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Evolution of Telco Networks in Cloud-Native paradigm

Published by LF Networking and contributed by Infosys

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A Linux Foundation Networking publication

Evolution of Telco Networks in Cloud-Native paradigm

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Abstract

The telecommunications industry is undergoing a transformative shift from traditional Telco models to agile, software-driven Techco architecture. This evolution is fueled by the convergence of networks and IT, enabling the adoption of Telco Cloud platforms that move beyond legacy NFV MANO frameworks to fully cloud-native environments. Declarative APIs and intent-driven automation are redefining service orchestration, with GitOps emerging as a key enabler for continuous delivery and operational consistency. Intelligent, cloud-native orchestration and integrated Agile DevNetOps practices are being essential to cater to multi-cloud, multi-vendor, and hybrid network ecosystem, supported by AI-driven network automation and observability. Despite these advancements, telecom operators face challenges in modernization, integration, and skill transformation. Open-source innovations driven by some Operators and collaborative industry initiatives like Sylva and Nephio are helping bridge these gaps, accelerating the journey toward scalable, resilient, and future-ready telecom infrastructure.

Preface from LF Networking

As telecom networks undergo one of the most significant transformations in their history, from appliance-centric infrastructures to cloud-native, software-defined platforms, the role of open source has shifted from “nice to have” to “non-negotiable.” Across the LF Networking (LFN) ecosystem, we see operators, vendors, and cloud providers converging around a common goal: build networks that are

programmable, automated, and resilient enough to support 5G, edge, AI-driven services, and whatever comes next—without locking themselves into any single vendor or stack.

This white paper, *Evolution of Telco Networks in Cloud-Native Paradigm*, sits squarely in that context. It traces how telco architectures are moving from monolithic and tightly coupled systems toward modular, cloud-native building blocks; how Kubernetes and modern CI/CD practices are reshaping lifecycle management; and how operational models and skills must evolve in parallel. These are exactly the questions LFN communities are working on every day through projects focused on automation, cloud-native infrastructure, data and AI for networking, and end-to-end blueprints.

LFN's value is to provide the neutral home where this evolution can be designed, implemented, and proven in the open. Our projects offer reference architectures, validated integration blueprints, and production-grade software components that map directly onto the patterns described in this paper. Together, they reduce risk for operators, accelerate innovation for vendors and cloud providers, and create a shared foundation on which differentiated services can be built.

We invite you to read this paper as both a technical guide and a roadmap for collaboration. The cloud-native journey is not one any organization can—or should—take alone. By engaging with LFN's open communities and broader ecosystem, contributing requirements and code, and adopting the practices highlighted here, the ecosystem can collectively deliver the flexible, automated, and intelligent networks that the next decade will demand.

Transitioning From Telco to Techco

Telecom Operators are rapidly navigating the inevitable transition from traditional **Telco** ecosystem to more dynamic, innovation-driven **Techco** organizations. This fundamental shift is powered by rapid evolution of standards, technology and processes, empowering Telcos to deliver beyond connectivity solutions. Operators are transforming both IT and Network ecosystems to deliver more agility and customer centric value to rapidly align to changing consumer demands.

