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Beamforming Technique for Satellite Based Wireless Sensor Network (WSN)

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Abstract-Wireless sensor nodes are small in size therefore a single node of wireless sensor network will not able to transmit the data to the faraway location where collector (Base Station) is situated. To overcome this limitation of transmission we try to send the data with the help of beamforming technique. For beamforming, several nodes of wireless sensor network (WSN) send data collectively after forming a linear or planner array. All nodes which are participating in linear or planner array should be synchronized and equally spaced. In such way sensor network (Terrestrial Network) links with satellite network (faraway collector/ base station) which forms satellite based wireless sensor network.

Keywords- Wireless Sensor Network (WSN), Beamforming, Antenna Array, Satellite based WSN, linear array

I. INTRODUCTION

As we have terrestrial and satellite networks. Therefore we try to make it hybrid by adding the advantages of both network and eliminating the limitations of them. We have different roles of hybrid approach of both networks like satellite multicast/broadcast to connect globally, traffic and load sharing, backup solution for critical infrastructure. To connect WSN with satellite/ unmanned aerialvehicle(UAV) / high altitude platform (HAP)[1], we use beamforming technique.

Wireless satellite networks, WSNs have to deal with the issue of consumption of energy. In this regard a technique called beamforming is focused on; it enhances the area up to which a single antenna spreads and thus reducing the overall consumption of energy. A single antenna is usually embedded on sensors which are not very expensive or large.

A beam can be easily directed in the direction needed if the sensors attached closely share their priori information and together transmit in the synchronous manner with the help of array formation. Collaborative beamforming [2] in place of cooperative enables sending beam collectively to the destination. Antennas follow the rules of phased arrays and this principle is strictly followed in collaborative beamforming with various different interesting utilities.Centralized beam forming and distributed beamforming are two common approaches. In the former the same oscillator is used by all the terminals and it has a fixed distance, however in the distributed there are different oscillators and it is necessary to deduce the phases or coordinates the array factor gain can be calculated by taking in following assumptions:

(i) An element called the isotropic antenna is embedded into each sensor.
(ii) The path losses are same for al nodes as they transmit with same energies.
(iii) No scattering or reflection I encountered.
(iv) Coupling effect is nullified as the sensor nodes are efficiently spaced.
(v) Synchronization of the node to reduce jitters or phase offsets for each node.

Coordination of the phases in sensor terminals paves way for collaborative beamforming. The various steps followed are as follows-

The transmitter clocks should be well studied in one approach. The receiver provides no feedback here. However the next approach considers a feedback. It utilizes the adjustments of the phases across the various sensor terminals and the transmitters keep the receiver informed regarding the strength of the signal.

Collaborative beamforming in WSN follows following criteria:

1. The transmission energy which is associated with each sensor is saved and thus with collaborative beamforming, the sensor networks reduce the black spots that arise. The electromagnetic waves come across the receiver with strong signals because each sensor can utilize the power level which is low. There is also reduction in energy loss.
2. Enhancement in the area of coverage results in spreading the sensors with collaborative beamforming, which are given more signal strength and extension in coverage.
3. Beamforming works by securing the data and decreases the flow of signals in unwarranted alleys

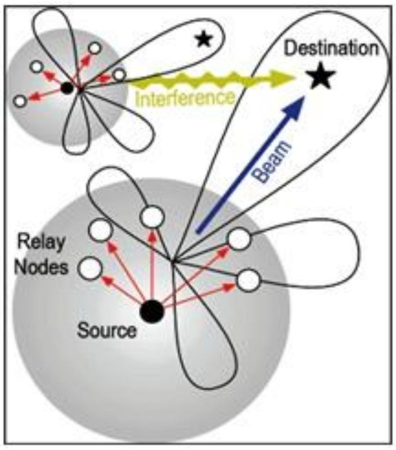


Figure 1.1 Collaborative Beamforming

II. UTILITY OF SATELLITE BASED WSN

Some applications of satellite based wireless sensor network are like remote area accessibility and traceability, emergency communication [3], critical infrastructure and environmental monitoring etc.

