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Editorial

State-of-the-Art in Satellite Communication Networks

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1. Introduction

Satellite networks provide a wide range of coverage throughout the globe and play a very important role due to their broadcasting capacity and bandwidth flexibility. They are able to provide broadband services to citizens in rural areas, to passengers aboard vessels, trains, or aircrafts, quick Internet access in emergency scenarios, and backhauling of other access technology. In terrestrial networks, many links and nodes are needed to reach long distances and cover large areas. Satellite networks are very useful in providing wide coverage to villages and places where wired networks are not possible, such as hills and forests. It should be noted that two-thirds of the world still do not have the infrastructure for Internet. This kind of network can be categorized according to their orbits. In particular, geosynchronous satellites, located over the equator, have the same angular speed as the Earth, allowing them to be a fixed point for users. New standards and technologies have been proposed in recent years to exploit the specific characteristics of these platforms, such as scheduling, mobility, routing, QoS, and many others. An important issue is related to the possibility of integrating satellite networks with other platforms to guarantee better services to the more exigent users. New architectures, such as Digital Video Broadcasting, are focusing on multimedia traffic streams with the possibility of using interactive services. This type of traffic requires high bandwidth and high levels of QoS to meet user requirements. Traffic shaping and rate/congestion control, bandwidth allocation, flow control, and video scalability are some of the technical challenges to be considered in managing multimedia traffic over satellite networks.

Hence, this Special Issue focuses on applications, platforms, and services where satellites can play an important role in stimulating the continued efforts of studying and analyzing the intrinsic issues of the satellite environment.

2. The Present Issue

This Special Issue features 11 papers, of which 10 present novel studies and approaches to resolve issues in the satellite environment and 1 review that shows a brief overview of satellite channel modeling for land mobile satellite systems starting from the early 1980s. These 11 papers are concisely described as follows.

Ortiz-Gomez et al. [1] discussed the architecture, implementation, and applications of Machine Learning (ML) for resource management in multibeam GEO satellite systems. Primarily, two types of systems are explored: one with power, bandwidth, and/or beamwidth flexibility, and the other with time flexibility, i.e., beam hopping, examining and evaluating several machine learning (ML) strategies suggested for these architectures, with a focus on the application of Supervised Learning (SL) and Reinforcement Learning (RL). Then, performance evaluations of different approaches of ML techniques for RRM on GEO multibeam satellites using Matlab R2020a for simulating the satellite environment are presented. Finally, the best system architecture as well as the benefits and drawbacks of each strategy are shown.

Zhang et al. [2] designed a two-step access and handover strategy for GEO/LEO heterogeneous satellite networks, considering signal quality, handover cost, and load balancing. Firstly, the GEO/LEO satellite network selection function is designed based on

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the utility function, and then an Importance-TOPSIS scheme to choose an LEO satellite if the users choose to access LEO satellites in the first step is proposed. Simulation results showed that the proposed method can reduce the number of handovers, thus improving the overall throughput of the system.

Deng et al. [3] proposed a Blockchain-based Authentication Protocol Using Cryptocurrency Technology (BAPC) to address the issue of extended pauses in satellite services caused by user access authentication in situations of frequent switching between satellites and ground users. Three stages of the authentication process are designed introducing the cryptocurrency technology. The satellite cluster is divided into multiple regions to improve the efficiency of block consensus. Their proposal is tested with an NS-2 simulator, verifying that BACP can greatly shorten the response time of switching authentication and significantly reduce the time of block generation and the network throughput.

Qiu et al. [4] proposed an algorithm able to perform an efficient iterative timing recovery via the steepest descent of low-density parity-check (LDPC) decoding metrics. The complete timing recovery is accomplished where the proposed scheme is combined with a Mueller-Müller (M&M) timing recovery algorithm to perform both the timing capture and the timing track. The simulation results using the proposed method indicate that the LDPC-coded BPSK system suffered from a large timing phase, and frequency offset performs excellently within 0.1 dB of the ideal code performance with rational complexity. Therefore, the proposed iterative technique can be efficiently used in satellites with weak signal timing synchronization.

