Tiansuan Constellation: An Open Research Platform

Shangguang Wang, Qing Li, Mengwei Xu, Xiao Ma, Ao Zhou, Qibo Sun
State Key Laboratory of Networking and Switching Technology
Beijing University of Posts and Telecommunications
Beijing, China
{sgwang;q_li;mwx;maxiao18;aozhou;qbsun}@bupt.edu.cn

***Abstract*—Satellite network is the first step towards interstellar voyages. It can provide global Internet connectivity everywhere on the earth, where most areas cannot access the Internet by the terrestrial infrastructure due to the geographic accessibility and high deployment cost. The space industry experiences a rise in large low-earth-orbit satellite constellations to achieve universal connectivity. The research community is also urgent to do some leading research to bridge the connectivity divide. Researchers now conduct their work by simulation, which is far from enough. However, experiments on real satellites are hindered by the exceptionally high bar of space technology, such as deployment cost and unknown risks. To solve the above challenges, we are eager to contribute to the universal connectivity and build an open research platform, Tiansuan constellation, to support experiments on real satellite networks. We discuss the potential research topics that would benefit from Tiansuan. We provide two case studies that have already been deployed in two experimental satellites of Tiansuan.**

***Index Terms*—Satellite Internet, Satellite Edge Computing, 6G, Testbed.**

I. Introduction

Human society is facing development bottlenecks such as global warming, prominent social contradictions, the coexistence of industrial surplus and resource depletion. Would human need interstellar voyages and expand the boundaries of human existence like the Age of Discovery? If yes, the satellite network will play a major role at the beginning of the era of interstellar voyages. Meanwhile, more than 80% of the land area and more than 95% of the ocean area cannot access the Internet[1]. It is impossible for the terrestrial network to provide ubiquitous broadband internet access due to the geographic accessibility and the high deployment cost.

Low Earth Orbit (LEO) satellites are promising to provide global internet and service due to the reduced cost of satellite manufacturing and launch. Multiple space companies are gearing up to deploy LEO constellations to provide global low-latency high-bandwidth Internet. Dated to November 2021, SpaceX has now launched 1,844 Starlinks and London-based OneWeb has launched 358 internet satellites. Besides, Microsoft and Amazon offer "Ground station as a service" for space customers[2].

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[1]https://www.ccidgroup.com/info/1096/21569.htm

[2]https://aws.amazon.com/cn/ground-station/

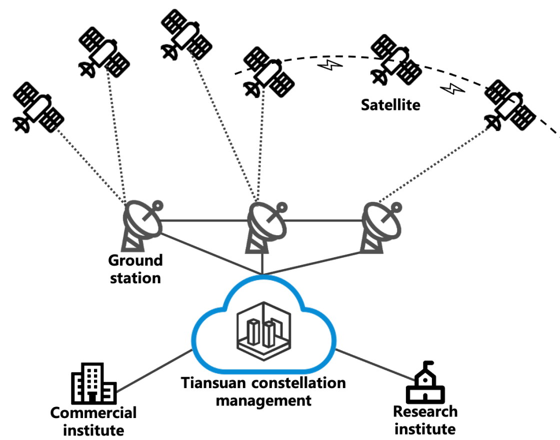

Fig. 1: Tiansuan Constellation Ecosystem.

This exciting development is taking shape rapidly in the industry, while the research community is urgent to do some leading research to bridge the connectivity divide. Large-scale constellations feature hundreds or thousands of low-volume satellites, each with an orbital period of 100 minutes. This new type of infrastructure brings inherent challenges. Recent work has highlighted the challenges brought by the dynamic connectivity at various fields such as network (e.g., topology [1], routing [2], congestion control [3]), earth observation [4], in-orbit edge computing [5]. While it is useful to explore these problems using simulation tools, ultimately, we would like to conduct experiment evaluations on real satellites. However, this is hindered by the exceptionally high bar of space technology, such as deployment cost and unknown risks. SatNetLab calls researchers to conduct some network experiments on commercial satellite Internet as users [6], while experiments changing the network settings or to be deployed on satellites may be not allowed.

