Quantum Burst Communication: A Redundant, Modular Approach to Short-Term Entangled State Messaging

Author: Brandon Foley

Abstract

We propose a novel quantum communication architecture based on short-lived, pre-entangled particle clusters that are transmitted in rapid bursts and captured through synchronized, localized measurement systems. Unlike traditional methods that rely on long coherence times and fragile entanglement preservation, this approach embraces decoherence and noise by leveraging statistical redundancy. Each message unit (e.g., a letter) is represented by a cluster encoding, which is sent multiple times in quick succession. Local tomography or projection-based measurement reconstructs the statistically dominant signal, confirming the intended message fragment. This system significantly reduces the need for ultra-high-purity materials, long-duration coherence, or complex environmental control, and instead prioritizes modularity, fault tolerance, and scalability. We present a minimal viable lab-scale design using existing quantum optics technology and outline the potential for real-time, burst-based entangled messaging systems.

1. Introduction

Quantum communication is limited by the fragility of entanglement and the short coherence times of quantum systems. Traditional architectures focus on preserving entangled states over long distances or durations, often requiring extreme isolation, cryogenic cooling, or advanced quantum memories. This paper proposes an alternative model inspired by modular, redundant, and distributed systems: a short-term burst communication protocol using entangled particle clusters that are pre-shared, quickly measured, and statistically validated.

2. System Architecture

The core of this system is a burst-based transmission model where each message character (e.g., a letter) is encoded as a specific cluster of entangled particles. These clusters are sent rapidly—hundreds to thousands of copies over a few seconds. At the receiving end, synchronized measurement devices (termed quantum cameras) perform partial tomography or targeted measurements to determine the most statistically likely message segment.

Each transmission event is short-lived, with coherence time requirements of milliseconds to seconds, greatly reducing the material burden on quantum hardware. Instead of requiring a single long-lived entangled state, the message is reconstructed from repeated, short-lived, redundant events.

Figure 1: Concept schematic of a burst-based entangled cluster communication system. Each burst represents a short-lived cluster encoding a single character, measured and reconstructed locally. (Diagram not shown here.)

3. Burst Mechanics and Statistical Confidence

For each letter in the message, a burst containing N = 1000 identical entangled particle clusters is transmitted within a short time window (typically 0.5–2 seconds). Local measurement systems detect incoming particles and compare outcomes against a predefined state basis. Once the system reaches a statistical threshold (e.g., 90% of clusters align with the intended encoding), the character is logged and transmission advances to the next burst. This structure builds inherent error tolerance and eliminates the need for prolonged coherence or perfect entanglement.

4. Measurement and Detection

Measurement at the receiver involves rapid, repeated reads of incoming entangled states using photon detectors and basic quantum tomography or projection-based analysis. Rather than decoding a single event, the system aggregates results across the entire burst to build statistical confidence. This enables robust performance even with imperfect equipment or partial decoherence.

5. Experimental Feasibility and Use-Case Scenario

This system can be prototyped using tabletop quantum optics equipment. Entangled photons can be generated via spontaneous parametric down-conversion (SPDC), directed through beam splitters and optical fibers, and captured using polarizing beam splitters and single-photon detectors (e.g., SNSPDs or avalanche photodiodes).

A short message like 'HEY' can be encoded using three distinct cluster types, each burst containing 1000 repetitions of its assigned quantum state. Detectors register outcomes over a 1–2 second window per letter, and a lightweight classical processor confirms each symbol before moving on. This setup would validate the feasibility of burst-based quantum messaging with current or near-term tools.

6. Benefits and Outlook

This architecture offers an alternative to long-term entanglement preservation by treating decoherence as a manageable variable rather than a flaw. It scales naturally, supports fault tolerance, and aligns well with real-world communication principles like redundancy and modular encoding. Future developments may incorporate entangled memory arrays, satellite bursts, and adaptive route selection for long-distance synchronization.

7. Conclusion

We introduce a practical, modular quantum communication protocol based on short-lived entangled clusters and burst-based transmission. By synchronizing local measurements and interpreting statistical patterns, the system achieves reliable message reconstruction without the need for perfect coherence or large-scale entanglement. This proposal presents a viable pathway toward scalable quantum messaging systems with near-term technological feasibility.