QOS in industrial WSN are used to find accuracy between received data and by sink node and occurring data in industrial field. To transmit the data over the personal network and other networks so that data can be accessed by plants personals by giving some security checks is an advance open research field [3].*

***2.1.2 The hardware architecture of an industrial WSN consists of some basic components****:*

***Sensor:*** *sensor is hardware device and produce measurable response to change in a physical conditions i.e. temperature, pressure, and voltage, current. The analog signals (received /produced by sensor nodes) converted to digital signals using converters. [2].*

***Processor:*** *The processing units associated with a small storage unit control the functionality of connected components. Perform process data monitoring and transmitted task.*

***Transceiver:*** *A radio communications are required to connect and processing of data from one node to another. A transceiver unit connects sensor nodes to networks.*

***Power source:*** *power source is the main components and research issue in the field of industrial WSN. Basically a battery is the main source in sensor network. Power consumption is divided into three domains i.e. sensing, processing and communications* ***[****2].*

***2.1.3 Network Topology:***

*The network topology has an important role in the designing of a sensor network. When choosing a topology different points are needed to be considered- like connectivity, adaptability, mobility and scalability. Some types of topology are mesh topology, star topology and sometimes combinations of star mesh topology [3].*

***2.1.4 Industrial Applications:***

*Process monitoring and control is a combination of architectures, mechanisms, and algorithms used in industrial factory. These controlling and monitoring processes are designed to achieve a desired goal [3].*

***Fig. 3 Temperature measuring process.***

*The**above fig.3 shows a temperature monitoring process where a control room monitoring the activities like VALVE positions i.e. open /closed and a temperature transmitter give the temperature value based on some threshold value.*

***2.1.5 Advantages of industrials WSN:***

*- Reduced your cabling cost.*

*- Real time measurements and monitoring.*

*- Supports GPS systems.*

*- Easy to maintenance.*

*- Reduced installation cost.*

*- Easy to reconfigure and integration.*

*- Better performance.*

***2.1.6 Security****: Security is also an important topic/process in industrials WSN. When designing the security mechanism for Industrials WSN low level and high level security mechanism are need to be considered [2].*

***Low level****: (key establishment and trust control, secrecy and authentication, privacy, robustness to communication denial-of-service, secure routing, and resilience to node capture).*

***High level****: (secure group management, intrusion detection, secure data aggregation).*

***2.1.7 Open research issues in industrial WSN:***

***QoS*** *supports (quality of services supports in heterogeneous network and multi-hop networks.) Security, threat analysis, confidently of information, integrity of information, availability of information etc. are the some open issue topics and need more and more improvement in further.*

***2.2 Digital oil and gas field WSN:***

*The oil and gas field industry is major industries that include effective measurements and monitoring of various different parameters (like temperature, pressure, flow of direction) for the purpose of safety and total optimization of process. An oil and gas industry include various process of explorations, extraction, refining, transportation from one place to another through pipe lines or some time local transportation are required* ***[****4].*

*WSN technology provides a much faster, low cost for implementation, more flexible and convenient as compare to wired sensor network.* ***MEMS (Micro- Electro- Mechanical system)*** *fulfill this demand of smart networks with small size, weight and cost feature [1].*

*The most common and important application’s in oil and gas industry are real time monitoring and process control, safety alert, maintenance and production improvement. Some are given below;-*

***2.2.1 Remote monitoring****:*

*Remote monitoring reduced the cost of implementations and maintenance. Examples of remote monitoring in oil and gas industry are pipeline integrity monitoring, tank level monitoring, and equipment’s conditions based monitoring, pipeline pressure relief monitoring, refineries pressure relief monitoring etc.[5].*

***2.2.2 Conditions monitoring:***

*Sensor may detect vibrations, temperature, gas dissolved, power consumption, electromagnetic properties, performance etc. failure of a control loop may cause of an unscheduled shutdown of process and increase the chances of accidents [5].*

