



# Energy Efficient Design of IOT

<sup>1</sup>Kuntal Mukherjee, <sup>2</sup>Jaya Pal

<sup>1,2</sup>Assistant Professor

<sup>1,2</sup>Department of Computer Science and Engineering  
BIT, Mesra, Ranchi, India

**Abstract :** Internet of Things (IOT) has opened a new era where all pervasive devices would be inter connected to provide our different day to day utility services. The sensing layer is considered as lowermost layer of IOT architecture and it plays a significant role for the whole IOT applications as they capture raw data from environment. Out of the different components of the sensing layer, Wi-Fi enabled sensors play very major roles to capture raw data from environment and then to send it to the uppermost layer for the successful operations of IOT applications. But these sensors are battery powered and may fail at any time that may cause malfunctioning of the whole IOT applications. In this context, this endeavor has proposed two approaches for the energy efficient design of sensor nodes-one is data prediction approach which involves with data prediction without actually exhausting sensor nodes and other one is the design of an energy efficient logical topology of Wi-Fi enabled sensors using artificial neural network. Experimental results have been shown to lay bare the effectiveness of the proposed approach.

**Keywords:** IOT; Energy efficient topology; Wi-Fi enabled sensors; Access Point; Neural Network; Data prediction

## I. INTRODUCTION

The old proverb “Necessity is the mother of Invention” has again found itself true in the current age of Information Technology. The need of the current age is to develop a mesh of network where all pervasive devices would be seamlessly interconnected to yield a virtual reality of connected devices. The agenda of such interconnected devices is to provide different day to day utility services to mankind, namely smart traffic, environment monitoring, surveillance etc. In the context to this fantastic idea where human, devices, computers etc. all are inter-connected to form a virtual utopian world is probably known as Internet of Things(IOT). As found in literature, this cutting edge technology IOT fundamentally comprises of three layers, namely sensing layer, network layer and application layer[1],[2],[3],[4]. The sensing layer is comprised of sensors, Radio-Frequency Identification (RFID), Global Positioning System (GPS) etc. in order to collect the raw data from environment. This raw data is sent to network layer and thereafter to application layer at which this raw data is processed using the different services of cloud computing. Now this processed data is provided to different day to day utility applications, which is shown in Fig.1. It is observed that apart from RFID, tiny sensors are widely used to capture raw data from environment for different IOT applications. These tiny sensors are battery powered and their failure is a routine matter. Nowadays Wi-Fi(IEEE 8.2.11b) enabled sensors are used in order to develop the IOT applications. It is observed that the Wi-Fi enabled sensor can straightforwardly be incorporated with the existing infrastructure due to their Internet Protocol(IP) compatibility features. Moreover, Wi-Fi enabled sensors can send as well as receive data within a small interval of time. The current challenges of IOT as found in literature include energy efficiency, protocol support, resource allocation, identity management, quality of service provisioning, security and privacy etc.[3],[4]. Out of these challenges, energy efficiency plays a significant role for the successful implementation of IOT in real life. That is why this chapter has focused only on the energy efficient aspect of the sensing layer of IOT. The sensors play a significant role to capture raw data from the environment. The failure of a sensor node in the sensing layer may cause malfunction of the whole layer. Hence, a proper power management of sensing layer along with its ability of self heal up is of the utmost need. The energy efficient design of IOT means a proper energy efficient design of the sensors, RFID etc. of the sensing layer. In this context, this endeavor has focused only on the energy efficient design of sensor network of IOT using artificial intelligence approach. The organization of the rest of the endeavor comprises of the state-of-the-art of the energy efficiency of sensors at the sensing layer of IOT, research gap, proposed framework, proposed data prediction approach, energy efficient design of WSN based on artificial neural network, design of algorithm for the energy efficiency, performance evaluation of the proposed approach and finally conclusions with the future directions of studies. The remaining part of the paper is structured as follows: Section II explains the related work of energy efficient design, Section III describes Research gap. The Solutions and Recommendations is explained in Section IV. Section V gives the Simulations and Results and the paper concludes in Section VI.

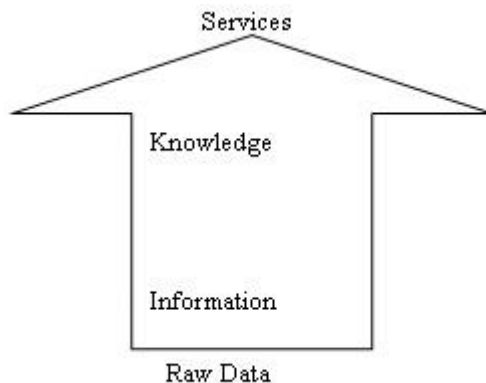


Fig. 1: Working process of IOT

**II. RELATED WORK**

IOT is the technique by virtue of which a mapping can be established between the physical world and the digital world [8]. As per Gartner report, IOT will hike up exponentially and 26 billion devices would be connected by 2020 [9]. Furthermore, the Information technology (IT) applications through IOT would be definitely different from conventional IT applications-a future threat for existing IT leaders [9]. Now, the million dollar question is what would be the optimal energy efficient design of sensor network? The subsequent section of this manuscript discusses the existing research work in this domain.

**2.1 Energy Efficient Design of IOT: State-of-Art**

The different components of the sensing layer of IOT namely, WSN, RFID etc. differ from each other in their working, but they are complementary technologies [11]. RFID involves in tracking objects, whereas sensors can provide various sensing ability to RFID tags[11]. Energy is the major constraint for both of them. RFID can undergo energy harvesting, whereas the energy of sensors in WSN are scarce [12]. Now, the rest part of this subsection has presented a detailed discussion regarding the energy efficiency in WSN and RFID as found in literature.

**2.2 Energy Efficiency in WSN**

The architectures, applications protocols of sensor networks, its major challenges are observed in the research work of [13]. The major challenges of WSN are energy efficiency, communication reliability, system mobility etc. [13]. The sensor network comprises of sensor nodes that are interconnected through wireless communication. The architecture of sensor network, as found in literature, comprises of sink node or base station and sensor nodes which are arranged over a huge geographic area called sensor field, which is shown in Fig. 2 [14]. Now two cases may arise, in one case both the sink and the sensor nodes are static, which is called static sensor network and other case is the mobility of sensor nodes [14].

**Case 1: Static Sensor Network**

In the research work of [15], the authors have experimentally exhibited that when sensor nodes involve in data transmission, they consume more energy as compared to data processing. That is why to reduce power consumption in WSN three main technologies exist, which are-duty cycling, data driven approach and mobility [14].

