SATELLITE AND SPACE COMMUNICATIONS **SSC**

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IEEE COMMUNICATIONS SOCIETY

SSC Newsletter **Vol. 31, No. 1, July 2021**

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The Satellite and Space Communications (SSC) Committee is a volunteer group actively involved in advancing satellite and space communication technologies within the IEEE. This committee is approved by the IEEE Communications Society and is governed by the constitution and bylaws of the IEEE as well as the other twenty-three Technical Committees in the Society. The committee belongs to the Technical Committee Clusters of Communication/Signal Processing (C/SP).

SATELLITE & SPACE

- JOIN US -

All conference attendees are welcome to join us in the SSC Committee meeting.

ONLINE MEETING URL:
https://zoom.us/j/91984872472?pwd=VDBH-VEI1ZktZc0FTdlBqZDFwRjdLZz09
Meeting ID: 919 8487 2472
Passcode: 051607

Time: Tuesday, July 20, 2021
07:00 AM - 9:00 AM EST

Future SSC Meetings
December 2021, Madrid, Spain
May 2022, Seoul, Korea

ICC 2021 SSC Committee Activities:

Symposium on Selected Areas in Communications:

SAC-SSC1 *Tuesday, June 15, 2021, 11:50 - 1:10 Montreal, Canada Time Zone*

SAC-SSC2 *Wednesday, June 16, 2021, 10:00 - 11:50 Montreal, Canada Time Zone*

SAC-SSC3 *Wednesday, June 16, 2021, 11:50 - 1:10 Montreal, Canada Time Zone*

SAC-SSC4 *Thursday, June 17, 2021, 11:50 - 1:10 Montreal, Canada Time Zone*

SAC-SSC5 *Thursday, June 17, 2021, 11:50 - 1:10 Montreal, Canada Time Zone*

HOW TO JOIN SSC COMMITTEE AND MAILING LIST

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SSC COMMITTEE OFFICERS

CHAIR
Prof. Song Guo
Department of Computing
The Hong Kong Polytechnic University
Hung Hom, Kowloon
Hong Kong
Tel: +852-2766-7259
Fax: +852-2774-0842
Email: song.guo@polyu.edu.hk

VICE CHAIR / EDITOR
Prof. Pascal Lorenz
University of Haute Alsace
France
Tel: +33 6 32 63 02 04
Email: lorenz@ieee.orf

SECRETARY
Prof. Mianxiong Dong
Muroran Institute of Technology
27-1 Mizumoto-cho, Muroran, Hokkaido, 050-8585, Japan
Tel: +81-143-46-5473
Fax: +81-143-46-5409
Email: mx.dong@csse.muroran-it.ac.jp

PAST CHAIR
Dr. Tomaso de Cola
German Aerospace Center (DLR)
Munchenerstr. 20, Oberpfaffenhofen, 82234 Wessling, Germany
Tel: +49-8153-28-2156
Fax: +49-8153-28-2844
E-mail: tomaso.decola@dlr.de

COMMITTEE HISTORIAN
Mr. Louis Pollack
c/o Pollack Associates
15321 Delphinium Lane
Rockville, MD, USA 20853
Tel: +1 301 929 1295

COMMITTEE ADVISOR
Prof. Desmond P. Taylor
Dept. of Electrical & Electronic Engineering
University of Canterbury
Private Bag 4800
Christchurch, New Zealand
Tel: +64 3 364 2213
Fax: +64 3 364 2761
e-mail: taylor@elec.canterbury.ac.nz

MESSAGE FROM THE CHAIR

Prof. Song Guo

I have completed my first year of service and I am honored to report that over the past year we have made excellent progress towards the initiatives as we planned despite the COVID-19 challenge.

