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AN INVESTIGATION ON BATTERY OPERATED IOT DEVICES AND FACTORS OF ENERGY DISSIPATION

Kiran Maraiya[1], Dr. Monika Tripathi[2]

Research Scholar[1], Professor[2]
Department of Computer Science and Engineering,
Shri Krishna University, Chhatarpur, India

Abstract: Researchers have been concerned about large-scale wireless networks for the Internet of Things, In the future; the Internet of Things will turn everyday things into intelligent virtual objects. In such dense networks, several types of battery-operated smart devices are widely encountered. These energy-limited components, such as wireless sensors, are expected to operate continuously for longer periods of time to suit specific application demands. As a result, with battery-operated devices, the most important task is to reduce total energy consumption so that the node can stay active for longer periods of time. This paper revisits major factors of energy dissipation in battery-operated IOT devices (sensors). This Paper has discussed the main components of a typical IOT sensor node, procedure for sensing, different types of IOT sensors and their classification. For Examples of everyday use battery operated IOT device (sensor) are also discussed.

***IndexTerms* - IOT, Sensors, Energy Dissipation, Sensor types, Battery, Classification.**

I. INTRODUCTION

The Internet of Things is quickly becoming a reality that surrounds us and impacts many areas of our lives. Pervasive connectivity and improvements in ICT technology have enabled the Internet to be accessed by an increasing number of devices. As a result, a new generation of apps is emerging that has the potential to transform how people live, learn, work, and entertain themselves. Sensors are essential for integrating the physical world (temperature, CO2, light, noise, and moisture) with the digital world of the Internet of Things. The availability of this data can help us be more proactive in our interactions with the world around us rather than reactive [1]. The Internet of Things (IOT) is the next step in the growth of the Internet. The success of the Internet of Things will be determined by applications that make a real difference in people's lives.

Sensors will very certainly play a key part in supplying the data streams that these solutions will be built on. People can track the quality of the air with mobile and home-based environmental monitors, for example. They can utilize this data to change their environment or their behaviors to maintain their health and wellness. As the value and impact of these applications become more generally recognized, the need for enhanced and innovative sensor technologies is expected to increase fast.

Sensors are crucial in the development of IOT solutions. Sensors detect external information and convert into a signal that humans and machines can understand. Sensors enable data collection in virtually any environment and are now employed in a wide range of industries, including medical care, nursing care, industrial, logistics, transportation, agricultural, disaster protection, tourism, regional enterprises, and many more. With the rise of fields in which sensors play a key role, the market for sensors continues to expand.

II. WHAT IS BATTERY OPERATED IOT DEVICE (SENSOR)

In this study an IOT device is that has minimum following four defining characteristics.

1. Tiny low cost computer.
2. Sensor and /or Actuator.
3. Transceiver.
4. Battery.

Architecture of IOT Device (sensor): To Function of the IOT Device required battery power. For better understanding of IOT network it is important to know about all the components of IOT Device (sensor node) .

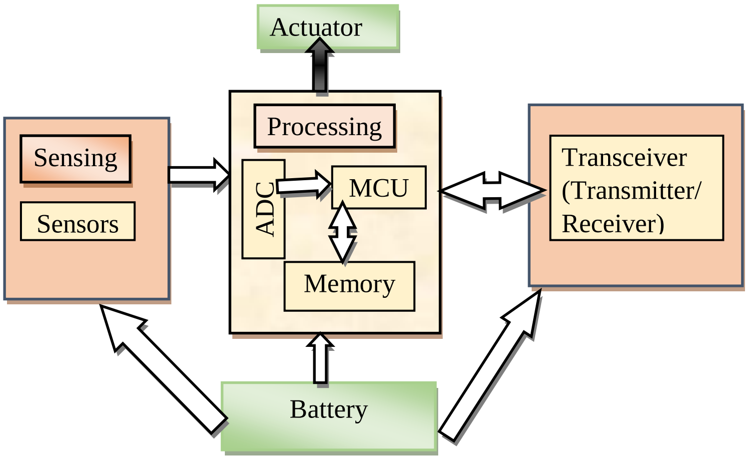

Fig 1: IOT Device (sensor) architecture

Common sensor node architecture is shown in Figure 1. The architecture of a generic wireless IOT device (sensor node) consists of four subsystems. A computing subsystem consisting of a microprocessor, ALU and memory, a communication subsystem consisting of a short range radio for wireless communication, sensing subsystem that links the node to the physical world and consists of a group of sensors and actuators, and a power supply subsystem, which houses the battery and the (optional) DC-DC converter, and powers the rest of the node. Each subsystem plays a main role in the sensor node.

Sensor: It translates physical phenomena to electrical signals. There exists a variety of sensors that measure environmental parameters such as temperature, light intensity, temperature, magnetic fields, sound, image, etc.

