Low Earth Orbit design for IoT satellites over Thailand †

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Abstract: Nowadays, we expect to use Internet of Things (IoT) every day, but in remote areas, we may be unable to connect to the core network. IoT satellites have the potential to allow IoT applications in every part of the world. We discuss the design of a low earth orbit satellite and service areas in Thailand that can adapt to an IoT system. We focus on the number of satellites that are visible above Thailand with the AGI STK program. We simulated with various attitudes and 500 to 600 kilometers heights to find the maximum number of visible satellites and efficient designs for a set of low earth orbit satellites. We want to improve data accession opportunities when the channel was busy and increase the storage, transmission, and analysis time of the data.

Keywords: Internet of Things; IoT satellites; AGI STK program; Low Earth Orbit satellites

1. Introduction

Low Earth Orbit (LEO) satellites orbit less than 2,000 km above the earth [1]. We use them for environmental survey, taking images, but a LEO satellite cannot cover any area all the time. Due to its high velocity due to its proximity to the Earth, an LEO satellite has many uses. One is the connection to the Internet of Things (IoT), which now caters to many individual needs, for example, e-health, home automation and elderly assistance, as well as industrial needs, *e.g.*, smart grids, business management, environmental monitoring, and smart cities [2],[3]. Therefore, design of LEO satellites for IoT applications with maximum efficiency becomes important. We varied the incline, Right Ascension of Ascending Node (RAAN) and attitude parameters to suit the desired altitude by simulating an LEO satellite and find the number of LEO satellites in orbit over Thailand and their mean durations or the length of time the satellites can send and receive data, *i.e.*, to find parameters that are most suitable for LEO satellites in combination with IoT [4]

2. General satellite attitude

From Qu *et al*. [5], we found that the height ranged from 500-600 km, so we chose that height for this study, because the decay lifetime of a LEO satellite at 500-600 km was four years and suitable for use.

3. Typical of satellites and Ground sensor stations

3.1 Ground Station Node

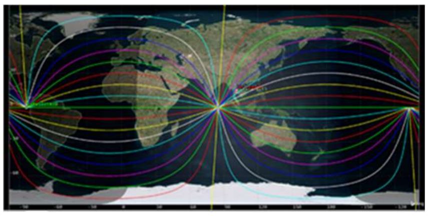
We simulated orbits using the AGI STK program (Analytical Graphics, 2021), based on the ground station point, that can send and receive information from the satellite, at King Mongkut's Institute of Technology Ladkrabang, 13.72264°N, 100.52931°E.

3.2 Simulation parameters

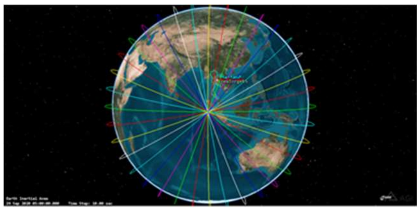
TABLE 1. The parameters used in our simulations.

Parameter	Value range
Satellite altitude	500 to 600 km
Inclinations	0 to 180°
Right Ascension of Ascending Node (RAAN)	0 to 360°

From Table 1. We assumed that we had installed sensors on satellites to collect data from the simulated IoT system.



(a) Display window in 2D format



(b) Display window in 3D format

Figure 1. Simulations for inclinations from 0° to 180° (**a**) Display window in 2D format (**b**) Display window in 3D format

4. Relations between line of sight and coverage

Table 2 shows the footprint coverage based on line of sight distance between ground station and Low Earth Orbit satellites at altitudes of 500 , 550 and 600 km. [6]

TABLE 2. Footprint at altitudes of 500, 550 and 600 km.

