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Integration of Network Management Agent (NMA) into ACTN-Based Optical Network

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Abstract

With the growth of optical network scale, the complexity of network operation and maintenance has increased dramatically. Enhancing the intelligence level of optical network operation and management and building high-level autonomous optical networks have become the common vision of global operators. The development of AI, especially large AI model technologies, provides a feasible technical path for realizing autonomous perception, decision-making, analysis, and execution. The existing ACTN architecture provides network abstraction and control functions for optical networks but lacks higher-level autonomous capabilities.

This document explores the introduction of AI based Network Management Agent(NMA) functions into ACTN-based optical networks to achieve high-level autonomy of optical networks. It discusses the ACTN-enhanced architecture of optical networks after the introduction of NMAs, including key components, interaction relationships, new interface requirements in the enhanced architecture, as well as typical use cases of agent-based autonomous operation and maintenance for optical networks. The document aims to improve the autonomy level of optical networks and promote the realization of autonomous optical networks by extending the original ACTN architecture.

Discussion Venues

This note is to be removed before publishing as an RFC.

Discussion of this document takes place on the Network Management Operations Working Group mailing list (nmop@ietf.org), which is archived at https://mailarchive.ietf.org/arch/browse/ccamp/.

Source for this draft and an issue tracker can be found at https://datatracker.ietf.org/doc/draft-zhao-ccamp-actn-optical-network-agent/.

Status of This Memo

This Internet-Draft will expire on 23 April 2026.

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1. Introduction

With the emergence and popularization of the SDN concept, [RFC8453] proposed the ACTN architecture, which provides network abstraction, service and connection control functions for optical networks and has been deployed in multiple operators' networks. Currently, as the scale of optical networks continues to grow, the complexity of network Operations and Maintenance (O&M) has increased dramatically. Existing existing existing optical network O&M management systems are complex; scenarios such as optical network service provisioning and fault handling require extensive manual involvement, leading to complicated collaboration processes among O&M personnel and long processing durations. Therefore, further enhancing the intelligence level of optical network operation and management, building high-level autonomous optical networks, and achieving the service experience of "Zero-X" (zero waiting, zero failure, zero touch) and "Self-X" (self-configuration, self-healing, self-optimization) have become the common vision of global operators.

The development of AI, especially large AI model technologies, provides a feasible technical path for realizing autonomous perception, decision-making, analysis, and execution. As one of the important forms of AI application implementation, the concept of AI Agent has gained extensive attention and recognition in the industry. An AI Agent is defined as an intelligent entity capable of perceiving the environment, making autonomous decisions, and executing actions, which can gradually achieve set goals through independent thinking and tool invocation. The four core elements of an AI Agent include planning, tools, execution, and memory. Most current AI Agents are based on Large Language Models (LLMs), i.e., LLM-based Agents. The relationship between an AI Agent and a large model can be summarized as: Agent = large model + memory + planning + tool use.

Currently, the IETF document [I-D.zhao-nmop-network-management-agent] has proposed an AI Agent for network O&M management, which can automatically perform network state perception, task intent parsing, task planning, decision-making, and task execution. Based on user task intent or preset goals, it enables closed-loop processing of scenario-oriented network O&M management tasks.

This document, building on the Network Management Agent (NMA) concept proposed in [I-D.zhao-nmop-network-management-agent], explores the introduction of NMA into the ACTN-based optical network architecture. By enhancing the capabilities of the agent, it aims to improve the intelligent O&M management capabilities of optical networks and drive the realization of high-level autonomy in optical networks. This document will first discuss the enhanced ACTN architecture of optical networks after the introduction of NMA, analyze in detail the key components, interaction relationships, and new interface requirements in the new architecture, and provide examples of typical agent-based autonomous O&M use cases for optical networks.

2. Terminology

2.1. Acronyms and Abbreviations

AI: Artificial Intelligence

LLM: Large Language Model

NMA: Network Management Agent, refers to AI based network management agent

Agent: Specifically refers to NMA, i.e., the AI Agent for network management.

2.2. Definitions

The document defines the following terms:

Network Management Agent (NMA): A network management entity built based on ML/AI and equipped with the autonomous task processing capabilities. It can automatically carry out network status perception, task intent interpretation, task planning, decision-making and task execution operations based on user task intentions or preset goals, so as to achieve closed-loop processing of scenarios-oriented network management tasks. For different application scenarios, NMA can be subdivided into multiple scenario-oriented agents.

