I. INTRODUCTION

This special issue is devoted to Satellite Communication advances so as to gather the most important contributions in this field from academia and industry. In particular, the importance of this issue is also due to the fact that the last issue appearing on IEEE JSAC about SatCom is dated back to 2004 and therefore many important technology advances have been testified in the meantime, actually revolutionizing the satellite industry. In particular, important innovations have been brought to the design of both ground and space segments, spanning physical layers up to upper layers of the protocol stack.

Just to cite some of the most relevant, a modernized concept of random access based on interference cancellation and multiple replicas [1] has been re-introduced in the design of satellite systems to favor the IoT (Internet of Things) satellite market. Besides this, MIMO concepts [2] have been applied to SatCom in order to further increase the overall system capacity. Similarly, the space segment implementation also experienced important technology progress owing to the availability of fully-digitalized processors, which paved the way towards the design of time- and frequency-flexible payloads [3], which helped the existing SatCom lower layers implementations better coexist with the IP-based protocol stack. The overall success of such an innovation struggle is ultimately testified by the consolidation of DVB standards, such as DVB-S2 and the more recent extension DVB-S2x for the forward link as well as the introduction of DVB-RCS2 for the return link.

The main technology advances have been, however, not limited to satellite scenarios but also had important implications in space environments (e.g., deep space missions). From this standpoint, it is worth mentioning the use of more sophisticated channel coding schemes based on LDPC for both telecommand and telemetry services [4]. Moreover, the consolidation of the DTN protocol architecture as CCSDS standard demonstrated the importance of BP and LTP protocol for the future space missions [5]. A final note has to be reserved to the increasing interest towards free-space optics communications [6], considered the next frontier for both satellite and space communication, in that they will be able to provide very large data rates, hence able to sustain the transfer of huge amount of data from the sky.

According to this view, it is immediate to see that the satellite industry is going through a very interesting and exciting period. New markets and applications, such as maritime and aeronautical communication, IoT, M2M (Machine to Machine) are fostering innovation at an unprecedented pace. This era of innovation started with the advent of High Throughput Satellites (HTS) [7], and is now extending via digital and flexible payloads, high-speed optical communications and Low Earth Orbit (LEO) constellations. New systems are being announced by satellite operators capable of delivering terabit/s throughput either regionally or globally. In addition, the paradigm of resources flexibility has pushed the satellite payload and ground segment towards new architectures with much higher efficiencies, supported by an unparalleled evolution of RF and digital processing technologies. Satellite-based IoT systems have started to materialize thanks to, on the one hand, the recent significant enhancements in the efficiency of random access technologies and on the other hand the fast time to market and reduced risk of cubesat-based constellations. Very high throughput links (in excess of 1 Gbps) have been demonstrated and new systems based on optical technologies are upcoming. Finally, mega-constellations are being conceived that comprise hundreds or thousands of satellites, which again will push innovation within the satellite communications industry forward for years to come.

As testified by the advance of satellite technology brought forward by the satellite industry, as above outlined, new services are expected to be enabled and better complementarity between satellite and terrestrial systems is going to be achieved. In particular, the anytime-anywhere communication paradigm offered by satellite systems will be conveniently conjugated with the recent evolution of 4G systems towards the development of a 5G ecosystem [8]. Moreover, meeting unprecedented high traffic user demands in scenarios such as maritime and aeronautical, where no terrestrial connectivity is usually available, will further increase the opportunity for the
satellite industry to consolidate important market use-cases. In this ecosystem, integration and convergence of satellite and terrestrial systems will build on defining suitable protocol architectures able to efficiently and seamlessly distribute data between machines and users. An effective design of such communication paradigm has however to be supported by a sophisticated network management strategy, whereby implementation of Network Function Virtualization (NFV) as well as Software Defined Networking (SDN) concepts [9] will be pivotal to achieve full network convergence.

From this standpoint, research activities [10] carried out by industry and academia in the field of satellite communications have been contributing to the consolidation of existing systems and to their evolution towards new generations. In particular, important implications of the physical layer design such as precoding and random access schemes have been gaining more and more importance in the last years. Likewise, definition of dedicated protocol architectures running on the higher layers of the protocol stack have been instrumental to enable new satellite-based services in scenarios with intermittent connectivity (by means of DTN) or where deep integration of heterogeneous distribution networks is envisaged (by means of SDN and network orchestration).

