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Copyright Statement

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Executive Summary

In work package 4 of the project QCI-CAT we planned task T4.3. It is described as follows:

Task 4.3: Comparison of QKD technologies

AIT will collect the experience from all use-cases and compare with the help of qtlabs the performance of the different involved QKD systems from several vendors (incl. EU-27 suppliers) and including available Free Space QKD Links.

Within the project we purchased ten QKD-devices from seven different manufactures. We laid the focus on manufacturers form EU27 although we included a system from the Swiss company IdQuantique as well. The network we decided to implement consisted of a metropolitan network in Vienna connecting mainly public authorities like ministries and a long-distance link (about 200 km) between Vienna and Graz. This network required the connection via optical fibers. Thus, no Free Space QKD links were implemented.

We investigated all devices in a laboratory environment and measured their properties before we installed them in a real live network using standard fibers.

It was possible to connect devices from different suppliers by using a common interface and to show the applicability of quantum key distribution both in a metropolitan environment and in a long-distance link.

During the implementation we gathered a lot of experience regarding the different properties of the devices that are using different QKD technologies. In this report we describe these findings and compare the devices with each other.

1. Introduction

1.1. Purpose and scope of the document

This document gives an overview of QKD devices manufactured in EU27 and compares the devices. It is a report regarding the investigation of the devices implemented in the metropolitan area network in Vienna and in the long-distance link between Vienna and Graz.

On the one hand key performance indicators like the secure key rate are compared with the key rates given by the manufacturers themselves and are listed in a table giving an overview of the systems. On the other hand, we describe our experience with the implementation and the operation of the devices.

1.2. Relation to other project work

The overall project aims at the implementation of a QKD network in Austria and at the implementation of dedicated use cases within this network. With this deliverable we describe and compare the used QKD devices and thus contribute to future decisions regarding the choice of further devices for further roll out of QKD infrastructure.

The data we collect for this deliverable will give us the opportunity to contextualize the behavior of the devices in the network and to optimize it for future application.

1.3. Structure of the document

In the first section of this document, we characterize the used devices. We gather the data given by the manufacturers and put it in a template that allows the direct comparison of the devices. We collected data of encoding scheme, wavelength, nature of the used channels, interfaces, key delivery protocol, hardware parameters monitoring, key rate and losses as well as the physical dimensions. We try to estimate the costs of a single key as well.

In the next section we describe how we performed the measurement, how we collected the data, and how we judged interfaces and behavior.

In the next section we describe the results of our measurements of the key rates. We describe at what attenuation the measurements were made and how the key rates behaved over time. Moreover, we tried to find explanation for unexpected behavior. In this section we give a table of the key rates of all investigated devices, both measured and given by the manufacturer.

Finally, we explain the observations we made during our work with the devices.

2. Investigated Systems

The procurement process was described in detail in deliverable D4.1. We decided to buy as many different QKD-systems from EU27 manufacturers as possible in order to get an overview of the European QKD market and in order to get the opportunity to perform an extensive comparison between these systems.

We added a system from IdQuantique/Nutshell as well, although this company is Swiss – not EU27. We took this system into the set of products to be compared because IdQuantique is the company with most experience in QKD systems. As we plan to hand the systems over to Austrian public authorities after the end of the project and these authorities only want to incorporate EU27 devices we decided to lease the Swiss product for the duration of the project, not to buy it.

Devices were bought – or leased – from the following manufacturers:

- ThinkQuantum, 3 Long Distance model, 1 short distance
- KEEQuant,
- LuxQuanta
- Quantum Optics Jena
- Q*Bird
- QTI/Telsy
- IdQuantique/Nutshell (only leasing)

In the following tables some data of the devices are listed as they were given by the manufacturer (empty boxes: no information from the manufacturer available). Moreover, we tried to compare the price of the different systems. But such a comparison is very difficult as the systems use different QKD-technologies and deliver very different key rates. Therefore, we compared how expensive the generated secure key (in bit/second) at a given attenuation is and indicated the result with a color code: Devices marked green are cheaper than devices marked in orange.

This color code is only a rough guideline as it does not regard other advantages or disadvantages of the respective device. A decision to buy a dedicated system cannot only based on the prize price per key.

Supplier	ThinkQuantum	www	https://www.thinkquantum.com
Type	QUKY		
Encoding scheme	Polarization 3 state efficient BB84 decoy		
Wave length	1550 nm (C-Band)		
Service channel	☐ dark fibre required / preferred ☐ multiplexing possible ☒ not required		
Quantum channel	☒ dark fibre required / preferred ☐ multiplexing possible ☐ not specified		
Port	RJ45	Single Ethernet Interface	☒
Interfaces	☒ SNMP ☐ HTTPs ☐ SSH ☐ NETCONF ☐ Other ______________		
Protocol for key delivery	☒ ETSI 004 ☒ ETSI 014 ☐ ETSI 015		
Monitoring of key hardware parameters	☒ Status ☒ Visibility ☒ Raw Key Rate ☒ Secret Key Rate ☒ QBER		
Restart	Restart time: 5 min ☒ automatic ☐ manual ☐ technician required		
Key rate @ 10 dB	2.500 bit/s		
Maximal losses	20 dB (30dB Premium System)		
Hight Units (standard rack)	2 HU	Depth	70 cm
Operating conditions	Temperature: 10°C to 30°C	Humidity	80 % r.h.
Electrical power consumption			
Price per key			

