LF NETWORKING

White Paper: Intelligent Networking, AI and Machine Learning

A Telecommunications Operator's Perspective

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1 Key Takeaways

- On the whole, the maturity of intelligent networking in the Telecom Industry is still relatively low
- Some intelligent networking has been deployed by Telecoms, but more research and development is needed to establish industry wide best practices
- Currently the industry is more interested in using artificial intelligence and machine learning to address operational, maintenance, and service assurance issues than network optimization
- The Telecom industry needs to develop common AI platforms and intelligent networking frameworks and methodologies to support the delivery of new services quickly and efficiently
- A shared understanding of intelligent networking will help to support interoperability
- Creating commonly understood sources of reliable data is difficult, both within a company across business units and across the Telecom industry
- The open source community can play a key role in furthering the development of these frameworks and best practices. Some projects that look promising include Anuket Thoth, O-RAN, 3GPP SA5 and ITU-T standards organizations, as well as the ONAP, O-RAN, and TIP open source projects

2 Overview

Telecoms need to be able to incorporate new technologies and next-generation connectivity such as 5G to customers and end users. To achieve these ambitious goals, they need to optimize their networks – make them more intelligent if you will. Some of the tools needed include artificial intelligence (AI), machine learning (ML) and artificial intelligence operations (AIOps). This document will explore what intelligent networking means to telecoms, vendors and customers, and how AI and ML technologies and tools can be used, the cultural shifts the industry needs to make it a success, and what to bear in mind when deploying machine learning across a telecom network.

The LF Networking (LFN) End User Advisor Group (EUAG) is publishing this document to identify and highlight the latest thinking and recommendations for building and supporting intelligent networking and the tools needed to achieve it. It will touch on the state of automation and adoption of intelligent networking tools by telecom operators. This is a new area for many in the telecom industry, so the focus will be on the requirements, tools and approaches that have been deployed, and some potential future scenarios for intelligent networking and AI/ML tools. Some of the topics covered will include:

- Fundamental issues and challenges that might be solved by applying Intelligent networking technology
- Establish a definition of intelligent networking
- The promotion of intelligent networking transformations
- Results from a February 2021 survey of telecom operators and vendors in the industry ecosystem about the current state of industry adoption
- How intelligent networking might be incorporated into networks and processes to improve operations and ensure that the solutions work as expected in production network environments
- Recommended approaches and the potential for open source projects to contribute to the next generation of intelligent networking tools

2.1 LFN EUAG: Role and Mission

The LF Networking (LFN) End User Advisor Group (EUAG)'s mission is to share views, challenges, and best practices among organizations in the telecommunications industry; particularly highlighting areas of opportunity for open source developer communities. The group is comprised of individuals from various organizations from the industry including telecommunications carriers, cable operators, network providers, and compute or storage service providers. As the voice of the operator end user community, it represents the operators' perspective for telecommunications related open source projects, and their adoption in the industry.

3 Problem Statement

Telecom operators are first and foremost technologists, but the reality is that there is constant pressure to increase the efficiency and capacity of operators' infrastructures to delivery more services to customers for lower operational costs – to make the business work more efficiently. The software industry, leveraging virtualization, cloud native approaches, agile methodologies, and test-driven development has long been able to build applications and infrastructure flexible enough to be seamlessly modified multiple times a day.

Could and should the Telecommunications industry, with its stringent requirements for high availability, and its distributed service delivery models, adopt these methodologies for its own infrastructure and systems? As software defined networking (SDN) becomes more robust, operators have found that it is not enough to just convert everything to software, step back and expect it to all work.

Based on the information submitted by participating operator and vendor organizations, the level of sophistication about intelligent networks is still relatively low, with little cross-departmental and cross community sharing or tools. This leads to further silos, fragmentation of development and research activities, and less efficiency across the industry.

It has been said that data is king and that is certainly true for any kind of AI tools. Machine learning needs lots of data, the more data to analyze; the more effective the results will be. As an example of this phenomenon, the problem of how to translate texts effectively and efficiently was long thought to be unsolvable. Then Google applied copious data sets in a brute force method that worked. While it is far from perfect, certainly not at the level of Star Trek's Universal Translator, Google Translate is a reasonably workable method of text language translation.