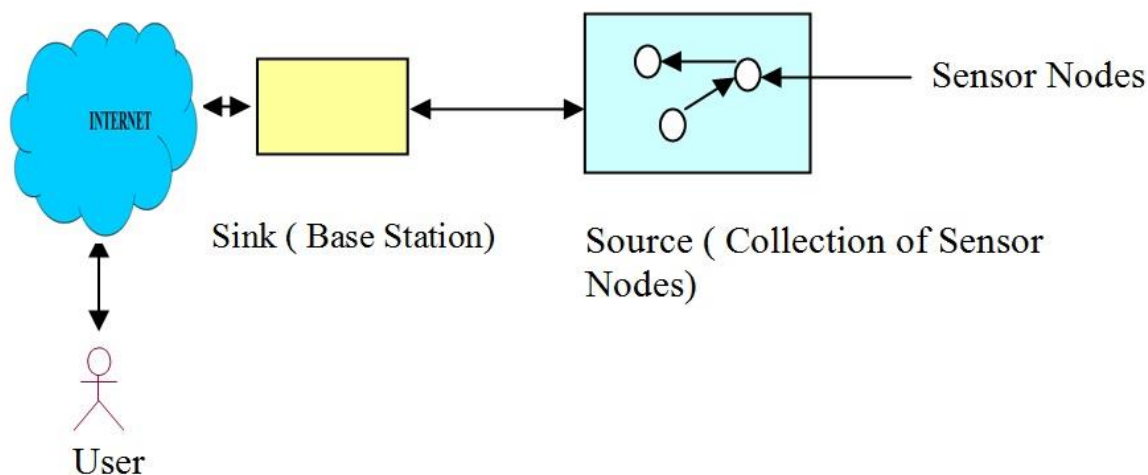


Fig. 2: Structural design of Sensor Network

In Duty cycling technique, the main focus is on networking subsystem. In other word, at Duty cycling the energy management is taken into consideration in the action of each single node and designing of networking protocol. Keeping all these in views, the taxonomy of duty cycling scheme includes topology control and power management approaches [14]. In the orientation of Topology control approach, the 1-connected and 2-connected energy saving topology control problems have been addressed by [20]. The authors of [20] have proposed CONNECT and BICONNAUGMENT algorithms for the same. But the major drawbacks of their proposed algorithms are centralized by nature with poor scalability. Further, the authors in [21] have proposed a cone-based distributed topology control algorithms. But their proposed work is based on directional antenna that is not used in sensor network-a major limitation. Moreover, LMST algorithm based on the local minimum spanning tree theory is observed in the research work of [22]. Here, the authors in [22] have only addressed 1-connectivity. A K-connected energy saving topology control algorithm for wireless sensor networks based on neighbor topology information with adjustment of its transmission power using Max-Min method, is observed in the research work of [23]. Again, the power management approach of duty cycling is based on the technique like sleep/wakeup protocols. In this technique, the idle nodes are kept into sleep state unless and until they are not needed to transmit data [14]. Moreover, an interesting subdivision of sleep/wakeup protocol is observed in the research work of [18], which comprises of on-demand approach, scheduled rendezvous and asynchronous approach. The logic behind on-demand approach is that a node would wake up only when another node wants to communicate with it [18]. The major challenge in this context is about the information to be sent to the sleeping node that some nodes are willing to communicate with it. In order to address such issues, the technique like scheduled rendezvous is very effective. It works on the principle that each node would wake up at the same time as its neighbors. Hence, a wake up scheduler exist that makes the node awake for a time interval, known as rendezvous time. During rendezvous time the nodes wake up and communicate with each other and after this time the nodes again go to sleep state [14][18]. Furthermore, in asynchronous approach the nodes would wake up unless and until they want to communicate with each other and can remain sustained for it. But during the operation of sensor nodes, they consume a lot of energy while capturing raw data and sending those to the base station. In order to optimize the consumption of energy during the whole process, data driven approach is best suited [14]. Data driven approach addresses energy efficiency in two ways. The first way involves in ceasing redundant data to sink whereas the second way suggests that communication among nodes should reduced when sensor nodes suffers from power deficiency [28]. The data driven approach is further classified as data reduction approach and energy efficient data acquisition approach [14]. In data reduction approach, energy efficiency is addressed by reducing the amount of data to be delivered to the sink node [14]. This approach is further divided into data compression technique and data prediction technique. The agenda of data compression approach is to compress the information sent by source to sink and thereby reduce the energy consumption during the whole process [14]. The overall technique is accomplished by compressing the data at source node and subsequently decompressing them at the sink node using the various data compression techniques available in the research work of [29],[30],[31]. Furthermore, the overall data prediction approach is based on the development of model in order to describe the sensed phenomenon. The model is deployed at both ends i.e. at source end as well as at sink end. Now the model is used to answer the queries of user without the transfer of actual data from source. As there is no transfer of data, energy consumption is less in the whole process. When the question arises about the testing of effectiveness of the proposed model, the predicted data generated by model is compared with the actual sample data produced by source node. If the comparison falls within application-dependent tolerance level then the model is valid, otherwise the model is updated by sample data sent by source node. Data dependency approach is further classified as stochastic approach, algorithmic approach. The stochastic model to predict sensed value is described in the research work of [14],[32]. In algorithmic approach, the model is based on heuristic characterization of the sensed phenomenon [33]. Now the energy efficient data acquisition technique of data driven approach involves the reduction of number of data acquisition i.e. data samples. The aim of this approach is to minimize energy consumption at the source node by simply reducing the data sampled there. Thus, in contrast to the previous approach, this approach reduces the energy consumption in two ways, firstly by reducing data sampled at source end and secondly by decreasing the number of communications between the source node and the sink node. This approach is based on data sampling, which is further classified as adaptive sampling, hierarchical sampling and model based sampling [34]. It is observed that some data changes slowly with time. That is why, one can use temporal correlation to reduce the number of data acquisition and consequently the minimization of energy consumption [35]. This fact is used in sampling approach [35]. In hierarchical sampling approach, the different nodes are organized in an hierarchical fashion with different functionalities and energy consumption. The agenda of this approach is to dynamically select the classes that can be activated in order to address trade off between accuracy and energy conservation [24]. Again, the model based active sampling approach relies upon the development of model that is built upon sample data in order to forecast values with a certain degree of accuracy. In this way, this approach reduces energy consumption by reducing data samples at the source node as well as by reducing the amount of data transmission between the source node and the sink node [36]. Apart from the above mentioned approaches, an interesting distributed power control technique is also found in literature [22],[30]. Here, a game-theoretic approach to address the power control problem in sensor networks has been addressed by [37], where the authors have used the non-cooperative game of incomplete information and they have considered the behavior of Nash equilibrium. Again, an energy efficient hop length optimization scheme for the sensors in a WSN has been presented by authors in [38]. Furthermore, an interesting discussion regarding the power efficiency of the routes in WSN is observed in the research work of [13], where the authors have highlighted the maximum available power route, minimum energy route and minimum hop route in sensor network.

## Case2: Dynamic Sensor Network

This latest trend is based on the concept of effective design of WSN by using mobility in sensor nodes [13]. But mobility is always associated with energy consumption. Mobility in sensors are achieved either by arming the sensors with devices for changing their locations or the utilization of elements which itself can move, as for example, animals, cars etc. In both the cases, for the sake of energy optimization, only special nodes are equipped with devices or can be placed on mobile elements [14]. Furthermore, connectivity is also a serious issue here [14]. This approach is further classified as mobile sink based approach and

mobile relay based approach [14]. The mobile sink based approach is based on the concept of Linear Programming optimization technique in order to optimize network lifetime [39]. Based upon Linear Programming optimization technique, the authors in the research work of [40] have addressed multiple mobile sinks. Moreover, an interesting work in this orientation is observed in the research work of [41], where the authors have considered the heuristic-based relocation scheme. Now, in the mobile relay based approach the message ferries are the key players to collect the data from the source node, carry them and finally send all to the destination node [50]. A popular work in this orientation is found in data-MULE system proposed by [25]. A very interesting work where the sensor nodes are kept on mobile elements is found in Zebrant system [42]. Its basic agenda is to trace and monitor wild life like Zebras.

### 2.3 Comparison between Static Sensor Network and Dynamic Sensor Network

The early stage of research in WSN was confined in static structure of sensor nodes. The research regarding energy efficiency design of WSN was based on the static state of sensor nodes. But with growing demand, nowadays the sensor nodes are dynamic also. The latest trend in this domain is mobility based energy conservation scheme for WSN. It is observed that in Case I, the data packets coming from the source sensor nodes follow multi-hop path to reach the sink nodes. Hence, congestion is bound to occur in networks that may cause premature energy-depletion, which is called funneling effect [43]. In contrast to this limitation of Case I, the mobility in sensor nodes can alter traffic flow and hence overcome funneling effect [14]. Thus, the movements of sensor nodes should follow limited multi-hop traversal. Furthermore, mobility may cause more energy consumption along with decrease in connectivity of sensor nodes. Thus, neither Case1 nor Case 2 is optimal. An optimal use of Case1 and Case 2 is best suited for efficient energy design of WSN in view of QoS(Quality of Service) parameter [14].

