IoT Sensing Capabilities: Sensor Deployment and Node Discovery, Wearable Sensors, Wireless Body Area Network (WBAN), Data Acquisition

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Chapter 5
IoT Sensing Capabilities: Sensor Deployment and Node Discovery, Wearable Sensors, Wireless Body Area Network (WBAN), Data Acquisition

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Abstract Internet of Things (IoT) is an emerging technological paradigm where the things can be connected from different fields through the Internet. The rapid advancement in communication technologies, actuators and low-cost sensing devices leads to extensive deployment of IoT devices. Such devices can be deployed in any public spaces provide detailed information about the behavior of individuals such as personalization, behavior change and personal health monitoring. IoT technology which is being deployed is specially designed to make it invisible, such that the technology does not manifest its presence to the users it is monitoring. For the IoT based healthcare applications, the Wireless Body Area Network (WBAN) is gaining much popularity as wearable devices spring into the marketplace. Multiple sensor nodes can be deployed on different locations of the human body to measure the heartbeat, body temperature distribution, and detect falls. In addition to medical signals, the sensor nodes can be placed to track environmental conditions around the human body as well. Hence, wearable sensor systems afford valuable information about the impact of human health. These systems are not only limited for personal use, can be fitted on animal, car, etc. to construct a wireless sensor network. According to previous estimation, healthcare IoT solutions lay down the platform for extremely accessible, personalized and on-time services that will attain $1 trillion by 2025 hopefully. Wearable systems have emerged as a prominent area in healthcare for managing cardiovascular,

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neurological diseases etc. These sensors are used on the body surface or inside the human body non-invasively, however it is distinct from invasive implantable devices. This system will be particularly helpful for sensing information inside the human body as the sensors are designed and supported by flexible technologies. The sensing device collects data which is transmitted through wireless communication protocols to a server that is responsible to gather the datasets available for further analysis. WBAN comprised of heterogeneous nodes fixed in and around the human body which is connected to the network. It is characterized by IEEE 802.15 communication standard; generating huge volume of data and gathering it play a vital role in electronic healthcare. Data residing in multiple wireless devices need to be collected and analyzed effectively. Within WBAN datasets may be fragmented across many nodes and if practitioner's node does not have the correct information then the quality of healthcare processing would be degraded. This chapter presents the overview of wearable sensors for tracking physiological and physical changes in daily life, their basics and applications. Wearable sensor based systems have enormous potentials to be completely explored and it is anticipated that advancement in technologies will afford the transformation how healthcare will be in future. It highlights the significance of localization in on-body area network and it gives an overview about evaluating the performance of localization systems. It also presents the several types of sensors and methodologies to fuse the data generated by sensors. Since we foreseen a future where the existence of miniature devices communicating through packet radio in both indoor and outdoor environments.

Keywords Sensors · Actuators · Deployment · Wearable devices · WBAN · Data acquisition · Localization

5.1 Introduction

IoT is an emerging technology which builds over the mobile and internet networks automatically expands the world's network even further. According to Gartner's Hype Cycle, it is anticipated that IoT will take next 5–10 years for market adoption. It consists of different technological layers that initiates a role from primarily connecting 'things' to building applications that declares a clear objective whether it is meant for industry grade IoT projects or consumer based applications [1–3]. Sensors are the significant building blocks of IoT and could be deployed everywhere, for instance, from military battlefield to agriculture farm fields, vineyards, golden gate bridge, redwoods etc. The sensors can be worn or implanted under human body skin, on a T-shirt or in a purse. IoT market has reached an exponential growth with immense range of IoT products in different areas such as people's private lives, enterprises, and controls huge industrial appliances. Basically, IoT exploits conventional standard networking technologies and protocols. However, the major protocols and various enabling technologies of IoT are low-energy radio protocols, low energy Bluetooth, low-energy wireless, RFID, NFC, WiFi-Direct

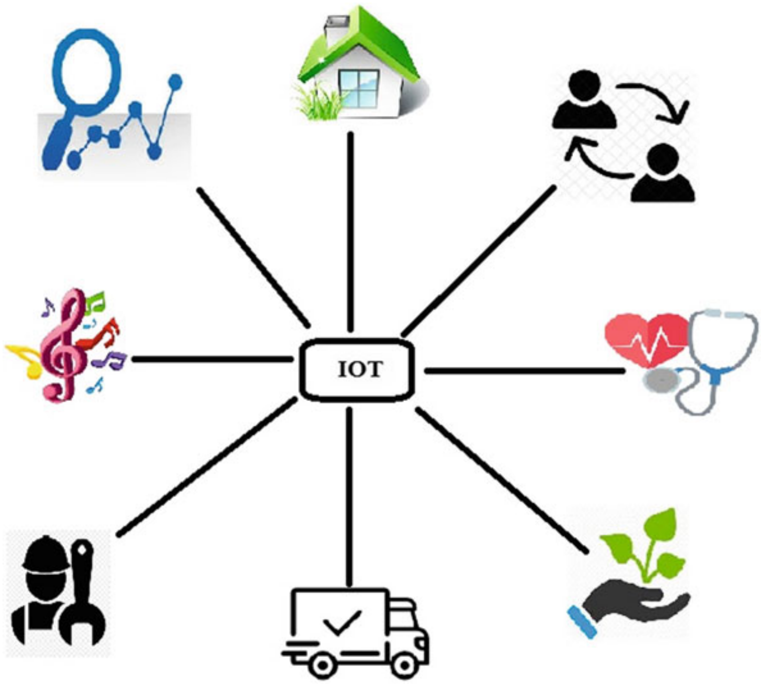

Fig. 5.1 Domains associated with Internet of Things

and LTE-A. The most significant factor of IoT makes anything "smart", means that it enriches people's life with the efficient data collection, processing and decision making [4–6]. Figure 5.1 tells about the domains where IoT is used to make life smarter and convenient. An efficient, scalable, secured, computing and storage resources are essential to realize the complete IoT vision.

