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ENERGY SAVING IN WSN EMPLOYING DIRECTED CONNECTIVITY THROUGH ANTENNAS WITH SPECIFIC DIRECTIONAL PATTERNS

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Abstract: Wireless Sensor Networks have been implemented in many indoor applications such as offices, hospitals, laboratories for monitoring the parameters such as temperature, humidity etc. Most of the commercial motes use omnidirectional antenna. There is a heavy energy overhead associated with this configuration. This paper reports the studies on energy saving in WSN employing directed connectivity using Loop, λ/2 Dipole ,Yagi Uda and Log Periodic antenna. Directivity increases energy saving but may be at the cost of redundancy. Optimization is attempted for improving energy efficiency and still maintaining redundancy.

Keywords: Directed coverage; Energy advantage; QoS; Redundancy

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INTRODUCTION

Ad hoc Wireless Sensor Networks use motes with variety of computational and communication abilities. The energy saving due to use of directed connectivity has been reported here. Most of the theoretical aspects of placement and directional characteristics of the variety of antennas have been discussed in the paper. Practical antennas having different directional characteristics are used in communication system. Indoor RF propagation is not the same as it is outdoors. This is due to the presence of solid obstructions, ceilings, and floors that contribute to attenuation and multipath signal losses.

Indoor environment can also be classified as near line of sight (LOS) and non LOS. In near LOS environments, where you can see the base station or the routers such as in the hallways, multipath is usually minor and can be overcome easily. The amplitudes of the echoed signals are much smaller than the primary one. However, in non LOS conditions, the echoed signals can have higher power levels, because the primary signal might be partially or totally obstructed, and generally more multipath is present. Shorter wavelengths have more probability to get absorbed and distorted by a building material.[2.] In large indoor environments, if the wireless sensor network is deployed, such energy losses are obvious. If we increase the power of individual nodes to achieve more coverage, we end up with coverage at the cost of large energy overheads.

Several surveys provide in-depth background research on sensor networks [3-6]. Typically sensor nodes avoid long distance communication with the base station directly. Instead the nodes use multihop communications to improve network lifetime, a lot of research has been done on designing the energy efficient MAC protocols. [7-9].Directional antennas have been used to improve throughput and delay in WSN.[10] Directional antennas provide angle-of-arrival information, which can be used for localization and routing algorithms in wireless sensor networks. Different designs of antennas have been tried to increase the communication range and reduce the number of hops[11]. The directional antenna patterns have been checked for various models where sensing range and communication range may vary randomly [12].

The energy overheads can be reduced significantly by use of larger number of nodes with small range which ultimately require less power as well as improve information resolution. Using these nodes multihop communication can be established achieving reduction in energy overheads.

In this paper Energy overheads with multi hop communication using Loop, λ/2 Dipole, YagiUda and Log Periodic antenna are calculated for obtaining certain level of redundancy with directed coverage is discussed.

1. Theoretical considerations

Omnidirectional antennas provide a 360 degree horizontal radiation pattern. These are used when coverage is required in all directions (horizontally) from the antenna with varying degrees of vertical coverage. Polarization is the physical orientation of the element on the antenna that actually emits the RF energy. An omnidirectional antenna, for example, is usually a vertical polarized antenna. Directional antennas focus the RF energy in a particular direction. Coverage distance increases and effective coverage angle decreases with directional gain. For directional antennas, the lobes are pushed in a certain direction and little energy is there on the back side of the antenna. Directivity (D) is the ratio of the radiation intensity in a given direction from the antenna to the radiation intensity averaged over all directions.