### 2.4 Energy Efficiency in RFID

The aim of RFID technology is to track and monitor different objects surrounding us including man, animal, smart phone, computer etc. RFID system comprises of tag and readers. The tags are embedded in objects for the purpose of tracking and monitoring objects. In RFID, the tracking of objects can be done using radio waves or by using sensing signals[4]. According to the powering method, the classification of RFID tag[4] is shown in Fig. 3.

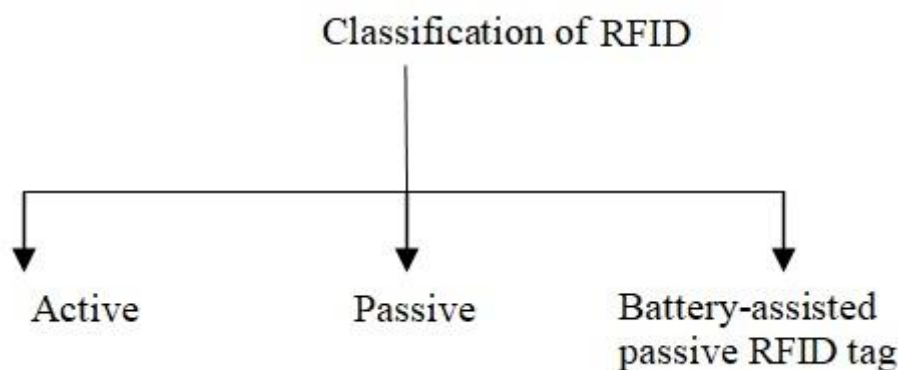


Fig. 3: Classification of RFID

The active RFID tags are operated by battery power, whereas the passive RFID does not possess any battery and is operated by an external source of energy [24]. It is observed that the passive tag gets energy by radio frequency carrier wave continuously supplied by the reader while the communication between it and reader takes place [11]. Moreover, harvesting energy from environment is the latest trend of research for energy efficiency in passive tag [26]. In this context, the different energy sources and their harvested power is found in the research work of [27], which is shown in Table 1.

The active RFID tags are operated by battery power, whereas the passive RFID does not possess any battery and is operated by an external source of energy [24]. It is observed that the passive tag gets energy by radio frequency carrier wave continuously supplied by the reader while the communication between it and reader takes place [11]. Moreover, harvesting energy from environment is the latest trend of research for energy efficiency in passive tag [26]. In this context, the different energy sources and their harvested power is found in the research work of [27], which is shown in Table 1.

**Table 1.** Harvested Power from different Source of Energy[11][27]

Energy Source	Harvested Power
Solar Energy	60 mW
Mechanical Energy	8.4mW
Thermal Energy	0.52 mW
Electromagnetic	0.0015mW

From Table 1, even though electromagnetic harvester provides the lowest harvested power still it can provide wireless power transmission, which is extremely applicable for RFID technology as RFID operates in a wireless environment. The concept of wireless power transmission was first demonstrated by eminent physicist Nikola Tesla at the year 1899[11]. Again, the battery assisted RFID tags need help from an external source to wake up the battery and then it functions by its own power[4]. Moreover, the authors in [11] have presented the guidelines regarding the energy efficiency in RFID network by using the proper selection of optimal network configuration.

Zebras.

## 2.5 Integration of WSN and RFID

RFID and WSN both are essential technologies to implement IOT in reality[9],[10],[19]. Sensor nodes are unable to detect and identify elements but RFID is competent in this regard. Furthermore, WSN can provide information and condition of the object and its environment which RFID can not. Thus, we see that a proper integration of both of these complementary technologies are of the prime importance in order to address IOT. The merging of RFID network and WSN may cause the tracking, monitoring, sensing the conditioning of object and its environment- all at a time, which is the main aim of IOT. These two different networks use different protocol, as for example, WSN uses Zigbee, WiFi etc., whereas RFID uses RFID standard. The communication technology used in WSN is multi hop, whereas in RFID it is single hop [49]. An interesting integration of RFID tag and WSN is found in mobile robots[49], where RFID guides the robot in order to detect the non-sensible objects and WSN helps the robot to collect information about environment [49](Liu et al., 2008). The taxonomy of the integration of RFID and WSN as found in literature [49],[45],[46][47], is shown in Fig. 4. Now, the main question is: how RFID and WSN would work seamlessly? An interesting research regarding the integration of distinct technologies, namely RFID and WSN in one system is found in the research work of [48]. Here, the authors have introduced reader management component to configure RFID data and WSN data in order to provide a uniform interface to seamless access of data at the upper layer irrespective of their nature. Reader Management Component uses universal plug and play(SNMP) and simple Network Management Protocol(SNMP) for the same. Moreover, the latest trend of software platform to integrate RFID and Sensor is "RFID Anywhere" developed by Sybase [45]. Again, WinRFID middleware presented by WINMEC(Wireless Internet for Mobile Enterprise Consortium Lab) is used in capturing, filtering, routing and providing the aggregation of data using variety of readers and tags. Furthermore, ReWINS(Reconfigurable Wireless Interface for Networking Sensors) which consists of wireless data collector and controller can be used to integrate with RFID network using WinRFID middleware [49].

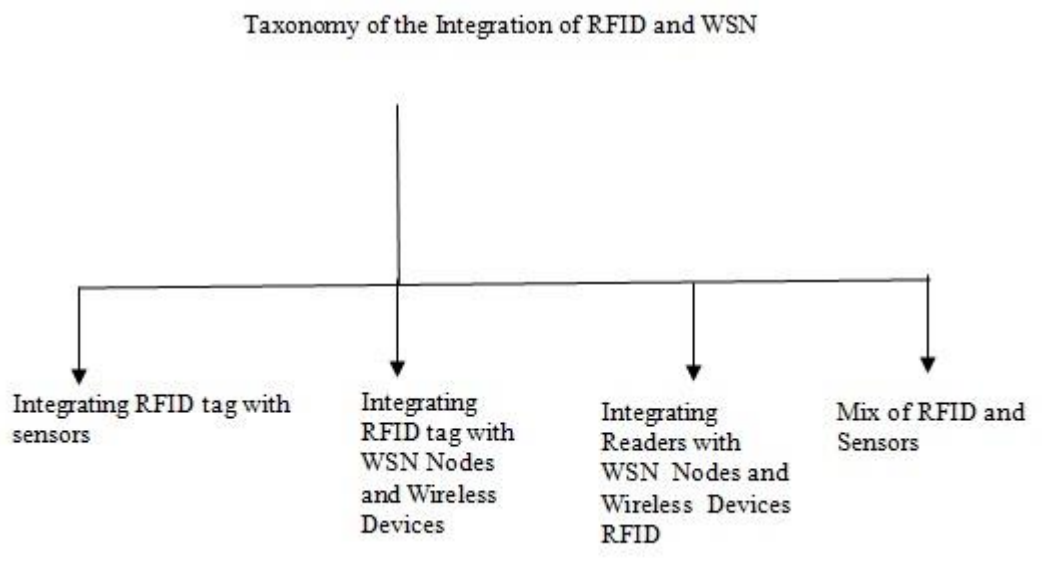


Fig. 4: Taxonomy of integration of RFID and WSN

## III. RESEARCH GAP

From the above discussions, it is obvious that there is considerable lack in research that can address static as well as dynamic sensor network of sensing layer of IOT. Furthermore, there is considerable lack in research regarding data prediction approach and energy efficient logical topology of sensor network. In this context, this endeavor has proposed a data prediction approach followed by an energy efficient logical topology of sensor nodes (which may be static or dynamic) based on an artificial intelligence approach.

## IV. SOLUTIONS AND RECOMMENDATIONS

This section comprises of proposed Framework followed by fuzzy-neural network controller to optimize the utilization of energy.