Remote Area Accessibility and Traceability:

With the advent of wireless senor networks the environmental and physical compositions that included space and time considerations gave way to an adaptive [4] and on- demand sensing. When we talk about in situ sensors, it is often seen that they work well with space-based sensors. The issues that need to be dealt with such sensors include the following: certain application want installations to be done in remote areas where the terrestrial infrastructure goes for a toss. Second flexible support to particular applications in terms of sensing potentials is required. Finally, the communication should happen in all kinds of situations and hence be robust. Surveillance takes place due to monitoring. Events lead to the generation of data by taking into account threshold parameters. Satellite communications allow data to travel across remote locations [5]. The features should be improved by adding localization of information and accessing information in remote areas. The Collaborative and distributive beamforming help to provide direct link to satellites.

Critical Infrastructures (CI):

One of the most popular applications of the wireless sensor networks is the protection of the critical infrastructures [6] and how to counter terrorism. Critical application areas of defense, power plants and airports need special security such that no data is lost during transmission or illegally accessed. Monitoring and control in CIs require a cost effective technology which can expand to large areas. WSNs require a low cost infrastructure and hence it is easy to be deployed no extra systems of satellites. Since the WSNs are covering a wide area thus surveillance and monitoring can be done easily.

It is the reliability of the wireless networks due to which the CIs can be effectively managed. The recovery mechanism and damage control are also done effectively. If a wireless network is smart enough to point an error condition then it becomes easier to rectify it in time. A WSN that is reliable, provides data integrity, controlled security make it a preferred choice.

Environmental monitoring

When it comes to monitoring the environment, natural changes that take place in due course of time are surveyed. These include floods, forest area monitoring, keeping vigil on animal movements, reporting a weather forecast with temperature control. Thus satellite and WSN should work in unison to provide better monitoring and control [7].

Various applications include:

- Study of pollution
- Afforestation
- Changing soil conditions
- Detection of fire
- Geographical and weather changes
- Control of flood

WSNs and satellite network have the ability to track and monitor in remote areas and this is what makes it the best choice to research on.

III. COLLABARATIVE BEAMFORMING (CB) TECHNIQUE

With this portion we bring to light the quantity of the nodes and characteristics of the antenna that are derived through collaborative beamforming. We have to give an expression for the Euclidean distance which is measured between the ***k-th*** node and the reference location$(\mathbf{A}, \emptyset, \boldsymbol{\theta})$.

$$\mathbf{d_k(\phi,\theta) = \sqrt{A^2 + r_k^2 - 2r_kA\sin\theta\cos(\phi-\psi_k)}} \text{.....(3.1)}$$

We are mainly concerned about the far-field region, because $(\boldsymbol{A \gg r_k})$.where the Euclidean distance can be approximated [2] as

$$\boldsymbol{d_k(\phi,\theta) \approx A - r_k \sin\theta \cos(\phi - \psi_k)}\ldots \quad \text{.....(3.2)}$$

To calculate the exact location of each node with respect to the destination, there phases have to be in sync. Thus for each node at its starting point, the initial phase has to be calculated. This will give the target direction of the receiver. It has been considered that the closed loop method where all nodes have their receivers synchronous with same clock time.Thus the initial phase is$\mathbf{\Theta_k}$ **,** where$\mathbf{\Theta_k = -2\pi d_k(\emptyset_0, \theta_0)/\lambda}$ which is the transmit signal of the node k and λ denotes radio frequency carrier and its wavelength. the realization of node locations

$\boldsymbol{r = [r_1, r_2, r_{3,} \ldots\ldots\ldots . r_{n,}] = [0, R]^N}$and

$\boldsymbol{\psi = [\psi_1, \psi_2, \psi_{3,} \ldots\ldots\ldots . \psi_{n,}] = [0, 2\pi]^N}$,

Then the normalized array factor for *N* sensor nodes, can be given by

$$\boldsymbol{F(\phi,\theta|r,\psi) = \frac{1}{N}\sum_{k=1}^{N} e^{j\theta_k} e^{j\frac{2\pi}{\lambda}d_k(\phi,\theta)}} \text{.....(3.3)}$$

To understand beampattern, an average beampattern is plotted in Figure (3.1) for various values of R and numbers of nodes are 16 and 256 in array.

