SATELLITE AND SPACE COMMUNICATIONS **SSC**

http://committees.comsoc.org/ssc/

IEEE COMMUNICATIONS SOCIETY

SSC Newsletter **Vol. 33, No. 2, November 2023**

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://zoom.us/j/93257646633?pwd=Ni9QdW9FUTRkQlk3TzE2RFhFckdNUT09

Time: Wednesday, Nov 15, 2023
18:00 PM -19:00 PM CET

Future SSC Meetings
December 2023, Kuala Lumpur, Malaysia
June 2024, Denver, USA

ICC 2023 SSC Committee Activities:

Symposium on Selected Areas in Communications:

SAC-SSC1 *Tuesday, May 30, 11:30 - 13:00, Rome Time Zone*

SAC-SSC2 *Tuesday, May 30, 14:30 - 16:00, Rome Time Zone*

SAC-SSC3 *Tuesday, May 30, 16:30 - 18:00, Rome Time Zone*

SAC-SSC4 *Wednesday, May 31, 14:30 - 16:00, Rome Time Zone*

SAC-SSC5 *Wednesday, May 31, 16:30 - 17:15, Rome Time Zone*

SAC-SSC6 *Wednesday, May 31, 17:15 - 18:00, Rome 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.

SSC COMMITTEE OFFICERS

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

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

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

SECRETARY
Prof. Gunes Karabulut Kurt
Polytechnique Montréal
2500 Chem. de Polytechnique, Montréal, QC, H3T 1J4, Canada
Tel.: 1 (514) 340-4711 x 4551
Email:
gunes.kurt@polymtl.ca

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

Pascal Lorenz

I have served the SSC technical committee as chair for the past two years 2022-2023 starting in July 2022.

It was truly a privilege to chair SSC 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 SSC TC.

I'm very confident that the new elected officers for the period 2024-2025 will receive the TC in a stable situation and wish SSC to attain a high recognition and visibility within ComSoc.

I would like to take this opportunity to thank all the members of the community for their efforts and dedication.

SCANNING THE WORLD

Pascal Lorenz

Starlink, SpaceX's satellite internet service provider, will be launching a new service for smartphones in 2024. With Direct to Cell, it will be possible to send and receive text messages as early as 2024, then in 2025 it will be the turn of calls and data. No need for special equipment, an application or a new smartphone: all existing devices, whether 4G or 5G, are compatible. To take advantage of the service, all you need to do is "see the sky" and subscribe to one of the participating national operators. The great advantage of this service is that it gives access to the network even in areas not served by traditional wireless networks.

Direct to Cell relies on SpaceX's network, whose future satellites will be equipped with an eNodeB (Evolved NodeB) modem, in charge of managing radio resources, controlling the user interface, routing data, and executing procedures for mobility and security. Thus equipped, the satellite can act as a cellular antenna in space. Starlink won't go so far as to reveal the price of Direct to Cell, but we imagine that this burden will weigh heavily on operators' shoulders. To give an idea, Apple's Emergency SOS service, which relies on Globalstar satellites, is free for two years after the purchase of an iPhone 14 or 15. This function is also limited to SMS, but the manufacturer has said nothing about voice and data support.

FORTHCOMING GLOBECOM AND ICC CONFERENCES

COSPONSORING / RELATED CONFERENCES AND WORKSHOPS

GLOBECOM 2023

4-8 December 2023 // Kuala Lumpur, Malaysia

http://globecom2023.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 2024

9-13 June 2024, Denver, CO, USA

http://icc2024.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 2023 34th International Teletraffic Congress	3 - 5 October 2023, Turin, Italy	https://itc35.itc-conference.org/ /
ICL-GNSS 2023 International Conference on Localization and GNSS	6-8 June 2023, Castellon, Spain	https://events.tuni.fi/icl-gnss2023/
VTC-Spring 2023 2023 IEEE Vehicular Technology Conference (VTC-Spring)	20-23 June 2023, Florence, Italy	https://events.vtsociety.org/vtc2023-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/.

Wireless Power Transfer in Mega-Constellations for Sustainable Energy Management

Baris Donmez and Gunes Karabulut-Kurt

Poly-Grames Research Center, Department of Electrical Engineering,

Polytechnique Montreal, Montreal, QC, Canada

email: baris.donmez@polymtl.ca

2 November, 2023

Abstract – **The number of small satellites (e.g., CubeSats) has been increasing in space, as do the constellations to address the need for various space missions. These smaller-sized satellites in mega-constellations, which are equipped with solar cells, can generate a limited amount of energy from the Sun due to their smaller solar arrays. Besides, eclipse encounters halt the energy generation from the Sun. To overcome these problems, schemes where the large solar-powered satellite (SPS) transfers its redundant energy to small satellites, can be considered. Although radiofrequency (RF) technology can offer multi-point transmission to many satellites in a constellation, the inter-satellite distances can be in the order of hundreds of kilometers, and hence, an alternative technology using very narrow beams will provide much more efficient links for wireless power transfer (WPT) by the SPS. Therefore, the free-space optics (FSO) technology can be considered for long-distance WPT in space where the atmospheric attenuation factors can be ignored. However, FSO technology has a major drawback due to the utilization of collimated laser beams, which is the random misalignment fading induced by mechanical vibrations. This perspective article discusses the FSO-based WPT between satellites.**

