Edge Computing Empowered Satellite-Territorial Networks: Service Architecture, Use Case, and Open Issues

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Abstract. Satellite-assisted Internet of Things (IoT) communications, artificial intelligent (AI) empowered wireless communications have been expected as two of the key enablers for 6G visions, since they can help 6G achieve better intelligence, coverage in diverse scenarios besides faster transmission speed than 5G. A straightforward way to enable this vision is moving computation facilities onto the satellites using the edge computing paradigm. At its current state, existing satellite edge computing proposals only describes a rudiment of the satellite design with revealing the service architecture of the edge computing empowered satellite-territorial networks. In this backdrop, this paper presents a service architecture of edge computing empowered satellite-territorial networks, which is a layered structure contains two pools and five layers. To exhibit the benefit of the service architecture, two use cases are presented, in which a satellites-based spectrum sensing use case is detailed, and the numerical test results are given and analyzed. Finally, several open issues in implementing our proposed architecture are outlined.

Keywords: Intelligent satellite · Satellite network · Architecture · Use case

1 Introduction

The fifth-generation (5G) mobile networks, which are on the eve of their large-scale commercial operation in 2020, are promised to provide high bandwidth and low delay communication services for devices on the ground. However, for areas with scarce infrastructure, like rural area, mountain area, disaster-hit area, and aerospace, the service coverage is far from meeting the requirements. In this backdrop, satellite networks are treated as an import complement of territorial networks for providing 3D coverage and seamless service in the 6G vision. A satellite network could be utilized as the communication relay or space base station for providing services for ground or aerial end-user devices in the infrastructure-less areas. The inherent wide coverage characteristic of satellite networks is believed to be an important enabler for Internet of Everything (IoE). In the envisioned ubiquitous communication scenarios in the 6G, satellite communications are utilized in

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combination with aerial and terrestrial communications to support super IoT communications [1]. Moreover, satellite networks could be utilized in combination with aerial and territorial networks to form a Space-Air-Ground integrated networks (SAGINs) for supporting diverse applications [2, 3].

Therefore, satellite networks, and especially layered networked Low-Earth-Orbit (LEO) satellites, have attracted much attention from both the academia and the industry. Besides traditional LEO satellite communication systems, like Iridium, a few cheaper satellites adopting commercial off-the-shelf (COTS) components, called small satellites, have been growth rapidly. Starlink, a project of the SpaceX company, plans to launch nearly 12,000 satellites in the space, and has already deployed more than 482 satellites in the orbit by June 04, 2020. Amazon released its project, named ‘Project Kuiper’, in which 3,236 satellites will be launched in the next 10 years [4]. Several other technology majors are working on space-based internet projects, like FaceBook, Google, Samsung, and OneWeb. In academia, how to integrating satellite networks into territorial and aerial networks in the 6G era is a burgeoning research area [5, 6]. For the layered satellite networks composed of high orbit satellites, medium orbit satellites, and earth orbit satellites, software defined networking (SDN) network function virtualization (NFV) are chosen as the protocols to realize efficient network management in satellite-territorial networks (STNs) [7, 8].

These efforts could significantly extend the coverage area of the Internet service while promoting the flexibility of the STNs. However, the long latency, high mobility, and asymmetry properties of satellite communications may seriously degrade the network performance and user experience. Moreover, in existing proposals, the satellite constellation is mainly treated as a data transmission path in the space and it does not participate in the data processing of diverse applications. This hinder the reduction of the task response latency. To tackle this problem, one of the key points is to place computational facilities and algorithms, especially artificial intelligence (AI) algorithms, on the satellites to process data near the source. However, it is a non-trivial task to move the cloud up onto the satellite due to three factors:

- First, the payload of a satellite is usually very limited compared with a server at the territorial cloud data center.
- Second, the common tight-coupling design of the satellite payloads is not flexible enough to support agile service deployment.
- Third, the high mobility nature of satellites limits the service time of each satellite for an area.

Tackling these challenges require a clean-state design of the satellite payload as well as the satellite network service construction/usage. On the one hand, the design of satellite payloads should be intelligent, modularized, and reconfigurable. On the other hand, the satellite network should be service-oriented and should be transparent to the end-user devices. A few efforts have been made on this topic so far, which introduce edge computing and AI to alleviate the problem incurred by the limited on-board processing capability of the satellites. However, most existing works only focus on the network/software/hardware architectures from the communication or computation perspective, and none of existing works are service-oriented [5, 9–11]. Moreover, an instructive use case of edge computing-empowered STNs from the service perspective is still in absence.

In this backdrop, we aim to establish the service architecture of edge computing empowered STNs from the service-oriented perspective. The main works and contributions of this paper are fourfold: first, the layered architecture in the perspective of service is introduced for satellite edge computing; second, two instructive use cases of our service architecture is illustrated through satellites-based video transmitting relay and spectrum sensing; third, several open issues are analyzed to stimulate future researches in this area.

