SATELLITE AND SPACE COMMUNICATIONS

SSC

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SSC Newsletter

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CONTENTS

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://polyu.zoom.us/j/96284191663?pwd=WGNRVS9TKzBKWWlEOVpsaThvS2VOQT0

Time: 8:00AM-9:00AM Eastern Time (20:00-21:00, Beijing, China), 29 April 2022

Future SSC Meetings

December 2022, Rio de Janeiro, Brazil

June 2023, Rome, Italy

ICC 2022 SSC Committee Activities:

Symposium on Selected Areas in Communications:

SAC-SSC1 *May 17, 11:30 - 12:00 Seoul, Seoul Time Zone*

SAC-SSC2 *May 18, 09:30 - 10:00 Seoul, Seoul Time Zone*

SAC-SSC3 *May 18, 11:30 - 12:00 Seoul, Seoul Time Zone*

SAC-SSC4 *May 19, 14:00 - 14:30 Seoul, Seoul Time Zone*

HOW TO JOIN SSC COMMITTEE AND MAILING LIST

If you like to join SSC Technical Committee: Please send your name and e-mail address to the SSC Secretary, optionally include your mail address, telephone and fax numbers.
If you like to join SSC Mailing List: Instructions on how to subscribe/unsubscribe are available at https://comsoc-listserv.ieee.org/cgi-bin/wa?A0=ssc.

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MESSAGE FROM THE CHAIR

Dr. Song Guo

I have been serving the SSCTC as chair in the past two years and my terms of SSC chair is completing end of June 2022. In general, leading the technical committee has been a great challenge given the COVID-19 pandemic that forced most committee activities and interactions running virtually.

It is the time to reflect what our technical committee has managed to achieve in the past two years. As set at the beginning of my term, 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. To achieve this goal, we have organized a series of online talks and launched two SSC Special Interest Groups (SIGs).

Online Talks and Seminars

- "LEO and HAPS Networks" was held on 18 December 2020 by Prof. Halim Yanıkömeroğlu from the Department of Systems and Computer Engineering, Carleton University, Canada.
- "Integrated Satellite-Terrestrial Networks Towards 6G: Architectures, Applications, and Challenges" was held on 20 July 2021 by Prof. Chunxiao Jiang from the School of Information Science and Technology, Tsinghua University, China.
- "OTFS for Next-generation Wireless Communications" was held on 12 November 2021 by Prof. Ronny Hadani from the Mathematics Department of the University of Texas at Austin and Prof. Emanuele Viterbo from Department of Electrical and Computer Systems Engineering, Monash University, Australia.
- "OTFS Transceivers Design using Deep Neural Networks" was held on 23 February 2022 by Prof. Ananthanarayanan Chockalingam from the Department of Electrical Communication Engineering, Indian Institute of Science, Bangalore, India.

Special Interest Groups

- *Orthogonal Time Frequency Space*: It 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.
- *Satellite Mega-constellations*: Communications and Networking: Mega-constellations of the 6G era satellite system are expected to have very high-speed inter-satellite links with efficient operation enabling network to be autonomous, intelligent, resilient, self-organizing & self-controlling as much as possible to reduce the cost and risk of human intervention. Distributed decision making, fault recovery, resilience, and scalability are among the important features of the envisioned satellite networks relying on AI techniques as much as possible at all levels: ground operations, on-board operations, as well as inter-satellite and satellite-to-ground links.

It was truly a privilege to chair SSC with glorious traditions, experts, and partners. Achieving these important results has certainly required important effort and I'm happy to share the satisfactory results with the other officers of the TC who have continuously helped me and supported in all planned activities. I'd like to take this opportunity to thank the outstanding services and support from our fellow officers and all members of SSCTC! I'm very confident that the new officers will receive the TC in a very healthy and stable situation and wish SSC to attain a very high recognition and visibility within ComSoc.

