INTERNATIONAL TELECOMMUNICATION UNION

TELECOMMUNICATION STANDARDIZATION SECTOR

STUDY PERIOD 2022-2024

SG13-TD340/WP1

STUDY GROUP 13

Original: English

Question(s): 6/13 Geneva, 13 – 24 March 2023

TD

Source: Editors

Title: Draft new Recommendation ITU-T Y.QKDN-qos-ml-fa: "Quantum key distribution networks: Functional architecture enhancement of machine learning based quality of service assurance"

Contact:	Taesang Choi ETRI Korea (Rep. of)	Tel:+82-10-2740-5628 Email:choits@etri.re.kr
Contact:	Ui-Jun Baek Korea University Korea (Rep. of)	Tel: +82-10-3182-2343 E-mail:pb1069@korea.ac.kr
Contact:	Jee-Tae Park Korea University Korea (Rep. of)	Tel: +82-10-9394-5846 E-mail:pjj5846@korea.ac.kr
Contact:	Myungsup Kim Korea University Korea (Rep. of)	Tel: +82-10-4367-0913 E-mail:tmskim@korea.ac.kr
Contact:	Jeongyun Kim ETRI Korea (Rep. of)	Tel:+82-42-860-5311 Email: jykim@etri.re.kr
Contact:	Hyungsoo Kim KT corp. Republic of Korea	Tel:+82-10-6808-5199 Email:hans9@kt.com

Abstract: The base line text is TD220/WP1 and this TD was created during Q.6/13 13-24 March 2023. The meeting agreed to accept proposals made by C-0273 based on the discussions during the meeting.

This document is based on this meeting's discussion and results on the following contribution:

No.	Title	Source	Main discussion and results
C-0273	Draft new Recommendation ITU-T Y.QKDN-qos-ml-fa: "Quantum key distribution networks: Functional architecture enhancement of machine learning based quality of service assurance"	Republic of Korea	This contribution is accepted as proposed.

Draft new Recommendation ITU-T Y.QKDN-qos-ml-fa

Quantum key distribution networks: Functional architecture enhancement of machine learning based quality of service assurance

Summary

This recommendation specifies functional architecture enhancement of machine learning based QoS assurance for the quantum key distribution networks (QKDN).

This Recommendation first provides an overview of functional architecture enhancement of machine learning based QoS assurance for the QKDN. It then describes a functional architecture enhancement of QoS assurance which includes functional components such as QoS data collection, data processing, data storage, data analytics, QoS anomaly detection and prediction, QoS policy decision making, enforcement and reporting. Based on the capabilities described in the functional architecture enhancement, this recommendation specifies operational procedures of QoS assurance for the QKDN.

Keywords

QKDN, QoS assurance, functional architecture.

Table of Contents

Page

Draft new Recommendation ITU-T Y.QKDN-qos-ml-fa

Quantum key distribution networks: Functional architecture enhancement of machine learning based quality of service assurance

1. Scope

This Recommendation specifies the functional architecture enhancement of machine learning based QoS assurance for IMT-2020 network, the scope of this recommendation is as follows:

- Overview of requirements of machine learning based QoS assurance for QKDN;
- Functional architecture enhancement of machine learning based QoS assurance for QKDN;
- Reference points of machine learning based QoS assurance for QKDN
- Procedures of machine learning based QoS assurance for QKDN;

This Recommendation uses machine learning only in the context of QoS assurance. Therefore any other use of machine learning is out of scope of this Recommendation.

2. References

The following ITU-T Recommendations and other references contain provisions, which, through reference in this text, constitute provisions of this Recommendation. At the time of publication, the editions indicated were valid. All Recommendations and other references are subject to revision; users of this Recommendation are therefore encouraged to investigate the possibility of applying the most recent edition of the Recommendations and other references listed below. A list of the currently valid ITU-T Recommendations is regularly published.

The reference to a document within this Recommendation does not give it, as a stand-alone document, the status of a Recommendation.

[ITU-T E.417] Recommendation ITU-T E.417 (2005), *Framework for the network management of IP-based networks*.

[ITU-T P.10] Recommendation ITU-T P.10/G.100 (2017), *Vocabulary for performance and quality of service*.

