Research on multiplexing of Data Transmission Resource based on CAS’s Space Science Strategic Priority Programs

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Space Science Mission Operation Center (SMOC) plays the role as the leader of Space Science Mission Operation in China. At present, SMOC undertakes various missions as follows, Dark Matter Particle Explorer (DAMPE) and Quantum Experiments at Space Scale (QUESS) are in the phase of in-orbit operation, while the Hard X-ray Modulation Telescope (HXMT), launched on June 2017, is in commissioning phase. All of them are parts of the CAS’S Space Science Strategic Priority Programs. The payload of DAMPE is composed of four sub-detectors. HXMT is Chinese first astronomical satellite. It will perform a broad band (1-250 keV) all-sky survey, in which a large number of massive black holes and other high energy objects will be detected. The payloads onboard HXMT include the High Energy X-ray Telescope, the Medium Energy X-ray Telescope, the Low Energy X-ray Telescope, as well as a Space Environment Monitor. The task of data transmission’s planning and scheduling is solved via multiplexing of time period. This kind of strategy is easy and robust which can guarantee the accuracy of data transmission task’s planning and execution while the staff of mission operation can easily master related skills. The frequency of the next seven-day data transmission station resource allocation is once a week for DAMPE, while the plan for the next day is determined daily for QUESS. To solve this problem, we noticed that the time of satellite’s passing territory is due to periodicity of satellite orbits. According to this, we could construct ground station multiplexing model and the scheduling model. Next, the permutation and combination of the station receiving time window would be calculated using the dynamic programming strategy. And the confliction of the ground station resources in receiving multi-satellites and multi-missions is overall considered and conclude the selective multiplexing schema list of data transmission resource. Then, considering the satellite’s data storage capacity and data transmission capacity, the model and the best evaluation technique is used to evaluate the multi-transmission solution on the arrangement of the ground station resources.

I. Nomenclature

<table>
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<tr>
<th>Abbreviation</th>
<th>Description</th>
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<tr>
<td>SPPSS</td>
<td>Strategic Priority Program on Space Science</td>
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<td>SMOC</td>
<td>Space-science Mission Operation Center</td>
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<td>DAMPE</td>
<td>Dark Matter Particle Explorer “Wukong”</td>
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<td>SJ-10</td>
<td>Shijian-10 recoverable scientific experimental satellite</td>
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<tr>
<td>QUESS</td>
<td>Quantum Science Experiments at Space Scale satellite “Mozi”</td>
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<td>KX02</td>
<td>Quantum Science Experiments at Space Scale satellite “Mozi”</td>
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<td>HXMT</td>
<td>Hard X-ray Modulation Telescope “Tianyan”</td>
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QKD = Quantum Key Distribution
GSS = Ground Support System

II. Introduction

The “Chinese Strategic Priority Program on Space Science” (SPPSS) project got the approval during the Twelfth Five-Year Plan, which kicked off in 2011. Beneath the project, four missions have been launched. They are respectively Dark Matter Particle Explorer (DAMPE)\(^1\), Shijian-10 recoverable scientific experimental satellite (SJ-10)\(^2\), Quantum Science Experiments at Space Scale (QUESS)\(^3\), and Hard X-ray Modulation Telescope (HXMT)\(^4\). Among these missions, except the SJ-10, currently the others are still in the orbit. The Space-science Mission Operation Center (SMOC) provides operational control services for these missions as the Ground Support System.

SMOC is the center for the integrated operation and management of the scientific missions of space science satellites. The main task of SMOC is to comprehensively plan and analyze space science missions based on scientific observation requirements and the conditions of the space-ground resources, and then to formulate a feasible scientific operation plan and to generate a payload control instruction, in the end data transmission is completed. Through the real-time processing of downlink data, the on-orbit control status and the status of the payload are monitored. At the same time, through the network remote service, we provide scientific utility systems and scientific users with public utility services for task analysis, observation planning, payload status monitoring, and analysis and evaluation.

DAMPE is the first satellite in the series of four space-science missions to emerge from the CAS (Chinese Academy of Sciences) SPPSS. The main scientific objective of DAMPE is to detect electrons and photons in the range of 5 GeV–10 TeV with unprecedented energy resolution (1.5% at 100 GeV) in order to identify possible DM (Dark Matter) signatures. DAMPE was launched on December 17 2015 and was nicknamed as Wukong after the Monkey King, who is the hero in the classic Chinese tale Journey to the West. The satellite is equipped with four scientific instruments: The plastic scintillator Detector; Silicon-Tungsten Tracker; the BGO Calorimeter and the Neutron Detector. DAMPE is capable of measuring precisely the energy of gamma ray and high energy electron, whose spectra and space distribution are used to search for dark matter particle. It can also detect heavy energetic nucleus at TeV level; which, together with the gamma ray spectrum, is useful for the study of the cosmic background radiation and the gamma ray astronomy. The measuring field of its instruments is covered from 5 GeV to 10 TeV and its spectral resolution is higher than 1.5.