***2.2.3 Components in a sensor network****:*

*The below fig 4. Gives a simple overview of basic components of an oil and gas field WSN. The below fig. 4 is like an assembly of distributed or localized sensor, interconnecting wireless sensor, a central point for information clustering and a set of computing resources* ***[****5]****.***

***Fig. 4. Basic components of an oil and gas filed WSN.***

***2.2.4 Pipeline and corrosion monitoring:***

*Pipelines have an important role and widely used in transportation, various filtering and refining process. A pipeline can be placed over the ground, under the ground and under the ocean. So effective monitoring and measurements are required to check the* ***leakage, pressure, direction and rate of flow, valve position, temperature changes*** *etc.* ***[****4].*

*WSN provide a cheaper and easy real time monitoring system for all kind of performed process in oil and gas field.*

***2.2.5 Conditional monitoring of plants:***

*To optimize production and to ensure safety, various conditional monitoring systems and parameters are required. WSN provide a simple and flexible mechanism used to monitor production process, detect oil and gas leakage, flow etc.*

***2.2.6******Open research challenges:***

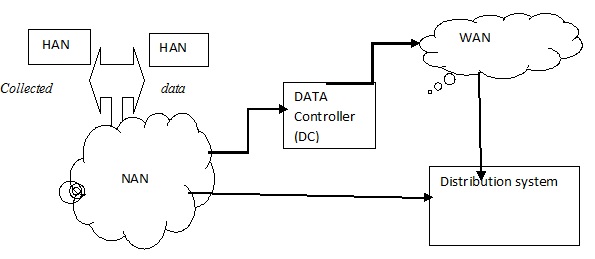
*To improve and provide performance, the sensing requirements must be determined, so that the demand of oil and gas industry fulfill. The type of sensors and antennas are research issues. Battery play an important role in the working of WSN so improving power consumption and more power sources and battery performance increase are other and important research topic.*

***2.3 Smart metering based on WSN:***

*A smart metering is an intelligent electricity network that manages information collecting, control and communication networks. The main role of smart network grid and metering is to save energy, reduced cost, increase reliability and monitoring for all the connected customers and home appliances. In smart metering short range wireless communications like Bluetooth are used to make interface between meter and customer devices. The IEEE 802.15.4 (ZIGBEE) and IEEE 802.11 (Wi-Fi) are used for smart meter interface between meter and LAN. The cellular wireless services like GPRS, UMTS, and 3G are used for interface between meter and central unit (base stations)* ***[****7].*

***2.3.1 Smart metering communications****:*

*Smart meter is a two way communications devices one for measuring energy consumption by the home appliances (energy can be electricity, gas, water or heat). A wireless automatic meter reading system (WAMR) automatically collects consumption details, diagnostic and status data from meter and transmit the sense data to central database for billing, troubleshooting and processing [7].*

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***Fig. 5 smart metering architecture. [7]***

***2.3.2 Explanation:***

*The above fig. 5 give an architecture of smart metering where a HAN (home area network) formed by electrical appliances inside the home using potential technology like-ZIGBEE, Wi-Fi, Ethernet, PLC. The HAN network range consists of tens of meters and data rate requirements are application dependents. The fig. 5 consists of another network i.e. NAN (neighbor area network) collects information from more than one HAN networks. The NAN network range consists of hundreds of meters and data rate requirements depends on node density (e.g. 2 KBPS in the case of 500 meters sending 60 byte metering data in every 2 minutes). After collecting all the data from HAN & NAN Networks data is send to controlling unit (i.e. DC-data concentrator). All the collected data are sends to the WAN (Wide area networks) which is just like a transport network, sends this data to interested parties. The range of WAN has tens of kilometers and data rate requirements are high like few hundred Mbps to few Gbps [7].*

