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Space Based Wireless Sensor Network: A Survey

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Abstract: In the recent years, the advancement in the technology has increased the need for earth observation, space exploration and Multimedia applications. Single huge satellite was used to meet application mission. This results in significant design complexity, where probability of functional fault is high, resulting in failure of the entire system. Other issue is the restriction on the amount of mass that is permitted to be put in the orbit. This avoids space debris caused due to satellite failure. The recent survey believes that space propulsion can no more support physical limitation of single large spacecraft. To reduce the impact of single large satellite, small distributed satellites are used in space [2] [3]. A significant breakthrough in terrestrial wireless sensor network has motivated to extend WSN to space applications as well. Here small satellites refer as nodes. The group of small satellites work collaboratively to form a distributed network very similar to WSN. This distributed structure of satellites forms Space Based Wireless Sensor Network (SBWSN). The capabilities and challenges of SBWSN with respect to launch mechanism, topology formation, communication protocols, routing protocols in stringent space environment are discussed.

Keywords: SBWSN, Small Satellites, Launcher, Deployment, Internet Protocol

1. Introduction

The space launch of small satellites is not new; it waves back in 1950's with the sputnik-1 as the first of its kind. Earlier the satellites were of low mass and low cost with limited functionality used for earth observation and for scientific data. Later due to increasing demand and growth in launching technologies increased the size to accommodate wide variety of functionality. The advent of computational extensive hardware and amateur radio resulted in increase in functionality and also in size resulting in Micro satellites. The first micro-satellite was launched in 1980, later many large computational intensive satellites were launched to meet the increasing demand of both scientific community and commercial applications. These phenomena of having single large satellite was a major concern, due to launch failure, module failure, functionality failure resulting in mission failure which incurs a huge loss [1]. To overcome this problem with large satellites, small satellites were designed which collaboratively work to reach the end goal very similar to the terrestrial WSN. Unlike terrestrial environment, space environment is still a mystery. The satellite network architecture, control strategies, communication protocol, inter satellite link and dynamic routing, automatic fault control etc., is more complex in space.

The space network still shares many similarities of wireless sensor network like small size, low cost, low error rate, high throughput, reliable network, self-adaptation network, energy efficient system [2]. One of the important objective is to adapt concepts of terrestrial WSN to Space and obtain a practical cost efficient miniaturized network. Objectives of SBWSN is to adapt concepts of terrestrial WSN to Space and obtain a practical cost efficient miniaturized low cost network [3] [4] [2].

In this paper we emphasize on small satellites capabilities, satellite launcher, deployment mechanisms, network topology and system requirements of SBWSN. This paper provides convincing opinion of SBWSN is better, compared to single large satellite.

2. Small Satellites

Miniaturization of satellites is the key factor of SBWSN. In the last few years [5] various technological capabilities of small satellites are demonstrated. In 1960 the group from California first developed a Nano satellite called OSCAR1 (Orbiting Satellite Carrying Amateur Radio) weighing a mass of 4.5kg. This small satellite covered 28 countries in 22 days and demonstrated simple Morse code using VHF band. This was the first time small satellite was demonstrated. Several other satellites like UoSat-1, UoSat-2, SME etc. were developed and launched for various application demonstrating the capabilities of small satellites. Initially these small satellites were used for a specific application of either monitoring a particular swath of earth or one/two parameters of scientific data.

Further the design of CubeSat created by Professor Jordi Puig-Suari and Professor Bob Twiggs has led a standard [2]. The standard specifies that 1 unit measures 10*10*10 cm^3 and shall weigh not more than 1.33kg with power consumption of few watts and data rates less than 1Mbps. CubeSat are designed, built, tested and launched from past few years. The cost of the entire mission is in the range of \$50, 000 − \$200, 000. This is comparatively cheaper than large satellite mission ranging in millions of dollars. The statistics of CubeSat mission launched for earth observation and its susceptibility of failure. This system architecture of small satellite helps in determination of the payload capabilities for application mission.

2.1. System Architecture of Small Satellites

The satellite consists of various subsystem namely attitude determination & control System, Command & Data Handling System, communication subsystem, electrical power subsystem and payload as shown in the figure 1.

Attitude Determination and Control System: Attitude Determination and Control System is also known as ADCS. The ADCS module estimates the orientation of the satellite and provides de-tumbling and stabilization to the satellite. ADCS is the most complex and expensive subsystem among other on-board subsystems. This becomes much more challenging with small satellites of low mass and impact of solar radiation, magnetic field and torques from sun and earth. The stabilization of the system is either passive determination or active.

Few passive stabilization methods include Gravity gradient (5^0 accuracy), Spin stabilized (1^0 accuracy), Dual spin, Momentum bias (1arcsec). Few examples of the sensors used in ADCS are Earth sensor, Star Sensors (ASTRO 10, ASTRO 15 and ASTRO APS), Gyros, Rendezvous and Docking Sensor RVS, Fine Sun Sensor FSS Sensors, magnetometers. The ADCS design considerations are shown in the figure [22] [6].