Prof. Song Guo
Satellite and Space Communications TC

SCANNING THE WORLD

Pascal Lorenz

SpaceX plans to operate fifty-two launches in 2022. This would be a new record for the company, which just set a new record in 2021 with thirty-one launches. Most of the launches operated by SpaceX are for its own Starlink satellite constellation, which aims to bring high-speed Internet to the world's most remote areas. Elon Musk's firm has already launched thousands of devices, and thousands more are yet to leave Earth. The reason SpaceX is able to maintain such a high launch rate is because of the reusability of its rockets. For example, one of the three launches the company has made since the beginning of the year was performed by a Falcon 9 that was being used for the tenth time. With recyclable launchers, SpaceX is able to not only increase the rate of its launches, but also lower their price. For example, a launch goes from about $60-90 million to less than $30 million with a recyclable rocket. In 2021, Elon Musk had announced forty-eight launches to finally achieve thirty-one... But if everything goes as planned, the company should break its own record by the end of the year.

Amazon has signed with Arianespace, Blue Origin and United Launch Alliance to perform a total of 83 satellite launches, from the Kuiper constellation. Amazon's desire to offer Internet access from space is becoming a reality. The investment is expected to enable Amazon to deploy the majority of its initial constellation of 3,236 satellites. Amazon's project is called Kuiper, a network of satellites positioned in low Earth orbit, designed to provide fast broadband to areas of the world that are currently poorly covered. The partnership with Arianespace, Blue Origin and United Launch Alliance will allow Amazon to launch its satellites over a 5-year period. Amazon is taking a big gamble by choosing three rockets that have yet to prove themselves: Vulcan, New Glenn and Ariane 6 have not made their maiden flight. They still have everything to prove, especially in terms of reliability.

Of course, the other solution for Amazon would have been to call on SpaceX, but that would have meant relying on its direct competitor, which is also in the business of Internet access by satellite. It will be interesting to see if all these launchers will be able to ensure the flight rate required by Amazon's ambitious project.
It is also impossible not to compare Amazon's project to Starlink: in recent years, SpaceX has demonstrated its efficiency in placing a constellation of satellites in Earth orbit. The central question is therefore whether Amazon is really able to match SpaceX's performance, knowing that Amazon is coming years later, and obviously needs partners to try to do so.

FORTHCOMING GLOBECOM AND ICC CONFERENCES

COSPONSORING / RELATED CONFERENCES AND WORKSHOPS

GLOBECOM 2022
December 4-8, 2022, Rio de Janeiro, Brazil
http://globecom2022.ieee-globecom.org/
IEEE GLOBECOM 2020 - 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 2023
May 28-June 1, 2023, Rome, Italy
http://icc2023.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 2021 - Featuring the latest developments in telecommunications from a technical perspective.

CONFERENCES CALENDAR

CONFERENCE	DATE & LOCATION	INFORMATION
ITC 2022 34th International Teletraffic Congress	14-16 September 2022	https://itc34.itc-conference.org/
ICL-GNSS 2022 International Conference on Localization and GNSS	7-9 June 2022, Tampere, Finland	https://events.tuni.fi/icl-gnss2022/
VTC-Spring 2022 2022 IEEE Vehicular Technology Conference (VTC-Spring)	19-22 June 2022, Helsinki, Finland,	https://events.vtsociety.org/vtc2022-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

Communications and Networking in Satellite Mega-Constellations

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Abstract — **Sixth-generation (6G) networks are expected to be a combination of the terrestrial network and the non-terrestrial network (NTN). NTN will be composed of not only aerial networking elements but also of low Earth orbit (LEO) mega-constellations. Clearly, the satellite mega-constellations in the 6G era will create unprecedented opportunities once the inherent challenges are identified and addressed by the research community. This article will provide a brief introduction of the enabling technologies to the LEO mega-constellations to address these challenges from communication and networking aspects. The associated challenges for their long term viability, the potential remedies and the open research directions will be discussed.**

INTRODUCTION

On the path towards 6G, wireless networks are evolving to accommodate aerial networking elements, including densely deployed Low Earth Orbit (LEO) satellite constellations, such as *SpaceX's Starlink* and *Telesat's Lightspeed*. By the year 2030, tens of thousands of LEO satellites are expected to be deployed, positioned at an altitude between 400 km to 2000 km [1]. Large coverage areas and low propagation delay due to their relatively low altitude are the most interesting features of LEO satellites. This rejuvenated interest is not only based on satellite communications but also on networking. Both the satellite and cellular (3GPP) industries aim at developing a seamlessly integrated single network with both terrestrial and satellite components.