To bridge the research gap, we are eager to contribute to the universal connectivity and propose Tiansuan constellation, an open research platform illustrated in Fig. 1. Tiansuan has three phases, the first phase with 6 satellites, the second phase with 24 satellites, and the third phase with 300 satellites. Except for satellites owned by our institute, satellites carrying our payloads and satellites joining our Tiansuan plan together form Tiansuan constellation. This open research platform would enable experiments on real satellites and testing practical solutions to improve the performance of constellations. Thus,

TABLE I: Satellite Parameters of Tiansuan Constellation Phase 1.

Number	Orbital Altitude	Mass	Battery Capacity	Spectrum	Uplink Rate	Downlink Rate	ISLs	Processors
1	500±50km	$\leq$ 30kg	118Wh – 236Wh	X-band	0.1Mbps – 1Mbps	100Mbps – 600Mbps	NO	CPU/NPU
2	500±50km	$\leq$ 30kg	118Wh – 236Wh	X-band	0.1Mbps – 1Mbps	100Mbps – 600Mbps	NO	CPU/NPU
3	500±50km	$\leq$ 30kg	118Wh – 236Wh	X-band	0.1Mbps – 1Mbps	100Mbps – 600Mbps	NO	CPU/NPU
4	$>$ 500km	$>$ 50kg	$>$ 360Wh	X, Ku, Ka bands	$\geq$ 200Mbps	$\geq$ 1Gbps	YES	CPU/NPU/GPU
5	$>$ 500km	$>$ 50kg	$>$ 360Wh	X, Ku, Ka bands	$\geq$ 200Mbps	$\geq$ 1Gbps	YES	CPU/NPU/GPU
6	$>$ 500km	$>$ 50kg	$>$ 360Wh	X, Ku, Ka bands	$\geq$ 200Mbps	$\geq$ 1Gbps	YES	CPU/NPU/GPU

it helps to study the impacts of the real physical environment (e.g., weather conditions), which is hard to fully capture in simulations. Moreover, real experiments on satellite constellations can uncover pitfalls to the solutions for commercial deployment potential.

In the following, we introduce the overall design of Tiansuan and how it could help the research community and LEO satellite industry in Section 2. We discuss research topics Tiansuan could support in Section 3. We provide case studies to be deployed on Tiansuan in Section 4 and conclude in Section 5.

II. Tiansuan Constellation Design

A. Overview

Tiansuan aims to build an open platform that supports experiments including but not limited to 6G core network system, Internet of data, satellite operating system, federated learning and AI acceleration, and onboard service capability opening. It has three phases, the first phase with 6 satellites, the second phase with 24 satellites, and the third phase with 300 satellites. There will be three types of satellites in Tiansuan. The first type belongs to our institute. The second type is owned by other institutes and those satellites carry our payloads which can collaborate with other payloads on the computing platform. The third type also belongs to others and can join our open computing platform through a unified interface.

As mentioned above, the first phase of the Tiansuan consists of 6 satellites, including two main satellites, two auxiliary satellites, and two edge satellites, with the first satellite expected to be launched in May 2022. The constellation will be completed in 2023. Satellites in Tiansuan are manufactured according to the standard [7] and the parameters of satellites in the first phase are in Table I. Most satellites will be launched into sun-synchronous orbit. The first three satellites combine edge computing capabilities with remote sensing applications. The last three satellites are mainly to explore communication capabilities with inter-satellite links. Control functions are provided by the onboard computer while the majority of the computing power is provided by the payloads listed in Table I. As shown in Fig. 1, ground stations receive data from satellites and distribute them through the Internet. Data is only transmitted when the satellite-ground link is available during 6-8 minutes with an average of one time per day. Ground stations also serve as gateways to the cloud computing platform as shown in Fig. 1.

B. Operation Mechanism

The constellation operates according to the open principle. For research institutes, it provides a platform for scientific research. Institutions can join Tiansuan either by submitting research requirements or by enhancing the constellation in collaboration. For satellite companies, Tiansuan is a complement to their ecosystems. Most companies find it inconvenient to complete some research work for profit reasons. Tiansuan fills this gap by gathering researchers to work on cutting-edge exploratory problems. As a result, the overall cost for companies and research institutes can be reduced to better stimulate industry development. Other organizations can take advantage of Tiansuan for testing new devices or payloads.