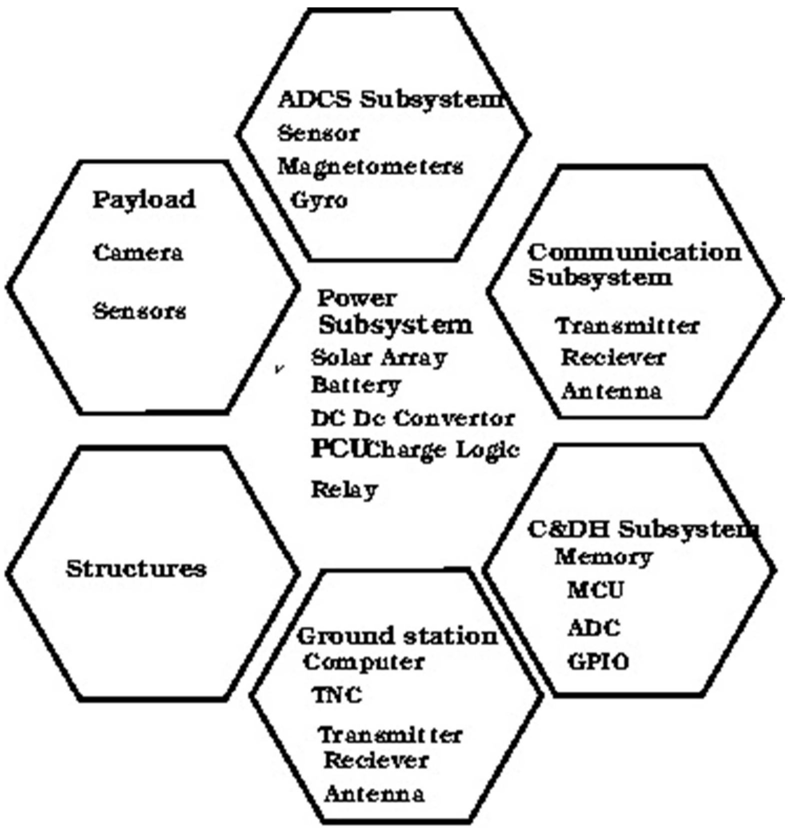

Figure 1. *System architecture of Small satellites.*

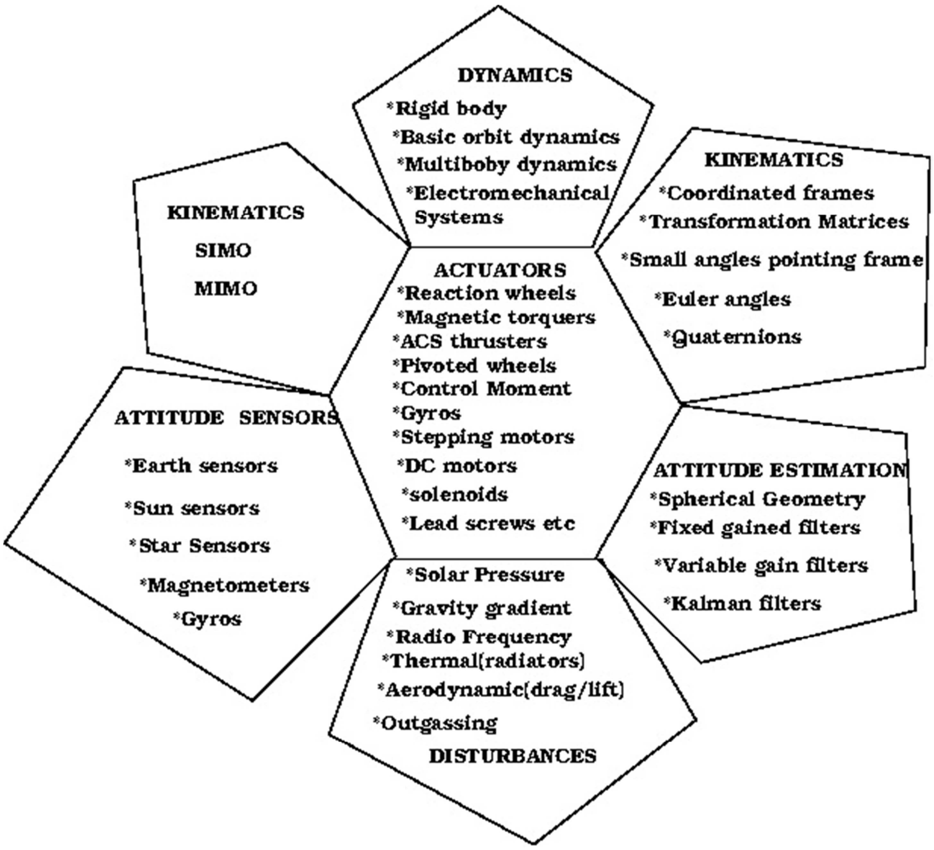

Figure 2. *ADCS engineering consideration.*

While the active control uses control laws for stability are Kalman filter, LQ methods, Gauss law, PID controller. The ADCS consists has three wheels with 2 × 51N ms and 2.1N ms yaw which spin at $\pm 1.6^0$ with L mode for speed control. The Texas Processor (TISBP 99890 a 16-bit processor is used for control law implementation with error detection and correction using hamming code.

There are still few errors which result during determination and control process which include Controller Error, Hardware Error, Sensor Error, Orbital State Error, Disturbance Torques, Ephemeris Error and Actuator Error. These are short term, medium term or long term error [7].

