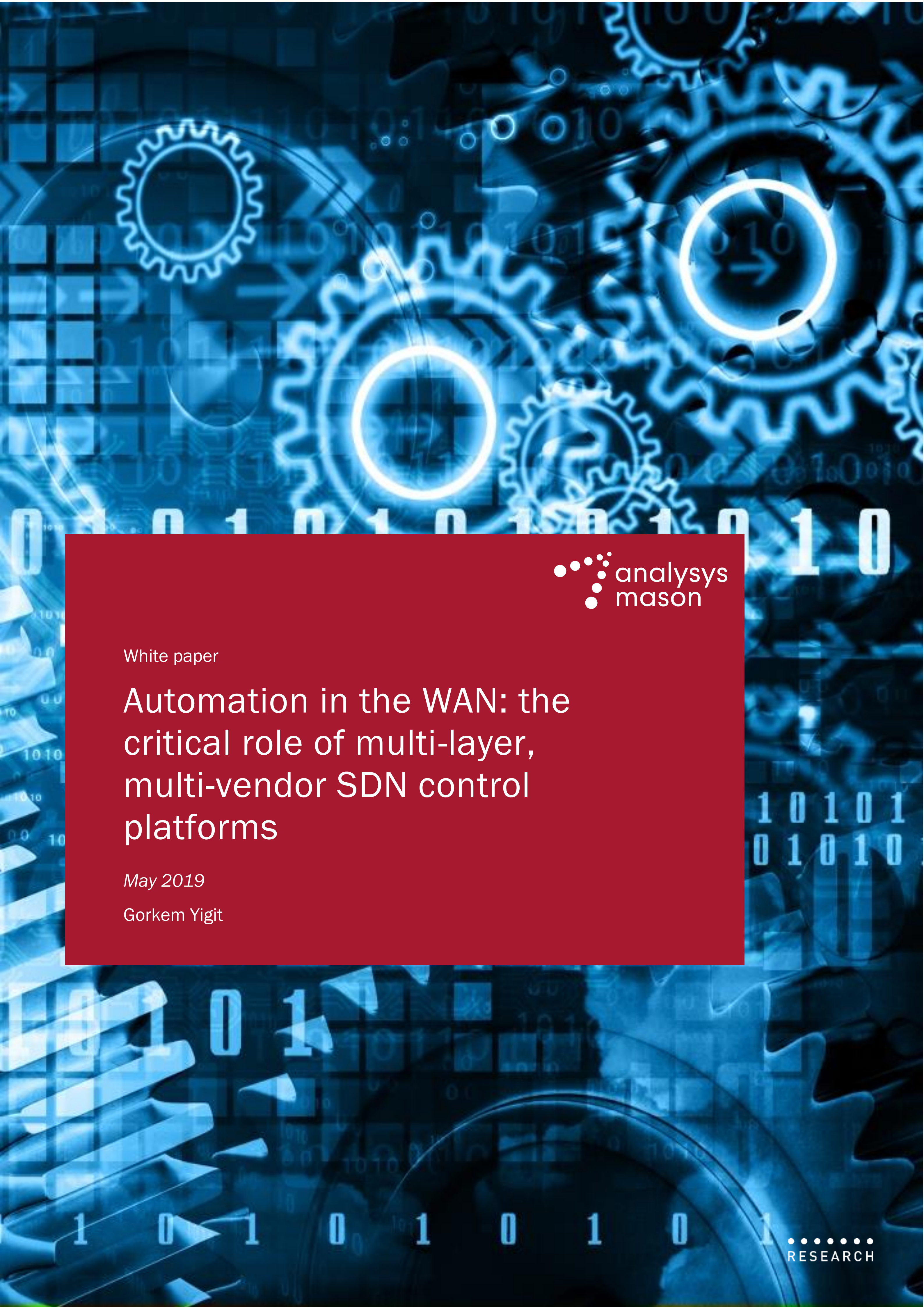

White paper

Automation in the WAN: the critical role of multi-layer, multi-vendor SDN control platforms

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RESEARCH

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1. Executive summary

Operators are increasingly embracing software-defined networking (SDN) across their networks, from data centres to wide-area networks (WANs) and the customer edge, as part of their automation journeys. Many operators worldwide are focusing their investments on using SDN to automate WANs in order to increase the efficiency of their network operations and to deliver the level of service agility and on-demand, customer-empowered experience that is required for 5G and enterprise services.

