Quantum Datagram Control Protocol (QDCP) for IP Optical Environments

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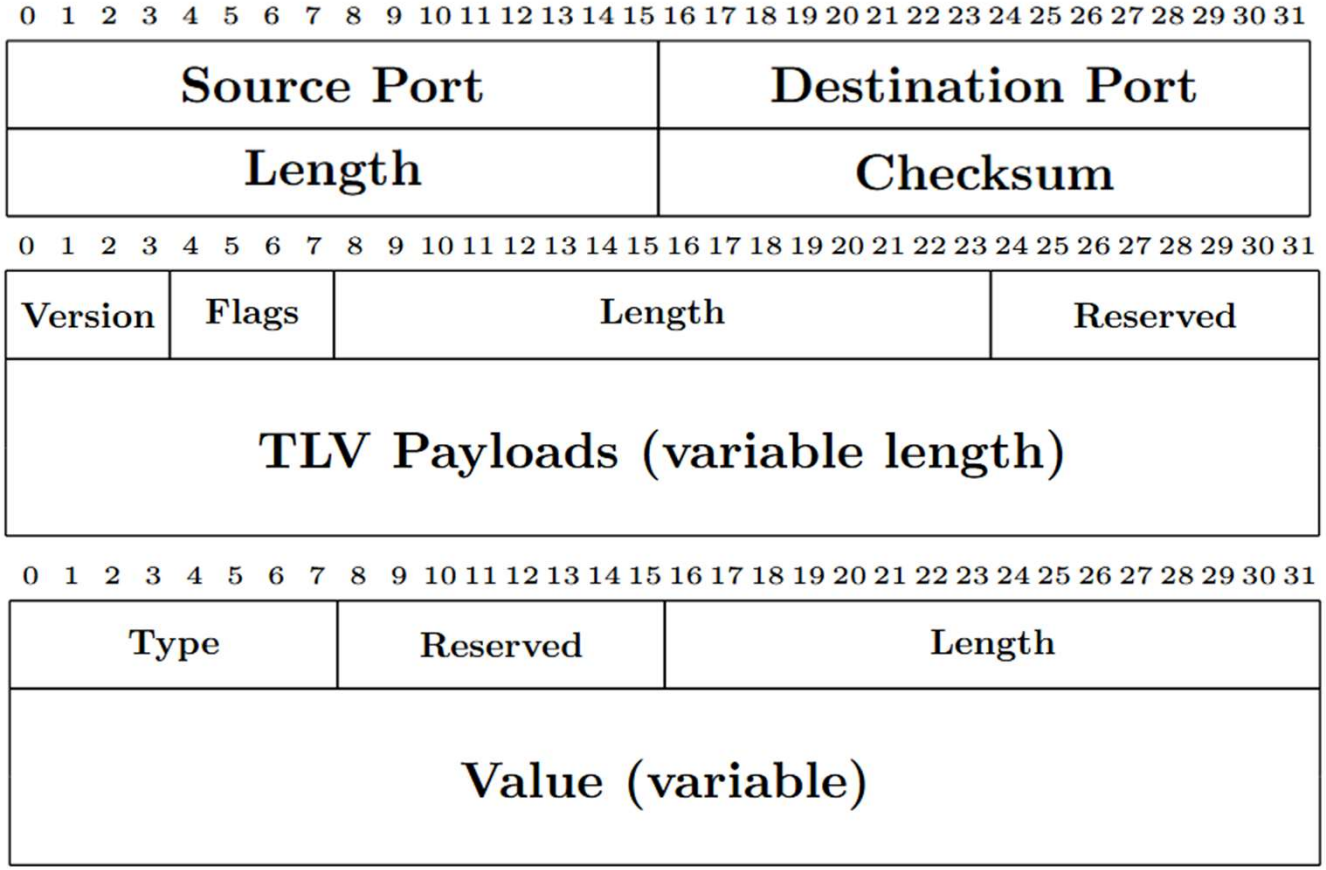
Why a “Quantum Datagram”?

- No Cloning -> Quantum information cannot be copied or retransmitted
- QDCP: Lightweight control metadata for quantum packets
- Current experiments demonstrate hybrid quantum-classical packet routing on commercial fiber (*Zhang et. al, 2025 Science).*