The sensors and actuators in IoT blend seamlessly in the surroundings around us and the information is communicated across different platforms in order to construct a Common Operating Picture (COP). The recent adaptation of several enabling device technologies such as Near Field Communication (NFC), RFID tags and readers, transforms the internet into a most expecting next revolutionary technology.

5.1.1 IoT Technology Stack

IoT technology stack comprises of IoT devices, actuators, sensors and gateways in IoT platform and it is viewed as a three layered model.

(i) IoT devices: Accurate sensors, actuators and devices produce accurate data which is vital for IoT.
(ii) IoT gateway: It can be connected to the internet for transferring data using 3G/4G/GPRS modem, Wi-Fi, Ethernet. Non-GPRS network is preferable for internet connectivity and this level is deserved because which is strongly connected towards consumer and business applications and services.
(iii) IoT platform: It acts as an interface between business applications and services and the first two layers.

IoT bridges the gap among the physical and digital world with the use of IoT devices which are available in various forms and shapes [7]. IoT devices consist of transducers such as actuators, sensors, and myriad objects called 'intelligent'/'smart'. A connected object may have any number of sensors and transducers. In car, telemetric box can be fixed to know about the car insurance which has a few sensors and an oil rig has thousands of sensors. The device connectivity enables the link between the physical things and the controller via communication and processing units [8–10].

IoT sensors:

Sensors are acting as a digital backbone of IoT and it is a device that measures any specific quantity such as motion, heat, light, moisture, pressure by converting them into electrical pulses. A transducer converts the signal from one form to another form. In the context, IoT sensors are capable of sensing the environment or in and around IoT devices to which they are attached [11–13]. Sensors can detect the changes in the surroundings and events or changes of some specific parameters are communicated to the system for further analysis and action. Sensors can sense about the environmental factors, parameters, and events such as temperature, sound, humidity, light, presence of gases or chemical components etc. It plays a significant role among all IoT components because it is the starting point of data gathering that needs to be very accurate. Figure 5.2 shows several sensor types available nowadays and it can be bought separately or fixed with sensor boards where many sensors are fixed that are required in the scope of different IoT use-cases or projects. For example, sensors boards for different applications such as smart traffic, smart city air quality monitoring etc. are available. Sensor boards could also be customized by adding the required sensors or precise boards can be built.

IoT actuators:

Actuators are transducers that act and activate after receiving a signal sets in motion for action in an environment. In smart building, actuators can be fixed in a radiator, actuators get triggered if the temperature level is low and reports that the energy saved as a result as a decision. The role of actuator in IoT is expected to reach 5.4% CAGR until 2025. Figure 5.3 shows that how a signal is transmitting from sensors to the actuators. Initially a sensor node detects heat or some noise. After that this signal is transferred to the control center and then the control center is responsible for sending the signal to initiate the command for the devices. There are several types of sensors and actuators available in the market. Electrical actuators turn energy into mechanical torque and some actuators control valves, for example

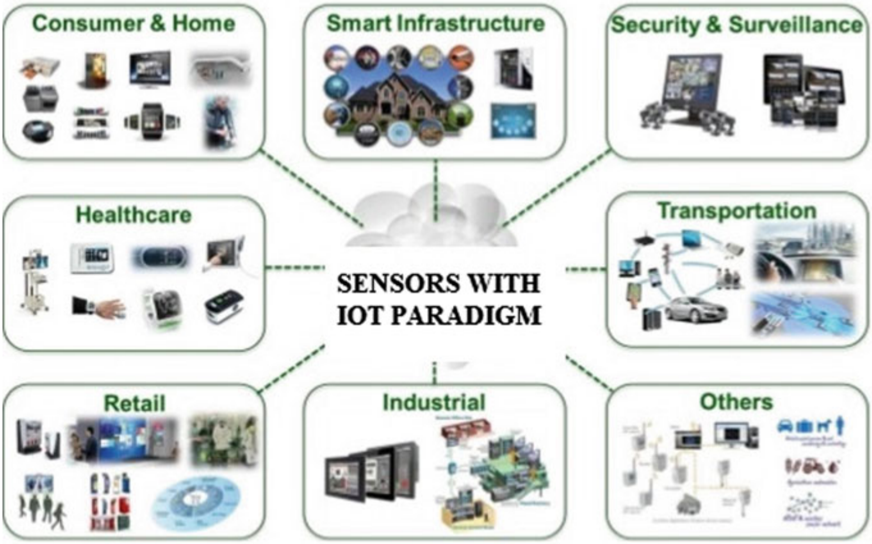

Fig. 5.2 Different types of IoT sensors based on application areas

Fig. 5.3 Data flow from sensor to actuators

water leakage. In robotics or industrial applications, the actuators are mainly used for grippers.

IoT Gateways:

It acts as an interface between devices and IoT platforms. It can be hardware, software or both and it is a separate layer provides more functionalities. It is a layer with multiple devices used for connectivity aggregation, encrypting and decrypting IoT data (to secure the data). Pre-processing can be accomplished in the gateway and the effective data analysis process is improved significantly.

IoT platform:

It is the third layer in IoT technology stack with various potential features [4, 5]. It is meant for gathering data and makes sense of data in order to provide the right services as the right time. IoT platform offers services such as connectivity support, device management, service enablement, application support.

5.2 IoT Technologies

The most widely used IoT technologies for the success of IoT products and services are [1, 2, 14]:

1. Radio Frequency Identification (RFID)
2. Wireless Sensor Networks (WSN)
3. Middleware
4. Cloud computing
5. IoT application software.