One of the most pressing problems is the lack of an understanding of the data itself and how it needs to be organized and processed to successfully apply machine learning to improving network efficiencies.

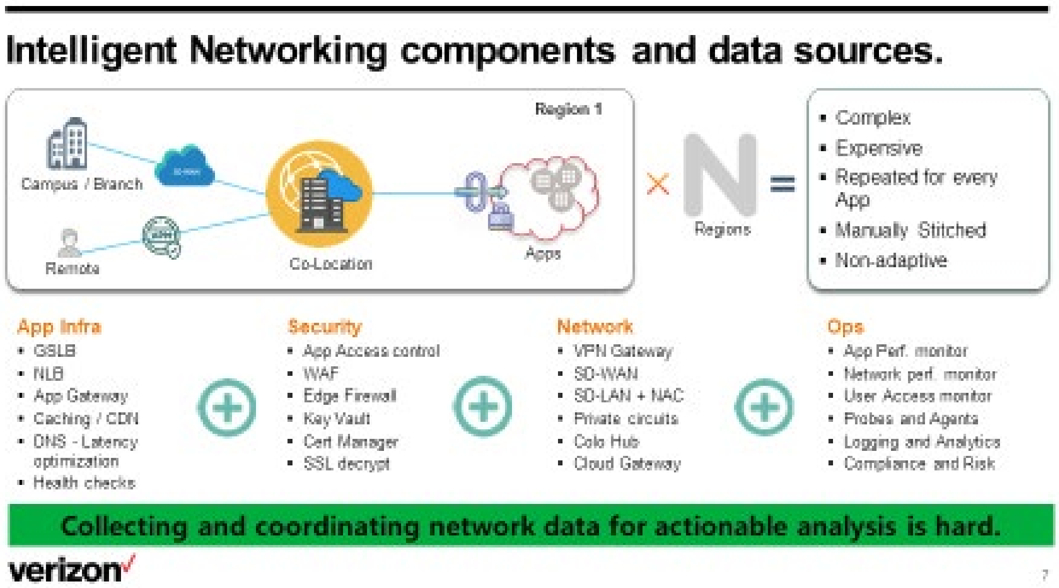


Figure 1: Some data types used for intelligent networking

There is a need for intelligent networking tools both in support of internal as well as customer facing processes. The amount of data needed to track network workflows to effectively create AI tools that will be able to do real-time predictive modeling. In summary, not only is there a very long list of components that need to be part of the Intelligent network, but capturing the right data and at the level of granularity that is needed to produce results is still very much more an art than a science.

4 What is Driving Intelligent Networking Adoption?

- **Market and Business Expansion:** For many telecoms, the consumer market has long been saturated, so there has been a strong push to look for new market opportunities. Technology changes have opened growth potential for digital transformation, which puts additional demands on network services.
- **Network Technology Evolution:** The industry's embrace of 5G, network slicing, Infrastructure and Network Functions Virtualization (NFV) and other cutting edge technologies, has put pressure on companies to develop new features such as flexible resource allocation and dynamic scheduling, as well as the need to support disaggregated network, software and hardware models.
- **Optimization for Operations Management:** As the complexity of networks and network interoperability increase, it becomes more difficult to support traditional network operation and maintenance management models. AIOps models could be a way to improve efficiency by aiding in process coordination, information screening and automation of operational management workflows. Some of the possible applications are service subscription, fault monitoring, and quality optimization.[1]

5 Purpose

Intelligent networking as a tool in the telecom industry is becoming more urgent as business and technical pressures increase. In order to gain a better understanding of the state of the use of AI and intelligent networking in the industry, a survey of 65 telecom operators and vendors was conducted [2]. From the results of the survey, the EUAG has developed some recommendations for improving the rate of adoption are proposed, including using industry cooperation models to achieve consensus, validate technologies, create reference models, formulate industry standards, and promote related open source activities.

6 Assumptions

- Intelligent Networking is something of common interest across the industry
- Care should be taken about how to share data and results across competing companies.
- Creating a shared understanding is beneficial to the entire industry – it is not a competitive advantage to have access to better AI tools.
- The open source communities and standards bodies are in the best position within the industry to develop some of the tools

7 Defining Intelligent Networking

Starting from a general definition of AI, according to the European Commission's High-Level Expert Group on AI, AI systems are software (and possibly also hardware) systems designed by humans that, given a complex goal, act in the physical or digital dimension by gaining an understanding of the environment through data acquisition, interpreting the collected structured or unstructured data, applying reasoning to that information, or processing the information, derived from this data and finally, deciding the best course of action to take to achieve the stated goal. AI systems can either use symbolic rules or a numeric model, and they can also adapt their behavior by analyzing how the environment is affected by their previous actions [3].

