Influence of ground station network distribution on orbit accuracy of low Earth orbit (LEO) satellites

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Since 2010s, many companies such as SpaceX, OneWeb, Amazon and Samsung showed their interests to launch hundreds and even thousands of low Earth orbit (LEO) satellites for global internet service. Due to their unique characteristics compared to medium Earth orbit (MEO) and geostationary Earth orbit (GEO) satellites, these LEO mega-constellations soon draw much attention from the scientific community. Studies from constellation design, to applications such as positioning, ionosphere modelling and gravity recovery are investigated by many researchers.

Orbit determination is a key to many applications. Traditionally, onboard Global Navigation Satellite System (GNSS) receivers are used to determine LEO satellite orbits. However, with thousands of satellites in space in the future, an independent system without relying on GNSS is worth to be studied. Since these LEO satellites are intended for internet service, connections between the satellites and to the ground are available by nature. But how would the distribution of a station network affect the orbit accuracy? How many stations would be sufficient to determine a precise orbit? Besides observations from ground stations, inter-satellite link (ISL) is also proposed and implemented by many current GNSSs. It already showed its potential to improve the orbits. Could this technique also be applied to the orbit determination of LEO satellites?

This simulation study investigates the influence of ground station distribution to orbit determination, as well as the benefit from ISL observations. By using a constellation with 60 LEO satellites, we show that for regional station networks, a high latitude network leads to worse orbit accuracy than a middle or low latitude network. With the help of ISL observations, orbit errors reach the same level as a global station network. We further investigate the influence of different number of stations contained in the network. The results prove that although increasing the station number could improve orbits, the improvement is minimal when the global network contains more than 16 stations. While for a regional network, even with 60 stations, the orbit errors are 1.5 times larger than for a small global network with 6 stations. This proves that the ground station distribution is more important than the number of observations. Furthermore, if the ISL technique is adopted, even a regional station network with 16 stations could be sufficient to determine an accurate orbit.