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MARKET RADAR

GigaOm Radar for Network Operating Systems v1.0

Vendor Assessment for Technology Decision Makers

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TOPIC: NETWORKING

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TABLE OF CONTENTS

1. Summary

Cloud-native architectures, new merchant silicon, and "open networking" offer networking agility, flexibility, resiliency, and scalability for those brave enough to take advantage of new, innovative, disaggregated tech stacks promising a massive leap in performance at the lowest possible cost. At the center are Linux-based network operating systems (NOSs) running on bare-metal servers and switches using merchant silicon.

With the primary focus on routing—instead of data center switching—the NOS landscape is rapidly evolving. The traditional incumbent vendors are reinventing themselves through acquisitions, alliances, and moves to "open" architectures. Open-source initiatives are leveraging contributed code and the collective power of communities to drive innovation. Last but not least, new players are emerging with disruptive, cloud-native approaches, significant financial backing, and high-profile early adopters.

This report provides an overview of the vendor landscape based on the following table stakes, which are mature, stable solution features that are common across all vendors:

- **Bare metal:** A bare-metal server or switch comes without software, allowing the network stack to be decoupled to implement hybrid network architectures incorporating cost-effective, best-in-class technologies. Bare-metal switches use merchant silicon and come with Open Network Install Environment (ONIE), a boot-loader from the Open Compute Project, facilitating zero-touch provisioning (ZTP) of the NOS of choice. Some cloud-native vendors offer virtualized or containerized versions for added agility, flexibility, and scalability.
- **Disaggregated:** Disaggregated routing and switching enable network architects to optimally mix and match best-in-class hardware and software to meet the needs of a given use case. This report only covers network operating systems that can be purchased independently from the hardware. However, it's important to note that in addition to making their product available as a standalone NOS running on bare-metal servers or switches, some traditional networking vendors are including it as part of a proprietary fully-integrated network appliance.
- **Standalone:** While the architecture and deployment process vary, each NOS included in this report is a standalone solution and does not require third-party components. Each can be installed on a bare-metal server or switch and operated with built-in control and management plane functionality. While additional options for analytics, management, and telemetry may be mentioned as complementary offerings from the vendor, these are not required for the NOS to run.

Based on these table stakes, NOSs such as Cisco's Internetwork Operating System (IOS), Juniper's JunOS, and NVIDIA's ONYX are not included because they—despite being disaggregated—are sold and supported only on the associated vendor's equipment. Vendors like Dell EMC have also been excluded because they either own a proprietary NOS or support an open-source solution like SONiC (which is hosted by the Open Compute Project and described in that section). While open and disaggregated, the Open Networking Foundation's (ONF) two NOS offerings, ONOS and Stratum, are not standalone and, therefore, are not covered.

Note: If you are aware of any NOS that meets the table stakes but is not included in this report, please email GigaOm and let us know.

Lastly, it's important to note that, in addition to significant projects hosted by the Open Compute Project (OCP), the Open Networking Foundation, and The Linux Foundation, several other organizations are shaping the direction and evolution of disaggregated networking.

Foremost among these is the Telecom Infra Project (TIP). Formed by Facebook in 2016, TIP is a global community of companies and organizations collaborating to accelerate the development of open, disaggregated, standards-based networking solutions spanning three strategic areas: access, core services, and transport. Many of the world's largest NSPs, together with most of the ODMs, merchant silicon, and NOS vendors mentioned in this report, are members of TIP.

As you read this report, please do so with an open mind. Driven by the demand for flexibility, performance, and scalability—combined with cost efficiency—the vendor landscape and NOS offerings are rapidly evolving. We recommend you use this report to create a shortlist of vendors that support your target market, deployment model, and use case. Then contact the relevant vendors for additional information on features and cost.

For additional information related to choosing a network operating system, please read the report, "Key Criteria for Evaluating Network Operating Systems: An Evaluation Guide for Technology Decision Makers," published by GigaOm.

HOW TO READ THIS REPORT

This GigaOm report is one of a series of documents that helps IT organizations assess competing solutions in the context of well-defined features and criteria. For a fuller understanding consider reviewing the following reports:

Key Criteria report: A detailed market sector analysis that assesses the impact that key product features and criteria have on top-line solution characteristics—such as scalability, performance, and TCO—that drive purchase decisions.

GigaOm Radar report: A forward-looking analysis that plots the relative value and progression of vendor solutions along multiple axes based on strategy and execution. The Radar report includes a breakdown of each vendor's offering in the sector.

Vendor Profile: An in-depth vendor analysis that builds on the framework developed in the Key Criteria and Radar reports to assess a company's engagement within a technology sector. This analysis includes forward-looking guidance around both strategy and product.