In the fifth century B.C, a Chinese scientist Mozi discovered that light travels in straight lines. He was likely to be the first person to record an image with a pinhole. On August 16th 2016, a satellite sharing the same name was launched to the space. That is the Quantum Experiments at Space Scale (QUESS). The scientific objectives of the QUESS mission include implementation of long-distance quantum communication network based on high-speed QKD (Quantum Key Distribution) between the satellite and the ground station, as well as Quantum entanglement distribution and quantum teleportation on a space scale and fundamental tests of the laws of quantum mechanics on a global scale. So far, a joint China-Austria team has performed quantum key distribution between the quantum-science satellite Micius and multiple ground stations located in Xinglong, Nanshan and Graz. Such experiments demonstrate the secure satellite-to-ground exchange of cryptographic keys during the passage of the satellite Micius over a ground station. Related research has been published on top magazines such as Nature and Science.

The Hard X-ray Modulation Telescope (HXMT), which is also known as "Insight", is China’s first X-ray astronomy satellite. There are three main payloads onboard Insight-HXMT, the high energy X-ray telescope (20-250 keV, 5100 cm\(^2\)), the medium energy X-ray telescope (5-30 keV, 952 cm\(^2\)), and the low energy X-ray telescope (1-15 keV, 384 cm\(^2\)). The HMXMT was launched on June 15, 2017 to observe X-ray binary system consisting of black holes or neutron stars and normal stars. It can also monitor gamma-ray bursts at the same time. The main scientific objectives of Insight-HXMT includes (1) Conducting X-ray surveys in large areas, discovering new celestial bodies or new activities of known celestial bodies; (2) Performing high-precision fixed-point observations on X-ray binary satellite systems, (3) Observing of X-ray bursts in isolated pulsars, strong magnetic neutron stars, and neutron stars X-ray binaries and studying the state equations of dense matter; (4) Monitoring storm imagery in the 200 keV-3 MeV energy region, researching Gamma-ray bursts, and looking for electromagnetic counterparts of gravitational wave bursts.

III. Data Transmission Resource Requirements

The data transmission resource planned by SMOC must support the tracking and reception of low-Earth Orbit Space Science satellites to achieve timely and reliable landing of space exploration data in near-Earth orbit, and
provide sufficient data support for subsequent space science research. The reception of space science satellite data has the following distinctive features:

1) **Real-time.** Different from remote sensing satellites, valuable space science exploration targets often appear suddenly. This requires the space science satellite data to be transmitted in real time so that the detection plan can be adjusted in time according to the detection target.

2) **Massive volume.** Space scientific explorer and payload continuously generate the scientific data with high temporal resolution and high spatial resolution and engineering parameter data.

3) **Variable volume.** The volume of scientific data generated by the science satellite will vary depending on different modes and the specific targets of detection.

4) **Limited storage.** The flash memory based SSR on the satellite is limited, which can only store data for a few days.

5) **Multiplexing.** Considering the limited ground stations and resources, massive space exploration data and multiple on-orbit missions require that data transmission resource and ground receiving stations can provide the multiplexing of the resources.

SMOC had effectively engaged in the mission operation for more than 2 years until now and there are only three X-band ground station to afford the data transmission task. DAMPE satellite generate more than 12G bytes of data per day in sky survey mode and hundreds of G bytes of data in fixed-point mode. HXMT generally generates and downlinks more than 200G bytes of data every day, which adds great pressure to data transmission resource and leads to conflicts among multi-satellites and multi-missions. QUESS produces relatively small amounts of the data, however, it will take up the receiving resources. The features mentioned above and the multi-missions require the operator to dynamically arrange the transportation controlling plan according the specific task schedule.

IV. **Multiplexing of Transmission Resource**

The orbital periods of the three space science satellite missions, currently under the duty of SMOC, are around 90 minutes. The orbital altitudes are about 500 kilometers. Both DAMPE and QUESS operate in sun-synchronous orbit considering adequate energy support by stable light condition. The DAMPE satellite orbit belongs to the morning and dusk orbit, and the QUESS satellite orbit belongs to the noon-sub-midnight orbit because of optical communication experiment on the night.

Compared the difference between the DAMPE satellite orbit and the QUESS satellite orbit, which depicted the DAMPE satellite runs around the earth’s Dusk circle while the QUESS satellite runs around the earth’s noon-sub-midnight circle. According to this principle, we can easily allocate the receiving resource and the X-band ground stations by time multiplexing.

![Fig 1 Orbit 3d-Graph of DAMPE and QUESS (KX02) and HXMT](image-url)
As a result, the DAMPE’s data transmission plan is scheduled every dawn and dark. The QUESS’s data transmission plan is usually carried out on midday and midnight. Considering the actual volume of QUESS satellite data, only the daytime transmission cycle is selected. Based on mission of DAMPE and QUESS data transmission plans, conflict resolution methods are applied to arranging HXMT reception plans. The HXMT mission enjoys the priority when facing conflicts between processing’s of HXMT mission and QUESS mission, or the processing’s of HXMT mission and DAMPE mission.

According to the above strategy, the SMOC obtains a multiplexing method of data transmission with high accuracy, high robustness while satisfying all requirements of each mission.

V. Conclusion

SMOC plays the role as the leader of Space Science Mission Operation in China and the role of charging of making the payload control strategy as the fight control decision advisor. It is also in charge of planning the scientific mission, operation scheduling and payload control; payload health check and monitoring the function of uplink and downlink chains. While making the work plan, we must ensure that the plan satisfies the various constraints as follows: satellite resources capacity, satellite running state, ground segments availability and payload parameters. This multiplexing of data transmission resource can be efficiently and easily applied to the mission operation about the ground station resources in receiving multi-satellites and multi-missions by the staff of the SMOC and this method can be applied to future operations.

Acknowledgments

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References