This white paper discusses the emerging blueprint architecture of the new operational stack for SDN-based automation in the light of the progress made by leading operators, industry standardization bodies and vendors. It introduces the three-layer hierarchical model that is being adopted by operators for implementing SDN control in WANs and analyses the key role that centralized multi-layer, multi-vendor WAN SDN control platforms play in this architecture. Finally, the paper outlines the key functionalities and architectural requirements that operators should look for when building their multi-layer WAN SDN control platforms, and provides an overview of the vendor landscape with an analysis of the main strengths and weaknesses of various vendor groups.

2. Drivers for SDN-based automation in the WAN

Network operations automation has become a top strategic imperative for many operators worldwide. Stagnating revenue from traditional services, high costs associated with rapidly growing network traffic driven by the demand for high-bandwidth video and cloud services and fierce competition in the enterprise connectivity market are putting significant pressure on operators to stay competitive. Moreover, 5G and edge computing will usher in a new era of services enabled by network slicing and URLLC applications that cannot be delivered with the existing inflexible, disjointed and manual network operations. As such, operators are transforming their networks and operations into software-defined and cloud-native infrastructures and highly automated processes, respectively, as they strive to become more digitalized, cost-efficient and agile.

Automating wide area networks that comprise operator IP/optical access and transport networks is a priority of many operators' automation initiatives. Operators are embracing SDN, enhanced by advanced analytics and AI/ML techniques, open APIs and common data models, to manage and control WAN infrastructure in order to improve end-to-end WAN automation, network visibility and programmability. Many operators have already implemented some level of SDN-based automation in the WAN, such as automated multi-vendor configuration of network devices and overlay traffic steering mechanisms (SD-WAN) at the enterprise edge and for multi-cloud connectivity. Operators are now increasingly extending SDN control into today's highly static, complex, multi-layer and multi-vendor IP/MPLS and optical networks to achieve the following business and operational benefits.

- **Opex reduction/increased productivity.**
  - — The automation of opex-intensive, manual service creation and provisioning processes for connectivity and communication services over the WAN (transport, VPN and UC) enables operations to become leaner and skilled staff to be reallocated to tasks that are more-strategic and higher-value.

  - The minimization of manual intervention reduces human error and its associated operational risks, and improves productivity.

- **Capex reduction/deferral.** Improved network capacity allocation, optimization and utilization with real-time, policy-based network control and multi-layer traffic steering reduces the need for overprovisioning and deferring expensive capacity upgrades in the WAN.

- **Reduced vendor lock-in and network complexity.**
  - An open interface and model-based abstraction of the complex multi-layer, multi-vendor networks can allow operators to reduce vendor lock-ins.
  - Disaggregation of hardware and software layers and increased software-based control of the networks enables the use of open-source and white-box components where appropriate in the network.

