Annex I:

Draft new Recommendation ITU-T Y.QKDN-amc

Quantum key distribution network – Requirements and architectural model for autonomic management and control

Summary

Autonomic Management and Control (AMC) is about Decision-making-Elements (DEs) as autonomic functions (i.e. control-loops) with cognition introduced in the management layer as well as in the control layer. Cognition in DEs, enhances DE logic and enables DEs to manage and handle even the unforeseen situations and events detected in the environment around the DE(s). As the number and diversity of devices that make up the individual QKDNs continue to grow, automating QKDN control and management tasks becomes ever-more important to improve the quality of services (QoS).

To cope with the challenges of QKDN control and management, while minimizing human intervention towards full automation of QKDN, this draft Recommendation specifies the requirements and architectural models for AMC in QKDNs including the overview, requirements, consideration for cognition process and architectural model.

Keywords

Autonomic Management and Control (AMC), Cognition, QKD (quantum key distribution), QKDN (QKD network)

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Draft new Recommendation ITU-T Y.QKDN-amc

Quantum key distribution network –Requirements and architectural model for autonomic management and control

1 Scope

To support the autonomic networking, cognitive networking and self-management for improving the QoS in a quantum key distribution network (QKDN), this draft Recommendation specifies the requirements and architectural models for autonomic management and control (AMC) in QKDNs. In particular, the scope of this Recommendation includes:

- Overview of AMC in QKDN;
- Requirements for AMC in QKDN;
- Consideration for cognition process of AMC in QKDN.
- Architectural model for AMC in QKDN;

2 References

[ITU-T Y.3182] Recommendation ITU-T Y.3182 (2022), *Machine learning based end-to-end multi-domain network slice management and orchestration.*

[ITU-T Y.3324] Recommendation ITU-T Y.3324(2018), *Requirements and architectural framework for autonomic management and control of IMT-2020 networks*.

[ITU-T Y.3800] Recommendation ITU-T Y.3800 (2019), *Framework for Networks to support Quantum Key Distribution*.

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

[ITU-T Y.3802] Recommendation ITU-T Y.3802 (2020), *Functional architecture of the Quantum Key Distribution network.*

[ITU-T Y.3803] Recommendation ITU-T Y.3803 (2020), *Key management for quantum key distribution network*.

[ITU-T Y.3804] Recommendation ITU-T Y.3804 (2020), *Control and Management for Quantum Key Distribution Network.*

3 Definitions

3.1 Terms defined elsewhere

This Recommendation uses the following terms defined elsewhere:

3.1.1 **Autonomic Management and Control (AMC)** [ITU-T Y.3324]: A behaviour or action which is determined in a reactive or proactive manner based on the external stimuli (environment aspects) as well as the goals they are required to fulfil, principles of operation, capabilities, experience and knowledge.

NOTE – In the case of software defined networks, this definition means that AMC has the ability to dynamically select the network's configuration, control and manage the network, through self-management functionality that reaches optimal decisions, taking into account the context of operation (environment requirements and characteristics), goals and policies (corresponding to principles of operation), profiles (corresponding to capabilities i.e. functional features supported), and machine learning (for managing and exploiting knowledge and experience.

3.1.2 **key manager (KM)** [ITU-T Y.3800]: A functional module located in a quantum key distribution (QKD) node to perform key management in the key management layer.

3.1.3 **quantum key distribution (QKD)** [b-ETSI GR QKD 007]: Procedure or method for generating and distributing symmetrical cryptographic keys with information theoretical security based on quantum information theory.

3.1.4 **quantum key distribution link (QKD link)** [ITU-T Y.3800]: A communication link between two quantum key distribution (QKD) modules to operate the QKD.

NOTE – A QKD link consists of a quantum channel for the transmission of quantum signals, and a classical channel used to exchange information for synchronization and key distillation.

3.1.5 **quantum key distribution module (QKD module)** [ITU-T Y.3800]: A set of hardware and software components that implements cryptographic functions and quantum optical processes, including quantum key distribution (QKD) protocols, synchronization, distillation for key generation, and is contained within a defined cryptographic boundary.

NOTE – A QKD module is connected to a QKD link, acting as an endpoint module in which a key is generated. These are two types of QKD modules, namely, the transmitters (QKD-Tx) and the receivers (QKD-Rx).

3.1.6 **quantum key distribution network (QKDN)** [ITU-T Y.3800]: A network comprised of two or more quantum key distribution (QKD) nodes connected through QKD links.

NOTE – A QKDN allows sharing keys between the QKD nodes by key relay when they are not directly connected by a QKD link.