Actuator: A device that turns energy into motion is known as an actuator. It does this by mixing an electrical signal with an energy source. A mechanical device or mechanism that can produce a physical action. Actuators make contact with the outside world. Sensors collect data from the environment. Analog or digital interfaces exist between the microcontroller and the sensors or actuators. A control signal and a source of energy are required for an actuator. The mechanism through which a control system operates on the environment is known as an actuator. Simple, software-based, human, or any other input can be used to operate the system.

Processing Unit: A microprocessor with minimal memory is contained within the processing unit. It takes data from the sensing unit and processes it before delivering it to the transceiver.

Microprocessor: Microcontrollers (also known as microprocessors or processors) are another significant component that often merges flash storage, RAM, analog-to-digital converters, and digital I/O onto a single integrated circuit. They're suited for usage in highly embedded systems like WSNs and IOT because of their close integration. A microprocessor is used in the following applications: Desktops, Laptops, Workstations, Server, Super Computers, and Routers

Transceiver: A wired or wireless electronic device or circuit that transmits and receives analogue or digital signals. Transceivers occur in a variety of shapes and sizes; a satellite transponder, for example, is a transceiver. Transceivers are also found in Ethernet adapters and telephones.

Battery: In an IOT Device (sensor) node, the battery is a critical component. It provides electricity to all of the sensor node's components. As a result, the lifespan of sensor nodes is entirely dependent on the battery, and the longevity of the network is entirely dependent on the lifetime of sensor nodes. It is necessary to examine the quantity of power that has been drained from a battery. Sensor nodes are typically tiny, light, and inexpensive, and battery capacity is restricted. (Battery technology advances at a considerably slower pace than semiconductor technology). Sensor nodes are used in unattended environments when battery replacement is not possible due to the large number of nodes in the network. As a result, energy consumption is a critical element in extending the lifespan of sensor nodes.

III. WHERE ARE BATTERY OPERATED IOT DEVICE (SENSORS) USED

IOT sensors can detect and measure a variety of physical phenomena such as heat and pressure, as well as the five human senses of sight, hearing, touch, taste, and smell. In the architecture of IOT devices, sensors are used. A device that responds to a measurement by producing an useable output. The sensor obtains a physical parameter and converts it into a signal that may be used to process (e.g., electrical, mechanical, or optical) the characteristics of any device or material in order to detect the presence of a certain physical quantity.

The sensor's output is a signal that is translated to a human-readable format, such as changes in characteristics, resistance, capacitance, impedance, and so on.

There are no standard descriptions of sensors or the sensing process. The definitions that are provided are frequently influenced by application views. A sensor can be defined as follows from a broad perspective:

- “A device that receives a stimulus and responds with an electrical signal” [2]. (Fraden, 2010)

- “A sensor generally refers to a device that converts a physical measure into a signal that is read by an observer or by an instrument” [3]. (Chen, et al., 2012)

- "A sensor differs from a transducer in that a sensor converts the received signal into electrical form only. A sensor collects information from the real world. A transducer only converts energy from one form to another" [4]. (Khanna 2012)

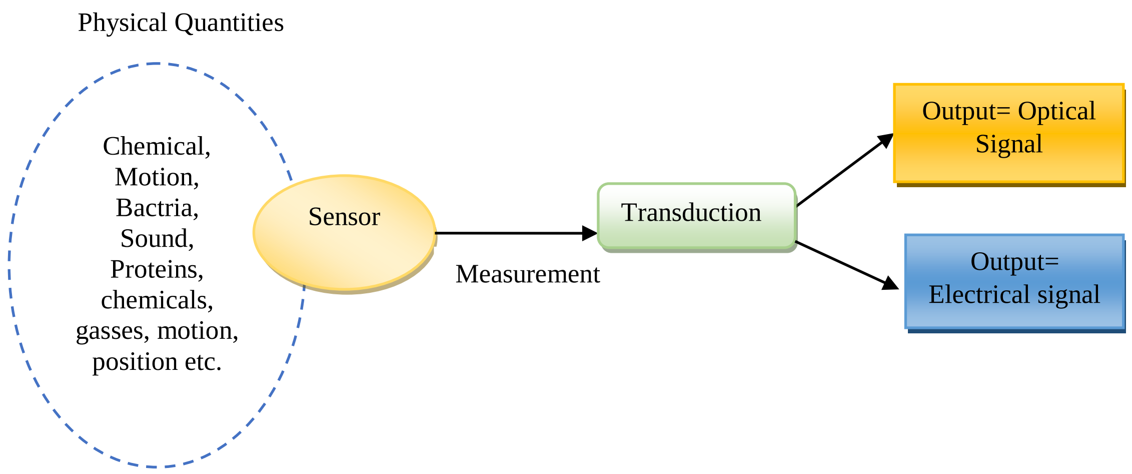

Fig 2: The procedure for sensing

As shown in Figure 2, IOT sensors can be used to measure or detect a wide range of physical, chemical, and biological parameters. A transducer converts sensor data into a signal that represents the quantity of parameter to an observer or the outside environment.

