

# Wireless Power Transmission for Wireless Sensor Networks

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**Abstract-** Wireless sensor network is an arrangement of sensors used to monitor and record environmental parameters like temperature, sound, pressure etc and send it to a remote destination for further processing. For these networks, a major limitation is a limited lifetime due to battery constraints which acts as a barrier for large scale deployment. One solution to this problem is wireless transfer of power, also called as 'WiTricity'. In this article we review basics of Wireless sensor network and WiTricity as a solution to energy constraints.

**Index Terms-** Witricity, Sensor nodes, Topologies, Resonance, Magnetic induction.

## I. INTRODUCTION

We live in a world of wireless devices. However battery charging technologies are still wired which requires a charger to be plugged into electrical wall output on one end and the device to be connected at the other end. Another option we

have is using batteries for power sources directly. This is mostly used in wireless sensor network configurations. However, a vital limitation associated to it is that these batteries have to be replaced frequently and hence they cannot be installed in hard to reach locations.

What if we could use rechargeable batteries such that it gets recharged wirelessly on its own? This next generation concept of wireless transfer of power is called witricity. Wireless power transfer (WPT) achieves the same goal but without the hassle of wires. The use of solar energy in energy harvesting WSNs can also be one option and its implementation has increased for practical applications; this is because of the fact that solar panels are easily available and they have a higher energy density as compared to other energy harvesting techniques. This high energy density allows the development of smaller sensor nodes. However, solar power strongly depends on sunlight and can therefore hardly harvest energy during the nighttime and the amount of harvested energy depends on the weather.

## 1. Wireless Sensor Network System Overview

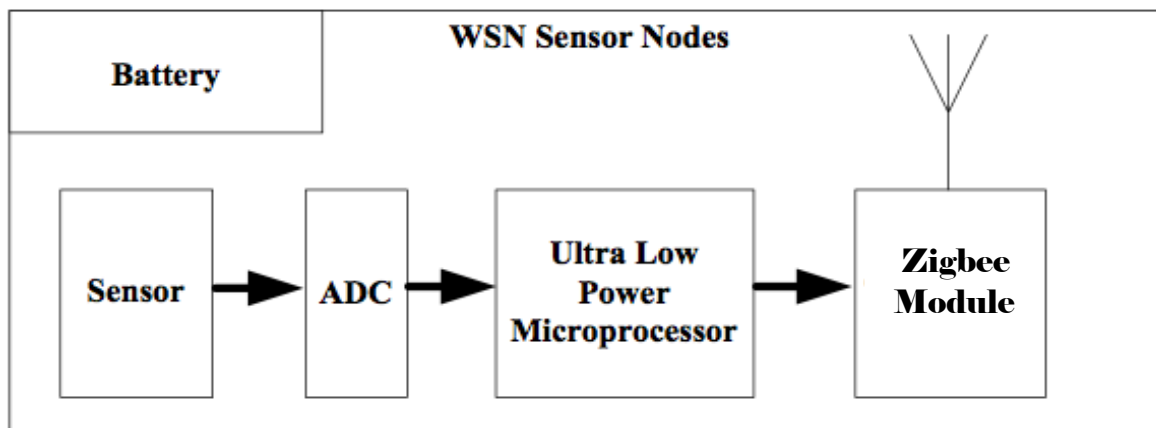


Fig:1.1 Basic Block diagram of Wireless sensor Node.

A WSN can be generally described as a network of nodes that cooperatively sense changes in environmental parameters and may control the environment, enabling interaction between persons or computers and the surrounding environment. The obvious advantage of wireless transmission is a significant reduction and simplification in wiring and harness. Many communication technologies, such as IrDA, Bluetooth and ZigBee, GSM/GPRS (General Packet Radio Service etc.), have been developed for different situations. Nowadays, a kind of real time systems in which multiple sensors connected simultaneously to one gateway unit become necessary, and they are transformed into wireless sensor networks (WSNs). The data is forwarded, possibly via multiple hops, to a Sink (sometimes denoted as *controller* or *monitor*) that can use it locally or is connected to other networks (e.g., the Internet) through a *gateway*. The nodes can be stationary or moving. They can be aware of their location and can also be homogeneous.

