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# Nanosatellites constellation as an IoT communication platform for near equatorial countries

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**Abstract.** Anytime, anywhere access for real-time intelligence by Internet of Things (IoT) is changing the way that the whole world will operate as it moves toward data driven technologies. Over the next five years, IoT related devices going to have a dramatic breakthrough in current and new applications, not just on increased efficiency and cost reduction on current system, but it also will make trillion-dollar revenue generation and improve customer satisfaction. IoT communications is the networking of intelligent devices which enables data collection from remote assets. It covers a broad range of technologies and applications which connect to the physical world while allowing key information to be transferred automatically. The current terrestrial wireless communications technologies used to enable this connectivity include GSM, GPRS, 3G, LTE, WIFI, WiMAX and LoRa. These connections occur short to medium range distance however, none of them can cover a whole country or continent and the networks are getting congested with the multiplication of IoT devices. In this study, we discuss a conceptual design of a nanosatellite constellation those can provide a space-based communication platform for IoT devices for near Equatorial countries. The constellation design i.e. the orbital plane and number of satellites and launch deployment concepts are presented.

## 1. Introduction

The Internet of Things (IoT) application is beginning to multiply significantly. Consumer products, durable goods, cars and trucks, industrial and utility components, sensors and other everyday objects are being attached with Internet connectivity and powerful data analytic capabilities that promise to transform the way we work, live and play. Projections for the impact of IoT on the internet and economy are impressive, with some anticipating as many as 100 billion connected IoT devices by 2025.

The existing wired and wireless network are almost being fully utilized by the current IoT for control and communication of the devices. However, as IoT devices continue to multiply greater data communications and data services are required, these existing networks will become increasingly

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stressed and congested, especially in remote regions. One of the solutions to overcome the need for greater data communication is investment in space infrastructure. Space-based data communication network have greater impact on humanity by delivering the required additional data communication to every part of the world.

Space-based data communication network is not something new as back in the 1990s there were several large space-based satellite network providers, such as Intelsat, Iridium, GlobalStar, Teledesic, etc. but these providers used bigger satellites which entailed high costs of deployment and operation. However, currently with the greatly advanced of satellite technology, the cost of the development and deployment has reduced significantly. With the current technology, nanosatellites can be mass produced and can be launched by the dozens at a time to Low Earth Orbit (LEO), reducing launch costs, while delivering performance comparable to larger, older satellites at higher orbits [1].

Nanosatellites ranging in mass between 1kg – 10kg are gaining momentum as an additional means to address targeted scientific and engineering programs in a rapid and very much more affordable manner. Within the group of nanosatellites, CubeSats have appeared as a more recognised space platform. The standardization of CubeSat defined in terms of 10cm x 10cm x 10cm in size and approximately 1 kg each called a 'U'. Originally, CubeSats were deployed as training programme to expose students to the challenges of real world satellite engineering practices and system design. However, CubeSats use has rapidly spread within academia, industry and government agencies globally to achieve various space missions.

A set of satellites distributed over a space to achieve a common mission objective is called constellation. While there are no absolute rules, there are a number of key issues which dominate constellation design trades, namely coverage, number of satellites, launch options, space environment, orbit perturbations for station keeping, collision avoidance, constellation build-up and required replenishment and number of orbital planes [2]. Recently, OneWeb proposed 650 satellites as a LEO constellation around the globe, to provide Internet access to rural and developing areas of the world with significant investments from Virgin Group and Qualcomm. Airbus Defence and Space was recently announced as the manufacturer for these satellites [3].

The good news is, the development of a LEO constellation to provide 365/24/7 coverage for countries near the Equator will be much less complex with only less than twenty-five CubeSats required. The orbit at or close to Equator will be extremely advantageous to countries straddling the Equator, whereby the footprint of the satellites will always cover the Equator and provide frequent revisits. Many existing constellations or geostationary satellites are already available to provide the data communication services, however, these require an extensive infrastructure on the ground for data transmission and most of them are expensive in terms of capital and operational expenditures. These two parameters are the cause for existing services not being applicable for IoT application.

For these reason, we are proposing a CubeSat Equatorial orbit constellation as a communication platform for IoT which will provide continuous coverage for the countries near the Equator at a low cost and low power, requiring smaller sized transmitters on the ground and provide sufficient data rate for the application of IoT devices which will communicate directly to the constellation of CubeSats in space to transfer the data in real time.

## 2. Space-Based IoT Communication Platform

A space-based IoT communication platform requires an infrastructure that will fit its various applications. The infrastructure requires a network of satellites in the Equatorial plane, ground stations, and IoT terminals that are interconnected. These variations in requirements can be used by different satellite design.

Every satellite has its own size and mass and Table 1 shows the differences between classic, micro, Nano and Pico satellites. Micro, Nano and Pico satellites are classified as small satellites, however, the nano and micro satellites tend to overlap while the definition of Microsatellite could be assumed to range between from 50kg and 100kg.