2.2. Communication Subsystem

The increasing demand in multimedia applications and real time monitoring would require both high temporal and spatial resolution. Distributed network of satellites is one approach to satisfy these needs. The communication between the satellites and the ground station is essential, as it becomes the backbone for satellite distributed network [8] [3]. Thus communication subsystem plays a major role in determining the mission capabilities. The traffic load, transceivers, antennas, orbital motion, network timing, handoff, routing protocols and link activation are determined based on communication subsystem. The communication subsystem has inter-satellite communication, Intra-satellite communication and ground station communication.

1. *Ground station communication:* The satellite communicates to ground station and delivers the data payload to the ground station at perigee. The ground station communication depends on the distance from the earth to the satellite and position of the orbit. The small satellites approximately 2 × 10 minutes once in every 12 hours with a transmission window of 90 minutes. Increasing the number of contact and using interconnected ground station points increases the delivery of payload. Generally, commercially-Off the shelf transceivers are used to communicate to the ground station using AX.25 protocol. The data rate varies based on the transceiver power and the attitude of the satellite orbit. Typically, data rate ranges from few hundreds of bytes to few kilo bytes [9].
2. *Intra-satellite and Inter-satellite communication:* The communication links between the satellites in different planes is called as Inter-satellite communication links (ISL) and the communication links between the satellites in the same plane is called as Intra-satellite links [8]. Both the communication links are bidirectional and the propagation delay remains constant for Intra-satellite link and varies for inter-satellite links. The communication range of these ISL in space ranges from 1-2000 km with 802.11 standards. The inter-satellite communication depends on the transceiver, spectral band and bandwidth [10] [11].
3. *Antenna models:* There are various antenna models used for communication for SBWSN. Patch antennas, a single fixed mount, antenna array, mechanically

gimbaled antenna etc. are selected based on the surface area of the satellite, receiver sensitivity, area of coverage, pointing angle, beam-steering and antenna aperture [3].

2.3. Electrical Power Subsystem

EPS is the first system to be active after the deployment of the satellite in the space. The first operation of the EPS is to melt the nylon wire to release the antenna system and the payload in space. The source of electricity for any satellite is obtained by Electrical Power System (EPS). EPS is a subsystem which involves generation, storage and distribution of the power to all the subsystem in the satellite. During the launch the kill switch prevents the power supply to the satellite. The mission life is also determined by the performance of EPS in the satellite.

The general architecture of any satellite EPS consists of solar panels, DC-DC convertors and control system as shown in the figure 4. Deployable solar arrays or solar panels mounted on the surface are used for power generation. There are various types of solar panels like standard 12 solar panel, skirt solar panel, side and Top solar panel etc. These solar panels are fabricated using photo voltaic cells, Si, CMOS, GaAs or silicon on insulator, chemical fuel, piezo electric method etc. The solar cells types and its efficiency is shown in the table I. The mass of the batteries is placed at the center of the satellite to balance the entire satellite. Maximum Power Point Tracking (MPPT) is a method used to track maximum operating point of the solar cell for maximum utilization at different conditions using different strategies like Perturb and observe incremental conductance and Constant voltage [12].

Table 1. *Solar Cell Technologies.*

Cell type	Practically Efficiency
Silicon	14.8%
Thin sheet amorphous Si	5%
Gallium Arsenide	18.5%
Indium Phosphide	18%
MultijunctionGaInP/GaAsp	22.0%

The EPS subsystem is built on the PCB with various layers. One such eps system has 6 layers of PCB, with more than 900 components having 10mΩ at ground plane resistance between the opposite corners. Solid tantalum capacitors are used for to reduce the noise and voltage fluctuation on Power bus (secondary bus) [5]. With all the latest techniques still power harvesting solar system provides only 30% efficiency producing 1.2W. Further is up converted to using charge pump. There are various batteries used in general like A123 APR18650M1A cells which use lithium-ferrite phosphate cells ($LiFePO_4$) which overcome the i-memory effect compared to normal Li-ion cells but $LiFePO_4$ heavier than Li-Ion battery. Due to this disadvantage some satellites still use LI-Ion battery which provide 12Wh at -5^0 to $+5^0$v(500mA). EPS has a protection circuit for main power bus and alternative secondary bus [13].