IV. PROPERTIES OF BATTERY OPERATED IOT DEVICES

The following are some of the most important features of battery-powered IOT devices:

1. Sense: The IOT devices (Sensor) that sense their surroundings in terms of temperature, movement, and the appearance of things, among other things.

2. Data transmission and reception: IOT devices (sensor) may transmit and receive data through a computer network.

3. Analyze: The IOT devices (sensor) are capable of analysing data received from other devices via internet networks.

4. Controlled: IOT devices (sensor) may also be controlled from a destination. Otherwise, the IOT devices will continue to connect with each other indefinitely, resulting in system failure [5].

V. BATTERY OPERATED IOT SENSORS CLASSIFICATION

IOT Sensors can be classified in a variety of ways into different categories as follows:-

Type of IOT Sensors	Description	Examples
Active Sensors	Active sensors (also known as parametric sensors) are sensors that work with the help of an external power source.	GPS and radar sensors are two examples of active sensors.
Passive Sensors	Passive sensors (also known as self-generated sensors) produce their own electric signal and do not require external power.	Thermal sensors, electric field sensing, and metal detection are examples of passive sensors.
Analog sensor	It generates a continuous signal or voltage that is equivalent to the amount being measured. Its output is analogue. Temperature, speed, displacement, pressure, and strain, for example, are analogue quantities since they are continuous in nature.	The temperature of a liquid may be measured using a thermometer or thermocouple, which responds to temperature changes when the liquid is heated or chilled.
Digital Sensor	It generates a discrete digital output signal or voltage that represents the quantity to be measured in digital form. • It generates binary output consisting of one's (1s) , zeros (0s) (0s). • Digital sensors eliminate the limits of analogue sensors and are utilised in a variety of applications including waste water, water, and other industrial processes.	Digital sensors are used to measure things like pH, conductivity, dissolved oxygen, ammonium, and nitrate etc.

	• A digital sensor comprises of the sensor, cable, and transmitter.	
Scalar Sensor	Scalar sensors give an output signal/voltage that is proportionate to the magnitude of the quantity to be measured. • A scalar sensor (e.g., a thermometer or a thermocouple) is used to detect the temperature of a room since it registers temperature changes regardless of sensor orientation.	Temperature, gas, strain, colour, and smoke sensors are all available.
Vector sensor	A vector sensor is a sensor that generates an output signal that is proportional to the magnitude, direction, and orientation of the quantity being measured. • An accelerometer is used to quantify body acceleration in terms of the x, y, and z coordinate axes.	Sensors such as accelerometers, gyroscopes, magnetic field and motion detectors, velocity sensors, and so on.

Table 1: Sensors can be categorized based on the physical mechanism used to measure sensory input

VI. BATTERY OPERATED IOT DEVICE (SENSORS) FOR DAILY USAGE

Sensors come in a variety of shapes and sizes, from the simplest to the most complicated. Sensors can be classified according to their specs, conversion technique, and kind of application. The material employed, the physical phenomena it detects, the qualities it measures, and the application field are all factors to consider.

1. Occupancy Sensors

The occupancy sensor, often known as a presence sensor, detects the presence of people or items in a given space. It may be used to monitor numerous characteristics such as temperature, humidity, light, and air from a distance. Authors in show how this form of sensor may be used in a similar way[6]. Because it is simple to detect any pressure variations or drops, the use of these sensors is advantageous not only in manufacturing but also in the maintenance of full water and heating systems [7, 8, and 9]. Example is electric eye, radar.

2. Position Sensors

By sensing motion, the position sensor determines the presence of humans or objects in a specific region. It may be used in home security to track the doors and windows of rooms and appliances from any location. It kept them informed about the open or closed state at all times and allowed them to follow intruders while they were away. It may be used in health care to track the whereabouts of patients, nurses, and physicians at a hospital [10], and in agriculture to track the where about of animals [11].examples are potentiometer, inclinometer, proximity sensors.

3. Motion detection sensors

A motion detector is an electrical device that detects physical movements in a particular area and converts it into an electric signal. Sensors are used in regions where no movement should be observed at all times, and they make it simple to notice anyone's presence when installed [12, 13]. Examples are electric eye and radar.