3. NMA-based enhanced ACTN architecture

3.1. Enhanced ACTN architecture

The enhanced ACTN architecture for optical networks after the introduction of NMA is illustrated in Figure 1 below. The AI agents (i,e. NMA) are introduced within the ACTN architectural framework as auxiliary components intended to augment and assist existing ACTN functional entities, rather than to replace them. In alignment with this design principle, the NMAs are conceptually implemented as design components within the MDSC, PNC, or CNC, rather than as independent entities external to these controllers. The agents can interact with existing ACTN functional components through standardized protocols such as the Management Control Protocol (MCP). This integrated design approach ensures backward compatibility with the established ACTN framework and enables seamless interaction with the existing ACTN interfaces and control logic.

```
            +----------------------------------+
            |           Enhanced CMC           |
            | +--------+ +--------+ +--------+ |
            | |  NMA1  | |  NMA2  | |  NMA3  | |
            | +--------+ +--------+ +--------+ |
            +-----------------^----------------+
                              |(1)Extened CMI
            +-----------------v----------------+
            |           Enhanced MDSC          |
            | +--------+ +--------+ +--------+ |
            | |  NMA1  | |  NMA2  | |  NMA3  | |
            | +--------+ +--------+ +--------+ |
            +-----------------^----------------+
                              |(2)Extended MPI
                         +----+-----------------------+-----------+
                         |                            |           |
  +----------------------v--------------------+  +----v----+ +----v----+
  |               Enhanced PNC1               |  |         | |         |
  | +----------+             +------+         |  |         | |         |
  | |          |        +----> NMA2 >----+    |  |         | |         |
  | | Original |        |(5) +------+    |    |  |  PNC2   | |   PNC3  |
  | | Function | (4) +--^---+   (5)  +---v--+ |  |         | |         |
  | |  Modules <-----> NMA1 >--------> NMA3 | |  |         | |         |
  | +----------+     +------+        +------+ |  |         | |         |
  +----------------------v--------------------+  +----v----+ +----v----+
                         |(3)Extended SBI             |           |
  +----------------------v--------------------+  +----v----+ +----v----+
  |               Network domain 1            |  | Domain2 | | Domain3 |
  +-------------------------------------------+  +---------+ +---------+
```

Figure 1: NMA-based enhanced ACTN architecture

The enhanced ACTN architecture includes the following key entities:

NMA-enhanced CNC (Customer Network Controller): As defined in

[RFC8453], the CNC is responsible for transmitting the customer’s Virtual Network Service (VNS) requirements to the network operator via the CNC-MDSC Interface (CMI). By integrating NMA entities related to service scenarios at the CNC layer, it can address operation and management needs specific to the service domain, enhance the intelligence level of end-to-end service operation and management, and enable intelligent service-domain capabilities such as automated service provisioning and automated work order flow.

NMA-enhanced MDSC (Multi-Domain Service Coordinator): As defined in [RFC8453], the MDSC undertakes core functions including multi-domain service coordination and network virtualization/abstraction. By introducing NMA entities for cross-domain scenarios at the MDSC layer, it can meet cross-domain O&M management requirements, strengthen closed-loop task processing capabilities in typical scenarios, and improve the efficiency of optical network management and control.

NMA-enhanced PNC (Provisioning Network Controller): As defined in [RFC8453], the Provisioning Network Controller (PNC) oversees configuring the network elements, monitoring the topology (physical or virtual) of the network, and collecting information about the topology (either raw or abstracted). By integrating NMA entities for single-domain scenarios (e.g., Fault Management NMA, Service Assurance NMA) at the PNC layer, it can address single-domain O&M management needs and enhance the ability to handle various network O&M tasks within the domain.

3.2. Enhanced ACTN interfaces

As shown in Figure 1, the architecture includes 5 types of interfaces:

1. Extended CMI: The interface between CNC and MDSC. After introducing NMA entities at each layer, the communication requirements between the original CMI interfaces will be enhanced from traditional transactional communication to include agent-oriented conversational communication. The CMI interface needs to be extended to meet the requirements of agent capability invocation and interaction between upper and lower layers.

2. Extened MPI: The interface between MDSC and PNC. Similar to CMI, after introducing NMA entities into MDSC and PNC, the original MPI also needs to be extended to support agent capability invocation and interaction between upper and lower layers.