***2.3.3 Smart Meters:***

*Example of microprocessor based system is digital tele wattmeter that transmit monthly data to the central office using telephone line and some pair of modems. The power line communication (PLC) has many limitations for data processing like complexity of networks, high cost for installation and maintenance. Different types of frequency band are required. At the other side the WIRELESS AUTOMATIC METER READING (WAMR) system that automatically collects meter data (consumption and current status), diagnostic the problem and transfer this data to central database for the purpose of billing , troubleshooting and processing of data. The WAMR system reduced the cost of installation as well as human efforts and provides real time data and errors report. The all the information is transfer using GSM/GPRS network [8].*

*Advanced features of electronic meter is given below:*

*Higher speed.*

*Automatic billing invoice.*

*Load management.*

*Alarm warning.*

*Remote accessible nature.*

*Temperature detection*

**

***Fig.6. Electromechanical meter vs. Electronic meter.***

*The above fig. 6 images shows previously used electromechanical meter and currently used electronic meter. Electromechanical meter provides poor accuracy of data and low chances of theft detection.*

***2.3.4 Open research areas:***

*Power factor improvement, instant payment options any ware in the world, consumption energy details, and Defect alerting systems are some open research areas in smart metering [8].*

***2.4 Smart lighting based on WSN:***

*The intelligent transport system (ITS) introduced by information and communication technology (ICT) is used to smart lighting and services in transports systems. The WSN have an important role in the designing of smart wireless lighting system with its silent features like low installation cost, flexibility and sometimes temporary development. Sensor nodes are provides a mechanism to minimize power consumption and collect information about vehicles travelling on road or highways. SCAT and SCOOT are the traffic control systems [9.].These systems can perform local optimization and changes respond on traffic demands. The main role of SCAT and SCOOT is to optimize the signals cycle times (durations for computing all phases of a signals), phase split (divisions of cycle times into the green signals), and the offset value (time relationship between the start of each phase).Intelligent lighting system and energy management systems are the perfect solution of energy saving in the field of public sector (20-30% in hospitals, 15% in factories, 10-15% in schools and 10% in residential buildings etc.)*

***2.4.1 Intelligent Driver For Light Emitting Diode Street Lighting:-***

*The LED technology comes with better performance, long lifetime. Due to these benefits LED are widely used in smart wireless lightning system [13].To take the advantages of LED better performance we need some electronics drivers based on the patented modules and derived from the thermal, photometric, and power electronic techniques. Some of intelligent drives include ac/dc converter, controller (performs function of soft startup i.e. full ON, half OFF and OFF).*

***2.4.2 LDR (Light Dependent Register) module:***

*In LDR module, there is two LDR in which first is placed on the top of the street lamp (gives information about day/night status) and second one is placed under the street lamp (gives information about lamp health conditions).After getting the all the information, LDR modules transfer this information to micro-controller module. The micro-controller module sends this data to a control unit by using the wireless technology i.e.* ***wireless X-bee*** *[13]****.***

***2.4.3******Timing Parameters and Flow monitoring:***

*The timing parameters are adjusted directly by the regional computer based on the traffic conditions. A fuzzy logic algorithm used to determine the green time extensions for traffic lights. The green light time durations can be extended based on current traffic conditions and volumes. The algorithms are based on measured traffic volume value through the WSN (wireless sensor networks) lighting. IEEE 802.15.4 network architecture with multiple levels of traffic flows monitoring, determine phase sequence and green light time durations [9]. The smart lighting systems works by sending wireless signals from controller to wired receiver units. The controller are battery operated, wireless connection oriented, and have radio waves communications systems.*

***2.4.4 Modes in smart lighting systems:***

*Dimming modes: controller acts as a 4 channel dimmer. Pressing button one switched on /off one light. The same procedures are followed by all the 3 buttons.*

*Central button operations: when controller central button is pressed, all channels will turn on/off at the same time.*

