Newest Committee: Packet Erasure Coding – Optical Communications Standard Committee Overview

Dr. Adina Matache (Senior Engineering Specialist, The Aerospace Corporation)

MOSA Packet Erasure Coding – Optical Communications Committee

Adina Matache, Chair
Phillip Nee, Vice-Chair

Modular Open Systems Approach (MOSA) Alliance Webinar
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Agenda

- Committee Objective
- Committee Leadership & Structure
- Background
- Alignment with MOSA Architecture
- Committee Responsibilities & Scope
- Development Roadmap
- Current Status & Milestones
- Summary & Questions

Committee Objective

- Mission:
  - Enable and facilitate interoperable near real-time space-to-ground (S2G) optical communications across the Big Three space systems while balancing technical merit, cost effectiveness, and future U.S. space mission needs

- Approach:
  - Recommend, tailor, or develop standards for **Ethernet-In, Ethernet-Out Packet Erasure Coding (PEC)** to mitigate atmospheric turbulence fading in S2G and ground-to-space (G2S) optical communication links

- Key Focus:
  - Enable interoperability
  - Preserve network stack
  - Enable COTS modem integration
  - Support high data rate operations (100G+)

Committee Leadership and Structure

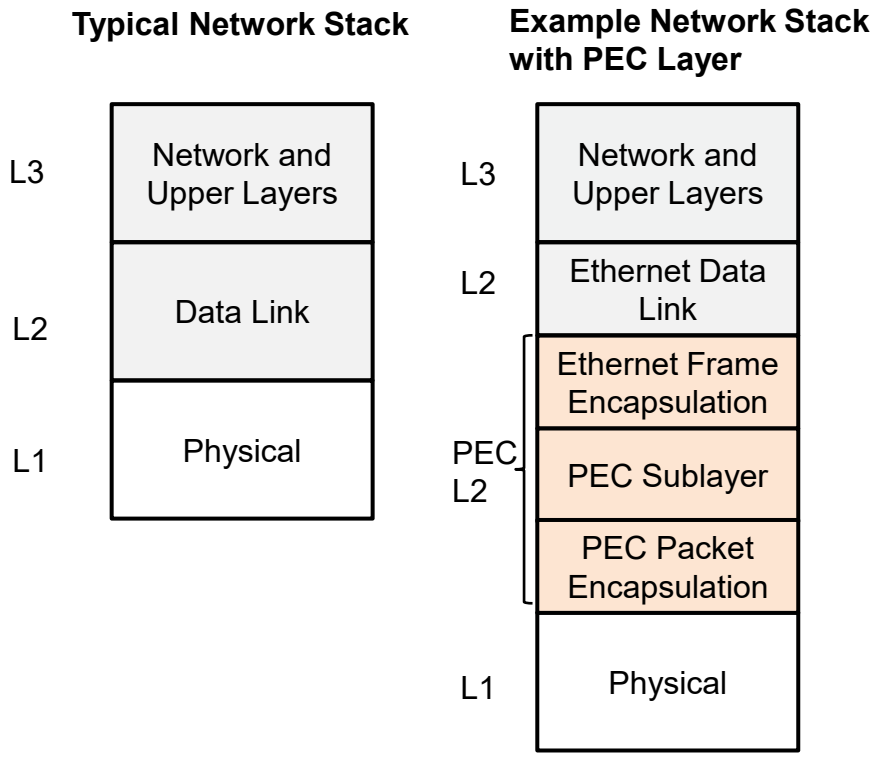
- **Committee Leadership:**
  - **Chair:** Adina Matache, The Aerospace Corporation
  - **Vice Chair:** Phillip Nee, The Aerospace Corporation
  - **Committee Manager:** Gloria Pugliese-Rosillo, The Aerospace Corporation
- **Technical Advisors (The Aerospace Corporation):**
  - Andy Walston
  - Flavio Lorenzelli
  - Ianko Chterev
  - Jeff Norman
  - Jeff Hubbard
  - Alvin Lin
  - Joe Touch