EL (degree)	LOS (km)	Footprint (km)	EL (degree)	LOS (km)	Footprint (km)	EL (degree)	LOS (km)	Footprint (km)
90	500	0	90	550	0	90	600	0
80	507.057	88.05	80	557.76	96.85	80	608.47	105.66
70	529.531	181.11	70	581.91	199.02	70	634.71	217.08
60	570.546	285.27	60	626.57	313.29	60	683.23	341.61
50	636.405	409.07	50	698.79	449.17	50	760.62	488.92
40	741.234	567.82	40	811.48	621.63	40	881.98	675.64
30	909.235	787.42	30	992.19	859.26	30	1075.53	931.44
20	1192.945	1121.01	20	1292.99	1215.01	20	1391.49	1307.57
10	1694.947	1669.12	10	1814.25	1786.69	10	1930.97	1901.63

0	2573.922	2573.92	0	2724.25	2724.25	0	2829.8	2829.80

4. PERFORMANCE EVALUATION

4.1 Access vs Incline

We simulated to find the number of satellites that orbit above Thailand or are accessible. We covered inclines from 0 to 180°, attitude of 500, 550 and 600 km above the earth and RAAN = 0°.

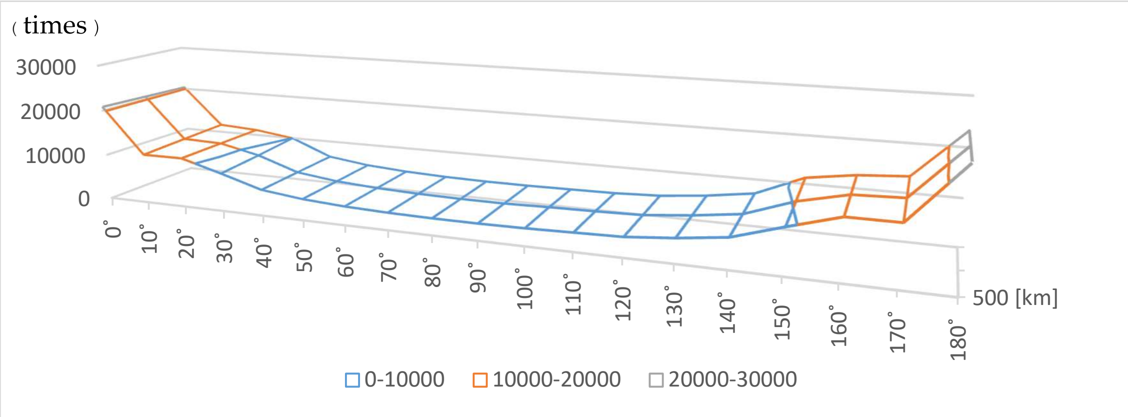


Figure 2. Number of Satellites that orbit above Thailand *vs.* inclination angle and altitude.

From Fig 2, Number of Satellites that orbit above Thailand vs. inclination angle and altitude. The largest numbers of satellites that orbit above Thailand at 500 km, incline = 180°, but incline > 90° is a retrograde orbit, which it is not usable, so the incline angle was constrained in the range 0 to 90°, i.e., in a prograde orbit. When incline decreased, the number of satellites in orbit above Thailand will decrease as well.

4.2 Access vs RAAN

Here, we simulated to find the number of satellites that orbit above Thailand, from the angle between the vernal equinox direction and ascending node or RAAN from 0 to 360°.

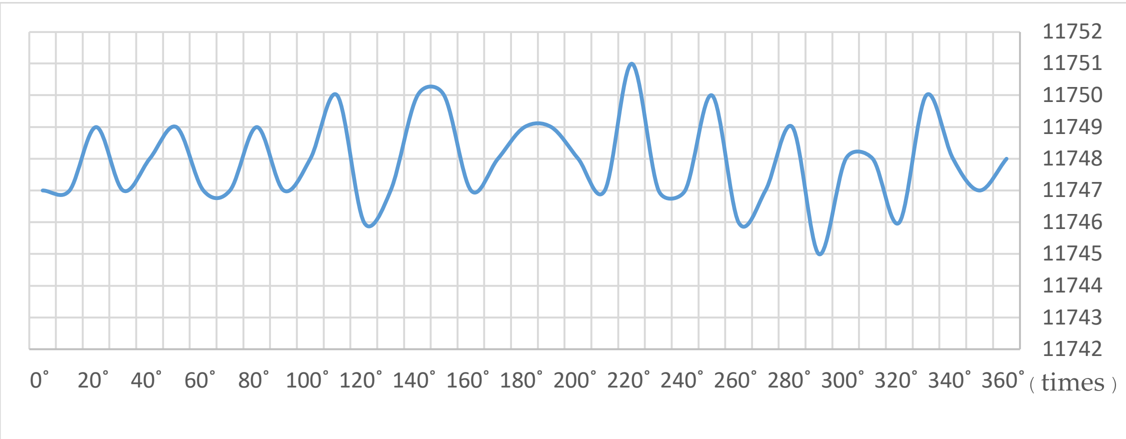


Figure 3. Number of satellites in orbit above Thailand when we varied RAAN.

