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Abstract: This document includes the output of Recommendation ITU-T Y.QKDN-amc “Quantum key distribution networks - requirements and architectural model for autonomic management and control” based on the discussion result of the Q16/13 July meeting, 2023.

Summary

This TD is the output document for the draft Recommendation ITU-T Y.QKDN-amc “Quantum key distribution networks - requirements and architectural model for autonomic management and control” based on the following input contributions and the discussion during the Q16/13 July meeting, 2023.

C-130	BUPT	Y.QKDN-amc “Quantum key distribution network – Requirements and architectural model for autonomic management and control”: Editorial revisions	accepted as proposed

- Proposal of contribution

– This contribution proposes to improve Draft Recommendation Y.QKDN-amc "Quantum key distribution network – Requirements and architectural model for autonomic management and control" with editorial revisions.

- Meeting result

– The editorial revisions are accepted.
– Additionally, the relationship between this draft and ITU-T Y.3324 needs the further clarification.

C-131	ETRI, Korea University, KT	Proposed revision of AMC cognition process description in the ITU-T Y.QKDN-amc	accepted as proposed

- Proposal of contribution

– This contribution proposes to revise AMC cognition process description in the clause 8 of Y.QKDN-amc.

- Meeting result

– The proposal is accepted.
– Additionally, the consideration for cognition process is suggested to be before the requirements, and keep consistent with the requirements.
– The explanation of decision-making elements (DEs) is needed. The use cases for AMC in QKDN is suggested.

Annex I:

Draft 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 avoid the untimely actions and 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 ~~A~~autonomic ~~M~~management and ~~C~~control (AMC)~~AMC~~ in QKDNs including the overview, requirements, consideration for cognition process and architectural model.

Keywords

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

Table of Contents

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Draft 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), t~~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*.

~~3 [ITU-T Y.3802] Recommendation ITU-T Y.3802 (2020), *Functional architecture of the Quantum Key Distribution network.*~~

~~4 [ITU-T Y.3803] Recommendation ITU-T Y.3803 (2020), *Key management for quantum key distribution network.*~~

~~5 [ITU-T Y.3804] Recommendation ITU-T Y.3804 (2020), *Control and Management for Quantum Key Distribution Network.*~~

~~6~~3 Definitions

~~6.1~~3.1 Terms defined elsewhere

This Recommendation uses the following terms defined elsewhere:

3.1.1 **a~~A~~utonomic ~~Management~~ management and ~~Control~~ 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~~3.1.10 **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.

~~6.2~~3.2 Terms defined in this Recommendation

None.

~~7~~4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

DE	Decision-making Element
KM	Key ~~m~~Manager
KMA	Key Management Agent
KSA	Key Supply Agent
ML	Machine Learning
NFV	Network Function Virtualization
QKD	Quantum Key Distribution
QKDN	QKD Network
SDN	Software-Defined Networking

~~8~~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.

~~9~~ 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.***~~

6

[Editor's note: The relationship between this draft and ITU-T Y.3324 needs the more clarification. The decision-making elements (DEs) are suggested to be clarified.]

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, so as to avoid the untimely actions and improve the QoS. AMC [ITU-T Y.3324] can enable the network to adjust to the varying network conditions and service demands in a timely and efficient manner without requiring human intervention. ~~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~~

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~~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 Consideration for cognition process of AMC in QKDN

[Editor's note: The use cases to illustrate the role and advantages of AMC in QKDN (e.g. AMC in key supply) will be helpful for readers to understand.]

The cognition process of AMC in QKDN is based on a decision making feedback loop of monitoring, learning, decision, and action sub-processes as shown in Fig. 8.1. The consideration for each sub-process is as follows.