### 4.1 Proposed Framework

The proposed Framework comprises of different loosely coupled services of IOT. The different services of IOT is capable to adapt to changes. Each service of IOT is isolated from each other and are actually reusable. The overall IOT applications need independent data types, heterogeneous technological mix, broad applicability of software objective etc. Now these features can be achieved using loosely coupling approach. Furthermore, as the services are heterogeneous by nature hence the proposed

framework should have standardized interface to access all types of IOT services that are developed by different technologies. Again late binding of these individual services are of the utmost need to develop an integrated dynamic services on demand. Obviously, all these features can be achieved using loosely coupling system. That is why the proposed framework comprises of loosely coupled services, which is shown in Fig. 5.

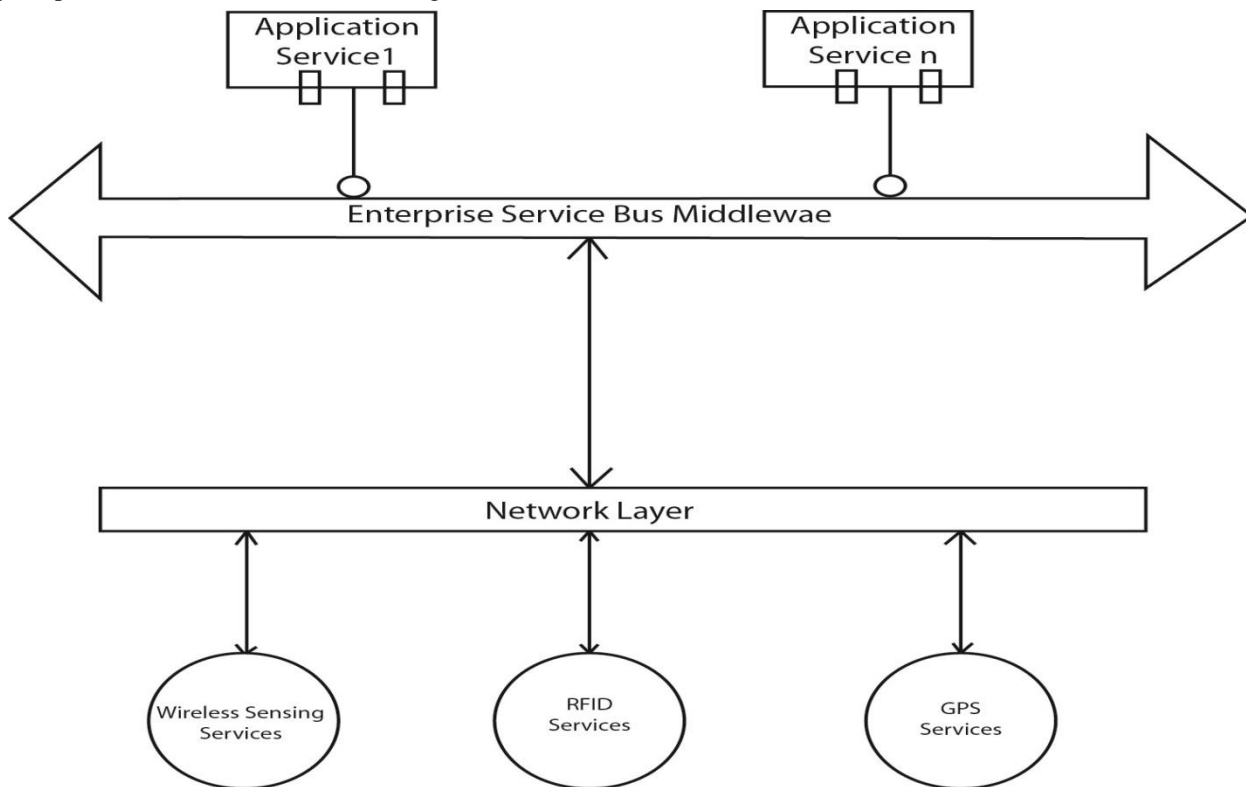


Fig.5. Loosely coupled IOT framework

Furthermore, the overall static design view of the system for the purpose of visualizing the structural model is shown in structural relationship ( Fig. 6). Starting from bottom, the composition of the sensing service are WSN services, RFID services, GPS services etc. Now the sensing service is associated with network service and network service is associated with middleware service. Furthermore, the middleware service is associated with different IOT services. The cardinality among the different classes of the structural relationship is shown in the Fig. 6. In this endeavor only the WSN services have been addressed in context of their energy efficient design using neural network. The subsequent section has addressed this issue in details.

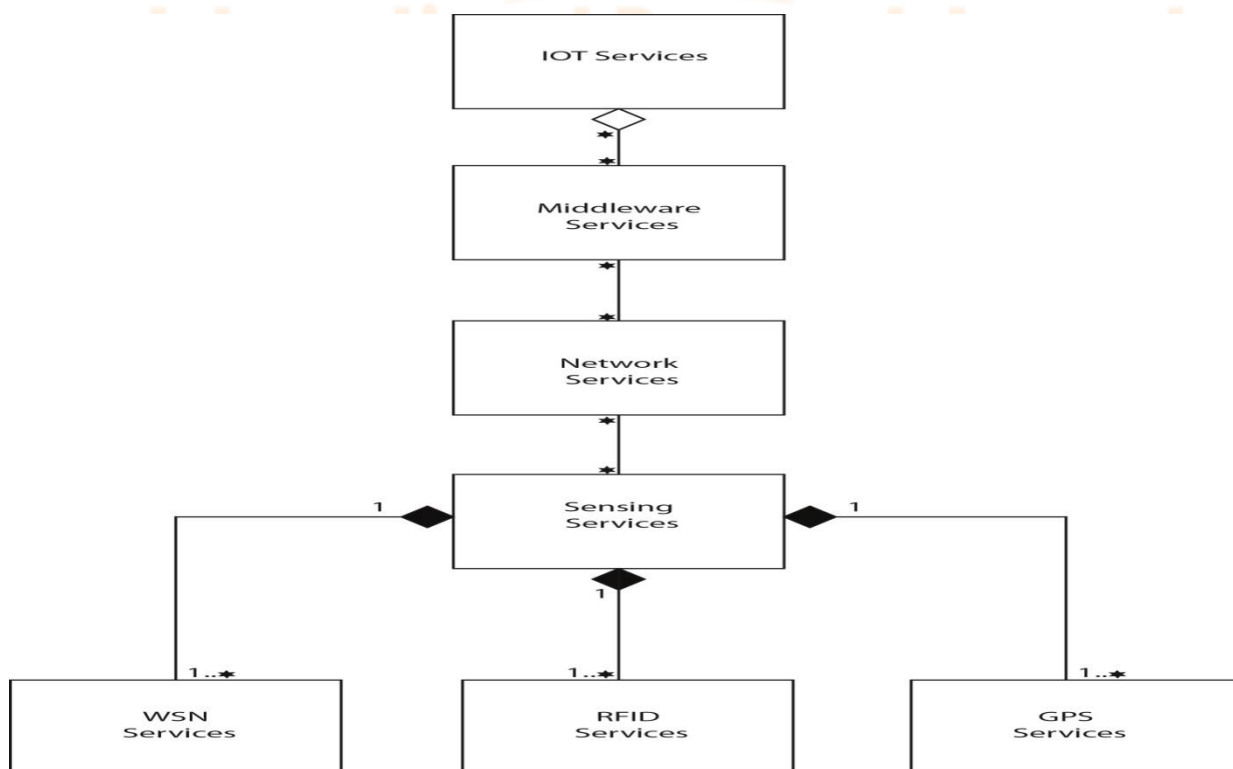


Fig.6. Structural Relationship

## 4.2 Energy Efficient Design of WSN Services

Actually, the Wi-Fi(IEEE 802.11a-802.11n) enabled sensors use Wi-Fi network[52],[54]. It is observed that in the Wi-Fi network the Wi-Fi router, which is known as wireless access point (AP), connects to the Internet straight forward [52],[54]. Actually Wi-Fi technology is better as compared to 3G services in context of bandwidth capacity[52],[54]. The major constraint of this technology is of its limited range(R) which is merely 300 meters, i.e. R= 300 meters[52],[54]. The Wi-Fi enabled sensor sends their data to access point(AP)directly and there is no relay node as compared to legacy wireless sensor networks[52],[54]. IOT technology uses Wi-Fi enabled sensors only[52],[54].That is why, no emphasize on relay node would be done here. Furthermore, these AP's are intelligent routers. The proposed energy efficient design of WSN services comprises of two cases, Case I has emphasized on the data prediction approach without actually exhausting sensor nodes where as the Case II has discussed actual data capturing from environment. To optimize the energy, Case II has discussed Energy Efficient Design using sleep and wake up methodology using artificial neural network.