***2.5 Smart home sensor networks:***

*Home automation is a major growing industry that changes the way of people lives. A smart home sensor network is a system with special need that can respond on voices commands and control of on/off status of electrical devices. These systems must be cheap in cost and easy to implement and configure**[14].In recent previous years, the demand of home sensors is increasing to monitor the environmental, control home electrical appliances, motion detection, temperature based decisions, and transferring the collected information to the home or office base stations. The smart homes also refer as intelligent homes or automated homes. Smart home sensor networks include remote controls over the lighting systems and electrical appliances, and remote monitoring of inner space [10].A smart home sensor network is a combination of passive infrared sensor, infrared (IR) sensor, photo capture sensor, temperature measure sensor, and motion detection sensor. The main advantages of wireless sensor network, one can easily monitor & control homes mechanical systems and appliances by using a cellular smart phones or internet. The GSM technology provides a mechanism for messaging system information’s, security and control systems units, remote based control. Sometimes data can be transferred in the form of an SMS. The system can monitor the room temperature , lighting control, fire alarm alert, gas leakage and when these types of problems are absorbed then an alarm or an SMS is send to ensure family safety. The smart (sensor based) homes system are based on different control set of program and system hardware.*

***2.5.1 Software support:***

*LABVIEW is a high level productive development environment for creating custom application that interacts with real world data or signals. The G programming is also called “LABVIEW programming “.The G programming can easily together with data analysis, logical operations and understanding how data is modified. The lighting system uses light dependent sensor register to sense the light presence and absence. The PIR motion sensor detects the movement in homes [10]. The main advantages of smart home sensor network is that it can automatically on/off light and other electric home appliances when they are not in used. Sometime the on/off switching process based on motion detection and sometime a specific time interval based decision process.*

***2.5.2 Security****: An important issue in the field of smart home sensor network. Security in the sense alarm alert, theft / robbery alert, fire or smoke alert, and other alert like gas leakage, short circuit alert, unwanted entry or some time things broken alert[1]. Infrared sensors are placed on the side of window. The system gives alarm notification and SMS alert (using cellular technology) when detect someone trying to enter from window. Smart sensor senses the data or motion signal at the bases of some decisions [10]. Family safety and security are the some open research issues in the field of smart home sensor network.*

***2.5.3 Smart Home Automation system:***

*These are the some available standard systems used in Smart home Automation systems i.e. given below:*

***2.5.4 uCONTROL in home automation:*** *uCONTROL is an integrated platform for home security, monitoring and automation (SMA). This system is a 7 inch touch screen display device that can connect wirelessly to security alarms and other home appliances [14].*

***2.5.5 Home Automated living:*** *HAL is a commercially available system for home automation. HLA software taps the power of a PC to control the home appliances. The main advantage of this system is that it can sends commands all over the house using the electrical wire insides the home walls. There is no need for special wiring so it can be easy to install and inexpensive in cost. [14.]*

***2.5.6 Handheld Microphone Module (MM):*** *The handheld MM are used to captures the human voice using a sampling rate of 8 KHz. It is known that the highest frequency component of a human voice is 20 KHz. [14]*

***2.6 Wearable sensor: Health and Wellness:***

*Wearable sensor is expanding the capabilities of health care system, improving diagnostic and monitoring system. The main advantages of wearable sensor is that sensor are easily adjusted on wearable things like hand band , cap, jacket etc. wearable WSN consists of number of applications in the field of diagnostic and monitoring equipment’s as well as physiology and biochemical sensing and motion sensing. Wearable sensor is developed according to the need of clinical applications and interest bases. Emergency situations are monitor and detected through processing data and previous stored data bases. An alarm is used and a massage sent to the central service center that can be a emergency ambulance, a hospital unit, or sometimes a relative. Health related information is gathered via body wearable’s sensor and sense data is transmitted to caregiver (family member, clinical emergencies) via an information gateway i.e. mobile phones [11].*