The priority is given to initiatives that encourage our members to further explore the evolution of new satellite and space-based systems and the application of new and emerging technologies, at all layers of the network protocol suite. In particular, we organized spotlight talks in our SSC technical committee meetings, delivered by world-class experts in the interested areas of our technical committee. The first talk "LEO and HAPS Networks" was held on 18 December 2021 by Prof. Halim Yanıkömeroğlu, a Fellow of the IEEE, Fellow of the Engineering Institute of Canada (EIC), and Fellow of the Canadian Academy of Engineering (CAE). He is is a recipient of the IEEE Communications Society Fred W. Ellersick Prize in 2021, IEEE Vehicular Technology Society Stuart Meyer Memorial Award in 2020, and IEEE Communications Society Wireless Communications Technical Committee Recognition Award in 2018. His talk attracted a large number of audiences and new members to our committee.

To foster the development of emerging topics of satellite and space communications, SSCTC will establish the first Special Interest Group (SIG) on orthogonal time frequency space (OTFS). OTFS provides the possibility to embrace localized delay and Doppler impairments and converts time-frequency selective channels into an invariant channel in the DD domain. More importantly, OTFS enjoys the full time-frequency diversity of the channel, which is the key to provide reliable transmissions for high-mobility environments, such as vehicular networks, aircraft communications, and LEO satellite systems. The SIG aims at providing a platform to bring together academic and industrial researchers in an effort to identify and discuss the major technical challenges, recent breakthroughs, and new applications related to OTFS. Topic of interest of this SIG include but not limited to:

- Capacity scaling of OTFS system
- Machine learning/AI assisted OTFS
- MIMO design for OTFS
- Multiple access schemes for OTFS
- System-level simulation, prototyping, and field-tests
- Network architectures and protocols for OTFS
- Integrated Sensing and Communication based on OTFS
- The application of OTFS in mmWave and Tera Hertz
- Coexisting of 5G and OTFS signalling

We look forward to receiving more proposals of SIGs which will promote technical publications, workshops, tutorials, student activities, standardizations, and other related activities in focused areas relevant to satellite and space communications.

Finally I take this opportunity to thank all members of the SSC community for your great efforts and dedication especially during these difficult times. I look forward to continuing to work closely with you in my second year term. Let us sustain our commitment, professionalism, and solidarity.

Prof. Song Guo, Chair
Satellite and Space Communications TC

SCANNING THE WORLD

Prof. Pascal Lorenz

The Federal Communications Commission (FCC) grants SpaceX the right to operate 2,814 Starlink satellites in lower orbits than originally planned. A project that Amazon and OneWeb had fought because they feared interference and risks of collision with their own satellites.

OneWeb has already launched 182 of its 648 planned satellites. Amazon's Kuiper network is scheduled to launch 3236 satellites in total, half of which could be operational by 2026.

From a safety point of view, the Commission believes that SpaceX will be able to get rid of its end-of-life or deteriorated satellites more quickly. Starlink will have to submit semi-annual reports mentioning all its incidents and announcing upcoming maneuvers. The constellation must also consult with other operators regarding the transmission of its signals, in order to avoid interference.

The FCC approval means SpaceX can lower the altitude of its next 2,814 satellites from 1,150 km to about 550 km. That's an orbit close to Amazon's future Kuiper constellation and Amazon's seems finally satisfied with the compromise found.

Moving the Starlink satellites to lower altitudes is also a plus for astronomers. Observations of the sky will be less obstructed by the constellation, provided that efforts to reduce the reflectivity of the satellites are maintained.

The other big advantage will benefit Starlink users: they are guaranteed to have lower than expected latency with their Internet connection. Elon Musk was counting on a latency below 20 ms.