Supplier	KEEQuant	www	https://www.keequant.com/
Type	Andariel		
Encoding scheme	CV-QKD, Quadrature Phase Shift Keying (QPSK)		
Wave length	1530 – 1560 nm (C-Band)		
Service channel	☐ dark fibre required / preferred ☐ multiplexing possible ☒ not required		
Quantum channel	☒ dark fibre required / preferred ☐ multiplexing possible ☐ not specified		
Port		Single Ethernet Interface	☐
Interfaces	☐ SNMP ☐ HTTPs ☐ SSH ☐ NETCONF ☐ Other ________________		
Protocol for key delivery	☒ ETSI 004 ☒ ETSI 014 ☐ ETSI 015		
Monitoring of key hardware parameters	☐ Status ☐ Visibility ☐ Raw Key Rate ☐ Secret Key Rate ☐ QBER		
Restart	Restart time: ☐ automatic ☐ manual ☐ technician required		
Key rate @ 10 dB	10.000 bit/s		
Maximal losses	16 dB		
Hight Units (standard rack)	2 HU	Depth	< 80 cm
Operating conditions	Temperature: 20°C to 30°C	Humidity	
Electrical power consumption			
Price per key			

Supplier	LuxQuanta	www	https://www.luxquanta.com/
Type	NOVA LQ		
Encoding scheme	CV-QKD		
Wave length	C-Band		
Service channel	☐ dark fibre required / preferred ☐ multiplexing possible ☒ not required		
Quantum channel	☐ dark fibre required / preferred ☒ multiplexing possible ☐ not specified		
Port		Single Ethernet Interface	☒
Interfaces	☒ SNMP ☒ HTTPs ☒ SSH ☐ NETCONF ☐ Other ________________		
Protocol for key delivery	☒ ETSI 004 ☒ ETSI 014 ☐ ETSI 015		
Monitoring of key hardware parameters	☒ Status ☐ Visibility ☒ Raw Key Rate ☐ Secret Key Rate ☒ QBER		
Restart	Restart time: 5 min ☒ automatic ☐ manual ☐ technician required		
Key rate @ 10 dB	500 bit/s		
Maximal losses	8dB (after update 16dB)		
Hight Units (standard rack)	3 HU	Depth	84 cm
Operating conditions	Temperature		Humidity
Electrical power consumption			
Price per key			

Supplier	Quantum Optics Jena	www	https://qo-jena.com/
Type	ELVIS 1500 QKD System		
Encoding scheme	Entangled polarization encoding		
Wave length	1550 nm		
Service channel	☐ dark fibre required / preferred ☐ multiplexing possible ☒ not required		
Quantum channel	☒ dark fibre required / preferred ☐ multiplexing possible ☐ not specified		
Port		Single Ethernet Interface	☒
Interfaces	☒ SNMP ☒ HTTPs ☒ SSH ☐ NETCONF ☐ Other ________________		
Protocol for key delivery	☐ ETSI 004 ☒ ETSI 014 ☐ ETSI 015		
Monitoring of key hardware parameters	☐ Status ☒ Visibility ☒ Raw Key Rate ☒ Secret Key Rate ☒ QBER		
Restart	Restart time: < 1 min ☒ automatic ☐ manual ☐ technician required		
Key rate @ 10 dB	300 bit/s		
Maximal losses	20dB		
Hight Units (standard rack)	3 HU	Depth	84 cm
Operating conditions	Temperature: 20°C to 30°C	Humidity	
Electrical power consumption			
Price per key			

Supplier	Q*Bird	www	https://q-bird.com/	
Type	Falqon			
Encoding scheme	Center-Hub and End Nodes, MDI with Decoy States			
Wave length	C-Band			
Service channel	☐ dark fibre required / preferred ☒ multiplexing possible ☐ not required			
Quantum channel	☒ dark fibre required / preferred ☐ multiplexing possible ☐ not specified			
Port	Quantum: LC/PC, User: RJ45, control: RJ45, Management RJ45	Single Ethernet Interface	☐	
Interfaces	☒ SNMP ☐ HTTPs ☒ SSH ☒ NETCONF ☐ Other ________________			
Protocol for key delivery	☐ ETSI 004 ☒ ETSI 014 ☐ ETSI 015			
Monitoring of key hardware parameters	☐ Status ☐ Visibility ☐ Raw Key Rate ☐ Secret Key Rate ☐ QBER			
Restart	Restart time: ☐ automatic ☐ manual ☐ technician required			
Key rate @ 10 dB	1.000 bit/s			
Maximal losses	40dB			
Hight Units (standard rack)	2 HU	Depth	70 cm	
Operating conditions	Temperature	18°C to 35°C	Humidity	30 – 60 %
Electrical power consumption				
Price per key				

Supplier	QTI/Telsy	www	https://www.telsy.com/
Type	Quell-X		
Encoding scheme	DV-QKD, time-bin encoding with decoy states, BB84		
Wave length	1550 nm		
Service channel	☐ dark fibre required / preferred ☒ multiplexing possible ☐ not required		
Quantum channel	☒ dark fibre required / preferred ☐ multiplexing possible ☐ not specified		
Port	RJ45	Single Ethernet Interface	☒
Interfaces	☒ SNMP ☒ HTTPs ☒ SSH ☐ NETCONF ☐ Other ________________		
Protocol for key delivery	☒ ETSI 004 ☒ ETSI 014 ☒ ETSI 015		
Monitoring of key hardware parameters	☐ Status ☒ Visibility ☐ Raw Key Rate ☒ Secret Key Rate ☒ QBER		
Restart	Restart time: 5 min ☒ automatic ☐ manual ☐ technician required		
Key rate @ 10 dB	2.500 bit/s		
Maximal losses	30 dB		
Hight Units (standard rack)	2 HU	Depth	70 cm
Operating conditions	Temperature: 10°C to 30°C	Humidity	80 %
Electrical power consumption	330 W		
Price per key			

