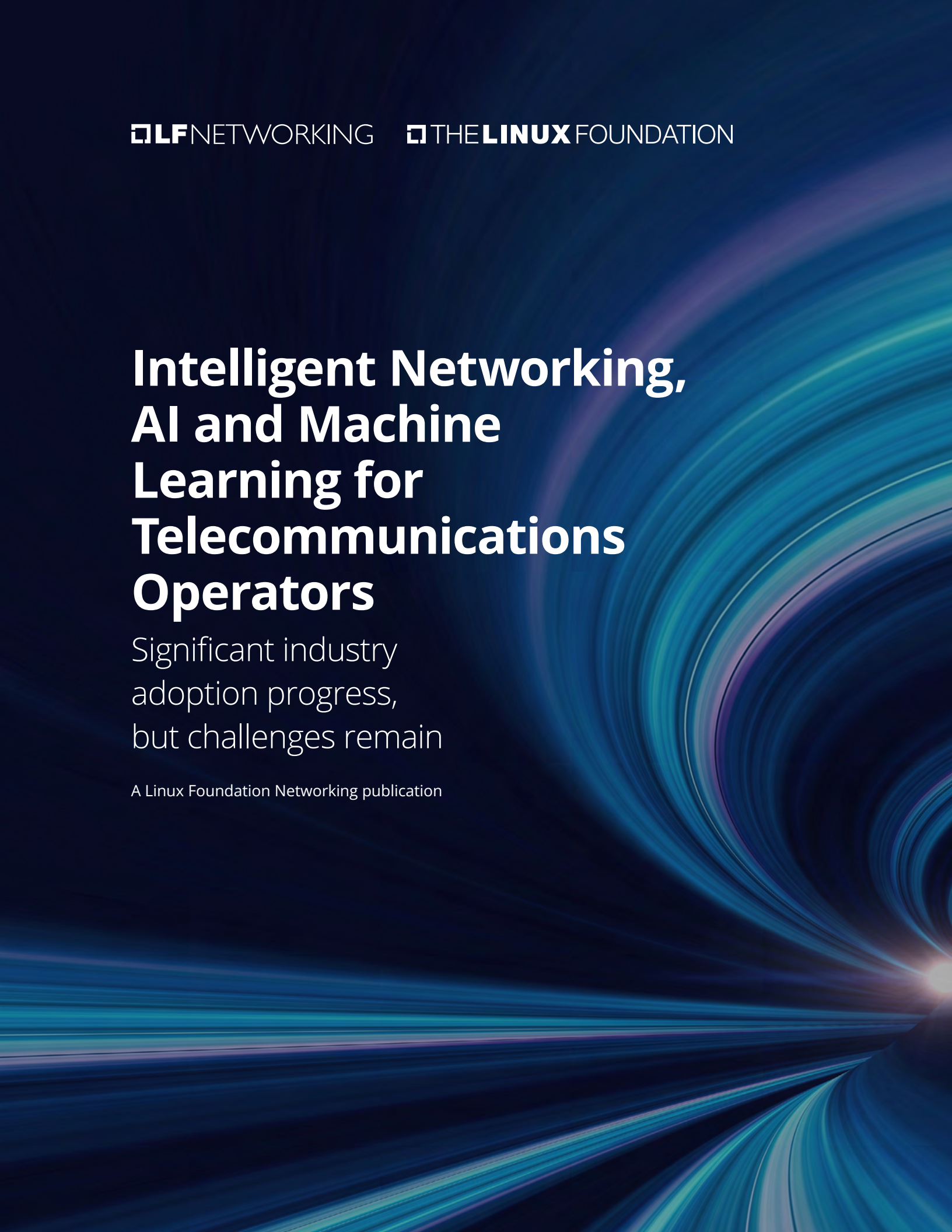
LF NETWORKING THE LINUX FOUNDATION

Intelligent Networking, AI and Machine Learning for Telecommunications Operators

Significant industry adoption progress, but challenges remain

A Linux Foundation Networking publication



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1. Executive Summary: Overview and Key Takeaways

Since LF Networking (LFN) published the seminal **Intelligent Networking, AI and Machine Learning While Paper** in 2021, the Telecom industry has seen tremendous growth in both interest and adoption of Artificial Intelligence (AI) and Machine Learning (ML) technologies. While it is still early days, the industry is now well past the tire-kicking, lab-testing phases that was then state of the art. Intelligent networking is coming into its own as Telecoms increasingly use it for operational support; whether that means deploying intelligence into next- generation networks, or for automation of network management tasks such as ticket correlation and predictive maintenance.

LFN and Open Source have a pivotal role to play in fostering and developing intelligent networking technologies through the continued support of key projects, ranging from building a common understanding of the **underlying data models** to **developing infrastructure models** and **integration blueprints**.

The future of Intelligent Networking and AI is in the hands of the individuals and organizations who are willing and able to contribute to new and existing projects and initiatives. Anyone involved in building and operating networks, developing network technology or consuming network services, should consider getting involved in LF Networking. Engaging with the LFN projects and communities can be an educational and rewarding way to shape the future of Intelligent Networking.