Prof. Pascal Lorenz, Vice Chair
Satellite and Space Communications TC

FORTHCOMING GLOBECOM AND ICC CONFERENCES

COSPONSORING / RELATED CONFERENCES AND WORKSHOPS

GLOBECOM 2021
December 7-11, 2021, Madrid, Spain
http://globecom2021.ieee-globecom.org/
IEEE GLOBECOM - IEEE Global Communications Conference (GLOBECOM) is one of the IEEE Communications Society's two flagship conferences dedicated to driving innovation in nearly every aspect of communications. Each year, more than 2,900 scientific researchers and their management submit proposals for program sessions to be held at the annual conference. After extensive peer review, the best of the proposals are selected for the conference program, which includes technical papers, tutorials, workshops and industry sessions designed specifically to advance technologies, systems and infrastructure that are continuing to reshape the world and provide all users with access to an unprecedented spectrum of high-speed, seamless and cost-effective global telecommunications services.

ICC 2022
May 16-20, 2022, Seoul, Korea
http://icc2022.ieee-icc.org/
The International Conference on Communications (ICC) is one of the two flagship conferences of the IEEE Communications Society, together with IEEE GLOBECOM. Each year the ICC conference attracts about 2-3000 submitted

scientific papers, a technical program committee involving about 1500 experts provides more than 10000 reviews, the conference being finally attended by 1500 - 2000 professionals from all around the world. IEEE ICC is therefore one of the most significant scientific events of the networking and communications community, a must-attend forum for both industrials and academics working in this area. IEEE ICC - Featuring the latest developments in telecommunications from a technical perspective.

CONFERENCES CALENDAR

CONFERENCE	DATE & LOCATION	INFORMATION
SPECTS 2021 International Symposium on Performance Evaluation of Computer and Telecommunication Systems	July 19-22, 2021 Fairfax, Virginia, USA	http://atc.udg.edu/SPECTS2021/
ITC 2021 33rd International Teletraffic Congress	Aug. 31st - Sep. 3rd 2021, Avignon, France	http://itc33.org/
CITS 2021 International Conference on Computer, Information and Telecommunication Systems	July 29-31, 2021, Istanbul, Turkey	http://atc.udg.edu/CITS2021/
ICL-GNSS 2021 International Conference on Localization and GNSS	1-3 June 2021, Tampere, Finland	https://events.tuni.fi/icl-gnss2021/
PIMRC 2021 IEEE International Symposium on Personal, Indoor and Mobile Radio Communications	13-16 September 2021, Helsinki, Finland	http://pimrc2021.ieee-pimrc.org/
Ka-Band/ICSSC 2021 The 26th Ka and Broadband Communications Conference and the 38th International Communications Satellite Systems Conference (ICSSC)	September 27 -30, 2021, Arlington, USA	http://www.kaconf.org/
VTC-Spring 2021 2021 IEEE Vehicular Technology Conference (VTC-Spring)	25 - 28 April 2021, Helsinki, Finland,	https://events.vtsociety.org/vtc2021-spring/

To all SSC members: If your postal address, telephone or fax numbers have changed, please update them with the committee secretary. You can review our current records on our web page at http://committees.comsoc.org/ssc/.

PERSPECTIVE ARTICLE

Integrated Satellite-Terrestrial Networks Towards 6G

Chunxiao Jiang, Xiangming Zhu

Beijing National Research Center for Information Science and Technology, Tsinghua University, Beijing 100084, China
E-mail: jchx@tsinghua.edu.cn

Abstract **—With the increasing communication demands, extending the connectivity to the rest areas has become imperative for future 6G networks. The integrated satellite-terrestrial network architecture is promising to provide global broadband access for all types of users, which has drawn much attention from both the academia and industry. This paper presents the main architectures for integrated satellite-terrestrial networks towards 6G. Then, typical applications of the integrated satellite-terrestrial networks are discussed based on the architectures.**