The remaining of this paper is structured as followers. Section 2 gives necessary research background and our research motivation. The service architecture of edge computing empowered STNs is introduced in Sect. 3. Section 4 presents motivating use cases, and the open issues are discussed in Sect. 5. Section 6 briefly summarizes our work in this paper.

2 Research Background and Motivation

2.1 Integrated Satellite Networks

Satellite networks are integrated with diverse network paradigms from different perspectives. Two typical proposals are STNs and SAGINs. STNs combine satellite networks with territorial networks to extend the service coverage while promoting service quality for IoT applications.

SAGIN is a new architecture aiming at extending the network coverage area to interconnect a huge number of IoT devices spread in diverse environments. Typically, a three-layer architecture, which contains space layer, air layer, and ground layer, is adopted to construct a SAGIN. In the space layer, a satellite network is established to provide long-range network service, and it may include satellites in different orbits; drones, balloons, and other unmanned aerial vehicles (UAVs) at different heights constitute the air-layer network; the ground-layer network refers to the territorial networks, like cellular networks, wireless sensor networks, etc. A few cross-layer wireless links are built between different layers to conduct traffic relay between heterogeneous wireless networks.

To tackle the complex management problem introduced by heterogeneous wireless network integration, software defined networking (SDN) [12] and network function virtualization (NFV) are widely accepted as the management framework for STNs and SAGINs. The controllers in SDN are usually implemented on the ground control stations (GCS) and high-orbit satellites, while low-orbit satellites and other air-layer platforms consist the data plane.

Incorporating satellite networks to territorial networks to support diverse services brings three main advantages. First, the satellites operate at high altitude have inherent advantage in its coverage area than any territorial or air networks. Second, the broadcast nature of satellite communications could greatly promote the transmission efficiency. Third, satellite transmissions are more robust than territorial or air networks, which could be easily affected by ground disasters, weather, etc. However, it is not straightforward to include satellite networks due to five main challenges. The first challenge lies into the heterogeneity between satellite networks and air/territorial networks in protocol, transmission speed, and management. Second, the long latency incurred by the space-ground-space data processing structure may fail the time-sensitive applications. Third, traditional satellites usually work in stand-alone fashion, and do not work as a satellite network. Fourth, traditional satellites' software and hardware are usually tightly orchestrated and coupled, and are hard to be reconfigured and reconstructed on demand. For instance, a navigation satellite cannot conduct earth-monitoring tasks due to the lack of proper cameras. Finally, compared with territorial communication stations, a satellite usually has limited payloads and could not support computation-intensive tasks.

To tackle one or two challenges mentioned above, a few proposals have been put forward. To shift intelligence on the satellite, in November 2019, China launched its first software-defined satellite, named Tianzhi 1, which carries a small-scale cloud platform to process its captured data locally rather than transmitting it back to the earth for processing [13]. Researchers at the Aerospace Corporation developed a project, named Space Cloud, in 2019 to demonstrate how Earth-based cloud computing and artificial intelligence can be moved into space for onboard processing, to enable satellites to detect and transmit only meaningful data to the earth [14]. Space Cloud is developed based on commercial available software and hardware components, including an Intel Movidius processor and Google's open-sourced Kubernetes tool. Denby et al. have introduced the concept of orbital edge computing (OEC) to address the limitations of a ben-pipe architecture. OEC supports edge computing at each camera-equipped earth-observing nanosatellite so that sensed data may be processed locally when downlinking is unavailable [15]. However, Denby et al. only focus on the operating models of OEC for nanosatellites without presenting an over-all service architecture overview, which is necessary for developing intelligent satellite systems.

2.2 Satellite Edge Computing

Cloud computing has achieved great success in the last decade, in which the computation facilities are centrally placed in the data centers, due to its nearly infinite computation capacity and bulk data process architecture. However, the centralized processing logic requires the service request and reply packets to be transmitted over the Internet, and this typically incurs a long delay and requires bulk transmission bandwidth. This will fail the service when the application is latency-sensitive or when the bandwidth is limited. In this circumstance, a new computing paradigm, called Edge Computing, in which data is processed where it originates, has emerged and attracted much attention in recent years. Compared with cloud computing, edge computing highlights the placement of computation devices at the network edge, and thus can greatly reduce the latency incurred by task offloading as well as relieve the burden at fronthaul/backhaul links. Moreover, computation at the edge server can better provide context-aware service and support device mobility.

For a satellite network, which usually has longer transmission latency and limited bandwidth, edge computing is a preferable computing choice due to the advantages mentioned above.