Key Takeaways

- Intelligent networking is rapidly moving out of the lab and being deployed directly into production
- Operational maintenance and service assurance are still a priority, but there is increasing interest in using AI/ML to drive network optimization and efficiency
- More research and development (R&D) is needed to establish industry-wide best practices and a shared understanding of Intelligent Networking to support interoperability
- There has been some work on developing common or shared data sources and standards, but it remains challenging
- LFN and the broader Open Source community are key contributors to furthering the development of Intelligent Networking now and in the future
- LF Networking communities and projects are already creating many of the building blocks of AI driven networks. Collaboration is open to all.

2. Background and History

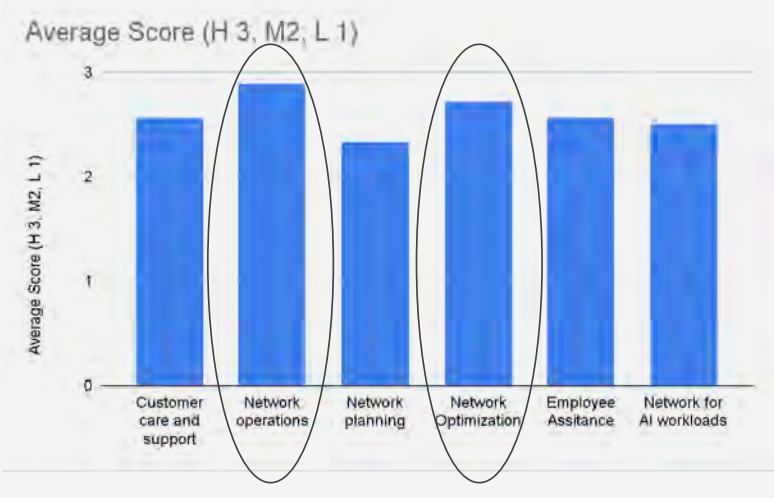
At their core, telecoms are technology companies driven by the need to scale networks to service millions of users, reliably, transparently, and efficiently. To achieve these ambitious goals, they need to optimize networks by incorporating the latest technologies to feed the connected world's insatiable appetite for ever more bandwidth.

To do this efficiently, the networks themselves need to become more intelligent. At the end of 2021, LFN published its first **white paper on the state of Intelligent Networking in the telecom industry**. Based on a survey of over 70 of its telecom community members, the findings pointed to a still nascent field made up of mostly research projects and lab experiments, with a few operational deployments related to automation and faster ticket resolutions. The survey did highlight the keen interest its respondents had in intelligent networking, machine learning and its promise for the future of the telecom industry in general.

Fast forward to 2023 when, at the request of the LFN Governing Board and Strategic Planning Committee, **the LFN AI Taskforce was created** to coordinate and focus the efforts that were already starting to bubble up in both new project initiatives (**Nephio**, **5G Super Blueprint**, just to name a few) and within existing projects (**Anuket**, **ONAP**). The Taskforce was given the charter by the Governing Board to look at and make recommendations on what direction LFN should take with this exciting emerging field of research and technology. The information provided in the rest of this document is based on the analysis and findings of the task force.

Some areas the Taskforce settled on included:

- How to create and maintain public Networking data sets for research and development of AI applications (ranked #1 in GB member survey)
- Identifying feasible goals (short term) in creation of AI powered Network Operations technologies
- Evaluating the existing Networking AI assets coming from member company contributions
- Analyze generic base AI models and recommend the creation of Network specific base models (ranked high in GB member survey)
- Recommended approaches and the potential for open source projects to contribute to the next generation of intelligent networking tools



Networking Use case group analysis - Macro

3. State of the Art: The rise of GenAI and LLMs

LLM (Large Language Models)

This breakthrough in AI research is characterized by vast amounts of easily accessible data, extensive training models, and the ability to quickly generate human-like text. These models are trained on enormous datasets from sources particular to a given area of research. LLMs have changed the way natural language processing tasks are interpreted. Some of the areas that have been particularly fruitful include: text generation, language translation, summarization, and automated chatbots and routine query responses.

"The rise of Gen AI has inspired numerous opportunities for business cases, from creating corporate logos, to corporate videos, to saleable products to end-consumers and businesses, to creating visual network maps on the basis of the datasets being accessed."

Generative AI (Gen AI)

Gen AI is a much broader category of Artificial Intelligence systems capable of generating new content, ideas, or solutions autonomously based on a human text, video, image or sound based input. This includes LLMs as resource data for content generation. As such, Gen AI seems to be able to produce human-like creative content in a fraction of the time. Content creation for web sites, images, videos, and music are a few of the capabilities of Gen AI. The rise of Gen AI has inspired numerous opportunities for business cases, from creating corporate logos, to corporate videos, to saleable products to end-consumers and businesses, to creating visual network maps on the basis of the datasets being accessed. Further, even being able to provide optimized maps for implementation to improve networking either autonomous or with human intervention are useful areas for further exploration.

The two combined open the question as to what Gen AI should be used for, and more importantly how is it distinguishable from human work. There are many regulatory bodies looking at solutions around identification of decisions and what content has been generated to solve a particular problem and solution. The foundation of this combination is to ensure security, safety, mitigate biases, and identify which behaviors were illustrated and acted upon by Gen AI, and which were not.