Clearly, that definition is far too broad to apply to intelligent networking. A better approach is to establish a common understanding of what it is within the telecommunications context. However, it is quickly apparent with a web search that AI, ML, and AIOps mean different things to different groups even within the networking and telecommunications industry. While AI and machine learning is often understood to be how automation can be used to optimize the network, making sure the networks, connections, and packet flows remain optimized as traffic naturally shifts over time. That optimization can happen within a telecom's own infrastructure or there might be tools that customers apply to their networks.

This can also be more broadly applied to operational aspects of the telecom infrastructure, which implies the use of AI/ML outside of the network itself, often referred to as AIOps. According to Gartner, AIOps combines big data and machine learning to automate IT operations processes, including event correlation, anomaly detection and causality determination [4].

For the purposes of this document, intelligent networking is a network empowered by AI technologies and systematic integration of AI and communication network on hardware, software, systems, and processes. This includes but is not limited to transforming network software and hardware into an AI system, as well as the operational intelligence represented by the AIOps components [5].

The relation between intelligent networking and AIOps could be further explained this way. The ultimate goal of intelligent networking is to turn a network composed of software and hardware into an AI system, which covers but is not only subject to AIOps.

8 Survey Results

8.1 Methodology

The LFN EUAG group developed the survey with the intention of gathering data about the current state of the use of intelligent networking within the telecom industry. The survey closed in February 2021 with a total of 65 respondents from within the LFN community, made up of a broad spectrum of telecom operators and vendors.

The criteria used for evaluating the findings and establishing the assumptions as part of that evaluation were:

- Overall industry type and size of respondents: Respondent profiles
- Resource capacity: Level of interest in developing intelligent networking tools

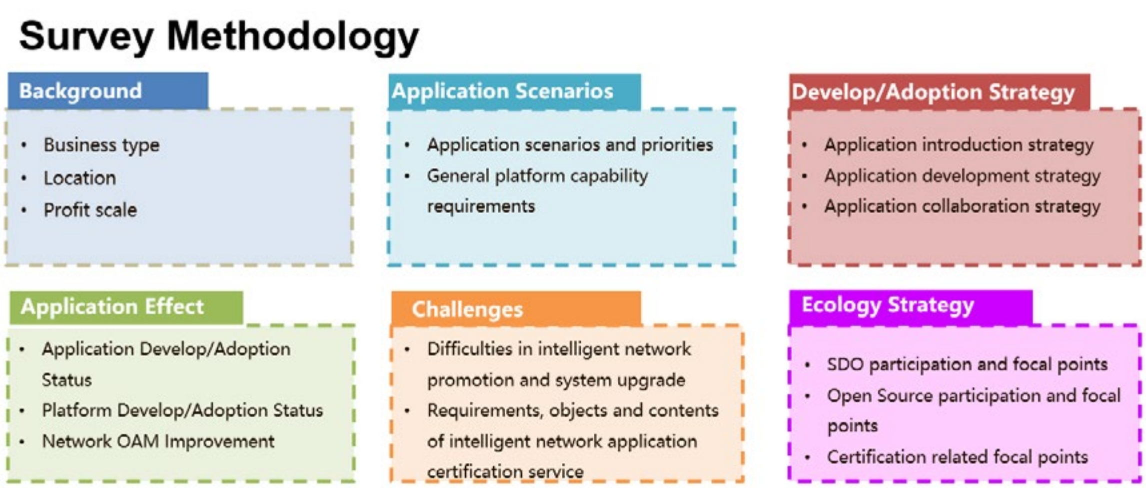


Figure 2: LFN Survey Methodology

As shown in Figure 2, the survey was organized into the following areas of interest: status of application requirements, research and development strategy, ecological strategy, and challenges. A comprehensive analysis of the data used a combination of classification, correlation and benchmarking techniques.

