Budapesti University of Technology and Economics
Faculty of Electrical Engineering and Informatics

# Quantum Communication Research at the Budapest University of Technology and Economics

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vice-dean for international affairs

# Quantum Technologies

- It is based on the laws of quantum mechanics
  - Wave particle duality
  - Uncertainty principle
  - The impossibility of quantum cloning
  - Quantum entanglement

**Computing**

- Quantum states of matter are used to store and compute information
- Fast quantum algorithms
- Modeling, code breaking

**Communication**

- It uses the principles of quantum mechanics to transfer and communicate information
- Secure data transfer
- Quantum internet

**Sensing**

- It senses small changes in the electromagnetic field
- Good sensitivity
- Positioning, navigation, lidar and radar

# Quantum Communication

- Uses the principles of quantum mechanics to create unbreakable, extremely secure communication channels.
  - **Quantum Key Distribution (QKD)**: create a shared key between two parties without the third party knowing anything about that key, even if the third party intercepts all communications between the other two parties.
    - Fiber-based, point-to-point QKD links are available
  - **Quantum Random Number Generation (QRNG):** Perfectly random number sequences based on quantum mechanical phenomena
    - QRNG devices (chips!) are available
  - Quantum internet
    - Under research

# BME: Leader of the quantum communications in Hungary

- Who are we?
  - Department of Networked Systems and Services @ Faculty of Electrical Engineering and Informatics, Budapest University of Technology and Economics
- Interest:
  - Quantum information theory, quantum internet
  - Quantum optimization
  - Quantum Key Distribution, QKD (fiber and free space)
  - Quantum Random Number Generation, QRNG
  - Beyond QKD
  - (Post quantum crypto)

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MCL
Mobile Communications & Quantum Technologies Lab.

# Quantum Communication Research Group

# Quantum Communication Activities in Budapest University of Technology and Economics

**Fibre-based**

- Own-developed systems
  - DV-QKD
  - CV-QKD
- QKD device qualifying measurement
- Integration of quantum and classical communication networks
- Own-developed QRNG
- New bit generation methods

**Free space and space**

- Optical background radiation measurement
- Quantum Communication Capable Optical Ground Station
- Own-developed Entanglement-based free-space QKD
- FSO synchronization channel
- Satellite systems

**Quantum Internet**

- Quantum repeaters
- Quantum memory

# Fiber-based

- BB84 QKD demonstration with own developed system (in cooperation with Ericsson Hungary)
- CV QKD long distance demonstration with own developed system as part of the national QKD network (in cooperation with Hungarian Telekom and Wigner Research Centre for Physics)
- Quantum channels in classical networks: QuantumGigalink (in cooperation with Hungarian Telekom)
- Own-developed Optical Quantum Random Number Generator
- Entanglement-based QKD system
- Beyond QKD: Developing entanglement-based medium access control; focusing on quantum internet
- Participation in the European Quantum Communication Infrastructure (QCIHungary)

# Free space and space

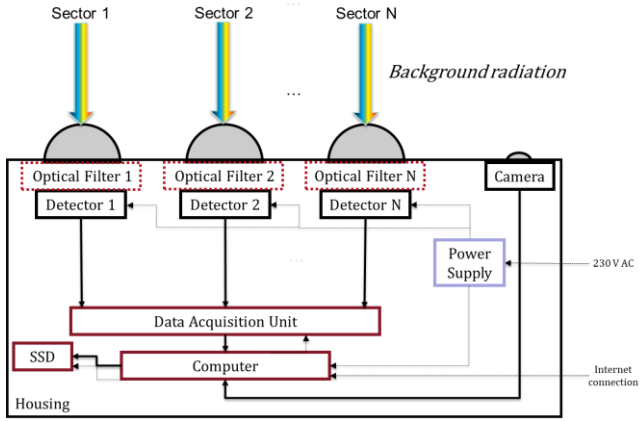
- Entanglement-based free-space QKD over the River Danube (in cooperation with Vodafone Hungary)
- Participating in two ESA projects (QuStation, Certain) (in cooperation with ATL, Relcom)
- Investigating the possibilities for CubeSat-based QKD
- Investigating the possibilities for quantum-capable optical ground stations
- Theoretical work on future satellite-based quantum communication systems