III. Potential Spectrum of Experiments

It is difficult to envision the full spectrum of experiments in Tiansuan, several research topics that it would support are as follows.

A. Networking

The ambitious plan for providing the Internet through satellite constellations has attracted the attention of both industry and academia [8]. Satellite communication, as an enabling technology of 6G networks, is crucial to achieve global coverage of mobile networks. Tiansuan can support networking-related experiments at the physical layer (e.g., link measurement), network layer (e.g., routing), transport layer (e.g., congestion control), and application layer (i.e., interactive applications). Besides, it can also support experiments on the network control plane (e.g., core networks).

Next, we discuss the deployment of 6G core networks in detail. With the rapid construction of space Internet infrastructure, traditional ways of managing constellations cannot keep up. Satellites are made from generic hardware and deployed using custom software. By doing so, the onboard network, computation, and storage resources can be utilized more efficiently. Core networks connect heterogeneous access networks and data networks. The combination of satellite constellations and next-generation core networks will lead to a variety of application scenarios. For example, LEO satellites are capable of delivering Internet services with lower latency

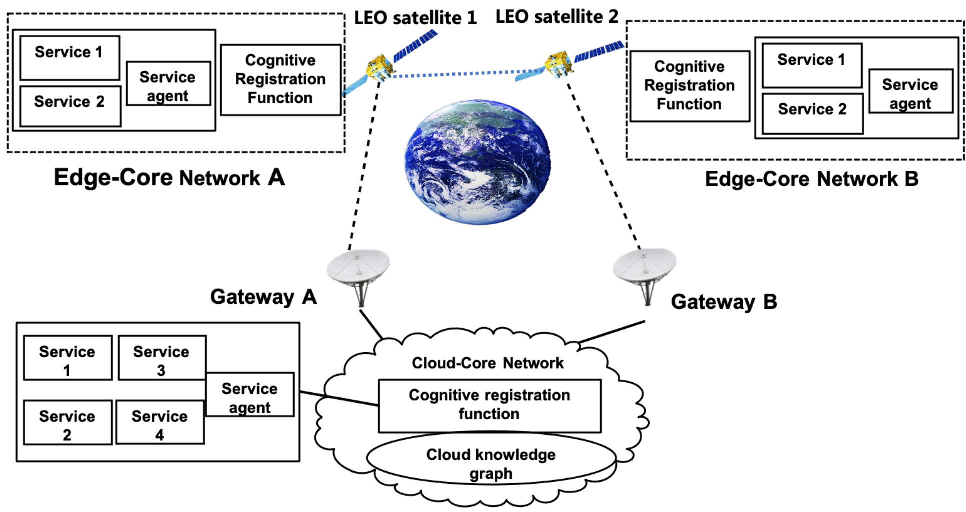

Fig. 2: Cognitive Service Architecture of 6G Core Network.

over long distances [9] [10]. Core networks deployed on satellites will reduce the latency of signaling interactions incurred by the control plane, enabling much more real-time services. On the other hand, satellite constellations can enhance their capabilities with the next-generation core networks. Satellite constellations are becoming increasingly difficult to manage due to their explosive growth. By deploying lightweight core networks on satellites, constellation management can be more flexible and agile.

Developing the core network functions for LEO satellite nodes is the key to integrate the 6G core networks with satellite constellations. However, there are two challenges to overcome. First, satellite networks are experiencing rapid changes in network topology and connectivity. The onboard core network should be able to adapt to the highly dynamic nature of satellites. Second, power supply and processing resources on satellites are limited. Network functions and applications should be orchestrated more efficiently. Thus, one of the key objectives of Tiansuan is to verify the cognitive service architecture for 6G core networks as shown in Fig. 2.