*2.1. Concept of operations*

The ground station two functions: telemetry and telecommand of the satellite operations and the data handling of the space IoT data. The terminal is equivalent to a very small device that is able to be placed on strategic devices for applications such as environmental monitoring, oil pipeline monitoring, smart grid, mobile tracking and control of water sources. The IoT terminal should be small but able to communicate with the satellites. The satellites, ground stations, and terminals all have an antenna, transmitter, receiver, and control equipment that enable them communicate with each other.

**Table 1.** Typical classification of satellites [4]

| | ***Mass (Kg)*** | ***Altitude (Km) / Orbit Period (Hour)*** | ***Construction Duration (Year)*** | ***Total Cost (Million, USD)*** |
|---|---|---|---|---|
| Classic | 1,000 | 10,000<br>5.8 | 10 | 150 |
| Micro | 10-100 | 500-2,000<br>1.6-2 | 2-5 | 1-30 |
| Nano | 1-10 | 300-800<br>1.4-1.7 | 2-3 | 0.1-10 |
| Pico | 0.1-1 | 200-600<br>1.4-1.5 | 1-2 | 0.05-2 |

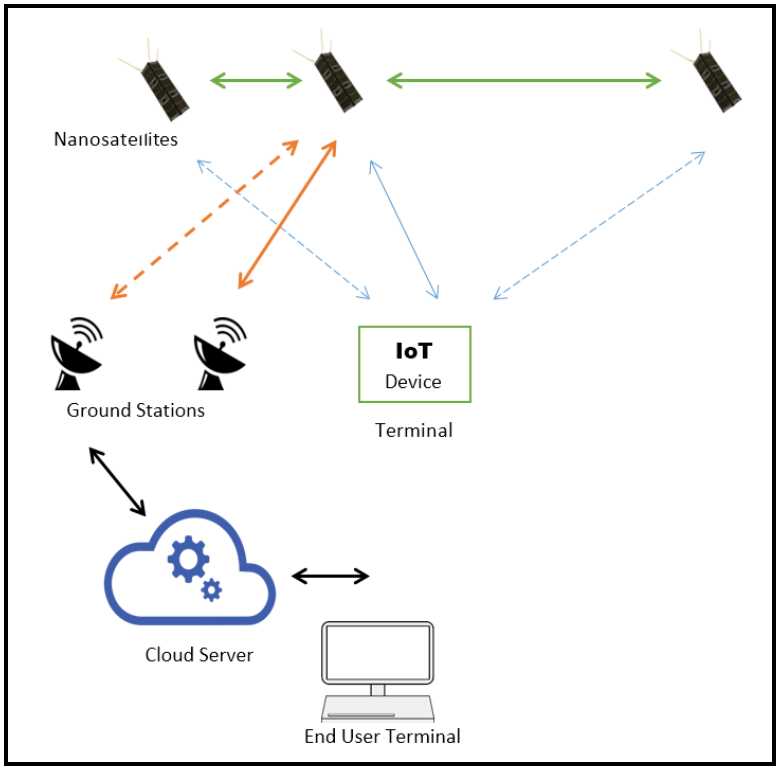



**Figure 1.** Space based IoT infrastructure concept.

The satellites in the equatorial orbit are in the same orbital plane. They broadcast data to multiple ground stations in different locations through broad or spot beams. The satellite transmitter must provide enough transmission power to Earth surface. The receiver has multiple channels to receive data from multiple IoT devices. The satellites will have the capability of store and forward messages to enable IoT data to be transmitted to the ground stations. An advance mode would enable Inter Satellite Link (ISL) communications to allow IoT data to be passed on to each satellite. However, the

satellites must be within line of sight and at the right distance. The IoT devices will directly send message to the satellite and can detect the satellite coming. To save power, the IoT device would be able to implement a sleep mode. The ground stations act as a gateway to the end-user and they would enable the IoT messages to be forwarded to the end-user. The ground station requires a tracking antenna since require to follow the motion of satellite, other functions of the ground station including providing the satellite operation and maintenance.

*2.2. Communication system*

In developing the communication system, the architecture of the communication architecture itself determines the link requirement for the system. The communication links will allow a satellite system to function by transmitting tracking, telemetry, and command data between the elements [5]. The communication link consists the uplink and downlink. Uplink means sending the signal from Earth station antenna to spacecraft antenna while the downlink means sending the signal from the satellite antenna to the Earth station antenna [6]. Other than the uplink and downlink, the inter-satellite link (ISL) plays an important role in relaying data from and to a satellite in the Equatorial orbit. ISL enable two satellites in orbit to communicate directly without using a ground station on Earth.

