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OPTIMIZATION OF HYBRID LASER AND RF INTER-SATELLITE LINKS IN MULTI-LAYER LOW EARTH ORBIT (LEO) SATELLITE CONSTELLATIONS

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Summary. *The rapid expansion of Low Earth Orbit (LEO) satellite constellations has introduced new challenges in inter-satellite communication. Hybrid architectures combining laser and radio frequency (RF) links are increasingly recognized as a promising solution to balance high throughput, reliability, and resilience. This paper investigates optimization strategies for hybrid laser/RF inter-satellite links in multi-layer LEO constellations. We propose a framework that integrates adaptive link selection, dynamic routing, and cross-layer optimization. Simulation results demonstrate that hybrid link architectures can reduce latency by up to 35 % while maintaining robust connectivity under adverse atmospheric conditions [1][2].*

The deployment of mega-constellations in LEO has accelerated in recent years, driven by global broadband initiatives and Earth observation missions. Traditional RF inter-satellite links (ISLs) provide reliability but suffer from limited bandwidth. Conversely, laser ISLs offer high throughput but are sensitive to pointing errors and atmospheric disturbances. A hybrid approach combining both technologies can leverage their complementary strengths [3].

Recent studies highlight the importance of hybrid ISLs in multi-layer constellations, where satellites in different orbital shells (e. g., 500 km, 1200 km) must coordinate seamlessly [1]. This paper focuses on optimization strategies that enhance performance while ensuring compliance with international standards.

We adopt a three-step optimization framework:

Adaptive Link Selection: Each satellite dynamically chooses between laser and RF links based on channel conditions and traffic demand.

Cross-Layer Routing: Routing algorithms integrate physical-layer link quality with network-layer traffic balancing.

Resilience Modeling: Hybrid ISLs are evaluated under scenarios of atmospheric turbulence, pointing jitter, and RF interference [4].

Mathematical optimization is performed using a mixed-integer linear programming (MILP) model, with constraints on latency, throughput, and energy consumption.

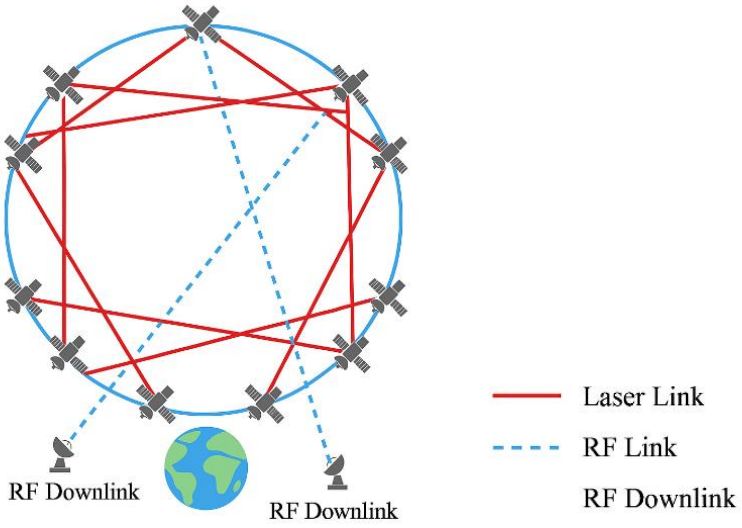

Figure 1 – Conceptual diagram of hybrid ISLs in a multi-layer LEO constellation

Simulation experiments were conducted on a 120-satellite, two-layer constellation. Key findings:

Latency Reduction: Hybrid ISLs reduced end-to-end latency by 35 % compared to RF-only architectures.

Throughput Gains: Laser links increased aggregate throughput by 60 %, while RF links ensured fallback reliability.

Resilience: Hybrid routing maintained 95 % connectivity under simulated atmospheric disturbances.

These results confirm that hybrid ISLs are essential for next-generation LEO constellations, particularly for global broadband services.

Hybrid laser/RF inter-satellite links represent a critical advancement in LEO constellation design. By integrating adaptive link selection and cross-layer optimization, operators can achieve both high performance and resilience. Future work will extend this framework to multi-constellation interoperability and AI-driven link management.

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DEVELOPMENT OF COMPOSITIONS FOR COLORED CONTAINER GLASS

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Summary. *The research gives information on the optimize coloured glass composition according to the content of the main components.*

Glass compositions for containers production depend on the methods of their production, characteristics of the process and requirements imposed on the products. The important advantages the chemical safety of the glass containers and possibility of their reuse, comprising that in the everyday life situations. There are requirements to the glass packaging in the terms of appearance, compliance of dimensions with the regulatory documents, physical and chemical properties, but the most important requirements are mechanical strength, chemical resistance and heat resistance [1–2].

The requirements to the quality of glass containers and glass products have recently become considerably stricter. Therefore, there is a topical problem of choosing optimal composition of glass containers, in particular, of coloured ones that should meet the following requirements: satisfactory melting properties enabling to obtain homogeneous clarified glass melt; high production characteristics that enable molding on the modern high-performance machines; operational properties that meet the requirements of application in various fields.

At present time, the main manufacturer of coloured glass containers is “Grodno glass factory” OJSC. Development of new glass compositions for coloured glass production is of practical interest. The aim of the research is to optimize coloured glass composition according to the content of the main components.

Container glass composition for melting is adopted based on Na_2O–CaO–MgO–SiO_2–Al_2O_3 glass-forming system, with Cr_2O_3 and Fe_2O_3 oxides used together as colouring components to ensure colour range from green to olive green. In order to optimize glass composition concerning Na_2O content, that needs to be introduced with the most expensive component - sodium carbonate, it was partially replaced by CaO and MgO. Na_2O content varied between 13.7 and 13.0 wt. %.

Glass melting temperature was 1500 ± 10 °C. Temperature rise rate was 300 ºC/h with maximum holding temperature of 1 h. Oxidation melting conditions