4. Challenges and Opportunities

While generative AI and LLM adoption becomes more widespread in many industries, Telecom has, ironically, lagged somewhat due to a number of valid factors. As was covered in the previous white paper, the overall industry challenges remain the same; specifically, the constant pressure to increase the efficiency and capacity of operators' infrastructures to deliver more services to customers for lower operational costs. The complexity and lack of a common standard understanding of network traffic data remains a barrier for the industry to speed the adoption of AI/ML to optimize network service delivery.

In this section, we'll further explore some of the challenges motivating continued research and adoption of intelligent networking across the industry.

4.1 Common Telecom Pain Points that May be Addressed by AI

- **Operational Efficiency:** The continuing need to reduce costs and errors, while simultaneous (potentially) increasing margins
- **Network Automation:** Right-sizing network hardware and software, optimizing location placement
- **Availability:** Identifying single points of failure in systems to improve equipment maintenance efficiency
- **Capacity Planning:** Avoiding unnecessary upgrades or poor network performance from overloaded nodes

KEY DRIVERS FOR INTELLIGENT NETWORKING

- **Network Planning and Design:** Generative AI for precise small cell placement, MIMO antennas, beamforming, and optimized backhaul connections
- **Self-Organizing Networks (SON):** Harnessing AI-based algorithms for autonomous optimization and network resource management
- **Shared Infrastructure:** Leveraging 5G RAN infrastructure resources for training and inference, enhancing AI capabilities and network efficiency
- **Network Protocol Code Generation:** Enabling co-pilot functionality for generating network protocol software
- **Capacity Forecasting:** Utilizing AI to optimize network capacity to avoid unnecessary upgrades or poor network performance due to overloaded circuits

KEY DRIVERS FOR AI/ ML FOR OPERATIONS

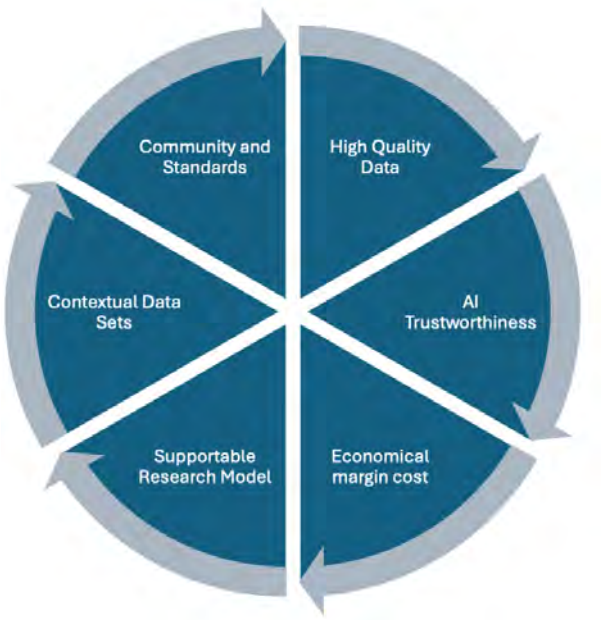
- **Network AIOps:** Implementing AIOps methodologies to automate, streamline and improve overall network efficiency.
- **Predictive Maintenance:** Utilizing AI to forecast equipment failures and improve maintenance efficiency
- **Technical Assistant/Customer Service:** Real-time guidance from LLM trained tech assistants

4.2 Challenges in Applying AI to Addressing Telecom Pain Points

Many of the pain points above could be successfully addressed by applying AI. However, deploying large models such as LLMs in production, especially at scale, raises several other issues:

NEED FOR HIGH QUALITY STRUCTURED DATA

Telecommunications networks are very different from other AI human-computer data sets, in that a large number of interactions between systems use structured data. However, due to the complexity of network systems and differences in vendor implementations, the degree of standardization of these structured data is currently very low, causing "information islands" that cannot be uniformly "interpreted" across systems. There is a lack of a "standard bridge" to establish correlation between them, and it cannot be used as effective input to incubate modern data-driven AI/ML applications.



AI TRUSTWORTHINESS

In order to meet carrier-level reliability requirements, network operation management needs to be strict, precise, and prudent. Although operators have introduced various automation methods in the process of building autonomous networks, organizations with real people are still responsible for ensuring the quality of communication and network services. In other words, AI is still assisting people and is not yet advanced enough to entirely replace human thought. Not only because the loss caused by the AI algorithm itself cannot be defined as the responsible party (the developer or the user of the algorithm), but also because the deep learning models based on the AI/ML algorithms themselves are based on mathematical statistical characteristics, resulting in sometimes erratic behavior, meaning the credibility of the results can be difficult to determine.

UNECONOMICAL MARGIN COSTS

There are a large number of potential network AI technology application scenarios, however, for one organization to independently build a customized data-driven AI/ML model for each specific scenario is a herculean task that is uneconomical and unsustainable, for both research and operations. Determining

"[F]or one organization to independently build a customized data-driven AI/ML model for each specific [potential] scenario is a herculean task that is uneconomical and unsustainable..."

how to build an effective business model between basic computing power providers, general AI/ML capability providers, and algorithm application consumers is an essential prerequisite for its effective application in the field.