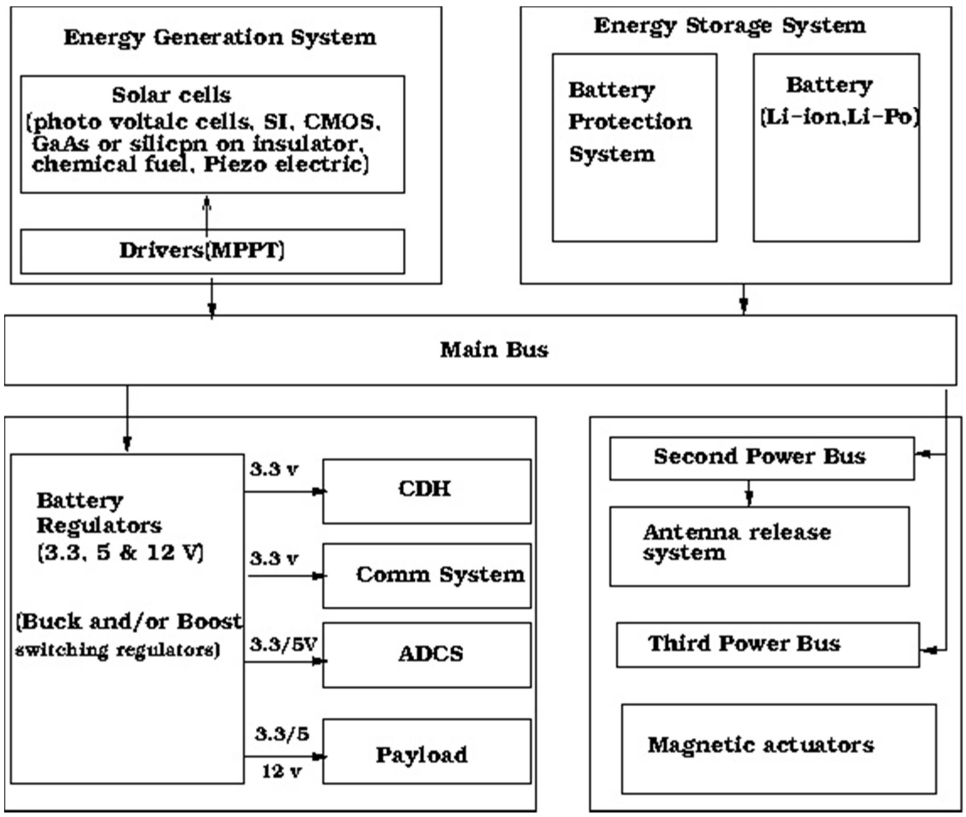

Figure 3. *Internal diagram of EPS subsystem.*

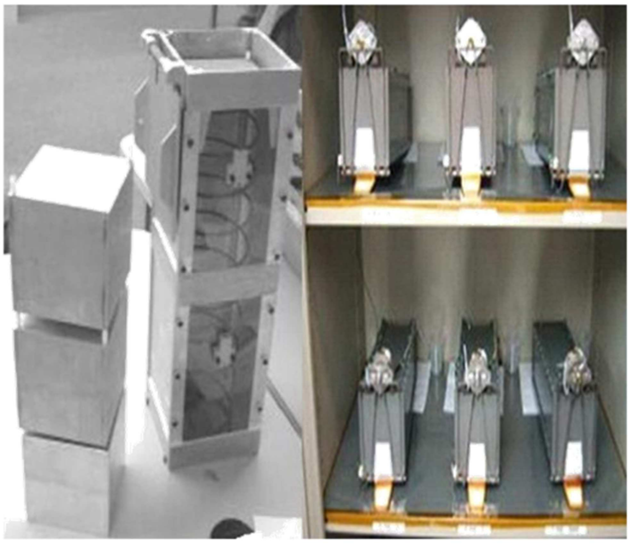

Figure 4. *Launch Stack of Small Satellites.*

Micro-controller also performs the tasks of managing beacon, logging and telemetry operations. The function of second power bus has constant supply of 200mA at 5v is to power the peripheral and also provides a failsafe path. This SPB also perform monitors the MPB failure and informs the processor before the complete shutdown of the system. Approximately 80ms is the time available from the time of MPB failure and the processor to take required operations. The TPB mainly consists of few mosfets, capacitor and a logic control. TPB is simple circuit as its main function is to drive DAC. Battery power circuit protection, centralized power regulation system, energy harvesting system has redundant circuit to ensure reliability of the system.

3. Launcher

The launchers carry the satellite to the space. Some examples are Spacecraft, Lander or Rover. The type of launcher is based on the mass that the launcher can hold. Launching of the satellite depends on the determination of optimum trajectory for the prescribed orbit. The launch trajectories can be direct ascent or Hohnmann transfer ascent. The selection of the trajectories methods depends on the destination orbit. The small satellite can be primary or secondary payload based on the vehicle fairing. Some of the examples where these satellites are secondary payload should follow the standard specification of the stack structure to hold the satellite in launcher fairing [2] [33]. Their exist several stacking mechanisms in the launcher like Canister, carriage launcher stack, single stack and multiple stack. Some of the commercial launch vehicles used for small satellite deployment are Poly-Picosatellite Orbital Deployer (P-POD), T-POD, X-POD, SPL, ISIPOD etc., as shown in the figure [14] Other example include pallet structure which had a central located motor to deploy the satellites in the pallet that holds multiple satellites. other is the shell structure which hold satellite in the lower part of the launcher which itself occupies a volume and mass in the launcher. Thus it is essential to have a launcher stack structure that occupies less volume with low mass and increase utilization of the space inside the launcher considering its additional torque generated due to the launcher stack itself [15].

Launcher is also used for satellite deployment for planetary exploration. These launch vehicles deploy multiple nodes at the same time. The launch vehicles are selected based on the location like air or ground. It also depends on the precision required, available resource and power. Ground launch system (GLS) is best suited for hard environmental condition. In (GLS) nodes are deployed at considerable distance. GLS is slow velocity system, but are efficient with respect to accuracy, power, reliability and robustness. The RF-WIPE is one example of GLS that is able to reach the target with in 2m circle with a distance of 40mts. They have UAV are best suited located placement (complex and power consuming) and for statistical for coarse deployment (cluster bomb or dropping of nodes) and later self-localization algorithms can be used to form a network. Other approach is by using rovers for both located and statistical placement. [16] [17].