Zhang et al. have presented satellite mobile edge computing (MEC), in which a user equipment without a proximal MEC server can also enjoy MEC services via satellite links in STNs [5]. Wang et al. have proposed a cooperative offloading scheme in a double-edge satellite-terrestrial (DESTN) network [9]. In order to use the satellite Internet of Things intelligently, Wei et al. have proposed an application scheme of satellite IoT edge intelligent computing, and analyzes how edge computing and deep learning play a role in satellite IoT image data target detection [10]. A game-theoretic approach in satellite edge computing was proposed by Wang et al. to the optimization of computation offloading strategy [11]. Moreover, Wang et al. have proposed to transform the traditional satellite into a space edge computing node, which can dynamically load software in orbit, flexibly share on-board resources, and provide services coordinated with the cloud [16]. Denby et al. have presented orbital edge computing, in which nanosatellite constellations are equipped with computational devices to process the data when downlinking is not available [15].

2.3 Motivation

Simply introducing edge computing to the STNs cannot directly make them intelligent. To reveal the full potential of intelligent STNs for supporting diverse applications, we need to develop a service architecture for the edge computing-empowered STNs from the service-oriented perspective. Moreover, the whole process of a service call needs to be identified. Use cases should be given to reveal the application pattern of the service architecture. Finally, the open issues to realize this service architecture cannot be neglected.

Through establishing the service architecture, our work can benefit practitioners in this area from three aspects: first, it paves the way from physical resources to user access interfaces for service usage; second, system-level virtualization is implemented in the network through building several virtualized resource pools; third, the network could provide the satellite service in a transparent and intelligent way to the users without revealing the implementation details.

In the following, we first introduce our service architecture in Sect. 3, and detail its layers and key technologies; Sect. 4 gives two use cases of the service architecture; the open issues are discussed in Sect. 5.

3 Service Architecture Design

This section introduces our service architecture, which treats all the components of the STNs as resources to provide service to the end-user devices. The service architecture is illustrated first, then comes the introduction of each layer in the architecture.

3.1 Service Architecture

The design principles of the service architecture are threefold: first, it can composite, manage, and utilize all the available resources in an intelligent way, including sensing, computation, storage, and transmission resources; second, all the resources can be efficiently scheduled, managed, and utilized to construct diverse basic services for enabling the provision of composited services; third, users could access services easily through open and standardized interfaces, like APPs on the smartphones.

Based on these principles, our service architecture is shown in Fig. 1, in which two pools are contained, i.e. resource pool and service pool. The resource pool at the bottom of the figure consists of two layers:

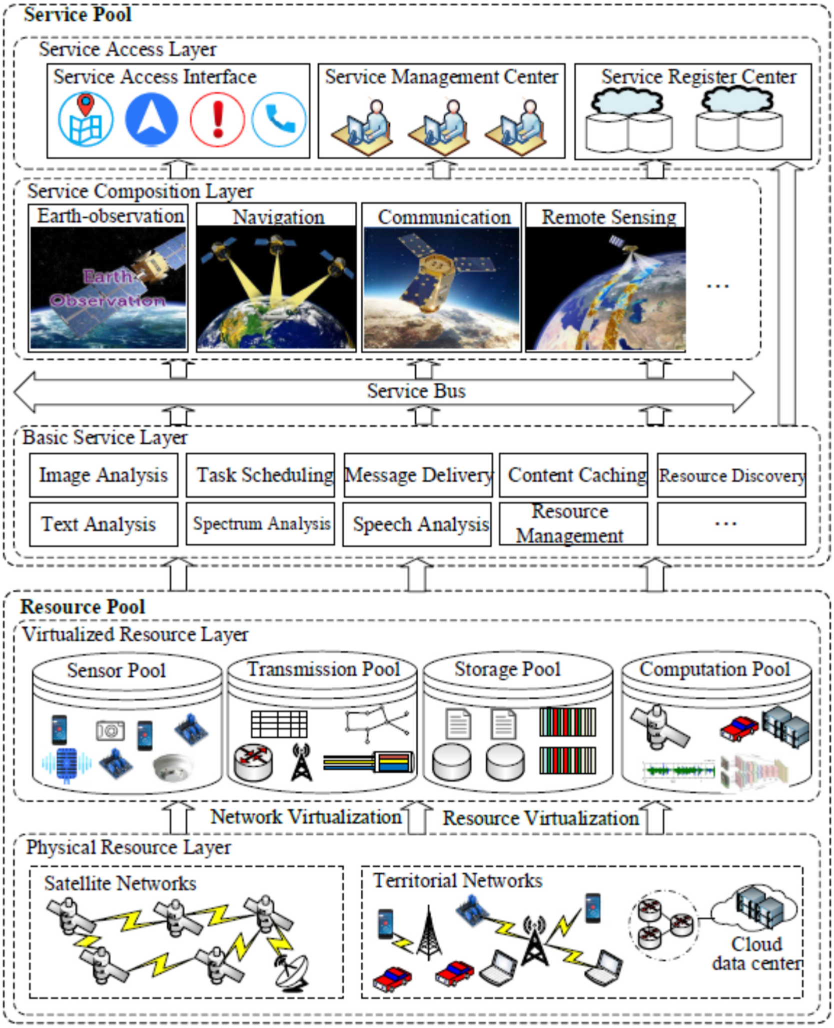

Fig. 1. Service Architecture of Edge Computing Empowered STNs.