UNSUPPORTABLE RESEARCH MODEL

Compared with traditional data-driven dedicated AI/ML models in specific scenarios, the research and operation of LLMs have higher requirements for pre-training data scales, training computing power cluster scale, fine-tuning engineering and other resource requirements, energy consumption, management and maintenance, etc. The telecommunications industry should look at more collaborative ways to address these requirements. Shared resources made available to an open source community could be one way to address this challenge.

CONTEXTUAL DATA SETS

Another hurdle that is often overlooked is the need for networking data sets to be understood in context. What that means is that networks need to work with all layers of the IT stack, including but not limited to:

- **Applications:** Making sure that customer applications perform as expected with the underlying network
- **Security:** Security is more important than ever as attack vectors expand; customers expect the networks to be protected
- **Interoperability:** The data sets must support transparent interoperability with other operators, cloud providers and other systems in the telecom ecosystem
- **OSS/BSS Systems:** The operational and business applications that support network services

"Using an open source centric approach with shared community resources could be a viable approach for enabling these cross-domain capabilities."

COMMUNITY UNITY AND STANDARDS

Although equipment manufacturers can provide many domain AI solutions for professional networks/single-point equipment, these solutions are limited in "field of view" and cannot solve problems that require a more global view, such as end-to-end service quality assurance and rapid response to faults. Operators will need to aggregate management and maintenance data in various network domains by building a unified data sharing platform, and based on this, further provide a unified computing resource pool, basic AI algorithms and inference platform (i.e. cross-domain AI platform) for scenario-specific AI, end-to-end scenarios, and intra-domain scenarios using an applied reasoning platform. Using an open source centric approach with shared community resources could be a viable approach for enabling these cross-domain capabilities.

4.3 Emerging Opportunities

The telecom industry has been working on converged infrastructure for a while (for example, Voice Over IP has long been an industry standard). However, there is far more that can be done to drive even more efficiencies with network and infrastructure convergence. For example:

CONVERGED INFRASTRUCTURE

Converged infrastructure is needed to support the growth and sustainability of AI. This is particularly important in the need for a single solution designed to integrate compute, storage, networking, and virtualization. Data volumes are trending to grow beyond hyperscale data, and with such massive data processing requirements the ability to execute is critical. The demands on existing infrastructure are already heavy, so bringing everything together to work in concert will be key to maintain and grow the demand for resources.

In order to do that, the components will need to work together efficiently and the network will play an important role in linking specialized hardware accelerators like GPUs (Graphics Processing Units) or TPUs (Tensor Processing Units) to accelerate AI workloads beyond current capability. Converged infrastructure solutions will lead to the ability to deploy AI models faster, iterate them more efficiently, and extract insights faster. This can pave the way for the next generation of AI.

CONVERGED SERVICES AND INTEGRATED SOLUTIONS

Converged Services and Integrated Solutions that combine AI with traditional services have the potential to deliver enhanced services to end customers, but more importantly these services need to leverage AI-driven insights, automation, and personalization to optimize user experience, improve efficiency, and drive innovation across industries. There are many existing industry use cases for this already which include healthcare, legal, retail, and incidence tracking. The analytics delivered by a converged service provide automated insights and tools that can provide real-time tracking, response and remediation.

BUSINESS INNOVATION: NEW REVENUE STREAMS

Data monetization encompasses various strategies, including selling the raw data, offering data analytics services, and developing data-driven products or solutions to customers. Organizations can monetize their data by identifying valuable insights, patterns, or trends hidden within their datasets that no group of human resources can possibly identify quickly. These insights can then be used to create new products and services that will better serve customers and organizations. This is a new strategic business opportunity for organizations looking to monetize anonymous data and leverage it for

increased business efficiency and to determine product direction and determine new go to market strategies.

DATA PRIVACY AND SECURITY

The ability to monetize Network Data comes with a big caveat, which is that the use of customer data must be handled with care to ensure data privacy, security and regulatory compliance. This requires clear policies and security procedures to ensure anonymity, safety and privacy at all times. The good news is that AI can be used to address the growing threat of network vulnerabilities, zero day exploits and other security related issues with predictive analytics and threat analysis.

DATA MODEL SIMPLIFICATION

Large language models can be used to understand large amounts of unstructured operation and maintenance data (for example, system logs, operation and maintenance work orders, operation guides, company documents, etc., which are traditionally used in human-computer interaction or human-to-human collaboration scenarios), from which effective knowledge is extracted to provide guidance for further automatic/intelligent operation and maintenance, thereby effectively expanding the scope of the application of autonomous mechanisms.

"Using an open source centric approach with shared community resources could be a viable approach for enabling these cross-domain capabilities."

5. What Makes Intelligent Networking a Unique Case for Applying AI?

A natural question arises on how the power of LLMs can be harnessed for problems and applications related to Intelligent Networking, network automation and for operating and optimizing telecommunication networks in general, at any level of the network stack. Datasets in telco-related applications have a few particularities unique to the industry. For one, the data one might encounter ranges from fully structured (e.g. code, scripts, configuration, or time series KPIs), to semi-structured (syslogs, design templates etc.), to unstructured data (design documents and specifications, Wikis, Github issues, emails, chatbot conversations).

