Proposal for a Wavelength Multiplexed Quantum Metropolitan Area Network
A. Ciurana¹, J. Martinez-Mateo¹, N. Walenta², H. Zbinden², M. Peev³, A. Poppe³, and V. Martin¹

¹ Research Group on Quantum Information and Computation, Universidad Politécnica de Madrid, Spain
² Group of Applied Physics, Université de Genève, Switzerland
³ Optical Quantum Technology, Austrian Institute of Technology, Austria

Quantum Key Distribution (QKD) is maturing quickly. However, the current approaches to its network use require conditions that make it an expensive technology. All the QKD networks deployed to date are designed as a collection of dedicated point-to-point links that use the trusted repeater paradigm. Instead, we propose a novel network model in which QKD systems use simultaneously quantum and conventional signals that are wavelength multiplexed over a common communication infrastructure. Signals are transmitted end-to-end within a metropolitan area using optical components. The model resembles a commercial telecom network and takes advantage of existing components, thus allowing for a cost-effective and reliable deployment.

Network Design
The design is an optical metropolitan area network [1] where quantum and conventional signals are wavelength multiplexed (WDM). QKD systems are located at the final users and any device capable of disrupting the quantum signals has been removed. Therefore, QKD systems are connected via direct optical paths. The network is divided into backbone (core) and access networks.

Dense WDM technology (DWDM).
Coarse WDM technology (CWDM).

Ring topology.
Star topology.

Traffic between access networks.
Traffic between QKD systems and the backbone network.

• Optical Add-Drop Multiplexers (OADM).
• Arrayed Waveguide Grating multiplexers (AWG).
• (Optional) Switches before the AWG to use QKD systems.

Based on the described network model and WDM grid, the network works under the wavelength-addressing paradigm: a QKD emitter can communicate with a QKD receiver by emitting at its assigned channels. However, the network is limited to a fixed communication scheme where QKD systems can only communicate with the ones connected to the same port of the AWG (periodical ones). If a more flexible, dynamic scheme is required, switches can be used before the AWG in order to connect the QKD emitter to the appropriate port of the AWG and thus be able to communicate with any QKD receiver.

The scheme is non-blocking since communications in both directions can be performed simultaneously between different access networks. This is illustrated in the network figure using colored dots to represent the communications.

Operating mode
Based on the described model and WDM grid, the network works under the wavelength-addressing paradigm: a QKD emitter can communicate with a QKD receiver by emitting at its assigned channels. However, the network is limited to a fixed communication scheme where QKD systems can only communicate with the ones connected to the same port of the AWG (periodical ones). If a more flexible, dynamic scheme is required, switches can be used before the AWG in order to connect the QKD emitter to the appropriate port of the AWG and thus be able to communicate with any QKD receiver.

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Test-bed
A test-bed of the proposed network has been deployed using 100 GHz 32-channel AWGs and self-made CWDM OADMs. The longest optical path (16 km) is between access network #2 and access network #3, and it has a loss budget of 20 dB.

After successfully checking its operation, measurements were done to characterize the noise contribution of the conventional signals. For this task, the longest path was used: a powerful emitter at the access network #2 and a single-photon detector (SPD) at the access network #3 (forward noise) and #2 (backward noise).

Experimental results
The figure shows the noise detection probability per 1 ns gate at the SPD over the total power emitted, an estimated quantum signal and the own noise of a SPD [3]. Using these parameters, we calculate the QBER for significant points of the curves (white boxes).

- The noise is indeed reduced with the spectrum separation (red curve vs blue curve).
- The backward noise is higher due to the losses of the scenario. However, it can be solved using filters at the access network and isolators at the OADMs.
- In this test-bed, based on the QBER, a total of 20+2 dBm power is allowed. This is enough for 32 conventional channels at − 13 dBm of 1 Gbps rate [4].

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References