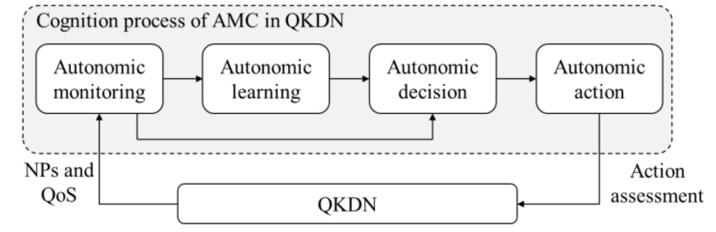

Fig. 8.1 Cognition process of AMC in QKDN.

- **Autonomic monitoring:** This sub-process involves collecting and analyzing information about the network performances (NPs) and QoS of the QKDN, such as QKD modules status and key manager status, etc. The monitoring data can be used to detect any changes, anomalies, or problems in the QKDN that require attention or intervention.
- **Autonomic learning:** This sub-process involves acquiring and updating knowledge based on the analyzed data about the QKDN and its environment, such as the characteristics, capabilities, and behaviors of QKDN functional components. The learning data can be used to improve the understanding and prediction of the dynamic QKDN performances.
- **Autonomic decision:** This sub-process involves selecting and planning the best course of actions to achieve a desired goal or to solve a problem in the QKDN. The decision data can be based on the monitoring and learning data, as well as on the predefined policies, rules, and objectives of the QKDN.
- **Autonomic action:** This sub-process involves executing and evaluating the chosen action to modify or optimize the QKDN. The action data can be used to assess the effectiveness and efficiency of the action, which will provide feedback for further monitoring and learning.

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

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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.

The cognition process described in the Fig. 8.1 is the general one. Any autonomic closed-loop should the follow the four general steps: monitoring, learning, decision, and action. However, these general steps can be further divided into more specific steps depending on the timing, priority, and action types. They are collect, normalize, ccompare, plan, decide, and act. Monitoring consists of collect and normalize sub-steps, Decision consists of compare, plan, and decide sub-steps. For example, when the cognition process of autonomic control and management is inititated for the first time, the98re are no learned or history information for an autonomic control and management action. In this case full cycle of monitoring, learning, decision, and action steps has to be executed. However, when learned or history information, decision, and/or actions exist, the cognition process can be executed more efficiently by skipping some steps, for example, learning, and/or decision making steps. The fastest loop (urgent), thus, can be monitoring, compare, and action steps only when the monitored event is learned or known in priori. Another faster loop (high priority) can be monitoring, decision (compare and decide), and action when the learned or history information exist but a further decision making step is necessary. The figure 8.2 illustrates the three types of autonomic management and control cognition process.

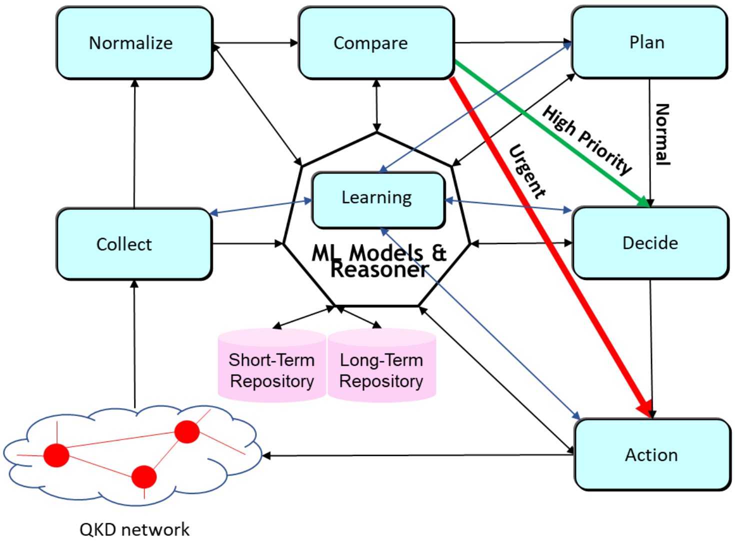

Fig. 8.2 Detailed cognition process of AMC in QKDN

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~~10~~8 Requirements for AMC in QKDN

~~10.1~~8.1 High-level requirements for AMC in QKDN

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

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

  NOTE – 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~~monitoring, learning, decision and action sub-processes. Autonomic management decisions and associated actions are made through this process.

