

Cost-Effective Air-to-Ground System and Network Design for 5G Inflight Connectivity in the Kingdom of Saudi Arabia

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Abstract

In our capstone design project, we present a cost-effective Air-to-Ground (A2G) system and network design that would consequently contribute into vitalizing domestic tourism in the Kingdom of Saudi Arabia. The advancement of 5G technology has created opportunities to enhance inflight connectivity (IFC) services, enabling passengers to stay connected and engaged during their flights. However, deploying such systems can be challenging in terms of cost and infrastructure requirements. Accordingly, we propose a cost-effective A2G system and network design capable of providing 5G-grade IFC for domestic flights taking advantage of the unique landscape properties of the Kingdom of Saudi Arabia. Our design incorporates the use of existing terrestrial base stations (TBSs) strategically deployed to cover the domestic flight corridors, ensuring seamless connectivity for passengers onboard. We also consider the optimization of network resources when utilizing 5G technology to provide high-speed and reliable inflight connectivity while striking a balance between the objective of reducing total cost of ownership (TCO) and that of delivering a 5G-grade inflight connectivity. We formulate an optimization model to address the issue of selecting a subset of the already deployed TBSs infrastructure, specifically those that overlap with the corridors of domestic flights, to be reutilized after being upgraded with up-tilted 5G-NR antennas. Using MATLAB, we conducted a grid partition analysis on the landscape of Saudi Arabia to gain a comprehensive understanding of the region allowing us to visualize their attributes across the country. Consequently, we associated each grid point with the factors influencing the TCO for the A2G network infrastructure. These factors include considerations such as geographical conditions, population density, and proximity to existing infrastructure among other relevant parameters. By incorporating these factors, we were able to assess the TCO implications at each grid point. Hence, our approach facilitates the identification of the most favourable sites for the placement of A2G TBSs and thus optimize the efficiency and cost-effectiveness of our network deployment, ensuring reliable 5G-grade IFC across Saudi Arabia. Through performance evaluations and cost analysis, we demonstrate the viability and cost-effectiveness of our proposed A2G system and network design. This research contributes to the fields of systems engineering and operations management by providing a practical and efficient solution for deploying and managing the A2G network systems, considering the capital and operational costs involved and the resource optimization required for providing seamless 5G-grade IFC in the Kingdom of Saudi Arabia.

Keywords

Domestic tourism, Inflight connectivity, 5G technology, Air-to-Ground, Cost-effective design.

Biographies

Danah Al Ateeq is a senior communications engineering student at college of engineering, Princess Nourah bint Abdulrahman University that have gained a valuable experience through a summer internship at Nokia KSA that exposed her to a wide range of telecommunication topics and is currently undergoing cooperative training at TAWAL in Saudi Arabia, within the international sector. The combination of her practical experience and academic knowledge

has enhanced the depth and credibility of her research making it rounded and insightful. Her current research interests include 5G mobile technology, telecom product management, operations management, A2G and A2A communication systems.

Rawan Al-Omari is a senior undergraduate student majoring in communications engineering at the college of engineering, Princess Nourah bint Abdulrahman University. She has prior experience working as a media department manager in a MAEEN community in 2020, served as a member of the academic committee in the electrical engineering department, and received a summer internship at the ALKHORAYEF commercial company during 2022 and continued since then working as a part-time employee. Currently, a CO-OP trainee in the control department of the Saudi Electricity Company (SEC). Her current research interest include 5G mobile technology, network topology design, operations management, A2G and A2A communication systems.

Aram Alblaihed is a senior undergraduate student at the college of engineering, majoring in communications engineering. She has prior experience working as intern in Saudi Standards Metrology and Quality Organization in the Department of Certification for Electrotechnical Devices, gaining valuable knowledge about the standards and regulations related to such devices. In 2023, she embarked on an internship at Nokia, a leading telecommunications company. During her time at Nokia, she worked as a communications engineer, and she achieved second place in the internship's graduation project competition, where they explored innovative ways to monetize 5G technology. She is currently undergoing cooperative training at TAWAL KSA within the engineering solutions department. Her current research interests include 5G mobile technology, operations management, Airship design, A2G and A2A communication systems.

Manar Alkahtani is a senior undergraduate student majoring in communications engineering at the college of engineering, Princess Nourah bint Abdulrahman University. She had an internship during 2023 at the General Authority of Civil Aviation (GACA) and learned a lot about communication aspects during aviation, including A2G and A2A communication. Currently, she is currently undergoing cooperative training at the Saudi Electricity Company (SEC). Her current research interest include 5G mobile technology, network topology design and modeling, operations management, A2G and A2A communication systems.

Eman Alhuthayl is a senior communications engineering student at the college of engineering, Princess Nourah bint Abdulrahman University that have an experience with the International Petroleum Technology Conference (IPTC) and undergone training in various courses and conferences, including the BAE Systems Workshop, Winter Enrichment Program, Fundamentals of Telecommunications Course, and the 9th Saudi Technical Conference and Exhibition (STCEX 2021). Currently, she is undergoing Co-Op training in the Load Forecasting Department at the Saudi Electric Company (SEC). Her current research interest includes 5G mobile technology, operational management, A2G and A2A communication systems.

Yazan M. Allawi is an assistant professor at the college of engineering, Princess Nourah Bint Abdulrahman University (PNU), Riyadh, Saudi Arabia. Prior to his current position, he served as the head of innovation and entrepreneurship department at the Scientific Research and Innovation Support Fund (SRISF), Ministry of Higher Education and Scientific Research, Jordan (2018 – 2019), manager of the Innovative Technology R&D Center and product manager with the global business division at HFR, Inc. for Mobile Internet, Republic of Korea (2015 – 2017), a research associate with the electrical engineering department and a lecturer with the Center of International Affairs at KAIST (2007 – 2015). Early on his career, he made contributions in the areas of resource provisioning in integrated optical-wireless access networks, design and optimization of survivable optical communication networks, the development of the first 5G-ready CWDM-based fronthaul solution for CPRI transport, and the realization of the first commercially viable OFDM-PON system. His current research interests include Network topology design & resource optimization, mission-critical real-time communication networks, vulnerability analysis, network resilience, disaster mitigation & preparedness, 5G and beyond (5GB) mobile systems and technologies.