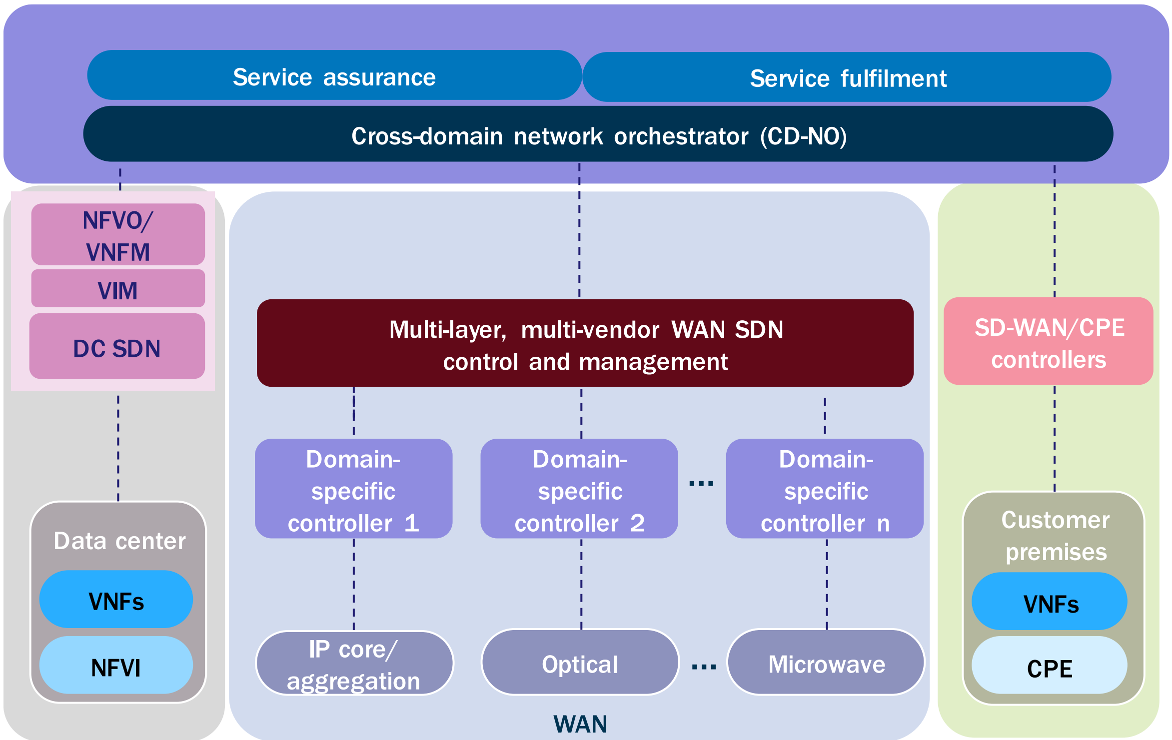
- **New revenue opportunities through dynamic, on-demand services.** WAN SDN can support the faster, more-automated and more-agile creation, delivery, modification and termination of in-network services such as network-as-a-service (NaaS) and data-center interconnectivity that is expected in today's highly competitive environment. WAN SDN will be a key enabler of 5G advanced connectivity services (for example, through network slicing) and will help operators to meet the capacity and low-latency demands of new services such as AR/VR, robotics and industry vertical applications.

- **Customer experience differentiators.** Operators will be able to differentiate themselves through on-demand, customer-initiated service provisioning, monitoring and changing, and improved quality of service and time to market.

3. The ideal SDN reference automation architecture for operators

A common understanding and a blueprint architecture of the new operational stack for SDN-based automation has emerged due to the increased progress in SDN, network virtualization and orchestration by leading operators, industry standard bodies and vendors over the last couple of years. This is illustrated in Figure 1.

Figure 1: Overview of the SDN-based automation stack in operator networks



Source: Analysys Mason, 2019

Operators are implementing SDN-based control and automation in their networks from three different directions.

- In data-center networking, SDN is implemented as a logical overlay network on top of the underlying fabric or white-box switches, using OpenFlow/OpenFlow-like approaches to support operator NFV and cloud infrastructure. Data-center SDN is controlled by the virtual infrastructure manager (VIM), for example, OpenStack Neutron.
- Multi-layer WAN SDN control extends existing vendor-/layer-specific network management systems (NMS), domain-specific SDN controllers and network control planes (for example, MPLS) with new SDN capabilities across IP/optical networks and layers (L0–3).
- SD-WAN provides a virtual overlay network with programmable SDN functionality at the WAN enterprise edge (CPE/uCPE) through SD-WAN and CPE controllers, which are typically vendor-specific.

These SDN approaches have diverse core technologies, operational requirements and maturity levels, and therefore they have been adopted and advanced separately from each other in operator networks. For example, to implement network programmability in the WAN, the existing highly-tuned packet control planes, the analogue nature of optical networks and the large distances mean that a different understanding and SDN approach is required compared to those needed in a data center. Telefónica provides a good illustration of this: its UNICA architecture includes data-center SDN, while its iFusion architecture focuses on the WAN.

However, operators are increasingly seeing the value of bringing their NFV/cloud, SD-WAN and WAN SDN automation together. For example, operators are tying their programmable underlay WANs to overlay SD-WAN implementations in order to offer better monitoring and more-favorable internet routing than over-the-top (OTT)

SD-WAN providers that do not have control of the network underlay. 5G network slicing will also require a coherent SDN-based automation approach in cloud-native core networks in data centers, as well as in the WAN, the edge and the RAN.