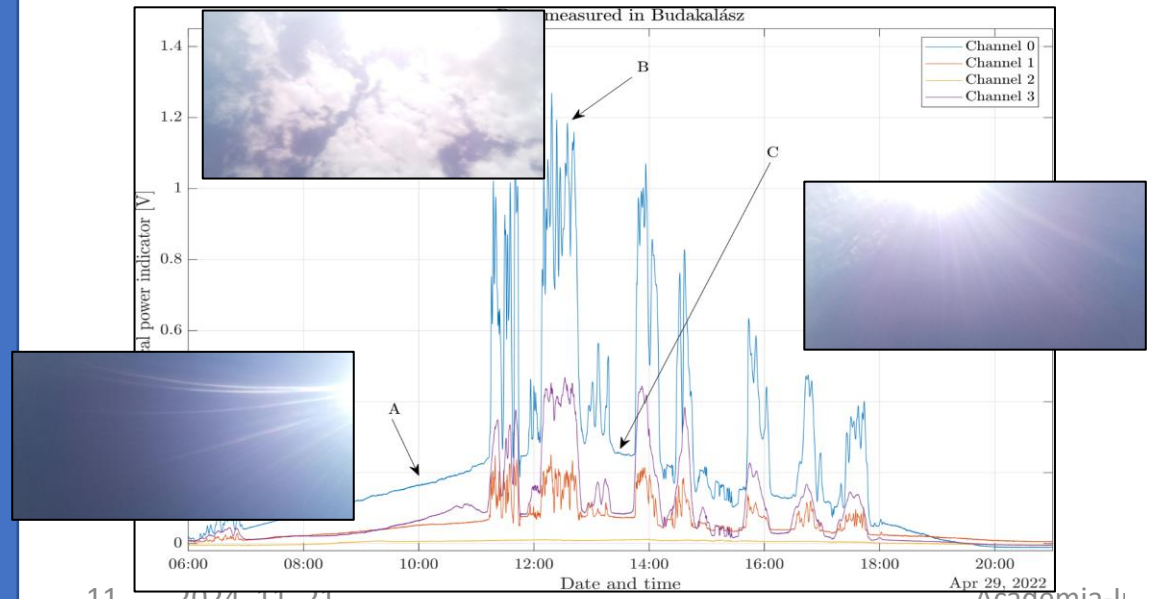
# Some example for industrial cooperation

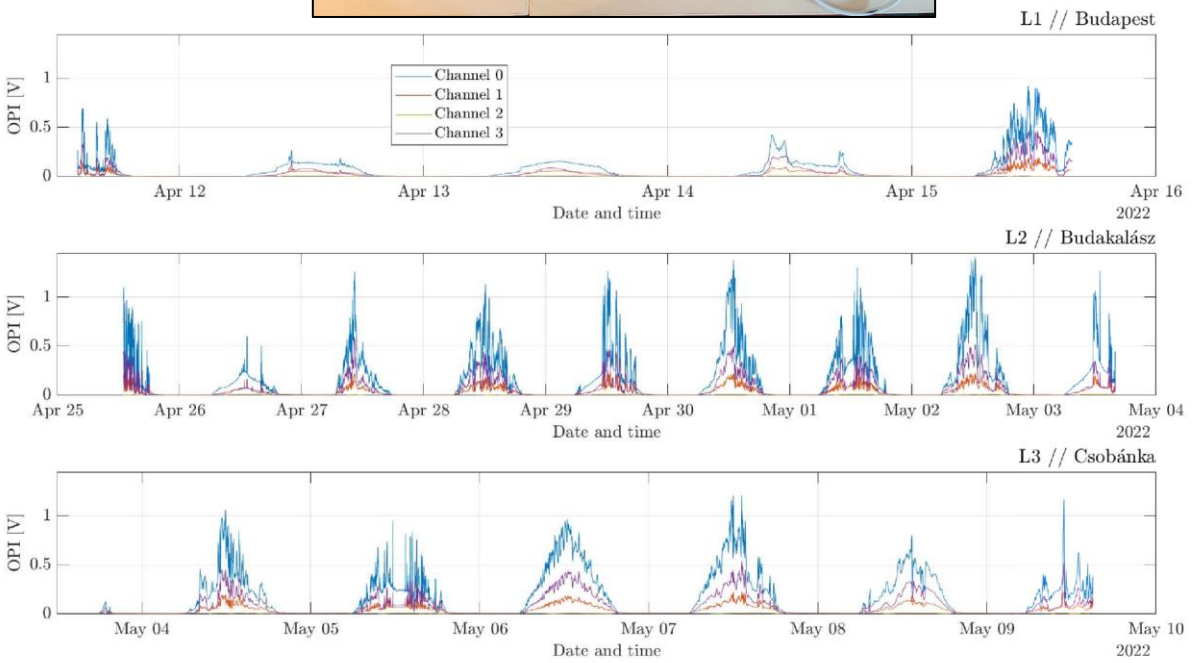
# QuStation, European Space Agency

- QuStation: Quantum Communications Capable Optical Ground Stations in Hungary
- Leader: ATL ltd, partner: BME
- Feasibility Study: the overview of the optical ground station technologies, a market survey and measurement of optical background radiation
- 2021-2022