QDCP Packet Design



Standard UDP Header

Figure 1: QDCP Packet Header and TLV Payloads

Figure 2: TLV Format for QDCP Control Fields

Current TLV Type Assignments

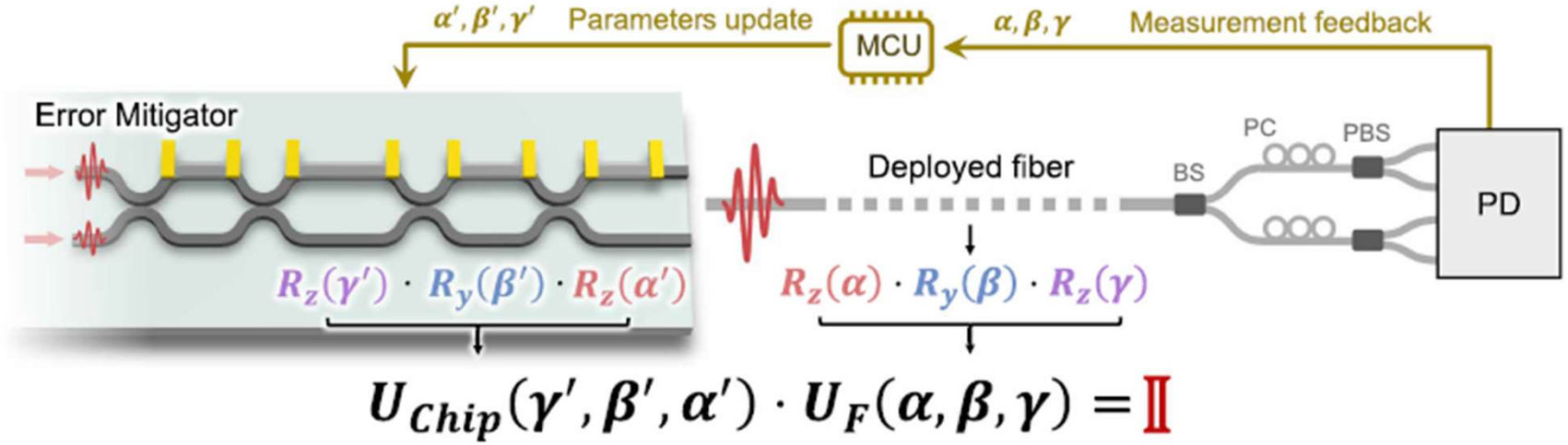
Type	Name	Value Format
0x01	Quantum Protocol	32-bit int (e.g., encoding)
0x02	Polarization State	32-bit float
0x03	Timestamp of Origination	128-bit int (ps)
0x04	ROADM Output Port ID	32-bit int
0x05	Quantum Packet Delay	128-bit int (ps)
0x06	Duration of quantum information	128-bit int (ps)
0x07	Center Frequency (GHz)	32-bit float
0x08	Optical Linewidth (GHz)	32-bit float
0x09	Polarization Correction	32-bit Variable Polarization

Figure 3: Initial TLV Type Assignments for QDCP

Example TLV Structure: Polarization Correction

Problem: Long distance fibers can change light polarization

Solution: Use classical light to identify this change and correct for it



Polarization Correction (cont.)

- Use Reserved TLV bits to specify sent polarizations
- Send 8 bytes of each polarization, GREASE the rest
- Length fixed at 32 bits

Bit	Polarization
0	Horizontal
1	Vertical
2	Diagonal
3	Anti-Diagonal
4	Right-Circular
5	Left-Circular

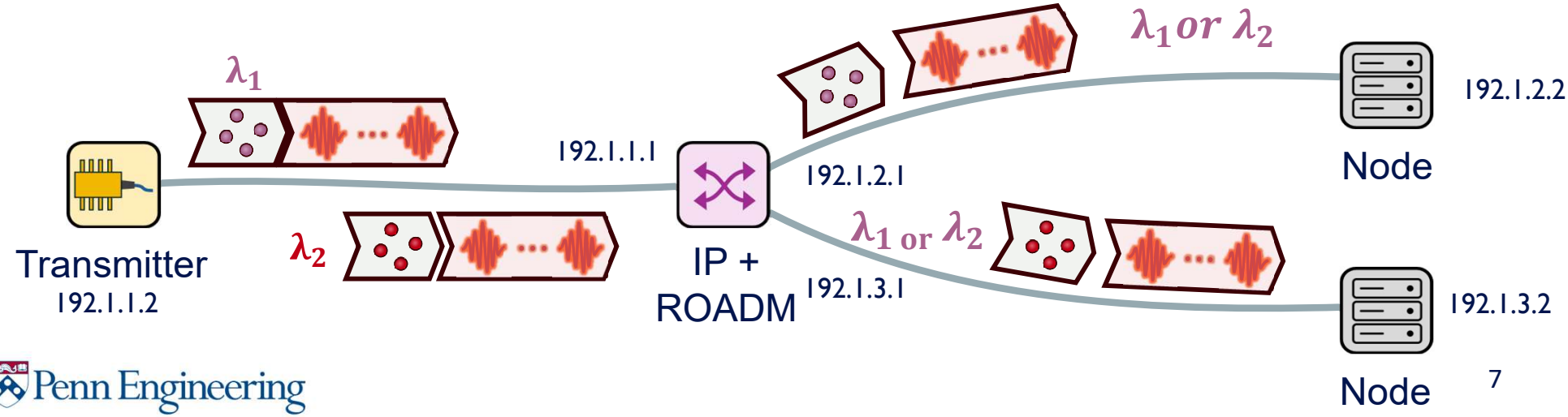
Figure 4: Polarization to Reserved Bit Mappings

0 1 2 3 4 5 6 7	8 9 10 11 12 13 14 15	16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31	
Type = 0x09	**Polarizations e.g. 00010001**	**Length = 0x20 (32 in Hex)**	
Right-Circular	**Horizontal**	**GREASE**	**GREASE**

Figure 5: Example TLV For Polarization Correction

Full Use Case Example – IPv4 Class C Network

Step 1	Step 2	Step 3	Step 4	Step 5
TLV 0x04: ROADM Configuration	TLV 0x06: Duration of Quantum Information	TLV 0x05: Quantum Packet Delay	TLV 0x09: Polarization Correction	Send Quantum Information



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Security Concerns

- QDCP inherits the risks of UDP:
  - spoofing, injection, replay
  - It MUST be run in trusted environments or protected by DTLS/IPsec
  - TLVs may reveal network state information and MUST be protected if confidentiality is required
- Future work on compatibility with TCP or QUIC

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Thank you!

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