Operators are looking to integrate these various SDN control and automation approaches at the cross-domain network orchestrator (CD-NO) level to achieve end-to-end service and network automation over their hybrid networks. This is referred to as Service Orchestrator in the ONAP architecture. However, it is possible that the increasing convergence of NFV/data centers and WANs around native SDN principles (for example, Telstra Programmable Network (TPN)) may encourage some operators to implement a lower-level horizontal integration layer across these SDN domains in the future.

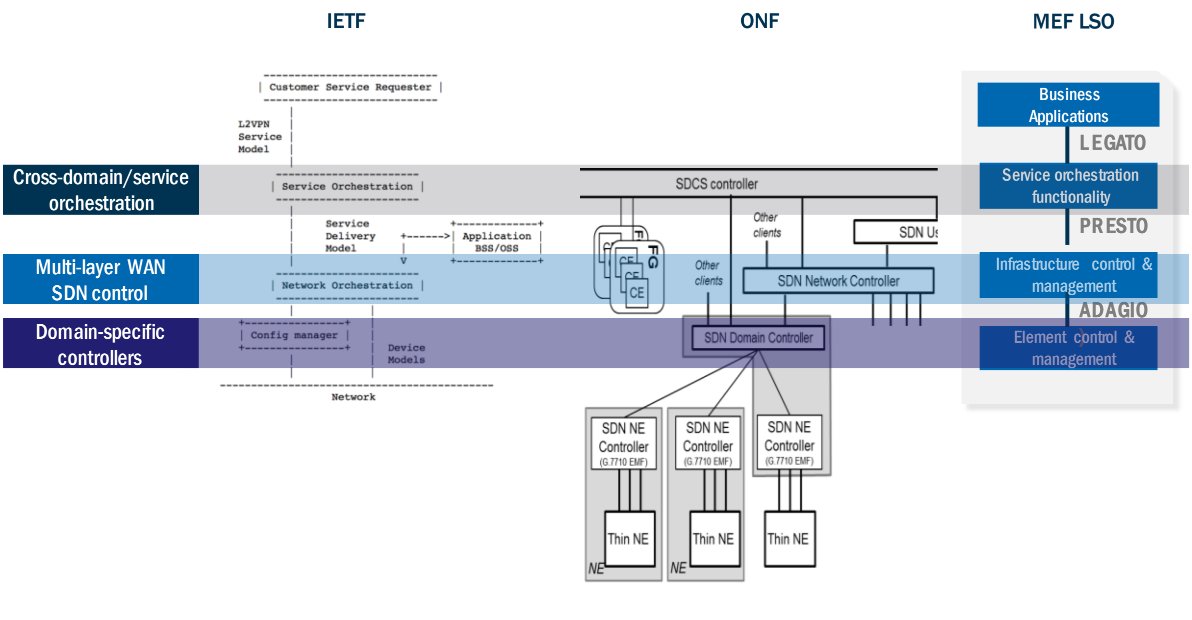
A three-layer hierarchical model is emerging for SDN control in the WAN

Several operator automation frameworks (Telefónica iFusion and Vodafone Ocean), industry collaborations (ONAP) and standardization groups (IETF, MEF, ONF and OIF) are commonly envisioning a three-layer hierarchical architecture for WAN SDN control and management. This comprises:

- distributed domain-specific controllers for different network technologies, layers and equipment vendors
- a centralized multi-layer, multi-vendor WAN SDN control and management platform
- a cross-domain orchestration platform.

This hierarchical architecture for WAN SDN control is illustrated in Figure 2. It is based on the leading industry standardization architecture.

Figure 2: WAN SDN control architecture based on industry standards



Source: IET, MEF, ONF, Sedona Systems and Analysys Mason, 2019

Domain-specific controllers include traditional NMS from incumbent vendors or their SDN-based evolution with added SDN capabilities such as dynamic traffic optimization and automation applications (for example, for assurance or planning). These are specialized solutions that are tightly coupled with the underlying network equipment (IP routers and optical and microwave gear), and typically provide single-vendor-, technology-, geography- or service-specific network management and control. Advanced operators generally start their WAN

SDN automation journey with a bottom-up approach by introducing automation in individual domains using these domain-specific controllers. However, they often plan to unify their management and control under a centralized, multi-domain/layer/vendor control platform for end-to-end service and network automation. To realize this, significant industry effort is engaged to create open, industry-standard northbound interfaces, protocols and modelling languages such as T-API, PCEP and YANG/NETCONF.

