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Hybridization of Satellite-Terrestrial Communication Network

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Abstract: The main concern of this hybridization is to facilitate the mobile users so that they can roam globally and get better services. This is achieved by enhancing the area where the service is provided. It is with the cooperative alliance of satellite network with the terrestrial network that service is delivered efficiently. Cooperative system for broadcast and multicast gave an idea of hybrid satellite terrestrial network in many applications. In the broadcast scenario, we prefer to use low-complexity relaying techniques, which are adopted to overcome the propagation impairments and the performance degradation. In the multicast system, we try to use radio resources management techniques. Improvisation of connectivity, capability and reliability can be ascertained by utilizing approaches like High Altitude Platform (HAP) and Mobile Ad-Hoc Network (MANET) in multicast system. Wireless sensor nodes are small in size therefore a single node of WSN will not able to transmit the data to the far away 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.

Key words: Satellite network, Terrestrial network, Wireless Sensor Network (WSN), Beamforming technique, Linear array.

I. INTRODUCTION

The Global Information Infrastructure (GII) is the desegregation of the terrestrial and the satellite network. Day by day, numbers of users of new technologies are increasing. The communication and network technology is playing a vital role to fulfill this requirement. Fast development in communication and network technologies, has brought different network as a complete whole network. Among the various existing system user can choose mobile telecommunication system, wireless data networks and satellite system for their communication. Integration of satellite communication and network with terrestrial communication enhance the capability of network, resulting in less response delay, localization assistance [1], combining the navigation and the interoperability of communication.

Now a days, internet and GPS like services have been very common so we have to provide better solution to meet users' needs. To develop seamless satellite-terrestrial infrastructure, resource management [1, 2] and network configurability techniques in hybrid satellite terrestrial network need to be addressed. To improve QoS, we must use cognitive network technique [3] in a hybrid satellite terrestrial infrastructure.

Satellite band width is a very scarce resource that comes under the microwave frequency spectrum. The range of electromagnetic energy when between 1GHz to 100GHz describes the microwave spectrum. The 1GHz to 40 GHz range usually covers the frequency range for most common applications [4]. Radio Society of Great Britain (RSGB) has designated the range of microwave frequency bands.

The interconnection between both networks must be dynamic and it must be transparent. Due to these nature frequent changes in topology, difficulties in geographical coverage, services, transmission speed, and physical medium exist. To design such network we have to deal with large no of issues [5]. There is no unique and uniform solutions exist till date for these problems. Therefore we always look forward to design a unique solution for it. First of all we must have some basic knowledge of both terrestrial and satellite communication network before going through hybrid approach.

II. SATELLITE COMMUNICATIONS AND NETWORKS

Satellite works as relay to transmit signal from one node to another. Two or more satellites are connected with each other by inter satellite link. Satellite service is divided into subservices according to their nature. The classifications are mentioned below.

Fixed Satellite Services- Fixed satellite services are all radio communication services among earth stations at fixed point or any fixed point within specified areas or given positions. These services are used nationally or internationally in both analog and digital transmission. Based on network topology, services are varying. Broadcast services like video, television and voice or sound transmission, are included. Fixed service satellite has following user

- Users fixed within isolated land access remote broadband through satellite coverage only. They need terminals for broadband access only. Interoperation of isolated lands is achieved through satellites.
- Users access services within satellite coverage only. They need terminals for satellite access only.

Mobile satellite services- Radio communications services between a mobile earth station or any mobile node on earth and space station comes under mobile satellite services. This communication service from satellite to node may happen with multiple levels. This service has following types of users [4].

- Users travelling in ship or aircraft from one place to another which has various satellite coverage. They want to connect with global network with the help of terminals with dedicated interface to utilize satellite service.
- Nodes are moving within satellite coverage only. They can access satellite without gateway or need terminals as gateway for satellite access.
- Users moving from cellular coverage to satellite coverage and vice versa or user are under the coverage of both cellular and satellite. They want dual mode terminals to communicate continuously and seamlessly. In this case, service provides exchange of information between host and users in both direction and uni-direction where one node is not fixed among all multi-layer or multi-level.

III. THE CLASSIFICATIONS OF SATELLITE ACCORDING TO THE NATURE OF ORBIT

Geostationary Orbit (GEO) Satellite- The satellite must revolve at same velocity as earth is rotating, to provide constant communication. It seems to be fixed above a spot. It is also called Geosynchronous Earth Orbit [6]. Its altitude is approximately 35786 km. We require 3 to 4 satellite for global coverage at a given point of time. There is no need of handover in GEO satellite and one way propagation delay is 250 to 280ms.It is mostly used for video broadcasting (TURKSAT satellites). It is also used for global communication, weather forecast, military application.