As shown in fig 1.1, system architecture consists of multiple sensors and zigbee module on sender side and receiving zigbee module serially connected to microcontroller through which it drives output devices. [2]

We use ZigBee modules based on IEEE 802.15.4/Zigbee Wireless Personal Area Network (WPAN) standard to build low power, low maintenance WSN. Small size, low power, low cost and long battery life are the reason for using Zigbee. Zigbee works with three major devices: 1) Zigbee Coordinator: This is the major part of a Zigbee module there is exactly one coordinator in each network. This device scans the RF signals and thereby selects the one which has minimum traffic. 2) Zigbee Router: It acts as an intermediate device passing the data from other zigbees. 3) Zigbee End Device: It can talk to the parent node but it cannot relay data from other devices. The coordinator is generally programmed with a Personal Area Network Identifier ID (PAN ID). When the device joins the Zigbee network it receives a Network Address which can be used with PAN to communicate. Once this procedure is completed the device starts communicating. Analog to Digital Conversion feature of Zigbee is used to collect analog data from each sensor. The sensors are used for sensing purpose and may vary according to the application this analog data from the sensors is converted into digital data and is given to the microprocessor. The Wireless Sensor Node architecture is further connected to multiple such nodes to hereby form a Wireless Sensor Network.

## II. DIFFERENT TOPOLOGIES

### Bus Topology:

In this topology, there is a node send message to another node on the network sends a broadcast message onto the network that all other nodes see, but only the intended recipient actually accepts and processes the message. Bus topology is easy to install but congestion of traffic and single path communication. However, bus networks work best with a limited number of nodes. If more than a few dozen nodes are added to a network bus, performance problems will likely result.[5]

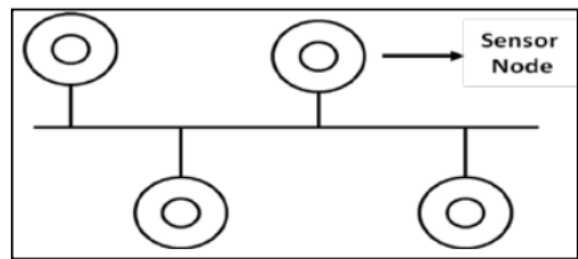


Fig.2.1 Bus Topology.

### Tree Topology:

The network use a central hub called a root node as the main communication router. In the hierarchy, central hub is one level below from the root node. This lower level forms a star network. The tree network can be considered a hybrid of both the Star and Peer to Peer networking topologies as shown in Fig 2.2. In sensor network path may be single hop or multi hop, sensor node for getting data sense the environment and sent them to the sink and sensor forwards them to its parent after receives data messages from its children. It is important to find an optimal shortest path tree with maximum lifetime and shorter delay but slightly high time complexity and but more suitable for distributed implementation. [5]

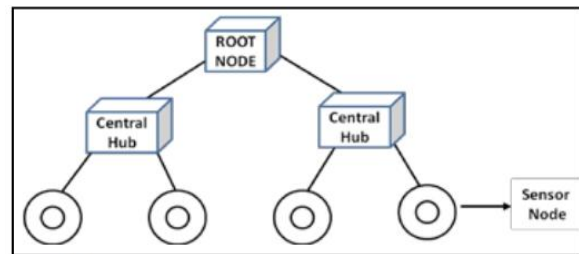


Fig. 2.2: Tree Topology

### Star Topology:

Star networks are connected to a centralized communication hub (sink) and the nodes cannot communicate directly with each other.

The entire communication must be routed through the centralized hub. Each node is then a “client” while the central hub is the “server or sink” as shown in Fig. 2.3. But there is disadvantage of single path communication.

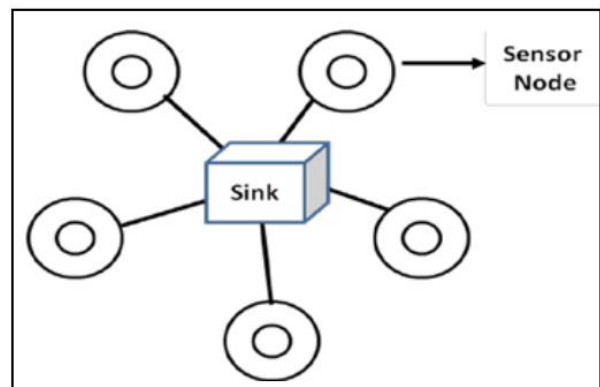


Fig. 2.3: Star Topology

**Ring Topologies:**

In a ring network, every node has exactly two neighbors for communication purposes. All messages travel through a ring in the same direction (either “clockwise” or “counterclockwise”). A failure in node breaks the loop and can take down the entire network. [5]