[ITU-T Q.1741.9] Recommendation ITU-T Q.1741.9 (2015), *IMT-2000 references to Release 11 of GSM evolved UMTS core network*.

[ITU-T Y.3172] Recommendation ITU-T Y.3172 (2019), Architectural framework for machine learning in future networks including IMT-2020.

[ITU-T Y.3174] Recommendation ITU-T Y.3174 (2020), Framework for data handling to enable machine learning in future networks including IMT-2020.

[ITU-T Y.3800] Recommendation ITU-T Y.3800 (2019))/Cor.1 (2020), *Overview on networks supporting quantum key distribution*.

[ITU-T Y.3801] Recommendation ITU-T Y.3801 (2020), *Functional requirements for quantum key distribution networks*

[ITU-T Y.3802] Draft Recommendation ITU-T Y.QKDN_Arch (2020), *Functional architecture of quantum key distribution networks*.

[ITU-T Y.3803] Draft Recommendation ITU-T Y.QKDN_KM (2020), Key management for quantum key distribution networks.

[ITU-T Y.3804] Draft Recommendation ITU-T Y.QKDN_CM (2020), Control and management for quantum key distribution networks.

[ITU-T Y.3806] Draft Recommendation ITU-T Y.QKDN_QOS_REQ (2020), Requirements of QoS assurance for quantum key distribution networks.

3. Definitions

3.1 Terms defined elsewhere

3.1.1 assurance [ITU-T X.1500]: The degree of confidence that the process or deliverable meets defined characteristics or objectives.

3.1.2 network performance [ITU-T E.417]: The performance of a portion of a telecommunications network that is measured between a pair of network-user or network-network interfaces using objectively defined and observed performance parameters.

3.1.3 quality of experience [ITU-T P.10]: The degree of delight or annoyance of the user of an application or service. [b-Qualinet2013]

NOTE – Recognizing on-going research on this topic, this is a working definition which is expected to evolve for some time. (This note is not part of the definition.)

3.1.4 quality of service [ITU-T Q.1741] : The collective effect of service performances, which determine the degree of satisfaction of a user of a service. It is characterized by the combined aspects of performance factors applicable to all services, such as: service operability performance; service accessibility performance; service retainability performance; service integrity performance; and other factors specific to service.

3.2 Terms defined in this Recommendation

None.

4. Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

QoE Quality of Experience

QoS Quality of Service

QKDN Quantum key distribution networks

5. Conventions

None

6. Overview

The QKDN is expected to be able to provide optimized support for a variety of different QKD services. The key performance indicators (KPIs) include optimal latency, accuracy, throughput, and availability for key distribution.

The one of the challenges of the QKDN is to assure the network performance [ITU-T E.417] and different quality of service (QoS) [ITU-T Q.1741]/quality of experience (QoE) [ITU-T P.10] requirements of different application scenarios.

The requirements specification of machine learning based QoS assurance for the QKDN is under development in Y.QKDN-qos-ml-req to address these challenges. Based on the requirements, this Recommendation specifies machine learning based QKDN functional architecture enhancement, associated functional components, reference points among them, and operational procedures.

7. Functional architecture enhancement of machine learning based QoS assurance for QKDN

According to [ITU-T Y.3802], the QKDN layered functional architecture and the associated functional components are defined. ITU-T Recommendation Y.3811 specified the functional architecture to assure quality of service for QKDN. Further, ITU-T draft Recommendation Y.QKDN-ml-fra is currently working on defining functional architecture to enable ML capabilities for QKDN in general. This Recommendation extends functional components required for machine learning based QoS assurance as depicted in Figure 1. For this, QoS assurance functions are added in each layer management function and cross-layer management and orchestration function in QKDN management layer. These QoS assurance enhancement functions will interact with each layer ML SRC/SINK to collect information and apply QoS assurance ML policies. Note that QoS assurance enhancement functions do not introduce any additional functionality to the QKDN ML layer but utilize them to achieve objective QoS assurance. These elements are interacting with QKDN control, key management, and quantum layer's QoS assurance functions to fulfil the target QoS KPIs. This includes planning, monitoring, analysing, optimizing, and provisioning.