For the uplink and the downlink design, the link budget equation is used to determine the communications link information such as antenna parameters, data rate, antenna size, propagation of path length and transmitter power. Using those parameters, we can calculate the $E_b/N_0$ of the link. The equation of $E_b/N_0$ is shown as below [7]:

$$\frac{E_b}{N_0} = \frac{PL_l G_t L_s L_a G_r}{kT_s R} \quad (1)$$

- $E_b/N_0$: Ratio of received energy-per-bit to noise-density
- P: Transmitter power
- $L_l$: Transmitter-to-antenna line loss
- $G_t$: Transmit antenna gain
- $L_s$: Space loss
- $L_a$: Transmission path loss(function of factors such as rainfall density)
- $G_r$: Receive antenna gain
- $k$: Boltzmann's constant
- $T_s$: System noise temperature
- $R$: Data rate

For advance communications using ISL, the distance between two satellites must be known. The complexity of calculating the distance between the two satellites is reduced at the Equatorial orbit where all the satellites are in the same orbit plane. Two satellites are required to define the sufficient distance for acceptable space loss based on receiver sensitivity, antenna gain and transmit power. The distance between two satellites can be calculated using orbit plane coordinate system and WGS-84 coordinate system. WGS-84 is a standard that is developed by the United States Department of Defense in order to provide a reference globally mainly for the Global Positioning System (GPS) constellation of satellite. The WGS-84 parameters consist of the Earth semi-major axis, the Earth flattening factor, the Earth Mean Angular velocity and the Earth Geocentric Gravitational Constant. The coordinate of a satellite is based on the Earth Centered Inertial where the x axis is the reference point pointing to the direction of vernal equinox, the z axis points to the Celestial pole or north and y axis is the normal to the x and z axis. The orbit plane coordinate is then transformed into the coordinate (X, Y, Z) of the satellite in WGS-84 coordinate system. The coordinate transformation equation is provided in equation 2 [8] below. **Ω** and *i*, denote the ascending nodes and inclination, respectively.

$$\begin{bmatrix} X \\ Y \\ Z \end{bmatrix} = \begin{bmatrix} x\cos\Omega - y\cos\Omega \\ x\sin\Omega + y\cos\Omega\cos i \\ y\sin i \end{bmatrix} \quad (2)$$

The distance *d*, between the two satellites are denoted by satellite S1 = ($X_1$, $Y_1$, $Z_1$) and satellite S2 = ($X_2$, $Y_2$, $Z_2$) and the distance can be calculated by using equation 3 [8] below:

$$d = \sqrt{(X_2 - X_1)^2 + (Y_2 - Y_1)^2 + (Z_2 - Z_1)^2} \quad (3)$$

The distance *d*, is inserted in the equation for the space loss ($L_s$) is shown as below [7] where *f* denotes the spectrum of the inter-satellite link.

$$L_s = 147.55 - 20\log d - 20\log f \quad (4)$$

Higher frequency such as Ka and V band frequency are the typical medium to transfer information between satellites. This is because the link is not being affected by rain attenuation which occurs between ground to satellite links [4]. High-throughput optical and Radio Frequency (RF) ISLs have been named as a medium to transfer information between satellites. Most satellites are using RF and microwave link to transfer data. However, the limitations of size on nanosatellites are the key challenges in implementing the ISL.

*2.3. Frequency allocations*

The frequency allocations are the main criteria in defining a space-based IoT communication platform as it requires approval from the International Telecommunication Union (ITU). The satellite services defined by ITU covers three areas namely mobile-satellite service, fixed-satellite service and space operation service. Mobile satellite services is a radio communication services between a mobile station on earth and one or more satellites, either with or without ISLA fixed-satellite service is between earth stations at fixed positions with one or more satellites are used. A space operation service is radio-communications exclusively used for the operations of a spacecraft, particularly for tracking, telemetry and telecommand. A combination of the three services is required for a fully operational Space Based IoT communication platform.

The driving criteria in defining the communications architecture functions of a space-based IoT communication platform mission are the RF spectra, the orbit, and the operational considerations for implementations, such as the ground network, cloud and IoT technologies, data rate, link availability, and link access time.

*2.4. Intersatellite link analysis and results*

The position vector of satellite is listed in Table 2 show the parameters of Kepler element that was used.

**Table 2.** Orbital Elements Simulated

| ***Parameters*** | ***Values*** |
|---|---|
| Angular Momentum, L | 53032.8 $km^2s^{-1}$ |
| Inclination, i | $0^o$ |
| Right Ascension (RA) of the Ascending Node, Ω | $61^o$ and $62^o$ |
| Eccentricity, e | 0.01 |
| Argument of Perigee, ω | $90^o$ |
| True Anomaly, v | $35^o$ |

The link analysis was conducted by using all the parameters that shown in table 3.