INTRODUCTION

With the development of information technology, wireless communication is now indispensable for providing connectivity in modern society. From the first generation (1G) wireless network to the fourth generation (4G) wireless network, terrestrial wireless network has proved a great success for the enhancement in communication speed and the quality of service (QoS). By means of mobile phones or other intelligent terminals, broadband services of low latency can be acquired within the coverage of terrestrial base stations (BSs). However, considering economic benefits, terrestrial networks are mainly deployed for developed areas, and areas of high−density populations, which is the same with the coming fifth generation (5G) wireless network. Moreover, for geographic constrains, the vast airspace and sea area cannot be covered by terrestrial networks. As a matter of fact, when it comes to connecting everything in the sixth generation (6G) wireless network, a more urgent need is coverage, instead of only intensity. It has been witnessed that the 6G wireless network would penetrate into a wide range of applications, such as industry, transportation, energy. The connection would commonly happen among humans, machines, and things in a vast area. Extending the connectivity to the rest areas has become imperative to move forward for future communications networks.

Satellite communication networks provide a direct solution for the coverage issue with the wide coverage ability. With the increasing communication demand and also the advances in communication technologies, achieving global coverage with satellite constellations has now become a hotspot for both the academia and industry. Various satellite constellation projects have been established to construct satellite communications networks for global coverage, such as Starlink, OneWeb, and Telesat [1]. On the other hand, conventional terrestrial networks cannot be replaced for providing the low cost and high-speed services when covering densely populated areas. Thus, combining the advantages of both satellite and terrestrial networks, the integrated satellite-terrestrial network architecture is promising to provide global broadband access, enabling ubiquitous network service. In the 3rd generation partnership project (3GPP) Rel-15, Rel-16 and Rel-17, 3GPP has studied the integration of terrestrial networks and non−terrestrial networks. With the wide coverage ability, non-terrestrial networks are expected to provide service for areas that cannot be covered by terrestrial network, ensure service continuity, and also provided efficient multicast/broadcast transmission. In the White Paper of the 6G wireless network, it has been proposed that the future wireless network must be able to seamlessly interface with terrestrial and satellite networks [2]. The integrated satellite-terrestrial network is the new development trend for the next generation communication network [3].

INTEGRATION ARCHITECTURE

The integrated satellite-terrestrial network architecture shows great potential in future wireless networks. Compared with the conventional single network architecture, the integrated satellite-terrestrial network architecture can help to increase network reliability, expand network coverage, improve resource efficiency, ensure service continuity and provide enhanced transmission. The main architectures for integrated satellite-terrestrial networks are summarized as follows.

A. Hybrid Satellite-Terrestrial Relay Networks

In satellite networks, the communication links between the satellite and users are unstable due to rain/fog attenuation, poor elevation angles, and obstacles, which may lead to the masking effect between the satellite and users. In this case, the direct links from the satellite to users will be unavailable, resulting in communication outage for the satellite users. To overcome the masking effect in satellite networks, the hybrid satellite-terrestrial relay network (HSTRN) was proposed by introducing terrestrial relays into satellite networks [4]. In the HSTRN, there is no direct link from the satellite to the user due to the masking effect. The total transmission process will consist of two phases. In the first phase, the satellite transmits the desired signal to the terrestrial relay. Then, in the second phase, the terrestrial relay forwards the received signal to the satellite user via the terrestrial link. With the help of the terrestrial relay, the satellite user can communicate with the satellite even when the direct link is masked, which increases the system stability.

B. Satellite-Terrestrial Backhaul Networks

For both economic and geographic constrains, conventional terrestrial networks cannot achieve 100% coverage, especially for the large populations in rural and remote areas. The key obstacle that prevents these areas from being connected is the construction of backhaul links. Deploying optical fiber backhaul links in these areas is inefficient and uneconomic due to the low population density. Fortunately, the wide coverage of satellites provides an alternative for establishing backhaul links in these areas. The architecture of the satellite-terrestrial backhaul network (STBN) can be applied for rural and remote areas [5]. In the STBN, the remote terrestrial network is constructed with BSs and building based access points. Then, the ground users access the BSs and access points for communication services based on 6G or Wi-Fi technologies. Differently, the BSs and access points in remote areas are linked to the core network by satellite backhaul links. For the remote terrestrial network of small scale, each BS and access point may establish the backhaul link separately. For the remote terrestrial network of large scale, a terrestrial gateway with antenna farms may be deployed to establish satellite backhaul links. Then a WLAN can be constructed in this remote area, in which the BSs and access points are linked to the terrestrial gateway by optical fiber for backhaul transmission.