- –It is required to support scalability of ~~autonomic management and control~~AMC functionality for QKDN.

  NOTE – ~~autonomic management~~AMC functionality should be scalable to be used in complex and large QKDN management and control environment.

- –It is required to support availability and reliability of ~~autonomic management and control~~ AMC functionality for QKDN.

- –It is required to support real, near-real, and/or non-real time ~~autonomic management and control~~AMC decision making and operations.

  NOTE – cognition process is required to support three modes of operations: expedited, high-priority, and normal to meet this requirement.

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

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

- It is required to support performance ~~of its~~ management functionality.

- It is required to support coordination functionality of ~~autonomic management and control~~ AMC capabilities.

~~10.2~~8.2 Functional requirements for AMC in QKDN

Based on the QKDN control and management requirements specified in [ITU-T Y.3801] and the functional requirements of AMC specified in [ITU-T Y.3324], AMC in QKDN is required to meet the following functional requirements~~: auto-configuration, auto-optimization, auto-monitoring and auto-diagnose~~.

[Editor's note: The functional requirements need the further improvement to keep consistent with the clause 7.]

~~10.2.1~~

~~10.2.2~~8.2.1 Functional requirements for autonomic knowledge management in QKDN

- ~~REQ 1.~~ It is required to support capability of autonomic ~~decision making element~~DE in the QKDN knowledge layer

  NOTE ~~1~~ – Autonomic ~~decision~~ DE~~making element~~ in the QKDN knowledge layer is responsible for an entire QKDN context. -Thus, a slow control loop operation is used in non-real time manner.

- ~~REQ 2.~~ It is required to support capability of ~~machine learning~~ML repository in the QKDN knowledge layer.

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- ~~REQ 3.~~ It is required to support capability of model-based information translation in the QKDN knowledge layer.
- ~~REQ 4.~~ It is required to support capability of cognitive management in the QKDN knowledge layer.
- ~~REQ 5.~~ It is required to support capability of control layer autonomic DE in the QKDN management layer.

  NOTE ~~5~~ – Control layer autonomic DE supports real-time or near real-time closed-loop operation.
- ~~REQ 6.~~ It is required to support capability of key management layer autonomic DE in the QKDN management layer.

  NOTE ~~6~~ – Key management layer autonomic DE supports real-time or near real-time closed-loop operation.
- ~~REQ 7.~~ It is required to support capability of quantum layer autonomic DE in the QKDN management layer.

  NOTE ~~7~~ – Quantum layer autonomic DE supports real-time or near real-time closed-loop operation.
- ~~REQ 8.~~ It is required to support reference points between the QKDN knowledge layer and QKDN ML layer.
- ~~1.~~ ~~REQ 9.~~ It is required to support reference points between the QKDN knowledge layer and QKDN management layer.

~~10.2.3~~8.2.2 Functional requirements for autonomic configuration management in QKDN

- ~~The QKDN controller~~It is required to provide autonomic configuration control of QKD modules, QKD links, KMs and KM links.
- ~~The QKDN manager~~ It is required to provide autonomic configuration management of virtual and physical resource provisioning.
- ~~The QKDN manager~~It is recommended to provide autonomic configuration management to support:
  - ~~1~~ autonomic routing and rerouting of key relay if the QKDN supports key relay.
  - ~~2~~ autonomic collecting and managing a network topology;
  - ~~3~~ autonomic resource configuration for inventory management;
  - ~~4~~ autonomic changing of managed resources based on the demand and availability;
  - ~~5~~ autonomic discovering QKD managed resources in the managed QKDN.
  -

~~10.2.4~~8.2.3 Functional requirements for autonomic performance management in QKDN

- It is required to support autonomic collection/receipt of the status information provided by the quantum, key management, and control layers.
- ~~The QKDN controller~~It is recommended to automatically provide fault, performance, accounting and configuration information to a QKDN manager.
  - ~~2. The QKDN manager is required to support autonomic collection/receipt of the status information provided by the quantum, key management, and control layers;~~
  - ~~3.~~