Another issue is domain adaptation. Language encountered in telco datasets can be very domain specific (including CLI commands and CLI output, formatted text, network slang and abbreviations, syslogs, RFC language, network device specifications etc.). Off-the-shelf performance of LLM models strongly depends on whether those LLMs have actually seen that particular type of data during training (this is true for both generative LLMs and embedding models). There are several approaches to achieve domain adaptation and downstream task adaptation of LLM models. In general these either rely on:

- In-context-learning, prompting and retrieval augmentation techniques
- Fine tuning the models
- Hybrid approaches

For fine tuning LLMs, unlike for regular neural network models, several specialized techniques exist in the general area of PEFT (Parameter Efficient Fine Tuning), allowing one to only fine tune a very small percentage of the many billions of parameters of a typical LLM. In general, the best techniques to achieve domain adaptation for an LLM heavily depends on:

- The type of data and how much domain data is available
- The specific downstream task
- The initial foundation model

In addition to general domain adaptation, many telcos will have the issue of multilingual datasets, where a mix of languages (typically English + something else) will exist in the data (syslogs, wikis, tickets, chat conversations etc.). While many options exist for both generative LLMs[1] and text embedding models[2], not many foundation models have seen enough non-English data in training, thus options in foundation model choice are somewhat restricted for operators working on non-English data. A solution to work around this issue is to use automated translation and language detection models on the data as a preprocessing step.

Beyond these approaches, an emerging technique for pre-training foundation models on network data holds potential promise. With this technique, network data is essentially turned into a language via pre-processing and tokenization, which can then be used for pre-training a new "network foundation model."[8] Initial research has successfully demonstrated this approach on Domain Name Service (DNS) data[9] and geospatial data.[10] As this area of research matures, it could allow for general purpose network foundational models that can be fine-tuned to answer a variety of questions around network data or configurations without having to train individual models for bespoke network management tasks.

While foundation models and transfer learning have been shown to work very well on general human language when pre-training is done on large corpuses of human text (such as Wikipedia, or the Pile[3]), it remains an open question to be answered whether domain adaptation and downstream task adaptation work equally well on the kinds of domain-specific, semi-structured, mixed modality datasets we find in the telecom industry. To enable this, telecoms should focus on standardization and data governance efforts, such as standardized and unified data collection policies and developing high quality structured data across a common definition and understanding.

"As this area of research matures, it could allow for general purpose network foundational models that can be fine-tuned to answer a variety of questions around network data or configurations without having to train individual models for bespoke network management tasks."

6. Projects and Research

6.1 3GPP Intelligent Radio Access Network (RAN)

The intelligent evolution of wireless access networks is in a phase of rapid evolution and continuous innovation. In June 2022, 3GPP announced the freezing of R17 and described the process diagram of an intelligent RAN in TR37.817, including data collection, model training, model inference, and execution modules, which together form the infrastructure of an intelligent RAN. This promotes the rapid implementation and deployment of 5G RAN intelligence and provides support for intelligent scenarios such as energy saving, load balancing, and mobility optimization.

AI AND MACHINE LEARNING DRIVE 5G RAN INTELLIGENCE

Artificial intelligence and Machine Learning technologies are playing an increasingly important role in 5G RAN intelligence. The application of these technologies enables the network to learn autonomously, self-optimize, and self-repair, thereby improving network stability, reliability, and performance. For example, by using machine learning algorithms to predict and schedule network traffic, more efficient resource allocation and load balancing can be achieved. By leveraging AI technologies for automatic network fault detection and repair, operation and maintenance costs can be greatly reduced while improving user experience. The intelligence of 5G wireless access networks also provides broad space for various vertical industry applications. For instance, in intelligent manufacturing, 5G can enable real-time communication and data transmission between devices, improving production efficiency and product quality. In smart cities, 5G can provide high-definition video surveillance, intelligent transportation management, and other services to enhance urban governance. Additionally, 5G has played a significant role in remote healthcare, online education, and other fields.

CHALLENGES FACING 5G RAN INTELLIGENCE INDUSTRIALIZATION

However, despite the remarkable progress made in the 5G wireless access network intelligence industry, some challenges and issues remain to be addressed, in parallel to some of the existing pain points across networking in general. For example, network security and data privacy protection are pressing issues that require effective measures to be implemented. The energy consumption issue of 5G networks also needs attention, necessitating technological innovations and energy-saving measures to reduce energy consumption. In the future, continuous efforts should be made in technological innovation, market application, and other aspects to promote the sustainable and healthy development of the 5G wireless access network intelligence industry.

