Sub-exponential Rate versus Distance with Time Multiplexed Quantum Repeaters

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Main Results

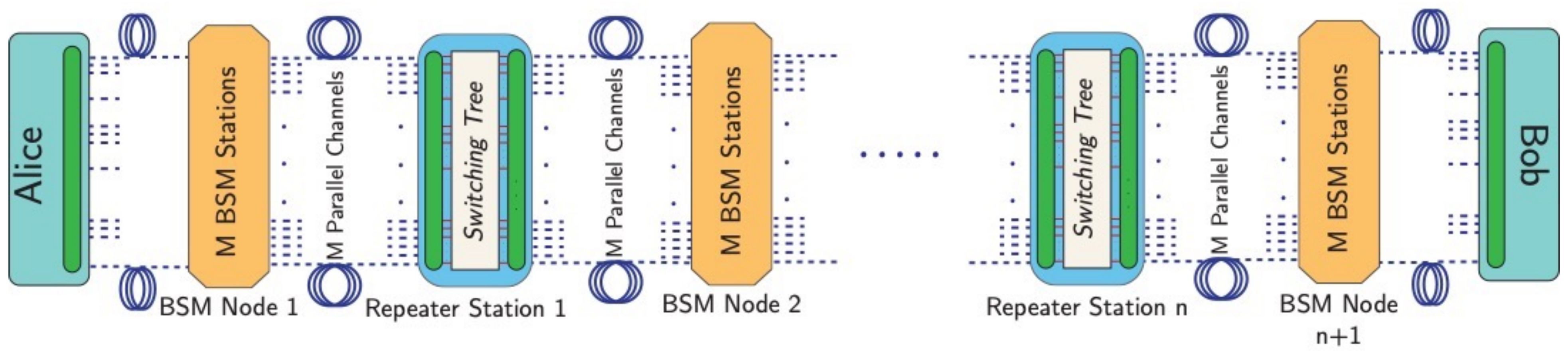
- We calculate the analytic performance for an improved form of multiplexing i.e. **temporal multiplexing**.

- With general QRs, multiple [3,4] demonstrate a rate-vs.-distance scaling of
$$R \sim \exp(-s\alpha L)\,;\, s \in (0,1)$$
as compared to repeaterless rate of $R \sim \exp(-\alpha L)$ [1].

- With temporal multiplexing, we demonstrate rate-vs.-distance scaling of
$$R \sim \exp(-t\sqrt{\alpha L})\,;\, t \in (0,1)$$

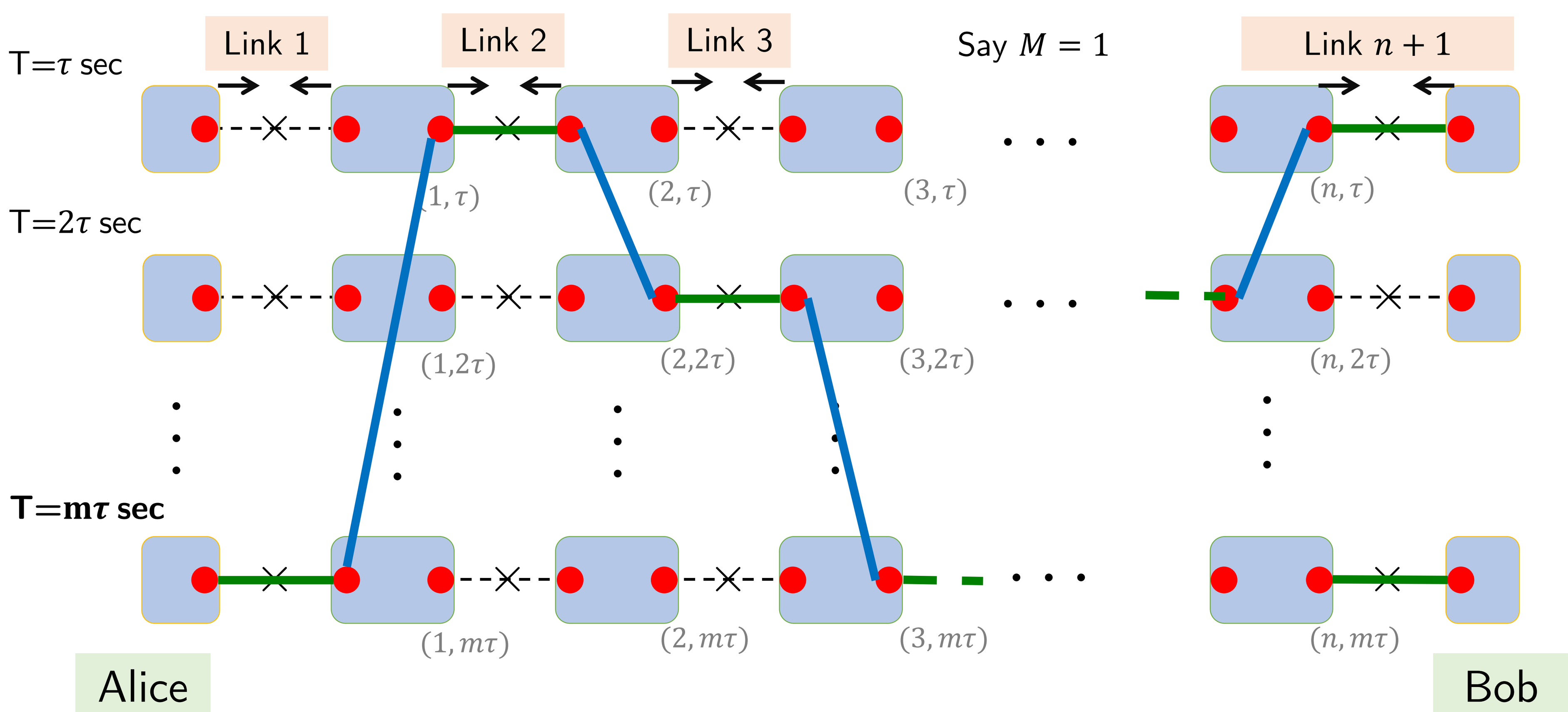
- Sub-exponential advantage is shown to be sensitive to device non-idealities and quantum memory decoherence.