# QuStation

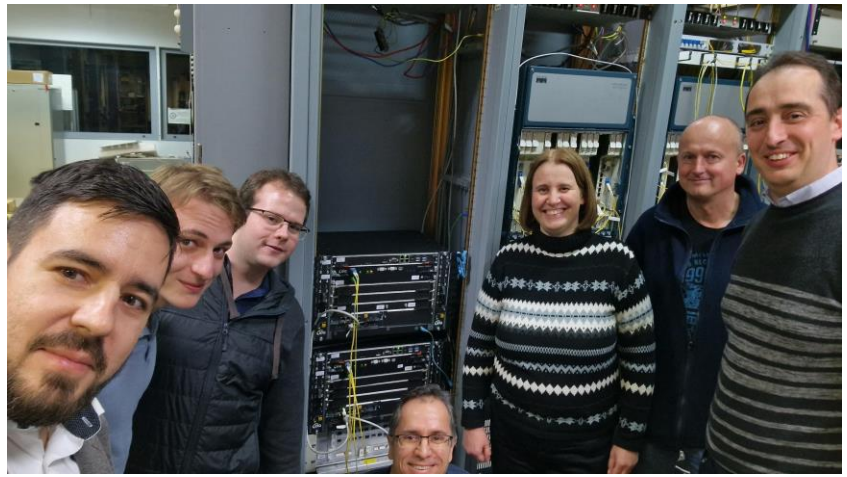

Sector 1
Sector 2
Sector N
Background radiation
Optical Filter 1
Optical Filter 2
Optical Filter N
Camera
Detector 1
Detector 2
Detector N
Power Supply
230 V AC
Data Acquisition Unit
SSD
Computer
Internet connection
Housing


measured in Budakalász
Channel 0
Channel 1
Channel 2
Channel 3
A
B
C
Date and time
Apr 29, 2022