**Table 3.** Intersatellite link analysis parameters

| ***Parameters*** | | ***Proposed Value*** |
|---|---|---|
| Ambient Temperature | $T_{amb}$ | 353 K |
| Centre Frequency | $f_c$ | 2.45 GHz |
| Bandwidth | B | 33 MHz |
| Link Distance | D | 70 - 120 km |
| Transmitter Power | $P_T$ | 1 - 4 W |
| Transmitter Losses | $L_T$ | 1 dB |
| Friis Path Loss | L | 139.3 dB |
| Receiver Losses | $L_R$ | 1 dB |
| Link Margin | LM | 2 dB |
| Signal-to-noise Ratio | SNR | 6 dB |
| Receiver noise Figure | NF | 4.6 dB |
| Noise Floor | N | -105 dB |
| Antenna System Gain | $G_T$, $G_R$ | 0 - 5 dBi |

The position vector was simulated using Matlab.

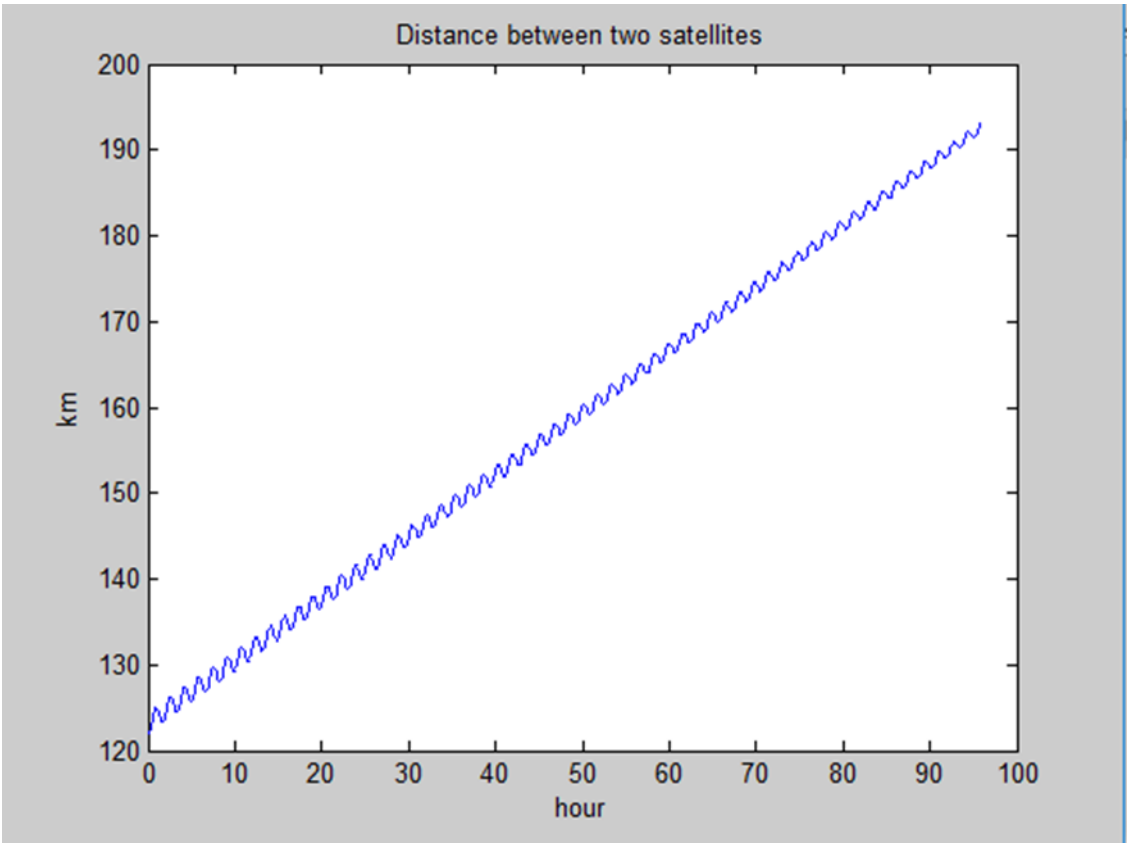



**Figure 2.** Distance variation between two satellites

Link budget parameter that was list in Table 3 was used and calculated. The main objective was to find the minimum value of Power Received, $P_R$ that was suitable for the ISL to take place. The

minimum value of $P_R$ was determine to be -140.5 dB. The calculation was made and it shows that there are many time where the value of $P_R$ was higher than -140 dB. Table 4 shows all the value that intersatellite link can take place with variation of distance, transmit power and antenna gain. It is therefore feasible to achieve intersatellite link between two satelltie in orbit.