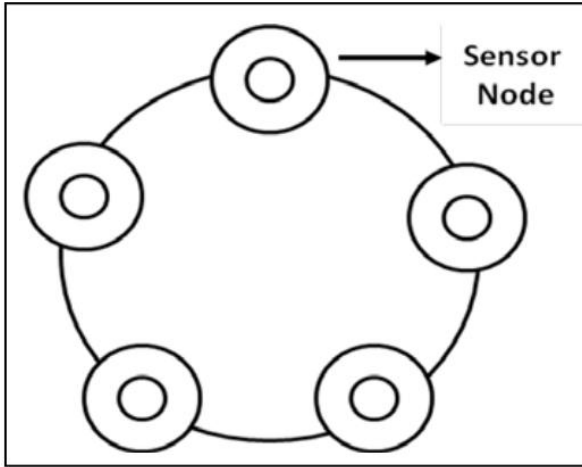


Fig. 2.4: Ring Topology

**Mesh Topology:**

Mesh topologies involve message can take any of several paths ) A mesh network in which every node connects to every other is called a full mesh and there is partial mesh networks also exist in which some devices (nodes) connect only indirectly to others from source to destination. [5]

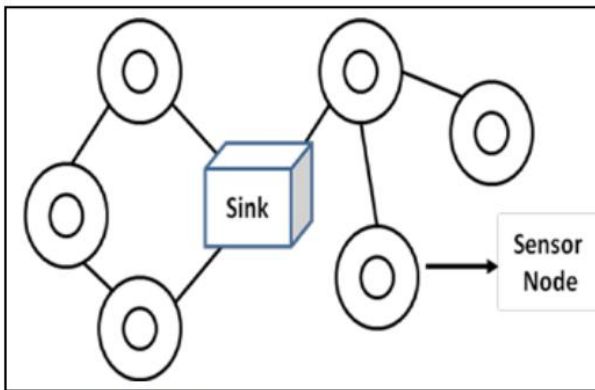


Fig. 2.5: Mesh Topology

**Circular Topology**

In this topology, there is a circular sensing area and that the sensing area has a sink (at center). The sensor nodes sense the event of Interest and transmit these data to the sink. The nodes are randomly deployed with uniform density all around the sink as shown in Fig.2.6. Depending on the distance of a node from the sink and the transmission range of the nodes, data have to traverse single or multiple hops before being received by the sink. The circular web topology is easy to establish, easy to maintain, and more efficient [5].

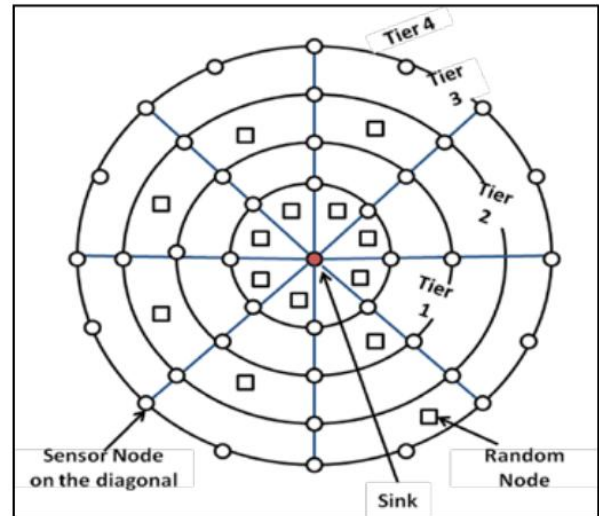


Fig. 2.6: Circular Topology

**Grid Topology:**

The sensor network field dividing into grids is shown in Fig 2.7. The network area is partitioned into non-overlapping square grid with same size. There should be at least one and only one node in working state in each grid at any time.