- Radio Frequency Identification RFID

RFID permits automatic identification and data captured using radio waves, a reader and a tag. The tag in RFID is capable of storing more data than conventional barcodes and it holds data in the form of Electronic Product Code (EPC) [3]. There are three types of tags commonly used:

(i) Passive tags: Passive RFID tags are not battery powered and it rely on radio frequency to obtain the energy for the tag.
(ii) Active tags: Active RFID tags can activate the communication with the reader and it has self-contained batteries. It also contains many external sensors to track pressure, chemicals, temperatures and some other conditions. These kinds of tags are mainly used in remote sensing, manufacturing and hospital laboratories.
(iii) Semi-passive tags: It is expensive than passive tags and use batteries to create energy.

According to International Data Corporation (IDC), IoT is anticipated to reach the Compound annual Growth Rate (CAGR) of 14.4% in the forecasted period 2017–2021 and it reaches $1 trillion in 2020 and $1.1 trillion in 2021. Figure 5.4 shows that no of devices connecting to internet are increasing rapidly at a very fast rate.

- Wireless Sensor Network (WSN): Sensor networks bridge the gap between the physical and computational world by providing reliable, scalable, fault tolerant and accurate monitoring of the physical phenomenon [15, 16]. A sensor network is composed of a large of sensor nodes that are densely deployed either inside the phenomenon or very close to it. The main task of the sensor networks can be categorized as: Sensing, Processing and Acting. After sensing the network, based on the query provided by the user, the sensor node may process the data, and sometimes may also aggregate the data sent to it by other nodes, and finally send it to the base station. It comprises of spatially distributed self autonomous sensor devices to monitor the environmental conditions and RFID systems are used to track the location, movement and temperature. WSN approaches multi hop

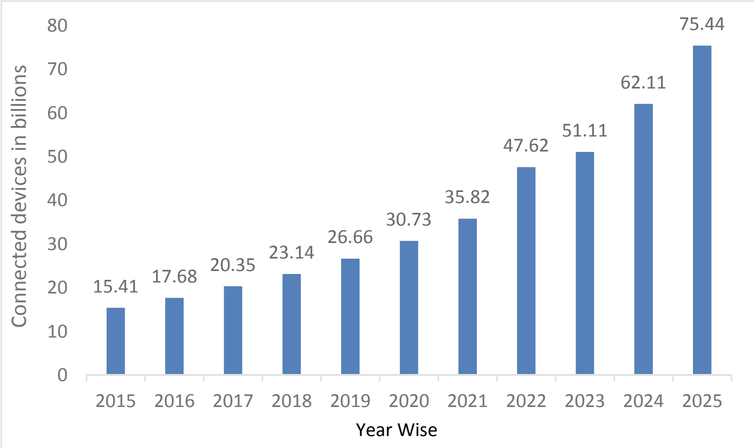

Fig. 5.4 No of devices connected to the internet

communication and different network topologies. The recent technological advancement in low power integrated circuits have made available low-cost, efficient, low power miniaturized devices to be utilized in WSN applications [17, 18]. WSN is primarily being preferable in logistics for efficient transportation of temperature sensitive products. It is also used for maintenance and tracking systems, for instance, General Electric (GE) deployed sensors in turbines, jet engines and wind farms. GE incurs less time and money by analyzing data in real time. Wireless Sensor Network (WSN) is the primary real-time application of ubiquitous computing and it bridges the gap between the physical and the digital world by offering scalable, reliable, accurate monitoring and fault tolerant of the physical phenomenon [14]. It is an intelligent distributed sensor network provides wide range of applications in both civilian as well as military domains linked via wireless links. WSN comprises of low-power, spatially distributed, low-cost and autonomous sensors with base stations to monitor the physical or environmental conditions such as temperature, pressure, motion or sound. The wireless sensor nodes are energy-constrained, battery powered. The sensed data would be communicated for assessing and self-organized after deploying. The sensor devices are low-powered consists of microcontroller for transforming the data, a microchip and senses ecological components such as light quality, dampness, heat range, etc. WSNs are useful in a great variety of application domains such as surveillance, intrusion detection, structural monitoring, ecosystem monitoring (e.g. for earthquake and fire prevention), localization of objects or animals, intelligence detection of ambient conditions such as weather or sea, medical monitoring and emergency operation like disaster relief.

- Middleware: It is a layer acts as an interface between software applications to perform input/output and communication process. The significant feature of this layer is hiding the technological details in order to provide software services that are not directly relevant to any specific IoT application. It facilitates the new type of services in the distributed computing environment. The Global Sensor Network (GSN) is a sensor based open source middleware platform enables sensor services with zero programming effort. A service oriented approach is followed in IoT middleware architectures that support dynamic network topology.

- Cloud computing: It is an on-demand access model with the shared storage of configurable resources such as networks, server, computers, storage, applications, software, services, etc., that is provisioned as Software as a Service (SaaS) or Infrastructure as a Service (IaaS). The most significant outcome of IoT is the huge amount of data generated from the devices connected to the Internet. Several IoT applications are in need of enormous amount of data storage, processing speed which enables high-speed broadband networks for streaming audio, video, or data that paves a way for efficient real-time decision making [11, 12, 19, 20]. It is acting as a perfect back-end for handling massive data streams with unpredictable count of IoT devices in real time.
- IoT applications: It enables human-to-device and device-to-device communication in a reliable as well as robust manner. IoT devices facilitate the development of user specific applications and ensure the effective communication occurred in a timely manner. For instance, in transportation and logistics applications the condition of transported goods such as dairy products, meat, fresh-cut produce, and fruits are monitored. The conservation status such as humidity, temperature etc. are tracked continuously to take appropriate actions automatically in order to avoid spoilage if the condition is out of range. Sense Aware is used in FedEx to track the location, temperature, and other important signs such as whether the package is tampered or opened on the way. Human centered IoT applications present information in an intuitive way that allows smooth interaction for end users with the environment. Moreover, IoT devices with its intelligence track the environment continuously, identify problems, allows communication among users, and problems are resolved without any human intervention [21].