**Table 4.** Summary of the result for intersallite link analysis

| ***Distance (km)*** | ***$P_T$ (W)*** | ***Gain (dB)*** | ***$P_R$ (dB)*** |
|---|---|---|---|
| 70 | 1 | 1 | -139.139 |
| 80 | 1 | 1 | -140.299 |
| 90 | 4 | 1 | -135.302 |
| 100 | 4 | 1 | -136.217 |
| 110 | 1 | 5 | -135.065 |
| 120 | 1 | 5 | -135.821 |
| 120 | 4 | 1 | -137.8 |
| 130 | 1 | 5 | -136.516 |
| 140 | 1 | 5 | -137.10 |
| 140 | 4 | 1 | -139.139 |

## 3. Orbit and constellation design

A trajectory is a line traced by a moving body and an orbit is a trajectory that is periodically repeated. While the path followed by the motion of an artificial satellite around the Earth is an orbit, the part followed by a launch vehicle is a trajectory called the launch trajectory [9]. The gravitational force that act on satellite creates a pulled down effect and if satellite did not have any motion of their own they would fall back to Earth, burning up in the reaches of the atmosphere. Instead, the initial energy acting to make satellite motion has a force associated with it pushing the satellite away from the Earth and make satellite rotating around the Earth. For any given altitude, for satellite remains stable in orbit, neither going higher nor lower, there is a specific speed for which gravity and the centrifugal force balance each other. The orbit that is chosen for a satellite depends upon its application, for example, those used for direct broadcast use the Geostationary orbit, those used for satellite phones, are in the Low Earth Orbit satellites while satellites for navigation, like Navstar for Global Positioning System (GPS), occupy the Medium Earth Orbits.

### *3.1. Constellation design*

A Constellation consists of multiple satellites that orbit the Earth in similar, but suitably shifted or arranged orbits. A famous example is the America's Global Positioning System (GPS), whereby a fully operational system comprises a total 24 satellites in six orbital planes at $55^o$ inclination. Four satellites each share the same orbit of 20,200km altitude, but are offset from their neighbours by a $90^o$ longitudinal phase shift. Meanwhile, each orbital plane are separated by $120^o$ and such configuration makes a minimum of 6 satellites always available to be linked to the ground GPS receiver. Due to the orbital period of 12 hours, the configuration of all satellites relative to Earth is exactly repeated twice every sidereal day. GLONASS, the Russian counterpart of the United States' GPS, utilizes a similar constellation of 24 satellites evenly distributed in three planes, with an orbital inclination of $64.8^o$ [10]. At an altitude of 19, 100km, the orbital period of 11.25 hours.

In the past decade, the high potential of Low Earth Orbit satellite constellations for global mobile communication was realized. The signal paths is shorter for low Earth satellites, signal link can be established from only hand-held devices in comparison requirement of huge user antennas setup for geostationary satellites. By making use of ISL, telephone calls can then be routed around the world to other mobile-phone user or to a suitable ground network terminal. A well-known example is

IRIDIUM, a 66-satellites constellation at an altitude of 700km, which was put into operation in 1999 [11]. Other constellations have been designed and partly implemented, which include Globalstar with 48 satellites at 1414km altitude, ICO with 10 satellites at 10,400km, ORBCOMM [12] and Teledesic with 288 satellites at 1,350km [13].

There are no absolute rules existing for designing a constellation. However, there are a number of key issues which dominate the constellation design trade. Table 5 shows the dominant parameters for constellation design.

**Table 5.** Principal issues that dominate the constellations design [2]

| *Issue* | *Why important* | *What determines it* | *Principal issues or options* |
|---|---|---|---|
| **Coverage** | Principal performance parameter | Altitude, minimum elevation angle, inclination, constellation pattern | Gap times for discontinuous coverage, Number of satellites simultaneously in view for continuous coverage |
| **Number of Satellites** | Principal cost driver | Altitude, minimum elevation angle, inclination, constellation pattern | Altitude, minimum elevation angle, inclination, constellation pattern |
| **Launch Options** | Major cost driver | Altitude, inclination, spacecraft mass | Low altitude, low inclination cost less |
| **Environment** | Radiation level and therefore, lifetime and hardness requirements | Altitude | Option are below, in or above Van Allen radiation belts |
| **Orbit Perturbation (Station keeping)** | Causes constellation to disassociate over time | Altitude, inclination and eccentricity | Keep all satellites at common altitude and inclination to avoid drifting apart |
| **Collision Avoidance** | Snowball effect can destroy entire constellation | Constellation pattern, orbit control | No option – Must design entire system for collision avoidance |
| **Constellation Build-Up, Replenishment and End-of-Life** | Determines level of service over time and impact | Altitude, constellation pattern, build-up and sparing philosophy | Sparing: on-orbit spares vs launch on demand; End-of-life deorbit vs raise to higher orbit |
| **Number of Orbit Planes** | Determines performance plateaus | Altitude, inclination | Fewer planes means more growth plateaus and more graceful degradation |

A circular Equatorial low Earth orbit constellation will be the simplest constellation as it eliminates many constellation design issues, such as orbit perturbation, number of orbit planes, and at the same time provides continuous coverage for the near Equatorial countries. The current analysis will only focus on the design of constellation with Equatorial orbit for near Equatorial countries.