From Fig 3, Number of satellites in orbit above Thailand, when we varied RAAN the longitude of a celestial sphere with a value from 0 to 360°. Changing the RAAN did not affect the number of satellites that orbit above Thailand.

4.3 Mean Durations vs Access

In this section, we compared the number of satellites that orbit above Thailand (access) and their mean durations.

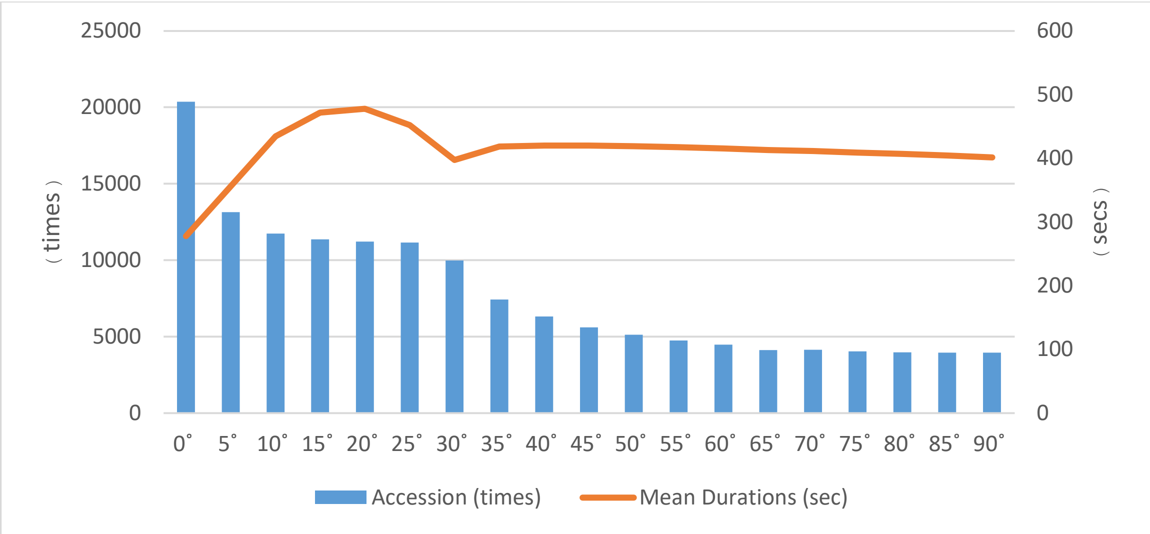


Figure 4. Mean Durations *vs* number of satellites that orbit over Thailand, when comparing the number of Satellites that orbit through Thailand (Access) with mean durations

From Fig 4, Mean Durations *vs* number of satellites that orbit over Thailand, when comparing the number of satellites that orbit above Thailand (Access) with Mean Durations found that the most suitable of the incline between 15 to 20°. we see that the mean duration was up to ~500 sec. Thus, an incline between 15° to 20° was suitable for an IoT system.

5. Conclusion

From an overview of LEO satellites for adaptation with IoT system, we determined the best parameters, that lead to the maximum number of satellites, that orbit above Thailand, and the maximum mean durations, so that we can design an efficient system. Decrease in incline led to decreasing access. Changing the position of ground stations did not affect access and mean duration. Overall, inclines suitable for adaptation with IoT were 15 to 20°. Also, only 500 km, incline 0° that has the number of satellites more than 600 km. So, an altitude of 600 km was best. This paper focused on incline, attitude, and RAAN only. It also depends on other parameters and the use of the satellite.

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