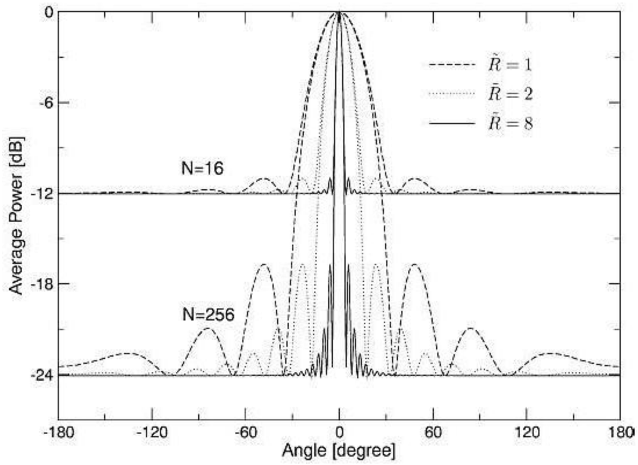


Figure (3.1) Average beampattern for different *R* and N = 16 and 256[2].

IV. PROPOSED MODEL OF LINER ARRAY

Nodes are randomly distributed in a specific area. We want to design an array of nodes in a cluster. Array must meet two requirements to form uniform linear array.

- It nodes in array must be linear
- Inter-node distance between two adjacent nodes must be **λ/2,** where λ is the wavelength (λ = *c* / *f*), *c* = speed of light and *f* =communication frequency of that node.

In that array, one node is decided as Cluster Head (CH). We consider cluster head in the middle of array to perform beamforming but it can be at any position in array. It is also assumed that nodes are distributed in square field

To decide the cluster head, we make circle hypothetically around each node with radius R_1 = Half of the side of square field. Then we calculate number of nodes inside that circle for each node. Which node has highest no of nodes insides hypothetically defined circle (radiusR_1), is declared as cluster head.

After deciding the cluster head, we find another node which is in the range of cluster head and at the distance of **λ/2**. This node becomes a node to participate in linear array formation. We compute the gradient between cluster head and participating node. We apply same recursive method with equal gradient and equal spacing of **λ/2**, at other nodes of WSN. Then at the last we find the nodes which has approximately same gradient. In such way we find linear array and nodes are equally spaced.

Algorithm to form liner array:

Step1- Identify the cluster Head(CH).

Step2- Identify another node of linear arrayat the distance of **λ/2.**

Step3-Select that node as liner array node.

Step4-Compute gradient between CH and node of array.

Step5- Perform Step2, Step3, Step4 for all nodes until we get required no. nodes in a linear array.

Step6- All linear array nodes transmit data synchronously.

Step7- Calculate beamforming gain in dB.

V. EXPERIMENT AND RESULT

Experiment performed on a scenario created in MATLAB simulator. In this scenario following parameter are taken.

Total number of sensor = 200

Sensor deployed area (m^2) = 100
Number of nodes in array = 9
Frequency (MHz) = 300

With the above parameters, We have randomly distributed 200 nodes in 100 meter square area which is mentioned in Figure(5.1). After distributing the WSN nodes, We identify the Cluster Head (CH). Cluster head mentioned in Figure (5.2).