Supplier	IdQuantique/Nutshell	www	https://www.nutshell-qs.com/
Type	Cerberis XG		
Encoding scheme	Coherent One Way QKD		
Wave length	1550 nm		
Service channel	☐ dark fibre required / preferred ☒ multiplexing possible ☐ not required		
Quantum channel	☒ dark fibre required / preferred ☐ multiplexing possible ☐ not specified		
Port		Single Ethernet Interface	☒
Interfaces	☒ SNMP ☒ HTTPs ☒ SSH ☐ NETCONF ☐ Other ________________		
Protocol for key delivery	☐ ETSI 004 ☒ ETSI 014 ☐ ETSI 015		
Monitoring of key hardware parameters	☒ Status ☒ Visibility ☐ Raw Key Rate ☒ Secret Key Rate ☒ QBER		
Restart	Restart time: 7 min ☒ automatic ☐ manual ☐ technician required		
Key rate @ 10 dB	2.000 bit/s		
Maximal losses	18 dB		
Hight Units (standard rack)	1 HU	Depth	61 cm
Operating conditions	Temperature: 10°C to 35°C	Humidity	80 %
Electrical power consumption	330 W		
Price per key			

3. Measurement: Procedure

3.1. Test Setup

All Quantum Key Distribution (QKD) systems were evaluated under controlled conditions to ensure consistency and comparability of environmental variables throughout the testing period. The majority of systems were installed and operated within the same room at the AIT facility. This approach was chosen to minimize external influences and maintain uniform testing conditions.

An exception was made for the Q*Bird system, which was installed in a dedicated server room. This decision was driven by the system's physical size and its reliance on helium-based cooling, which necessitated a specialized environment to ensure safe and stable operation.

For connectivity, the systems were directly linked using short fiber optic cables ranging from two to three meters in length, with 10 dB optical attenuators applied to simulate realistic transmission conditions. The ThinkQuantum long-distance systems were subjected to varying attenuation levels between 15 dB and 30 dB to assess performance across a range of link losses. Due to software limitations in the version delivered, the LuxQuanta system was tested at its maximum supported attenuation of 8 dB. The Q*Bird system was configured with 15 dB attenuation on each leg between the two Alice nodes and the central hub, resulting in a total link attenuation of 30 dB.

3.2. Performance Data Collection

At the time of writing, all QKD systems included in the evaluation, except for the KeeQuant system, offer mechanisms for exporting performance-related data. This typically includes metrics such as key generation rate and other system-specific operational indicators. These data points are essential for assessing the stability and overall performance of each system under test.

Most of the systems support the Simple Network Management Protocol (SNMP), which facilitates straightforward integration into monitoring platforms by enabling automated data retrieval and system state tracking. Notably, Q*Bird and LuxQuanta provide access to performance metrics via a dedicated web API, allowing for flexible and programmable data collection. In contrast, QTI offers a manual download option through its web interface, available on both nodes. While this method still permits performance data extraction, it significantly limits the ability to automate data ingestion into centralized monitoring tools.

To standardize performance monitoring across all systems and ensure consistent data visualization, the open-source monitoring platform Zabbix was selected. Zabbix supports a wide range of data collection interfaces, making it well-suited for heterogeneous environments such as this one. It also provides built-in graphical visualization capabilities, eliminating the need for third-party tools to interpret and present the collected data.

For the generation of performance figures presented in this document, data were exported from Zabbix using its web API. The exported datasets were then processed using a custom Python script, which enabled the calculation and visualization of key rate boundaries—where sufficient data granularity was available. In cases where systems only provided cumulative key generation data (e.g., total bits produced since the last key block), the analysis was limited to single-point estimates, restricting the ability to derive statistical bounds.

3.3. Recovery Behavior

System resilience was evaluated by simulating connection losses and power outages. All systems, with the exception of Q*Bird, were tested for their ability to autonomously recover from disruptions such as loss of connection to the peer node or complete power failure of one or both nodes. Each of the tested systems demonstrated the capability to recover without manual intervention, typically requiring only a brief recalibration period before resuming normal operation.

3.4. Interface Requirements

The interface requirements varied significantly across the tested QKD systems. Most systems, excluding LuxQuanta, required a dedicated dark fiber for quantum communication. LuxQuanta offers a more flexible approach by allowing the photon source wavelength to be adjusted, enabling the integration of classical Dense Wavelength Division Multiplexing (DWDM) channels alongside the quantum channel. Additionally, some systems can be configured with photon sources operating in the 1310 nm wavelength range, depending on deployment needs, but reducing the maximum range.

Classical communication interfaces also differed across systems. Some devices required only a standard Ethernet connection, which could be integrated into existing classical network infrastructure. Others necessitated a dedicated ITU channel, either unidirectional or bidirectional. Some systems requiring ITU channels supported SFP+ modules, allowing users to define the specific ITU channel used for communication. In cases where predefined ITU channels were necessary, vendors provided the option to deliver systems pre-configured with the required channel specifications. The disadvantage of this option is that the ITU channel cannot easily be changed after delivery.

3.5. Key Delivery Interface

All QKD systems included a dedicated Ethernet interface for the delivery of generated quantum keys. The standardized protocol used across all systems for key exchange was ETSI GS QKD 014, ensuring interoperability and compliance with industry standards. Some of the systems also have the option to provide the key using the management interface.

4. Measurement of key rates: Results

A crucial KPI for application in a real word environment is the key rate. Therefore, most effort was put into measuring and comparing the key rates. We wanted to confirm the specifications provided by the manufacturers, to compare the different devices. to analyze the stability of the key rates over time, and to estimate – if possible – how the key rate depends on external factors

Figure 1 is a comparison of the key rates of the devices of five manufacturers measured in a laboratory setup. ThinkQuantum (TQ) appears twice as we bought ThinkQuantum devices both for the city network in Vienna and for the long distance (LD) transmission between Vienna and Graz. All devices were measured at 10 dB, only LuxQuanta (LuxQ) was measured at 8 dB and Q*Bird was measured at 30 dB.