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~~10.2.5~~8.2.4 Functional requirements for autonomic fault management in QKDN

- ~~The QKDN manager~~It is required to provide autonomic fault management to support autonomic analysis of the status information collected/received for fault indicators.
- ~~The QKDN manager~~It is required to support autonomic diagnose of the known faults (e.g., traffic affected faults or non-traffic affected faults).
- ~~The QKDN manager~~It is recommended to support autonomic healing, for example, based on autonomic location and autonomic correction of the root cause of known failures.

  NOTE – Since the target failure in this requirement is known in the past, autonomic location and autonomic correction of the same types of failure can be supported. Autonomic healing is the overall process to remedy such known failures based on these two functionalities (i.e., autonomic location and correction).

- ~~The QKDN manager~~ It is required to support autonomic protection of QKDN including virtual ones from malicious attacks and unauthorized access

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~~10.2.6~~8.2.5 Functional requirements for autonomic security management in QKDN

- ~~The QKDN manager~~It is recommended to automatically provide security management to support auto-management of authentication and authorization.

~~10.2.7~~8.2.6 Functional requirements for autonomic optimization in QKDN

- ~~The QKDN controller~~It is required to provide auto-routing control of key relay if the key relay function is supported by a QKDN based on the resource status and the service requirements.
- ~~The QKDN controller~~It is recommended to provide autonomic ~~quality of service (~~QoS~~)~~ policy control.
- ~~The QKDN manager~~It is recommended to automatically provide security management to support auto-management of authentication and authorization.

~~10.2.8~~8.2.7 Functional requirements for other autonomic management and control in QKDN

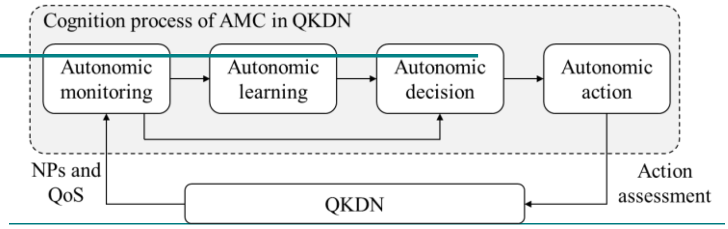
- It is required to support interface with the management functionality of QKDN.
- It is required to support information model for the interface with the management functionality of QKDN.

~~11 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.~~

~~The cognition process of AMC in QKDN is based on a decision making feedback loop of monitor, learn, decide, and act sub-processes as shown in Fig. 8.1. The consideration for each sub-process is as follows.~~



~~Fig. 8.1 Cognition process of AMC in QKDN.~~

- ~~**Monitor:** This sub-process involves collecting and analyzing information about the network performances (NPs) and QoS of the QKDN, such as QKD modules status and key manager status, etc. The monitoring data can be used to detect any changes, anomalies, or problems in the QKDN that require attention or intervention.~~
- ~~**Learn:** This sub-process involves acquiring and updating knowledge based on the analyzed data about the QKDN and its environment, such as the characteristics, capabilities, and behaviors of QKDN functional components. The learning data can be used to improve the understanding and prediction of the dynamic QKDN performances.~~
- ~~**Decide:** This sub-process involves selecting and planning the best course of actions to achieve a desired goal or to solve a problem in the QKDN. The decision data can be based on the monitoring and learning data, as well as on the predefined policies, rules, and objectives of the QKDN.~~
- ~~**Act:** This sub-process involves executing and evaluating the chosen action to modify or optimize the QKDN. The action data can be used to assess the effectiveness and efficiency of the action, which will provide feedback for further monitoring and learning.~~

~~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.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.~~

~~12~~ Architectural model for AMC in QKDN

~~9 *Editor's note – This clause will describe the architectural model to enable the AMC in QKDN.*~~