3.1.7 **quantum key distribution network controller (QKDN controller)** [ITU-T Y.3800]: A functional module, which is located in a quantum key distribution (QKD) network control layer to control a QKD network.

3.1.8 **quantum key distribution network manager (QKDN manager)** [ITU-T Y.3800]: A functional module, which is located in a quantum key distribution (QKD) network management layer to monitor and manage a QKD network.

3.1.9 **quantum key distribution node (QKD node)** [ITU-T Y.3800]: A node that contains one or more quantum key distribution (QKD) modules protected against intrusion and attacks by unauthorized parties.

NOTE – A QKD node can contain a key manager (KM).

3.1.10 **quality of experience (QoE)** [b-ITU-T P.10]: The degree of delight or annoyance of the user of an application or service.

3.1.11 **quality of service (QoS)** [b-ITU-T Q.1741.9]: 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;

– 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:

KM	Key manager
KMA	Key Management Agent
KSA	Key Supply Agent
ML	Machine Learning
QKD	Quantum Key Distribution
QKDN	QKD Network

5 Conventions

In this Recommendation:

The keywords "is required to" indicate a requirement which must be strictly followed and from which no deviation is permitted if conformance to this document is to be claimed.

The keywords "is recommended" indicate a requirement which is recommended but which is not absolutely required. Thus, this requirement need not be present to claim conformance.

6 Overview of AMC in QKDN

Editor's note – This clause will describe the faced challenges of QKDN, the advantages and key technologies to enable the AMC in QKDN.

Recently, the four emerging computing and networking paradigms that have influenced ICT/telecommunication industries are cloud computing, software-defined networking (SDN), network function virtualization (NFV), and machine learning. Fundamental research on these paradigms has quite matured and enough results are available for exploitation. Another network paradigm which is of the same importance is autonomic management and control (AMC) of networks and services. Its fundamental research has also matured. Further developments, however, are needed to take advantage of the benefits of these five paradigms when combined together in the design of future network including quantum key distribution network.

AMC is about Decision-making-Elements (DEs) as autonomic functions (i.e. control-loops) with cognition introduced in the management layer as well as in the control layer (whether these layers are distributed or centralized). Cognition (learning and reasoning used to effect advanced adaptation) in DEs, enhances DE logic and enables DEs to manage and handle even the unforeseen situations and events detected in the environment around the DE(s). DEs realize self-* features (self-configuration, self-optimization, etc.) as a result of the decision-making behaviour of a DE that performs dynamic/adaptive management and control of its associated Managed Entities (MEs) and their configurable and controllable parameters. Such a DE can be embedded in a network node (Network Element (NE) in general) or higher at a specific layer of the outer overall network and services management and control architecture. DEs (software components) are meant to empower the networks and the management and control planes to realize self-* properties: auto-discovery of information/resources/capabilities/services; self-configuration; self-protecting; self-diagnosing; self-repair/healing; self-optimization; self-organization behaviours; as well as self-awareness.

As the number and diversity of devices that make up the individual QKDNs continue to grow, automating QKDN control and management tasks becomes ever-more important to improve the quality of services (QoS). To cope with the challenges of QKDN control and management, while minimizing human intervention towards full automation of QKDN, this draft Recommendation specifies the requirements and architectural models for AMC in QKDNs including the overview, requirements, consideration for cognition process and architectural models

7 Requirements for AMC in QKDN

AMC of QKDN is required to meet the following high-level requirements:

REQ-1. It is required to support autonomic management capabilities including knowledge layer with cognitive management functionality for QKDN and services

NOTE 1 – knowledge layer provides necessary functionality to support autonomic management of QKDN and services. The one of the main functions of the knowledge layer is a cognitive management process which is a control loop of observe, normalize, compare, learn, plan, decide, and act sub-processes. Autonomic management decisions and associated actions are made through this process.

REQ-2. It is required to support scalability of its management functionality

NOTE 2 – autonomic management functionality should be scalable to be used in complex and large management environment

REQ-3. It is required to support availability and reliability of its management functionality

REQ-4. It is required to support real, near-real, and/or non-real time autonomic management

decision making and operations

NOTE 3 – cognition process supports three mode of operations: expedited, high-priority, and normal to meet this requirement.

REQ-5. It is required to support interworking with the management functionality of QKDN to enable autonomic management functionality

NOTE 4 – autonomic management should co-exist with other management functionality. It is a supporting functionality of the other management functionality.