4. Temperature sensors

By monitoring heat energy, temperature sensors assist in the detection of physical changes in the body. Temperature sensors were utilised by the authors in [14] to monitor the surrounding environmental variables. The acquired data is subsequently sent to the cloud through Wi-Fi for analysis. All of this is accomplished using an Android smart phone. The authors [15] employ a similar type of sensor for smart agriculture, which allows farmers to improve their total productivity and product quality by receiving real-time live data from their field. Example is thermometer, calorimeter, and temperature gauge.

5. Proximity Sensors

Proximity sensors can readily determine the location of any close item. These sensors detect the presence of an item by emitting electromagnetic radiation such as infrared. Proximity sensors are widely used in a variety of fields, including security, energy efficiency, and many more [16, 17].

6. Humidity Sensors

The humidity in the surroundings is measured using a humidity sensor, which monitors both air temperature and moisture. The authors [18] employed humidity sensors for smart agriculture, allowing farmers to improve their total output and product quality by receiving real-time live data from their field. Example is hygrometer, humistor, soil moisture sensor.

7. Optical sensor

An optical sensor measures the quantity of light present and transforms it to an electrical signal. They're employed in a variety of fields, including healthcare, environmental monitoring, energy, aerospace, and more. They are used by oil businesses, pharmaceutical firms, and mining industries to monitor environmental changes while ensuring employee safety [19, 20].

8. Gyroscope Sensors

By measuring angular velocity, gyroscope sensors detect any tilt or angular movement in the object. It is widely used in 3D mouse games, sports training, robotics, industrial automation, and many other applications [21]

9. Chemical sensors

Chemical sensors are used in a variety of uses, together with manufacturing environmental monitoring and process control, detecting harmful chemicals released intentionally or inadvertently, explosive and radioactive detection, composting processes on the International Space Station, the pharmaceutical industry, and laboratories [22, 23]. Example is breathalyzer, olfactometer, smoke detector .

10. Gas sensor

In coal mines, the oil and gas industry, and chemical laboratory research, gas sensors are used for air quality monitoring, poisonous or combustible gas detection, and hazardous gas monitoring. They work in a similar way as chemical sensors, only they monitor air quality and detect other gases [24, 25].

11. Sound sensor

A sound sensor, often known as an auditory sensor, detects the volume of sound. It outputs an electrical signal by converting the acoustic wave. These sensors can also detect sound pressure waves that aren't audible, making them useful for a variety of applications. The majority of sound sensors are employed for security purposes.

12. Smoke sensor

A smoke sensor measures both the amount and kind of smoke (airborne particles and gases). Smoke detectors are commonly used in industries such as manufacturing, HVAC, construction, and hospitality[26, 27].

13. Image sensors

Image sensors are electronic devices that convert optical images into electrical signals that may then be displayed or stored. Image sensors are used in a variety of applications, including digital cameras and modules, medical imaging and night vision equipment, radar, thermal imaging devices, sonar, and biometrics [28, 29].

14. Infrared Sensors

To sense certain aspects of its environment, an infrared sensor produces or detects infrared light. It can also detect and quantify the amount of heat emitted by the objects it detects. They're now being used in a variety of IOT applications, mostly in the healthcare sector [30, 31].

15. Velocity sensors

A linear or angular velocity sensor can be used. It's a sensor that determines the rate of change in continuous measurement and position readings at predetermined intervals. It may be used in smart city applications such as traffic and road sensors for intelligent cars and smart energy management [32, 33] example is Accelerometer, gyroscope.

16. Water quality sensor

Water sensors are essential for a range of applications because they monitor water quality. For a variety of reasons, water quality sensors are utilised in water distribution systems. Non potable water cross-connections, filthy water entering the distribution system and microbial development are all concerns that must be handled [34, 35].

17. Colour sensor

A colour sensor is used to detect and identify distinct colour patterns before converting them to the correct frequency. Color light signals are detected by photodiodes, which generate square wave signals with a frequency precisely proportionate to light intensity. These signals are sent to a microcontroller, yielding a colour output.

18. Seismic sensor

A seismic sensor detects and records minor ground movements by measuring, amplifying, and recording them. It's usually utilised to measure the finer points of earthquakes, volcanic eruptions, and other electrical mechanical phenomena.

19. Magnetic sensor

Magnetic sensors produce a proportional output in response to the presence or interruption of a magnetic field, such as flux, intensity, and direction. It turns magnetic data into an electrical signal that the electronic circuit can process. A magnetic sensor is utilised in a variety of applications, including sensing an object's location, velocity, and movement.

20. Biosensors

Biosensors detect organisms, tissues, cells, enzymes, antibodies, and nucleic acids, among other biological constituents. Biosensors for blood glucose and pulse oximetry are two examples.