Introduction

Thousands of satellites are currently deployed for various space use cases since the launch of the first satellite, Sputnik 1, in 1957. Many satellites by which mega-constellations are formed establish space networks, and they are used in the following applications: deep-space explorations, interplanetary network (IPN), solar system internet (SSI), and other use cases such as lunar mining, moon village, space farming, and space tourism [1]. In light of these envisioned space applications, it is inevitable that many small spacecraft that are not self-sufficient, such as CubeSats, must be charged by external sources due to the lack of energy generation due to tiny solar arrays and, even worse, no energy harvesting occurs during an eclipse. Since tethered solutions using physical cables are not feasible (i.e., mobility limitations, cost, etc.), there is no option other than utilizing the wireless power transfer (WPT) method. This is why energy harvesting in space is a must for sustainable space networks. Ubiquitous radiofrequency (RF) and free-space optics (FSO) wireless technologies are considered solutions to address this problem in the

literature [2, 3]. Since the main goal is to propose self-sufficient (i.e., green) and robust WPT solutions in space networks, the most advanced technology that satisfies these requirements shall be considered.
FSO is the state-of-the-art technology for energy harvesting in deep-space missions due to its capability of transmission over higher-order distances due to less attenuation by the utilization of the very narrow beam divergence angles of laser diodes. Although the FSO space systems establish a point-to-point link, any small satellite in a constellation can be used as a relay to transfer power to its neighbors in various schemes [4]. However, FSO technology is more susceptible to atmospheric attenuation and misalignment loss when compared to its counterpart RF technology. There is negligible atmospheric attenuation in space, but mechanical vibrations of the satellites cause random misalignment fading. The azimuth and elevation misalignment error angles at the transmitter and receiver can be modeled statistically with zero-mean, independent, and identically distributed (*i.i.d.*) Gaussian distribution. As the inter-satellite distance increases, the necessity of the acquisition, tracking, and pointing (ATP) mechanism becomes more significant [3].

FSO-based WPT in Lunar Networks

Currently, there are a number of activities that mainly focus on lunar communication architectures. Supplying continuous power for lunar missions, especially during an eclipse, is one of the objectives of the National Aeronautics and Space Administration (NASA) [5]. Also, the Lunar Surface Innovation Consortium (LSIC) collaborates with academicians, members of industry, and government to define the lunar surface technology requirements and make recommendations for applicable development plans to achieve successful lunar exploration missions. The key technology gaps that their surface power team focuses on are multi-kW power generation technologies, sub-kW power generation technologies, power distribution with FSO-based WPT, large-scale energy storage (e.g., regenerative fuel cells), and radiation-tolerant electronics [5].

Furthermore, very recently, on the 23rd of August 2023, The Indian Space Research Organization (IRSO) made an achievement and became the first nation to land on the southern pole of the Moon [6]. Scientists know that this region hosts water in the form of ice, and the water is essential for life. It can also be used for purposes other than drinking, such as cooling the machinery, or even used as fuel after breaking H_2O down into oxygen and hydrogen elements. Therefore, sustainability in space is not far away, and this will lead to many opportunities in the future.

Moreover, the Defense Advanced Research Projects Agency (DARPA) of the United States announced a 10-year Lunar Architecture, or LunA-10, project that looks forward to hearing interesting ideas about the Moon framework over the next ten years. For instance, FSO technology can be used to establish simultaneous lightwave information and power transfer (SLIPT) systems on the lunar surface [7]. In addition, many lunar opportunities will emerge once the following vital sectors are developed: mining, energy, agriculture, robotics, life sustainment, communications (i.e., SLIPT), and position, navigation, and timing (PNT).

Research Challenges

Although FSO-based WPT between satellites provides many advantages, there are significant challenges to overcome, as detailed below.

Improvement in Conversion Efficiencies

In an FSO system model, the following two conversion efficiencies are considered. First, the electrical power as input of a laser diode is converted to optical power, and there is a significant loss during this conversion of around 50 percent, depending on wavelength and the laser diode type [3]. On the receiver end, the optical power as input is converted to the electrical DC power by a solar cell (i.e., semiconductor diode), which yields a loss during this optoelectrical conversion too. This energy harvesting conversion efficiency (EHCE) parameter is wavelength-dependent, and hence, the solar cell material should be chosen according to the transmitter wavelength. For instance, if the wavelength of the system is 1064 nm, InGaAsP-made solar cells having 26.4% EHCE can be selected instead of GaAs-made solar cells, yielding almost 60% at around 800 nm [3]. It should be noted that the shorter the wavelength, the higher the misalignment loss. Therefore, hardware improvements that increase these efficiencies are necessary since there are many small satellites in mega-constellations that can be used as relays.

