Wireless Access to Quantum Networks

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Despite the recent progress in quantum key distribution (QKD) systems, QKD needs to be made more conveniently available to the end users of communications networks. In this work, we address *wireless* access to hybrid quantum-classical networks; see Fig. 1. This work resemble a quantum Li-Fi system, possibly, in parallel with a classical Li-Fi, that enables end users to exchange secret keys with other network users in a convenient way. We first assess the feasibility of wireless QKD in indoor environments [1], [2]. Then, we consider hybrid links, with or without a trusted/untrusted relay point, between a wireless end user and the corresponding central office in an access network [3], [4]. This is done by adopting wireless indoor QKD links and embedding them into fiber based passive optical networks. By considering the effect of various sources of noise, different setups for embedding wireless indoor QKD links into quantum-classical access networks are investigated [3], [4]. The proposed schemes could provide the first link within a larger quantum network or facilitate the use of QKD in common areas for many users.

In our analysis, we account for the Raman noise in hybrid networks as well as the background noise in wireless setups. Figure 2 shows how different sources of noise contribute to the total background noise in the system. In this figure, setup 1 refers to a configuration where a trusted relay node is available in the room. Setup 2 replaces the QKD receiver on the ceiling with a collection element with dynamic alignment, and, this way, directly connects the wireless user to the central office. This setup must then tolerate a certain amount of coupling loss. Setups 3 and 4 rely on measurement-device-independent QKD, where in setup 3 the Bell-state measurement is done in the room, where in setup 4, that would be done at the splitting point. Our results highlight the importance of these new sources of noise in hybrid wireless networks as they both are typically higher than the dark count rate in a typical fiber-based QKD system.

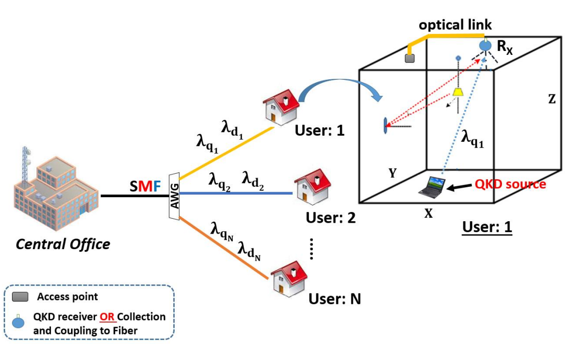

Fig. 1. Schematic view of exchanging secret keys between an indoor wireless user with a central office at the end of an access network.

Despite the challenges of background, Raman noise, and path loss, our results show that there would exist a practical

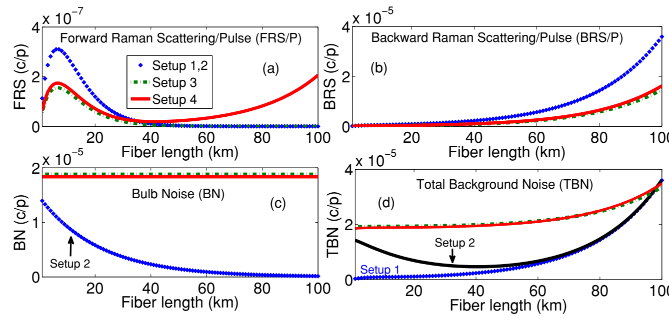

Fig. 2. Noise counts due to (a) forward Raman scattering, (b) backward Raman scattering, (c) the artificial lighting source at 10^{-5} W/nm of power spectral density, and (d) the total background noise at 10 dB coupling loss.

regime of operation within which such a wireless QKD system could generate secret keys in indoor environments [1], [2], [3], [4]. We show that with proper beam alignment it is possible, in both discrete-variable (DV) and continuous-variable (CV) QKD, to achieve positive key rates for both trusted and untrusted relay points in certain indoor environments; see Fig. 3. Our analysis can identify the winner in realistic setups, where background noise from the environment as well as the Raman noise in the fiber are both taken into account. This promises high-rate wireless access to future quantum networks.

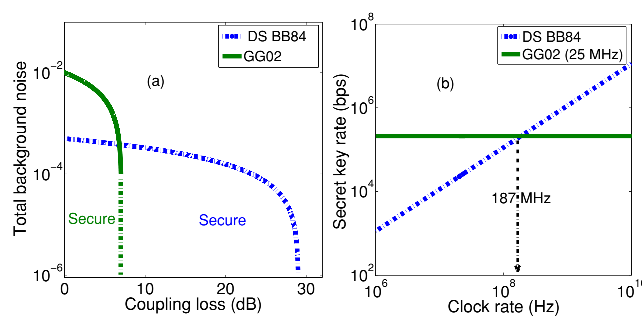

Fig. 3. (a) Regions of secure operation for decoy-state BB84 and GG02 protocols in setup 2. The curves show the maximum tolerable background noise at different values of coupling loss. (b) Comparison of the two systems when the CV repetition rate is fixed to 25 MHz at 5 dB coupling loss.

References

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