In line with the aforementioned satellite technology advances supported by both academia and industry, the present IEEE JSAC Special Issue comprehensively illustrates the main trends and the expected evolutions of the satellite ecosystem, providing an exhaustive summary of the main research activities and the most relevant results achieved in the last five years.

Given the large number of accepted papers, the special issue has been subdivided into two parts, the first being reported in this issue. In the following section, a short overview of each paper being accepted is given, classified according to the main paper scope: networking, random access, physical layer, and other (including two papers addressing GNSS and UAV communications, respectively).

II. SUMMARY OF ACCEPTED PAPERS

A. Networking

The paper “Joint Placement of Controllers and Gateways in SDN-Enabled 5G-Satellite Integrated Network” by Jiajia Liu et al., deals with the optimized design of integrated 5G-satellite networks. In particular, the authors assume an SDN network architecture framework and study the optimal placement of gateways and SDN controllers in order to maximize the overall network reliability under certain delay constraints, as typical in the design of present telecommunication networks.

The paper “WiLiTV: Reducing Live Satellite TV Costs Using Wireless Relays” by Rajeev Kumar et al., propose the simultaneous use of different wireless links (including satellite ones) to improve and boost the penetration of TV distribution into areas typically suffering from limited broadcasting technology deployment. The authors show that the proposed architecture is able to reduce the overall service implementation costs, without however impacting on TV quality of experience perceived by users.

The paper “A Distributed Trust Management Scheme for Data Forwarding in Satellite DTN Emergency Communications” by Philip Asuquo et al., explores the problem of security management in DTN satellite networks. Taking as reference the case of emergency communications, where link disruptions and multi-hop routing are typically experienced, the store-forward functionalities offered by DTN are certainly an added value but introduce important design implications from a security standpoint. The paper proposes a distributed trust management in order to cope with these network characteristics and different solutions are analysed with respect to different performance metrics.

The paper “FRUDP: A Reliable Data Transport Protocol for Aeronautical ad hoc Networks” by Qin Luo et al., address the problem of achieving reliable data distribution in aeronautical networks, which shows highly dynamic topology as well as propagation impairments which together can be hardly be observed in common terrestrial and wireless networks. To improve reliability performance, the combined use of UDP and Raptor codes is proposed along with a dedicated congestion control scheme to decouple the occurrence of congestion events to the frequent handover cases.

The paper “Multi-Resource Coordinate Scheduling for Earth Observation in Space Information Networks” by Yu Wang et al., addresses the problem of Earth observation data distribution under QoS constraints. To meet the service requirements demanded by typical Earth Observation applications, a multi-resource coordinate scheduling approach is proposed so as to optimize the use of the available network resources.

B. Random Access

The paper “Random Access Preamble Design and Detection for Mobile Satellite Communication Systems” by Li Zhen et al., deal with the efficient design of preamble for random access schemes applied in mobile satellite communications. Moreover, in order to reduce the complexity and improve the multi-user access, a fast timing detection approach is proposed, which eventually turns out to offer outstanding performance results in multi-users scenarios.

The paper “On the Modeling and Performance Assessment of Random Access With SIC” by Alberto Mengali et al., analyses the performance of well-consolidated random access schemes for satellite communications, such as CRDSA, IRSA, CSA, and E-SSA with respect to fundamental figures of merit like throughput and packet loss rate. In particular, the authors show that previous work on the same subject available in the literature considered a simplified collision channel model, which lead to inaccurate performance analysis. Taking advantage of a more precise reception model, this paper provides fundamental insights into performance offered by the aforementioned random access schemes.

C. Physical Layer

The paper “Achievable Rate Maximization for Cognitive Hybrid Satellite-Terrestrial Networks With AF-Relays” by Zhetao Li et al., proposes a power allocation scheme to maximize the system capacity for cognitive hybrid satellite-terrestrial networks with two-path successive relays. The rate
maximization problem is formulated and solved in closed form. Performance analysis, supported also by numerical simulation, demonstrates the efficiency of the proposed scheme.

The paper “Fast and Accurate Estimation of Angle-of-Arrival for Satellite-borne Wideband Communication System,” by Kai Wu et al., addresses the design and performance evaluation of a novel algorithm for angle-of-arrival estimation in the context of a satellite-borne communication system. Performance analysis of the proposed estimation approach demonstrates a drastic improvement of the estimation accuracy along with a significant complexities and training requirements reduction.