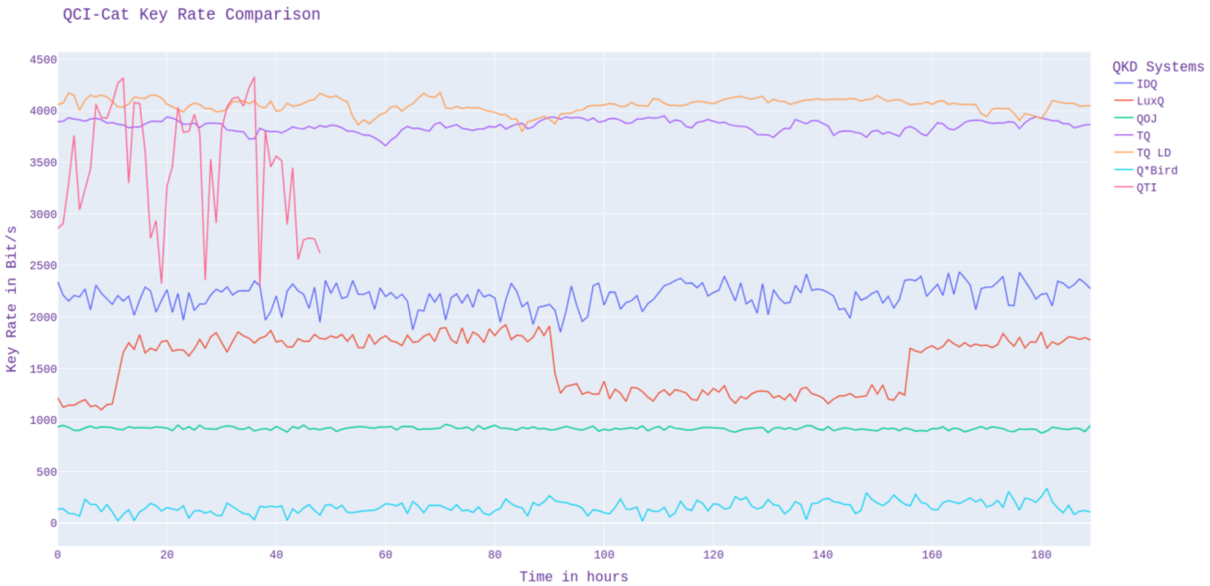

Figure 1 – Comparison of key rates of QKD devices from 6 suppliers

Figure 1 shows the key rates as follows:

- Nutshell/IdQuantique (IDQ) has a key rate of about 2.200 bit/sec and seems stable over time. Compared to this measurement the one in the real-life testbed (Figure 2) is not so stable. The maximum key rate is about the same as in the laboratory, but obviously there are disruptions that have a great influence on the real key rate.
- LuxQuanta (LuxQ) was measured at 8 dB and the key rate switches between 1.200 and 1.800 bit/sec. In another measurement session shown in Figure 3 LuxQuanta showed an oscillating behavior. At 1 dB it oscillates around 10 kbit/sec, at 8 dB around 1.800 bit/sec. In the real life testbed the key rate is not very stable.
- The key rate of Quantum Optics Jena (QOJ) is very stable at about 1.000 bit/sec. In another measurement cycle (Figure 4) we experienced that an optical component of the device seemed to be under mechanical tension. Thus, the key rate was much lower (about 500 bit/sec). Gradually the tension was reduced and the key rate decreased. After readjustment the key rate increased to about 900 bit/sec but decreased again over time. Finally, we installed the device in the testbed where it was less stable than in the laboratory.
- There were two Think Quantum (TQ) devices measured as we implemented it both in the Vienna city network and in the long-distance link between Vienna and Graz. Therefore, we bought several devices and wanted to compare the key rates between devices of the same

type, too. The key rates are nearly equal at about 4.000 bit/sec but vary by a few hundred bit/sec. Figure 5 shows another measurement cycle of a ThinkQuantum device that gives the fluctuation range in more detail. We measured the key rate of a ThinkQuantum device at different attenuations (Figure 6). At 15 dB the key rate was about 1.700 bit/sec, at 25 dB it as about 750 bit/sec. Even at an attenuation of 30 dB we produced a key rate of about 100 bit/sec.

- The key rate of the Q*Bird device at 30 dB of attenuation was at about 150 bit/sec and oscillated strongly. The measurement is seen more detailed in Figure 7.
- The QTI system was measured separately (Figure 8). As we only received the system recently, we were only able to capture a few days' worth of data and could not conclude the long-time stability test of the system. We deployed the system in our test bed between Vienna and Graz, with a fiber attenuation of about 20 dB.
- The key rate of the KEEQuant device could not be measured in the same way, as the data could not be read out directly from the device.

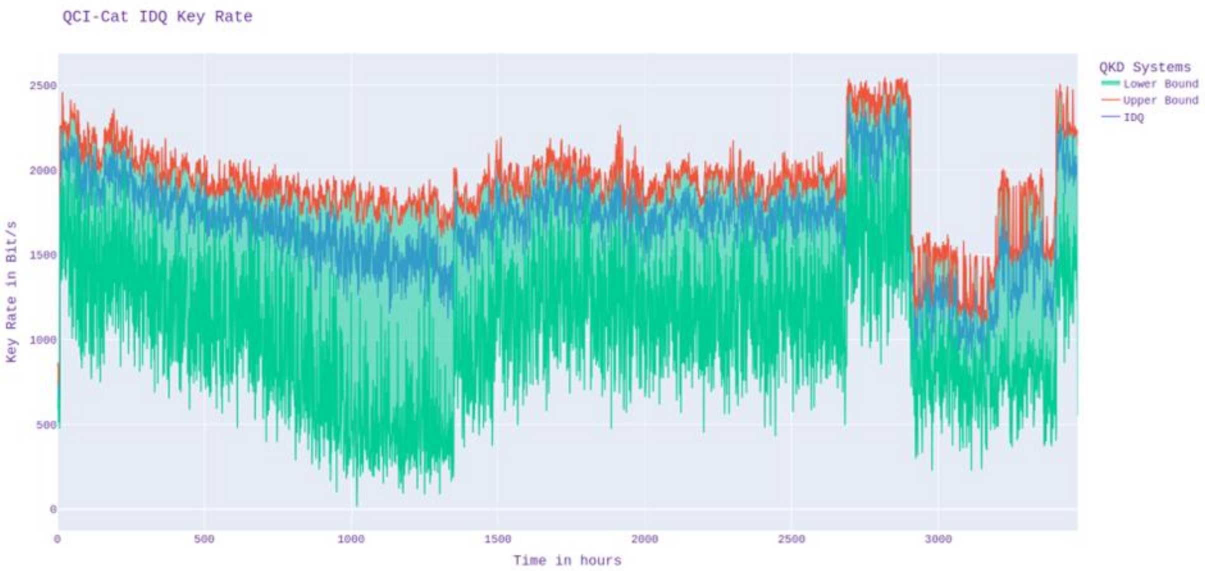

Figure 2 – Secure key rate of the Nutshell/IdQuantique device in the real life testbed