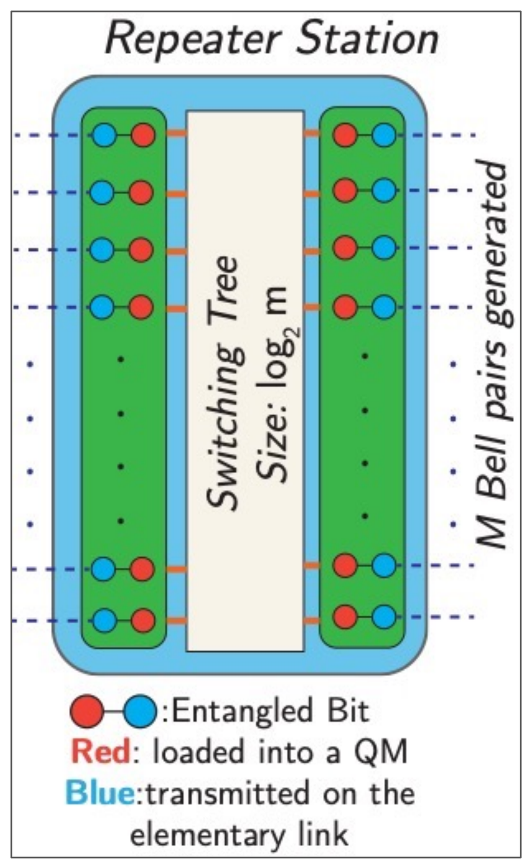
Repeater Protocol Design



L: Length of channel
n: No. of repeaters
α: Fiber loss (dB/km)

M: Spatial multiplexing order
m: Time multiplexing order
τ: Source repetition time





Sub-exponential Rate Scaling: Discussion

- The end-to-end entanglement generation rate, in terms of n and m is therefore given by:
$$R_{m,n}(L) = \left[\left(1-\left(1-\mu e^{-\frac{\alpha L}{n+1}}\right)^{Mm}\right)^{n+1} \times q^{n}\right] / (m\tau) \text{ ebits/mode.}$$

- We determine tight upper and lower bound to the rate envelope in Thm. 1 of the main manuscript [2], each showing the same aforesaid scaling.