It encompasses quarter of the earth's surface and due to this long distance it provides a large cover. Hence, facilitating services for broadcast. But, the point to point connection is hindered because of the not so strong signals with held up signals. For Geo-satellite communication, high transmission power is needed and launching of satellites is a complex and expensive task.

Medium Earth Orbit (MEO) Satellite- Its altitude is 10.000 – 15.000 km approximately. We need 10 to 15 satellites for global coverage. It takes 6 hours orbit period and one way propagation delay is 100 – 130 ms [7]. These are mostly used in navigation system (GPS, Galileo, Glonass) and sometimes used for Communications. MEO satellites cover a wider range of area when compared to LEO satellites but lesser coverage area than GEO satellite [6]. A MEO satellite provides better visibility period and the footprints are large enough than LEO network but more compared to GEO network. The distance of the MEO satellite results in signals which are weak and longer delay in comparison to LEO, though it is better than GEO satellite.

Low Earth Orbit (LEO) Satellite- Covering a range from 500 to 2000 km the distance of the LEO satellite from the earth is less than that of the MEO and GEO satellites. LEO satellites do not follow a constant path with respect to the surface and hence for each pass they appear for 15 to 20 minutes. A network of LEO satellites is necessary to make LEO satellites useful so we need more than 32 satellites for global coverage [6]. Frequent handovers and routing is necessary from one satellite to another in the LEO satellite network for continuation of communication. It has One-way propagation delay of 5 – 20 ms and Orbit period of 2 hours. It is used for Earth Observation, Communications: Globalstar, Search and Rescue. (SAR): COSPAS-SARSAT. LEO satellite network has frequent handover and less coverage area

Unmanned Aerial Vehicle (UAV) and High Altitude Platform(HAP)- It is a aircraft with no pilot onboard and it flies less than height of LEO satellite. It is programmed and remote controlled. It combining information from different sensors for use on onboard the vehicles.[8]

IV. Access Schemes

Monitoring and surveillance of specific area can be done with the help of Satellite-WSN (Hybrid satellite terrestrial network). For particular scenario we have two different approach of satellite based WSN.

Satellite-WSN Communication with Gateway (Sensor Gateway)- In a cluster of sensor we choose most energy- efficient node. In general we call it sink node. In Zig Bee standard, sensor nodes of a cluster try to send information towards sink node. Sink node collect the data and forward to sensor gateway (as mentioned in Figure 4.1). After that sensor gateway sends all composite data to HAP/satellite. In such case we can deploy various useful clustering algorithms to reduce energy consumption by which life time of network can be increased.

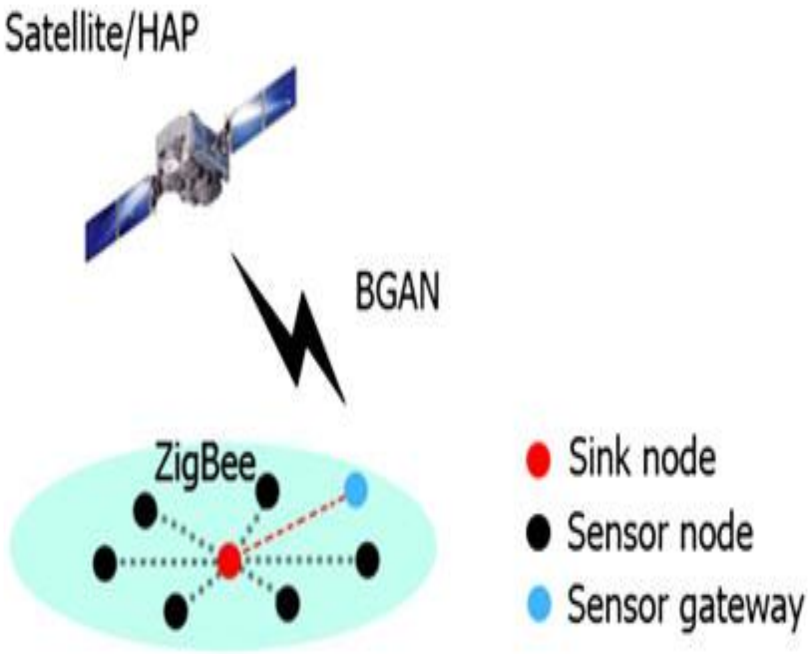

Figure 4.1 Satellite-WSN communication with Sensor Gateway

Satellite-WSN communication without gateway- This is different approach for similar scenario. In this approach direct communication between sensor node and HAP/satellite is establish (as mentioned in Figure 4.2). There is no need of gateway sensor node. Distance between sensor and satellite is very large .Therefore, collaborative beamforming is only away for communication. Collaborative beamforming [9] technique is used for direct communication between satellite and sensor.

