A Novel Concept of Entanglement Distribution in Optical Networks

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A major road-block in bringing QKD to the market is the missing scalability of a single QKD-link connecting two users to a use-case with many users in the same metropolitan area network (MAN). The typical trusted node concept [1] used for this, beyond requiring the trust on all intermediate nodes, is not able to distribute entanglement without the help of quantum manipulations that have yet to be demonstrated. Here we extend the concept of entanglement to many pairs of users by the introduction of novel structures [2]. The goal of this work is the design of a MAN for quantum and co-propagating classical signals to allow an arbitrarily high number of users not bounded by e.g. the number of CWDM or DWDM channels in the ITU grid. The number of coexistent multiplexed links is clearly limited by this usable fibre bandwidth, but the network must be able to select the corresponding user out of a large pool of possible communication partners (as in mobile phone networks).

The use of standard wavelength-division multiplexing equipment together with broadband sources of entangled photon-pairs opens the possibility of entanglement distribution to multiple users in a MAN in a convenient way [2-3]. A complete network design with a fixed wavelength plan is shown in Fig. 1. This is a typical design of a metropolitan optical network of tree-type access networks connected through a ring where entangled photon-pairs are distributed to any pair of users, independently of their location. Each passive network node (OADM) hosts photon-pairs sources with different central wavelength matched to the wavelength plan. The network is built out of off-the-shelf components and uses the existing infrastructure, allowing for moderate deployment costs.

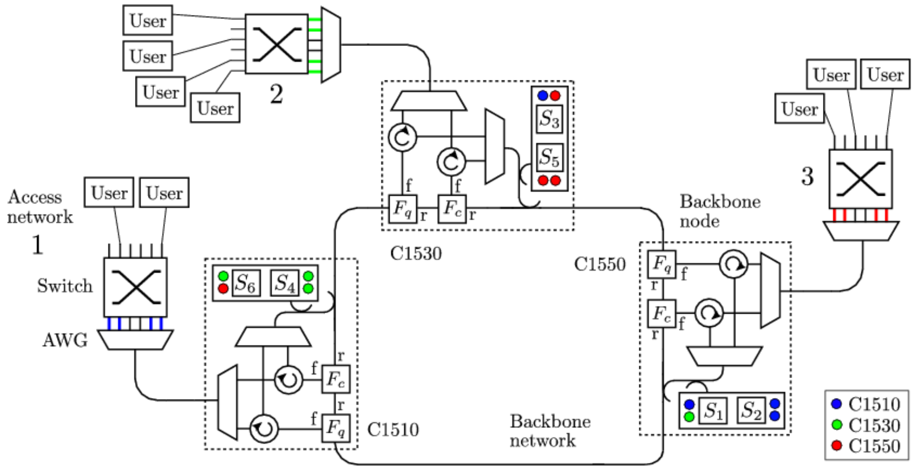

Fig. 1 Typical MAN with a backbone ring and access trees adapted for a QKD network. A CDWM-band is assigned to each ring node (dotted boxes) and all quantum and classical signals are passively routed by the drop-filters F. The sources of entangled photons S are located in the nodes and generate pairs matched to the user requests.

This design is limited to 3 access networks with current quantum technology (approx. 48 simultaneous users). With switches and other existing telecom equipment we can upscale the number of possible users to above 500.

We further developed other designs with increased complexity including a channel plan and a network-architecture design to provide a direct optical path between any pair of users, thus allowing classical and one-way quantum communication as well as entanglement distribution. This allows the simultaneous operation of multiple quantum information technologies. Including optical switches also in the node modules, even more flexible backbone architectures are feasible, pushing away the load limitations of the original network design by extending its reach, number of users and capabilities.

These conceptual network designs call for an experimental realization with the challenges to design broadband sources of entangled photon pairs with tailored central wavelengths. The cost efficient and, at the same time, minimal loss designs of the corresponding nodes for a highly scalable solution, together with the corresponding prototypes and field tests are the topics of current research.

References

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