1) Mobility Management: Satellites in highly elliptical orbits will have a long latency. While LEO satellites can reduce latency significantly, they still suffer from short link duration. Even though a large ground-orbiting satellite constellation can solve the short link duration problem, frequent handovers will affect the quality of the service. Thus, the mobility management of the integrated satellite-terrestrial network is an important experiment of Tiansuan.

2) Core Network Coordination: Inspired by the distributed nervous system of the octopus, we propose a cognitive service architecture for the 6G core network [11]. One main difference between our cognitive service architecture and previous architecture is that we divide the 6G core network into the edge and cloud core networks. The edge core networks are similar to the peripheral nervous system of an octopus's arms, as they provide the majority of the network control. The cloud core networks, acting as the central brain of octopus, are only responsible for guiding and assisting the coordination between edge core networks. In addition to satellite communication, the edge core network will be deployed on satellites. With the help of Tiansuan, we will deploy edge core networks and evaluate their performance.

3) Serverless and Stateless Design: Serverless and stateless design is an effective way to achieve lightweight deployment. The original network element is split into several independent functions. Each functionality can be independently developed, tested, deployed, and evolved. Different functionalities can call each other through flexible interfaces. Stateless separates status from functions for network elements. This will benefit satellite network reconfiguration and synchronization.

In an integrated space-air-ground network, the limited resources and weak capabilities of space-based nodes must be considered. The 6G core network can be implemented on the satellite with more efficient resource usage by utilizing serverless network functions. By using the remote interface, network functions can access abundant resources on the ground. This allows us to deploy lightweight applications. By using this design, network functions can be deployed in different locations according to business needs and resource availability. In addition, it also supports network function cancellation and redeployment.

4) Knowledge Graph: Satellite networks are highly dynamic and have uncertain links. It is more difficult to select a reasonable node and plan an optimal flow path for users. Creating a knowledge map of users, networks, and services can provide an overview of their real-time status and logical relationship. In addition, it provides real-time user plane node selection and dynamic traffic path planning.

The control plane of onboard core networks controls access and mobility, as well as establishes and schedules user sessions. With the uncertainty of the network, large-scale user access, and the dynamics of satellite-to-ground services, the control plane signaling process has become increasingly complex. Through its knowledge extraction and reasoning capabilities, the knowledge graph can support decision-making processes in the network. Therefore, it simplifies signaling interactions in the network.

Nodes and attributes are the basic elements of the knowledge graph. When the collected information has temporal characteristics, it can be used to describe the state of the nodes. The mobility of satellite networks and the need to ensure service continuity necessitate frequent network element migration. The characteristics of the knowledge graph can be used to plan reasonable migration strategies for network element functions. As a result, the knowledge graph ensures better service continuity.

B. Computing

LEO satellite constellations promise to provide global, low-latency, high-bandwidth Internet service. There is also a potential opportunity that constellations offer computing services wherever people want. Motivated by edge computing on the ground, satellite edge computing has been proposed by placing computing resources at the LEO satellite constellation [12], [13]. Tiansuan would support satellite-borne computing platforms, constellation resource management, general computing service, and heterogeneous satellite data integration. Tiansuan could also provide technical references for supporting the construction of space data centers. In the following, we provide more details on two topics of processing space-native data, namely real-time earth observation and AI in space. Besides, we also discuss how to provide general computing services for ground users.

1) Real-Time Earth Observation: About 45% LEO satellites in orbit are used for earth observation, which can be further used in various applications, such as disease spreads [14], crop monitoring [15], and natural disaster management [16] (e.g. forest fires, floods). As the constellation size increases, the conflict between large space-native data volume and limited downlink capacity is the bottleneck of real-time Earth observation. There are two potential ways to address the challenge, The first way is to model the freshness of the interested information and only download the freshest information while the second way is to leverage multiple distributed ground stations to schedule downloads effectively.