One main difference between the legacy satellite systems and the mega-constellations of the 6G era (next-generation) satellite system is the networking aspect. Hence, LEO constellation networks need to operate harmoniously with the terrestrial networks to satisfy the ever-increasing demand of wireless network users. Thus, aligned with the objective of seamless integration with the terrestrial networks, the emerging LEO satellite constellations need to target over 100 Gbps data rates. Additionally, these constellations will also offer new capabilities in diverse services and applications for economic sustainability.

The goal of our special interest group on "Satellite Mega-Constellations: Communications and Networking" is to bring experts from industry, academia, and agencies to foster synergy between leading research teams. Reflecting our perspective, this article aims to provide an easy-to-read overview of the supporting new technological enablers of LEO mega-constellations and highlight the novel design aspects and the open research directions.

SUPPORTING NEW TECHNOLOGIES

As a significant change in the network architecture, the emerging mega-satellite networks, composed of the low Earth orbit (LEO) satellites, have the potential to address the access inequality, thus making an impact on humanity on a global scale through network design [2]. These networks can serve not only the rural areas but they can also serve densely populated cities to improve the quality of access for the residents to increase the corresponding demand. For long term viability, New technologies, emerging due to high-rate intersatellite links (ISLs) that are connecting the constellation elements, the use of high carrier frequency with the potential of wider bandwidths, and use of metasurface antennas and reflective intelligent surfaces, and finally, the newly introduced non-terrestrial networking elements can also help the satellite mega-constellations improve global connectivity, in ultimately providing access equality.

A. Next-Generation Intersatellite Links

The networking aspect for the mega-constellations can only be introduced through the presence of high-data rate ISLs. While ISL technology is in place since last century, next generation ISLs to connect LEO satellites are essential not only for enabling connections between satellites but also to allow multi-path connectivity options to improve ground-to-satellite integration. Current satellites transmit an optical signal to enable free-space optical (FSO) based communications. The receiver, in the presence of a line-of-sight path with the transmitter, uses an optical receiver to capture the signal that is transmitted through the vacuum of space. Classification of laser ISLs based on the location of satellites within a constellation and the duration is presented in [3]. It is worth noting that although the ISLs are frequently used laser communication links, the use of RF frequency bands is under consideration by the International Telecommunication Union (ITU), specifically by the Working Party 4A (WP 4A).

B. Higher Carrier Frequencies and Wider Frequency Bands

One of the promising solutions to address the high data rate requirements of LEO mega-constellations is to increase the carrier frequency to have access to wider transmission bandwidths. Current frequency bands of interest include the use Ka-band (26.5 to 40 GHz) and the V band (50-75 GHz). This increase in carrier frequency has proven to be successful in 5G networks through the use of millimeter-wave (mmWave) links (24 - 40 GHz). As the rate demand increases, a natural evolution on the network side is to consider higher frequencies.

Frequencies from 100 GHz to 300GHz, referred to as sub-terahertz (sub-THz) bands, emerge as a promising solution to address the high data rate and low latency requirements of the next generation of wireless communication systems because of the available wide swaths of the unused and unexplored spectrum. However, the wider frequency bands come at the cost of increased levels of molecular absorption, i.e., they are attenuated significantly due to weather events, including rain and snow [4]. The absence of an atmosphere between satellites emerges as a promising advantage for use in ISLs. The need for careful frequency planning between the satellite-to-satellite and the ground-to-satellite connections also becomes apparent in consideration of the frequency bands.

C. Metasurfaces and Reflective Intelligent Surfaces

The challenging operational condition introduces the requirement to maintain the communication link over a sufficient time span. Hence satellites should be able to scan a high-gain beam over a wide angular range. Although phased arrays may be used for this purpose, that will typically require too many active ports, especially when large effective areas need to be covered at mm-waves with half-wavelength spacing arrays. Alternatively, scanning may be carried out with metasurfaces, which can be defined as leaky wave antennas made of a dielectric substrate with sub-wavelength patches that exhibit a certain spatial modulation.