6.2 Core Network Transformation

Mobile core networks can be thought of as the brains of mobile communication. In recent years, these networks have experienced a huge transformation from legacy proprietary hardware to telecom cloud native systems. Today, the majority of mobile core networks are deployed based on telco cloud architectures supported by NFV technologies. Intelligent networking most benefits

the packet core networks such as 5GC and UPF which are responsible for packet forwarding, IMS which support delivery of multimedia communications such as voice, message and video, and operational functions that manage the core network itself including telco cloud infrastructure and 5G network applications. There have been three areas where intelligent networking shows benefits:

NETWORK INTELLIGENCE ENABLES EXPERIENCE MONETIZATION AND DIFFERENTIATED OPERATIONS

For a long time, operators have strived to realize traffic monetization on MBB (Mobile Broadband) networks. However, there are three technical gaps: non-assessable user experience; limited or no dynamic optimization; and no-closed-loop operations. To bridge these gaps, there is a need for an Intelligent Personalized Experience solution, designed to help operators add experience privileges to service packages and better monetize differentiated experiences. Typically in the industry, the user plane on the mobile core network processes and forwards one service flow using one vCPU. As heavy-traffic services increase, such as 2K or 4K HD video and live streaming, microbursts and extremely large network flows become the norm, it becomes more likely that a vCPU will become overloaded, causing packet loss. To address this issue, Intelligent AI supported 5G core networks need to be able to deliver ubiquitous 10 Gbps superior experiences.

SERVICE INTELLIGENCE EXPANDS THE PROFITABILITY OF CALLING SERVICES

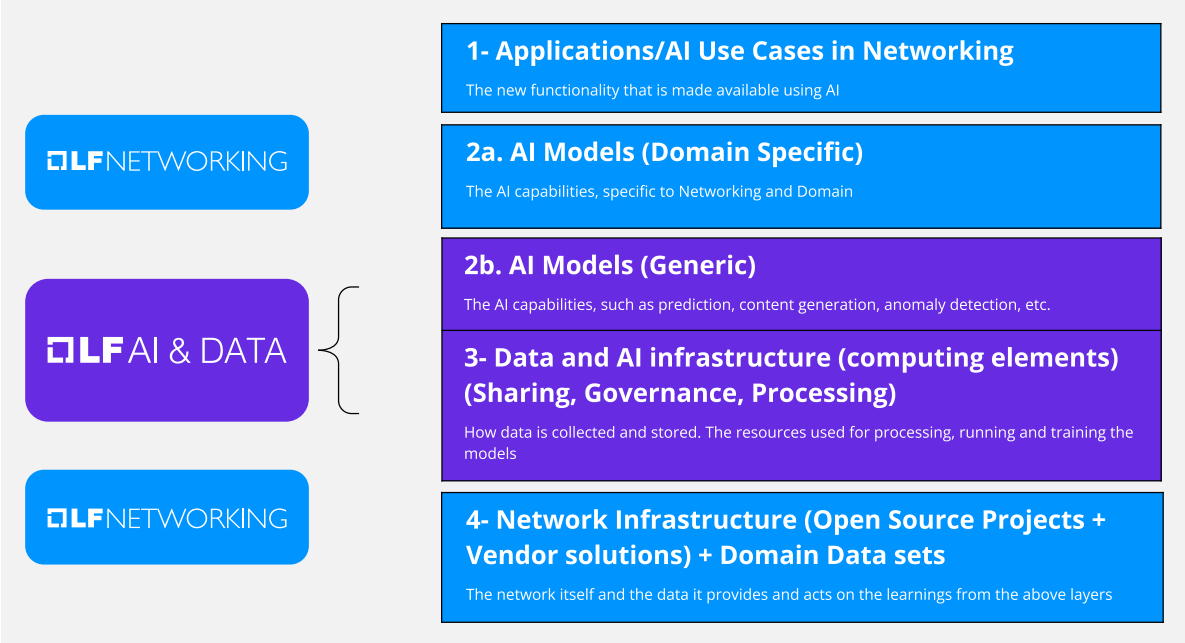
In 2023, New Calling was put into commercial use, based on a 3GPP specification; it can enhance intelligence and data channel (3GPP specification)-based interaction capabilities. Additionally, it enables users to use multi-modal communications, and helps operators construct more efficient service layouts. 3GPP architecture also allows users to control digital avatars through voice during calls, delivering a more personalized calling experience. One example where this can be seen as a business opportunity might be an enterprise using the framework to customize its own enterprise ambassador avatar to promote their brand.

O&M INTELLIGENCE ACHIEVES HIGH NETWORK STABILITY AND EFFICIENCY

Empowered by the multi-modal large model, Digital Assistant & Digital Expert (DAE) based AI technology could reduce O&M workload and improve O&M efficiency. It can reshape cloud-based O&M from “experts+tools” to intelligence-centric “DAE+manual assistance”. Using the DAE, it is possible that up to 80% of telecommunication operator trouble tickets can be automatically processed, which is far more efficient than the manual processing that is seen for the most part today. DAE also enables intent-driven O&M, avoiding manual decision-making. Before, it commonly took over five years to train experts in a single domain; with the multi-modal large model it is now possible for it to be trained and updated in mere weeks.