The statistics show the more than one third of nodes fail due to launch failures. Major players in SWSN are USA followed by Russia, India, Japan, China and Brazil. Mission success depends on launch success. We see the statistics of mission success and the launch success. Since 1997 around 77 small satellites were launched in 25 launches.

Deployment

The distributed network architecture mainly depends on deployment and topology formation of nodes. The deployment process determines the sequence of deployment of satellite, single launch or multiple launch, number of satellites, orbital injection and formation of topology. Unlike the terrestrial WSN, node deployment in SBWSN is a continuous process in space. In interplanetary deployment the initial deployment of nodes position and orientation are imprecise. Accuracy between nodes varies from application to application and from node to node. For example, in planetary exploration border access control require precision in centimeters (cms) thus self-localization (using beacon systems, stellar positioning and/or odometer) is used to organize to form a network. New nodes can be added subsequently based on the application or replace failed nodes [18]. New nodes added after established network, autonomously configure to network and network recognizes the new node. Mobility in deployment can also be used by the nodes to achieve the coverage area and maintain the distance between the nodes during self-organizing. [19] [20] The location of deployment is based on application, launch opportunity and coverage area. Many are deployed in polar sun and non-sun synchronous orbits as the orbital apogee is low in LEO (600850) and inclination of 100^0. Typically, satellites are deployed at relative velocity of 1.5m/s. Separation velocity is 188msis acceptable. The drift of nodes is approximately 10km/day. This is one main reason for reduced life time of SWSN. Hence nodes forming the network are sometimes referred to as mobile sensor network [21] [22] [23]. All neighboring nodes work collaboratively and most of the times nodes are uniform in functionality and ability. The communication distance depends on the sensing range of the nodes and in turn relies on the deployment formation. Here are few protocols like Full coverage, Virtual force and partial coverage used for deployment formation [24] [25].

4. Distributed Networking

The process of two or more satellites combined to perform a particular task is known as Distributed satellite system or distributed satellite mission (DSS) as shown in the figure 5. The first DSS was demonstrated using 3 satellites in 1963, later 66 satellites constellation were used, for mobile users to provide global communication. This concept of DSS was enforcing the researches to use many small satellites using distributed processing to achieve the objectives of single large satellite. The WSN has proved well on land and underwater. The space shares many similarities of terrestrial WSN [20], hence researchers envisage a huge scope to realize WSN in space, considering the small satellites as nodes (including Nano, Pico, Femto satellites). This marks the beginning of space based wireless sensor network (SBWSN). Small satellites (like Nano and Pico satellite are now forming a Distributed Satellite based Wireless Sensor Network (DSWSN) that collaborate themselves to establish a satellite based wireless sensing network which actively participates in creating a smart environment. Thus small satellite (like Pico/Nano satellites) provides perfect platform for realizing SBWSN [26] [27].

The network architecture in DSWSN has three different classifications in formation of distributed network in Space namely

1). Constellation
2). Formation flying and
3). swarm/local cluster [2] [8]

Constellation: A group of satellites are said to be in constellation, if each of the satellite in the orbit after deployment is controlled by ground station. The satellites in orbit don t interact with each other for maintaining its position in the orbit. There is no on-board controlling process [9].

Formation flying: A group of satellites are said to be in formation flying if they maintain the relative distance between them with the on-board control system. The satellites interact with each other, to maintain the formation of the satellites. There are several ways of implementation the formation like one leader and the rest are followers where all the followers follow the leader as the reference or the entire system of satellites in formation is controlled by a single satellite, or else each one takes their own measurements and later collaboratively realign to maintain the formation intact.

Swarm/cluster: The group of similar satellites coordinated to achieve a common task is known as cluster of satellites. Swarm is basically referred when; formation is using biological inspired methods. These satellites determine their own position and align themselves by their relative position comparing with the neighboring satellites, such that coordination is maintained to perform the task collaboratively [28].

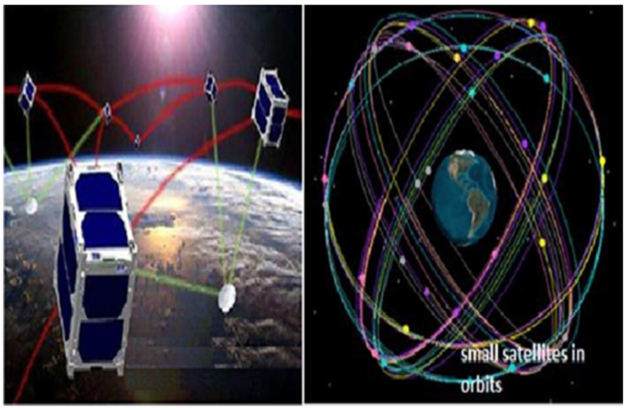

Figure 5. *Distributed Network of Small satellites.*

DSWSN provides access to information anytime, anywhere by collectively processing, analyzing and disseminating data. These advantages also come with some challenges. The current challenges in DSWSN are the deployment, formation flying of the satellites, scalability, time synchronization, routing, power crunch (generation and store), ability to withstand harsh environmental conditions, ability to cope with satellite failures, mobility of satellites, communication failures, heterogeneity of satellites, scalability, limited communication spectrum and bandwidth.