- **Member Organizations:**
  - Amazon Leo
  - Airborn
  - BAE Systems, Inc.
  - Blue Origin
  - European Space Agency
  - General Dynamics Mission Systems
  - HartSCI
  - Lockheed Martin Space
  - Loft Orbital Federal, LLC
  - Northrop Grumman
  - RTX
  - TESAT
  - ViaSat

Meeting Cadence: Weekly virtual meetings (1 hour)

Background

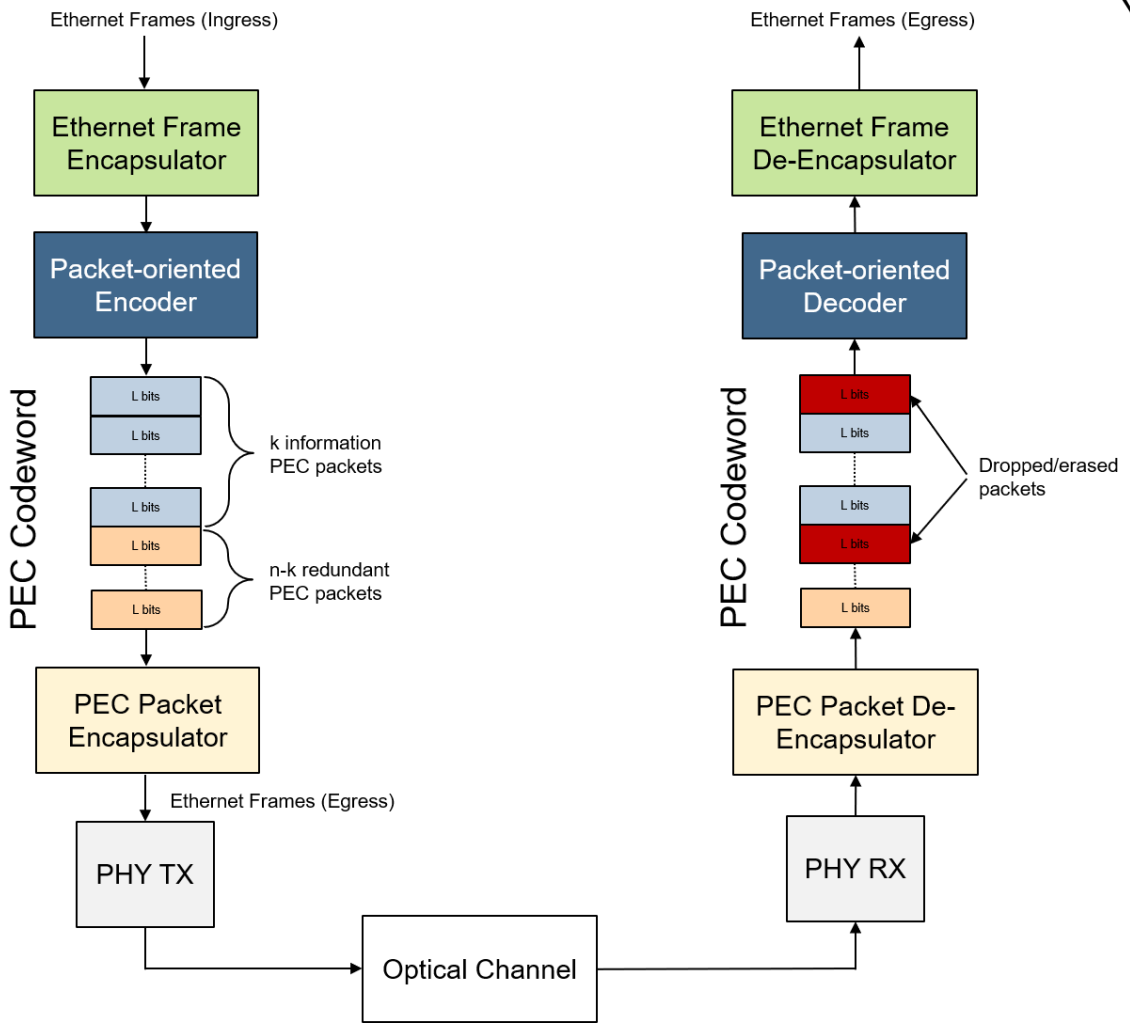
- **Why Packet Erasure Coding for Optical Comms?**
  - Atmospheric turbulence causes burst packet losses that degrade optical link performance
  - Bit-level codes at the physical layer are simply too short to overcome the long fade durations
- **PEC Overview**
  - The packet erasure code is a very long block code that works on packets (codeword symbols) to correct erased (corrupted or missed) packets
  - Unlike bit-oriented channel codes at the physical layer, PEC operates above PHY Layer and can be "wrapped around" existing commercial off-the-shelf (COTS) modems without expensive ASIC redesigns
  - PEC does not replace the bit-oriented channel FEC code at the physical layer
- **Key Advantages**
  - Network stack preserved (transparent to upper layers)
  - No COTS modem modification required
  - Packet-level recovery without retransmission latency