Freshness of Information. Since real-time applications need fresh information for decision-making, it is critical to make sure that the received information is valuable and timely. Thus, one of the main reasons behind the difficulty in the deployment of various real-time earth observation applications is the hardness of obtaining fresh data. Unlike traditional terrestrial transmission, data must wait on the satellite before it establishes a link to a ground station. This adds to the staleness of data received by the ground stations. In addition, when the constellation size is small, each ground station is connected to the per satellite only for a few minutes, it is very difficult for them to download much high-quality image data in such a limited time; when the constellation size is large, the ground stations are also bottle-necked by the limited bandwidth and resource contention. Thus, data received by ground stations can be stale due to large transmission delays. Age of information (AoI) [17], [18] as a metric of capturing the freshness from the destination is widely used in time-sensitive applications. This motivates us to conduct AoI-aware research on the data sampling, transmission, and processing on Tiansuan for improving the performance of earth observation systems.

Ground Station Deployment. The current centralized ground stations incur high deployment cost [4], large delay jitter [3], and weak scalability. In general, the cost of deploying a ground station is around a million dollars, primarily due to the current demand for professional equipment and maintenance [4]. For new entrants, the cost of permitting and establishing ground stations is prohibitive. To meet the specific delay requirements of different users at different times, we could study a suitable ground station deployment strategy. The development of lightweight and scalable ground stations will also be non-trivial to realize the interconnection and intercommunication of the satellite-to-ground network. With a large number of satellites and ground stations, we must dynamically schedule ground-satellite links while taking into account orbits, the quality of the link, and the weather. We can avoid congestion and improve transmission efficiency by dynamic ground station-satellite link planning Forecasting is considered a good way to solve this problem [4]. Traditional traffic forecasting methods are unable to accurately predict traffic on satellite networks due to the spatial and temporal correlation characteristics. Spatial-temporal predictions have received considerable attention in recent years, mainly on traffic flow predictions [19]–[21]. The satellite downlink rate varies with the conditions of the channel at a given location. By using historical data and environmental information (e.g., weather conditions) to create a satellite link spatial-temporal prediction model, we can analyze the mutual influence between different links and the autocorrelation over time.

2) AI in Space: The rapid development of satellite edge computing and satellite Internet will promote the popularity of onboard applications, such as satellite-based AI techniques.

Federated Learning in Space. Federated learning (FL) [22]–[24], as a distributed learning paradigm, has great prospects for widespread deployment in satellites. Traditional image detection methods transmit these images to the ground station for recognition. But these methods face two key challenges. The first challenge is the uplink and downlink bandwidth is limited and thus the transmission process has a large latency. The second challenge is the transmission process is relatively fragile and then the transmission may be interrupted. In addition, privacy protection is also a key requirement for satellite applications. By FL, we can directly process and analyze the collected information on the satellite and protect the satellite's data privacy [25]. We propose to establish a federated learning and AI acceleration platform in Tiansuan, through which we further study and verify the following research points: (1) machine learning model training and acceleration capability verification based on space-borne computing equipment, (2) design and verification of AI algorithms for specific satellite application scenarios, and (3) establishment and verification of federated learning experimental platform based on Tiansuan.

Meanwhile, FL, just like traditional deep learning systems [26], [27], often demonstrates incorrect or unexpected corner-case behaviors, especially in the harsher space environment. We can design a systematic testing tool for automatically detecting erroneous behaviors of FL-driven satellites that can potentially lead to data invalidation analysis [28]. Our tool is designed to automatically generate test cases leveraging real-world changes in the space environment like meteorites, lighting conditions, shooting angle. We can further show that the test inputs generated by our testing tool can also be used to retrain the corresponding FL model to improve the model's robustness.

Inference in Space. As mentioned above, offloading all deep learning tasks to the ground station is one of the current mainstream research methods [29], [30]. However, the challenge is the limited bandwidth in practical applications. It's reported that about two-thirds of the earth's surface is covered by clouds at any time and satellites often capture and save a large number of useless images, which cause the downlink bandwidth occupied and great uncertainty. The current experimental satellites have airborne AI processing capabilities. It's possible to leverage onboard inference to identify and remove useless images and only send useful ones to the ground station for subsequent processing. It is promising to accelerate AI tasks using onboard heterogeneous computing platforms [31]. Moreover, speculative inference can benefit data-driven applications that involve the fusion of multi-modal satellite signals [32]. Real-time actuation can benefit from speculative inference. For instance, satellites navigation or grasping can leverage multi-modal signals from different points to finish difficult tasks in complex environments.