8.2 Survey Analysis

Overall progress in adopting intelligent networking

Based on the survey results, there is much that needs to be done before operators and vendors achieve a fully intelligent network. Nearly half of the operator respondents are still in the early stages of assisted operational management – one of the first steps in making a network more intelligent. Respondents indicating they have a conditional autonomous network or higher only account for about a quarter of respondents.

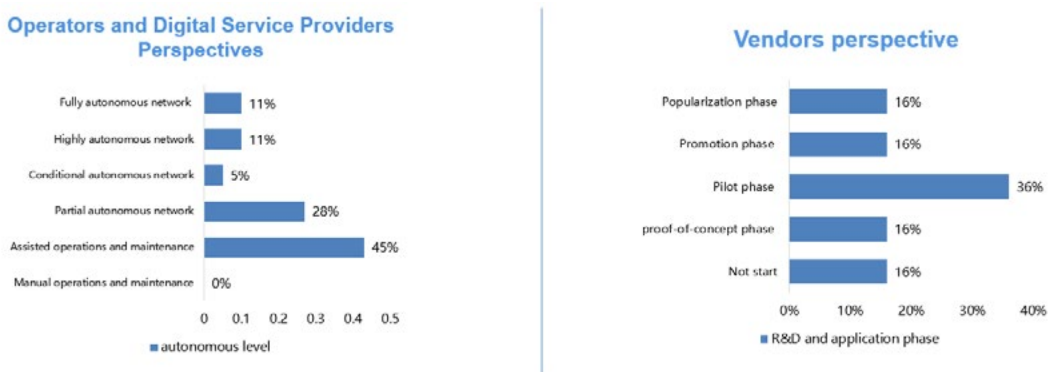


Figure 3: Industry Progress

On the other hand, over 80% of vendors claim to have already applied AI technology in some form in their products. Further analysis notes that 36% are only piloting their solutions, so the claim that vendors have AI solutions seems to be more aspirational than real at this point. Also interesting to note is that only 16% of vendors have a long-term plan for deployment of AI into their architecture or products. From these results, it can be inferred that many vendors are just starting to dip their toes into the intelligent networking waters, so to speak.

Development strategy

The responses indicate that companies at more advanced stages of their AI/ML adoption are more likely to adopt the strategy of building a unified AI platform that can be used for all intelligent network application scenarios, rather than a piecemeal approach to building their systems.

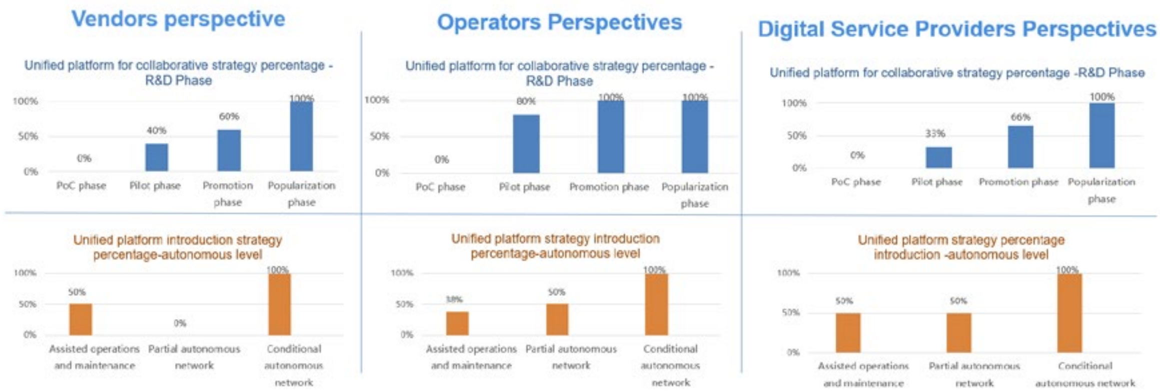


Figure 4: Development Strategy Analysis

Looking at the more detailed responses specific to what respondents are looking for, 60% said that basic AI algorithms, algorithm frameworks, and training capabilities were considered most desirable. However, more than half of the respondents said that they needed to focus on data access, which includes the availability of raw data, training data and subject data. Less than half attached any importance to providing reusable common business capabilities and applications based on network intelligence, organized research and development, deployment of common intelligent networking capabilities, and trusted AI capabilities. This might be more related to the fact that few of the respondents are researchers, while most are architects and network engineers, who are going to be more interested in practical solutions that can be applied directly to solving their immediate business problems.