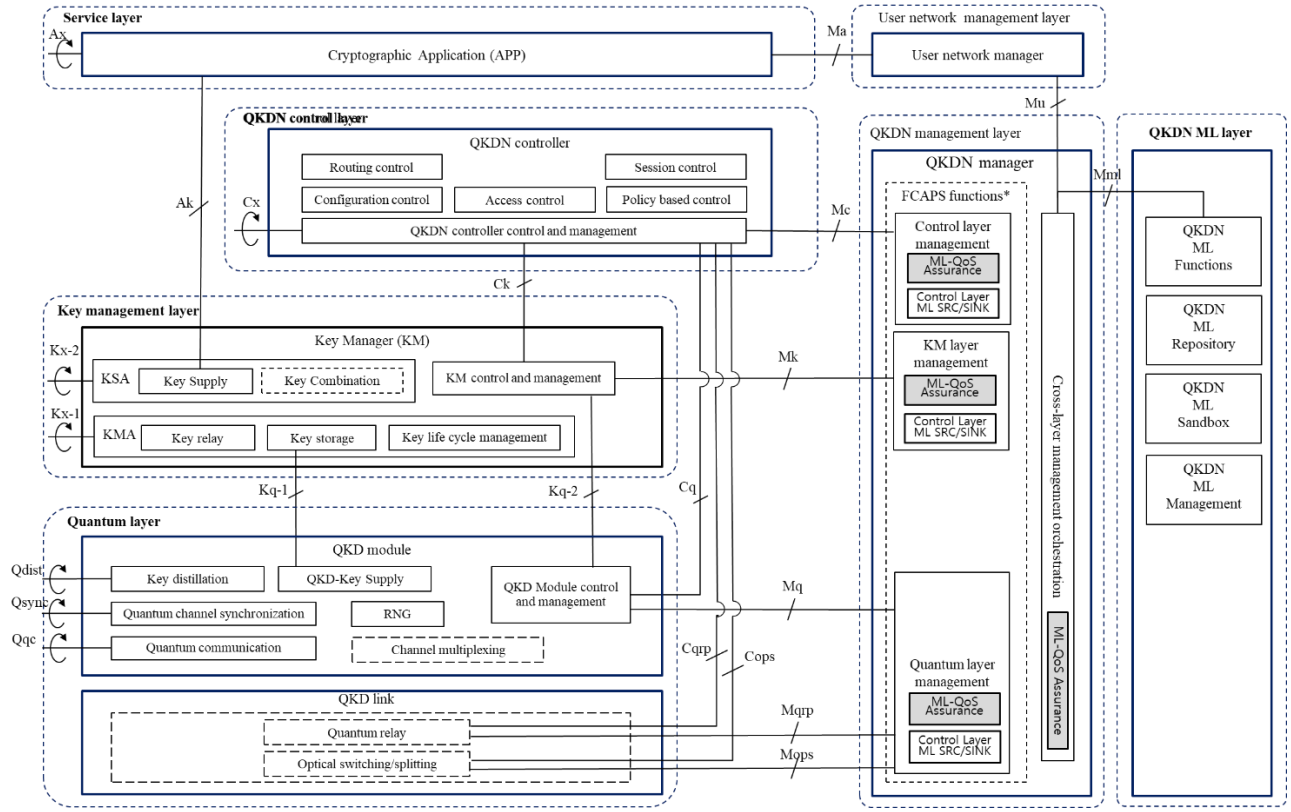

Figure 1 – Functional architecture of ML based QoS assurance for QKDN

7.1 Functional entities for ML-based QoS assurance management enhancement

The ML-based QoS assurance management functional entities and associated enhancement are illustrated in Figure 2. The dark shaded functional entities are ML-enabled QoS assurance enhancement. The QKDN control layer ML-based QoS assurance functional entities include: QoS ML-based data analysis, QoS ML-based policy generation, and QoS ML-based policy provisioning functions. The key management layer ML-based QoS assurance functional entities include: key management layer (KML) QoS measurement, KML QoS ML-based policy enforcement, and KML QoS ML-based mapping and abstraction functions. The quantum layer ML-based QoS assurance functional entities include: quantum layer (QL) QoS measurement, QL QoS ML-based policy enforcement, and QL ML-based QoS mapping and abstraction. The cross-layer management and orchestration ML-based QoS assurance functional entities include: QKDN QoS capability exposure to external management systems, QKDN service level agreement (SLA) support, QKDN ML-based QoS planning and optimization, and QKDN QoS cross-layer support functions.