3) Space Service Computing: The ground-satellite connectivity and inter-satellite connectivity are time-varying due to the dynamics of the satellite network topology. In such a dynamic context, there are two challenges for providing reliable network service. The first challenge is how to select the ground-satellite path and inter-satellite path, The second challenge is how to realize the dynamic service deployment, computing offloading, service migration and coordination. Micro-service and function as a service are the lightweight application architectures for services in satellites. They decompose applications into finer-grained service components which can be deployed and executed quickly and independently. Many research topics still need to be explored. First, how to partition applications into a set of micro-services or functions? Second, how to deploy dependent micro-services and functions dynamically? Third, how to register and manage the highly distributed micro-services and functions?

4) Cluster Orchestration: Satellite edge computing can realize computation offloading and process the computation tasks at LEO satellites, which can save satellite-ground or inter-satellite link transmission bandwidth and reduce the impact of large satellite-ground link delays. However, there are some issues to be addressed. First, due to the limited computing power of a single LEO satellite, we have to utilize satellite clusters to process the task cooperatively. In addition, we should design an efficient cooperation strategy to compensate for LEO satellites' high mobility and wide-area load imbalance. Lastly, we need to consider how to distribute computation tasks to achieve a balance between multiple objectives, such as energy efficiency, computing delay, and communication transmission delay.

It is necessary to manage a large number of satellites in the constellation. Traditional cluster orchestration technology has been widely adopted to manage a huge number of computation and storage resources in the network [33]–[36]. With the development of edge computing [37], integrating the emerging edge nodes and platforms to cluster management provides a huge number of benefits, such as resources utilization improvement, the software deployment process simplification, and the compatibility with cloud-native software stack [38], [39]. Treating LEO satellites as edge nodes gives a unified way to schedule the applications on the satellite. This approach avoids re-developing the platform-specific programs while moving toward the vision of *software-defined satellite computing*. Previous work has investigated the difficulty of deploying traditional container orchestration technology on the satellite co-located with the ground station [40], where we call this inter-satellite orchestration. However, there may be a bunch of computing units in a single satellite (e.g., Raspberry Pi). Scheduling tasks to these computing units efficiently can fully utilize the computing resources on the satellite. Inspired by the inter-satellite orchestration, we can also integrate computing units inside the satellite and provide services (e.g., KubeEdge [41]). We call this inner-satellite orchestration. With this multi-level management technology, the computing efficiency can achieve a great enhancement.

C. Satellite Operation System

To the increasing demand for satellite software [40], [42], it is urgent to design and develop an underlying operating system for the satellite Internet. This new operating system features miniaturization, ubiquity and universalization. It will be installed and verified on the satellite to build an open satellite software environment.

However, the lack of support software and APIs in the current operating system ecosystem prompts us to develop a novel real-time operating system with hardware-software co-design for embedded devices. Therefore, the satellite operating system needs to support users' definable and quantifiable multi-task real-time requirements, such as databases, machine learning engines, image and video processing. However, the implementation may face many challenges. First, how to propose an approach to upload third-party software while guarding the security and extensibility? This requires the operating system to support a variety of technologies, such as static code analysis, run-time stain analysis, and execution sandbox. Second, how to ensure memory safety during software runtime? We can leverage the Rust programming language to implement the operating system for maximum memory safety [43], [44]. We also need to improve the relevant toolchain and system middleware to pave the way for future development. Third, how to ensure the reliability of the operating system in the extreme environment of space (e.g., single event flipping)? This requires the developers to research on multi-machine backup and fault-tolerance technology to ensure the stability of the software.

D. Security and Reliability

The security and reliability of satellite constellations are fundamental to enable its great potential. Tiansuan would support solutions that guarantee security and reliability.