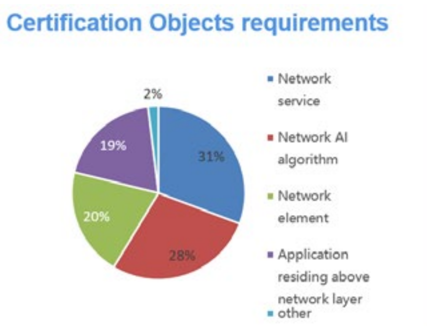
Application scenarios

The top three AI application use cases the industry was most interested in are operations and maintenance, service assurance and network optimization. This is not surprising, since these use cases have direct application to serving customers and front-line operations.

Autonomous network elements, energy efficiency, and application optimization were generally of less interest, mostly due to a perceived lack of feasibility and lack of operators’ control over the algorithms and immaturity of the technology.

Ecology strategy

Questions related to the ecology strategy showed that there is not yet a consensus on what open source projects, standards groups, and certifications (which do not currently exist) should take priority. However, higher priority was given to network service and AI algorithms certification efforts. Lower priority was given to certification of network elements and applications residing above the network layer.



Certification environment requirements

Ranking	scenario	Score
1	Effectiveness evaluation and testing system for intelligent applications	2.42
2	General automatic evaluation DevOps pipeline for 3rd party software	2.03
3	Open intelligent network application certification laboratory, providing a unified surrounding test environment	1.58

Figure 5: Ecology Strategy Analysis

9 Survey Respondents' Challenges

From the survey results, clearly there is much work to be done. AI and machine learning is still fairly new in the industry. Many telecoms have done optimization by hand over the years – looking at historic data and tweaking networks – but what has changed recently is the ability to do it more in real time. However, the technology and its adoption are still evolving.

The operators, as the consumers of network intelligent technology, identified a lack of a truly controllable and experimental network environments, no shared or open network data sets, scarce AI talent, and technical reserves. These represent long-term common challenges faced by operators, wherever they are on the intelligent networking journey. According to the survey results, the lack of quantitative indicators for intelligent network applications and third party testing and certification services effects, is a problem that operators must solve. Building a test and certification effect evaluation system oriented to intelligent networking is a common industry demand. From the operator's perspective, the more fruitful targets for automation and AI are operations and network management components.

From the vendor perspective, network element standardization and lack of research environments are the common challenges. A lack of trust in the ability for intelligent network control is the main challenge for vendors to continue long-term intelligent network planning and development of network intelligent tools and systems. A lack of unified and trusted data normalization, shared and open network data sets are also challenges for vendors to their commitment to develop intelligent networking tools.

Yes, we have come a long way in building the intelligent network, but don't be fooled, the Real-Time enterprise requires significant integration work to pull together all the components needed to support it. It is not just a matter of dropping in some new equipment; it requires fundamental changes to the very business delivery model itself. There are opportunities to inject intelligence at all these different points, from the customer experience, automatic portals that anticipate customers' needs and interests at the front end. The very nature of how networks are supported has to change. And not just one component, but all the piece parts changing in a coordinated manner.

10 Survey Implications

- In general, the telecom industry is still in the early stages of transformation, with relatively low levels of intelligent networking deployed
- As part of the overall industry intelligent transformation strategy, operators and vendors should coordinate intelligent network applications through a unified understanding of the AI platforms
- For now, operators are most interested in AI applications for operations and maintenance, service assurance, and network optimization
- Many companies are involved in open source and standards bodies such as O-RAN, 3GPP SA5 ITU-T, ONAP, and TIP
- Certifications and standards for intelligent network services and AI algorithms are needed
- Operators need to prepare for the long-term challenges of introducing intelligent networking. These include, the development of intelligent network element and data standardization, open research environments, and the establishment of shared data sets

10.1 Build a Common Understanding of AI Platforms

The industry has just started down the intelligent network transformation journey. To achieve the ultimate goal of fully autonomous networks, the recommendation is that operators avoid introducing AI capabilities in specific, scattered use cases. Rather, it makes more sense to build an enterprise-level unified AI platform or framework for all intelligent network application use cases, with the goal to provide intelligent application for all the required infrastructure services including centralized computing power, algorithm frameworks, and reusable AI capabilities, therefore creating one-stop management of operational and intelligent network applications.