5.3 Wireless Body Area Network (WBAN) in IoT Paradigm

IoT is a fast growing technological paradigm which connects things from several fields through the internet. In IoT based healthcare applications, the Wireless Body Area Network (WBAN) gains popularity as wearable devices which turns attention of many users [10]. The multiple sensor nodes are deployed in different locations of the human body to measure the heartbeat, body temperature, distribution etc. Wearable sensor devices can be deployed to monitor the health condition around the human body such as in safety application. Wearable sensor systems could provide the useful information about the impact on patient's health. The users' can gain a deep understanding of the local environment. A wearable system can be installed on a car, bicycle, and animal to build a wearable wireless sensor networks. For instance, a sensor node can be installed on a bicycle to track the environment. WBAN consists of heterogeneous nodes that can be attached to the human body in order to provide a variety of services. Body Area Network (BAN) is the network which handles immense amount of heterogeneous data with complex relationship. The sensor nodes attached to the human body that is connected to a local or wide area network for providing remote services to the users [10, 22–24].

WBAN is characterized by IEEE 802.15 communication standard for miniaturized devices attached to the human body. A WBAN interfaces communicate with the hubs using a local controller. Data gathered via BAN plays a significant role in the patient care process. It is mandatory to maintain the high standard quality data for efficient decision making. BAN generates massive amount of data, managing such a huge dataset is highly challenging. The sensing devices are subjected to hardware constraints and inherent communication including unreliable network links, limited power and interferences. The complete sensor readings in healthcare domain should be compulsorily validated in terms of reducing false alarm generation. The data available in multiple devices need to be gathered and analyzed effectively in a seamless fashion. In BAN, the most significant patient datasets could be fragmented across many laptops or PCs. If adequate patient related information is not available in medical practitioner's mobile device, then the quality will be automatically degraded in healthcare system. WBAN is a self-organizing network which consists of heterogeneous devices that are miniaturized, low-power, hardware constraint (limited storage capability and processing) and fixed (or implanted) to a human body. Sensors attached to the human body gather signals about the physiological signs (temperature, heartbeat), movement (orientation, acceleration), environment (toxic gases, temperature) [17, 25].

Wearable devices can be attached on the human body such as smart rings, watches, T-shirts, badges, pendants, glasses, bracelets, fitness trackers, and any other accessories as many users are gaining health benefits. A wearable device that is kept closer with the user is able to monitor the wellness, health of a person and collected data would be transmitted to the central hub station for analysis. Some of the wearable devices are shown in Fig. 5.5.

Wearable devices comprise of three main components such as sensor devices, computing architecture and display unit. The sensor devices gather data in an aggregate form about the particular user; the collected data is computed and displays the information that helps in making decision. The gadgets accomplish some basic functionality and provide various biological information to the users such as blood pressure, heart-rate, steps walked, and calories burned, and time- spent on exercising etc. The impact of such devices is quite extensive, powerful and gain more attraction in monitoring physical health. The main drawback of these wearable devices is regarding the potential of interpreting massive amount of information that is generated. Once the information generated is interpreted well, then the strength of wearable's becomes extremely effective.

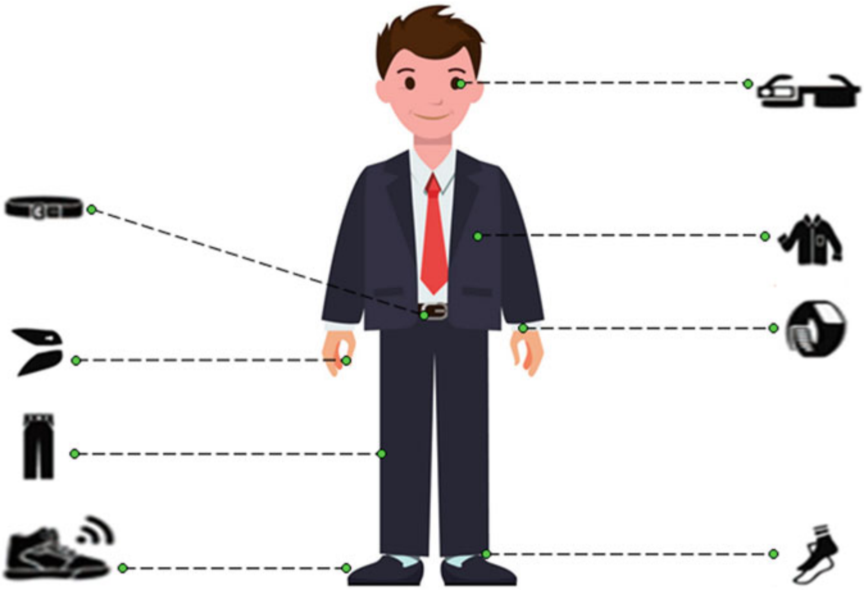

Fig. 5.5 Wearable devices

Wearable technology plays a significant role in several domains of daily life such as sports and fitness, augmented reality, healthcare (monitor the physiological signals), localization and many more. Wearable systems are envisioned for many potential applications such as rescue management as well as workers safety. It also plays a vital role in saving human lives and protecting valuable assets. Typically, wearable solutions are based on various standards such as Bluetooth (IEEE 802.15.1), Wi-Fi (IEEE 802.11a, IEEE 802.11b, IEEE 802.11 g), and zigbee (IEEE 802.15.4, IEEE 802.15.4a, IEEE 802.15.4j). IEEE 802.15.6 standard is designed specifically for wearable applications and their design requirements. To meet the design constraints of different applications, some of the below-mentioned key features of Medium Access Control (MAC) layer of IEEE 802.15.6 standard are focused for analysis.

- Reliability
- Quality-of-service
- Energy efficiency
- Data transmission rate.