Background

- **PEC Structure and Operation:**
  - PEC Encoder takes K information PEC packets to produce a PEC codeword
  - PEC codeword
    - K information PEC packets
    - N-K redundancy packets obtained by XOR-ing of information PEC packets
  - PEC packets contain a header, payload, and CRC
  - PEC decoder recovers dropped/erased information PEC packets with high probability

- **Common PEC Types:**
  - Low Density Parity Check (LDPC) codes
  - Fountain codes (Raptor/RaptorQ)



Alignment with MOSA Standards

Topic	S2G-OC (Vol. 1–2) Alignment	S2S-OC Alignment	PEC-OC Contribution
Atmospheric Fade Mitigation	S2G-OC Volume 2 provides analytical framework for fade statistics, ARQ performance, deep interleaving, and packet erasure coding (PEC).	S2S-OC guide defines SDA & OpenZR+ frameworks but lacks PEC guidance.	PEC-OC extends atmospheric-focused digital mitigation by providing a **standardized PEC solution tuned to slow fading.**
Digital Layer Techniques	S2G-OC identifies PEC as promising but not yet standardized; recommends PEC for future adoption.	S2S channels do not natively include PEC; ARQ is optional (SDA).	PEC-OC fills this gap with **Ethernet-to-Ethernet PEC encoder/decoder requirements**.
Integration with COTS Modems	S2G-OC emphasizes the need for “wrap-around” solutions (above PHY) to avoid ASIC refresh.	S2S systems cannot easily accept deep interleaving or FEC changes.	PEC-OC provides a **non-invasive, deployable** wrapper around COTS modems.
Network Stack Preservation	Stressed as essential in Volume 2 (Ethernet-in/Ethernet-out).	Same applies for S2S due to rigid PHY pipeline.	PEC-OC standard formalizes **stack-transparent PEC deployment.**

PEC-OC acts as the bridge between atmospheric-specific needs (S2G) and space-to-space (S2S)interoperability, by providing a common, higher-layer mitigation mechanism that both link types can adopt without hardware redesign.

Committee Responsibilities & Scope

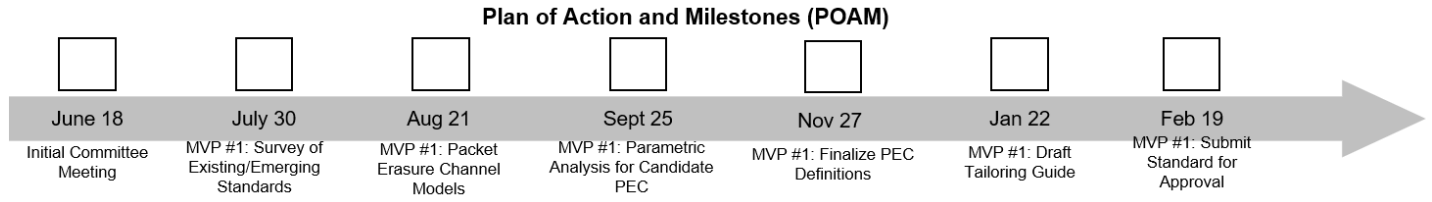
- **The PEC-OC Committee is responsible for:**
  - **Standards Landscape Analysis**
    Survey existing commercial and government PEC standards and recommend adoption, tailoring, or new development
  - **Packet Erasure Channel Modeling**
    Develop atmospheric fade models and synthesize packet erasure channels
  - **PEC Parameter Analysis**
    Define code rates, block sizes, packet sizes, and interleaving strategies
  - **Encapsulation Specification**
    Define Ethernet-In, Ethernet-Out "wrapper" to preserve network stack
  - **Standard Development**
    Draft PEC-OC standard documents meeting MOSA exit criteria

