

Entanglement-Assisted Data Transmission as an Enabling Technology: A Link-Layer Perspective

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Entanglement for data transmission

- In current networks, physical layer secrecy can violate the end-to-end principle
- Entanglement-assisted data transmission is a compromise:
- It does not violate the end-to-end principle, but is harder to implement
- Promises dramatic increase in bandwidth. Only local entanglement distribution.

Impact on the network

Link layer:

- Generates entanglement between adjacent links whenever idle
- Stores entanglement whenever the buffer is not full
- Transmits data with entanglement assistance whenever possible
- Calculates frequent bandwidth updates

Network layer:

- Will need to handle varying bandwidth of a link
- Link state packets might need to be sent more frequently

Benefits:

- Increased average bandwidth
- Decrease in number of dropped packets
- Easy to integrate: Direct impact only on layers one and two

Analytical modeling and results

Buffered Entanglement Assisted Message Queue

The parameters for such a queue are $\mathfrak{J} = (G, C, L, t_A, t_N, r, \lambda, \tau)$ where:

- 1 A classical buffer at the sender, $\mathbf{S}_B := \{1, \dots, L\}$.
- 2 The entanglement buffer $\mathbf{S}_E := \mathbb{N}$ at sender and receiver.
- 3 The job arrival indicator $\mathbf{S}_A := \{0, 1\}$.
- 4 The total amount of transmitted data $\mathbf{S}_T := \mathbb{N}$.
- 5 The active job register $\mathbf{S}_J := \{0, A, N\}$.
- 6 The total number of dropped jobs $\mathbf{S}_D := \mathbb{N}$.

A state of the system is a tuple $s = (a, b, d, e, j, t)$. It is an element of $\mathbf{S}_A \times \mathbf{S}_B \times \mathbf{S}_D \times \mathbf{S}_E \times \mathbf{S}_J \times \mathbf{S}_T$. The transition matrix is

$$T(s'|s) := (1 - \lambda) \left((1 - r) \cdot T_0(s'|s) + r \cdot T_1(s'|s) \right) + \lambda \left((1 - r) \cdot (E \circ T_0)(s'|s) + r \cdot (E \circ T_1)(s'|s) \right). \quad (1)$$

Throughput T and job rejection rate R

T and R are with high probability described by T, R defined via

$$T(\mathfrak{J}) := r \cdot L \cdot (1 + r \cdot (D(\mathfrak{J}) - 1))^{-1}, \quad (2)$$

$$R(\mathfrak{J}) := r \cdot (D(\mathfrak{J}) - 1) \cdot (1 + r \cdot (D(\mathfrak{J}) - 1))^{-1} \quad (3)$$

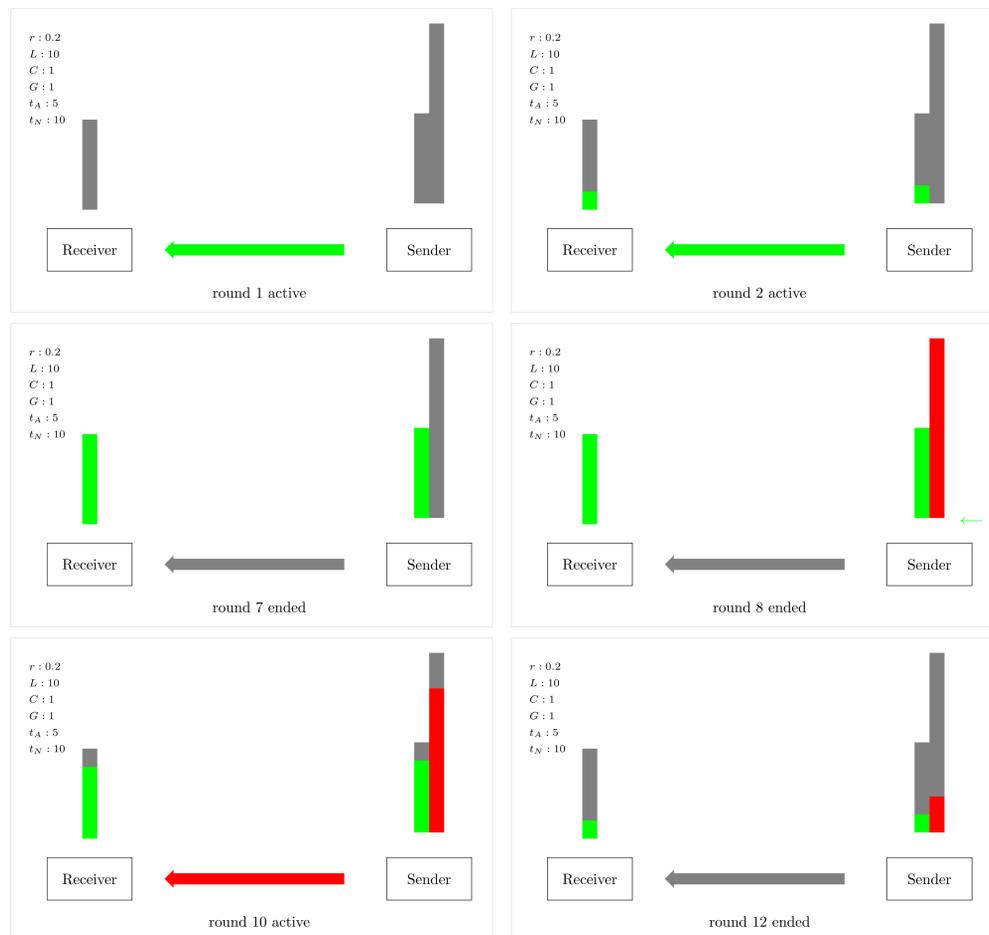
where the average job duration is described by

$$D(\mathfrak{J}) := \theta \cdot t_A + (1 - \theta) \cdot t_N, \quad (4)$$

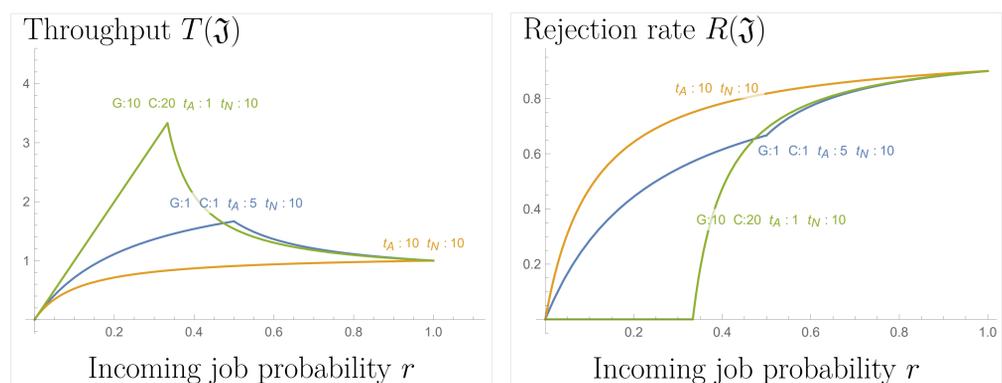
$$\theta := \begin{cases} \theta', & \theta' \leq 1, \\ 1, & \text{otherwise,} \end{cases} \quad (5)$$

$$\theta' := \frac{1-r}{r} \cdot (G + \lambda\tau) + t_N \cdot \lambda\tau \cdot (C + \lambda\tau(t_N - t_A))^{-1}. \quad (6)$$

Design principle: "Generate entanglement when idle"



Key metrics show phase transitions



References

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This work was funded by the DFG via grant NO 1129/2-1