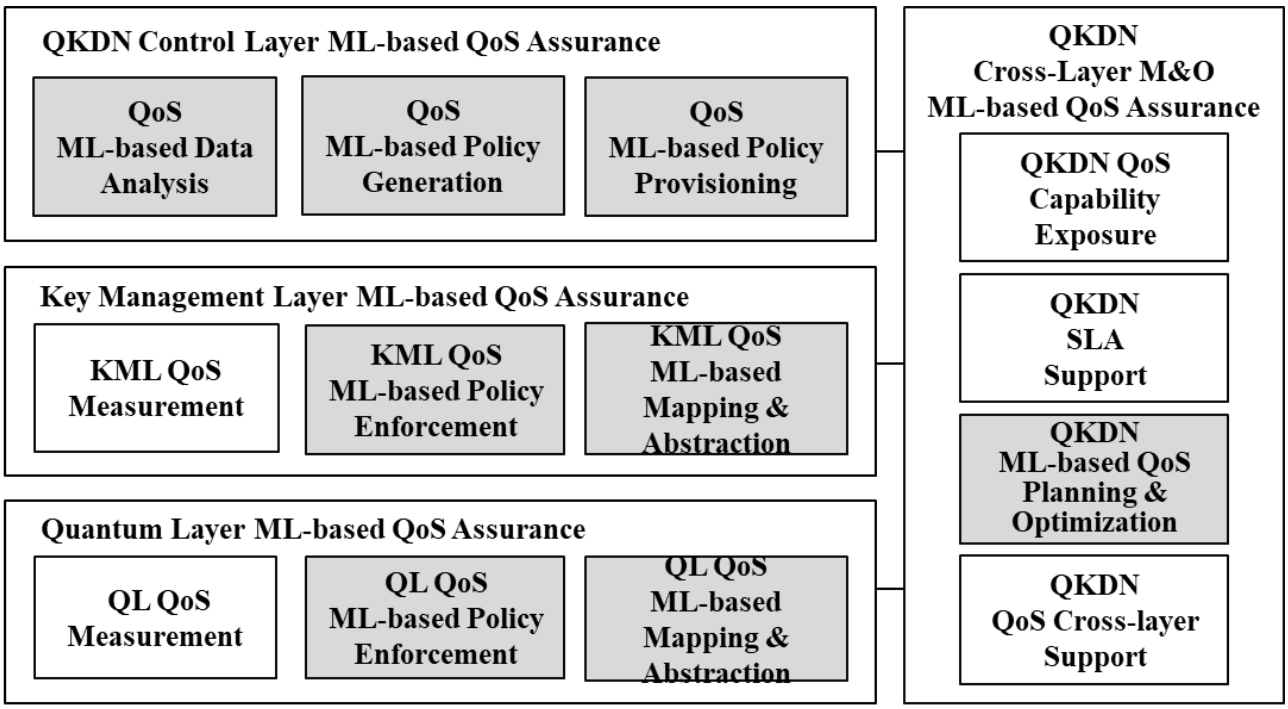

Figure 2 – QKDN ML-based QoS assurance functional entities

7.1.1 QKDN control layer ML-based QoS assurance functional entity

The QKDN control layer ML-based QoS assurance functional entity includes the following functions:

- **QoS ML-based data analysis**

The QoS ML-based data analysis functional entity receives QoS related information from QL and KML QoS measurement functional entity and performs ML-based analysis for QoS assurance. For example, it can construct correlation relationship between QoS information and QoS anomalies based on the ML models generated by training of the measured data sets.

Based on such analysis, it can detect or predict QoS related anomalies which can be utilized for achieving QoS assurance of QKDN.

- **QoS ML-based policy generation**

The QoS ML-based policy generation functional entity generates QoS policies to guarantee the quality of QKDN services based on the analysed results supplied by the QoS ML-based data analysis functional entity. The policies include KML QoS policies and QL QoS policies. They are delivered to the corresponding layer's QoS enforcement functional entity for further layer specific enforcement.