5.3.1 History of Wearable Sensors

In the year 1960s, there is a need to check the astronaut health when they are in space. This paves the way to develop wearable sensors which transmits the data back to earth from space craft. In the late 80s, the general people came to know the importance of wearable sensors. In the year 1977, the Finnish National Cross-Country Ski team has developed a Wireless electrocardiogram (EKG) contributed by Prof. Seppo Säynäjäkangas to monitor the health of heart. The reach of this machine shed light on the production of wearable devices and the invention of Sport Tester PE2000, pulse oximeter is made. In the year 2002, Cygnus introduced GlucoWatch, which uses 2 gel pads over the skin [26]. Wearable Sensors are the devices used to sense or detect various physical quantities from the surroundings. The sensed input may be moisture, light, motion, heat, vibration, pressure etc. The output signal is send out through a network for further procedure. The sensors are classified depending upon the types of input. In this era, wearable sensors play a vital role in the form of smart wrist watch, medical patches, smart clothing etc. Wearable sensors can be categorized based on configuration, sensing method, power and data, sensing function and it is shown in Fig. 5.6.

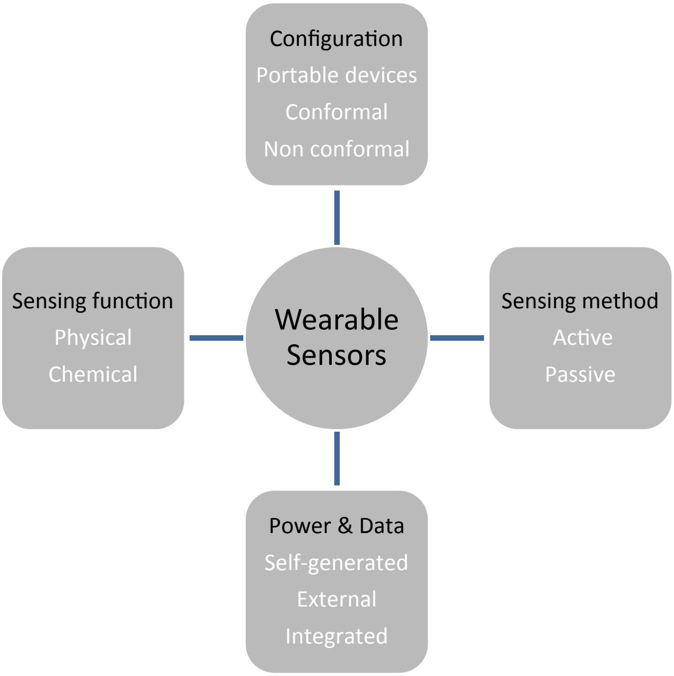

Fig. 5.6 Conceptual categorization of wearable sensors

5.3.2 Wearable Sensors in Healthcare

Physiological measurements include the respiratory rate, heart rate, muscle activity, blood oxygen saturation and blood pressure provides the indication of health status with diagnostic value. In the recent past, the continuous monitoring of physiological parameters is done in hospitals. In contrast to this, today with the help of technological advancement researchers has developed wearable sensors for accurate real time monitoring of physiological activities through signals.

5.3.2.1 Gyroscope and Accelerometer

Gyroscope measures angular velocity which is applicable for navigation purposes as it involves rotation and orientation. Accelerometer tracks human movement like inclination, tilt and overall orientation of the body. The accelerometer is often paired with gyroscope to produce 3D representation of movements involved during workout.

5.3.2.2 Altimeter

This type of indispensable sensors plays a major role in designing wearable devices required for mountain climbers to measure the altitude.

5.3.2.3 Proximity Sensor

Proximity sensor is used to find a particular nearby subject varies from non-living objects to human being. The designer should estimate the beam width or distance to design a wearable device. This sensor is used to detect obstacles or metal objects in the industrial setup.

5.3.2.4 Physical Sensors

Physical sensor is used to sense physical factors like pressure, strain and temperature. The factors monitored by the Physical sensor indicate the condition of blood pressure, skin and body temperature, skin strain and pulse rate.

5.3.2.5 Optical Sensors

Optical sensors convert light energy into electronic signals and it measures the physical quantity of light, transforms it into readable form by the instrument.

It works both in distributions of points and in single point. In distribution method, the sensor is reactive along single fiberoptic array or acts as a long series of sensors. In single point, a single change in phase is required to activate the sensor. Optical sensor proves its dominance in many applications ranging from medico technologies and remote sensing. Many types of optical sensors are available using novel manufacturing materials such as nano, micro and meta material. The advantages of optical sensors are electrical passiveness, high sensitivity, wide range dynamic, multiplexing capabilities and independent of Electromagnetic interference.

5.3.2.6 Temperature Sensors

A temperature sensor is a device that detects and measures hotness and coolness and converts it into an electrical signal. Temperature is the major parameter related to biological, chemical, physical, electronic and environmental systems. Wearable temperature sensors application ranges from food safety, electronic skins, environmental temperature measurement and human–machine interface and robot sensors [27–30]. Some of the temperature sensors are thermo resistance temperature sensors [31], thermocouple sensors [32], and thermal responsive field-effect transistor [33]. The global temperature increases rapidly and now it is necessary to choose the clothes to wear depending upon the climate change. These temperature sensors analyses the body temperature and inform the users what to wear. Wearable basal body thermometers act as fertility indicator by tracking the ovulation cycle of women with the aid of basal body temperature. This sensor can be integrated to a smart mobile phone app to indicate the chances of getting conceive.

5.3.2.7 Pressure Sensor

A pressure sensor is a device that senses pressure and converts it into an electric signal where the amount depends upon the pressure applied. In early days, a device called sphygmograph was dedicated to measure blood pressure. The later device is the cuff based diagnostic tool to monitor the blood pressure. However, these devices are used to measure the diastolic and systolic pressures only and it cannot monitor continuously. The materials used in making the pressure sensors are gold nanowires [34], polymer transistors [35] and piezoelectric materials [36]. Pressure sensors with light weight, high flexibility, good workability and high sensitivity are highly needed in health monitoring devices [37].

5.3.2.8 Force Sensors

Palo Alto Research Center, Impact Measurement and the Stanford Tae-kwondo Program has jointly developed a force sensor for martial arts sparring ring.