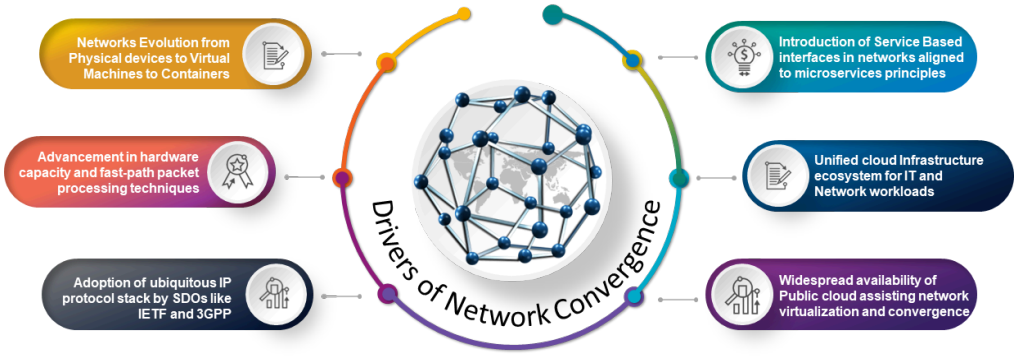
Alongside IT ecosystems, Networks are also embracing agility to rapidly serve changing customer demands through the adoption of virtualization, software-defined and cloud-native technologies faster than ever. They are rapidly transitioning to become autonomous, intelligent and programmable platforms supporting faster service deployment, real-time analytics, and the ability to scale to serve ever increasing service volumes.

Networks and IT Convergence

The Tele-communication Industry has undergone a profound convergence in the last couple of decades, propelled by a relentless pace of innovation. Networks have gradually transitioned from hardware-centric architectures reliant on physical devices to flexible environments leveraging virtual

machines and, more recently, lightweight containers. This shift has been facilitated by rapid advancements in processing power of silicon and sophisticated fast-path packet processing techniques, complemented with advancements in **software-defined networking** (SDN) and **network function virtualization** (NFV) techniques.

Standard Development Organizations (SDOs) like the **IETF** and **3GPP**, through the ubiquitous IP protocol stack, have been pivotal in driving this convergence, fostering interoperability and a unified communication paradigm. The adoption of open interfaces in 5G networks, mirroring the principles of microservices, has further accelerated this trend, paving way for modularity and agile development within network infrastructures.



This convergence is empowering Network Operators towards a **unified Telco Cloud infrastructure** layer, capable of handling both traditional IT workloads and virtualized network functions. This unification not only streamlines operations but also improves efficiency, agility, and innovation across the entire digital ecosystem. The expansive reach and ubiquitous presence of public cloud providers are further accelerating network virtualization, offering scalable and resilient platforms for deploying and managing network services globally.

Telco Cloud: Cloud Native Network Transformation

Telco Cloud has fostered Service Providers to transition from rigid, hardware-based networks to agile, software-defined infrastructure. This agility is further getting strengthened through movement of Telco Cloud from legacy on-premises models to a flexible hybrid cloud environment, combining private and public cloud resources.

Telco Cloud journey began with the **ETSI NFV MANO** (European Telecommunications Standards Institute's Network Functions Virtualization Management and Orchestration) framework founded on virtualization paradigm but was often complex and monolithic. Since last few years, industry is rapidly embracing modern Platform Architecture built on cloud-native principles and centered around Kubernetes for Telco workloads. This new model is designed to automate the lifecycle of both legacy **Virtual Network Functions (VNFs)** and modern **Cloud-native Network Functions (CNFs)** on a common infrastructure.

Modern Telco Cloud platforms are built on principles that drive automation and efficiency via adoption of key Cloud-Native principles and Industry trends as explained further below.

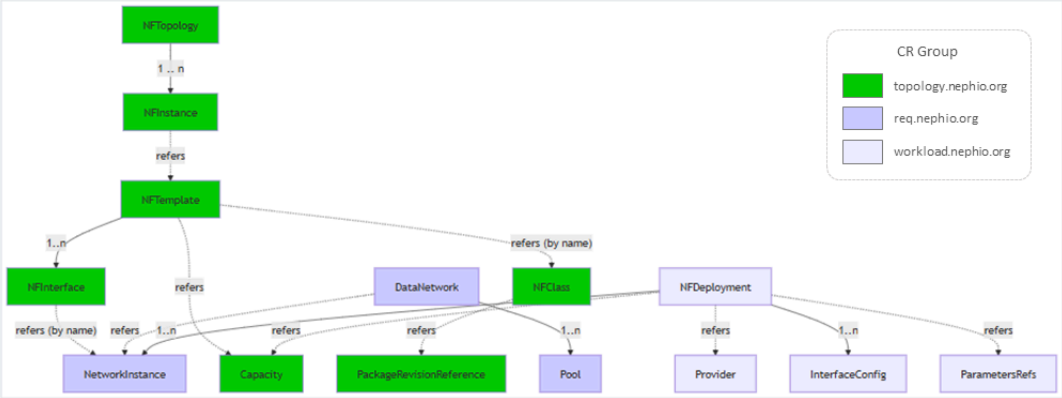
Intent Driven Orchestration using Declarative APIs