Topology formation in distributed network has few design considerations like launch orbit type, shape of the orbit, mass of satellites, number of satellites, swath coverage, altitude control, orbital velocity, relative velocity, angular distance, orbital drift, drag, perturbation, solar radiation pressure, avoidance mechanism of orbital debris etc.

The other option to increase the efficiency of the EPS sub-system is by distributed design that locally reduces the loss by switching off the inactive modules and reduced transmission thereby increases the overall performance of 86% and low power consumption.

Orbital Impact

Orbit is one of the key deciding factors for satellites mission. The altitude control, orbital drift, drag, perturbation, solar radiation pressure, orbital velocity and avoidance mechanism of orbital debris avoidance is determined by the orbital mechanism. The injection velocity required during launch of satellites in space also depends on the orbital mechanism. Orbit decides on possible swath, temporal and spatial resolutions. The gravitational force plays a vital role in the determination of the orbit or knowing the orbit, we can determine the gravity using global gravity model. These in turn help in determining the air drag. The shape of the orbit generally used for satellites launch can either be circular or elliptical. Center for Orbit Determination in Europe (CODE) have some set standards which helps in determination of computation of orbits. Here we list some of the basic orbits parameters that one has to consider for satellite mission.

Orbital Debris: Space waste is also known as space debris. There are two types of debris namely

a) manmade debris.
b) Natural solar debris.

The natural debris are resulted due to solar storms and are quite dangerous as the large flux damage the components, due to gradual electrical discharge. The man made debris due to launch failure or failed satellites or non-active satellites. It will be surprising to know that 20,000 metric tons of material is being placed in the orbit from the beginning of space exploration since 1957. The statistics shows that man-made debris in space is around more the 3,00,000 objects of size 1-10 centimeters and more than 1 million objects less than 1 centimeter. The debris in LEO of 10cm can be tracked while in GEO it should be minimum of 1 meter to track. Debris moving with a velocity greater than 7Km/sec is a serious issue with increased chances of colliding with new satellite launches or other debris resulting in further fragmentation of the debris. The fragmentation is caused by a) Deliberate Breakup b) Propulsion System c) Aerodynamics d) battery and e) Unknown cause. One such incident was a military satellite had to take evasive action to avoid collision. This is a major threat in future as the number of satellite will exponentially increase in the future. From the analysis it is determined that if the number of satellites increases in this fashion, number of collision with debris will be greater than 50% in LEO and next 10-15 years.

5. Protocol Stack

Today satellite network has become a backbone for communication in various fields like military services, mobile networks, Internet etc [2]. SBWSN provides a wide range of coverage throughout the globe and plays a very important role due to its broadcasting capacity and bandwidth flexibility. It should be noted that the 2/3 of the world still does not have the infrastructure for the Internet using terrestrial network. Thus SBWSN are used for providing information anywhere and anytime using well proven internet protocols. Some of the protocols used by terrestrial network like internet protocols, IEEE standard wire-less protocols (like WiMAX 802.16) and adhoc network protocols are used in space [29] [30].

IP Protocol Stack

The protocol stack is as shown in the figure 6 which is derived from the OSI model. It consists of physical layer that uses radio frequency for communication between in the satellites in space. The data link layer uses HDLC framing which is well proven in terrestrial network for several years and for huge networks. The data link layer uses various communication protocols like HTTP, 802.11, AX.25 etc. The network layer support IP with UDPs these are delay tolerant protocols [31]. Network layer topology uses either proactive or reactive schemes based on the mobility and node failure. For example, end-to-end propagation delay from ground to ground is 20-25msec for a LEO, 110-130msec for MEO and 250-280msec for GEO systems [32]. These protocols are used in UoSAT-12, UWE-1. The TCP cannot be used as the delay for to receive acknowledgment is high in space based network. This again depends on the different range of altitudes. The adhoc networking protocols used are IEEE 802.15.3, while WIMAX, Wi-Fi can be used for ISL communication with OFDM to provide high data rates in the distributed network. Multi-hop communication support to have large network scaling more than 100 nodes. The intra satellite links protocols like WiMedia (IEEE 802.15.3), ZigBee (IEEE 802.15.4) and Bluetooth (IEEE 802.15.1) for communication [19].