### 4.2.1 Case I: Energy Efficient Design using sleep and wake up methodology

In this endeavor, we have used an algorithm for the efficient design using sleep and wake up methodology has been implemented here. We have used a neuro fuzzy network that on output giving the biased value (b) for the operation of either of Quantum Neural Network (QNN) or for the operation of Sensor nodes. Here QNN will work when  $b = 1$  and sensor node will work when  $b = 0$  as per the value give by fuzzy neural network. In this way we are using a sleep and wake up type of methodology for the efficient energy management and for the better operation of our complete Fog computing model. Which algorithm is given below :

As we know that neuro fuzzy system (NFS) can be defined as follow :

$$NFS = (F_n, F_m, \tilde{I}, \tilde{O}, A, L, f)$$

Where all these symbols consist the regular meanings of fuzzy logic.

Step-1 : Store this output as biased value (b).

Step-2 : Check for value of b, if  $b = 1$  then go to step 3, otherwise go to step 4.

Step-3 : Activate the system for Quantum Neural Network (QNN) to start working, then go to step 5.

Step-4 : Activate the system for sensor node to start working.

Step-5: End.

### 4.2.2 Case II: Data Prediction Approach

From the above literature survey, it is observed that periodical sleep and wake-up of sensor nodes is one of the good techniques to save energy for sensors at the sensing layer of IOT. But this concept has been modified here using Artificial Intelligence approach. Apart from traditional approach, the proposed approach will wake-up sensor nodes when needed otherwise they would be kept in dormant state to enhance their longevity. For this, energy efficient logical topology has been proposed here. The logical topology comprises of two non empty sets  $U_1$  and  $U_2$ , where  $U_1$  comprises of wireless access point (AP) and  $U_2$  comprises of Wi-Fi (IEEE 802.11b) enabled sensors. Here access points (APs) can be charged by electric power, so energy crises is not associated with them but their major advantage is that they can act as a coordinator and no sensor node needs to behave as a relay node [52]. The Wi-Fi enabled sensors are battery powered and their energy saving framework is the main agenda of this manuscript. For this, energy saving logical topology has been proposed here. The proposed energy saving logical topology can mathematically be viewed as a Graph  $G(V,E)$ , where  $V$  is set of vertices and  $E$  is set of edges[53]. Now, let the set  $V$  is portioned into two subsets  $U_1$  and  $U_2$  such that  $U_1 \cap U_2 = \emptyset$ . Now edge  $e_i \in E$  joins the vertices  $U_1$  and  $U_2$  or the vertices of  $U_2$  as per the hypothesis (HT) of the proposed logical formation of topology.

Hypothesis 1(HT1): The vertices  $u_i \in U_1$  are always static.

Hypothesis 2 (HT2): The vertices  $v_j \in U_2$  may be static or dynamic.

Hypothesis 3(HT3): The AP i.e.  $u_i \in U_1$  intelligently coordinates  $v_j \in U_2$ , for this  $u_i \in U_1$  generate signal, whereas  $v_j \in U_2$  listen the signal, sends data packet to  $u_i \in U_1$  or may be in dormant stage.

Hypothesis 4(HT4): The signal generated by AP i.e vertices  $u_i \in U_1$  is equal or more than a threshold value  $\theta_1$  and less than threshold value  $\theta_2$  then only  $e_i \in E$ , join  $u_i \in U_1$  and  $v_j \in U_2$ ,  $\forall u_i, v_j$

Hypothesis 5(HT5): Those  $v_j \in U2$  are in active state that are joined with  $u_i \in U1$ , rest becomes in dormant state. In this way  $u_i \in U1$  intelligently manages  $v_j \in U2$  and forms an intelligent energy efficient topology for sensors.

Hypothesis 6(HT6): The edge between  $u_i \in U1$  and  $v_j \in U2$  are wireless  $\forall u_i, v_j$ , where as the edge between different vertices of  $U1$  may be wired or wireless.

Hypothesis 7 (HT7): vertices  $v_j \in U2$ ,  $\forall v_j$  are not at all joined with each other.

Obviously, the hypothesis HT2 provides a general view of sensors nodes that may be static or dynamic state as per the requirement of IOT applications. Based on the above hypothesis, the proposed logical energy efficient topology is shown in Fig.7.

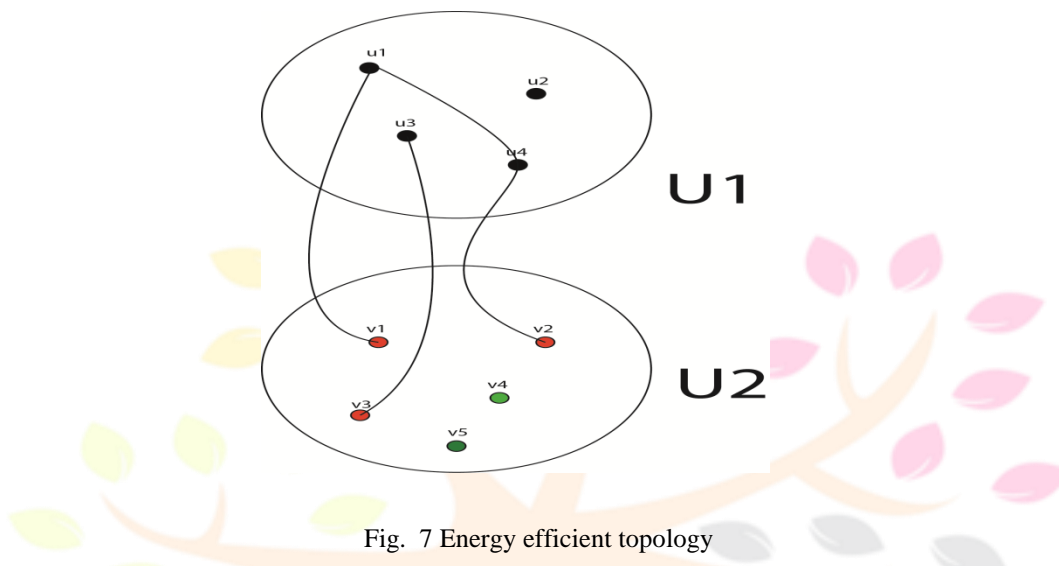


Fig. 7 Energy efficient topology

The proposed artificial neural network comprises of a number of inputs that are excitatory inputs with weight  $+W_1$  and inhibitory inputs with weight  $-W_2$ . The excitatory inputs are denoted as  $x_1, x_2, \dots, x_m$ , whereas the inhibitory inputs are denoted as  $x_{m+1}, x_{m+2}, \dots, x_{m+n}$ . The bias is denoted by  $b$ . The proposed system which would comprise of fuzzy logic, quantum neural network etc for fetching data from sensor nodes or data prediction is shown in Figure 8. Let us first discuss on data fetching process and after that data prediction approach is shown in case II.

