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FIELD PROGRAMMABLE GATE ARRAY-ACCELERATED PAYLOAD DATA HANDLING UNIT FOR SECURE AND EFFICIENT SPACE DATA TRANSFER IN EARTH OBSERVATION SATELLITES

Abstract

As new generation satellite constellations generate vast amount of Earth observation data, The need for real-time onboard data processing is originated. This paper presents an FPGA-accelerated Payload Data Handling Unit (PDHU) designed to deliver data integrity and provide data compression, encryption, packetization, secure lossless transfer, error detection and correction (EDAC). The proposed approach optimizes the effective utilization of readily accessible hardware resources while ensuring power-efficient, fast, and reliable space data transfer by leveraging the parallel processing capabilities of radiation-tolerant FPGAs. To optimize bandwidth consumption without compromising data fidelity, the PDHU incorporates CCSDS-compliant compression techniques, such as CCSDS image compression and lossless data compression. Data security and integrity can be assured through hardware-accelerated encryption (AES-256, RSA) and error detection/correction techniques (CRC, Reed-Solomon coding). The system utilizes On-chip embedded SERDES, Ethernet, SpaceWire, and CAN interfaces for secure and high-speed data transfer between satellites and ground stations. To further enhance fault tolerance, radiation-hardening techniques and triple modular redundancy (TMR) are implemented, ensuring resilience in extreme space environments. The PDHU also supports real-time packetization and telemetry processing using CCSDS File Delivery Protocol and Space Packet Protocol, enabling seamless data distribution across mission networks. FPGA's DSP blocks are utilized for high-speed signal processing and error correction, while reconfigurable logic ensures adaptability to evolving mission requirements. Designed for high-data-rate Earth observation satellite constellations, this FPGA-based PDHU architecture provides a secure, scalable, cost efficient and high-performance solution for modern spacecrafts.