*3.2. Constellation design analysis and results*

The main objective of the analysis or the study is to identify the feasibilities and number of satellites for continuous coverage most often requires that the Near Equatorial region of interest must be seen continuously by at least one satellite in the constellation. To narrow down the simulation scenarios, we are required to define few conditions or parameters. The first condition is that the near Equatorial region of interest has been set to $\pm 10^{o}$ latitudes. Bigger satellites can generate bigger power and can be utilized for communication power system. However, the proposed constellation comprising nanosatellites will have limited power generation, therefore, it will limit the communication distance between the IoT devices and satellites. The trade-off study for this analysis are perform for altitudes between 500km – 800km. The link margin effect from the elevation mask has a strong impact on the communication link availability. A smaller degree of elevation mask means more interference from the atmosphere which interrupts the link availability, while a higher degree of elevation mask will

narrow the communication footprint and increase the number of satellites in the constellation. The value for the elevation mask is always dependent on the receiving or transmitting terminals on ground. For this simulation scenario, we have constrained the elevation mask value to be 20°. Based on these parameters we calculate the communication beam angle for altitude 500km – 800km by referring to the Figure 4 and equations (5), (6) and (7). Table 6 shows all the calculated communication beam angle (η) and Earth central angle (λ).

**Table 6.** Calculated Nadir Angle and Earth Central Angle for altitude 500km – 800km

| *Altitude (km)* | *Orbital Radius, r (km)* | *Nadir Angle, η (deg)* | *Earth Central Angle, (deg)* |
|---|---|---|---|
| 500 | 6878.14 | 60.62 | 9.38 |
| 550 | 6928.14 | 59.89 | 10.11 |
| 600 | 6978.14 | 59.19 | 10.81 |
| 650 | 7028.14 | 58.52 | 11.48 |
| 700 | 7078.14 | 57.86 | 12.14 |
| 750 | 7128.14 | 57.23 | 12.77 |
| 800 | 7178.14 | 56.61 | 13.39 |

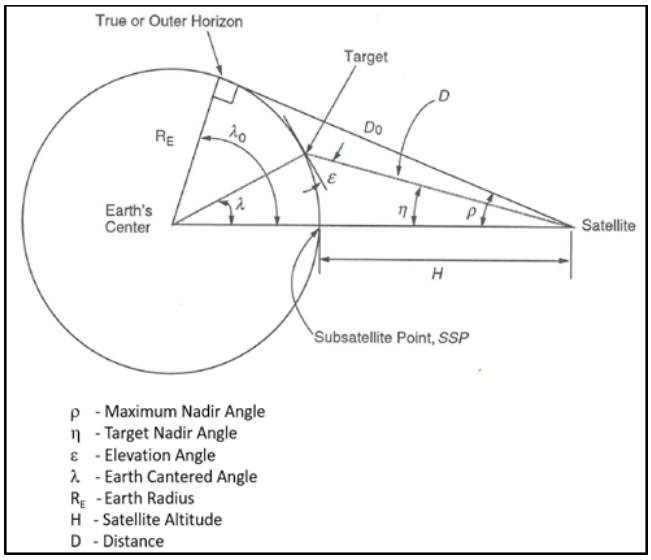



**Figure 3.** Definition of angular relationship between the satellite and earth's centre. [7]

$$Sin\ \rho = \frac{R_E}{R_E+H} \quad (5)$$

$$Sin\ \eta = Cos\ \varepsilon Sin\ \rho \quad (6)$$

$$\eta + \lambda + \varepsilon = 90 \quad (7)$$

The required number of satellites, *N*, to provide continuous coverage with at least one satellite for the near equatorial region of ±10° latitudes are calculated based on Figure 5 and equation (8) and (9). The results are shown in Table 7.