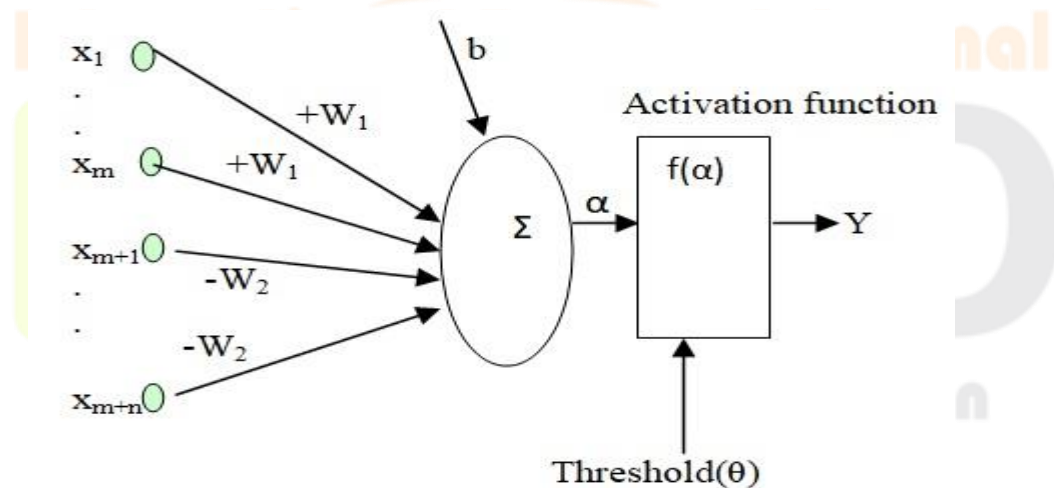


Fig. 8. Proposed Neural Network

Here,  $\alpha = \sum x_i W_1 + \sum x_j (-W_2) + b$

The activation of  $Y$  is defined as:

$Y = f(\alpha) = 1$ , if  $\alpha \in [0, \theta_1)$

$= -1$ , if  $\alpha \in [\theta_2, \infty)$

$= 0$ , otherwise

If  $Y=1$  then an edge exists between  $u_i \in U1$  and  $v_j \in U2$ . If  $Y = -1$  then an edge exists between  $u_i \in U1$  and  $u_k \in U1$ , where  $i \neq k$ . If  $Y=0$ , there is no such edge neither between the vertices of  $U1$  and  $U2$  and not between the vertices of  $U1$ . The overall process has been represented in the following matrices:

$$\mathbf{A} = [a_{ij}]_{m \times n}$$

$$\mathbf{B} = [b_{ij}]_{m \times n}$$

where  $i = 1$  to  $m$  and  $j = 1$  to  $n$ .

Obviously  $a_{ij} = 1$  if  $u_i \in U1$  (AP) linked to  $v_j \in U2$  (sensor node)  $\forall u_i, v_j$  where  $U1 = \{u_1, u_2, \dots\}$  is set of AP and  $U2 = \{v_1, v_2, \dots\}$  is the set of sensor nodes.

The Access Points (APs) provide short and rhythmic broadcast of the signals for the purpose of motivating the tiny sensors to send the data to the gateways. The strength of the broadcasting signal is the function of distance ( $r$ ) and noise in the environment ( $p$ ) i.e.  $f(r, p)$ . The rules for the establishment of connection between APs and sensor nodes as well as the dormant states of sensor nodes have been discussed below:

**Rule 1:** All the AP broadcast signals for short interval of time and will follow a rhythm.

**Rule 2:** Signal strength will decrease with the increase of distance and increase of noise in the environment.

**Rule 3:** If broadcast signal, say,  $\psi$  is equal or above the threshold value  $\theta_1$  but less than the threshold value  $\theta_2$  then a link gets establish between APs and sensor nodes.

**Rule 4:** The sensor nodes which are not linked with APs are made in dormant state.

**Rule 5:** The sensor nodes which are in dormant state would neither capture data from the environment nor send data to the AP. But at this state the tiny sensor nodes would still be active enough to listen signals periodically broadcast by APs. It is observed that when Wi-Fi enabled sensor nodes receive signals then they would consume very very less energy as compared to capturing or broadcasting of data to the APs [54].

Based upon the above discussions, the proposed algorithm for the better utilization of sensor nodes in context of energy efficiency is given below:

#### Algorithm2: Energy Efficiency

**Step 1:** Initially  $U2 = \{v_1, v_2, v_3, \dots\}$  be the set of sensor nodes and  $U1 = \{u_1, u_2, u_3, \dots\}$  be the set of Access Point. Define objective function  $f(r, p)$ . Define parameters  $r$  and  $p$ .

**Step 2:** For each  $v_i \in U2$ , generate signals  $\psi_i$ . All sensor nodes  $u_i \in U1$  listen to the signals  $\psi_i$

**Step 3:** For  $i=1$  to  $m$

do

For  $j=1$  to  $n$

do

If  $\psi_i \in [\theta_1, \theta_2]$  then  $a[i][j] = 1$

Else if  $\psi_i \in [\theta_2, \infty)$  then  $b[i][j] = 1$

Else  $a[i][j] = 0$ ,  $b[i][j] = 0$

End for  $j$

End for  $i$

**Step 4:**

For  $i=1$  to  $m$

do

For  $j=1$  to  $n$

do

If  $a[i][j] = 1$  then the edge is established between  $u_i \in U1$ ,  $v_j \in U2$  (sensor node)  $\forall u_i, v_j$ .

If  $b[i][j] = 1$ , then edge is established between  $u_i, u_m \in U1$ ,  $\forall u_i, u_m$ , where  $i \neq m$ .

Check the already availability of data using Algorithm 1.

If  $a[i][j] = 0$  then no edge is established between  $u_i \in U1$  and  $v_j \in U2$ ,  $\forall u_i, v_j$

If  $b[i][j] = 0$  then no edge is established between  $u_i, u_m \in U1$ ,  $\forall u_i, u_m$ , where  $i \neq m$ .

End for  $j$

End for  $i$

**Step 5:** Eliminate those edges between  $u_i \in U1$  and  $v_j \in U2$  whose Euclidian distance is strictly greater than  $R$ , i.e.  $d(u_i, v_j) > R$ ,  $\forall u_i, v_j$ .

Where  $d(u_i, v_j)$  represent Euclidian distance and  $R$  represent ranges of WiFi enabled sensors to receive signal from APs.

**Step 6.** Make those  $v_j \in U2$  are made in active state upon which edges are incident, rest are made in dormant state.

Step 7. End

## V. SIMULATION AND RESULTS

The proposed Algorithm 2 is evaluated using simulation. For this, it is assumed that 'k' sensor nodes and 'l' Access Points are uniformly distributed in a  $p \times p$  square area. Initially, the sensor nodes are having 5 Joule of energy. Obviously the Access Points (AP) are not power constrained as they are continuously charged by electric energy. Here two cases have been considered, namely case I when the sensor nodes are in static position and case II when sensor nodes are in dynamic position. In MATLAB version R2013a, Intel(R) Core(TM) i3 CPU 2.30 GHZ with 6 GB RAM at 64 bit operating system of Windows 10, the proposed algorithm has been evaluated. In the whole simulation, the Access points were located at centre of the square area. The energy consumption by the proposed algorithm is shown in Fig. 9 and Fig. 10 respectively. Here, Fig. 9 is representing when sensor nodes are in rest whereas Fig.10 is representing when sensor nodes are in motion. In Fig. 9 and Fig. 10 the Gateways are actually the Access points (Aps).