Transmitter Design

The long distances between satellites in space compel space system designers to work on how to obtain very narrow beam divergence angles, especially when the receiver aperture diameter is very small, such as 0.2 m [3]. However, the beam divergence angle is inversely proportional to the transmitter aperture diameter, and hence, to be able to provide very narrow divergence angles (i.e., sub-microradian) to ensure maximum received power, a very large and expensive transmitter aperture is required. For instance, NASA calculated the requirement of a 50 m transmitter aperture diameter for a 61,000 km distance between Lagrange point L1 and a lunar limb by considering 800 nm wavelength and 2.4 m receiver aperture diameter [8]. The mass of the satellite varies between 10–50 tons as a function of the transmitter aperture diameters in various receiver aperture diameters [8]. It should be noted that the larger the receiver aperture diameter, the smaller the required transmitter aperture diameter. The amount of challenge will be different as per the missions and corresponding system designs.

Optimization Requirement to Ensure Fairness

Since the distances between the solar-powered satellite (SPS) transferring the power and the small satellites in a mega constellation vary due to the different locations of these satellites, the received power and, hence the harvested power can change significantly. In addition, there will be aforementioned conversion losses in multi-hop systems in which small satellites are used as relays. Therefore, a significant unfairness between these satellites during energy harvesting occurs. Thus, this optimization problem needs to be addressed by considering the various network topologies, missions, and satellite battery conditions. Besides, the protocols of the medium access control (MAC) and network layers can be designed to provide fairness between the satellites [4].

Conclusion

As the population of small satellites is increasing day by day, the necessity of recharging them by external sources becomes vital. Free-space optics technology is more useful than ubiquitous radiofrequency technology in space since the former is able to transmit the power to a tiny spot area even for thousands of kilometers distances. However, it is imperative to utilize the acquisition, tracking, and pointing module for long-distance links (i.e., spatial links) to mitigate the misalignment losses between satellites [3].

There are many ongoing researches that focus on wireless power transfer by using laser transmitters in lunar networks. The Lunar Surface Innovation Consortium is working on powering the dark side of the moon since this side experiences two weeks of total darkness each month. Furthermore, the Defense Advanced Research Projects Agency (DARPA) of the United States is also working on a 10-year Lunar Architecture, or LunA-10, project over the next ten years.

On the other hand, there are significant challenges in wireless power transfer using FSO technology. The conversion efficiencies of electrical-to-optical and optical-to-electrical need to be improved. Moreover, deep-space missions such as lunar missions use transmission channels whose path lengths are ten thousand kilometers thus, a very narrow beam divergence angle is required. To satisfy the required beam divergence angle, a huge and expensive transmitter aperture must also be manufactured and then transported to space. Alternative solutions may reduce the size significantly. Last but not least, the optimization scheme and adaptive configuration along with the design of medium access control and network layer protocol can minimize the unfairness in energy harvesting between satellites in a mega constellation.

References

[1] M. Y. Abdelsadek, A. U. Chaudhry, T. Darwish, E. Erdogan, G. Karabulut Kurt, P. G. Madoery, O. Ben Yahia, and H. Yanikomeroglu, "Future space networks: Toward the next giant leap for humankind," IEEE Transactions on Communications, vol. 71, no. 2, pp. 949–1007, 2023.

[2] K. Tekbıyık, D. Altinel, M. Cansiz, and G. Karabulut Kurt, "Wireless power transmission on Martian surface for zero-energy devices," IEEE Transactions on Aerospace and Electronic Systems, vol. 58, no. 5, pp. 3870–3880, 2022.

[3] B. Donmez, I. Azam, and G. Karabulut Kurt, "Mitigation of misalignment errors over Inter-Satellite FSO energy harvesting," in 2023 Workshop: Mega Constellation Satellite Network for 6G (PIMRC'23 WS MCSN-6G), Toronto, Canada, Sep. 2023, p. 5.

[4] G. Pan, H. Zhang, R. Zhang, S. Wang, J. An, and M.-S. Alouini, "Space simultaneous information and power transfer: An enhanced technology for miniaturized satellite systems," IEEE Wireless Communications, vol. 30, no. 2, pp. 122–129, 2023.

[5] "Lunar Surface Innovation Consortium." Accessed: Oct.29, 2023. [Online]. Available: https://lsic.jhuapl.edu/Our-Work/Focus-Areas/index.php?fg=Surface-Powerljkl

[6] "Chandrayaan-3." Accessed: Oct.29, 2023. [Online]. Available: https://www.isro.gov.in/Chandrayaan3.html

[7] "SAM.gov." Accessed: Oct.29, 2023. [Online]. Available: https://sam.gov/opp/54586656144548e598d75adea4d129b7/view

[8] Williams, M. D. (1993). *Power transmission by laser beam from lunar-synchronous satellite* (Vol. 4496). National Aeronautics and Space Administration, Office of Management, Scientific and Technical Information Program.