8 Consideration for cognition process of AMC in QKDN

Editor's note – This clause will describe the consideration for cognition process of AMC in QKDN, which can be the base for the architecture. The realization technologies for AMC in QKDN such as SDN, ML, Cloud computing can be considered.

A cognitive management process which is a control loop of observe, normalize, compare, learn, plan, decide, and act sub-processes. Autonomic management decisions and associated actions are made through this process.

Cloud computing, SDN, NFV, and ML are core enablers of AMC. AMC requires the seamless intelligent decision making feedback loop of the precise monitoring of status of managed resources, intelligent decision making and necessary policy generation based on the monitored information and open programmable enforcement of generated policies. Cloud computing provides an abundant resource pool which complex autonomic decision making processes are required for. SDN provides open control capability of enforcing autonomic decision policies. NFV provides a virtual programmable execution environment that autonomic decision entities could run. Lastly, ML provides an intelligence for optimal decision making of the complex networking environment. The built-in cognitive management integrates ML as part of the workflows and operations to support intelligent operations.

9 Architectural model for AMC in QKDN

Editor's note – This clause will describe the architectural model to enable the AMC in QKDN.

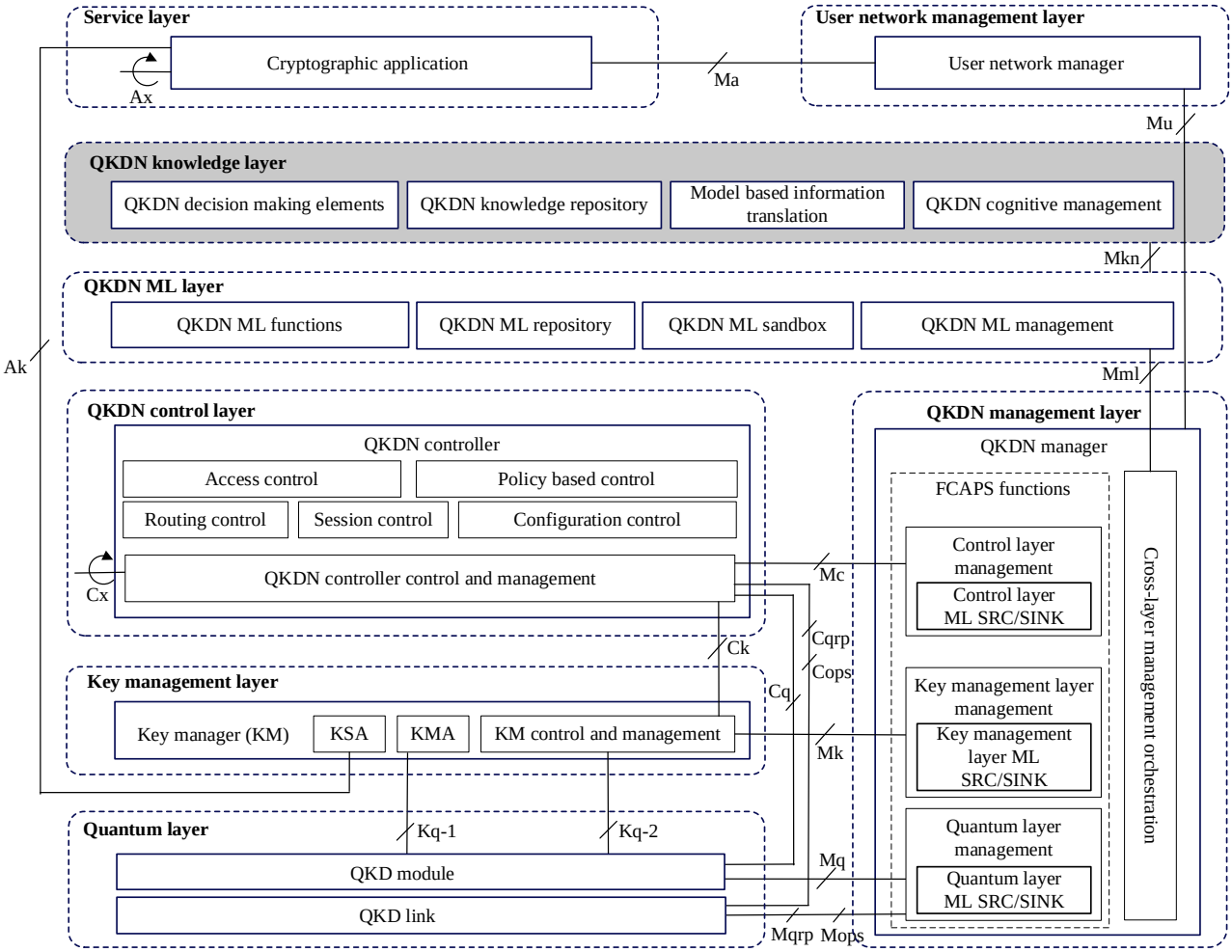

Fig. 8.1. Architectural model for AMC in QKDN

The new QKDN knowledge layer is added based on the architecture model of ML-enabled QKDN in [ITU-T Y.QKDN-ml-fra]. It includes QKDN decision making elements, QKDN knowledge repository, model-based information translation and QKDN cognitive management. QKDN cognitive management can realize the cognitive process with closed loop for different objectives.

Bibliography

[1] ETSI White Paper no. 16: The *Generic Autonomic Networking Architecture Reference Model for Autonomic Networking, Cognitive Networking and Self-Management of Networks and Services*: http://www.etsi.org/images/files/ETSIWhitePapers/etsi_wp16_gana_Ed1_20161011.pdf

Annex II

A.1 justification for proposed draft new ITU-T Y.QKDN-amc "Quantum key distribution network – Requirements and architectural model for autonomic management and control"

Question:	Q16/13 **Proposed new ITU-T Recommendation**	Geneva, 14-25 November 2022	
Reference and title:	ITU-T Y.QKDN-amc "Quantum key distribution networks - Requirements and architectural model for autonomic management and control"		
Base text:	Annex I	**Timing:**	2024, July
Editor(s):	Taesang Choi, Qingcheng zhu, Xiaosong yu, Yongli zhao, Ui-Jun Baek	**Approval process:**	AAP

Scope (defines the intent or object of the Recommendation and the aspects covered, thereby indicating the limits of its applicability):