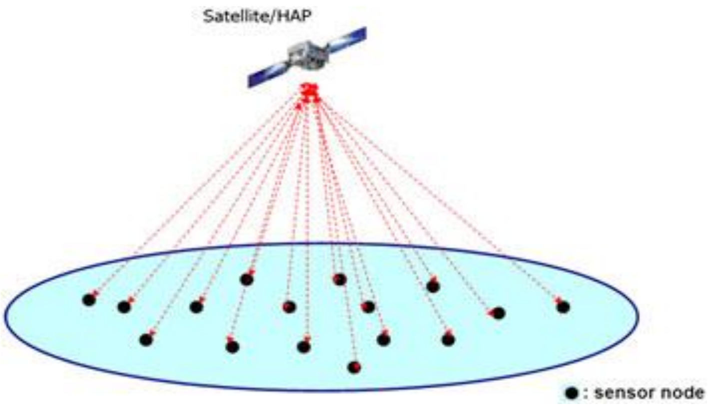

Figure 4.2 Satellite-WSN communication without Sensor Gateway

V. COLLABORATION BEAMFORMING (CB) ANTENNA BEAM PATTERN

To define geometric configuration of satellite based wire sensor network, we use polar coordinates system, as according to figure (3.4), In figure (3.3) the polar coordinates (r_k, ψ_k) are used to give the location of the ***k-th*** node. Where r_k limits between **[0,R]** means $r_k \in [0, R]$ and it denotes radial coordinate. Azimuth coordinates is given as $\psi_k \in [0, 2\pi]$. The spherical coordinates denoted by $(A, \emptyset, \theta)$ are the reference points, where A is the radial and the azimuthal direction is given as θ. The coordinates $(A, \emptyset_0, \theta_0)$give the destination location. 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$(A, \emptyset, \theta)$.(as mentioned in Figure 5.1).

$$d_k(\phi, \theta) = \sqrt{A^2 + r_k^2 - 2r_k A \sin\theta \cos(\phi - \psi_k)} \qquad \text{.....(5.1)}$$

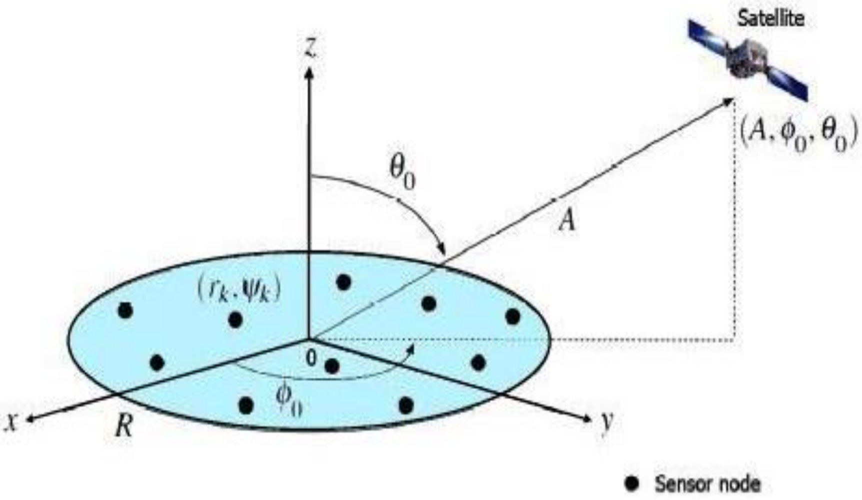

Figure 5.1- Location of satellite (or UAV/HAP) with respect to WSN nodes

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

$$d_k(\phi, \theta) \approx A - r_k \sin\theta \cos(\phi - \psi_k) \qquad \text{.....(5.2)}$$

Then the normalized array factor for *N* sensor nodes[10], can be given by

$$F(\phi, \theta | r, \psi) = \frac{1}{N} \sum_{k=1}^{N} e^{j\theta_k} e^{j\frac{2\pi}{\lambda} d_k(\phi,\theta)} \qquad \text{....(5.3)}$$

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

$$\boldsymbol{r} = [\boldsymbol{r_1}, \boldsymbol{r_2}, \boldsymbol{r_3}, \dots \dots \dots . \boldsymbol{r_n}] = [\mathbf{0}, \boldsymbol{R}]^N \text{and}$$

$$\boldsymbol{\psi} = [\boldsymbol{\psi_1}, \boldsymbol{\psi_2}, \boldsymbol{\psi_3}, \dots \dots \dots . \boldsymbol{\psi_n}] = [\mathbf{0}, \mathbf{2}\boldsymbol{\pi}]^N,$$

VI. EXPERIMENTAL RESULTS

Experiments performed on various frequency domain with different number of nodes (No of nodes = 7 and 9)[10] to calculate the gain of resultant beam on MATLAB simulator. Following criteria are mentioned for experiments.