In order to extend the network life time, the nodes in a grid should work in turn. Inside each grid, one node is selected as a grid head which is responsible for forwarding routing information and transmitting data packets. Routing is performed in a grid-by- grid manner. Grid-based multi-path routing protocol intended to route packets fast, utilize and extend sensor nodes energy in addition to avoiding and handling network congestion when happens in the network.[5]

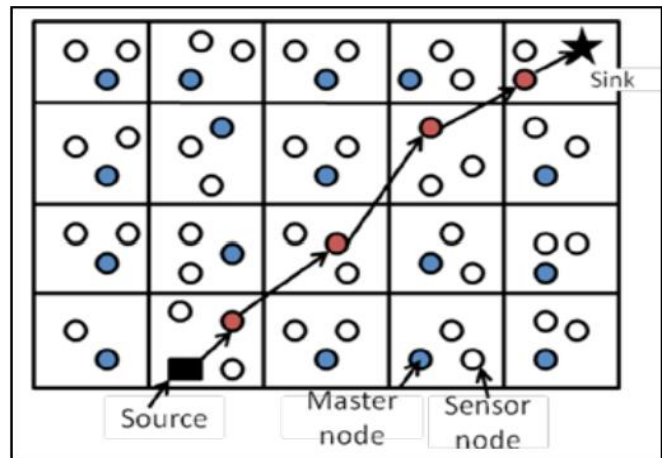
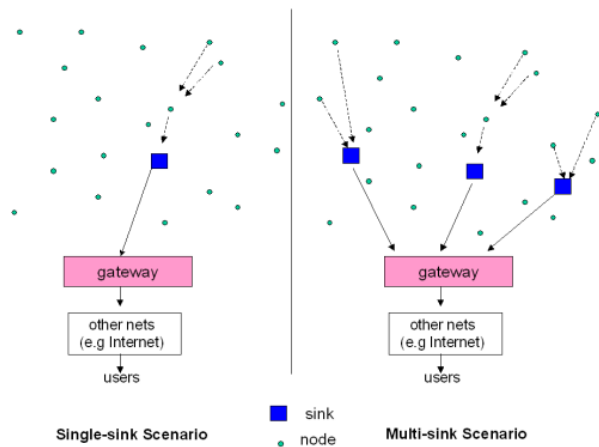


Fig. 2.7: Grid Topology

**III. WIRELESS SENSOR NETWORKS**

Wireless sensor networks can more broadly be defined as several nodes which can communicate with one another via wireless links. There by transferring data via multiple hops to a sink which uses it locally or maybe connected to a network via internet to a gateway. These nodes can be static or dynamic. [1]



**Fig: 3.1 (a) Single-sink Scenario (b) Multi-sink Scenario.**

Wireless sensor networks are of two major types depending on the number of sinks they use. Figure 3.1 shows both the networks. The left part single sink wireless sensor network where the major issue lies with the fact that here several nodes causes the amount of data gathered by the sink to increase. Once the capacity of the sink is attained the network size cannot be augmented. The other type of network as shown in the fig 3.1 on its right is a multiple-sink network. In principle, a multiple-sink WSN can be scalable (i.e., the same performance can be achieved even by increasing the number of nodes), while this is clearly not true for a single-sink network. In many cases nodes send the data collected to one of the sinks, selected among many, which forward the data to the gateway, towards the final user. From the protocol viewpoint, this means that a selection can be done, based on a suitable criteria like, minimum delay, maximum throughput, minimum number of hops, etc. Therefore, the presence of multiple sinks ensures better network performance with respect to the single-sink case (assuming that the same number of nodes is deployed over the same area), but the communication protocols must be more complex and should be designed according to suitable criteria. [1]

#### IV. WITRICITY

##### What is WiTricity?

WiTricity is nothing but wireless electricity. Transmission of electrical energy from one object to another without the use of wires is called as WiTricity. WiTricity ensures that cell phones, laptops, iPods and other power hungry devices get charged on their own, eliminating the need of plugging them in everytime. WiTricity technology is transferring electric energy or power over distance without wires with the basics of electricity and magnetism, and work our way up to the WiTricity technology. Even better, because of WiTricity some of the devices won't enquire batteries to operate. No, this concept of wireless electricity is not new. In fact it dates back to the 19th century, when Nikola Tesla used conduction- based systems instead of resonance magnetic fields to transfer wireless power. Further, in 2005, Dave Gerding coined the term WiTricity which is being used by the MIT researchers today. Moreover, we all are aware of the use of electromagnetic radiation (radio waves) which is

quite well known for wireless transfer of information. In addition, lasers have also been used to transmit energy without wires. However, radio waves are not feasible for power transmissions because the nature of the radiation is such that it spreads across the place, resulting into a large amount of radiations being wasted. And in the case of lasers, apart from requirement of uninterrupted line of sight (obstacles hinders the transmission process), it is also very dangerous. [3]