The paper “Next Generation High-Rate Telemetry,” by Alessandro Ugolini et al., proposes and discusses possible ways to improve the spectral efficiency of the data return link of high-rate telemetry systems employed in Earth observation missions. The proposed techniques are either a revision and/or an extension of the currently adopted modulation and coding formats, or are related to an enhancement of the transceiver architecture. The benefits of the proposed techniques are assessed by means of computer simulations with reference to a realistic scenario where real non-linear amplifier, filters, and impairments are considered.

The paper “Design of Digital Satellite Processors: From Communications Link Performance to Hardware Complexity,” by Vincenzo Sulli et al., is an original treatment of the digital transparent processor (DTP) design. The paper proposes a design approach for DTPs and analyses the complexity of one implementation based on a specific study case. The performance analysis relates the implementation complexity to the performance of the DTP in terms of noise floor and processed bandwidth.

D. Other

The paper “A GNSS/5G Integrated Positioning Methodology in D2D Communication Networks,” by Lu Yin et al., focuses on the integration methodology of GNSS and device to device (D2D) measurements in 5G communication system by analyzing the characteristics of this integration and proposing a high-efficiency D2D measure protocol, i.e., crossover multiple-way ranging (COMWR), consuming less communication resources. Three integrated algorithms are proposed and evaluated in specific scenarios showing outperforming performance with respect to the non-integrated approaches.

The paper “Beam Tracking for UAV Mounted SatCom on-the-Move with Massive Antenna Array,” by Jianwei Zhao et al., addresses a blind beam tracking approach for Ka-band UAV-satellite communication system, where UAV is equipped with a large-scale antenna array. The effects of UAV navigation are firstly released through the mechanical adjustment, which could approximately point the beam towards the target satellite through beam stabilization and dynamic isolation. Then, the precision of the beam pointing is blindly refined through electrically adjusting the weight of the massive antennas, where an array structure based simultaneous perturbation algorithm is designed. Simulation results demonstrate significant performance gain of the proposed algorithm with respect to state-of-the-art.

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REFERENCES


Alessandro Vanelli-Coralli (S’93–M’97–SM’07) received the Dr. Ing. degree in electronics engineering and the Ph.D. degree in electronics and computer science from the University of Bologna, Italy, in 1991 and 1996, respectively. In 1996, he joined the University of Bologna, where he is currently an Associate Professor with the Department of Electrical, Electronic, and Information Engineering “Guglielmo Marconi,” and the Chair of the Ph.D. Board in electronics, telecommunications, and information technologies. From 2003 to 2005, he was a Visiting Scientist with Qualcomm Inc., San Diego, CA, USA. He participates in national and international research projects on wireless and satellite communication systems: he has been a Project Coordinator and Scientific Responsible for several European Space Agency and European Commission funded projects. His research interests are in the area of wireless communications, digital transmission techniques, and digital signal processing. He has been appointed as a member of the Editorial Board of the Wiley InterScience Journal on Satellite Communications and Networks and has been a guest co-Editor for several special issues in international scientific journals. He has served as the General Chairman and the Technical Chairman of several scientific conferences. He was a co-recipient of several Best Paper Awards.
Tomasso de Cola was born in Manosque, France, in 1977. He received the “Laurea” degree (Hons.) in telecommunication engineering in 2001, the Qualification degree as a Professional Engineer in 2002, and the Ph.D. degree in electronic and computer engineering, robotics and telecommunications from the University of Genoa, Italy, in 2010. From 2002 to 2007, he was with the Italian Consortium of Telecommunications (CINT), University of Genoa Research Unit, as a Scientist Researcher. Since 2008, he has been with the German Aerospace Center (DLR), where he is involved in different European Projects focusing on different aspects of DVB standards, CCSDS protocols, and testbed design. In particular, he has been serving as the Deputy Area Director of the Space Internetworking Services area within CCSDS and taking part to the CCSDS Engineering Steering Group, since 2015. Dr. de Cola is a co-author of over 70 papers, including international conferences and journals. He has served on the technical program committee at several IEEE International Conferences and was involved in guest editorial initiatives for the IEEE ISAC, the IEEE Network, and the IEEE Wireless Communication Magazine. He is member of the IEEE Communications Society, where he is serving as the Chair of the Satellite and Space Communications technical committee.