Zhang et al. [5] dealt with beam hopping (BH) for satellite systems, which represents a promising technology to provide a high level of flexibility in satellite applications. In the paper, a genetic algorithm approach is proposed in order to study the dynamic time slot allocation under the effect of time-varying rain attenuation in the context of a DVB-S2X satellite environment where opportune MODCODs can be used in order to obtain optimal spectrum efficiency for each beam in different time slots. The simulation results demonstrate that compared to traditional techniques the proposed dynamic approach is able to better manage time slot allocation, thus guaranteeing an improvement of the overall system performance.

Deng et al. [6] studied a cross-layer and cross-dimension radio resource optimization model based on a firefly algorithm that takes into account the channel state information (CSI) and QoS of the satellite communications in a multi-satellite and multi-beam scenario. Their study tries to improve the resource management in the overall system and then obtain high spectrum efficiency throughout a packet segmentation scheme able to map different packets to radio resources. Their simulations show an improvement in the system throughput and in the user satisfaction index.

Ruggerini et al. [7] proposed the design of a Tx/Rx multibeam antenna based on a discrete lens integrated with a reflector system. This approach allows a reduction in the active lens's size as well as a reduction in the radiating system's complexity. The Tx/Rx radiating elements have been built and tested. The design procedure's efficiency was demonstrated by the agreement between simulated and measured data.

Rotshild et al. [8] presented a continuously reconfigurable metasurface reflector based on unit cell mushroom geometry that was integrated with a varactor diode able to operate in an optimized manned in an X-band and Ku-band satellite system and improve the quality of service. The authors have designed a unit cell of the metasurface. The losses and dynamic reflection phase range of the unit cell design parameters were investigated. The magnitude and phase reflection of the unit cell are illustrated over a wide frequency spectrum, with good agreement between all the measurements and the simulations.

Papafragkakis et al. [9] dealt with the use of Ka and Q/V bands for obtaining a high data rate in satellite services. Clearly, at these frequencies, the signal attenuation is an important aspect to take into account. To face with this issue, a micro-scale site diversity system has been proposed and evaluated in terms of capacity gain using rain attenuation time series generated using the Synthetic Storm Technique (SST). A considerable capacity

gain can be shown in all of the cases studied, indicating that micro-scale site diversity systems might be a realistic option for corporate users looking to boost data rates and enhance connection availability.

Petrovic et al. [10] explored the challenges and constraints when the over-the-horizon (OTH) maritime surveillance service utilizes the Internet of Things (IoT) as its backbone. The authors have examined the service performance under various meteorological conditions specific to the Gulf of Guinea. The analysis aims to mathematically describe the impact of harsh weather conditions on the performance of the service. The goodness of the proposed analysis is proven, as demonstrated through the high quality of service with an outage probability of just 0.1%. The work presented by the authors aims to be a sort of guideline for the deployment of maritime surveillance service solutions in other equatorial regions.

Finally, Tropea et al. [11] presented a comprehensive review of the most recent developments in satellite channel communications related to mobile services and, in particular, for the land mobile satellite systems. They presented all different types of Markov models, from single-state to multi-state models, that have been proposed in the literature since the early 1980s.

3. Future

Satellite systems are and will be an important technology for guaranteeing adequate communications to users, especially in all those areas where infrastructures are difficult to be installed. Nowadays, in the satellite panorama, a new form of satellite object is emerging: the *cubesat*. They are a type of miniaturized satellite that have a cubic shape, the electronics of which are made using COTS components. The simplification of the satellite structure makes it possible to design and build functioning satellites at a low cost. Standardizing the interface between the launcher and the payload reduces the work required to couple the satellite to the launcher. Thus, the exploration of the satellite world continues to be a fascinating universe to explore.

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