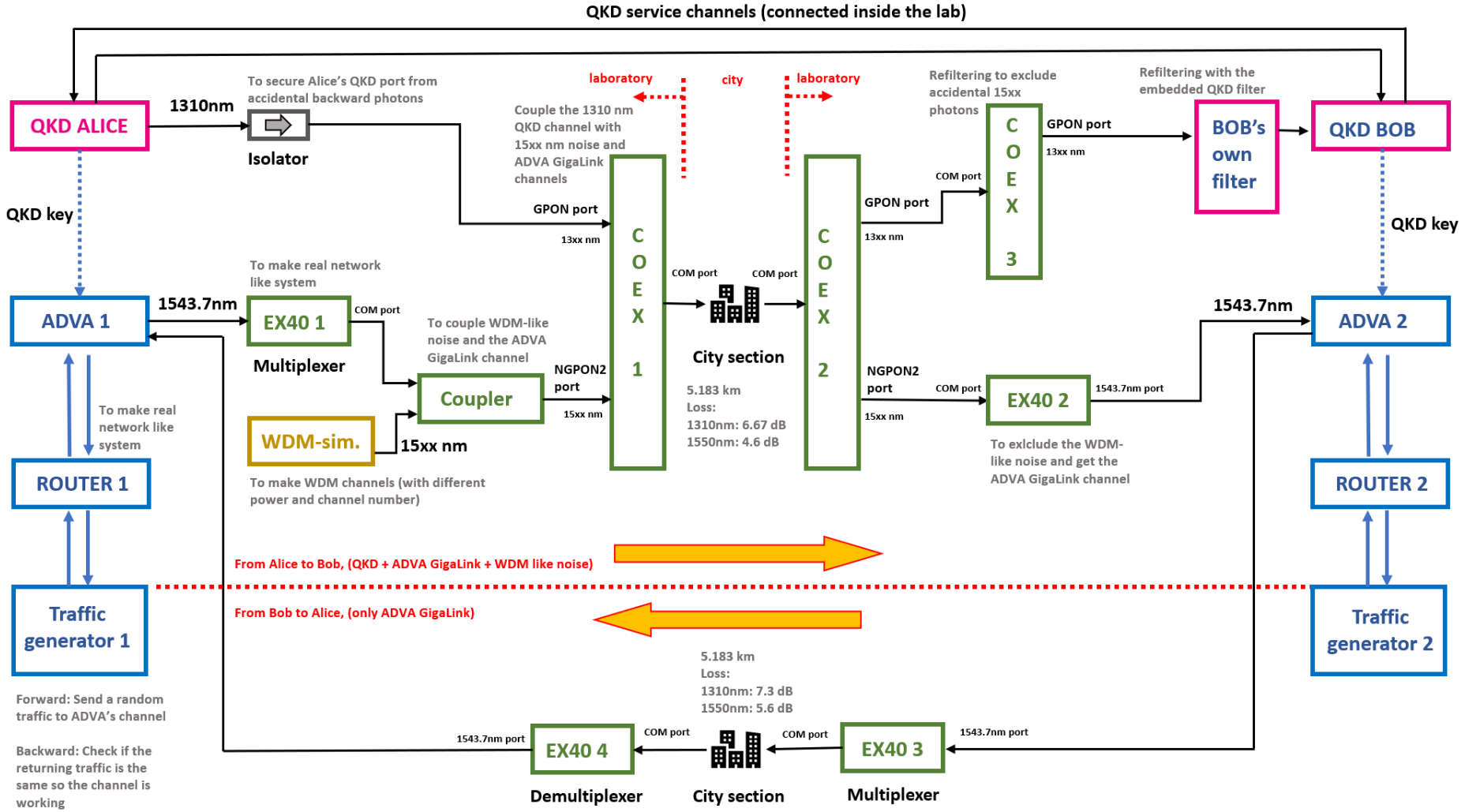

L1 // Budapest
L2 // Budakalász
L3 // Csobánka
OPI [V]
Channel 0
Channel 1
Channel 2
Channel 3
Date and time
2022

# QuantumGigalink in cooperation with Hungarian Telekom

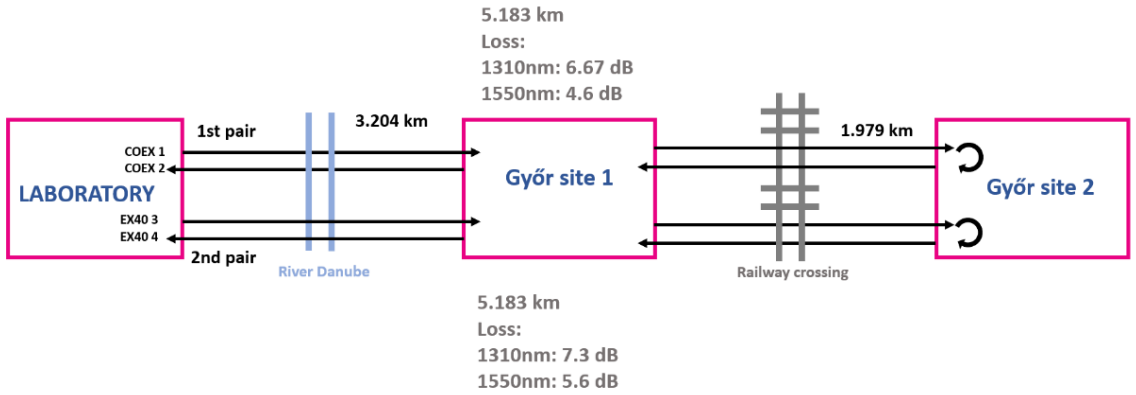
- OpenQKD EU project, QuantumGigalink, 2023
- Cooperation with Hungarian Telecom
- IDQ QKD device pair:
  - Cerberis 3, time-bin qubits, COW protocol, 1310nm
- Experimental work
  - Metropolitan network, Hybrid system
  - QKD channel integration classical optical networks
  - Quantum channel @1310nm: Higher optical attenuation, limited link length
  - High-speed DWDM channels @1550nm
    - 65 DWDM channels; 1 encrypted channel using quantum keys