Frederik Simoens received the B.S. and M.S. degrees in electrical engineering from Ghent University, Belgium, in 2003, where he received the Ph.D. degree in wireless communications from Telecommunications and Information Processing Department. From 2003 to 2008, he was with Telecommunications and Information Processing Department. Since 2008, he has been with Newtec, where he is currently CTO. Newtec is specialized in designing, developing, and manufacturing equipment and technologies for satellite communications. He is co-author of several patents and over 50 publications in international peer-reviewed journals and conference proceedings. His research interests include satellite communications, wireless mobile communications and multi-antenna communication systems. He is contributing to several standardization activities and member of the DVB Steering Board. He is also a member of the executive committee of the IEEE Benelux COM/VT Chapter.

Bassel F. Beidas received the M.S. degree (Hons.) from the California Institute of Technology, Pasadena, CA, USA, and the Ph.D. degree from the University of Southern California, Los Angeles, CA, USA, both in electrical engineering. He held the position of a Principal Engineer with Corvis Corporation, Columbia, MD, USA, where he developed innovative signal processing algorithms for 40 Gb/s ultra long-haul optical communications. He currently holds the position of an Advisory Engineer with the Advanced Development Group, Hughes, Germantown, MD, USA. He is responsible for research and development in advanced transmission technologies, which have been successfully incorporated into several premier product lines in cellular and satellite communications. He holds over 25 U.S. patents on digital communications techniques and has several patents pending. His research interests include signal classification, interference cancellation, adaptive signal processing, synchronization, and nonlinear systems. Dr. Beidas is a Member of Phi Kappa Phi, Eta Kappa Nu, Tau Beta Pi, and his biography appears in The National Dean’s List. He was a recipient of the prestigious Fred W. Ellersick MILCOM 2014 Award for the Best Paper in the Unclassified Technical Program. In addition, he was a recipient of numerous awards from Hughes, including the 1997 Outstanding Achievement Award, the 1999 Special Award for Exceptional Contributions to Third-Generation Wireless Technology, the 2008 Engineering Excellence Award for Significant Contributions to Advanced Technology Development, and the 2012 Certificate of Achievement for Excellence in the Area of System Transmission and Satellite Design.

Song Guo received the Ph.D. degree in computer science from the University of Ottawa. He was a Professor with the University of Aizu from 2007 to 2016. He is currently a Full Professor with the Department of Computing, The Hong Kong Polytechnic University. He has authored or co-authored over 400 papers published in major conferences and journals. His research interests are mainly in the areas of big data, cloud computing and networking, and distributed systems. His work was recognized by the 2016 Annual Best of Computing: Notable Books and Articles in Computing in ACM Computing Reviews. He was a recipient of the 2017 IEEE Systems Journal Annual Best Paper Award and five other best paper awards from IEEE/ACM conferences. He was an Associate Editor of the IEEE TRANSACTIONS ON PARALLEL AND DISTRIBUTED SYSTEMS and an IEEE ComSoc Distinguished Lecturer. He is now on the Editorial Board of the IEEE TRANSACTIONS ON EMERGING TOPICS IN COMPUTING, the IEEE TRANSACTIONS ON SUSTAINABLE COMPUTING, the IEEE TRANSACTIONS ON GREEN COMMUNICATIONS AND NETWORKING, and the IEEE Communications Magazine.

Dr. Guo also served as General, TPC, and Symposium Chair for numerous IEEE conferences. He currently serves as an Officer for several IEEE ComSoc Technical Committees and a Director in the ComSoc Board of Governors.

Alberto Ginesi was born in Parma, Italy, in 1967. He received the Dr. Ing. degree (cum laude) and the Ph.D. degree in electronic engineering from the University of Pisa, Italy, in 1993 and 1998, respectively. In 1996–1997, he spent one year with Carleton University, Ottawa, ON, Canada, performing research on digital transmissions for wireless applications. He joined Nortel Networks, Ottawa, ON, Canada, and Catena Networks, Ottawa, in 1997 and 2000, respectively, where he worked on digital subscriber loop technologies and contributed to the definition of the second-generation ADSL standards within the ITU-R standardization body. Since 2002, he has been with the ESA Research and Technology Centre (ESTEC), Noordwijk, The Netherlands, where he is currently Head of the Telecommunication-TT&C Systems and Techniques Section of the Technical and Quality Management Directorate and is responsible for the Research and Development of satellite telecommunication and TT&C systems. He is co-author of over 60 scientific publications and over 20 international patents on subjects covering both DSL and satellite communication systems. His main research interests lie in the area of advanced digital communication systems and techniques from theory to HW implementation.