Applicable Existing Standards

Standard	Type	Key Features
CCSDS 131.5-O-1 (Ad-Hoc IRA LDPC Baseline)	• Quasi-Cyclic(QC) Ad-hoc IRA LDPC	• Fixed block sizes k = {512,2048,16384} and 3 code rates • Non-rate-compatible
CCSDS 131.5-O-1 (Flexible F-IRA LDPC Baseline)	• Flexible IRA LDPC	• Variable code parameters • Non-rate-compatible
ESTOL v3.1 (QC IRA LDPC)	• QC IRA LDPC	• Fixed block size n=3600 and 5 code rates • Non-rate-compatible
IETF RFC 5170 (LDPC)	• Block-based LDPC • Staircase / Triangle structures	• Configurable n <= 16000 • Flexible code rates • Non-rate-compatible
IETF RFC 6816 (LDPC for FLUTE)	• PRNG-constructed LDPC Staircase	• Configurable • k<=2^15 for ½ <= R < 1 • k<=2^14 for ¼ <= R < ½ • Non-rate-compatible
IETF RFC 5053 (Original Raptor)	• Legacy Fountain Code (Pre-coder + LT)	• Configurable 4<=k<= 8192 • Rateless
IETF RFC 6330 (RaptorQ)	• Advanced Fountain Code	• Configurable 6<=k<=56403 • Rateless
SMPTE 2022-5:2013	• 2D XOR Linear Block Code	• Configurable block size • Fixed code rate based on matrix dimensions

Development Roadmap

- The PEC-OC committee will develop the standard documents in 3 Minimum Viable Products (MVPs) over ~18 months
  - MVP #1 (6-8 months) – MOSA-IF-T-004 Vol 1
    - Standards landscape analysis
    - Packet erasure channel modeling
    - PEC parameter space analysis
    - Decision: Adopt, Tailor, or Develop New
  - MVP #2 (6 months) – MOSA-IF-T-004 Vol 2
    - Detailed performance evaluation
    - Refinement of PEC parameters
    - Latency & complexity analysis
  - MVP #3 (6 months) – MOSA-IF-T-004 Vol 3
    - Encapsulation specification (ECDU format)
    - Hybrid ARQ/PEC framework
    - Adaptive PEC framework



Current Status & Milestones

- **Where we are today:**
  - ✅ **Committee Established** (June 2026)
  - ✅ **Charter Approved** by SAC and voting members
  - ✅ **Participants Engaged** (13 organizations)
  - 🔄 **Currently:** Standards assessment and down-selection phase
- **Standards Evaluation Framework:**

Criterion	Key Considerations
Hardware Feasibility	Algorithm complexity, throughput, latency, memory footprint, parallelization
Erasure Correction Capability	Burst loss resilience, coding overhead, efficiency
Flexibility	Rate compatibility, adaptive coding, block size flexibility
Maturity/TRL	Flight heritage, proven implementations
Interoperability	Compatibility with other MOSA standards
End-to-End Feasibility	Source encode/sink decode practicality

- **Current Activity:**

  Committee members scoring standard candidates using weighted criteria for down-selection

Summary & Questions

- **Takeaways:**
  - ✅ MOSA Alliance's **newest committee** addressing critical gap in optical comms
  - ✅ **13 member organizations** actively engaged
  - ✅ **18-month roadmap** with 3 MVP deliverables
  - ✅ Currently in **standards down-selection phase**
  - ✅ Focused on **Ethernet-In, Ethernet-Out PEC** preserving network stack
  - ✅ Aligned with **S2G-OC and S2S-OC** MOSA standards

- **Key Benefits:**
  - **Modular Design:** PEC as pluggable component with standardized interfaces
  - **Vendor Neutral:** Multiple implementation options without modem redesign
  - **Technology Refresh:** Swap modems while keeping PEC layer constant
  - **Interoperability:** Common approach across atmospheric S2G/G2S links
  - **Reliability**: Improves optical link reliability