5.3.2.9 Humidity Sensor

A humidity sensor or hygrometer is a device that detects and measures water vapour. The ratio of air moisture to the highest amount of moisture at a particular air temperature is often called relative humidity. Humidity sensors work by detecting changes that alter electrical currents or temperature in the air. There are three basic types of humidity sensors, namely

1. Capacitive
2. Resistive
3. Thermal.

Humidity sensor is found as a part of air conditioning systems, home heating and ventilating system.

5.3.2.10 Piezoelectric Sensors

Sensors which follows the concept of piezoelectricity is called piezoelectric sensor, in which when mechanical stress is applied to a material it produces electricity. The types of piezoelectric sensors are Flow sensors, Level sensors and Accelerometers. Piezoelectric sensors play a vital role in wearable technology. The invention of piezoelectric pacemaker makes lot of notable changes in the heart health. It works by the rhythm of the heart beat thus eliminates the urge of complicated surgery to replace battery. Piezoelectric sensors can be placed under the vehicle seat of the driver to monitor the respiration and heart rate. Piezoelectric blood pressure cuffs monitor the blood pressure via phone app. Smart fabric is made by embedding piezoelectric sensors to monitor measure and harvest energy. Piezoelectric sensors are used in shoes to measure the step counts and pressure.

5.3.2.11 Wearable Electrodes

Human heart rate is read by electrodes using the electric pulses by sticking the electrodes directly onto the skin. An electrode in the wearable device is used in devices like Electrocardiogram (EKG), Electroencephalogram (EEG) and Electromyography (EMG). These electrodes can be embedded into clothes to measure various parameters and it can be washed without removing the sensors.

5.3.2.12 Biochemical Sensors

Biochemical Sensors in a wearable device converts chemicals into electric signal. It works on the principle of chemical resistive detection in a wearable configuration. In wearable devices these sensors monitors EtG (ethyl glucuronide) through human sweat to measure the metabolic rate. It is also used to find the amount of alcohol consumption.

5.4 Wearable Wireless Sensor Networks

Wireless Sensor Networks is a network with self-organizing capability. It accommodates smart devices with miniature hardware and low power constraint. Sensors are connected on the human body to collect movement and physiological signs. Wearable Wireless Sensor Networks has many applications in the field of sports, healthcare, ambient intelligence, fashion, augmented reality and localization. Wearable Wireless Sensor Networks standards are Bluetooth, Wifi and zigbee [38]. The designing of Wireless Sensor Networks should follow the designing strategies like quality-of-service, reliability, energy efficiency and data transmission rate. The application layer governs the communication stack which handles packet transmission rate, the traffic patterns and the network topology. Other important building blocks in the Wireless Sensor Networks designs are feasible medium access, selection of appropriate routing strategies, security, privacy and mobility modeling [18].

The requirements for different applications are data rate, traffic patterns, sensor devices and its types, miniaturization etc. In healthcare systems, vital sign, EEG or ECG and the coordinating node should be enough powerful to obtain an access to the nearby access point. In particular, for remote monitoring system, the coordinator node should be capable of supporting various standard and functionalities with less battery constraints. In terms of games, sports and fitness, few specific sensors such as heartbeat, gyroscope, sweat, accelerometer etc. are used that can operate stand-alone without any intervention of any external communications. Some critical applications require reliability, better QoS and adequate resources.

In some systems, on-body and off-body communications are essential that append various constraints and requirements. For instance, few sensors are generally used to track the orientation, health and movement of fire fighters. Some requirements which are common to many applications are shown in Table 5.1 with various parameters and their requirements. Table 5.2 shows the comparison of various IEEE standards of wearable wireless sensor network.

Table 5.1 Parameters and requirements for BAN applications

Parameters	Requirements
Devices used	Sensors, actuators, smart phones, base station
Sensor types	Vital signs: Breath rate/Heart beat, sweat, stress, oxygen saturation, temperature, blood pressure, glucose level Body movement: Fall detection, acceleration, orientation Environment: Humidity, heat, pressure, carbonic gases, light intensity
Traffic type	Audio, video, raw data, encoded data
Traffic pattern	Periodic, event driven, burst traffic
System co-ordination	Centralized (intra-BAN) Distributed (inter-BAN
Location awareness	Absolute/relative

Table 5.2 Comparison of IEEE standards for wearable WSN

	IEEE 802.11 a/b/g/n (Wi-Fi)	IEEE 802.15.1 (Bluetooth)	IEEE 802.15.1 (Bluetooth-LE)	IEEE 802.15.4 (Zigbee)	IEEE 802.15.6 (WBAN)
Modes of operation	Ad hoc	Ad hoc	Ad hoc	Ad hoc	Ad hoc
Power consumption	High	Medium	Low	Low	Ultra low
Network topology	Infrastructure based	Ad hoc (small networks)	Ad hoc (small networks)	Ad hoc, Peer-to-peer, Star, Mesh	Intra-BAN, Inter-BAN, ½-hop star
Target applications	Data networks	Voice links	Healthcare, fitness	Sensor network, home automation	Body-centric
BAN architectures	Off-body	On-body	On-body	On-body, Off-body	On-body

5.5 Global Wearable Sensors Market Share

The chart shows the global wearable sensors market share by 2020 and it is shown in Fig. 5.7.

5.5.1 *Sensor Deployment Strategies*

IoT along with WSN has made the major foundation for an incredible growth of smart and sustainable cities. The self organized distributed nature of WSN with low-power autonomous nodes has envisioned the formation of novel solutions which cover multi-disciplinary domains such as telecommunications, embedded computing architecture, industrial technologies and microelectronics [39, 40].