In the new paradigm, Operators define the desired state of the network instead of providing step-by-step instructions in an imperative manner. The Network Controller then strives to achieve and maintain that state. For example, target network is provisioned by indicating "provide 5G coverage with up to 2000 active subscribers for a locality" instead of "identify 3 sites and radio spectrum, deploy gNodeBs, configure and provision backhaul connectivity to core network".

This is being realized through the definition of well-defined, measurable Intent at multiple levels. For instance, Service intent which represents the desired KPIs of Network Service e.g. bandwidth, latency etc. is further decomposed based on underlying connectivity infrastructure and active consumers to determine Resource intent needed to guarantee the desired Service KPIs.

In context of Kubernetes ecosystem, intent is generally described in terms of Domain-specific **Custom Resource Definitions (CRD)** which are processed by **Operators / Controllers** into K8S resources representing the Network Functions which are then monitored for their running state to match desired state. Custom Resources are being standardized to represent desired Network state covering all dimensions of Cluster Infra, Network Functions, Topology and Day 0/1 configurations.

Refer to the relationship diagram below with Kubernetes CRs representing a Network Topology covering Network functions and their connectivity; taken from **Nephio** which is an LF Networking project focusing on Cloud-Native automation solutions for 5G networks.



Source: https://docs.nephio.org/docs/apis/#topology-and-network-apis

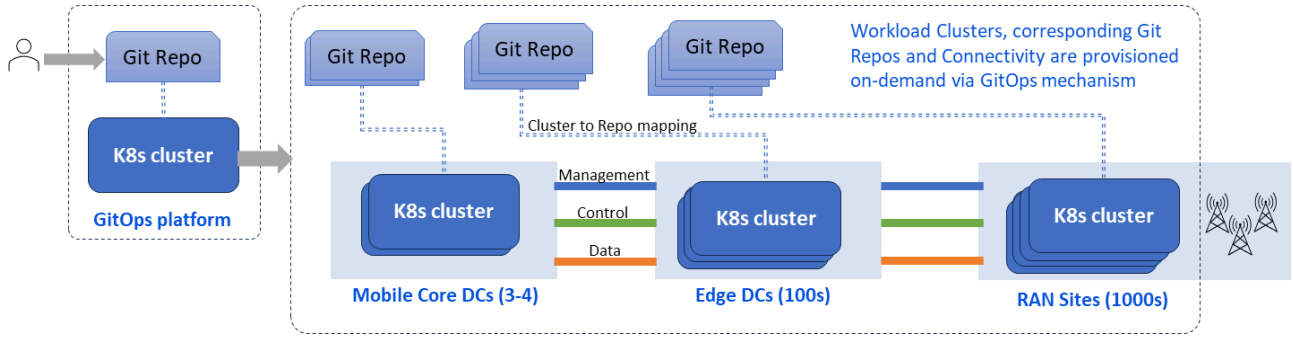
Network Rollout via GitOps principles

GitOps approach establishes the foundation of Declarative API; with desired state of Network and Applications published to Git Repo by deployment teams. A Kubernetes controller (e.g. ArgoCD, Flux, Configsync etc.) constantly monitors changes to the Git Repo and replicates the desired state into Kubernetes cluster mapped to it. It is a mature mechanism driving rollout of all infrastructure and workload configurations to K8S clusters, enabling automated and auditable deployments.