Multi-layer WAN SDN control platforms sit on top of the disparate domain controllers and enable operators to rationalize and simplify these silos with a common, horizontal programmable management/control layer. Standards bodies and operators are referring to this layer differently, as shown in Figure 2 above. For example, ONF terms this the SDN Network Controller, while MEF calls it the Infrastructure Control & Management. These platforms will not necessarily replace the domain-specific controllers (especially in the analogue optical layer), but will provide a unified, end-to-end network view (network topology, performance data and SLA requirements) by understanding the specific constraints of and the relationships between the various domains and layers underneath and converging their control and management with cross-domain/layer policies.

Multi-layer WAN SDN control also allows the **CD-NO** to create and provision services end-to-end by abstracting the complexity of underlying networks through an open interface, without having to understand specific details of the individual network domains.

Having a clear, modular, layered architecture with open interfaces is critical. Each layer requires unique functional capabilities, and operators should be able to develop new service capabilities quickly (for example, with DevOps and frequent functionality updates/upgrades) without running into the integration and testing complexities and vendor roadmap problems that typically occur in monolithic architecture.

4. Key considerations for building multi-layer WAN SDN control platforms

As discussed in the previous section, multi-layer WAN SDN control platforms play an important role in WAN automation by extending existing network control planes and domains and delivering a high level of programmability. Leading operators are forging ahead with a step-wise approach in introducing automation into various domains across the WAN, while simultaneously planning to join up the automation of these fragmented domains under a centralized multi-layer WAN SDN control platform. Analysys Mason forecasts that multi-layer SDN control software and related professional services spending by operators worldwide will grow from USD84 million in 2017 to USD965 million in 2022, at a CAGR of 63%.

This section discusses the key functionalities, platform architecture and ecosystem requirements that operators should take into consideration when they are building their multi-layer WAN SDN control platforms.

Key functionalities of multi-layer WAN SDN control platforms

Figure 3 provides an overview of the key functional capabilities that should be part of a multi-layer WAN SDN control and management platform.

Figure 3: Main functionalities of multi-layer SDN control platforms

Functionality	Description
Multi-domain/multi-layer support	End-to-end, unified view, automated and policy-based control and management across multiple network domains (IP, optical and microwave) or layers (L0–3), regardless of which vendor supplies which network component. It must provide a true source of network information (for example, near real-time, automated topology) in order to move away from traditional manual entry, offline inventory.
Traffic steering/engineering	• Near real-time or real-time computation and implementation of traffic paths (for example, path computation engine (PCE)) across multiple network layers to improve utilization, avoid congestion and provide differentiated SLAs. • Application-/service-/network-aware rapid, policy-based traffic rerouting, for example, diversion from a network node that is congested or under attack (D-DOS) to a healthier/higher-performance part of the network.
Multi-vendor configuration	Automated distribution (and, if needed, rollback) of network element configuration using model-based abstractions and standard protocols (for example, YANG/NETCONF) or REST APIs.
Network lifecycle management	Network planning (supporting 'what-if' analysis and 'just-in-time' capacity management and optimisation capabilities), network management, monitoring, assurance and provisioning.
Analytics	• Support for real-time telemetry; able to collect and consume data from multiple sources and vendor devices using standard flow control protocols, IPFIX and gRPC. • Support for machine-learning models and algorithms. • Policy engine for policy control, monitoring and governance.

Source: Analysys Mason, 2019

As detailed in Figure 3, multi-layer WAN SDN is bringing the network control (traffic engineering and multi-vendor configuration) and OSS-like lifecycle management (service creation, assurance and planning) functionalities together. However, it is important for operators to implement the control layer as a lightweight, independent module from management in order to meet the high performance and near real-time requirements of network control (for example, PCE dynamic traffic steering). For example, Vodafone separates its Hierarchical Transport SDN Controller from the resource management layer in the Ocean architecture. Moreover, the modularity between control and management functions can also enable operators to deploy best-of-breed components and allow faster and simpler upgrades and replacements when needed.