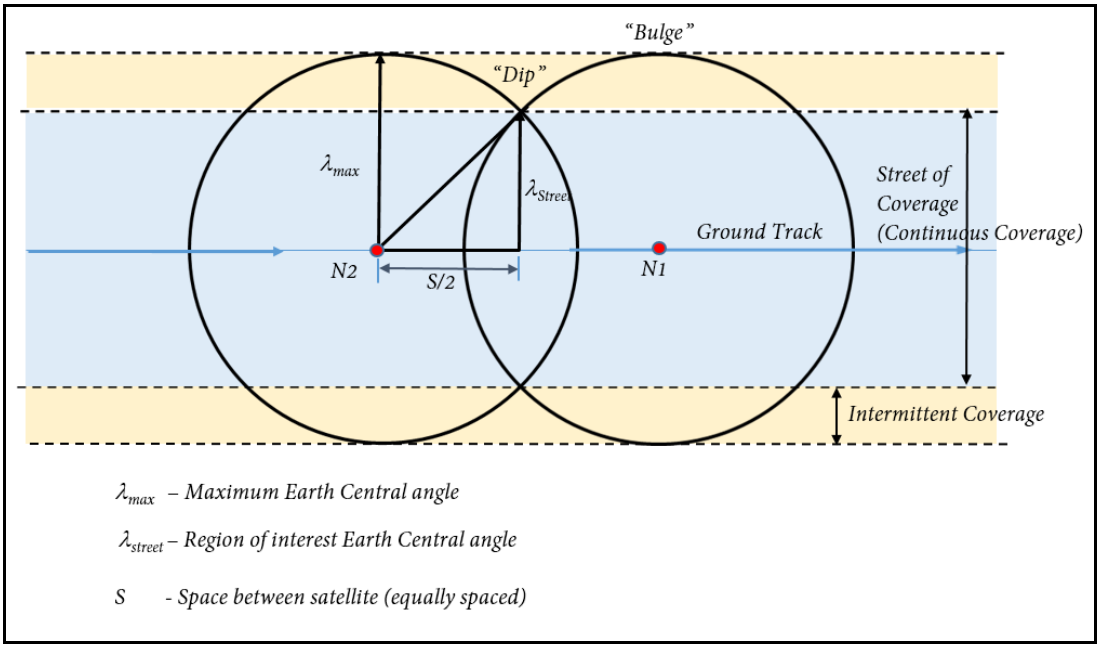



**Figure 4.** Street of coverage for constellation.

$$S = \frac{360}{N} \tag{8}$$

$$Cos\ \lambda_{Street} = \frac{Cos\ \lambda_{max}}{\cos(\frac{S}{2})} \tag{9}$$

**Table 7.** Number of Satellites required for continuous coverage of latitude region of ±10

| *Altitude (km)* | *Earth Central Angle, (deg)* | *Number of Satellites, N* |
|---|---|---|
| 500 | 9.38 | No continuous coverage |
| 550 | 10.11 | 121 |
| 600 | 10.81 | 44 |
| 650 | 11.48 | 32 |
| 700 | 12.14 | 27 |
| 750 | 12.77 | 23 |
| 800 | 13.39 | 21 |

The Table 4 shows that at 800km attitude with 20$^o$ elevation mask a minimum of 21 satellites will be required to provide continuous coverage for the Equatorial region between ±10$^o$ latitudes. Figure 4 shows the satellite coverage on a 2D Earth map. As for coverage redundancy, the constellation can be increase to 25 satellites which will provide four satellites in orbit redundancy.

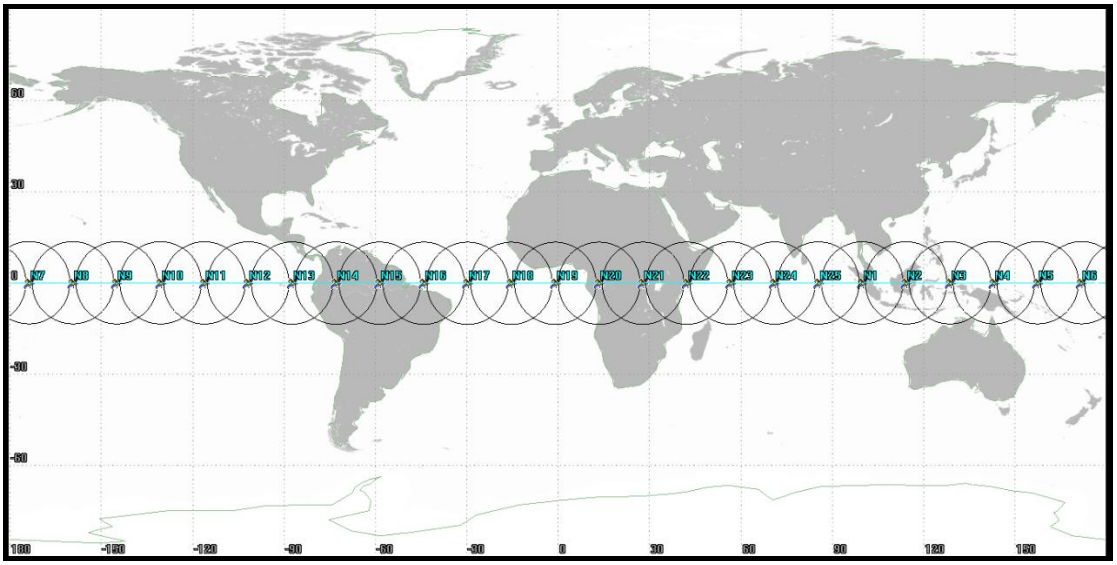


**Figure 5.** Satellite coverage for equatorial orbit constellation with 25 number of nanosatellites.

## 4. Launch and constellation deployment

The basic goal of the launch vehicle is to expel hot gases at velocities on the order of 2 to 3 km/s to active a final vehicle velocity of 8 km/s or more, even for low Earth orbit [2]. This means that the mass of any launch vehicle will be dominated by the propellant and that the vehicle itself will need to be designed for minimum excess weight. This in turn implies that the launch will incur the greatest cost and will entail significant risk since each launch vehicle on the launch pad is more than 95% explosive propellant.