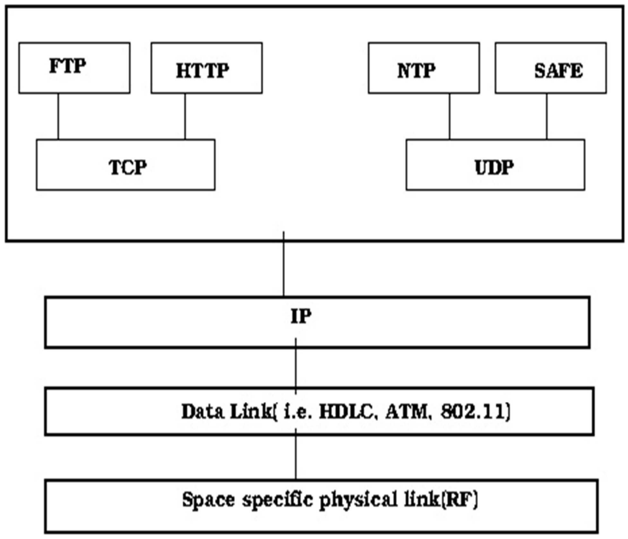

Figure 6. *OSI network model for SBWSN.*

6. Routing Protocols

Routing is the act of moving information across an inter-network from a source to a destination. Along the way, at least one intermediate node is typically encountered. It's also referred to as the process of choosing a path over which to send the packets. When the data, voice, videos and any multimedia is transmitted through the satellite network it has its own parameters like security, packet loss, jitter, bandwidth, cost, transmission rate and so on. Different services have different QoS like file transfer will focus on packet loss; videos or live transmission will focus on jitter and delay. There are various parameters on which the route path is determined. For example, energy efficient routing, Routing in LEO orbits, Multi-layered routing, on demand routing, delay tolerant routing etc. Some of the issues in routing in SBWSN are Extremely long and variable propagation delays, Asymmetrical forward and reverse link capacities, High link error rates for radio-frequency (RF) communication channels, Intermittent link connectivity, Lack of fixed communication infrastructure, Effects of planetary distances on the signal strength and the protocol design, significant power, mass, size, and cost constraints for communication hardware and protocol design.

SSCOP (Service-Specific Connection-Oriented Protocol) is an efficient protocol for error recovery in ATM network, and also for reliable end-to-end delivery of data in the ATM environment and designed to compensate for long propagation delay, which is the case in satellite ATM networks. It performs the flow control, error reporting, local data retrieval, and status reporting. The Green SR shows energy efficient routing protocol used to increase the life time of the network. The results have shown 40% increase in battery life that satisfies the required QoS and increases link utilization [33].

Reconfigurable WDM Add/Drop Multiplexers in Free-Space (ADM) The utilization of WDM might greatly enhance an optical satellite network. Dynamic routing can be performed by changing the wavelength light paths without modifying the physical topology. Figure 2 depicts a simple illustration of diverse data traffic. Each satellite or node can have the capability to modulate/demodulate any subset of these waveforms, while forwarding the remaining waveforms on to other nodes. ADM alleviates the unnecessary detection and processing of channels destined for other nodes. In the configuration WDM input is de-multiplexed into individual wavelength channels. Some of these channels are dropped and electrically or optically re-routed. Simultaneously, additional channels are added prior to multiplexing with the through traffic at the output of the ADM. To ensure network flexibility, it is probably desirable that the ADM be reconfigurable.

Store and Forward: To overcome frequent loss of connectivity and/or interactivity is sparse in LEO systems, the transmitted message may be stored in intermediate nodes during a period of time until conditions are met for it to be forwarded. This also supports for communication even when no direct link exists between source and destination. It is commonly used in networks with transient connectivity and reasonable expectation of eventual delivery. A typical single-hop LEO store-and-forward communication system comprises one spacecraft and one or more geographically distributed terrestrial stations.

7. Space Environment and ITS Challenges

Space has a stringent environment subjected to various orbital dynamics, radiation, debris, vacuum, perturbations, absorption of radio frequencies at various atmospheric layers etc. This makes space atmosphere quite challenging compared to terrestrial atmosphere. The atmosphere in space is critical to handle due to neutral gas, solar spectrum (UV/FUV/VIS/NIR), electron plasma flux and temperature. These unusual conditions of space demands for space grade quality of components and layouts to sustain such rigid environmental condition further drastically increasing the cost of the mission.

Atmospheric Environment: The atmosphere in space is divided into various layers as shown in the figure. The troposphere, stratosphere, mesosphere and thermosphere form the layers of space atmosphere. The Ionosphere and exosphere together form the thermosphere. The atmosphere especially after the magnetosphere sphere is a key factor to be considered for any space mission. The impact of cosmic radiation, solar flares, Van Allen belts, dayside mid-latitude trough, equator ward trough, solar ionization, Flux tubes, ionosphere plasma depletion and SAA play a major role in the performance of a mission. The ionosphere has extreme high energy protons, heavier ion and neutrons caused due to sun's radiation. One of the major impact of radiation is the vulnerability of SRAM devices due to deposit of heavy ions from cosmic rays on SRAM cells causing single bit error resulting in circuit corruption. Solar cycle and earth's magnetic field results in spatial and temporal variation. One way to protect the system from these extreme high energy radiations in space is by providing radiation shelter. Silicon shielding is one of the shielding methods used to as radiation-shielding. This also has other advantages that can be used as optic substrates better with thermal conductivity and mass density. It is also a heat sink and proved to be stronger than steel. The RF signal through this layer suffers alteration or deflection of signals. The alteration of RF signals may be small scale or large scale, varying from few centimeters to few thousands of kilometers. This impact of RF signals plays vital roles in LEO satellite mission.

1). *Stratosphere:* The stratosphere is the second major layer of the atmosphere. It lies above the troposphere and is separated from it by the tropopause. It occupies the region of atmosphere from about 12 to 50 km, although its lower boundary tends to be higher nearer the equator and lower nearer the poles. The stratosphere defines a layer in which temperatures rises with increasing altitude. At the top of the stratosphere the thin air may attain temperatures close to 0 degree centigrade. This rise in temperature is caused by the absorption of ultraviolet (UV) radiation from the Sun by the ozone layer. Such a temperature profile creates very stable atmospheric conditions, and the stratosphere lacks the air turbulence that is so prevalent in the troposphere. Consequently, the stratosphere is almost completely free of clouds or other forms of weather. The stratosphere provides some advantages for long-distant flight because it is above stormy weather and has strong, steady, horizontal winds.