- Physical resource layer: it contains all the physical resources in the STNs, like sensors equipped on the satellites, vehicles, and IoT devices; computation facilities located on satellite edge computing platforms, vehicle computation platforms [17], cloud data centers on the ground, and mobile devices with idle resources; storage disks installed on aerospace and ground platforms; transmission devices and links between diverse networked platforms; and other resources.
- Virtualized resource layer: the resources at the physical resource layer are virtualized into different resource pools at this layer. The sensor pool integrates all the sensing components in the network, e.g. radars and cameras; the transmission pool virtualizes the network and transmission resources using SDN, NFV, software defined radios (SDRs), etc.; the storage pool treats the storage devices in the network in a layered fashion, and the storage space is provided and managed according to the users' requirements on storage volume and read/write speed through storage virtualization technologies; the computation pool utilizes the available computation units on the edge computing empowered-satellites, vehicle edge devices, cloud data centers, etc. built on heterogeneous units, including central processing units (CPUs), Graphics Processing Units (GPUs), Field Programmable Gate Arrays (FPGAs), etc.

The resource pool serves as the underlying resources for constructing diverse services in the service pool, which is shown on the top of Fig. 1 and consists of three layers:

- Basic service layer: it is in charge of providing basic services that typically have simple functions, like image analysis based on Convolutional Neural Networks (CNNs), text/speech analysis based on Recurrent Neural Networks (RNNs), content caching based on popularity-aware algorithms, task scheduling based on heuristic methods, machine learning algorithms like cluster analysis, random forest, etc. Some of these services are time-consuming and resource-intensive and need the support from storage, computation, transmission pools based on the sensed data derived by different sensors at the sensor pool.
- Service composition layer: this layer could composite any basic services to provide satellite services on demand, such as earth-observing, navigation, reconnaissance, remote sensing, etc. To support these satellite services, equipping satellites with reconfigurable payloads and loading them on demand are essential. In contrast, this is infeasible for traditional satellite with fixed and tightly-coupled payloads.
- Service access layer: this layer interacts with the end-user devices as an interface between satellite services and the end users. To be specific, the service register center collects all the basic and composited services that can be utilized by end-user devices, and publish them to the end users. One or multiple services could be called in different styles, like functions, Docker images, virtual machines, or physical devices, by the end users through scandalized interfaces and protocols. The service manager center manages the services provided by the network; moreover, it holds the system service, like resource and service discovery, update, etc.

3.2 Service Provision Process

Under the framework established in Fig. 1, the service provision process of the network is shown in Fig. 2. First, a user initiates a service request to the service access layer in the service pool; the request is directed to the service access interface, and then is relayed to the service register center for service information. After receiving the response, a request is launched by the interface to the service management center, which resolves the request and delivers it to the service composition layer as well as the basic service layer. In the service composition layer, the request is analyzed and divided into several parts, and the corresponding resources are calculated; according to the results, service calls are initiated to utilize basic services. Based on all the received service requests, the basic service layer calculates the total needed resource, and starts a service monitoring thread. All the service requests then are directed to the virtualized resource layer to decide the resource requirements for different types of resources, i.e. sensing, transmission, storage, and computation. Finally, these mapped virtual resources are mapped back to their physical devices in the physical resource layer. The satellite networks reconfigure its functions and payloads and allocate the requested resources to this request; moreover, the territorial networks do the same things without reload its payload.