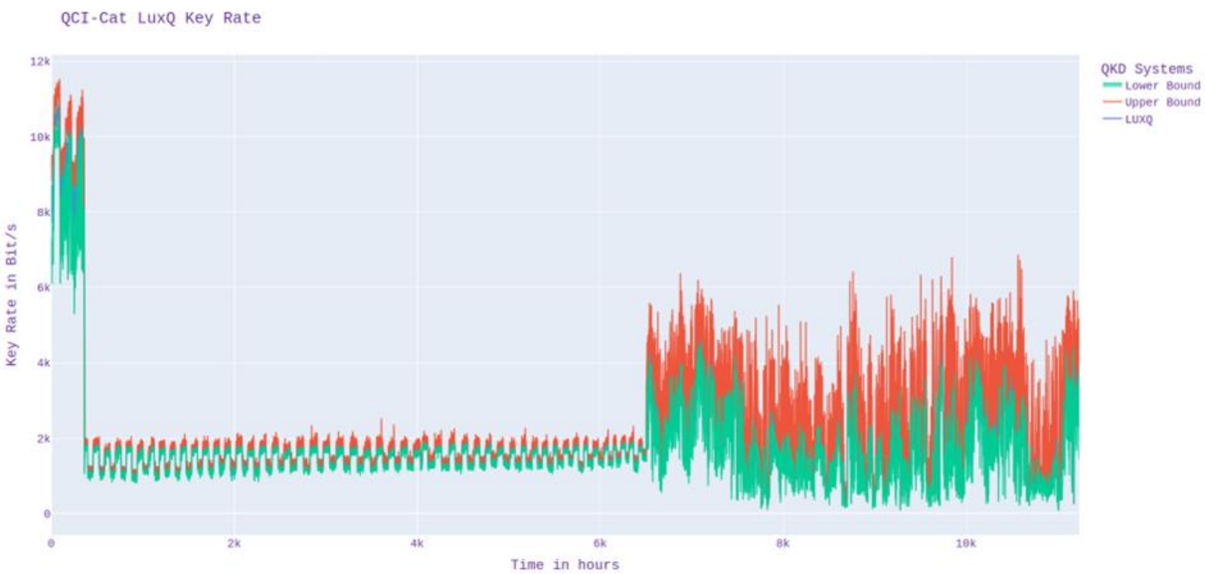

Figure 3 – Secure key rates of the LuxQuanta device: left at 1 dB at the laboratory, in the middle at 8 dB in the laboratory, right in the real life testbed

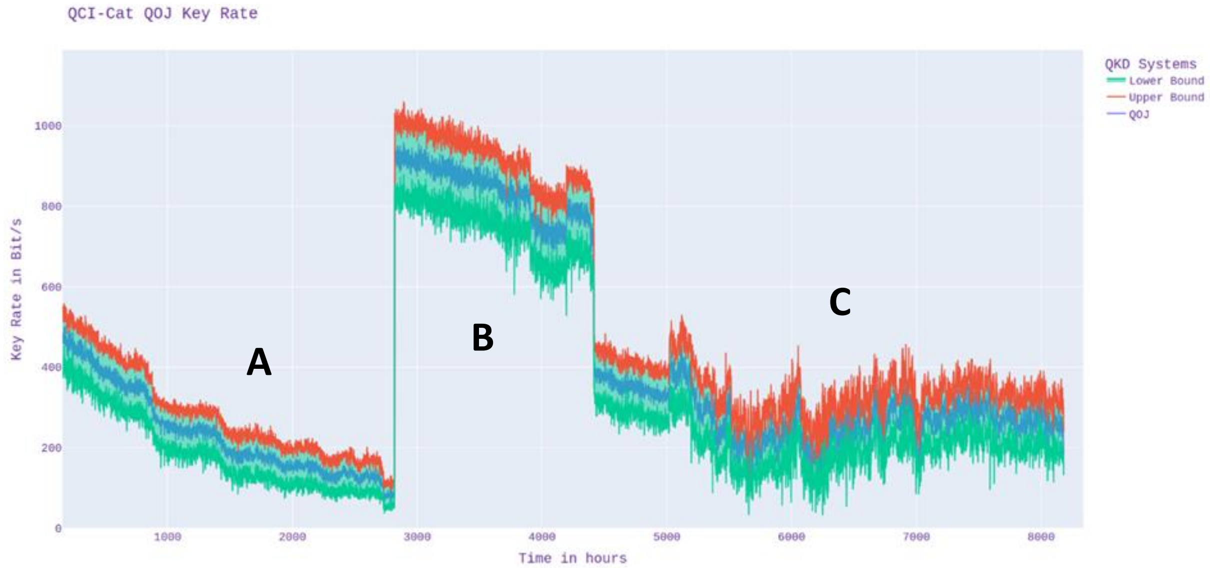

Figure 4 – Secure key rate of the Quantum Optics Jena device. In the first part of the measurement (A) a component was under mechanical tension and slowly lost this tension. Then it was recalibrated and the key rate increased immediately (B). The final part of the measurement (C) shows the behavior in the real-life testbed