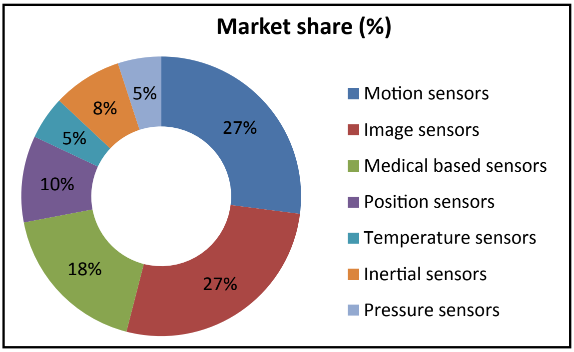

Fig. 5.7 Global wearable sensors market share, by Type, 2020 (%)

The system design optimization can be done in different contributions such as radio propagation, power awareness, sensor coverage, embedded software capabilities and hardware cost. The deployment techniques for WSN turn the researcher's attention towards random strategies in which uniform, non-uniform and grid distributions are converged with coverage optimization analysis in order to balance/maximize the network connectivity.

5.5.2 Design Issues in Deployment Strategies

The various design issues related to Wireless Sensor Networks have been addressed [41, 42].

Reliability:

The reliability can be checked out on the basis of packet/event and end-to-end/hop-to-hop level. Wireless medium is highly prone to error; the surety of solid exchange of information is not assured among sensor nodes. Packet dependability guarantees that all the packets transmit sensed information which is gathered from the sensor nodes to the sink node [15, 16, 43]. Event dependability ensures that the sensed information gathered from the sensor nodes will be conveyed to the sink node and it accumulates the adequate data around a particular event. In hop-by-hop methodology, the next hop ensures the reliable transmission whereas end points are responsible for the successful data transmission in end-to-end reliability.

Density and network size: The network size affects accuracy, reliability and data processing algorithms. The density of the network starts from less number of nodes to huge number of sensor nodes and it is calculated by considering the amount of scattered sensor nodes in the transmission range [44, 45].

Sensor network topology: The sensor network topology determines the capacity, robustness, and latency. The sensor hubs define the three phases related to topological changes and maintenance:

1. Pre-deployment
2. Post-deployment
3. Redeployment.

Energy consumption: The lifetime of a sensor node is completely dependent on battery life-time and it plays a vital role on the strength of sensor node and energy effectiveness; recharging power sources are difficult in some critical situations. The main objective of sensor hubs is sensing data, information handling and transmission (Sensing, computation, communication). The researcher's attention turns the investigation on power aware protocols with the objective of minimizing the energy utilization [46, 47].

Hardware Constraints: The sensor hub contains several parts such as radio transceiver, storage space, implanted processor, and sensors. The sensor nodes transmit the gathered data to a CPU for processing.

Data aggregation: This method assists in reducing the amount of message that is being transmitted and the distributed data in different messages will be aggregated together to form as a single message. In most of the sensor network applications, the constant rate of data supply is required. Hence, the quality of service is considerably affected by huge amount of data loss.

Transmission media: A wireless transmission medium is used in multi-hop sensor network for connecting nodes which enables communication among sensor nodes. The connections may be provided using Bluetooth, infrared and optical medium.

Quality of Service: The data should be delivered within a bounded latency otherwise it is of no use in many applications. The conservation of energy in sensor network is actually required when compared to the quality of delivered data. Hence, there is a trade-off between the energy conservation and quality of service according to the desired purposes.

Coverage: The capability of sensor nodes relies in the coverage area of the environment though it is limited in range and accuracy [45].

Connectivity: The connectivity is a significant factor since it has a huge impact on communication protocols and data dissemination techniques. The permanent link exists among two sensor nodes that define the actual network connectivity in the sensor network [16, 48].

5.5.3 Sensor Node Deployment Models

Sensor network is capable of monitoring the real-world phenomena at a large scale and embeds the sensor nodes of wireless network in the real world. Deployment is concerned about the set-up process of an operational sensor network in the real world [48, 49]. Deployment is cumbersome and labor-intensive as bugs may be triggered or the performance is degraded that was not observed at the time pre-deployment. The real world has an influence on the functionality of sensor network by influencing the quality of communication links, tracking the output of sensors, and by having physical strain on wireless sensor nodes. Deploying sensors by covering the complete area is considered as a design problem in various WSN applications. The three common deployment approaches are random deployment, deterministic deployment and grid (pattern) based deployment [50, 51]. Deterministic deployment is suitable for small-scale applications because of deliberate location of sensors. Non-deterministic deployment is commonly suitable for large-scale applications.

- Random deployment: It is quite challenging to locate the spot for each device since there is no prior configuration in randomized sensor deployment. In uniform random deployment, the ‘n’ number of sensors has an opportunity to place the sensor node at any point in a given field. WSN applications prefer uniform random method because of ease deployment and cost-effective.

Post self-deployment strategies obtain the desired connectivity and coverage [40, 52, 53, 54, 55]. The parameters that can be considered in uniform random deployment are the number of nodes and transmission range.

- Grid Deployment: The most popular grid layouts followed in grid deployment are a unit square, triangle, hexagon etc. Grid deployment [40, 52, 53, 54, 55] is suitable for several WSN applications due to its coverage performance. This kind of deployment is performed by placing sensors row-by-row based on moving carrier. The time interval is maintained between consecutive droppings to obtain the desired distance. However, this deployment model is not ideal because of placement errors. In unreliable grid model, if n nodes are spotted on a square grid with certain probability where the nodes are active in the defined transmission range. Scalability is a challenging issue if location constraints are rigid where nodes can or cannot be spotted for a given environment. If the number of nodes is less according to the operational coverage area size, then the number of routing and sensing nodes should be optimized.

On-site deployment optimization

The set-up mode of sensor nodes considers communication mechanisms and platform parameterization (hardware/software) by triggering a configuration procedure from the on-site deployment tool [56]. The target node performs two main actions by executing the frame dissemination task at the MAC layer,

(i) Network connectivity adaption with the surrounding environment (permits bidirectional routing).
(ii) Platform setup parameters (service provision, data transmission rate mask, power mode configuration, synchronization) and node properties (cluster based configuration entries, node weight) are distributed in the specified area.