When leveraging GitOps for Telco Cloud workloads, operators are faced with additional considerations and challenges.

Cluster Provisioning: With virtualization of RAN components (e.g. O-RAN) and increasing needs of Edge deployments, k8s clusters need to be provisioned in 100s of Edge locations and 1000s of Mobile sites as

well. Hence, it is imperative to perform K8S Cluster Provisioning also in an automated manner. GitOps approach is also being leveraged for this for better scalability and alignment to disaster recovery scenario.



Day 0/1 Configuration: To establish Git repository as the Single source of truth of network state, the current network configuration should also be propagated to devices via GitOps approach for all operational tasks. Unfortunately, many CNFs have not still transitioned to cloud-native way for configuration management (configmap, secrets, CRs) and **are still following traditional approaches** (CLI, Netconf, SNMP etc.) for their configuration. This needs specialized controllers to be designed for propagation of configuration from Git repo to corresponding CNFs running in the clusters with support for handling commit failures, rollbacks and atomic updates spanning multiple devices.

Hierarchical, Synchronized Orchestration: Provisioning of end-to-end network based on CNFs often needs hierarchy of cluster, network function and their configuration orchestrated sequentially via GitOps paradigm. The orchestration solution needs to be designed to perform their provisioning in an iterative, synchronized manner to optimally achieve rollout of 100s of Edge/Mobile sites. For example, the O-Cloud Orchestration layer (FOCOM) in O-RAN SMO has well-defined procedures to coordinate cluster provisioning via O2IMS interface and workload placement via O2DMS interface to seamlessly deploy a virtualized RAN site.

Cloud Native Automation and Intelligence

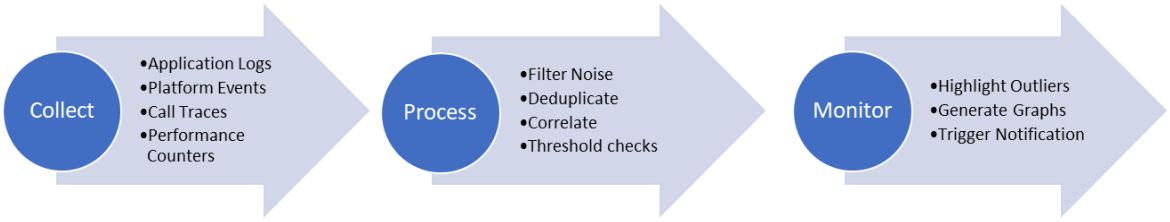
With the adoption of Cloud-Native approach for Telco Cloud built-up, Operators are embracing various platform capabilities to improve the availability, security and maintainability of the Network Services.

Network Vendors are increasingly making their Containerized Network Functions (CNFs) compliant to **12-factor app principles** to reap the inherent benefits of better Resilience, Portability and Scalability. Although a lot of progress has been made, there remain gaps in some of the features due to legacy reasons. For example, much of the Network Function configuration is still being pushed by traditional Element Management System (EMS) after initial deployment of Network Functions violating the principle of “Store Configuration in the environment”. Principles where such deviations are still visible are highlighted with Amber Text in diagram below.

The extensive set of inbuilt features and 3rd party controllers powering **integrated Policy-driven Security enforcements** in Cloud-Native ecosystem are being leveraged increasingly to improve access security to the Telco Cloud environment and workloads, such as

- Role Based Access Control for users and applications
- Network Policies for intra-cluster and external access
- Pod Security Standards and Policies to restrict Elevated access and avoid associated Risks
- Resource Usage policies to ensure fair utilization of cluster across workloads
- Admission Control for Resource validation and mutation

Further on, **full Observability** capabilities available in Cloud-Native ecosystem are being utilized for Data Analytics to gain Realtime Insights into health and performance of workloads. Events and metrics are further processed through AI-powered Operations (AIOps) techniques to generate notifications and intelligent recommendations for incident remediation, thus reducing Mean-time-to-Repair (MTTR).