21. Radiation sensors

Radiation sensors detect radiation in the environment. Radiation can be sensed by scintillating or ionization detection. Example is a Geiger-Muller counter, scintillator, and neutron detector.

22. Light Sensors

Light sensors detect the presence of light (visible or invisible). Example is an infrared sensor, flame sensor, or photo detector.

23. Acoustic sensors

Acoustic sensors detect sound levels and translate the data into digital or analogue signals. Microphone, geophone, and hydrophone are among examples.

24. Flow Sensors

Flow sensors detect if a physical force is applied and whether the magnitude of the force is greater than a predetermined threshold. Example is touch sensor, viscometer, force gauge.

VII. WHY ARE BATTERIES REQUIRED IN IOT DEVICES

Sometimes it is required to place these IOT devices in a place where a fixed power source is not available. In that case, a battery is an essential part of the IOT device, but since these batteries are very limited, often recharging of the battery is not possible. The idea is to maximize the life of the IOT device by minimizing the energy consumption at various levels. The question is how and where the power is consumed in different IOT devices (sensors).

VIII. FACTORS OF ENERGY DISSIPATION: BATTERY OPERATED IOT DEVICES

The communication unit has been shown in several tests to be relatively energy hungry[37]. The processing, transmission, and receiving of data in WSNs and IOT consume the majority of the energy required to meet the application's requirements. Reducing data transfers will, of course, save energy for these energy-constrained devices. A lot of studies in the field of communication have discovered that a significant amount of energy is wasted in methods that contribute nothing to the application, such as [38].

1. Collision

A packet collision happens when a node receives two or more packets at the same time [64]. As a result, the packets are either deleted or routed back to their originating node, necessitating retransmission, which increases packet delay and energy consumption, reducing network lifespan [40].

2. Ideal Listening

In active mode, a node consumes a substantial amount of energy. The quantity of energy wasted must be kept to a minimum. It does not have to be in a working state to be useful. Idle listening is the state of being ready to send data but not receiving or sending packets. There are several methods for reducing overall active time. The sleeping sensor nodes restore to active mode after a certain length of time. After a wake-up signal has been processed, or for a certain amount of time.

3. Control Packet Overhead

During data transmission, high-density sensor nodes cause interference with neighbouring nodes. This is referred to as overhearing. This is a problem with the nodes within reach. As a result of obtaining and processing meaningless information, energy resources are used up [38].

4. Interference.

Interference: Each node with two or more nodes within transmission range suffers from interference caused by the nodes in its immediate vicinity. Interference grows as the number of neighbouring nodes grows [41]. It causes congestion and competing signals, which may result in retransmission. As a result, avoiding greater node interference might lower packet loss and hence network energy usage [42].

5. Redundant data

Because sensor nodes are often planted at random, certain locations may be monitored by two or more sensors at the same time [43]. However, this form of deployment will result in more duplicated data being reported in the network. As a result, energy is lost when duplicated data is aggregated, processed, and sent [36]. By minimising the superfluous functioning of a node, energy consumption might be reduced.

6. Non Clustering

Non-clustering: because of the higher energy consumption, direct transmission distance from each source node to the BS might considerably shorten the WSN and IOT lifespan. Hierarchical routing protocols are utilised as a solution, as shown in Figure 3, which depicts the most commonly used protocols: chain-based, cluster-based, and tree-based protocols [44]. In a chain-based protocol, nodes are placed in a chain-like configuration, with one node serving as the Cluster head node, which transmits data from all nodes to the Base Station [45]. Cluster-based divides nodes into sub-clusters, with each sub-cluster having some sensor nodes connected to a Cluster head node for data transmission to the Base Station [46]. All sensing data is delivered from each sensor node to its parent (Cluster Head node) in tree-based clusters using the multi-hop approach [47].Clustering is the best approach for minimising communication costs and extending the life of sensor networks.