1- Frequency (KHz)- 300.

2- All nodes in an array must linear and equidistance.

3- Space between nodes in an array is

Case 1- λ,

Case 2- λ/2,

Case 3- λ/4.

4- Each node in an array must be isotropic.

It means that gain of each antenna should be unity (Gain = 1) individually.

In the following graphs **x-axis** is Azimuthal Angle (Degree) and **y-axis** is Normalized Power(dB).

Case-1 (Space between nodes - λ.)

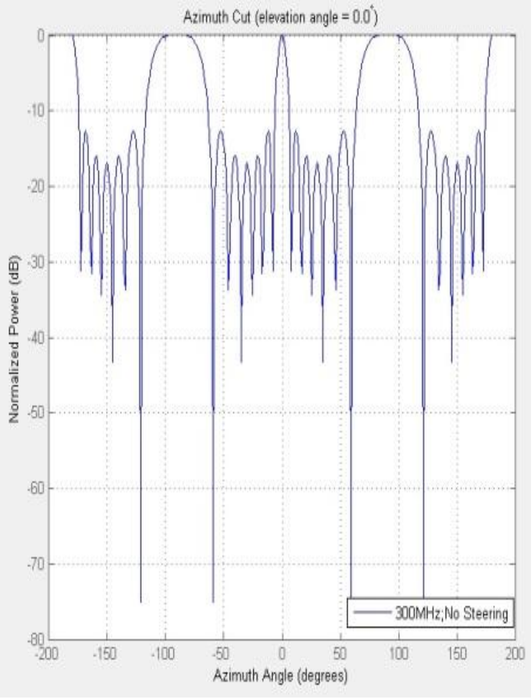

Fig.6.1-Beampattern when No. of nodes in array is 7.

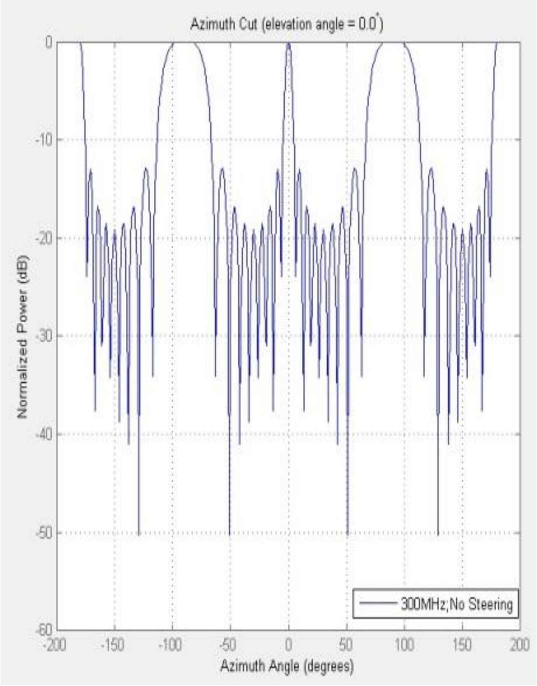

Fig.6.2-Beampattern when No. of nodes in array is 9.

Case-2 (Space between nodes - $\lambda/2$)

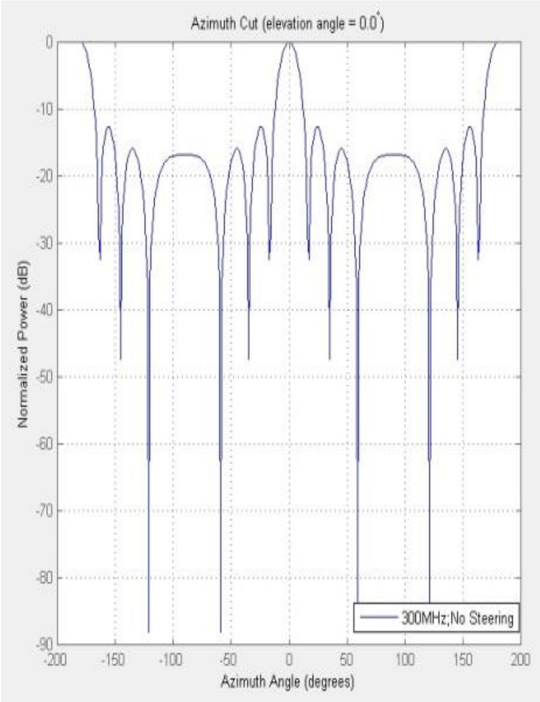

Fig.6.3-Beampattern when No. of nodes in array is 7.