Key platform architecture requirements

Figure 4 summarizes the common characteristics of solutions/components that operators should look for when building their multi-layer WAN SDN control platforms.

Figure 4: Key characteristics of an ideal multi-layer control platform architecture

Platform requirement	Description
Modularity	Modular and plug-and-play functionalities rather than a single monolithic system. The platform should be flexible enough to allow operators to deploy or swap the pieces they need as separate modules at varying levels of granularity depending on the operator's desire and ability to handle integration, for example, path computation engine, model-driven configuration or management applications (assurance and planning).
Openness	• Can be inserted between CD-NO and domain-specific controllers through open northbound and southbound interfaces/APIs with minimal integration effort. • Large ecosystem support with open APIs, SDKs and a developer community. • Compatibility and easy integration with a coherent set of third-party and open-source applications and components.

Platform requirement	Description
Standards- and model-based	Support for industry standard data modelling languages, protocols and APIs such as those from MEF, TMF, IETF and ONF as well as compatibility with legacy SNMP-/CLI-based operations.
Extensibility/gradual deployment	Operators need flexible, adaptable and cloud-native WAN SDN software platforms to enable them to start small today and expand to multiple services and domains over time. This will also require legacy/backwards compatibility with existing infrastructure.
Cloud-native platform architecture	Set of common and shared micro-services/functions; can accommodate rapid onboarding of new functions to meet future requirements. Support for all types of cloud deployment models: private, software-as-a-service (SaaS) and hybrid.

Source: Analysys Mason, 2019

Choosing the right multi-layer control platform suppliers

There is strong competition in the multi-layer WAN SDN control market between various vendor groups: traditional NEPs such as Ciena, Cisco, Fujitsu, Huawei, Juniper and Nokia that are competing against each other; new ISV market entrants, such as Sedona Systems; and OSS/orchestration ISVs such as Amdocs and NEC/Netcracker that are pushing into network management (either through their own solutions or partnerships). These different players are all trying to govern the master SDN controller of layers 0–3 across WAN domains. Also, open-source platforms such as OpenDayLight (ODL) are emerging as viable alternatives, and a mix of vendor-proprietary and open-source components-based multi-layer control platforms are being introduced to the market.

It is critical for operators to carefully evaluate the benefits and limitations of vendor approaches to meet their automation goals, both today and in the future, given the fragmentation in the market. Figure 5 provides the main advantages and disadvantages of selecting certain supplier types when building a multi-layer control ecosystem.

Figure 5: Overview of the main strategies, strengths and weaknesses of various supplier types in the multi-layer control market

Supplier type	Analysis	
NEPs	NEPs, including IP/optical infrastructure vendors, want to protect their network equipment positions by dominating WAN control.	
	Strengths: • Deep networking expertise, R&D resources and understanding of the networks and operations where they are incumbent. • Many operators follow a bottom-up automation strategy allowing NEPs to bundle multi-layer control attractively in large network projects. • Large NEPs have extensive professional services capabilities to help with operational transformation.	**Weaknesses:** • Commercial conflict of interest against other NEPs which might make multi-vendor projects more difficult as NEPs are unwilling to expose their domain-specific controllers to their rivals because these systems could provide competitive insight into their equipment. In addition, they might be slow to develop capabilities that differentiates the equipment of their competition. • Might be less incentivized to optimize network capacity to reduce equipment capex compared with other types of vendors.