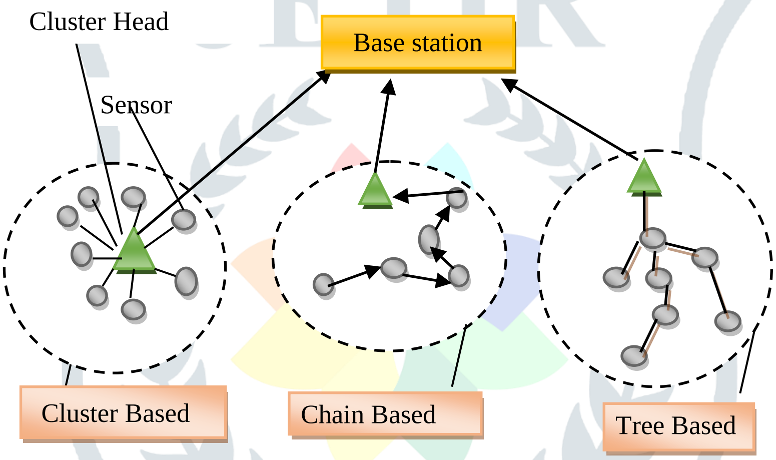

Figure 3: Hierarchical clustering in IOT and WSN

7. Frame Collision

IOT-based sensor networks are made up of a huge number of smart sensor nodes, each of which may begin transmitting data at the same time. When two nodes try to transmit at the same time over the same shared media or channel, their data frames may interfere with one another, resulting in damaged packets [48]. As a result, in such dense IOT-based systems, a huge number of severe collisions may occur, necessitating the transmission of redundant data packets in order to retransmit damaged packets. Frame collision can also be caused by hidden-terminal problems, simultaneous node wake-up, and high network traffic stress. Frame collision, on the other hand, wastes time and energy during the transmission and receipt of retransmitted packets in wireless networks, which affects network throughput and overall lifetime while also increasing transmission delay. A variety of approaches, such as employing TDMA RTS/CTS based processes, are used to reduce frame collision problems in wireless networks.

8. Data Frame Overhearing

The MAC layer's frame overhearing behaviour wastes energy. When a sensor node receives, processes, and sends data frames supplied by its neighbours, even though they are irrelevant and have previously been received, such as flooding messages, this happens. In flooding systems, wireless nodes transmit data packets, such as route discovery messages, to all of their neighbour nodes, who then receive, process, and transfer the message to all of their neighbours [49]. Flooding broadcast and other similar strategies result in a huge number of duplicate packets being sent out. Receiving and transmitting excessive data that is not necessary results in the communication unit squandering a significant amount of energy, thus reducing the battery life.

9. Packet Loss

Environmental factors, network and application types, transceiver circuit characteristics, and coding processes all have a role in the effective transmission of data packets [50]. When a network fails to deliver a travelling packet to its destination, packet loss occurs, which may be particularly problematic in multi-hop routing systems. Packet losses can occur for a variety of reasons.

Network congestion, signal attenuation owing to distance, non-uniform radio signal strength, malfunctioning networking hardware or drivers, propagation effects (multi-path fading), packet drop attack, asymmetry in wireless communication networks, and concealed terminal interference are all examples of this. However, in order to ensure reliable packet delivery, transmission protocols employ a variety of strategies such as congestion avoidance and packet retransmission, which results in increased energy consumption as the number of missed packets increases.

IX. CONCLUSION

The Internet of Things is rapidly transforming into a reality that surrounds us and affects many aspects of our life. Sensors are essential for integrating the physical world with the digital world. A battery is an essential part of the IOT device, but since these batteries are very limited, often recharging of the battery is not possible. The expansion and wide-scale deployment of IOT-based wireless devices has resulted in substantial energy loss. As a result, there is a pressing need to research new mechanisms and techniques that can help battery-operated devices save energy and the last longer. The various major units of a typical IOT sensor node are shown in this paper. We have discussed the major energy dissipation factors in IOT-based wireless nodes in this paper. This study will be beneficial to future research in the field of IOT .

REFERENCE

[1] Evans, Dave, “The Internet of Things - How the Next Evolution of the Internet Is Changing Everything”, Cisco, 2011.

[2] Fraden, Jacob, Handbook of Modern Sensors, 4th ed. New York: Springer, 2010.

[3] Chen, K. Y., K. F. Janz, W. Zhu, and R. J. Brychta, “Redefining the roles of sensors in objective physical activity monitoring,” Medicine and Science in Sports and Exercise, vol. 44, pp. 13–12, 2012.

[4] Khanna, Vinod Kumar, Nanosensors: Physical, Chemical, and Biological. Boca Raton: CRC Press, 2012.

[5] IOT Devices - Javatpoint .

[6] N. Nesa, and I. Banerjee. "IOT-based sensor data fusion for occupancy sensing using Dempster–Shafer evidence theory for smart buildings", IEEE Internet of Things Journal, Vol. 4, No. 5, 2017, pp. 1563-1570. Available Online: DOI: 10.1109/JIOT.2017.2723424

[7] D. Tandeske, Pressure Sensors: Selection and Application, CRC Press, 1990.

[8] S. Rab, S. Yadav, R.K. Sharma, L. Kumar, V.K. Gupta, A. Zafer, A. Haleem, Development of hydraulic cross floating valve, Rev. Sci. Instrum. 90 (8) (2019), 085102.

[9] R. Kumar, S. Rab, B.D. Pant, S. Maji, R.S. Mishra, FEA-based design studies for development of diaphragm force transducers, MAPAN 34 (2) (2019) 179–187.