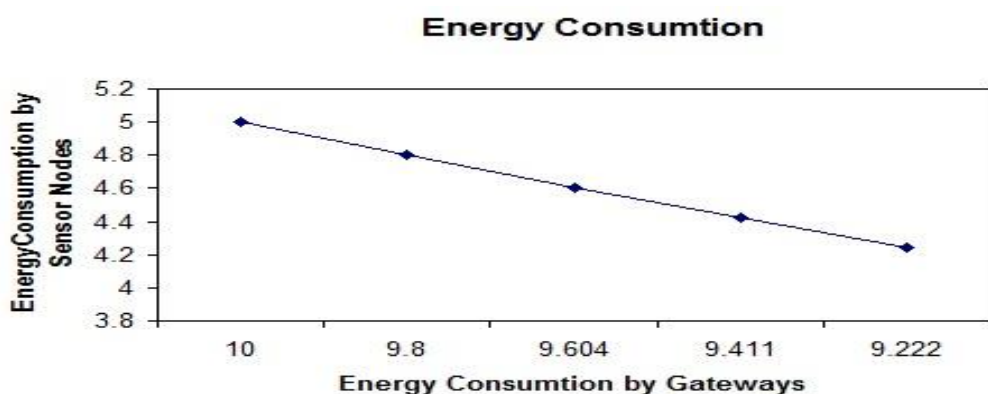


Fig. 9. Energy Consumption when sensor nodes are in rest

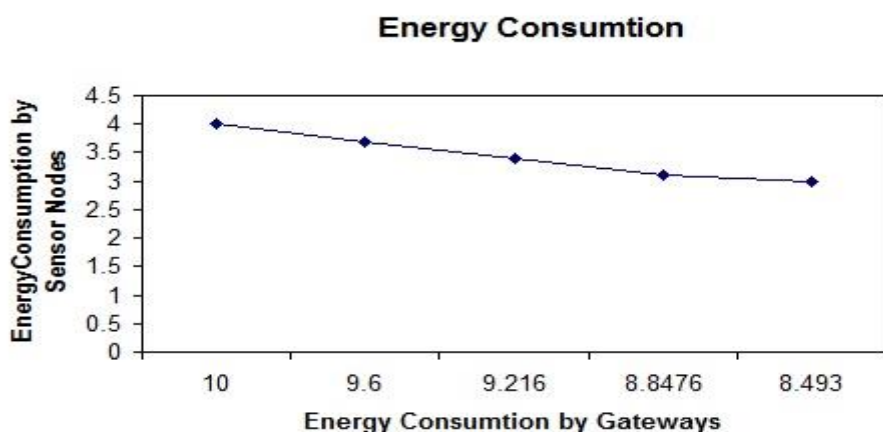


Fig. 10. Energy Consumption when sensor nodes are in motion

## VI. CONCLUSIONS WITH FUTURE DIRECTION OF STUDIES

IOT has recently emerged as one of the cutting edge technologies. But it is still in its infancy. A lot of issues are to be addressed namely, energy efficiency in its design process, lack of variety of wired and wireless connectivity standards, security and privacy etc. in order to make it a mature technology. In this context this endeavor has focused on its energy efficiency issue only using the data prediction and energy efficient logical topology concept.

## REFERENCES

- [1] Sheng, Q. Z, Zeadally, S., Luo, Z., Chung J. and Maamar Z.: Ubiquitous RFID: Where are we? Journal of Information Systems Frontiers, 12 (5), pp. 485-490(November 2010)
- [2] Friedewald, M., Raabe, O. :Ubiquitous computing: An overview of technology impacts. Journal of Telematics and Informatics, 28 (2), pp. 55-65(May 2011)
- [3] Aazam, A., Khan, I, Alsaffar. A., Huh, E., Z. :Cloud of Things: Integrating Internet of Things and Cloud Computing and Issues Involved. 11th International Bhurban Conference on Applied Sciences and Technology(IBCASST) Islamabad, Pakistan , pp. 414-418(2014)
- [4] Hwang, Kai, Fox Geoffrey, C. and Dongarra, Jack J.: Distributed and Cloud Computing From Parallel Processing to the Internet of Things.Morgan Kaufmann, Waltham, USA (2012)
- [5] Moreno, M.V., Úbeda, B., Skarmeta A.F., and Zamora, M.A.: How can we tackle energy efficiency in IoT based smart buildings? Journal of Sensors, 14 (6), pp. 9582-9614(May 2014)

- [6] Gubbi, J., Buyya, R., Marusic S., and Palaniswami, M.: Internet of things (IoT): A vision, architectural elements, and future directions. *Future Generation Computer Systems*, 29 (7), pp.1645 -1660(September 2013)
- [7] Lopez, T. S., Ranasinghe, D. C., and Harrison, M.: Adding sense to the internet of things: An architecture framework for smart object systems. *Personal and Ubiquitous Computing*, 16 (3), pp. 291-308(March 2012)
- [8] Vermesan, O., Friess P., Guillemin, P., Sundmaeker, H., Eisenhauer, M., Moessner, K., Gall F. Le, and Cousin P.: *Internet of Things Strategic Research and Innovation Agenda., Internet of Things: Converging Technologies for Smart Environments and Integrated Ecosystems*, O. Vermesan and P. Friess(eds.), River Publishers, Denmark(2013)
- [9] Mukhopadhyay S.C.and. Suryadevara N. K.: *Internet of Things: Challenges and Opportunities, Internet of Things Challenges and Opportunities*, S.C. Mukhopadhyay(eds.), Springer International Publishing, Switzerland (2014)
- [10] Jin, J., Gubbi, J., Lou T., and Palaniswami M.: Network Architecture and QoS Issues in the Internet of Things for a smart city. In *Proceedings of International Symposium on Communications and Information Technologies*, Gold Coast, QLD(October 2-5, 2012)
- [11] Duroc, Y.and Vera, Andia, G.: *Towards Autonomous Wireless Sensors: RFID and Energy Harvesting Solutions. Internet of Things*, S.C. Mukhopadhyay, Palmerston, North(eds.), Springer International Publishing, Switzerland(2014)
- [12] Zhang, L., Wang, X., and Dou, W.: A K-Connected Energy- Saving Topology Control Algorithm for Wireless Sensor Networks. *Proceedings of the 6th International Workshop on Distributed Computing*, Kolkata, India(December 27-30, 2004)
- [13] Akyildiz, I. F. and Kasimoglu I. H.: *Wireless Sensor and Actor Networks: Research Challenges*. *Ad Hoc Networks Journal*, 2(4), pp. 351-367 (October 2004)
- [14] Anastasi, G., Conti, M., Francesco, M. Di, and Passarella A.: *Energy Conservation in Wireless Sensor Networks: a Survey*. *Journal of Ad Hoc Networks Elsevier*, 7(3), pp. 537-568 (May 2009)
- [15] Raghunathan, V., Schurghers, C., Park, S., Srivastava M.: *Energy-aware Wireless Microsensor Networks*, *IEEE Signal Processing Magazine*, 19(2), pp. 40-50 (March 2002)
- [16] Anderson, J.S., Chase, D.C., Thakar, P.N., Vahdat A.M., Doyle R.P.: *Managing energy and server resources in hosting centres*. In: *Proceedings of the 18<sup>th</sup> ACM Symposium on operating systems principles*, ACM, New York, USA (2001)
- [17] Anydin H., Melhem R., Moss D. Mejia-Alvarez P.: *Power-Aware Scheduling for Periodic Real-Time Task*. *IEEE Transactions on Computers*, 53(5), pp. 584-600(May 2004)
- [18] Armstrong, T.: *Wake-up based power management in multi-hop wireless networks.: Term Survey Paper for ECE1717 Quality of Service Provisioning in mobile Networks course*, University of Toronto, Canada (2005)
- [19] Atzori, L. and Lera, A., Morabito, G. (October 2010): *The Internet of Things: A Survey*. *Computer Networks*, 54(15), pp. 2787-2805
- [20] Ramanathan, R.and Rosales-Hain, R.: *Topology control of multihop wireless networks using transmit power adjustment*. *Proceedings of the Nineteenth Annual Joint Conference of the IEEE Computer and Communications Societies*, TelAviv, Israel(March 26-30, 2000)
- [21] Li, L., Halpern, J.Y., Bahl, P., Wang, Y.M., and Wattenhofer, R.: *A cone-based distributed topology control algorithm for wireless multi-hop networks*. *IEEE/ACM , Transactions on Networking*, 13(1), pp. 147-159 (February 2005)
- [22] Li, N., Hou, J.C., and Sha, L.: *Design and analysis of an MST based topology control algorithm*. In *Proceeding of IEEE INFOCOM*. San Francisco, USA(April, 2003)
- [23] Gao, Q., Holding, D.J., Peng, Y., and Blow, K.J.: *Energy Efficiency Design Challenge in Sensor Networks*. In: *Proceedings of London Communications Symposium*, London, UK(2002)
- [24] Basseville, M., and Nikiforov I.V.: *Detection of Abrupt Changes: Theory and Application*. Prentice-Hall Inc., USA(1993)
- [25] Buonadonna, P., Gay, D, Hellerstein J., W. Hong and S.: *Madden TASK: Sensor Network in a Box*. In: *Proceedings of the IEEE European Workshop on Wireless Sensor Networks and Applications* (2005 January 31-February 2002)
- [26] Boaventura, A., Collado, A., Carvalho, N.Borges, Georgiadis, A.: *Optimum Behavior: Wireless Power Transmission System Design Through Behavioral Models and Efficient Synthesis Techniques*. *IEEE Microwave Magazine*, 14(2), pp. 26–35 (March-April,2013).
- [27] Bui, N., A.,Georgiadis, M.,Miozzo, M.,Rossi, X.Vilajosana.: *SWAP Project: Beyond the state of the art on harvested energy-power wireless sensors platform design*. In: *Proceedings of 2011 IEEE International Conference on Mobile Ad-Hoc and Sensor Systems*, Valencia, Spain (October 17-22, 2011)
- [28] Vuran, M. C., Akan, O. B., and Akyildiz, I. F.: *Spatio-Temporal Correlation: Theory and Applications for Wireless Sensor Networks*, *Computer Networks Journal*, 45(3), pp. 245-261 (June 2004)
- [29] Pradhan, S. S., Ramchandran, K.: *Distributed source coding using syndromes (DISCUS): design and construction*. *IEEE Transactions on Information Theory*, 49(3), pp. 626-643 (March 2003)
- [30] Tang, C., Raghavendra, C. S.: *Compression techniques for wireless sensor networks*. In: *Wireless Sensor Networks*, Raghavendra C. S., Sivalingam K.M., and Znati T. (eds.), Kluwer Academic Publishers Norwell, USA(2004)
- [31] Xiong, Z., Liveris, A. D., Cheng S.: *Distributed source coding for sensor networks*. *IEEE Signal Processing Magazine*, 21(5), pp. 80-94 (September 2004)
- [32] Chu, D., Deshpande, A., Hellerstein, J.M, Hong, W., *Approximate.: Data Collection in Sensor Networks using Probabilistic Models*. In: *Proceedings of the 22nd International Conference on Data Engineering*, Atlanta, USA(April 3-8, 2006)
- [33] Godfrey, P. B., Ratajczak, D.: *Naps: Scalable, Robust Topology Management in Wireless Ad Hoc Networks*. In: *Proceedings of the 3rd international Symposium on information Processing in Sensor Networks (IPSN '04)*, Berkeley, California, USA(April 26-27, 2004)
- [34] Raghunathan V., Ganeriwal S., Srivastava M.: *Emerging techniques for long lived wireless sensor networks*. *IEEE Communications Magazine*, 44(4), pp. 108-114(April 2006)
- [35] Alippi, C., Anastasi, G., Galperti, C., Mancini, F. and Roveri, M.: *Adaptive.: Sampling for Energy Conservation in Wireless Sensor Networks for Snow Monitoring Applications*. In: *Proceedings of IEEE International Workshop on Mobile Ad-hoc and Sensor Systems for Global and Homeland Security(MASS-GHS 2007)*, Pisa, Italy(October 8, 2007)