3. SBI: The interface between PNC and physical network devices, which is out of scope of ACTN discussions.

4. Interfaces between NMAs and original functional modules at each layer: These are internal system interfaces, which can be implemented through private interfaces or interface solutions such as MCP, and are not within the scope of discussion in this document.

5. Interfaces between NMAs within same layers: These are internal system interfaces that can use private interfaces or general agent communication interfaces (e.g., A2A, ACP, etc.), and are out of scope of ACTN discussions.

Since NMAs can be deployed on different controllers within the ACTN hierarchy, two possible inter-controller AI-agent communication scenarios can be identified. For example, when there is a need for direct communication between NMAs in the upper-layer MDSC and those in the lower-layer PNC (A2A Communication), it will manifest as a single communication channel physically but multiple communication processes logically (i,e.including multiple A2A communication processes).

Figure 1 illustrates these scenarios between the MDSC and PNC (The case between the MDSC and CNC is similar and omitted here for simplicity).

As shown in Figure 1(a), when both the MDSC and PNC host AI agents, they can communicate directly through agent-to-agent (A2A) protocols (or other solutions). In contrast, when only one controller is equipped with an AI agent—as depicted in Figures 1(b) and 1(c)—the agent communicates with the other controller, which lacks an agent, via the existing ACTN MPI. For example, in Figure 1(b), the AI agent residing on the MDSC uses a RESTCONF client to interact with the PNC through MPI calls.

```
+---------------------+ +----------------------+ +----------------------+
|         MDSC        | |          MDSC        | |          MDSC        |
|                     | |          +----------+| |                      |
|+-----------+   +---+| |+---+  MCP|   other  || |+----------++--------+|
||  Other    |MCP|   || ||   | +--->functional|| || Original ||Restconf||
||functional <--->NMA|| ||   | |   |  modules || ||functional|| Client ||
|| modules   |   |   || ||NMA<-+   +----------+| ||  modules ||        ||
|+-----------+   +-^-+| ||   | |   +----------+| |+----------++---^----+|
|                  |  | ||   | |MCP| Restconf || |                |     |
|                  |  | |+---+ +--->  Client  || |                |     |
|                  |  | |          +-----^----+| |                |     |
+------------------|--+ +----------------|-----+ +----------------|-----+
                   |A2A                  | MPI                    | MPI
+------------------|--+ +----------------|-----+ +----------------|-----+
|         PNC      |  | |          PNC   |     | |         PNC    |     |
|                  |  | |                |     | |          +-----v----+|
|+-----------+   +-v-+| |+----------++---v----+| |+---+  MCP|   other  ||
||   Other   |MCP|   || || Original ||Restconf|| ||   | +--->functional||
||functional <--->NMA|| ||functional|| Server || ||   | |   |  modules ||
||  modules  |   |   || ||  modules ||        || ||NMA<-+   +----------+|
|+-----------+   +---+| |+----------++--------+| ||   | |   +----------+|
|                     | |                      | ||   | |MCP| Restconf ||
|                     | |                      | |+---+ +--->  Client  ||
|                     | |                      | |          +----------+|
+---------------------+ +----------------------+ +----------------------+
```

Figure 2: Inter-controller NMA communication scenarios between MDSC and PNC

4. Use cases

The ACTN architecture enhanced by NMA can effectively improve the automation and intelligence levels in typical O&M management scenarios of optical networks by building agents for different scenarios. Examples of typical application scenarios include:

1. Service Provisioning: enable users to describe services in natural language and to automate service design, provisioning, and deployment processes.

2. Service Assurance: ensuring compliance with service-level agreements (SLAs), including assisting in risk detection, prediction, and decision-making for preemptive actions to prevent service degradation.

3. Fault Handling: support anomaly detection, fault localization, root cause analysis, and generate fault repair solution to accelerate fault resolution and improve network reliability.

4.1. Service provisoning

TBD

4.2. Service Assurance

TBD

4.3. Fault Handling

TBD

5. Security Considerations

TBD

6. IANA Considerations

This document has no requests for IANA action.

7. References

7.1. Normative References

7.2. Informative References

[I-D.zhao-nmop-network-management-agent]
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[RFC8453] Ceccarelli, D. and Y. Lee, "Framework for Abstraction and Control of TE Networks (ACTN)", RFC 8453, DOI 10.17487/RFC8453, August 2018, <https://www.rfc-editor.org/rfc/rfc8453>.

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