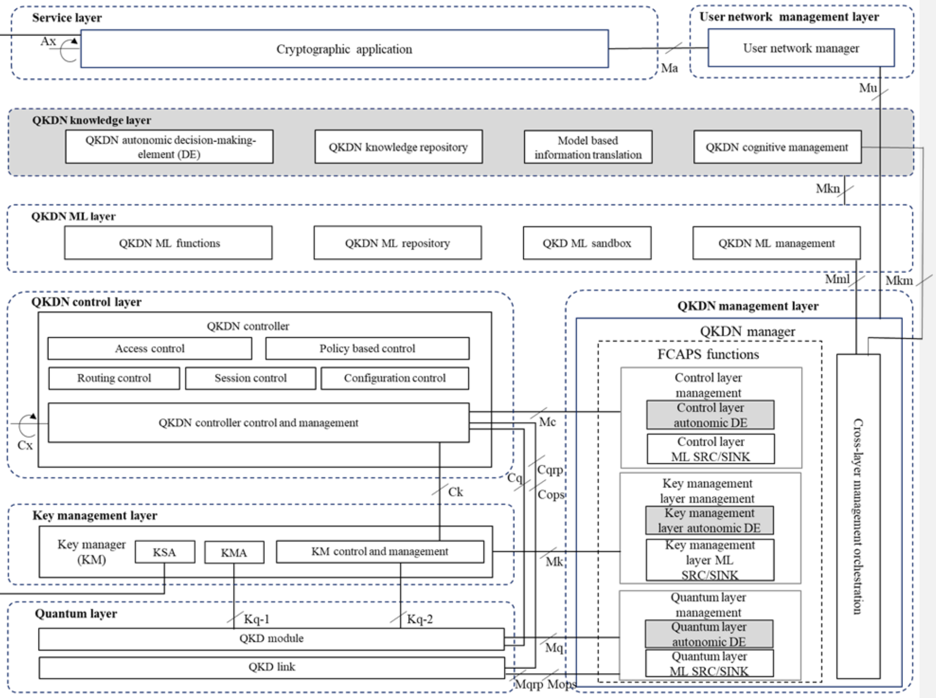


Fig. 8.1. Architectural model for AMC in QKDN

[Editor's note: The decision-making elements (DEs) need the more description.]

The new QKDN knowledge layer is added based on the architecture model of ML-enabled QKDN in [ITU-T Y.~~QKDN-ml-fra~~3814]. It includes QKDN ~~decision-making element~~DEs, QKDN knowledge repository, model-based information translation and QKDN cognitive management.

- In the QKDN knowledge layer, QKDN ~~decision making element~~DEs provide global ~~autonomic control and management~~ AMC capabilities for QKDN. It makes autonomic policy decisions that encompass quantum, key management, and control layers as a slow closed-loop.
- The local autonomic DEs specific to the quantum layer, key management layer and QKDN control layer are located in the QKDN management layer make faster closed-loop decisions based on the local AMC policies provided by the QKDN knowledge layer~~;~~.
  - For quantum layer, it provides self-management capabilities of quantum modules and links.
  - For key management layer, it provides self-management capabilities of optimal key storage and distribution~~.~~.
  - For control layer, it provides self-management capabilities of control plane resources and functional entities for the autonomic control orchestration and control entities management, etc.
- QKDN knowledge repository provides capabilities to store the QKDN-wide self-management policy information in a distributed manner to deal with the scalability of large volumes and performance of accessing distributed repositories.

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- Model-based information translation provides translation of self-management policies into layer specific provisioning rules. To support heterogenous types of information, a translation model is used to translate from/to heterogeneous information into a common one.
- QKDN cognitive management provides a realization of the cognitive process~~, which is a control loop of observe, normalize, compare, learn, plan, decide, and act sub-processes~~. It also supports interaction with QKDN management layer to deploy the DE decision policies into control layer autonomic DE, key management layer DE, and quantum layer DE and to monitor status of operation of DEs.

Bibliography

~~4 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~~