While it is hard to draw conclusions directly from the survey, it does make sense for the telecom community to unite with the common goal of building a testing and certification platform for intelligent network solution across the industry; if for no other reason but to provide effective evaluation and testing methods for validating intelligent applications and models. It is also critical to provide an open certification laboratory, as well as a unified testing environment and general evaluation DevOps pipeline for both in-house and outsourced solutions. The current candidates for this work are some of the standard bodies already engaged in this work, such as O-RAN, 3GPP, and ITU-T. Nearly half of the survey respondents are already participating in ONAP or O-RAN, so these projects seem like a natural place to start.

In conclusion, the industry is currently in need of both specification and open certification of intelligent network service and network AI algorithms.

10.2 Encourage Development of AI Skillsets

As intelligent networking becomes more prevalent in the industry, operational personnel roles will change as many formerly manual processes are replaced by automation and intelligence. This means that staff need to know how to manage automated workflows. The operators will need to make changes to how operations staff are trained and to develop the specific skill sets that are required for successful operation support.

10.3 Promote Industry Collaboration through Open Source Projects

In the process of deploying intelligent networks, the operations and maintenance activities will gradually shift from people to autonomous network systems. The basis for system decision-making will extend from explainable experiences to complex AI algorithms and models. That is not just a simple technical issue, but requires industry cooperation to establish fair and objective evaluation standards, open and reusable test environments, and well-recognized certification services.

In terms of industrial ecology, the following standard organizations and open-source communities are expected to be relevant:

- ONAP is a project building a reference implementation for an open source autonomous network platform under the LF Networking umbrella. It currently has few components that can be used to promote AI/ML activities, but it is a project that has the support across the industry, so might serve as a jumping off platform.
- Anuket is a project that is defining reference models and architectures in support of cloud native Virtual Network Functions (VNF). It is under the LF Networking umbrella. It recently started an intelligent networking project called Thoth.

- ETSI ZSM ISG defines an automation framework for the whole process of delivery, deployment, configuration, SLA, and optimization of cross-domain E2E network operation and maintenance. Again, while there are few elements in the platform today that can be used for AI/ML projects, it might serve as a jumping off platform.
- O-RAN considers network autonomy as one of its most important development directions. By introducing big data, artificial intelligence and other methods, it helps realize efficient operation and maintenance management in complex network environments and improve the utilization of spectrum resources, as well as reduce network energy consumption.
- TM Forum has taken the initiative of organizing cross-organization collaboration for autonomous networks and establishing a working group. It is defining a level-based architecture for autonomous network, proposes the concept of autonomous domains, and evolves resource management into relatively independent autonomous domains.

While all this activity looks very promising, there is little or no coordination or collaboration of projects or deliverables among the standards bodies or participating organizations. For the most part, each of them only focuses on a specific area of interest. The situation is further aggravated by the different standards groups and open source projects having both overlapping and conflicting objectives of the few standards that do exist, with no shared definition of how to support Day 2 operational infrastructure changes. This has resulted in unnecessary barriers for vendors, promoted technology silos and increased complexity across the industry in general. As NFV applications and workloads mature, hardware and software disaggregation will increase with more multi-vendor solutions, requiring a more detailed understanding of the virtualized environments and more integration testing of the intelligent networking systems and tools.

It makes sense to focus on building a reference implementation of intelligent networking that can be used across the standards bodies and open source organizations.

10.4 Promote Data Model Sharing

Data standardization and shared data sets and models have been long-term challenges for the adoption of intelligent networking. A common understanding of the data models themselves is a basic requirement. For example, how jitter is defined can vary wildly across operators or even within a single operator. Even something as seemingly simple as a basic AI algorithm framework is a much needed capability to advance the industry.