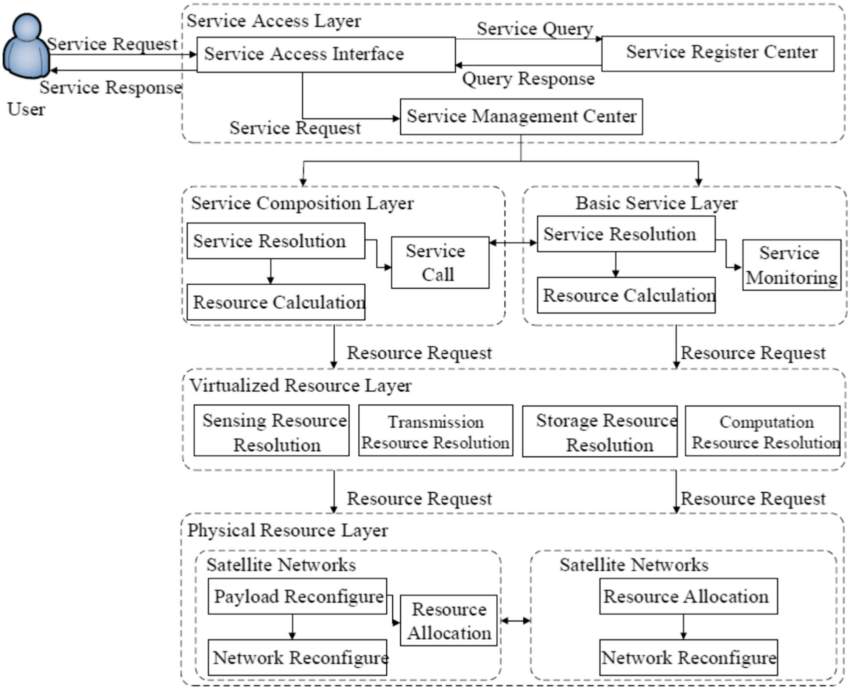

Fig. 2. Service provision process of the service architecture.

4 Use Case and Analysis

Edge computing empowered satellite networks could be utilized to support diverse applications as shown in Fig. 1. This section presents two typical use cases. In the first use case, a single edge computing empowered satellite is adopted as the communication and processing relay for video transmitting between a plane equipped with a camera that captures videos in some area. In the later use case, multiple satellites conduct collaborative spectrum sensing for dynamic spectrum access (DSA) in cognitive radio networks, to show the advantages of our service architecture.

4.1 Satellite as the Video Transmission Relay

In this use case, as shown in Fig. 3, an iSAT acts as the communication and processing relay between the plane-loaded cameras and the ground station for transmitting live videos. Here, several video processing functions could be conducted on the plane as well as on the iSAT. For example, video compressing using neural networks could be conducted on the plane to greatly reduce the size of the transmitted data; on the other hand, the iSAT could further alleviate the burden of the satellite links through conducting edge computing-based inter-video frame redundancy reduction between multiple video sources.

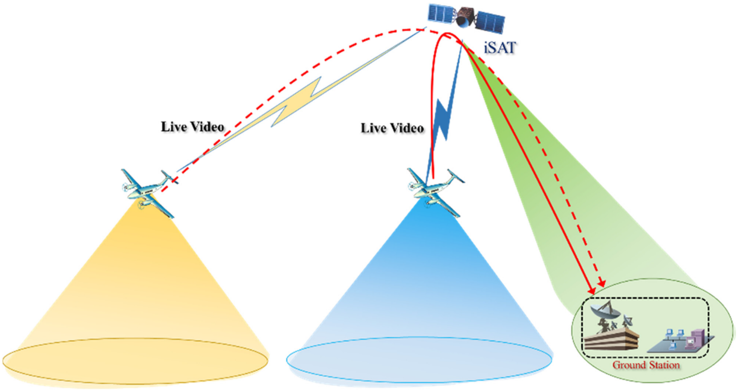

Fig. 3. The Video transmission relay scenario.

4.2 Satellites-Based Spectrum Sensing

To realize DSA or spectrum sharing in the interested area shown in Fig. 4, a few satellites flying over this area need to work collaboratively for spectrum sensing. An intuitive method to conduct satellite-based spectrum sensing is let the satellite collect the raw radio frequency (RF) data, and a ground facility is in charge of processing the RF data to derive the sensing results. To be specific, a satellite (take iSat3 as an example in Fig. 4) needs to receive radio frequency (RF) data first (①) after receiving the spectrum sensing task from the ground station, and then sends the data to the ground station directly or via a relay satellites (②). The ground station will offload the data to a cloud data center for processing (③), which processes the data and returns the results to the ground station (④). For the simplicity of description, this strategy will be referred as ‘Raw-data back’ in the following analysis.

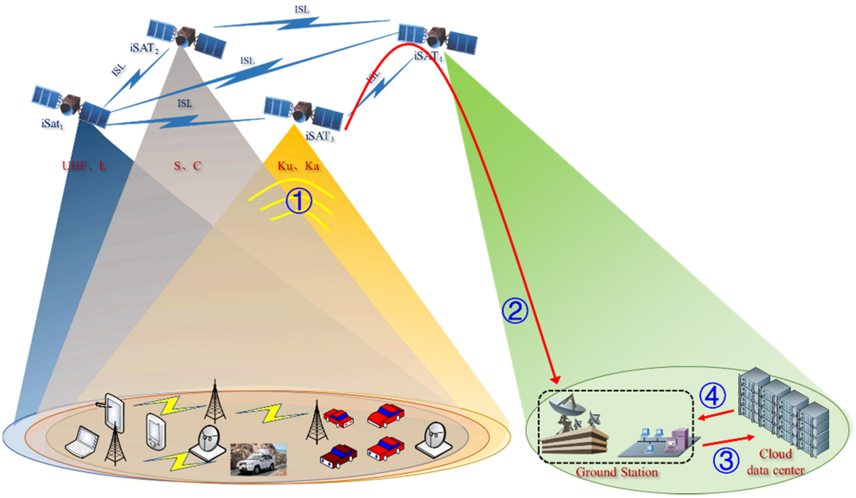

Fig. 4. Raw-data back scenario for satellites-based spectrum sensing.