In terms of effective antenna aperture, Ae, power density of plane wave incident on antenna, S and wavelength λ, we can express the power delivered by antenna to receiver as

$$P = S*Ae= (S\lambda^2 D_{0)}/4\pi \ldots\ldots\ldots\ldots\ldots(1)$$

The equation (1) shows that power received is directly proportional to the directivity of the antenna. The power required for omnidirectional antenna is more as it radiates in all directions. As the directivity increases, it is observed that the range increases.

$$\text{Fractional Energy saving} = \frac{\left(Po - \frac{Po}{Pd}\right)}{Po} \ldots\ldots\ldots\ldots(2)$$

Where P_o is Power radiated by omnidirectional antenna and P_d is the power radiated by directional antenna.

2.1 Energy advantage with directional antennas:

Now next step is to calculate actual energy advantage using practically available directional antennas. The power required is calculated using equations (3) and (4). Energy advantage is calculated by further comparing it with the power required for the same distance connectivity using isotropic antenna.

Power required is calculated by calculating the area covered by the directed beam of the antenna.

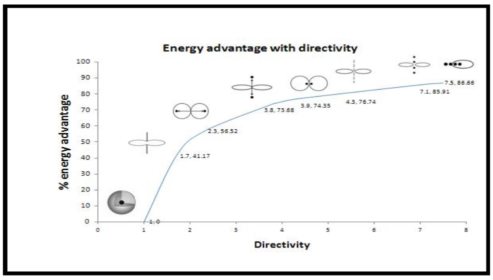


Fig 1: % energy advantage Vs Directivity

The energy advantage increases with the increasing directivity as shown in fig. 1. The isotropic antenna has directivity 1 and radiates energy to all directions. It is observed from fig. 1 that the use of directional antenna is always advantageous in terms of energy saving. But as the directivity increases, the redundancy is lost.

2.2 Energy Overheads to achieve Redundancy:

Now if the node under consideration fails, then connectivity is completely lost. If we try to achieve connectivity with redundant nodes located at adjacent positions, we have to increase the power. This concept is explained in fig. 2

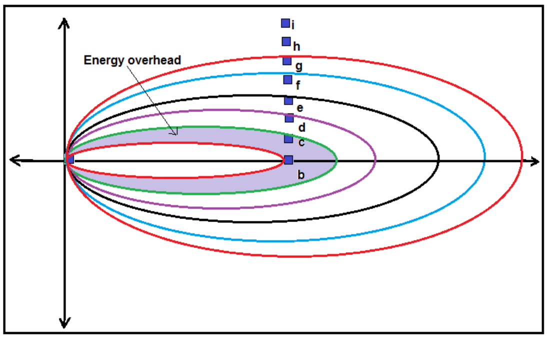


Fig 2: Redundant nodes at adjacent locations

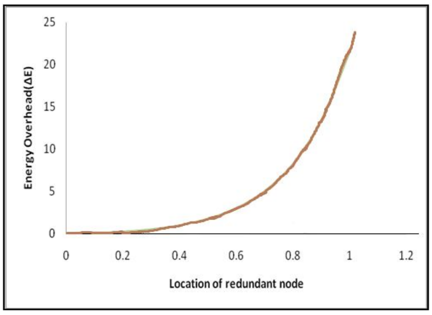


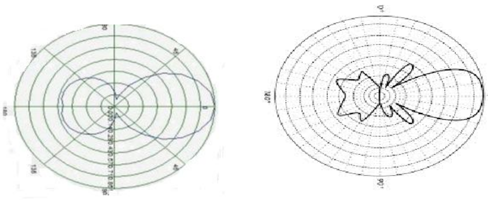
Fig.3: Energy overheads with change in Node location

The nodes ‘b’ to ‘i’ are placed at different positions. The antenna corresponding to the inner lobe covers certain area and if the node is placed above that boundary, then we have to increase the power so as to achieve that coverage. Node ‘b’ is covered by the inner lobe but if we need redundancy so as to achieve coverage of node ‘c’ as well then we have to increase the power by certain amount. This is an energy overhead for that antenna. Similarly we can consider for coverage of nodes c, d, e, f , g ,h or i at different heights. The amount of overhead will increase as we go on increasing the distance of the node from the reference position with respect to the antenna under consideration. Figure 3 shows the energy overheads due to change in the location of the nodes.