2). *Mesosphere:* The mesosphere (literally middle sphere) is the third highest layer in our atmosphere, occupying the region 50 km to 80 km above the surface of the Earth, above the troposphere and stratosphere, and below the thermosphere. It is separated from the stratosphere by the stratopause and from the thermosphere by the menopause. Temperatures in the mesosphere drop with increasing altitude to about -100 degree centigrade. The mesosphere is also the layer in which a lot of meteors burn up while entering the Earth's atmosphere [26].

The Earth's magnetic field extends out into space forming the magnetosphere. As the solar wind expands out from the sun, it encounters the magnetic field of Earth. On the sunward side of Earth, the solar wind compresses the magnetic field in toward the Earth, increasing the magnetic field strength in the compressed areas. On the opposite side of Earth, the solar wind acts to stretch out the magnetic field thus giving it a teardrop shape. Magnetopause, the boundary of the magnetosphere. It is where the pressure of the solar wind is balanced by Earth's magnetic field pressure. The magnetopause is most defined on the sunward side where it is located approximately 10 Earth radii (10 times 3962 mi) from the Earth. This boundary fluctuates between 7 to 14 Earth radii during magnetic disturbances resulting from large variations in the solar wind. Magneto tail On the side of Earth opposite from the Sun, the solar wind draws the magnetic field out into a long tail, called the magneto tail. This tail extends out to 1,000 earth radii or more. Located within the magneto tail is a region of high density, high energy plasma, known as the plasma sheet. It may extend out past 300 earth radii. Within the plasma sheet is the neutral sheet. This is where the magnetic field lines reverse direction from a component towards Earth (Northern lobe) to a component away from Earth (Southern lobe). Shock Wave When the solar wind encounters Earth's magnetic field, it is deflected and a shock wave is produced. The location and shape of this shock wave is similar to that of the wave caused by the bow of a boat as it moves across the surface of a body of water. This shock wave is called the bow shock and marks the transition from undisturbed to disturbed solar wind. Its front lies on the sunward side between 10 and 15 earth radii from Earth.

3). *Thermosphere:* The thermosphere (literally "heat sphere") is the outer layer of the atmosphere, separated from the mesosphere by the menopause. Within the thermosphere temperatures rise continually to well beyond 1000 degree centigrade. The few molecules that are present in the thermosphere receive extraordinary amounts of energy from the Sun, causing the layer to warm to such high temperatures. Air temperature, however, is a measure of the kinetic energy of air molecules, not of the total energy stored by the air. Therefore, since the air is so thin within the thermosphere, such temperature values are not comparable to those of the troposphere or stratosphere. Although the measured temperature is very hot, the thermosphere would actually feel very cold to us because the total energy of only a few air molecules residing there would not be enough to transfer any appreciable heat to our skin. [26]

The lower part of the thermosphere, from 80 to 550 km above the Earth's surface, contains the ionosphere. Beyond the ionosphere extending out to perhaps 10,000 km is the exosphere or outer thermosphere, which gradually merges into space.

Ionosphere The ionosphere is a layer of ionized air in the atmosphere extending from almost 80 km above the Earth's surface altitudes of 600 km and more. Technically, the ionosphere is not another atmospheric layer. In this region of the atmosphere the Sun's energy is so strong that it breaks apart molecules and atoms of air, leaving ions (atoms with missing electrons) and free floating electrons which allows propagation of electromagnetic waves. The impact of cosmic radiation, solar flares, Van Allen belts, dayside mid latitude trough, equator ward trough, solar ionization, Flux tubes, ionosphere plasma depletion and SAA play a major role in the performance of a mission. This layer also impacts SRAM cells causing single bit error resulting in circuit corruption. The RF signal through this layer suffers alteration or deflection of signals during day and night based on D and E regions. The alteration of RF signals may be small scale or large scale, varying from few centimeters to few thousands of kilometers. There are also some specific frequencies bands between 300 MHz and 300 GHz that are subject to absorption by molecules in the atmosphere. This impact of RF signals plays vital roles in LEO satellite mission.

Exosphere The exosphere is the highest layer of the atmosphere. The exosphere extends to 10,000 km above the Earth's surface. This is the upper limit of our atmosphere. Air atoms and molecules are constantly escaping to space from the exosphere. In this region of the atmosphere, hydrogen and helium are the prime components and are only present at extremely low densities. This is the area where many satellites orbit the Earth.

8. Conclusion

Satellite based wireless sensor network aims in taking the advantages of well proven terrestrial WSN concepts to space using the commercial of the shelf components. These distributed of SBWSN proves to reduce the debris when compared to large satellite failure. Here the design consideration of small satellites, its network environment, power consideration, network layer issues and challenges of mobility of satellites are addressed. The comparison of WSN and SBWSN is emphasized and concepts.

WSN which don't fit directly into SBWSN and need a re look into the underlying issues are outlined.

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