After introducing edge computing-empowered intelligent STNs, spectrum sensing is a service in the service pool in our service-oriented architecture. The users can initiate the spectrum sensing service via an APP, and multiple satellites (e.g. 3 satellites in Fig. 5) will separately switch to spectrum sensing mode, and receiving RF data in different frequency bands (①). In Fig. 5, iSat$_1$ works at UHF and L bands; iSat$_2$ receives signals at S and C bands; iSat$_3$ conducts spectrum sensing at Ku and Ka bands. Through this band division, the cost and design complexity of the payloads on each satellite can be greatly reduced. Then, the received data is processed by the edge computing payload or edge server on each satellite (②) separately. Here, data processing contains the signal processing at multiple domains, including time domain, frequency domain, space domain, modulation domain, etc. In the time domain, the active times of each signal in this area can be derived; in the space domain, the transmitter of each signal may be located through the efforts of multiple satellites or the antenna array carried on one single satellite. Then, the sensing results will be derived on the aerospace without the intervention of the ground station. Note that, in order to tackle the challenges brought by the high mobility of the satellites, another satellite, i.e. iSate4 in Fig. 5, acts as the relay between satellites and the ground station to get the sensing results back (③). For the ease of presentation, this strategy is called ‘Sensing-results back’ in the following analysis.

Considering that a satellite may can only pre-process its sensed data due to its limited processing capacity. In this circumstance, it needs to send the reduced data to the ground

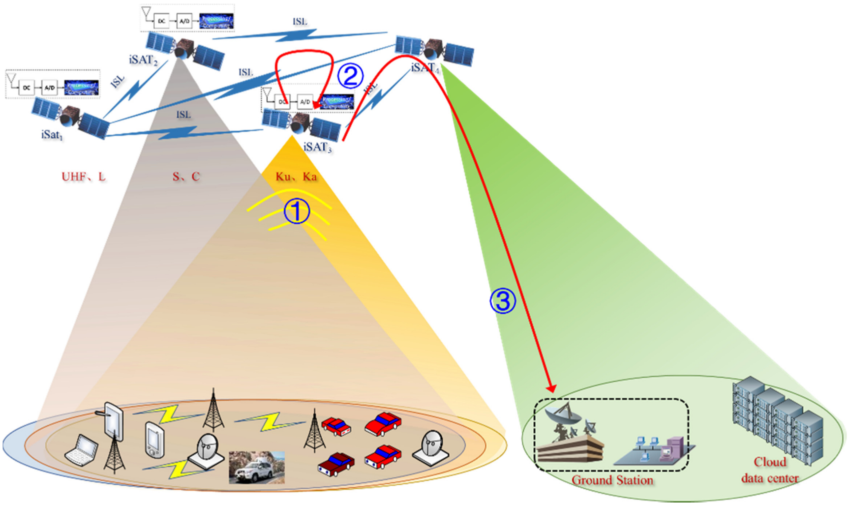

Fig. 5. Sensing-results back scenario for satellites-based spectrum sensing.

station via the relay satellite. This strategy is named ‘Partial-data back’ in the following analysis.

4.3 Numerical Results and Analysis

To highlight the different between different strategies illustrated above, we conducted a series of numerical tests. The parameter settings of our tests are as follows. The size of the raw data received at a satellite is S bits; the transmission bandwidth from the relay satellite to the ground station is B_{SG} bps; the bandwidth of an inter-satellite link is set to be B_{SS} bps; each sensed bit needs c_s processing cycles for deriving the sensing results; each sensed bit needs c_s processing cycles for calculating reduced data; to reduce p percent of each sensed bit, c_r processing cycles will be consumed; the processing frequency of the edge server on a satellite is f_e; the processing frequency of the server in the data center is f_c; the propagation delay from a satellite to the ground station is t_p; the bandwidth from the ground station to the cloud is B_{GC}. The default parameter settings are shown in Table 1.

The most important performance concern of spectrum sensing is the latency, which is defined as $t_2\ t_1$. Here, t_1 is the time when the raw data is received by a satellite; t_2 is the time when the ground station gets the sensing results. The sensing results are very small in relative to the transmission bandwidth in the network. Therefore, we only consider the propagation delay between satellite and ground station while neglect the transmission time of the sensing results and the spectrum sensing message from the ground station to the satellites.