When the directional antenna is used , energy can be saved but while addressing the redundancy issue it is disadvantageous. More over we have to increase the power of the antenna so as to achieve reduandancy upto certain level. The amount of power required to achieve redundancy upto say node ‘e’ with the maximum directional antenna is still less than the amount of power utilized by the omnidirectional antenna Thus we can conclude that directional antennas offer energy advantage over omnidirectional antenna depending upon the amount of reduandancy required by the application.

Following section presents the results and discussions on systematically carried out study in this direction. The directional patterns for four specific antennas used in the present study are shown in Fig. 4

Dipole antenna Yagi-Uda Antenna



Log Periodic Loop Antenna

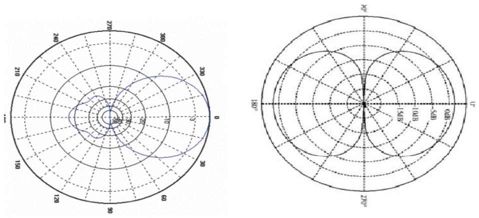


Fig.4 Polar plot for different antennas under the experiment

2. RESULTS AND DISCUSSIONS

3.1 Observations of the Different Antenna Parameter variations

Various experiments were carried out in order to know the practical aspects of different antennas. The transmitting frequency for the setup was kept constant at 750 MHz and the Input Signal power, the distance between the transmitter and the receiver, Angular position of the transmitter antenna were varied and observations were noted. The observations were taken with the help of a RF Detector.

Table 3 Directivity and Fractional Energy saving for antennas

Antenna Type	Directivity	Fractional Energy Saving
Loop Antenna	1.761	0.4321
λ/2 Dipole antenna	1.156	0.1349
Log Periodic	2.25	0.5555
Yagi-Uda antenna	11.8	0.9152

The comparative study for the antennas under consideration shows similarities with the estimated calculations. If it is tried to cover more number of nodes in the vicinity of the network, the power reduces as the distance increases.

3.2 Directional antennas in Indoor Environment

In case of directional antennas placed in the large food grain warehouse, depending upon the three different possibilities of base station positions are considered in this set up. In such scenarios, if omnidirectional antennas are placed, at all locations, it will transmit the power in all directions and hence energy radiated near walls will be wasted.

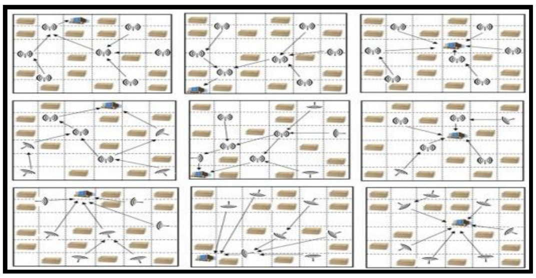


Fig. 5 In Indoor WSN with various arrangements of base station and combinations of antenna

In the matrix of figure 9the upper row shows case 1 where such deployment is demonstrated. In second case, the FGW with the same arrangement but omnidirectional antennas in the middle sections and directional antennas near the walls can save excess energy wasted towards the walls. This arrangement has advantage of flexibility. The interior can be covered and redundancy can be achieved with the omnidirectional antennas. The third row is special case where in all directional antennas are used. This arrangement has advantage of considerable energy saving but that at the cost of flexibility.

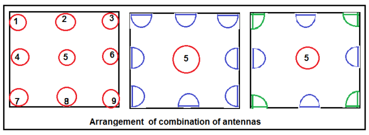


Fig.6 Arrangement of various antennas

Another arrangement of WSNs with combination of Omnidirectional and The three arrangements give 0% , 50% and 60% Power saving respectively. Thus, Combination of Omnidirectional antenna at the center of the Hall and use of Directional antennas at the side walls and in the corner can save more energy.

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