C. Cognitive Satellite-Terrestrial Networks

Due to the increasing demand of broadband communication services, spectrum resources are always insufficient for both satellite and terrestrial networks. In addition to exploit higher frequency bands such as millimeter wave and terahertz, improving the spectrum efficiency of existing spectrum resources by spectrum sharing is another promising method. Thus, the technique of CR was proposed to enable dynamic utilization of spectrum resources among networks. With the development of satellite-terrestrial networks, the CR technique is also applied to satellite-terrestrial networks. The cognitive satellite-terrestrial network (CogSTN) was studied to make full use of the spectrum resources. The CogSTN is composed of the primary satellite network and the secondary terrestrial network. The primary satellite network owns the license of the spectrum resource, and is free to transmit at any time. The secondary terrestrial network shares the licensed spectrum with the primary network, but it can only transmit when it does not affect the normal operation of the primary network. By sharing the spectrum resource between the two networks, higher spectrum efficiency can be achieved [6]. However, since the secondary network has no license of the spectrum, specific constraints are required to mitigate the interference caused to the primary network.

D. Cooperative Satellite-Terrestrial Networks

While the terrestrial network has been well deployed in areas of high-density populations, enabling broadband access to the Internet at low cost, the satellite network is able to provide ubiquitous coverage with the top-down nature. Taking advantages of both the two networks, the cooperative satellite-terrestrial network (CooSTN) is a promising architecture to further promote the development of wireless networks [7]. In the CooSTN, when a user is located in the coverage of terrestrial networks, generally in urban areas, the user will access the terrestrial cellular network for broadband services. However, when the user moves to areas without terrestrial networks, such as rural areas, sea areas, and airspace, the user will be transferred to the satellite network for continuation of the service. Based on the cooperation of the two networks, ubiquitous coverage and continuous service are achieved in the CooSTN. In addition to achieving ubiquitous coverage with the complementary architecture, the CooSTN can also be exploited in the enhanced architecture for areas where the terrestrial link is weak or insufficient. The users in the CooSTN are not strictly differentiated into terrestrial users or satellite users. Instead, the users are equipped with dual-mode terminals, and can access both the terrestrial network and the satellite network. The satellite network and the terrestrial network cooperate to provide enhanced communication services for ground users. Different from the complementary architecture, the satellite link or the terrestrial link is not the only connection to the Internet for users. Deep cooperation of the two parallel links is enabled in the enhanced CooSTN architecture [8].

APPLICATION CASE

A. Rural Coverage

According to the statistics of ITU, nearly half of the populations in the world have no access to the Internet by 2019. Then, based on the wide coverage of the satellite, the integrated satellite-terrestrial network can extend the communication service to rural areas, connecting the remaining half of the populations. For sparsely populated rural areas, mobile users can access the satellite-terrestrial network by their own terminals, which may be capacity-limited based on the type of users and terminals [9]. Also, for residences or buildings in rural areas, fixed satellite antennas can be deployed to provide relative broadband service for users inside based on 6G or Wi-Fi technologies. Then, for densely populated rural areas, as discussed in the STBN architecture, a terrestrial gateway with antenna farms may be deployed to establish satellite backhaul links. Users can access the satellite-terrestrial network by BSs or other access points with satellite backhauls. Furthermore, the satellite-terrestrial network can also provide additional links to enhance the transmission in rural areas without broadband terrestrial networks, as discussed in the CooSTN architecture.