Table 1. Parameter settings.

Parameter	Default value	Parameter	Default value
S	100 Mb	p	0.5
B_{SG}	100 Mb	c_r	10
B_{SS}	100 Mb	f_e	2 GHz
B_{GC}	10 Gb	f_c	2 GHz
c_s	100	t_p	10 ms

The three processing strategies' latency could be calculated by:

$$t = \begin{cases} \frac{S}{B_{SS}} + \frac{S}{B_{SG}} + \frac{S}{B_{GC}} + \frac{S \times c_s}{f_c} + 2t_p, & Raw - data\ back \\ \frac{S \times p}{B_{SS}} + \frac{S \times c_r \times p}{f_e} + \frac{S \times p}{B_{SG}} + \frac{S \times p}{B_{GC}} + \frac{S \times c_s \times p}{f_c} + 2t_p, & Partial - data\ back \\ \frac{S \times c_s}{f_e} + 2t_p, & Sensing - results\ back \end{cases} \quad (1)$$

When S increases from 100 to 500 Mb, the three strategies' latencies are shown in Fig. 6. From Fig. 6, we know that introducing edge computing could reduce the sensing latency in the interested area under the parameter settings in Table 1. Transmitting the raw data back incurs long latency due to limited transmission bandwidths of satellite links. On the other hand, the sensing latency increases as the raw data size increases. This is a straightforward conclusion due to the fact that large data requires long processing latency as well as long transmission latency.

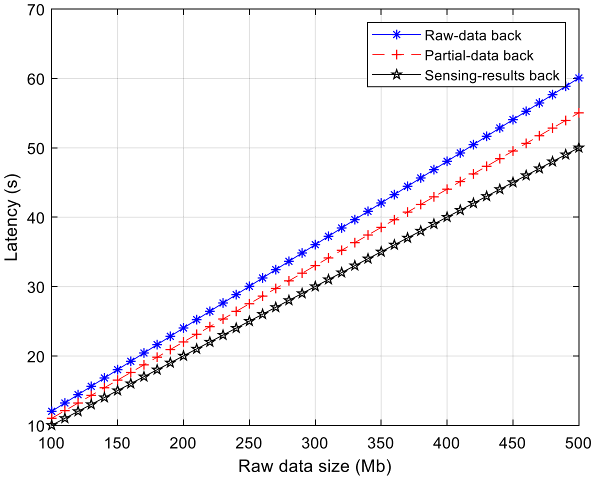

Fig. 6. Three strategies' latencies with different raw data size.

Figure 7 shows the test results when the transmission bandwidth between satellites increases from 100 to 500 Mb. The general observation is that the latency decreases slowly as the inter-satellite bandwidth increases for the Raw-data back and Partial-data back strategies due to the reduction of the data transmission delay in the aerospace. Moreover, the change of the bandwidth has no impact on the third strategy, i.e. sensing-results back, since no raw data transmission is needed. Note that we can draw similar observation when the bandwidth between a satellite and the ground station increases.

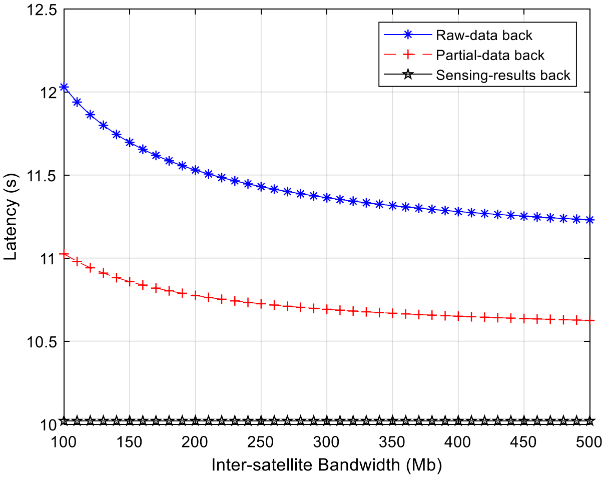

Fig. 7. Three strategies' latencies with different inter-satellite bandwidth.

Figure 8 shows the latencies when the edge server's processing frequency increases from 1 to 3 GHz. From the figure, we know that the increase of the on-satellite processing frequency could reduce the latency under partial-data back and sensing-results back strategies. Figure 9 shows the test results when the processing frequency of the server in the cloud increases from 1 to 2 GHz. It is notable that when the processing frequency in the cloud server is large than 1.3 GHz, the latency of the raw-data back will be the smallest among the three strategies. This means that the larger the processing frequency of the edge server on the satellite, the better the satellite edge computing is.