1) Security of Constellation: Blockchain is a decentralized data storage technology. It ensures data transparency, integrity, and immutability. SpaceChain[3] employs blockchain on satellites to provide secure orbit data storage, reducing the dependency of blockchain on the ground network. Two nanosatellite-based blockchain nodes have been launched into orbit aboard Chinese Long March rockets in 2018. A successful test of space-to-ground blockchain transactions has been done by SpaceChain in 2019. Blockstream[4] has launched the service of Blockstream satellite aimed at broadcasting the Bitcoin blockchain to the entire planet via satellite. Mital et al. [45] demonstrate Tiansuan blockchain's smart contract and distributed ledger for multi-sensor satellite by employing software STK.

While these works demonstrate their implementation of blockchain on satellites, there are remaining issues. As satellites are the main source of spatial data, the storage of data on satellites and the transmission to the ground is one of the most crucial issues. Digital signature on the satellite is required to be researched to provide the traceability of data to ensure immutable storage. The satellite-ground collaborative blockchain transmission is a promising solution to guarantee the reliability of links and the credibility of data. The limited resource and the special architecture of satellite networks increase the difficulty of problem modeling and analysis. Moreover, simulations on the ground are insufficient to conduct further researches. Fortunately, Tiansuan provides the opportunity for real experiments, which would speed up the evolution of blockchain deployment on satellites.

2) Reliability of Constellation: Benefiting from the wide application of commercial-off-the-shelf in LEO satellites, the cost of LEO satellites has been further reduced. At the same time, LEO satellites are also endowed with excellent application compatibility. However, the commercial-off-the-shelf is not designed for the harsh environment of space. In the LEO environment, there is almost no atmosphere and satellites mainly rely on thermal radiation for heat dissipation. In the illuminated area, the temperature can rise to 400K, while in the non-illuminated area it drops to 150K [46]. The low-mass LEO satellites frequently enter and exit the illuminated area, causing their working temperature to fluctuate drastically and frequently. Besides, the computing power of the satellite will fluctuate greatly due to the energy distribution strategy and overheating protection strategy on the satellite. On the other hand, high-energy charged particles are affected by the earth's magnetic field, forming a high-energy particle radiation belt. The commercial-off-the-shelf components within its range may have a single-event effect [47]. This can lead to calculation errors, temporary, or even permanent failures of the components. Traditional reliability assurance strategies, such as the introduction of redundancy, checkpoints, are difficult to apply to complex and large-scale satellite service instances on satellites with extremely limited energy reserves and computing power. Therefore, the service reliability guarantee of LEO satellites is also a key point in Tiansuan.

[3]https://spacechain.com/

[4]https://blockstream.com/

E. Hardware Testing

Tiansuan also supports space experiments and in-orbit testing of new hardware devices. For example, the performance of sensors, cameras, and antennas can be tested onboard. Besides, computing acceleration equipment such as acceleration boards can also be deployed to verify its performance and reliability in the space environment. Furthermore, Tiansuan can also carry out the distributed deployment of the computing platform to evaluate its performance in the satellite environment.

IV. Case Study

We have deployed two use cases in both experimental satellites of Tiansuan named Baoyun and Chuangxingleishen, which will be launched on December 7, 2021.

A. Satellite-borne B5G Core Network

On August 9, 2021, we deployed a 5G core network system on the satellite called TY20. This is the first time in the world to show that the core network of mobile communications has been deployed on orbiting satellites. We tested the signaling interaction between the onboard B5G core network and the terrestrial private 5G network in both the control plane and the user plane. Satellite control commands were sent through the uplink telemetry link. The B5G core network on the satellite successfully realized user registration, session establishment, and control of satellite equipment. Downlink telemetry showed that the three main functional components of the core network worked normally. It also showed that the core network control data was generated correctly. The control data generated by the B5G core network was downloaded to the terrestrial private 5G network. In this way, we realized the local offloading of edge computing controlled by satellites and conducted tests such as video calls. As shown in Fig. 3, we have successfully deployed a lightweight B5G core network on both Baoyun