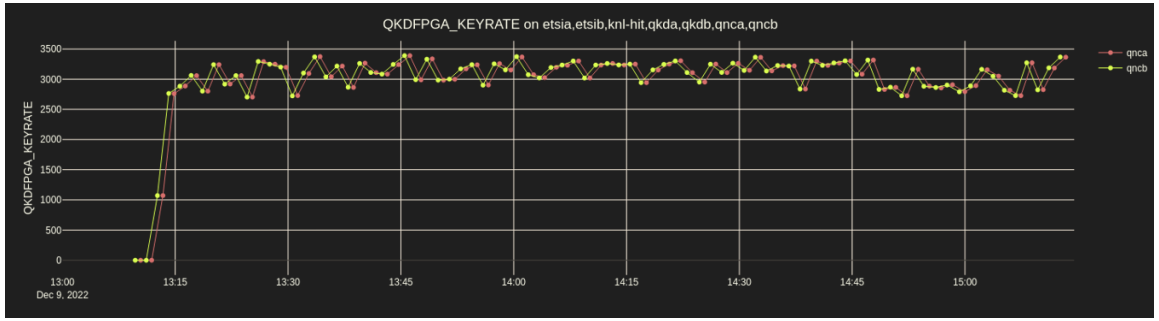


# QuantumGigalink: Laboratory setup

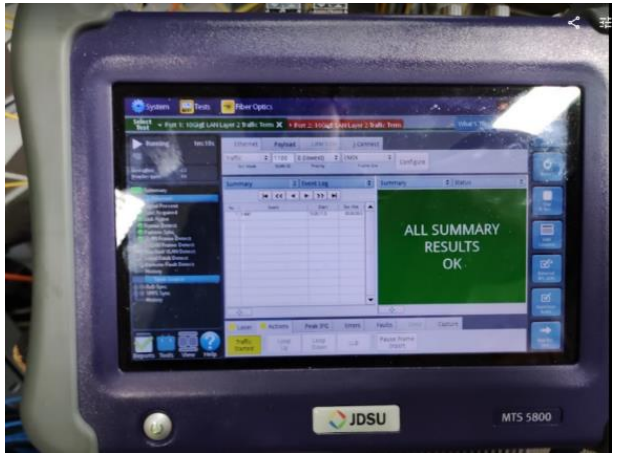


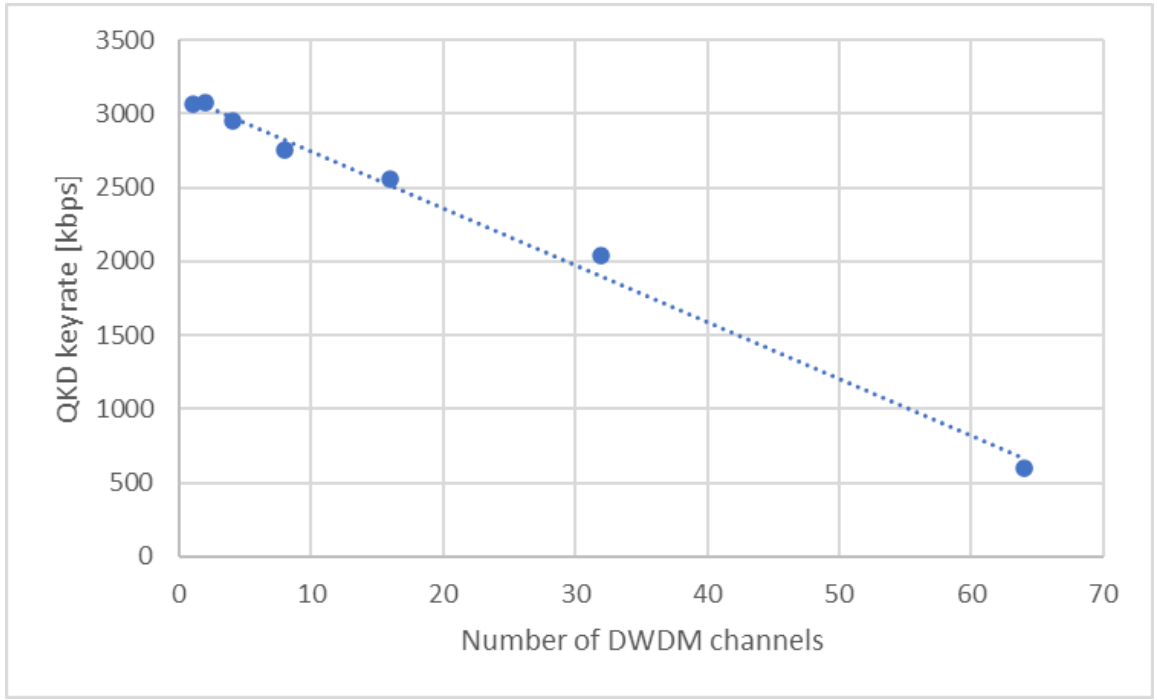
# QuantumGigalink: results







# Modeling, analysis, planning, implementation and operation support of QKD networks

Netvisor
IT and Communications Ltd.