B. Sea Area Communication

While traditional terrestrial networks can only support offshore communication, the satellite system is able to cover the whole sea area with the wide coverage ability. The integrated satellite-terrestrial network can connect the isolated sea area with land, extending conventional terrestrial based services to the sea area for various users. For a cruise liner on the sea, the users inside can obtain the same terrestrial services as on land based on the integrated satellite-terrestrial network. Also, maritime information collection and maritime monitoring play an important role in guaranteeing the safety and security of the sea area. The concept of maritime Internet of Things (IoT) is recently introduced for data collection and integration, for which reliable communication means are the basis. The integrated satellite-terrestrial network can provide efficient storage, transmission, and calculation for the collected maritime information, improving the ability of continuous situational awareness of the sea area.

C.Airborne Communication

The airborne network generally consists of balloons, airplanes and UAVs, among which airplanes are in great need of broadband access to satisfy the urgent communication demands of passengers. With the wide coverage ability, the integrated satellite-terrestrial network can provide continuous broadband service for passengers during the flight [10], connecting the air with ground. Since airplanes move at high speed, geosynchronous earth orbit (GEO) or medium earth orbit (MEO) satellites can be utilized to avoid frequent handover between satellites, while low earth orbit (LEO) satellites can be utilized to reduce the communication latency. Besides, the integrated satellite-terrestrial network is also applicable for communication of balloons and UAVs, which can be deployed for regional coverage, environmental monitoring and border surveillance.

D. Emergency Communication

Communication support is critical for public protection and disaster relief to safeguard the life safety of people in emergency cases. Since terrestrial networks are deployed based on ground BSs and underground optical fiber, which are unreliable and vulnerable, terrestrial based communication may be paralyzed or destroyed in emergency cases. Since satellites are deployed on orbits of 500 to 36,000 kilometers, they are immune to most of the disasters and wars on the ground. Thus satellite-based communication can still be maintained in most emergency cases. The integrated satellite-terrestrial network comes to be a promising solution to provide communication guarantee for emergency cases, in which conventional terrestrial networks may be out of service due to damage of infrastructures. In the enhanced CooSTN architecture, users are equipped with dual mode terminals, and can access the Internet by both satellite and terrestrial links. In normal conditions, terrestrial networks are preferred for broadband services, while satellite networks act as the complementary for enhanced transmission. Then, when terrestrial networks are unavailable in emergency cases, such as earthquakes and hurricanes, satellite networks turn to be the dominant network for emergency communication. Also, for areas with only terrestrial links in normal conditions, the STBN architecture can be utilized to establish emergency communication links and construct a temporary WLAN. The single-mode terrestrial users can access the Internet by satellite based temporary BSs or emergency vehicles. In the worst cases, the terrestrial network is completely destroyed, and thus the satellite network is the only choice. In better cases, part of the terrestrial infrastructures may remain working if undamaged. Then, cooperation between the survival terrestrial network and the satellite network can be implemented to improve the communication capacity and avoid network overload.

E. Multicast/Broadcast Transmission

With the top-down nature, satellites are inherently suitable for multicast/broadcast transmission. Taking advantages of both satellite networks and terrestrial networks, the integrated satellite-terrestrial network is promising to further enhance the network performance with integrated multicast/broadcast transmission. The integrated multicast/broadcast transmission can be implemented in several modes. First, the combined unicast and multicast transmission mode can be implemented for content delivery with the enhanced CooSTN architecture. The common and popular contents are transmitted by the satellite with multicast transmission, while the unique contents required by individual users are transmitted by the terrestrial BSs with unicast transmission. Second, the cooperative multicast transmission mode can be implemented to overcome the large fluctuation of terrestrial channels with the enhanced CooSTN architecture [11]. The ground users are simultaneously served by the terrestrial network and the satellite network for multicast transmission. By combining the signals from the two networks using the MRC technique, the multicast capacity can be significantly improved.

ACKNOWLEDGMENTS

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