Supplier type	Analysis	
		• Many NEPs' software capabilities are still coupled to their hardware; they lag behind ISVs in standalone software expertise. However, several, such as Ciena and Nokia, are aiming to change that by increasing their software focus and development efforts.
OSS/orchestration vendors	The traditional OSS/BSS ISVs are seeking to move down the operational stack and compete for network management business that was previously unavailable to them.	
	Strengths: • Traditionally strong in interfacing their OSS with multi-vendor networks. • Strong inventory capabilities. • They are building large SDN/NFV ecosystems around their orchestration platforms which can allow them to bring in specialized partners for best-of-breed capabilities.	**Weaknesses:** • Their main interest lies in controlling the orchestration and OSS/BSS, hence they are incentivized to push bundled offerings which may not be attractive to operators that want to build disaggregated, best-of-breed stacks. • Typically, they are weaker in IP/optical networking expertise then NEPs except those that also have equipment businesses they can tap (such as NEC/Netcracker).
New-entrant ISVs	New players with software-based networking expertise and innovative solutions are aiming to capture a share from the shift towards software-centric networks.	
	Strengths: • They have less commercial conflict of interest in multi-layer control as they do not have legacy equipment or OSS business competing against incumbents' portfolios. This gives them a 'neutral third party' advantage in multi-vendor implementations. • Typically more agile and nimble in software development and have more at stake to advance their solutions as it is their core business. • As they are software-centric with no legacy business to protect, vendor lock-in risk is lower, and they can also provide new and more-disruptive commercial models than NEPs and OSS vendors.	**Weaknesses:** • They usually do not have market reach, R&D and professional services resources and financial stability comparable to the large incumbents, making them a riskier commitment. • The strength of their proposition depends on healthy, continuous relationships with the equipment and OSS vendors as well as the progress in standardization in APIs/interfaces.
Open-source platforms	Large industry collaborations are driving open-source projects such as ODL to reduce reliance on traditional proprietary solution providers and foster innovation.	
	Strengths: • Operators can tailor the open-source platform to their specific operational requirements and have maximum	**Weaknesses:** • The cost of testing, supporting and updating the underlying code is significant. Few operators are equipped with strong in-house

Supplier type	Analysis		
		control over application development and roadmaps.	capabilities to handle this, hence, require upstream vendors and/or professional services partners.

Source: Analysys Mason, 2019

There is no clear winner among these options. An operator's choice of multi-layer control supplier will be dependent on their strategy and internal capabilities. For example, new-entrant ISVs and open-source-based multi-layer control platforms may be appealing to operators that aim to reduce vendor dependence and create best-of-breed, disaggregated SDN automation stacks, while other operators may prefer pre-integrated, best-of-suite offerings to minimize ecosystem and integration complexity. However, it will be important for all suppliers to comply with the key requirements discussed in Figure 4, most notably supporting a broad range of third-party solutions northbound and southbound across the domains/layers that they are addressing.

5. Conclusions and recommendations

Operators are implementing SDN-based network and service automation in three main domains: data centers, the WAN and the enterprise/customer edge. Each of these SDN domains has distinct technological and operational requirements and starting points that result in the adoption of different architectural approaches. SDN in the WAN calls for a three-layer hierarchical control structure that is being implemented by operators such as Telefónica and Vodafone with modular components and open interfaces. A horizontal, multi-layer, multi-vendor control and management platform is at the core of this architecture; it extends existing control planes from domain-specific controllers with capabilities that allow more-programmatic control of traffic and automation of operational processes without the need for ripping and replacing legacy infrastructure. CD-NO is placed at the top of this hierarchy and provides end-to-end service lifecycle management. It also brings these different SDN domains together to deliver existing and future services across the hybrid networks.

The adoption of a multi-layer WAN SDN control platform is a critical step in the transformation towards automated WANs. Operators should look for open and extensible solutions that can support their gradual SDN automation deployment journey with broad, third-party vendor and open-source support through standard APIs, protocols and data models. In addition, operators should consider disentangling the control and management layers of WAN SDN to support the high-performance and near real-time requirements of network control and to achieve faster and simpler upgrades and replacements when needed.

The multi-layer control market is populated with a large number of suppliers and solutions, each of which has unique strengths and weaknesses. When building their multi-layer control platforms, operators should carefully evaluate the benefits and limitations of each vendor and select the vendors that best align with their deployment strategies (for example, best-of-breed versus best-of-suite) and ecosystem strategies (for example, existing relationships versus opening up to new vendors to foster innovation through competition), as well as their internal capabilities and the level of professional services support that is needed (for example, the ability to manage integration/ecosystem complexity and maintain in-house software development).