- [36] Deshpande, A., Guestrin, C., Madden, S., J. M. Hellerstein, W. Hong.: Model-Driven Data Acquisition in Sensor Networks. In: Proceedings of the 30th International Conference on Very Large Data Bases (VLDB 2004), Toronto, Canada(August 29 - September 3, 2004).
- [37] Sengupta, S. and Chatterjee, M.: Distributed Power Control in Sensor Networks: A Game Theoretic Approach. In: Proceedings of the 6th International Workshop on Distributed Computing, Kolkata, India (2004 December 27-30)
- [38] Peng, Y., He, U. and Choi, J.: Energy Efficient Hop Length Optimization for Laterally Connected Wireless Sensor Networks. In: Proceedings of IOT workshop, Berlin Germany(2012)
- [39] Wang, Z. M., Basagni, S., Melachrinoudis, E., Petrioli, C.: Exploiting Sink Mobility for Maximizing Sensor Networks Lifetime. In: Proceedings of the 38th Annual Hawaii International Conference on System Sciences (HICSS '05), Hawaii(January 03-06, 2005)
- [40] Gandham, S. R., Dawande, M., Prakash, R., Venkatesan, S.: Energy efficient schemes for wireless sensor networks with multiple mobile base stations. In: Proceedings of IEEE Globecom, San Francisco, USA (2003)
- [41] Akkaya, K., Younis, M.: Energy-aware to mobile gateway in wireless sensor networks. In: Proceedings of the IEEE Globecom 2004 Workshops, Dallas, USA (November 29–December 3, 2004)
- [42] Juang, P., Oki, H., Wang Y., Martonosi M., Peh, L., and Rubenstein D.: Energy-Efficient Computing for Wildlife Tracking: Design Tradeoffs and Early Experiences with ZebraNet. In: Proceedings of the 10th international conference on Architectural Support for Programming Languages and Operating Systems (ASPLOS), California, USA(October 05-09, 2002)
- [43] Li, J., Mohapatra, P.: Analytical Modeling and Mitigation Techniques for the Energy Hole Problem in Sensor Networks. *Pervasive Mobile Computing*, 3(3), pp. 233-254(June 2007)
- [44] Duroc, Y., VeraG, Andia.: Considerations on the backscattered wireless communication links. *Microwave and Optical Technology Letters*, 55(3), pp. 554–559(March 2013)
- [45] Cho, N., Song, S.J., Kim, S., Kim, S., Yoo, H. J.: A 5.1-uW UHF RFID Tag Chip Integrated with Sensors for Wireless Environmental Monitoring. In: Proceedings of the 31st European Solid-State Circuits Conference (ESSCIRC), Grenoble, France(September 12, 2005)
- [46] Kitayoshi, H. and Sawaya, K.: Long Range Passive RFID-tag for Sensor Networks. In: Proceedings of 62nd IEEE Vehicular Technology Conference, Dallas, USA(September 25-28, 2005)
- [47] Philipose, M., Smith, J.R, Jiang, B., A. Mamishev, S. Roy, and K. Sundara-Rajan. Battery-free Wireless Identification and Sensing. *IEEE Pervasive Computing*, 4(1), pp. 37-45(January 2005).
- [48] Sung, J., Lopez, T.S., and Kim, D.: The EPC Sensor Network for RFID and WSN Integration Infrastructure. In: Proceedings of the 5th Annual IEEE International Conference on Pervasive Computing and Communications Workshops, New York, USA (March 19-23, 2007)
- [49] Liu, H., Bolic, M., and Nayak, A.: Taxonomy and Challenges of the Integration of RFID and Wireless Sensor Networks. *Journal of IEEE Network*, 22(6), pp. 26-35(December 2008)
- [50] Zhao, W., Ammar, M. and Zegura, E.: A Message Ferrying Approach for Data Delivery in Sparse Mobile Ad Hoc Networks. In: Proceedings of ACM MobiHoc 2004, Tokyo, Japan(May, 2004)
- [51] Limin, F.: *Neural Networks in Computer Intelligence*. Tata McGraw-Hill Publishing Company Limited, New Delhi, India (2003)
- [52] Tozlu, S. : Feasibility of Wi-Fi Enabled Sensors for Internet of Things. In: Proceedings of International Wireless Communication and Mobile Computing(IWCMC 2011), Istanbul, Turkey, July 2011
- [53] Harary, F.: *Graph Theory*. Narosa Publishing House, India, 1988.
- [54] Tozlu, S., Senel, M., Mao, W., Keshavarzian, A. and LLC Bosch Robert.: Wi-Fi Enabled Sensors for Internet of Things: A Practical Approach. *IEEE Communications Magazine*, pp. 134-143(June 2012).