[10] S. K. Dhar, S. S. Bhunia, and N. Mukherjee. "Interference aware scheduling of sensors in IOT enabled health-care monitoring system", In: Proc. of 2014 Fourth International Conference of Emerging Applications of Information Technology, IEEE, pp. 152-157, 2014. Available Online: DOI: 10.1109/EAIT.2014.50

[11] M. S. Mekala, and P. Viswanathan. "A novel technology for smart agriculture based on IOT with cloud computing", In: Proc. of 2017 International Conference on I-SMAC (IOT in Social, Mobile, Analytics Available Online: and Cloud)(I-SMAC), IEEE, pp. 75-82, 2017. DOI: 10.1109/EAIT.2014.50

[12] J. Newman, H. Zhou, H. Hu, Inertial sensors for motion detection of human upper limbs, Sens. Rev. (2007)

[13] A. Baca, P. Dabnichki, M. Heller, P. Kornfeind, Ubiquitous computing in sports: a review and analysis, J. Sports Sci. 27 (12) (2009) 1335–1346

[14] S. Zafar, G. Miraj, R. Baloch, D. Murtaza, and K. Arshad. "An IOT Based Real-Time Environmental Monitoring System Using Arduino and Cloud Service", Engineering, Technology & Applied Science Research, Vol. 8, No. 4, 2018, pp. 3238-3242.

[15] N. Nayyar and V. Puri, “ Smart farming: IOT based smart sensors agriculture stick for live temperature and moisture monitoring using Arduino, cloud computing & solar technology”, In: Proc. of The International Conference on Communication and Computing Systems (ICCCS-2016), 2016. Available Online: DOI: 10.1201/9781315364094-121

[16] K. T. V. Grattan, and T. Sun. "Fiber optic sensor technology: an overview", Sensors and Actuators A: Physical, Vol. 82, no. 1-3, 2000, pp. 40-61. Available Online: https://doi.org/10.1016/S0924- 4247(99)00368-4

[17] T. Kwaaitaal, "The fundamentals of sensors." Sensors and Actuators A: Physical, Vol. 39, No. 2, 1993, pp. 103-110.

[18] N. Nayyar and V. Puri, " Smart farming: IOT based smart sensors agriculture stick for live temperature and moisture monitoring using Arduino, cloud computing & solar technology", In: Proc. of The International Conference on Communication and Computing Systems (ICCCS-2016), 2016. Available Online: DOI: 10.1201/9781315364094-121

[19] J.L. Santos, F. Farahi (Eds.), Handbook of Optical Sensors, CRC Press, 2014.

[20] M.F. Ferreira, E. Castro-Camus, D.J. Ottaway, J.M. Lopez-Higuera, X. Feng, W. Jin, Q. Quan, Roadmap on optical sensors, J. Opt. 19 (8) (2017), 083001

[21] C.F. Coombs(Jr), "Electronic Instrument Handbook", Second Edition, Mc Graw Hill, pp.5.1, 1994.

[22] J.R. Stetter, W.R. Penrose, Understanding chemical sensors and chemical sensor arrays (electronic noses): past, present, and future, Sensor. Update 10 (1) (2002) 189–229.

[23] K.S. Johnson, J.A. Needoba, S.C. Riser, W.J. Showers, Chemical sensor networks for the aquatic environment, Chem. Rev. 107 (2) (2007) 623–640

[24] N. Yamazoe, Toward innovations of gas sensor technology, Sensor. Actuator. B Chem. 108 (1–2) (2005) 2–14.

[25] H. Nazemi, A. Joseph, J. Park, A. Emadi, Advanced micro-and nano-gas sensor technology: a review, Sensors 19 (6) (2019) 1285.

[26] A. Gaur, A. Singh, A. Kumar, A. Kumar, K. Kapoor, Video flame and smoke based fire detection algorithms: a literature review, Fire Technol. 56 (5) (2020) 1943–1980

[27] A.Z. Adamyan, Z.N. Adamian, V.M. Aroutiounian, Smoke sensor with overcoming of humidity cross-sensitivity, Sensor. Actuator. B Chem. 93 (1–3) (2003) 416–421

[28] M. Bigas, E. Cabruja, J. Forest, J. Salvi, Review of CMOS image sensors, Microelectron. J. 37 (5) (2006) 433–451.

[29] K. Shimonomura, Tactile image sensors employing camera: a review, Sensors 19 (18) (2019) 3933.