- **QoS ML-based policy provisioning**

The QoS ML-based policy provisioning functional entity translates its QoS policies to resource-facing KML and QL specific optimal provisioning rules to enforce QoS assurance control, QoS interworking and mapping, and efficient end-to-end(E2E) QoS provisioning. It then triggers each layer QoS policy enforcement functional entity to complete provisioning processes. It also performs verification of the intended provisioning.

7.1.2 Key management layer ML-based QoS assurance functional entity

The QKDN key management layer ML-based QoS assurance functional entity includes the following functions:

- **KML QoS ML-based policy enforcement**

The KML QoS ML-based policy enforcement functional entity enforces KML QoS policy sent from the control layer. It is mainly focusing on queue management associated with KML links such as KMA and KSA links. An important goal of queue management is to minimize the steady-state queue size while not under-utilizing link as well as avoiding the lock-out phenomenon where a single connection or flow monopolizes the queue space. The detailed QoS enforcement functions include packet marking, congestion avoidance, queue shaping, and queue scheduling with a finer level of QoS granularities (e.g., per-flow). Schemes for queue management differ mainly in the criteria for dropping packets and what packets should be dropped. The use of multiple queues introduces further variation in the schemes, for example, in the way packets are distributed among the queues. It can utilize weighted random early detection (WRED) queue management algorithm, priority queuing (PQ), and weighted round-robin (WRR) queue scheduling algorithms.

- **KML QoS ML-based mapping and abstraction**

The KML QoS ML-based mapping and abstraction functional entity is used to support proper QoS interworking between networks that packets traverse different network domains (e.g., mapping key management (KM) access network QoS classes to KM backbone network QoS classes). QoS class can be associated with three attributes: priority, packet delay budget and packet error loss rate.

7.1.3 Quantum layer ML-based QoS assurance functional entity

The QKDN quantum layer ML-based QoS assurance functional entity includes the following functions:

- **QL QoS ML-based policy enforcement**

The QL QoS ML-based enforcement functional entity enforces QL QoS policy sent from the QoS ML-based policy provisioning functional entity in the QKDN control layer. It is mainly focusing on queue management associated with quantum and classical channels. An important goal of queue management is to minimize the steady-state queue size while not under-utilizing link as well as avoiding the lock-out phenomenon where a single connection or flow monopolizes the queue space. The detailed QoS enforcement functions include packet marking, congestion avoidance, queue shaping, and queue scheduling with a finer level of QoS granularities (e.g., per-flow). Schemes for queue management differ mainly in the criteria for dropping packets and what packets should be dropped. The use of multiple queues introduces further variation in the schemes, for example, in the way packets are distributed among the queues. It can utilize WRED queue management algorithm, PQ, and WRR queue scheduling algorithms.

- **QL QoS ML-based mapping and abstraction**

The QL QoS ML-based mapping and abstraction functional entity is used to support proper QoS interworking between networks that packets traverse different network domains (e.g., mapping

quantum access network QoS classes to quantum backbone network QoS classes). QoS class can be associated with three attributes: priority, packet delay budget and packet error loss rate.

7.1.4 QKDN Cross-layer M&O ML-based QoS assurance functional entity

The QKDN cross-layer M&O ML-based QoS assurance functional entity includes the following functions:

- **QKDN QoS ML-based planning and optimization**

The QKDN QoS ML-based planning receives the knowledge of real QKDN QL and KML traffic estimates and topology, utilisation of accurate models for control and user data (e.g., key information, etc.) transmissions, and implementation of the actual QKDN functional entities characteristics, functionalities and parameters. Then, QoS planning provides an estimate of the QKDN coverage, capacity and resources requirements.

The QKDN QoS ML-based optimisation can update the QoS planning results to improve the overall QKDN quality, user's QoE and to ensure that the QKDN resources are efficiently utilized.

The estimation and optimization results are realized by QoS provisioning in the underlying QKDN.

8. Reference points of machine learning based QoS assurance for QKDN

9. Procedures of machine learning based QoS assurance for QKDN

10. Security considerations

.

_____