7. How Can Open Source Help?

It is important to understand the current landscape of Open Source Software (OSS) projects and initiatives and how they came into existence to see how OSS is well positioned to address the challenges of Intelligent Networking. Several such initiatives have already laid down the groundwork for building Network AI solutions, or are actively in the process of creating them. Building on these foundations, it is easy to envision the critical role open source software can play in unleashing the power of AI for the future generations of networking. Some of the required technologies are unique to the Networking industry, and will have to be addressed by existing OSS projects within the current landscape, or by the creation of additional ones. Some pieces of the technologies are more generic, and will need to come from the broader community of AI OSS. Here is a rough outline of the different layers of Networking AI and the sources for the required technology:



In addition, successful development of AI models for use in Networking relies on the availability of data that could be shared under a common license. The Linux Foundation created the Community Data License Agreement (CDLA) for this purpose. Using this license, end users can share data and make it available for researchers, who in turn can further develop the necessary models and applications that benefit the telecom ecosystems and ultimately the end users.

7.1 Related Open Source Landscape

The legal and technical framework for sharing research is important, but what is really essential for driving innovations is the ability for Open Source to provide a forum for creating communities with shared purpose. These communities, by allowing people from various companies, diverse skill levels and different cultural perspectives to collaborate, have the potential to spark real innovation in ways that are not really possible in any other context.

NETWORK COMMUNITIES

Open Source Software communities have been successfully creating projects that provide the building blocks for commercial networks for over a decade. OSS projects provide the underlying technology for all layers of the network, including the data/forwarding plane, control plane, management and orchestration. A vibrant ecosystem of contributing companies exists around these projects, consisting of organizations that realize the value of OSS for speeding the development of networking technology:

- Shared effort to develop the foundation layers of the technology, freeing up more resources to develop the value-added layers
- A neutral platform for innovation where individuals and organizations can exchange ideas and develop best-of-breed technology solutions
- An opportunity to demonstrate thought leadership and domain expertise
- A collaboration space where producers and consumers of technology can freely interact to create new business opportunities

Many of the networking OSS projects are hosted by the Linux Foundation. Most of them are part of **LF Networking**, **LF Connectivity** and **LF Broadband**.

AI COMMUNITIES

The same principles are now being applied to the shared development of Network AI technologies, where the open source community fosters innovation and potentially stimulates business growth. AI innovation has been strongly propelled by OSS projects that were initiated following the same principles of open collaboration. It is hard to imagine doing any modern AI development without heavily relying on OSS. OSS AI and ML projects range anywhere from the frameworks for development to libraries and programming tools. OSS work means that data scientists who develop domain specific models, such as networking and telecommunications, can focus on innovation by leveraging OSS projects to jump start their work. It would be almost impossible to mention all the relevant OSS AI projects here as there are already so many, and the list only keeps growing. The Linux Foundation AI & Data maintains a useful dynamic landscape **here**.

OPEN AI MODELS

There is a lot of debate on the definition of what an "Open AI model" really means. While it is out of the scope of this paper to try and settle any of those debates, it is obvious that there is a clear need to create the definition of "open LLM". The sooner such definitions are created and blessed by the industry, the faster innovation can happen.

In the area of open source LLMs, both with respect to generative models[1] as well as more specialized, discriminative models such

"It is hard to imagine doing any modern AI development without heavily relying on OSS."

as text classifiers, QA, summarization, and text embedding models,[2] has been particularly vibrant and have evolved rapidly over the past five years. A number of global platforms are being widely used for sharing open models, code, datasets and accompanying research papers have been particularly instrumental in democratizing access to cutting edge technologies and fostering an environment of global collaboration. Among these platforms, Huggingface[4] has played a particularly pivotal role. At the time of this writing, HuggingFace hosts[31] over 350K models, 75K datasets and 150K demo apps (Spaces), in more than 100 languages. It also maintains Transformers, a popular open source library that facilitates integrating, modifying and performing downstream task adaptation for thousands of foundation models from this vast repository. It also provides the Datasets library, as well as several widely used benchmarks and leaderboards[1,2] that are very instrumental for researchers and developers implementing LLM solutions. Other important platforms used by the AI/ML open source community in general (not necessarily LLM-focused) are Kaggle[6] (used for public datasets and high profile ML competitions in all areas) and Paperswithcode[7] (this platform links academic research papers to their respective code and implementation, as well as providing benchmarks and leaderboards comparing different competing solutions for a wide area of ML tasks).

INTEGRATION BLUEPRINTS

In recent years The Linux Foundation Networking launched a set of Open Source Networking "**Super Blueprints**" that outline architectures for common networking use cases and are built using OSS technology. Those blueprints consist of collections of OSS projects and commercial products, integrated together by the open source community and documented for free use by any interested party. Several of these blueprints started incorporating AI technologies and that trend is expected to accelerate, as existing blueprints inspire additional AI-driven solutions. One promising area is intent-based network automation. There is current work on blueprints that use NLP and LLM to translate user intent, expressed in natural spoken language to network requirements, and generate full network configuration based on those requirements. Such an approach can significantly simplify existing network operation processes, and enable new automated services that can be directly consumed, commonly known as Network-as-a-Service (NaaS).