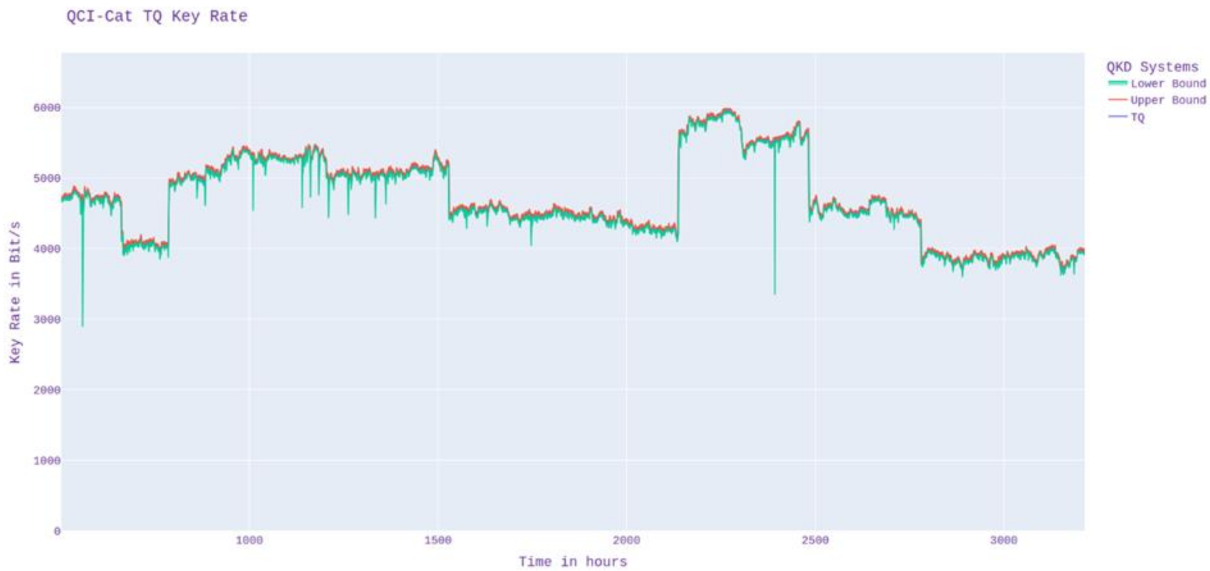

Figure 5 – Secure key rate of a ThinkQuantum device at 10 dB over time

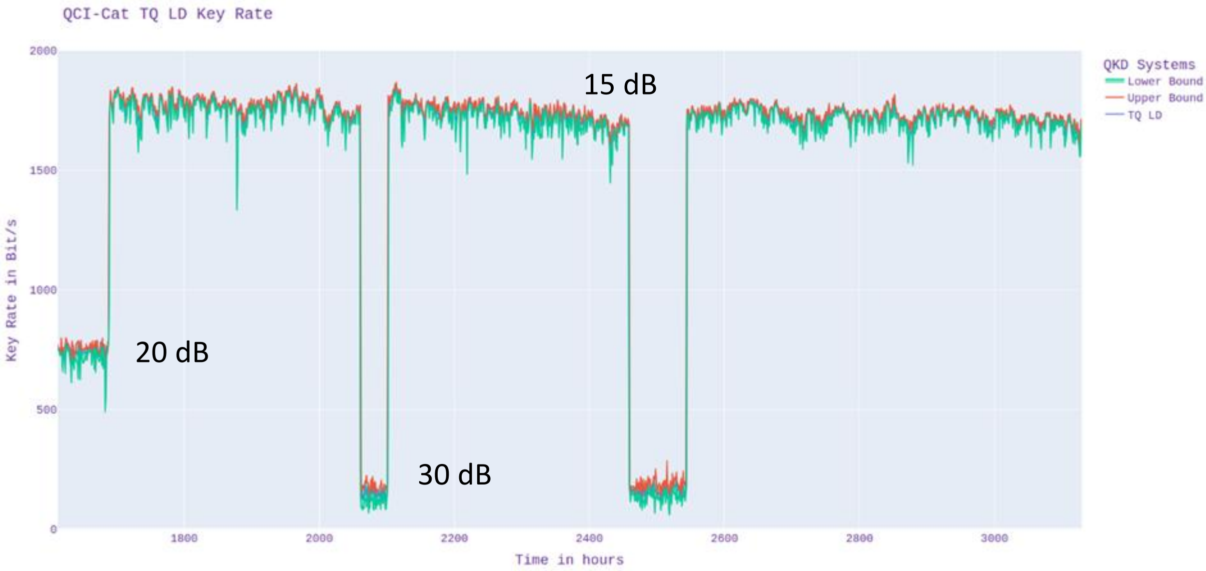

Figure 6 – Measurement of the key rate of a ThinkQuantum device, variation between 15, 25 and 30 dB