Vendors and operators need to develop common AI models for data through a mechanism for model and data sharing. An AI/ML and model sharing project [6] would be a good way to foster industry collaboration and promote the sharing of data and models through the joint construction of intelligent networking scenarios. Some use cases under consideration include:

- Congestion Prediction & Mitigation, which focuses on how AI/ML may be used to predict congestion and perform closed loop automation for executing configuration changes to mitigate
- Sleeper Cell Detection, which is used to predict a cell going to "sleep" and handover a critical UE (e.g. ambulance) to another cell
- Traffic Steering, which aims to improve Quality of Experience (QoE) by steering UE traffic among multiple cells
- Soft fault detection and resolution, which is used to detect "soft" faults that are not often caught and hidden by the redundant systems
- Deterministic Predictive capacity planning, which is used to detect usage patterns so that the network can be used more efficiently

10.5 Establish a Unified Testing and Certification Program

From the feedback of the survey, the highest priority for testing and certification service for intelligent network is effectiveness evaluation and testing system for intelligent applications (test cases, data collection, and quantitative metrics).

Therefore, the recommendation is to invest in building a testing and certification program that could evaluate various intelligent applications with objective performance metrics and evaluation approaches by scenarios, categories, and levels. It would be used for the entire lifecycle management of AI application research and development, deployment, expectation management, feasibility analysis, closed loop upgrading, provisioning and cancellation, etc., to improve the objectivity and effectiveness of related process decisions.

The Compliance and Verification Committee (CVC) is a community driven body within LF Networking which defines policies and oversight for compliance and verification programs. The CVC Anuket Assured program [7] is an open source, community-led compliance and verification program to demonstrate the readiness and availability of commercial cloud native and virtualized products and services using Anuket and ONAP components. It offers testing of commercial products built on requirements from ONAP, multiple standards bodies, and the LFN EUAG to demonstrate the readiness and availability of commercial products based on the Anuket and ONAP project work.

11 Conclusion

There is still a long way to go to achieve intelligent transformation for networks with many challenges along the way. However, the industry must incorporate these technologies into the infrastructure to meet the demands for telecommunications in the twenty-first century.

- In general, the telecom industry is still in early stages of intelligent transformation, with relatively low levels of autonomous, intelligent networking deployed.
- As part of the overall industry intelligent transformation strategy, leading operators and vendors should introduce and coordinate intelligent network applications through a unified understanding of AI platforms. A consensus could be reached that developing a unified platform is essential to reach the goal of intelligent network autonomy.
- For now, operators are most interested in AI applications for operations and maintenance, service assurance, and network optimization. Therefore, operational personnel are encouraged to improve AI-related skills.
- Establishing a cross-industry shared data model poses considerable challenges; however, data sharing amongst not only operators, but between operators and vendors as well brings significant benefits.

12 Glossary

AI	Artificial intelligence
AIOps	Artificial Intelligence for Operations
CSP	Communications Service Providers
CVC	Compliance & Verification Committee
ETSI	European Telecommunications Standards Institute
EUAG	End User Advisory Group, a working group within the LFN
LFN	Linux Foundation Networking
ML	Machine Learning
M-SDO	Multiple- Standards Organizations
ONAP	Open Network Automation Platform
O-RAN	Open-Radio Access Network
QoE	Quality of Experience
SDO	Standards Organizations
TM Forum	TM Forum is a global industry association for service providers and their suppliers in the telecommunications industry.
ZSM	Zero-touch network and Service Management

13 Detailed Definitions

Communication network is structured by different layers. Network intelligence is defined with the same logic:

- Terminal intelligence: the end-side intelligence embedded in various terminal equipment. It performs 2 main functions: end-side data collection and presentation of intelligent services to users. Data collection typically includes measurement, signaling and sensing data concerned with end-side user experience, network quality and environment awareness. This is also the network intelligence closest to users.
- Network element intelligence: the distributed intelligence of network elements and their related OMC, which collects real-time data on the network side, provides closed-loop control capability for fundamental network functions in the network element layer and network domain, such as protocol processing, data transmission, route control, session management, resource management, mobility management, etc., and executes decision made in operation and service intelligence layer.
- Operation intelligence: centralized intelligence possessed by the network management center of operation and maintenance. Based on the 5 core capabilities of prediction, perception, diagnosis, decision-making and control, it achieves whole lifecycle management of network planning, deployment, maintenance, optimization and operation, supporting the service layer intelligence.
- Service intelligence: as the interface between network and users, it supports end-to-end network service intelligence. Using core technologies such as intention, network slicing and SLA, service intelligence is able to meet the diversified, and customized needs of users, realize the closed loop of end-to-end service perception, assurance and optimization, and provides customers with open capabilities to empower their own business.

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