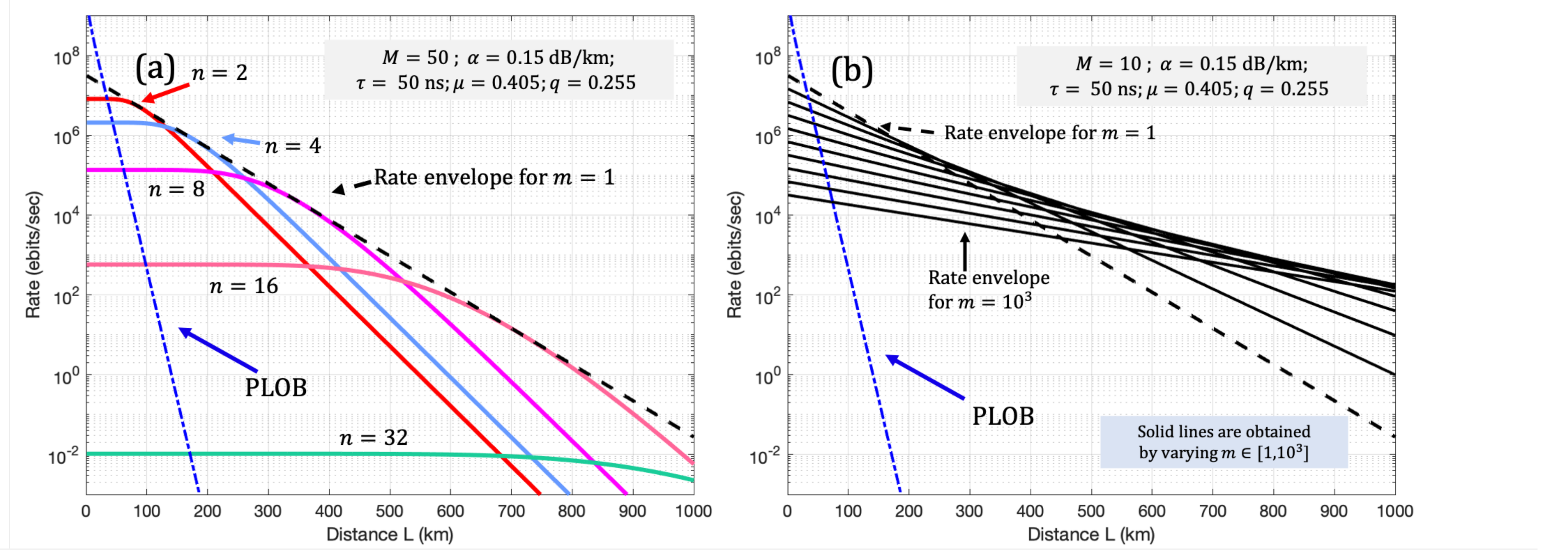


Fig. 1 – (a) Exponential rate-distance envelope (black dashed line) for a purely spatially multiplexed (m = 1) architecture with increasing number of repeaters in the chain (various coloured lines; value of n marked). (b) Rate-distance envelopes for increas ing values of m (black lines), with n optimized at any given L.

- Consideration of switching loss and quantum memory decoherence shows degradation in sub-exponential advantage. Thms. 2 and 3 of [2] describe exact details. Overall qualitative behavior is shown in Fig. 2.

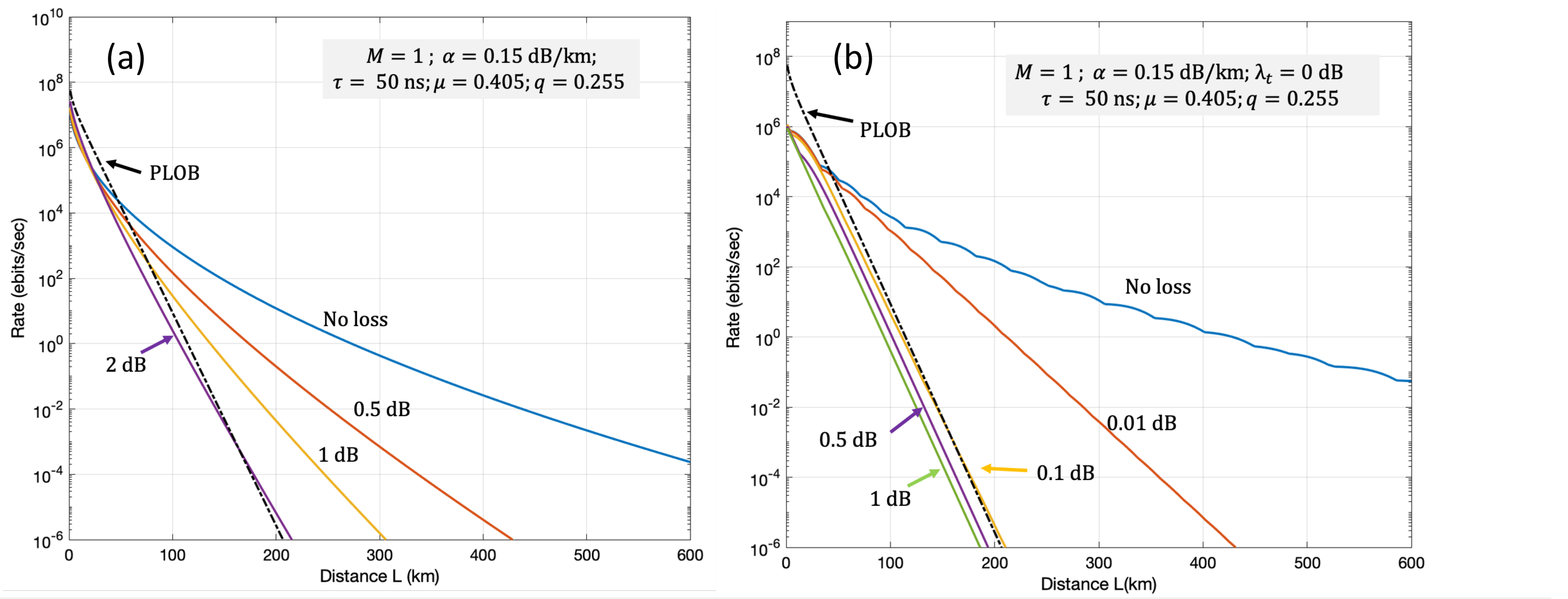


Fig. 2 – Effect of (a) switching loss and (b) quantum memory decoherence on protocol rate-vs.-distance scaling performance

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[4] M. Razavi et. al. Phys. Rev. A, 80(3):032301, September 2009.