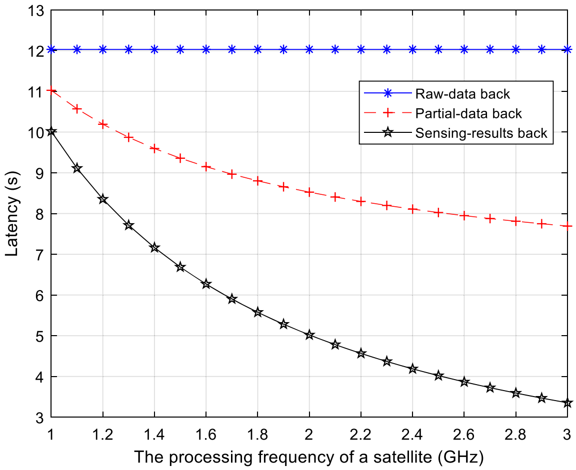

Fig. 8. Three strategies' latencies with different processing frequency of the edge server on a satellite.

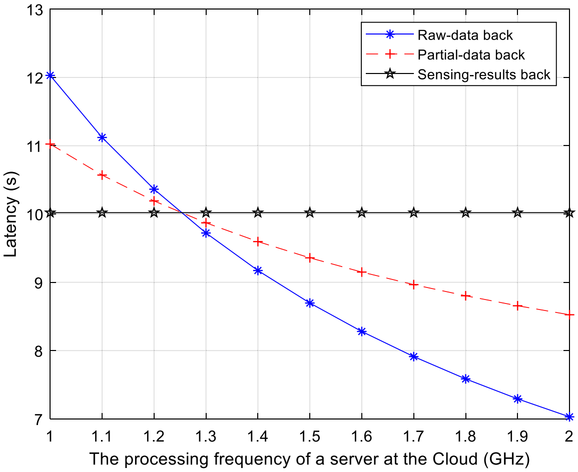

Fig. 9. Three strategies' latencies with different processing frequency of the server in the cloud.

5 Open Issues

To realize the full potential of our service architecture for the edge computing empowered intelligent satellite-territorial networks, the following open issues deserve further investigation in the future:

- Reconfigurable payloads design on the satellites: traditional satellites adopt tight-coupling design principle, which makes their payload fixed and hard-to-change on demand. In iSat architecture presented in [16], in which the payloads can be installed and configured as a service. iSat made an initial step for reconfigurable payloads in

the aerospace. But we still have a long way to go for achieving fully reconfigurable satellites to incorporate different components in limited space on the satellites. Part of the challenges lie to the fact that many components still cannot be integrated due to the hardness of miniaturization, low-power, generality, and anti-radiation design.
- Lightweight edge computing platform design: the limited power supply, and space on the satellites have severely limited the installation of powerful edge computing platforms. General edge computing platforms developed for the ground devices are hard to be directly transferred onto the satellites due to software and hardware compatibility. The operating systems, middleware, and application software, on which edge computing platforms are built, are usually not supported on the satellites.
- Heterogeneous network convergence: satellites have unique characteristics, such as bandwidth, latency, etc., that are different from territorial networks. This brings many challenges for interconnecting satellites and territorial networks in different aspects, including application design, protocol adaption, etc. For the edge computing part, it faces many challenges when interconnecting with heterogeneous platforms.
- Security issues introduced by the open architecture: traditional enclosed design of the satellites can ensure the security of the hardware and software on the satellites; however, the transformation to an open architecture will bring great security challenges to the satellites. On the one hand, the software installed on the satellites can not be fully tested for all kinds of cyber attacks. On the other hand, the services loaded on the satellites may introduce new vulnerability. What is and how to achieve the tradeoff between openness and security needs further investigation.
- Resource cognition and scheduling: a STN may consist of more than 10,000 satellites in the space and even more devices on the ground. It is a heavy burden for the network to discover and manage a huge number of heterogeneous devices in real time due to the long latency of satellite links and randomness of wireless transmission. Interference caused by congested wireless spectrums may make things worse. Therefore, the resource pool should be designed and maintained carefully to incorporate the above-mentioned factors.

6 Conclusion

From the service perspective, this paper presents a service architecture of edge computing empowered satellite-territorial networks, which is a layered structure contains two pools and five layers. In the resource pool, all the computation, storage, communication, and sensor resources in both satellite networks and territorial networks are organized into resource pools using virtualization techniques. The resources in the resource pool are utilized to construct diverse basic services, which are organized into composited services in the service pool. Moreover, a service access layer is provided for the users to access the service in a transparent fashion. To exhibit the benefits of our service architecture, two use cases, i.e. satellite-based video transmitting relay and spectrum sensing, are detailed with numerical analysis. Numerical results have shown that introducing edge computing could reduce the latency of the spectrum sensing under typical parameter settings. A few open issues several open issues in implementing our proposed architecture are outlined to stimulate further research in the future.

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