As a supplementary solution to maximize the signal-to-noise ratio (SNR) at the receiver, reconfigurable intelligent surfaces (RIS) mounted on the relay satellites of mega-constellations can be used to adjust the incident wave phase. RIS could improve communication performance in a passive and energy-efficient way [5]

D. Supporting Network Elements and Network Management

Also referred to as space-air-ground integrated networks, 6G networks are expected to be a combination of the terrestrial network and the non-terrestrial Network (NTN) as defined in Technical Report 38.811 of the Third Generation Partnership Project (3GPP). NTN will be base stations with 3D mobility, and in addition to LEO satellites, it will include unmanned autonomous vehicles (UAVs) and high altitude platform station (HAPS) systems. The presence of such NTN elements not only introduces new features in terms of coverage, computation, localization, and sensing, but they also serve as additional resources for the management of the satellite mega-constellations. HAPS systems, and HAPS constellations, in particular, are expected to play a significant role in the seamless integration of the mega-constellations with the terrestrial networks, as they may serve as the quasi-stationary network elements, located about 20 to 50 km from the surface of the Earth, to help with the network management of highly mobile LEO satellites, serving as anchor points. Also, it is worth noting that the use of sub-THz/THz communications will be a suitable complementary solution to free-space optical communications for aerial and space links between NTN elements due to the line of sight visibility

OPEN RESEARCH DIRECTIONS

Mega-constellations are expected to satisfy critical services and user applications with strong rate-reliability-latency requirements. The corresponding challenges and the open research directions are summarized below.

A. Seamless Integration with the Terrestrial Networks

Current mega-constellations are being built as an independent network from their terrestrial counterpart, and they operate with specialized ground stations and customized user terminals. However, one of the critical aspects to enable long-term economic sustainability of the satellite mega-constellations is to have sufficient demand for their services. The high demand is expected to emerge from the integration of the terrestrial networks with the emerging space networks. The services should be provided in a seamless manner. This introduces the clear standardization requirements currently under study in the standardization groups, including the 3GPP. Furthermore, the number of subscribers of the satellite-based connectivity services can also be substantially increased in the case when the specialized terminal requirement is eliminated, and the conventional phones will be able to connect directly to the satellite. The corresponding antenna design research and the multi-antenna array processing techniques are on their way, yielding promising results. The corresponding analytical performance analysis framework, where the network elements are mobile, is still an open research problem.

B. The Role of Artificial Intelligence (AI)

For efficient operation, the network will have to be autonomous, intelligent, resilient, self-organizing, and self-controlling as much as possible to reduce the cost and risk of human intervention in such highly complicated settings. Distributed decision making, fault recovery, resilience, and scalability are among the important features of the envisioned satellite networks. These networks will rely on artificial intelligence (AI) techniques as much as possible at all levels. The corresponding technical aspects are still open research problems.

C. Innovative Services and Applications

The role of mega-constellations will extend beyond internet connectivity. The full benefit of LEO mega-constellations with advanced routing features and mobile-edge computing (MEC) are expected to be included in the near future as the 3GPP is shaping the network evolution towards 6G in Rel. 21(expected to be finalized in 2028). MEC enables the network components to transfer a part of the computational workload of an over-utilized host to another (group of) underutilized host(s). Furthermore, as computational tasks can be completed in closer proximity to the user, the task completion times and reliability can be significantly improved. Equipped with communication and computation capability, the number of applications that will be supported via mega-constellations is expected to increase, spanning from space tourism and space exploration support to positioning timing and navigation services. Classical use-cases, including maritime and agricultural sensor networks, will continue to flourish [6] while providing support to autonomous terrestrial networks to revolutionalize the related industries.

D. Safety and Security

The security aspects of satellite mega-constellations still have not yet received sufficient attention, yet they constitute a key issue for their safe operations. Their vulnerability to the open nature of the wireless channels and their distant positions pose a desperate need for security protection, not only against eavesdropping and jamming attacks but also spoofing/man-in-the middle attacks [7]. The development of lightweight, scalable authentication techniques is also a must for the network nodes. Regarding the safety aspects, international cooperation, standardization and regulation are needed to account the effects of tens of thousands of satellites and the fulfilment of the 1967 Outer Space Treaty. **Overall, with the potential of mega-constellations, exciting times are ahead!**

REFERENCES

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