To support the autonomic networking, cognitive networking and self-management for improving the QoS in a quantum key distribution network (QKDN), this draft Recommendation specifies the requirements and architectural model for autonomic management and control (AMC) in QKDNs. In particular, the scope of this Recommendation includes:

- Overview of AMC in QKDN;
- Requirements for AMC in QKDN;
- Consideration for cognition process of AMC in QKDN.
- Architectural model for AMC in QKDN;

Summary (provides a brief overview of the purpose and contents of the Recommendation, thus permitting readers to judge its usefulness for their work):

Autonomic Management and Control (AMC) is about Decision-making-Elements (DEs) as autonomic functions (i.e. control-loops) with cognition introduced in the management layer as well as in the control layer. Cognition in DEs, enhances DE logic and enables DEs to manage and handle even the unforeseen situations and events detected in the environment around the DE(s). As the number and diversity of devices that make up the individual QKDNs continue to grow, automating QKDN control and management tasks becomes ever-more important to improve the quality of services (QoS).

To cope with the challenges of QKDN control and management, while minimizing human intervention towards full automation of QKDN, this draft Recommendation specifies the requirements and architectural model for AMC in QKDNs including the overview, requirements, consideration for cognition process and architectural model.

Relations to ITU-T Recommendations or to other standards (approved or under development)**:**

ITU-T Y.3800 "Overview on networks supporting quantum key distribution"

ITU-T Y.3801 "Functional requirements for quantum key distribution networks"

ITU-T Y.3802 "Quantum key distribution network – Functional architecture"

ITU-T Y.3803 "Quantum key distribution networks – Key management"

ITU-T Y.3804 "Quantum key distribution networks - Control and management"

ITU-T Y.3805 "Quantum key distribution networks – Software-defined networking control"

ITU-T Y.3806 "Quantum key distribution networks - Requirements for QoS assurance"

ITU-T Y.3172 "Architectural framework for machine learning in future networks including IMT-2020"

ITU-T Y.3177 "Architectural framework for artificial intelligence-based network automation and fault management in future networks including IMT-2020"

ITU-T Y.3182 "Machine learning based end-to-end multi-domain network slice management and orchestration"

ITU-T Y.3812 "Quantum key distribution networks - Requirements for machine learning based quality of service assurance"

Liaisons with other study groups or with other standards bodies:

ITU-T SG2, FG-AN, ETSI ISG-QKD.

Supporting members that are committing to contributing actively to the work item:

Beijing University of Posts and Telecommunications, China; CAS Quantum Network Co. Ltd., China; QuantumCTek Co., Ltd., China; China Academy of Information and Communication Technology (CAICT), MIIT. P.R. China; Electronics and Telecommunications Research Institute (ETRI), Korea; Korea University, Korea.