- Quantum Network
- 2024-2026
- Goal
  - Development of network planning software suitable for supporting QKD channels
  - Beyond the point-to-point QKD connections, a solution, procedure, and planning system for protecting L1, L2, and L3 level channels between network nodes, as well as the process control system, must be developed.

# QuantumNetwork

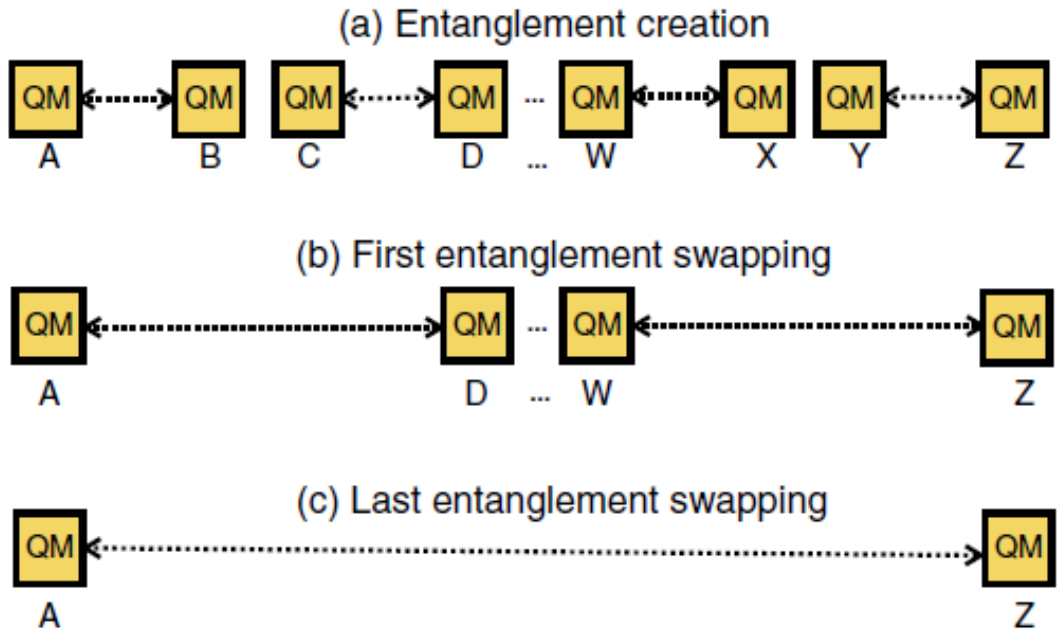
- Literature overview
- Planning Software development
- Operation Support system development
- Testbed
- Laboratory and live network test



# Future research

# Quantum Internet - Entanglement swapping

- QKD is only a short term goal, the real challenge is a global quantum network which connects quantum computers to share quantum information among them.
- No-cloning => Repeated teleportation
- Entanglement purification/destillation is needed to eliminate the „noise” introduced by the process i.e. to regenerate perfect entangled pairs between the endpoints.
- Problem: quantum memories are required!




Source: Na Chen et al, End-to-end entanglement establishment with lower latency in quantum networks, Quantum Information Processing 23(2)

# 3 generations of Qrepeaters

- 1st
  - Today’s quantum processors are very error prone. To make up for this, 1st generation repeaters will use a process called entanglement distillation.
  - The idea behind entanglement distillation is that you can “distill” a high quality entanglement from many copies of low quality entanglement.
  - it’s communication rate is highly limited
- 2nd
  - As error rates improve, quantum repeaters can transition from relying on entanglement distillation to quantum error correction to handle operation errors.
- 3rd
  - once quantum devices have improved enough, quantum error correction will be able to be used to handle both loss and operation errors.
  - This will significantly improve the rate of communication and unlock more applications

# Summary

- Quantum communication research group at BME
- Active industrial cooperation
  - ATL
  - Magyar Telekom
  - Netvisor
- Future research direction

## Thank you for your kind attention