VERIFICATION PROGRAMS

Experience with OSS in other domains shows that whenever there is an OSS technology that powers commercial products or offerings, there is a need to validate the products to make sure they are properly using the OSS technology and are ready to use in a predictable manner. Such validation/verification programs have existed as part of OSS ecosystems for a while. The Cloud Native Computing Foundation (CNCF) has a successful "Certified Kubernetes" program that helps vendors and end users ensure that Kubernetes distributions provide all the necessary APIs and functionality. A similar approach needs to be applied to any OSS Networking AI projects. Users should have a certain level of confidence, knowing that the OSS based AI Networking solution they use will behave as expected.

THOTH PROJECT - TELCO DATA ANONYMIZER

The **Thoth project**, which is a sub project under the **Anuket infrastructure project**, has recently focused on a major challenge to the adoption of intelligent networks: the lack of a common data set or an agreement on a common understanding of the data set that is needed. AI has

"AI-enabled interfaces, coupled with distributed computing, will pave the way for end-to-end AI applicability, fostering convergence across the telecommunications and computing domains."

the potential for creating value in terms of enhanced workload availability and improved performance and efficiency for NFV use cases. Thoth's work aims to build machine-Learning models and Tools that can be used by telecom operators (typically by the operations team). Each of these models is designed to solve a single problem within a particular category. For example, the first category chosen is Failure prediction, and the project plans to create six models — failure prediction of VMs, containers, nodes, network links, applications, and middleware services. This project also will work on defining a set of data models for each of the decision-making problems, that will help both providers and consumers of the data to collaborate.

7.2 Common Vision: Intelligence Plane for XG Networks Powered by Open Source Software

As we embark on the journey towards 6G and embrace the vision outlined by the International Telecommunication Union (ITU) for IMT-2030, it becomes clear that AI can and will play a pivotal role in reshaping network operations.

At the heart of this transformation lies the concept of the intelligence plane, where AI-driven systems leverage natural intent interaction to seamlessly bridge the gap between users and networks. Smart orchestration ensures optimal resource allocation and dynamic adaptation to meet evolving demands, thereby enhancing network performance and user experience. Real-time meta network verification, powered by AI algorithms, ensures continuous monitoring and validation of network behavior, preempting potential issues and maintaining operational integrity. Additionally, built-in knowledge open-loops enable networks to autonomously learn and adapt, fostering resilience and responsiveness.

The concept of ubiquitous intelligence envisaged by IMT-2030 underscores the pervasive presence of AI across the telecommunications community. AI-enabled interfaces, coupled with distributed computing, will pave the way for end-to-end AI applicability, fostering convergence across the telecommunications and computing domains. Open source community under the Cloud Native Computing Foundation (CNCF) and LF Networking have been working on that convergence and are now applying AI to build those AI powered networks.

Drawing from the IMT-2030 vision, the integration of AI into mobile networks unlocks transformative capabilities. Future networks that will support extended reality (XR), haptic sensors, immersive experience and smart machines will be built using the building blocks provided by Open Source Software projects implementing the latest AI technologies.

8. Call for Action

The Linux Foundation's role in joining the AI revolution underscores the importance of open-source collaboration in advancing network capabilities. By harnessing open-source technologies, network operators can leverage the collective expertise of the community to accelerate innovation and adoption of AI-driven solutions. This collaborative approach not only democratizes access to advanced AI capabilities but also fosters interoperability and scalability across diverse companies and network environments.

"By harnessing open-source technologies, network operators can leverage the collective expertise of community to accelerate innovation and adoption of AI-driven solutions."

The future of Intelligent Networks and AI adoption in the telecom industry is in the hands of the individuals and organizations who are already contributing to projects and initiatives, and those who will join them. If you are involved in building and operating networks, developing network technology or consuming network services, you are most heartily encouraged to get involved. Engaging with OSS communities is a way to shape the future of networking. Your contribution could be small or large, and does not necessarily involve writing code. In fact the community is very much in need of contributors of white papers such as this one, evangelists and big thinkers who want to drive the realization of some really cool and useful leading edge technologies. Some of the ways to contribute include:

- Attending Project meetings
- Attending Developer events
- Joining approved Projects
- Proposing a new Project
- Writing documentation
- Contributing use cases
- Analyzing requirements
- Defining tests / processes
- Reviewing and submitting code patches
- Building upstream relationships
- Contributing upstream code
- Start or join a User Group
- Hosting and staffing a community lab
- Answering questions
- Giving a talk / training
- Creating a demo
- Evangelizing the projects

Ways to get involved in Intelligent Networking and AI:

- Collaborate on Network Super Blueprints or develop new ones: **https://wiki.lfnetworking.org/x/ArAZB**
- Work on the **Thoth** project - Telco Data Anonymizer Project
- Join LFN AI mailing list: **https://lists.lfnetworking.org/g/lfn-ai-taskforce**

Final Thoughts

In conclusion, the future of networks in the era of 6G and beyond hinges on the transformative power of AI, fueled by open-source collaboration. By embracing AI-driven intelligence, networks can enhance situational awareness, performance, and capacity management, while enabling quick responses to address undesired states. As we navigate this AI-powered future, the convergence of technological innovation and open collaboration holds the key to unlocking boundless opportunities for progress and prosperity in the telecommunications landscape.

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