##### The Concept

WiTricity works on the principle of magnetic induction i.e a loop or coil of conductive material like copper, carrying an alternating current (AC), is a very efficient structure for generating or capturing a magnetic field. If a conductive loop is connected to an AC power source, it will generate an oscillating magnetic field in the vicinity of the loop. A second conducting loop, brought close enough to the first, may "capture" some portion of that oscillating magnetic field, which in turn, generates or induces an electric current in the second coil. The current generated in the second coil may be used to power devices. This type of electrical power transfer from one loop or coil to another is well known and referred to as magnetic induction. Some common examples of devices based on magnetic induction are electric transformers and electric generators [4]. Energy coupling occurs when an energy source has a means of transferring energy to another object. Magnetic coupling occurs when the magnetic field of one object interacts with a second object and induces an electric current in or on that object. In this way, electric energy can be transferred from a power source to a powered device. However, as in case of a transformer, the distance between the coils as well as their alignment plays an important role in deciding the amount of energy transferred and the amount of energy lost to the surrounding. Thus we use resonators to eliminate distance and placements constraints such that maximum power transfer is achieved. Resonators work on the principle of resonant coupling, i.e., by having magnetic resonant coils operate at the same resonance frequency so that they are strongly coupled via non radiative magnetic resonance induction. Under resonant coupling, energy can be transferred efficiently from a source coil to a receiver coil while losing little energy to extraneous off-resonant objects. Compared to inductive coupling, magnetic resonant coupling can achieve higher transfer efficiency while significantly extending the charging distance from a very close range (i.e., distance less than the coil diameter, usually several centimeters) to several times the coil diameter.

##### WiTricity in WSN



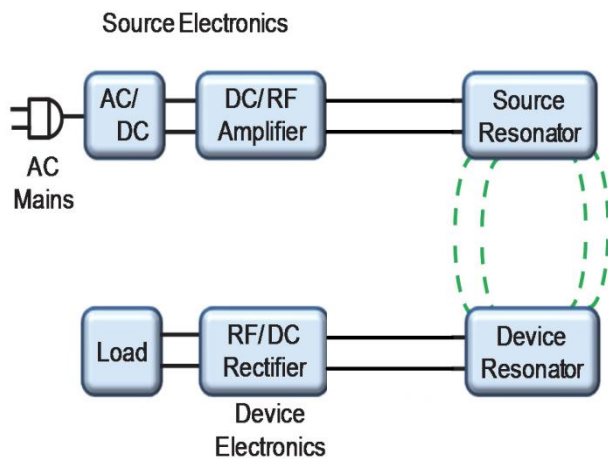


Fig 4.1 Block diagram of wireless energy transfer system

The above block diagram illustrates principle of WiTricity in WSN. It is generally used in applications where node installations are done at hard to reach areas and hence frequent replacement of batteries is not feasible. The charging station consists of an ac to dc converter which converts AC mains into Dc. This is amplified using several stages of amplifier and fed to a resonator circuit. The input resonator at the charging node and the destination resonator at the sensor node operate at the same frequency. Hence the input signal generates a magnetic field in the resonator and an equivalent magnetic field is induced at the receiver resonator. This causes an electric current to be induced at the destination node which is converted to DC signal and thus used for charging the on board battery.

This principle is used in two ways depending on the requirement of the application. In some applications a charging station is installed to continuously charge nearby nodes. Resonant coupling allows several destination nodes to be charged using a single source node. Thus if the controller or monitor station is near to the installed network, charging station can be installed along with monitoring devices or it can be installed separately near sensors. In other applications, such as military, node to node charging is also possible. If battery level in one node falls below threshold, it checks for nodes with greater power levels around its vicinity. Transfer of energy takes place from one node to other using transceivers.

## V. CONCLUSION

In this article, we reviewed the basics of wireless sensor networks and its various architectures. As a focus application we considered WiTricity to eliminate the most crucial drawback of WSN, that of power constraints thus reviewing the basic concept of WiTricity and its working principle. Since its inception, extensive research has been carried out towards the development of this technology. Yet, a lot of areas still need development to design a complete product based on it. The most important finding is that once properly designed, a Wireless power transfer technology, such as magnetic resonant coupling, can offer a WSN infinite lifetime. Tesla once predicted in 1906: "The transmission of power without wires will very soon create an industrial revolution and such as the world has never seen before." This pronouncement was ahead of its time then, but will soon become a reality.

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