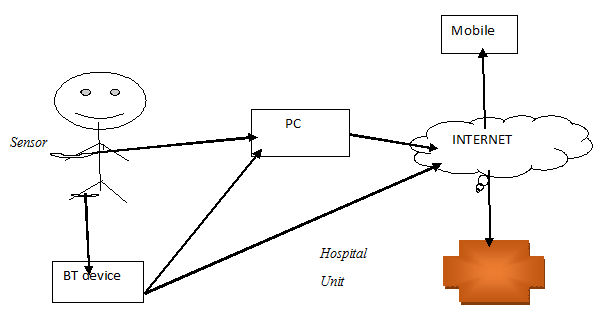
*Recent development in the field of micro- electronics has allowed developing miniature circuits, enabling sensing capabilities, amplification of signals and data and radio transmission communications. The main focus of Wearable sensor is on improving health monitoring, early detection of disorder etc. so clinical applications are best example of wearable sensor WSN. Mobile technology also has an important role in the working of wearable sensor. Mobile technology provides a remote monitoring environment with the help of GPS system. The GPS systems are integrated with the wearable’s sensor so that in the case of emergency, it is easy to locate patient location. IMEC provide an SMART phone based ECG monitoring system that allow low power ECG sensor to communicate wirelessly with phone. Some applications area is given below where wearable sensor is implemented [12].*

***Fig. 7 Applications area in wearable WSN.***

*The above arrow (fig. 7.) gives information about various application area where wearable sensor are implemented. Wearable SENSOR ensure use to enable long term physical monitoring , important for treatment of many clinical disease , neurological disorder , mental health issues, depression , drug addiction etc. wearable sensor, mobile phones, web camera’s, are the some health support systems. The wearable sensor can be easily integrated with clothing garments such as hats, wrist bands, socks, eye glasses, and headphones.*

***2.6.1 Autism Spectrum Disorders (ASD)****-The term spectrum refers to the wide range of symptoms, skills, and the level of disability. The scientist does not know the actual causes of ASD. Accordingly genetic factors, two twins share the same genetic code, if one has the problem of ASD then the second also have the chances of ASD [11] In environmental factor, anything’s outside the body that can affect our health comes under the environmental factor.*

***2.6.2 Electro Dermal Activity (EDA)****-EDA is a valuable tool in behavioral medicine as a biomarker of individual characteristics of emotional responsiveness. Electro dermal activity also known as skin conductance galvanic skin response [12]. EDA required low power and circuit to be simple. The motivations of wearable’s sensors network is to create technology that monitor and track the patient’s progress continually. Active areas of research for EDA include sleep disorder and detection of diabetic shock.*

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***Fig. 7.Architecture of mobile health monitoring system. ref. [11]***

*The above referenced fig. 7 shows the architecture of mobile health monitoring system where a human wear some sensor bands (hats, wrist bands, socks, eye glasses, and headphones etc.). Sensor bands sense the health data and transfer the data to mobile phones using radio transmission technic like Bluetooth. Mobiles phones applications are connected to a central hospital unit or a personal PC and gives all the sense data.*

***2.6.3 Mobile Photoplethysmo graphy (PPG)*** *– Photoplethysmo graphy (PPG) technology has been used to develop small, wearable, pulse rate sensors. PPG devices consist of small infrared LED (light emitted diodes), photodetectors, and a simple and reliable low cost infrastructure [12]. The most important cardiopulmonary is blood pressure and blood flow. Blood flow is related to blood pressure. Wearable pulse rate sensors are the best examples of PPG.*

***2.6.4 Wireless connectivity tools Bluetooth-*** *Bluetooth was to design to allow low bandwidth wireless connections. Many mobiles applications are used Bluetooth technology for better connectivity and radio modules [11].*

***2.7 Sensor cloud:***

*The Sensor Cloud called* ***Sensor Plus the cloud*** *from LORD MICROSTRAIN sensing system. The amount of data sense by the sensor network is huge in size and multidimensional in nature. To store this data we need more storage space and computing resources. But in wireless sensor network the storage space and computing power is limited. Integration of cloud computing with WSN overcome this problem. There are three areas in cloud computing with WSN i.e.*

*- Sensor cloud database.*

*- Sensor data sharing platform (based on different cloud).*

*- Cloud based sensor data processing.*

*The NIST (****National Institute of Standard and Technology****, US) define that cloud computing is model for enabling convenient, on demand access to a shared pool of computable resources like network servers, storage application and services [15].*

