Satellite based QKD: Digital Mission Planning

qtlabs
Quantum Technology Laboratories

Satellite-based QKD: Digital Mission Planning Software Tools

Here we present our current status (and vision) for a complete digital mission planning software for satellite-based QKD systems. Our tool currently consists of three main parts: Mission Design, Link Budget Simulation, and Finite Secure Key Simulations for different QKD protocols such as BB84-Decoy, BBM92-SPDC, and Twin-Field MDI-QKD. Our results show that a worldwide operation using a trusted-node-based LEO constellation delivers secure key rates of up to 1 Mbit/sec under reasonable assumptions. For trusted-node-free QKD networks covering the EU-27 countries employing either the BBM92-SPDC or Twin-Field MDI-QKD protocols, secure key rates of approx. 1 kbit/sec are expected.

Part of this work was performed in cooperation with the European space agency (ESA), contract number 4000128302/19/UK/AB.

Mission Design

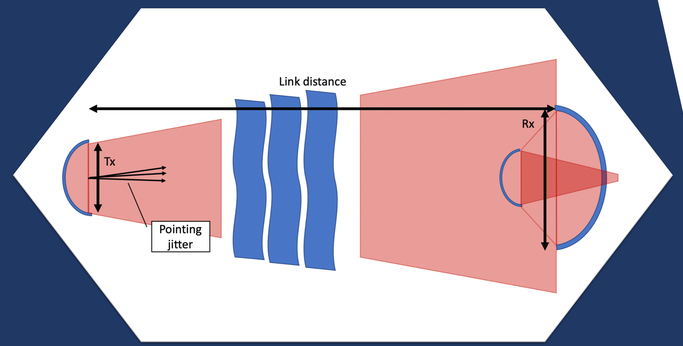
Network Topology
Trusted node based/free

Geographical locations
e.g. Lisbon ↔ Helsinki: 3500km

Orbital Constellation
LEO, MEO, GEO, # of satellites

The workflow of our simulation tool follows the user requirements, such as the network topology (trusted node based/free), the geographical locations of the users, or the required secure key rate per year, for example. Under these user-defined restrictions, we can choose an optimal satellite constellation regarding orbital height (LEO, MEO, GEO) and the number of satellites to optimize the geographical coverage.

Link Budget Simulation



Atmospherical Link Conditions
Cloud-coverage, turbulence, etc.

Optical Ground Station
Telescope diameter, beam pointing/ tracking errors

Satellite
sending telescope diameter, pointing jitter

The highest impact on the final secure key rate for QKD systems stems from the loss experienced by the photons. Hence, it is of utmost importance to find the optimal balance between low loss and low cost. Our "Link Budget Simulation" can include the sizes of the respective sending and receiving telescope, the tracking inaccuracies, atmospheric turbulence, wavefront errors as well as cloud coverage, among other essential properties.

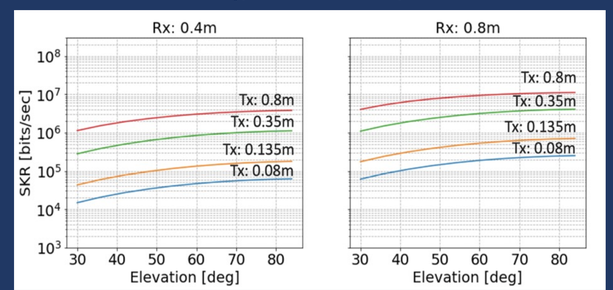
Finite Secure Key Simulations

QKD Protocol
BB84-Decoy, BBM92-SPDC, TF-MDI

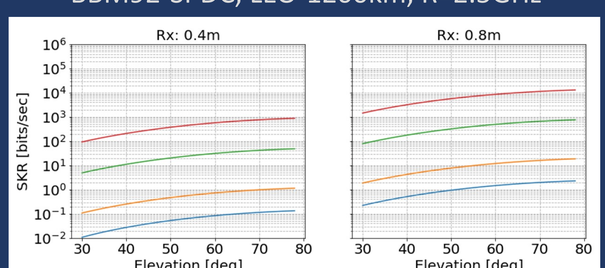
Satellite
Source parameters

Post-Processing
Finite-size net secure key rate

BB84-Decoy, LEO-500km, R=1GHz



BBM92-SPDC, LEO-1200km, R=2.5GHz



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