### *4.1. Small satellite launch option*

The absence of sufficiently small or inexpensive launch vehicles for the delivery of nanosatellites to orbit presents a significant barrier to the development of nanosatellite missions with smaller budgets. The launch opportunities as a secondary payload for small satellites normally addressed the issue of access to orbit, where normally the main payload will either offer share launch capacity through clustering or share rides or allow to use the excess launch space capacity for a commercial value, which is called piggybacking. Unless arranged through a subsidised launch programme (e.g. NASA CubeSat Launch Initiative and Educational Launch of Nanosatellites), the cost of secondary payload opportunities is generally greater than the specific cost ($/kg) of the launch vehicle itself [14]. However, these opportunities still allow nanosatellites to achieve the orbit at a significantly lower total cost than a dedicated launch. Piggybacking or secondary payload opportunities always constrains by main payload or primary satellite launch schedule and orbit destination, therefore the small satellites need to be flexible in their mission and final orbit destination. Further restrictions on the launch of small satellites by utilising secondary payload opportunities can include the requirement to be compatible with a certain class of deployment mechanism (e.g. P-POD, X-POD, ISIPOD), they reducing the level of certification required by the secondary payloads by isolating them from the launch vehicle and primary payload [15]. All the constrains limit the volume, mass possible provision for deployable structure such as antennas or solar panels

As the growth of the small satellite launch multiplied, a number of new launch services also growing to fill the gap for dedicated launch of microsatellites and nanosatellites via the use of smaller rockets. The goal for the smaller launch vehicle is to provide launch services for payload range from 10 to 300 kg for the same launch cost of current secondry payload. Notable examples include the Virgin Galactic LauncherOne which will be air-launched from the White Knight Two carrier aircraft

and will have a capacity on the order of 225 kg to LEO [16], a 10kg payload launcher deployed from the XCOR Aerospace Lynx Mk.III suborbital vehicle [17] and DARPA ALASA program involving several companies working towards the launch of a 45kg payload to orbit for less than USD 1 million. These vehicles will support the dedicated launch of microsatellites and nanosatellites, avoiding the potentially mission critical issues related to secondary payload launch opportunities [14].

*4.2. Launch and constellation deployment*

Traditionally, a constellation of nanosatellites has been populated through many launches. However, due to high mission launch costs in comparison with nanosatellites development cost, launches in this manner are not economically viable for the discussed Equatorial nanosatellite constellation. Since the proposed constellation will only be in single orbital plane in Equatorial orbit, the first possible option will be a dedicated single launch for deployment of all the nanosatellites in the Equatorial orbit constellation by the launcher itself. An earlier planning and mission design of the final stage of the launcher, it should made capable of staying in the final orbit to deploy all the 25 nanosatellites will the required orbital spacing.

Alternately we shall share the launch with other satellites to similar orbit. In the second possible option the use of satellite network deploy adapter is used [18]. The satellite network deployment adapter will be similar to the final stage of the launch vehicle which carries propulsion and will use the advantage of orbit perturbation to transfer the nanosatellite to final orbits with optimum use of fuel. Both the discussed options are considered the use of a single launch for deployment of the full nanosatellite constellation. Thus, option is provided because the launch for any space missions a major contributor of the programme cost and multiple launches will dramatically increase the cost.

## 5. Conclusion

The main application of IoT is to collect data from sensors that are remotely deployed and the ability to send command remotely to activate the actuators. Satellite communication is a platform to enable IoT in remote applications to be implemented. Satellite communications are enable through a GEO stationary satellite or an established global LEO communications network such as GlobalStar and Iridium. The Conceptual design of a nanosatellite constellation as an IoT communications platform for Near Equatorial countries is feasible as shown in this paper. In realising IoT through satellite, factors such as 1) interoperability between satellite systems, IoT device terminal with sensors and actuators and 2) compatibility of IPv6 on board the satellite [19] has to be thoroughly studied. The study shown that the near Equatorial countries can benefit from the Equatorial orbit constellation by deploying a minimal number of nanosatellites comparing to hundreds of nanosatellites needed for global coverage with Polar orbits. The current antenna technology for nanosatellite application can only produce smaller antenna beam widths. However, the conceptual design study using basic beam width shows the communications platform for the IoT can be achieved and with the advancement of the antenna design in the future for nanosatellite the design of constellation can be improved. The conceptual design study has shown at 800km altitude with a $20^{o}$ elevation mask, 25 nanosatellites with 4 in-orbit spaces will be sufficient to build the IoT communications platform which will provide continuous coverage for ±10 latitudes near Equatorial countries.

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