Integrated Agile DevNetOps

In modern telecom environments, DevOps principles are revolutionizing how network functions are developed, tested, and deployed. Instead of relying on traditional big bang upgrades that occur only a few times a year, operators are now embracing frequent, incremental updates to network functions—often every few weeks. This agile approach enables faster rollout of new features, reduces risk, and enhances responsiveness to evolving service demands. Central to this transformation are highly automated DevOps pipelines that rigorously validate each new network function release across both functional and non-functional parameters.

To further safeguard service continuity, operators leverage digital twin environments that emulate live network conditions. These virtual replicas allow for comprehensive regression testing and scenario

simulation, ensuring that updates do not negatively impact live services. Together, these practices enable a more resilient, adaptive, and innovation-driven network ecosystem.

Additionally, Zero-touch In-Service Software Upgrade (ISSU) techniques are transforming how network services are maintained and evolved, ensuring minimal disruption and maximum availability. By leveraging a combination of **Blue-Green** and **Rolling upgrade deployment strategies**, operators can seamlessly introduce new software versions while maintaining live traffic on stable instances. This automated mechanism enables continuous delivery of updates without impacting service quality, supporting the stringent requirement of **five 9's (99.999%) availability**. Such intelligent upgrade frameworks are essential for achieving true autonomy in network operations. For example, Telefonica O2 and Ericsson recently demonstrated the first upgrade of user plane of 5G core network in Germany without causing any Service disruption.

Hybrid and Heterogenous Network Ecosystem

Network vendors are increasingly embracing open standards and supporting deployments over standardized infrastructure platforms and public cloud environments. This has empowered Telecom operators to leverage the elasticity of public cloud infrastructure to enhance network resilience and scalability. By deploying the primary network functions on-premise within a Telco Cloud and using public cloud instances as active failover environments, operators can ensure seamless continuity in case of outages or capacity spikes. This hybrid approach enables dynamic **capacity augmentation on-demand**, as demonstrated by leading operators like Swisscom and Telefónica, allowing networks to scale efficiently while maintaining high availability and performance.

Furthermore, evolution of network architectures and the standardization of protocols have paved the way for a robust multi-vendor ecosystem across both infrastructure and network services. This interoperability enables telecom operators to compose and deploy network functions from diverse vendors, fostering innovation and flexibility.

Furthermore, although Telco CNFs are deployed similar to IT apps (Helm chart, Kustomize, Kpt package etc.), there are few nuisances to be handled correctly when hosting them in Cloud-native Kubernetes environment.

Multiple Network Interfaces: Telco Workloads need Separation of management, control and data plane traffic for better network planning and control. Hence, multiple networks need to be configured in Cluster using Container Network Interface (CNI) plugins like multus, macvlan etc. as well as over Transport underlay while designing the Data center network.

Network Interface Direct Access: Many CNFs like UPF perform Fast-path Packet processing of Data plane traffic leveraging technologies like Data Plane Development Kit (DPDK), Single Root Input/Output Virtualization (SR-IOV) etc., which needs installation of custom CNIs to get direct access to Network Interface from PoDs.