[30] D. Xu, Y. Wang, B. Xiong, T. Li, MEMS-based thermoelectric infrared sensors: a review, Front. Mech. Eng. 12 (4) (2017) 557–566

[31] L. Zhu, J. Suomalainen, J. Liu, J. Hyypp€a, H. Kaartinen, H. Haggren, A Review: Remote Sensing Sensors, Multi-purposeful application of geospatial data, 2018, pp. 19–42

[32] M. Strohbach, H. Ziekow, V. Gazis, and N. Akiva. "Towards a big data analytics framework for IOT and smart city applications", Modeling and processing for next-generation big-data technologies, Springer, Cham, pp. 257-282, 2015. Available Online: DOI: https://doi.org/10.1007/978-3-319-09177-8_11.

[33] R. B. Pendor, and P. P. Tasgaonkar. "An IOT framework for intelligent vehicle monitoring system", In: Proc. of 2016 International Conference on Communication and Signal Processing (ICCSP), pp. IEEE, 1694-1696, 2016. Available Online: DOI: 10.1109/ICCSP.2016.7754454

[34] A. Ailamaki, C. Faloutos, P.S. Fischbeck, M.J. Small, J. VanBriesen, An environmental sensor network to determine drinking water quality and security, ACM Sigmod Record 32 (4) (2003) 47–52.

[35] K.S. Adu-Manu, C. Tapparello, W. Heinzelman, F.A. Katsriku, J.D. Abdulai, Water quality monitoring using wireless sensor networks: current trends and future research directions, ACM Trans. Sens. Netw. 13 (1) (2017) 1–41.

[36] Shabna VC, Jamshid K, and S. Manoj Kumar. Energy minimization by removing data redundancy in wireless sensor networks. In 2014 International Conference on Communication and Signal Processing, pages 1658–1663, Apr. 2014.

[37] Jau-Yang Chang and Ting-Huan Shen. An Efficient Tree-Based Power Saving Scheme for Wireless Sensor Networks With Mobile Sink. IEEE Sensors, 16(20):7545–7557, Oct. 2016.

[38] Pascale Minet. Energy Efficient Routing. Bentham Science, 2009.

[39] A. H. Ab.Halim and K. Zen. MAC protocol to reduce packet collision in wireless sensor network. In 2008 International Conference on Computer and Communication Engineering, pages 1290–1293, May 2008.

[40] Ye Chen, Wei Liu, Tian Wang, Qingyong Deng, Anfeng Liu, and Houbing Song. An adaptive retransmit mechanism for delay differentiated services in industrial WSNs. EURASIP Journal on Wireless Communications and Networking, 2019(1):258, 2019.

[41] Nadeem Javaid, Abdul Majid, Arshad Sher, Wazir Zada Khan, and Mohammed Y. Aalsalem. Avoiding Void Holes and Collisions with Reliable and InterferenceAware Routing in Underwater WSNs. Sensors, 18(9):1–25, Sept. 2018.

[42] Musaloiu-E Razvan and Terzis Andreas. Minimising the effect of WiFi interference in 802.15.4 wireless sensor networks. International Journal Sensor Networks, 3(1):43–54, Dec. 2008.

[43] Ravneet Kaur, Deepika Sharma, and Navdeep Kaur. Comparative Analysis of Leach And Its Descendant Protocols In Wireless Sensor Network. International Journal of P2P Network Trends and Technology (IJPTT), 3:22–27, Jan. 2013.

[44] J. Zhang, Q. Wu, F. Ren, T. He, and C. Lin. Effective Data Aggregation Supported by Dynamic Routing in Wireless Sensor Networks. In 2010 IEEE International Conference on Communications, pages 1–6, May 2010.

[45] S. Lindsey and C. S. Raghavendra. PEGASIS: Power-efficient gathering in sensor information systems. In Proceedings, IEEE Aerospace Conference, Mar. 2002.

[46] W. B. Heinzelman, A. P. Chandrakasan, and H. Balakrishnan. An ApplicationSpecific Protocol Architecture for Wireless Microsensor Networks. IEEE Transactions on Wireless Communications, 1(4):660–670, Oct. 2002.

[47] J. Liang, J. Wang, and J. Chen. A Delay-Constrained and Maximum Lifetime Data Gathering Algorithm for Wireless Sensor Networks. In 2009 Fifth International Conference on Mobile Ad-hoc and Sensor Networks, pages 148–155, Dec. 2009.

[48] G. Anastasi, M. Conti, M. D. Francesco, and A. Passarella, "Energy conservation in wireless sensor networks: A survey," Ad Hoc Networks, vol. 7, no. 3, pp. 537 – 568, 2009.

[49] Bachir, Abdelmalik et al., "Abstract Frames for Reducing Overhearing in Wireless Sensor Networks", 5th International IFIP-TC6 Networking Conference, pp. 880–891, 2006.

[50] C. Cirstea, M. Cernaianu and A. Gontean, "Packet loss analysis in wireless sensor networks routing protocols," 35th International Conference on Telecommunications and Signal Processing (TSP), pp. 37-41, 2012.