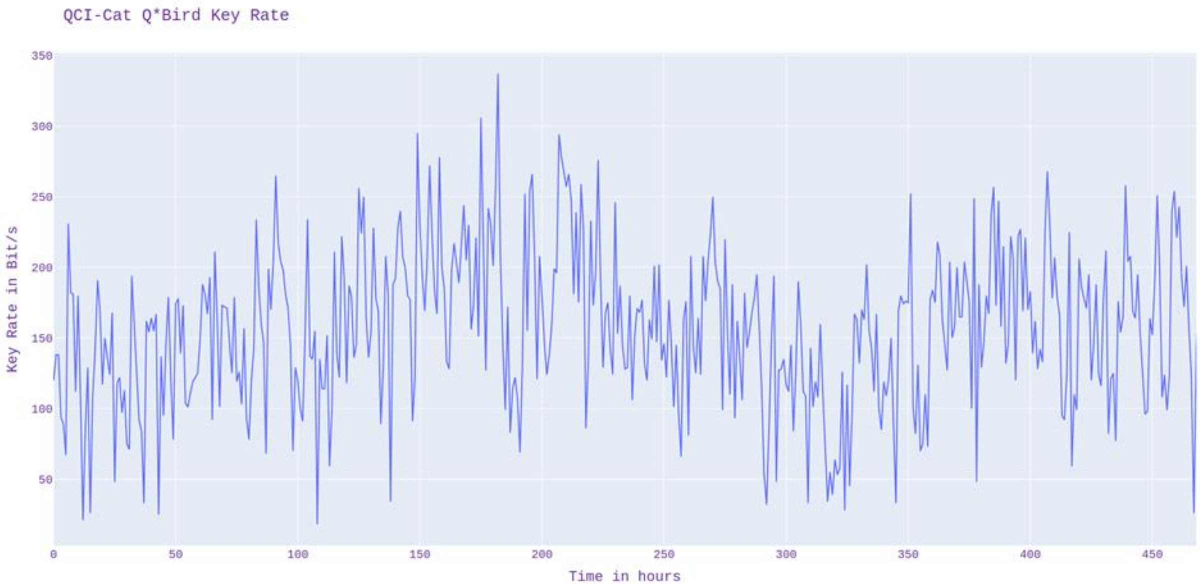

*Figure 7 – Secure key rate of the Q*Bird device at 30 dB over time*

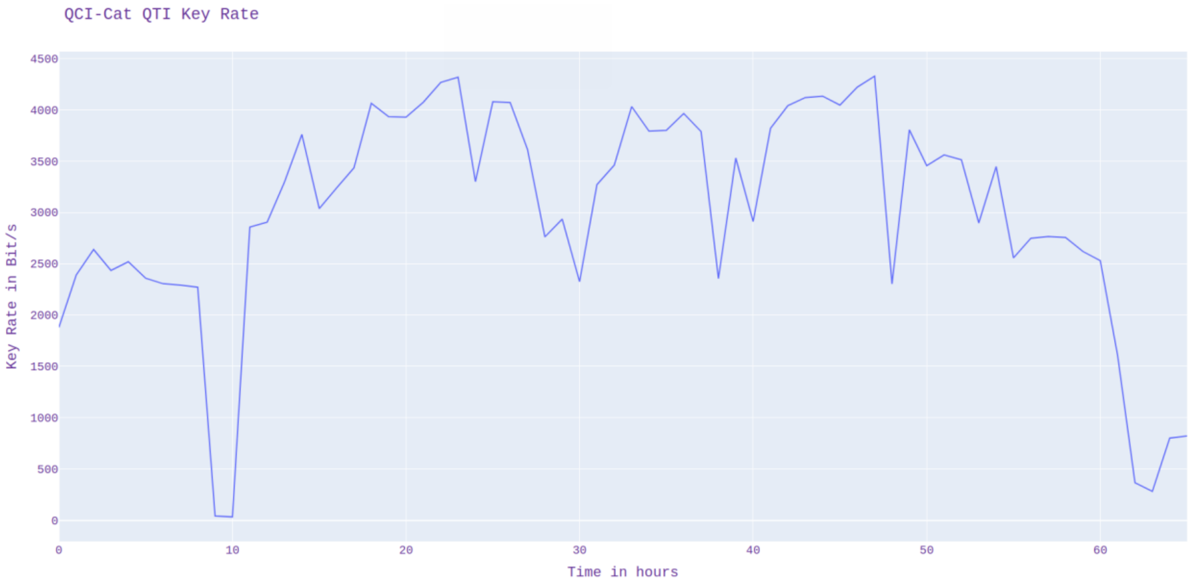

Figure 8 – QTI measured key rate between 10dB and 20dB of attenuation

The list below compares the data given by the manufacturers with our measurement data.

Table 1 – Measured secret key rate in comparison to numbers given by the manufacturer.

Manufacturer	**Key rate given by the manufacturer (at 10 dB loss)**	**Key rate measured in bit/sec (at 10 dB loss if not specified otherwise)**
Nutshell/IdQuantique	2.000	2.200
LuxQuanta	500	1.500 (measured at 8dB)
Quantum Optics Jena	300	1.000
ThinkQuantum	2.500	4.000
Q*Bird	1.000	150 (measured at 30dB)
QTI/Telsy	2.500	3.400
KEEQuant	10.000	Not measured

In general, the measured key rate is higher than the key rate specified by the manufacturer. Only the Q*Bird key rate is lower. But we must keep in mind that the devices are in a very early stage of the product life cycle and improvements may sometimes be achieved by close interaction between the manufacturer and the early-stage users.

5. Additional Observations

There are some advantages but also disadvantages to all of the systems tested. In the following section those advantages and disadvantages are described further.

5.1. ThinkQuantum

The system offers a relatively straightforward configuration process, primarily facilitated through SSH connectivity. This allows for remote access and basic management tasks with minimal effort.

However, diagnostic capabilities remain limited. In cases where the system fails to operate as expected, the available status information is often insufficient for effective troubleshooting. While recent updates have introduced some improvements in this area, the diagnostic feedback still lacks the depth required for comprehensive fault analysis.

A recurring operational issue observed during testing is the system's tendency to stop key generation, which in some instances could only be resolved through a full power cycle. A standard reboot via SSH proved ineffective in restoring functionality, indicating a deeper issue within the system's recovery mechanisms.

The specific hardware version procured for testing exhibited several reliability concerns. These included multiple defective LAN ports and a non-functional detector, both of which significantly impacted usability. As a result, several units had to be returned to the vendor for hardware servicing as well as some for firmware updates.

5.2. KeeQuant

The system occupies 3U of rack space at each endpoint, which places it among the more voluminous solutions in terms of vertical footprint. Despite this, it distinguishes itself by being notably lightweight and shallow in depth, offering advantages in environments where depth constraints are critical considerations.

However, from a performance point of view, the system currently supports a maximum attenuation of 10 dB.