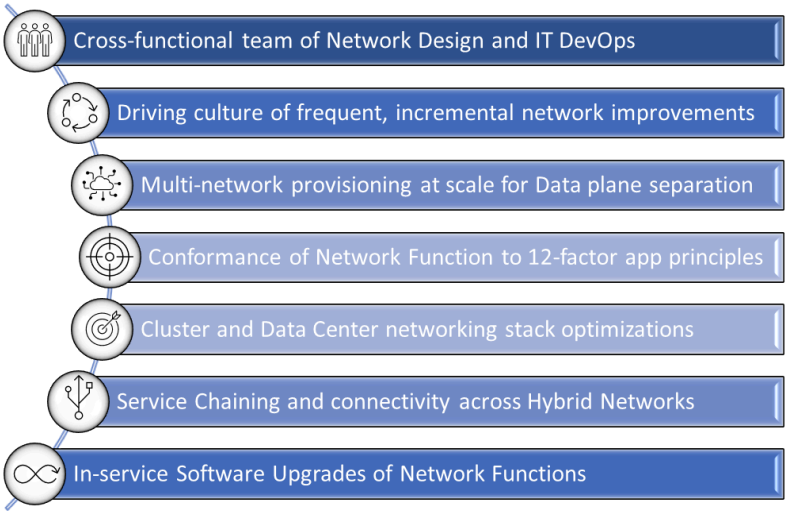
VM Support: Some Legacy Virtualized NFs from 3G/4G era are available only as Virtual Machines (VM) and need to be run as KubeVirt resources in the cluster for realizing unified Telco Cloud environment

AI Driven Network Automation

AI plays a critical role in Telco cloud network automation and orchestration by enabling intelligent, real-time decision-making and operational efficiency. Through **advanced analytics and machine learning**, AI automates the provisioning, scaling, and lifecycle management of network services, reducing manual intervention and accelerating service delivery. Tools like **ONAP** (Open Network Automation Platform), **Nephio** and AI-enhanced orchestration engines analyze vast amounts of network data to optimize resource allocation, predict demand, and ensure service continuity. This results in more agile, self-optimizing networks that can adapt dynamically to changing conditions while maintaining high performance and reliability.

Telecom Operators: Current Struggles and Challenges

One of the key challenges faced by telecom operators in their digital transformation journey is fostering effective collaboration between traditionally disjoint teams. Aligning cross-functional teams—particularly network design and IT DevOps—is essential for defining a cohesive platform architecture and strategy that supports agile, cloud-native network operations. Additionally, driving a culture of frequent, incremental network improvements poses its own set of challenges, especially in environments accustomed to large, infrequent upgrades. Embracing agile methodologies and DevOps practices demands not only technical alignment but also organizational change, making it a complex yet critical endeavor for achieving scalable, resilient, and future-ready networks.



In the new cloud-native paradigm of Telco Cloud platform, provisioning and management of multi-network environments at scale also poses significant challenges, especially with the separation of management, control, and data planes. This complexity demands robust orchestration and automation capabilities. Additionally, ensuring all network functions adhere to 12-factor app principles is essential to fully leverage cloud-native benefits like scalability, resilience, and portability. However, aligning legacy systems and vendor solutions with these modern design principles remains a significant hurdle.

The standard Kubernetes cluster networking plugins leverages multiple levels of packet encapsulation for network virtualization and segmentation, which can lead to increased latency and reduced performance

if not carefully managed. Considering the traffic volumes handled by Telcos, it is imperative for them to devise new techniques to optimize cluster and data center networking to manage the overhead caused by excessive encapsulation of overlay paths. Additionally, integrating modern cloud-native architecture with legacy network infrastructure introduces significant architectural complexity and requires meticulous planning, robust abstraction layers, and advanced orchestration capabilities.

Another technology hurdle to overcome is ensuring seamless service delivery across hybrid networks, particularly when implementing service chaining and maintaining consistent connectivity between on-premise and cloud environments. Additionally, achieving in-service software upgrades with zero downtime and no session disruption remains a complex task. It demands advanced automation, intelligent traffic steering, and resilient architecture to ensure continuous service availability while introducing new features or patches.

Open-source Innovation and Industry Initiatives

The evolution of Telco Cloud platforms is being driven by a rich ecosystem of open-source projects that deliver agility, scalability, and automation across the telecom stack. These projects, curated by **Cloud Native Computing Foundation (CNCF)**, **Linux Foundation Networking (LFN)** and other communities, enable Communication Service Providers (CSPs) to build resilient, cloud-native networks that meet the demands of 5G and beyond.