6. About the author

Gorkem Yigit (Senior Analyst) is the lead analyst for the Digital Infrastructure Strategies and Video and Identity Platforms programmes, focusing on producing market share, forecast and research collateral. He has published research on NFV/SDN services business cases, identity management in the digital economy, and has been a key part of major consulting projects including Telco Cloud Index and IPTV/OTT procurement. He holds a cum laude MSc degree in Economics and Management of Innovation and Technology from Bocconi University (Milan, Italy).

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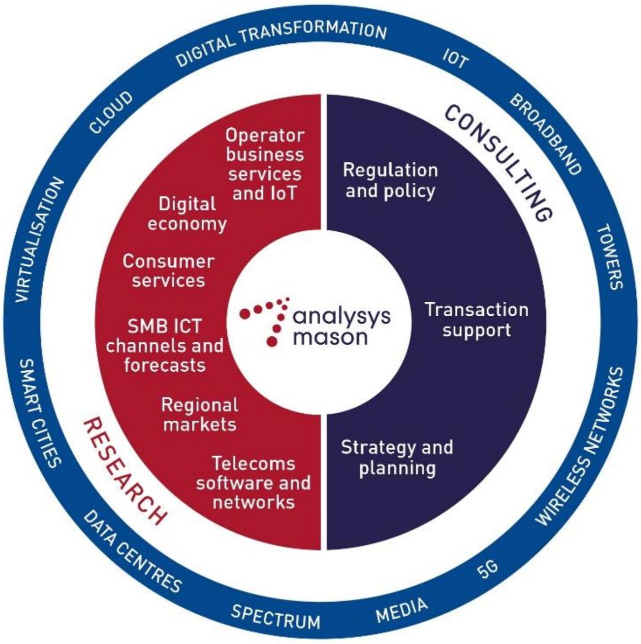

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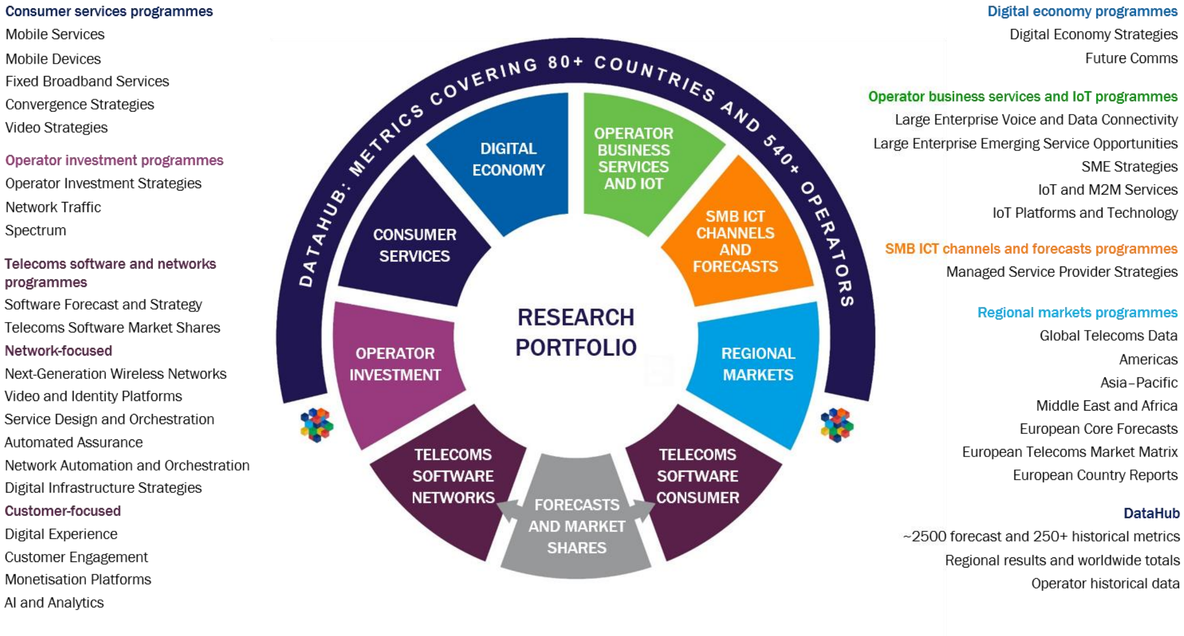

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