5.6 Data Acquisition and Localization in Sensor Networks

Data acquisition with IoT gathers data from various kinds of devices/ objects and shared with multiple devices for processing in several IoT applications [57–59]. The reliable and efficient data aggregation techniques generally increase the network lifetime using appropriate sensors. The data acquisition process is facilitated in different technologies that consist of sensors, actuators, camera, RFID, GPS etc. The short-range communications enables information sharing among heterogeneous devices in IoT environment. IoT devices cover a wide range of applications across the globe, such as agriculture, transportation, healthcare, market, industry, smart school, smart home, smart city etc.

The information about the particular location is significant to know the current situation. Localization in WSN is the process of determining the location of unknown network sensor nodes. Localization plays role in many practical applications by determining the location of patients, equipments or personnel in a hospital, swarm of robots work together toward a common goal. GPS is the straightforward solution for localization but it is not suitable for all applications. Router communicates the identity of its location and it can be realized using the two most significant bits of one byte data structure. The following possibilities are enabled: indoor and outdoor in a public area, personal indoor area, restricted area.

In indoor systems, there is no direct connection from GPS signal to satellites. However, there are obstacles in many situations where it blocks the direct communication with the GPS satellites in outdoor systems. Some other issues of GPS in WSN nodes are cost, size, and power consumption. Moreover, in various WSN applications, the localization problem is solved using network parameters, features of the received radio signal and location of fixed nodes (known as anchors or beacons). The localization problem is categorized into two levels:

i. Distance between two nodes are estimated
ii. Location of all unknown nodes is determined.

Distance estimation: There are several techniques available for distance estimation problem and the criteria for comparing the methods are: computational power, position accuracy and precision, robustness, hardware requirements.

Position accuracy: It shows that the estimated position is close to the real position using a particular technique. In fact, higher the accuracy leads to better quality of localization. Position precision determines that how the system works consistently and how frequently the accuracy is achieved.

Computational power: It refers the computational requirements of algorithms used for localization. It is considered as a significant metric, because it has an impact of the power consumption of the node. Clearly, lower the computational power, better the performance.

Hardware requirement: It indicates that the localization technique is in need of hardware features. For example, directional or multiple antennas are the requirements which have an impact of size and cost.

Robustness: It refers that how the system functions if input parameters do not exist or values are corrupted. The data gathered from the sensor node is processed to avoid data duplication and save limited resources. The steps involved in data processing are data aggregation and fusion. In data aggregation, network delay is minimized because of self-adaptive mechanism [60–62].

5.7 Open Research Issues and Challenges in IoT

IoT will face multiple challenges for adopting with several enterprises. According to Gartner report, due to the creation of enormous amount of data by IoT machines, data centers is the storage pool which would face challenges in consumer privacy, storage management, security, enterprise, server technologies and network communication [13].

Data vulnerability: The sensor devices connected with internet are highly vulnerable to various potential risks. Every sensor device should have the control in order to preserve confidentiality of gathered data and integrity of the data that is transmitted.

Data management: IoT sensors are generating huge amount of data that is to be processed and stored for further processing. The data center which is currently available is not efficient in handling heterogeneous data retrieved from different sources. Data centers would become more distributed in terms of improving response time and processing efficiency as IoT devices are widely used nowadays and consume lot of bandwidth. Massive amount of data is available for further processing and analysis, the preference of utilizing data mining tools becomes mandatory. The streamed data are about temperature, humidity, location, vibration, movement, and chemical changes in the air. The data mining tools invoke the correct action for the operational issues or the concerned authorities will be intimated in case of competitor's strategies steps and the preference of customer's will have an impact of both short and long term business activities.

Data privacy: The vision of IoT makes the people's everyday life easy and increases the efficiency of employees and productivity of businesses. The streamed data which is gathered assist in making smarter decisions and have a high impact on privacy expectation also. Suppose the data gathered from the connected devices is compromised, then the trust level of IoT will be decreased. In smart health equipment, IoT devices provide massive amount of data on IoT user's movement, location, purchasing preferences, health conditions, etc.—it is all about privacy concern. Preserving privacy is considered as counter-productive in the aspect of service providers, hence there is a trade-off between the quality of people's lives and service providers cost. According to TRUSTe IoT privacy index, 22% of internet users consented that the benefits outweighed the privacy concerns. With the wearable devices and smart home systems, IoT gains confidence whereas it highly depends on user's privacy protection.

Cloud attacks, security issues and botnet problems: The immense amount of IoT devices generated data is stored in the cloud and there is a growing awareness of cyber security is necessary to defend against the potential scale of threat. For ransomware attack, the magnitude of threat has grown 35 times larger since the last year and other types of attacks are also yet to arrive. As a growing number of heterogeneous connected devices in IoT networks, the potential threats escalate exponentially. IoT applications support strategic services and sensitive infra-structures such as smart grid, facility protection in terms of privacy concern. IoT botnet directs massive swarm of connected devices like sprinkler controllers or thermostats cause unexpected spikes and severe damage in infrastructure usage which leads to destructive water hammer attack, power surges, minimized the availability level of infrastructure on a city or state level. Solutions do exist for these types of attacks; the software can categorize the emergent and erroneous data and there is a boundary on which devices are allowed to transmit the data and how often they can transmit. Securing sensor devices is highly challenging especially when they are connected with the shared infrastructure.

In upcoming years, the real issue lies on making people to understand the updations and implications clearly and to proceed with corrective actions for the benefit of potential upside. IoT as connected devices become smarter day-by-day and expectations are increased to gain deep insight for financial value increase in IoT data. Algorithms and visualization techniques are also evolved so that the future use-cases can have the benefit of older ones. The exponential growth of IoT will bring down sensor device and acquisition costs that enable more viable business cases which were too expensive earlier.

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