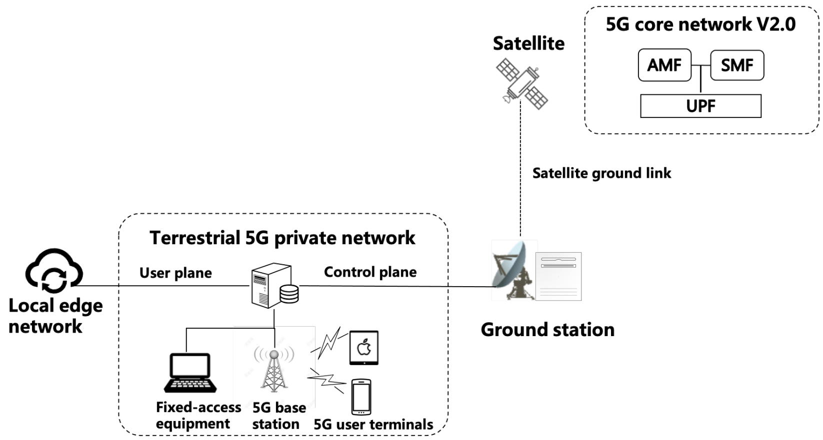

Fig. 3: Satellite-Borne B5G Core Network.

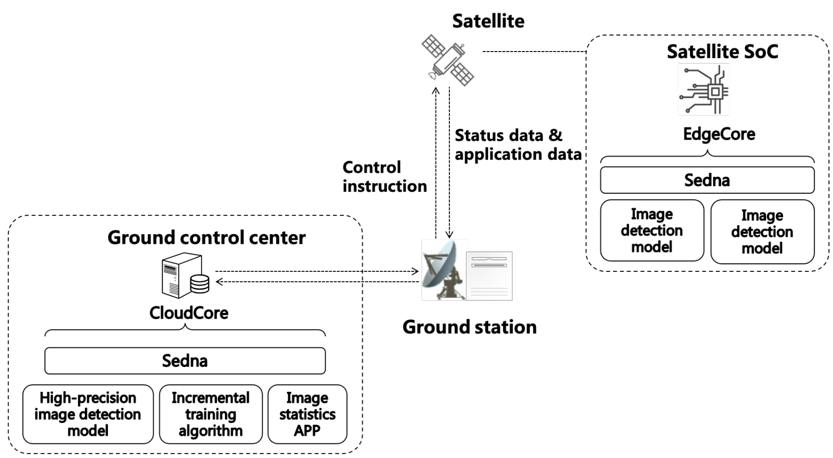

Fig. 4: Image Inference Based on KubeEdge.

and Chuangxingleishen satellites. This core network is the updated version of the former 5G core network. It enhances the signaling interactions and can be used to set up video calls based on session initiation protocol. Tests of functionalities and performance will be conducted after the two satellites are launched.

B. *Image Inference Based on KubeEdge*

We have implemented KubeEdge and the corresponding AI-related system on both Baoyun and Chuangxingleishen satellites as shown in Fig. 4. In this system, we deployed a central controller using a Linux server on the ground. The satellite establishes an intermittent connection with the central controller inside the KubeEdge runtime according to the position of the satellite. Based on Sedna, the KubeEdge AI extension, we deployed two image detection models, a lightweight model and a high-precision model on the satellite and the central controller respectively. During the inference of the AI pipeline, the satellite will capture the image and detect whether it is an object of interest. When the confidence of inference is high, the satellite will use this concrete result for later processing. Only when the confidence is low, the satellite will transfer the image to the central controller on the ground, aiming to get an exact inference result using the high-precision image detection model. Such a collaborative approach utilizes the computing resources on the satellite, which reduces the end-to-end latency in an AI pipeline.

V. Conclusion

To meet the demand for real experimental evaluations on LEO satellites, we introduce an open research platform, Tiansuan constellation. We present the goal and key designs of Tiansuan and then state how various institutes can use Tiansuan. We also discuss potential research topics such as 6G core network systems, satellite edge computing, federated learning and AI acceleration, satellite operating system, constellation security and reliability. Finally, we provide two case studies of real deployment.

In the future, we hope that more institutes and individuals interested in LEO satellites can join us in this exciting research area.

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