*According to IBM report “cloud is a new consumption and delivery model for many IT based services”. The user has no need to know anything about the technology and implementation. The consumer has no need to control and manage the infrastructure but must have a control over the operating system, network application, and storage and network components.*

***2.7.1 Models presented by development scenario [17]]:***

*There are four models are presented by considering the development scenario i.e.*

***Private cloud:*** *The cloud infrastructure are operated by a single organization and managed by the organization or some time by a third party based on its location.*

***Public cloud:*** *Public clouds are owned and operated by third party.*

***Community cloud:*** *This cloud infrastructure is implemented by number of organization and resource sharing is based on common policy.*

***Hybrid cloud:*** *Combination of public cloud and private cloud is known as hybrid cloud.*

*Commonly monitored parameters are temperature, humidity, strain, pressure, wind direction and speed, vibration intensity, sound intensity, power line voltage etc.* ***[17]****.*

***2.7.2 Cloud computing:***  *cloud computing is a term used for describe a platform as well as application. A cloud computing platform provide a provision for configuration, reconfiguration of servers as needed.*

***2.7.3 Features of cloud computing:***

***Shared infrastructure:*** *Cloud computing**enables the sharing of physical storage, services and computing capabilities.*

***Network access:*** *The standard APPLICATION PROGRAMMING INTERFACE (API) can be accessed through the network by using PC, laptops and mobile applications at any place.*

***Cost saving:*** *By using the cloud computing there is no need to**implement an infrastructure for storage of data and required applications [18].*

***Maintenance:*** *cloud computing do not required to install an application into the PC. So maintenance of system are less.*

***Mobile accessible****: data is accessed anywhere in the world on a mobile application through internet [18].*

***2.7.4 Services offered by cloud computing:***

***Software as a Service (SaaS):***

*In this type of services, a complete application is offered to the client as service on demand. A single application needs to be hosted and maintained. The single instance of application is run on cloud and n numbers of used the application [18].*

***Platform as a Service (PaaS):***

*In this service a number of software or development environment is summarized. The user has to choice to build an application, run on the provided environment.* ***Example LAMP (Linux, PHP and MySQL*** *[18]****.***

***Infrastructure as a Service ( IaaS ):***

*The* ***IaaS*** *provides a cluster of networks, storage, and system software. IaaS enhance the functions of an entire data center.*

***2.7.5 Need for a Sensor Cloud:*** *Sensor Cloud is useful where a large amount of data sensed by the sensor network need to be store, monitored and analysis. The data sense by the sensor network Hugh in size and multidimensional in nature. But in WSN, the storage and computable resources are limited. At the other side cloud computing provides a maximum storage space and more computable resources (based on above discussed models). There is no need to install an application separately on every user site. A single application is hosted and this single application is accessed by n number of users.*

***2.7.6 Role of Sensor Cloud in Oil and Gas WSN:***

*In the field of oil and gas industry, for making the best drilling process under the ground, access of real time data is very important. In the ground drilling process, monitoring of machinery health and equipment’s are necessary to avoid breakdown due to unnecessary maintenance or part failure.*

*Sensor nodes sense and collect data based on some environmental and machinery conditions like vibration, strain, pressure, torque, temperature, humidity and load etc. real time monitoring start with real time data aggregation. By combining the sensor network with cloud computing, sense data can be efficiently used, analysis, and stored for further used or some time given to any automated system as an input. Sensor cloud computing change the procedure of how company produce, consume and share information. Sensor cloud reduced the cost of maintenance and implementation of infrastructure.*

***Conclusion:***

*WSN are widely used in various real world applications due to its cheaper in size and limited computable resources. Wireless sensor network are easy to implement with low cost, limited infrastructure, limited computable resources, battery operated power sources. WSN reduced the cost of wire, maintenance and implementation of network. Sense data is easily transmitted at a specific distance and real time monitoring is performed on sense data. Sometime this previously stored data can also be used for analyzing and diffracted with current data.*

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