CNI Plugins like **Cilium**, **Calico** and **Flannel** provide secure and scalable network connectivity for containerized workloads while foundation of policy-driven governance and zero-trust architecture for Telco cloud clusters is delivered by **Open Policy Agent (OPA)** and **Kyverno**. **Istio** and **Envoy** enable service mesh capabilities with traffic encryption, authentication, and telemetry.

GitOps tools like **Argo** and **FluxCD** automate network function deployment and lifecycle management leveraging declarative CI/CD pipelines. On the other hand, **Nephio** focuses on intent-based orchestration of Telco workloads.

Augmenting the network orchestration track, **Kubenet** and **Paraglider** support dynamic network configuration and multi-cloud integration capabilities while **Crossplane** executes provisioning of cloud resources using Kubernetes-native APIs.

Multiple community-based projects are powering observability space for Telcos providing deep visibility into workload and infra health. Some prominent once includes **Prometheus** and **OpenTelemetry** to collect and export metrics and traces, while **Jaeger** enables distributing tracing of interactions across services. **Fluentd** is another major tool which aggregates and forwards logs across environments.

Few other important tools around cloud-native ecosystem are relevant for Telco workloads. For example, **KubeVirt** enhances K8S clusters to run VMs alongside containers while **KubeEdge** brings Kubernetes to edge nodes. **Litmus** has established itself as the foundation of chaos engineering for resilience testing. **KEDA** empowers Telco workloads to auto-tune to traffic demands through event-driven autoscaling for microservices.

Several telecom operators have showcased production-grade Telco Cloud deployments built on in-house platforms using open-source technologies. **Deutsche Telekom** has developed a comprehensive **Kubernetes Cluster-as-a-Service (CaaS)** platform called, **Das Schiff**, entirely from open-source components, enabling the hosting of Mavenir's 5G Standalone (SA) network functions across multiple geographies. This demonstrates the scalability and maturity of open-source in real-world telecom environments. Meanwhile, **Orange** has emerged as a key promoter and active user of **Project Sylva**, a collaborative initiative aimed at creating a standardized cloud-native infrastructure for telecom. Orange is currently conducting trials to deploy Nokia's 5G Core over the Sylva platform, further validating its readiness for commercial-grade Telco Cloud operations.

These deployments highlight the growing confidence in open-source ecosystems to deliver robust, flexible, and vendor-neutral cloud-native infrastructure for next-generation telecom networks.

Similarly, the **Cloud Native Telecom Initiative (CNTi)** under LF Networking focuses on accelerating the adoption of cloud-native technologies in telecom by documenting best practices and establishing a unified conformance program.

Infosys remain deeply committed to fostering innovation within the open-source ecosystem. As a Platinum member of both LF Networking and CNCF under the Linux Foundation umbrella for the past three years, Infosys has actively contributed to development and Industry adoption of several community-driven projects including ONAP, Nephio, Camara, Kyverno, Backstage, Meshery, Jaeger etc. Leveraging its extensive expertise in enterprise digital transformation, Infosys continues to champion the adoption of open-source technologies in cloud-native solutions and transformation initiatives—sharing valuable insights and opportunities with the broader open-source community.

Conclusion

The evolution of telco networks into cloud-native platforms marks a strategic shift toward agility, openness, and innovation. Telecom operators are building future-ready networks by embracing open-source technologies, standardized frameworks, and collaborative ecosystems that are empowering them to meet the demands of ultra-low latency, massive scale, and rapid service innovation. As 5G matures and edge computing expands, the cloud-native paradigm will continue to redefine the foundation of global connectivity.

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Girish has over 2 decades of rich experience in Telecom domain with expertise in Telco Cloud Orchestration, GitOps methodology, SDN/NFV technologies and VoIP/IMS Architecture. Girish is an avid open-source contributor and has led architecture definition and development of multiple Client projects and Solution Initiatives from Concept to Market in networking domain using open-source libraries and platforms like ONAP, Nephio, VOLTHA/SEBA, Mobicents and Magma.

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