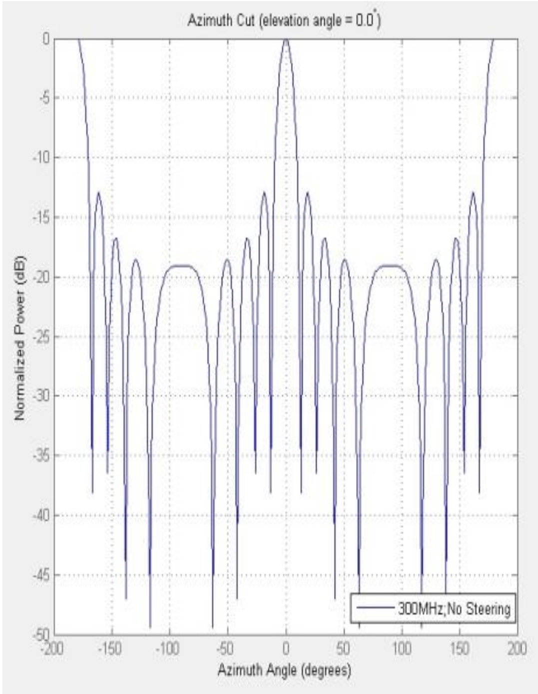

Fig.6.4-Beampattern when No. of nodes in array is 9.

Case-3 (Space between nodes - $\lambda/4$)

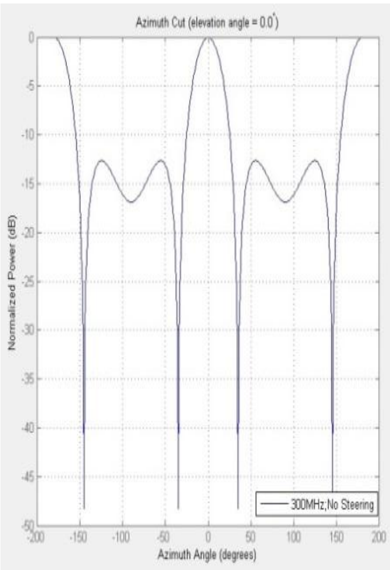

Fig.6.5-Beampattern when No. of nodes in array is 7.

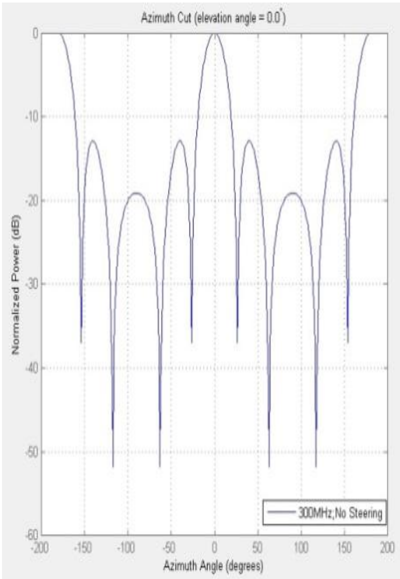

Fig.6.6-Beampattern when No. of nodes in array is 9.

Total linear array gain:

Gain (When number of nodes in array is 07) = 8.45 dB

Gain (When number of nodes in an array is 09) = 9.54 dB

VII. Conclusion

It is represented in the above graph that $\boldsymbol{\lambda/2}$ and $\boldsymbol{\lambda/4}$ spacing between nodes is providing beam at 0 degree azimuthal angle but $\boldsymbol{\lambda}$ spacing between array nodes is providing beam at 90 degree azimuthal angle.. Therefore according to users need we set the spacing between nodes in an array. It is also a concern that when space between nodes is $\boldsymbol{/2}$, beam is more convergent compare to the beam which is formed with $\boldsymbol{\lambda/4}$ spacing between nodes.

We also observe that as number of nodes in an array is increasing, gain is also increasing. It is mean that isotropic antenna collectively providing a directional beam with high gain. In this way WSN nodes form an array and transmit data collectively to

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a faraway collector or base station (HAP or UAV), After that UAV or HAP will send the data to satellite. In such way, communication completes between WSN nodes and the satellite nodes.

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