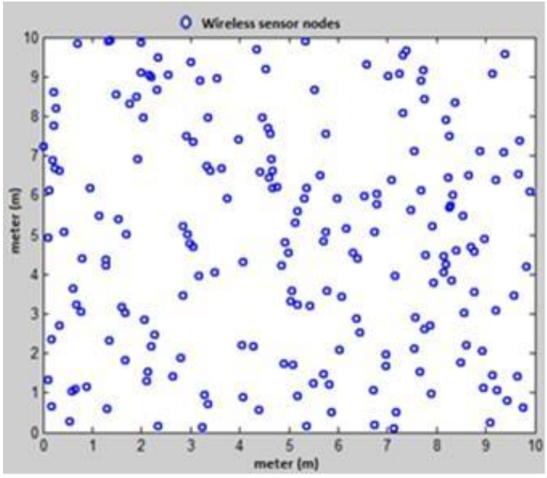
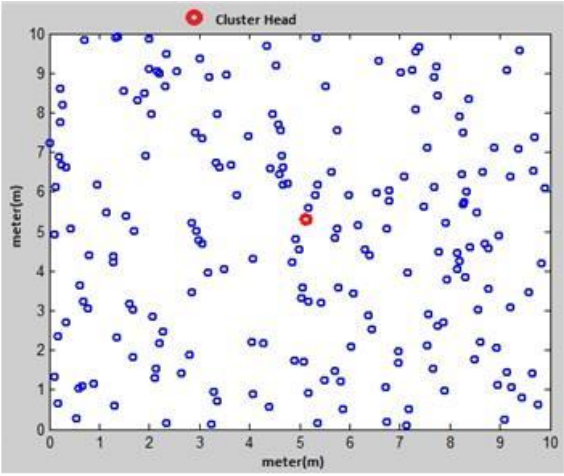


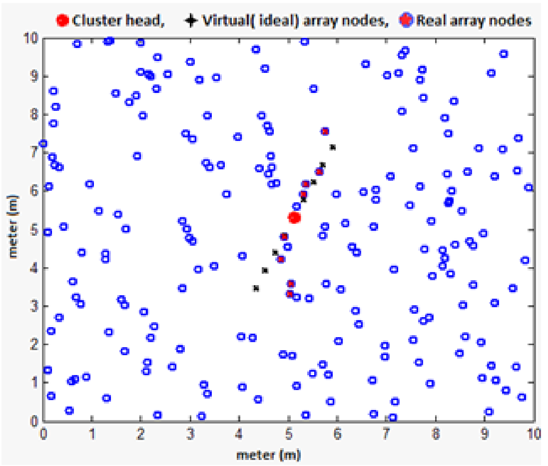
Figure (5.1)- Randomly distributed WSN nodes



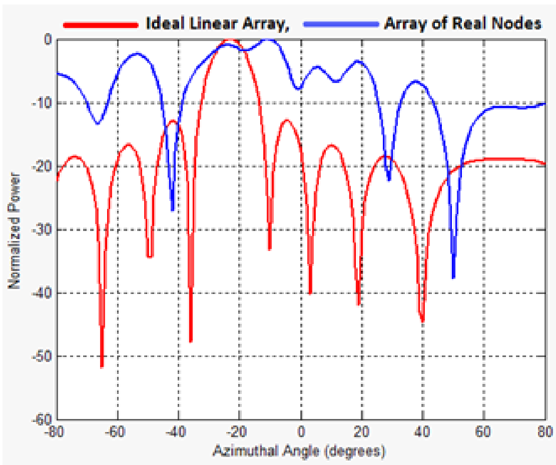
Figure(5.2)- Cluster Head of WSN

As we find the cluster head, We apply the proposed algorithms to find the linear array element, as mentioned in figure (5.3). Red dots are real nodes of a linear array and black dots are virtual line where we were expecting to find the nodes but due to randomization of nodes, real nodes are not present there.

These real linear array and virtual linear array gives resultant beam, which is mentioned in figure (5.4).



Figure(5.3)- Linear array nodes



Figure(5.4)- Beampattern formed by linear array nodes

VI. CONCLUTION

From the above result, we can conclude that beam pattern of real node array (blue color line in figure (5.4)) is close similar to the beam pattern of ideal linear array (red color in figure (5.4)). This is the reason that gain of beampattern of real WSN nodes is approximately equal to gain of beampattern of ideal nodes (virtual nodes). We also know that azimuthal angle of ideal vertical array is zero degree but in figure (5.4), array of real node is slightly incline therefore azimuthal angle is sifted from zero to near about 20 degree. In figure (5.3) Black dot points are ideal linear array nodes and red dot points are real nodes of WSN present in an array which explains that it optimum solution to achieve ideal array.

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