A significant drawback at this stage is the absence of an integrated interface for performance data collection. This omission hinders the ability to monitor and analyze system behavior over time, which is essential for proactive maintenance and optimization. Additionally, there is no provision for consumer-level access to system logs, which further limits transparency and troubleshooting capabilities.

5.3. LuxQuanta

Among the seven different vendor systems evaluated, the Lux Quanta solution demonstrated the highest level of operational stability.

The initial setup process for the Lux Quanta system was notably intricate, requiring a more involved configuration compared to other systems in the evaluation.

At present, the system supports an attenuation threshold of up to 8 dB. However, according to the vendor, a forthcoming software update will extend this capability to 16 dB, significantly enhancing its applicability in more demanding network environments.

Physically, the system occupies 4U of rack space at each endpoint, positioning it among the larger solutions in terms of form factor.

5.4. Quantum Optics Jena

The system demonstrates a commendable level of operational stability under standard conditions. However, it is important to note that the Key Management Server (KMS) associated with the Bob endpoint requires periodic reboots to maintain consistent performance. This is probably easily fixed by a software update.

One of the standout features of this solution is its graphical user interface (GUI), which is widely regarded as the most visually appealing and user-friendly among all systems evaluated. The interface design contributes positively to the overall user experience, particularly in terms of navigation, clarity, and accessibility of key functions.

From a physical infrastructure perspective, the system requires 3U of rack space on one side and 5U on the other. While this configuration results in a relatively large footprint, the hardware components are notably lightweight.

The system architecture was originally designed with the quantum entanglement source positioned at the Alice node. While this configuration aligns with the intended operational model, it is important to note that, in principle, the entanglement source in such systems can also be placed at a central location between the two nodes—provided the system is engineered to support such a topology.

However, in the current implementation, this flexibility is constrained by the use of an 810 nm wavelength on one side of the link and 1550 nm on the other side. The wavelength of 810 nm introduces limitations in terms of fiber transmission characteristics and therefore can only be used over a short distance.

5.5. Q*Bird

The central node of the system requires a substantial physical footprint, occupying 6U of rack space for its core components. In addition, it relies on an external compressor unit, which in our deployment was positioned behind the rack due to space constraints. This compressor is a critical part of the system's operation and introduces several important infrastructure considerations.

Specifically, the compressor requires a dedicated 16A electrical circuit and should not share a breaker with any other equipment to ensure stable and safe operation. Since the compressor utilizes helium, it may be necessary to consult with facility management or safety officers to confirm whether such a device can be installed in the intended location, particularly in environments with strict safety or ventilation requirements.

One of the system's components, the Retina Driver, exhibited some instability during testing. The graphical user interface (GUI) occasionally became unresponsive, necessitating frequent reboots via SSH to restore functionality. Compounding this issue, the built-in update mechanism did not function as expected, making it likely that a future update will need to be performed manually by a technician.

Notably, this is the only system in the evaluation that offers Integrated Lights-Out (ILO) capabilities, providing remote management features that can be highly valuable for monitoring and maintaining the system in production environments.

5.6. QTI/Telsy

The system requires an additional ITU channel in one direction to support the service channel. This should be factored into the overall network design and wavelength planning.

Performance-wise, the system operated reliably under test conditions, maintaining stable functionality with up to 20 dB attenuation on the quantum channel and 25 dB on the service channel.

USB-based Hardware Security Modules (HSMs) are used by this system to function. While these modules provide an added layer of cryptographic protection, they were somewhat finicky during initial setup. Physical adjustment or re-insertion was required before the devices were properly recognized by the system. However, once successfully initialized, the HSMs functioned reliably without further issues.

Due to the limited evaluation period of only a few weeks, only one instance was observed where the system became unresponsive and required a full power cycle to restore connectivity. This suggests a generally stable system behavior, though further long-term testing would be necessary to fully assess reliability under continuous operation.

5.7. Nutshell/IdQuantique

The system distinguishes itself as the most compact solution among all evaluated, requiring only 1U of rack space. This minimal footprint makes it particularly well-suited for environments where space efficiency is a critical factor.

One notable requirement is the use of an additional service channel, which should be considered during network planning and integration.

In real-world deployments, the system has proven to be more stable and significantly easier to set up compared to lab environments using optical attenuators.

A key strength of the system lies in its configuration capabilities. It features a powerful configuration tool that utilizes a structured configuration file, allowing for efficient and flexible parameter adjustments. This streamlines the setup process and simplifies ongoing maintenance.

Furthermore, the system includes a comprehensive logging mechanism, which provides detailed diagnostic information. This feature greatly facilitates troubleshooting by enabling users to quickly identify and resolve issues, thereby minimizing downtime and support effort.

Summary

The devices we got for this project are very different, using different technologies, implementations etc. Nevertheless, it is possible to compare the key properties of quantum key distribution: the secure key rate.

The key rate at a given attenuation alone is not sufficient to judge the quality of a system. The choice of a system depends on the use case and the environmental conditions. In this deliverable we listed the key facts of the investigated devices in order to give the use the opportunity for his best choice.

We also described our experience with the implemented devices. Most of them are at a very early stage in the product life cycle. So, the interaction with the manufacturers was very important - both for us as user and the manufacturer to gather feedback.

This deliverable gives a good overview of the current situation of QKD-devices in EU27 and may support the future roll out of QKD networks in Europe.

Appendix A - List of Acronyms

- QKD: Quantum Key Distribution
- CV-QKD: Continuous Variable QKD
- DV-QKD: Discrete Variable QKD
- SNMP: Simple Network Management Protocol
- HTTPS: Secure Hyper Text Transfer Protocol
- NETCONF: Network Configuration Protocol
- SSH: Secure Shell
- QBER: Quantum bit error rate
- HU: Height unit
- W: Watt
- BB84: QKD protocol introduced by Charles Bennett and Gilles Brassard in 1984
- QPSK: Quadrature Phase Shift Keying
- MDI: Measurement device independent QKD