2. Market Categories and Deployment Types

For a better understanding of the market and vendor positioning (**Table 1**), we categorized solutions for network operating systems by their target market segment:

- **Cloud Service Providers (CSP):** Providers delivering on-demand, pay-per-use services to customers over the Internet, including infrastructure as a service (IaaS), platform as a service (PaaS), and software as a service (SaaS).
- **Network Service Providers (NSP):** Providers selling network services—such as network access and bandwidth—delivering access to backbone infrastructure or network access points (NAP). In this report, NSPs include data carriers, ISPs, telcos, and wireless providers.
- **Managed Service Providers (MSP):** Providers delivering application, IT infrastructure, network, and security services and support for businesses on customer premises, in the MSP's data center (hosting), or in a third-party data center.
- **Enterprises (Large, Medium, Small):** All businesses responsible for planning, building, deploying, and managing their applications, IT infrastructure, networks, and security in either an on-premises data center or a colocation facility.

We also recognize three deployment models for solutions in this report: Enterprise Data Center, Wide Area Network (WAN), and Campus/Extended Edge.

- **Enterprise Data Center:** An on-premises data center or colocation facility managed by either the enterprise or a CSP, NSP, or MSP running the Spanning Tree Protocol (STP), spine-and-leaf topologies, or modern fabric architectures.
- **Wide Area Network:** The telecommunications network using link technologies and protocols to provide network connectivity between distributed devices across data centers, colocation facilities, and the campus or extended edge.
- **Campus/Extended-Edge:** Remote network resources—supporting various applications through which information is produced, processed, and consumed with minimal latency—positioned between the end-user device and the hyperscale cloud or Internet.

Table 1: Vendor Positioning

	MARKET SEGMENT				DEPLOYMENT MODELS		
	Cloud Service Providers	Network Service Providers	Managed Service Providers	Enterprise	Enterprise Data Center	Wide Area Network (WAN)	Campus & Extended Edge
ADVA	-	+++	-	-	-	+++	+++
Arista	+++	+++	+++	+++	+++	+++	+++
Arrcus	+++	+++	-	++	++	+++	+++
DriveNets	+++	+++	-	-	-	+++	+++
Exaware	++	++	-	+	+	++	++
Infinera	+++	+++	-	-	-	+++	+++
IP Infusion	+++	+++	+++	+++	+++	+++	+++
Kaloom	++	++	-	++	++	++	++
Linux Foundation	-	++	-	-	-	++	++
Nokia	++	++	++	++	++	-	-
NoviFlow	-	++	-	++	-	++	++
NVIDIA	+++	+++	+++	+++	++	-	+++
Open Compute Project	+++	++	+++	+++	+++	++	++
Pica8	++	+++	-	++	-	+++	+++
Pluribus Networks	+++	++	+++	+++	+++	+++	++
RtBrick	-	++	-	-	-	++	-
Stateless	++	++	-	++	-	++	++
Volta Networks	++	+++	++	-	-	+++	++
VyOS	++	++	++	++	++	++	++

+++: strong focus and perfect fit of the solution
++: The solution is good in this area, but there is still room for improvement
+: The solution has limitations and a narrow set of use cases
-: Not applicable or absent.

3. Key Criteria Comparison

Following the general indications introduced with the "Key Criteria for Evaluating Network Operating Systems," **Table 2** summarizes how each vendor included in this research performs in the areas that we consider differentiating and critical for modern data protection. **Table 3** presents how well each vendor fulfills our evaluation metrics—top-level characteristics that determine the value of the solution to the organization and the impact on it. The objective is to give the reader a snapshot of different solutions' technical capabilities and define the market landscape's perimeter.

Table 2. Key Criteria Comparison

	KEY CRITERIA							
	Supported Hardware	Openness	Switching	Tunneling	Routing	Telemetry & Management	Security	Customer Support
ADVA	+++	++	+++	+++	+++	++	++	++
Arista	+	+	+++	+++	+++	+++	++	+++
Arrcus	+++	++	+	++	+++	+++	++	+++
DriveNets	+++	+++	+	++	+++	++	++	+++
Exaware	+++	++	++	++	++	++	++	+
Infinera	++	+++	++	++	++	++	++	+++
IP Infusion	+++	+++	+++	+++	+++	++	+++	++
Kaloom	++	+++	+++	++	+++	++	+	+++
Linux Foundation	+++	+++	++	++	++	++	++	+
Nokia	+	++	+++	+	++	+++	+	+++
NoviFlow	++	+++	++	++	+++	+++	+++	++
NVIDIA	+	+++	+++	+	+++	++	+	++
Open Compute Project	+++	+++	+++	++	+++	+	+	+
Pica8	+++	+	+++	++	+++	+++	+	++
Pluribus Networks	+++	++	+++	++	+++	+++	+	++
RtBrick	+	+++	+	+	+++	++	+	++
Stateless	++	+	+	++	++	++	++	+
Volta Networks	++	+	++	++	++	+	++	+
VyOS	+	+++	+	++	++	++	+	+

+++: strong focus and perfect fit of the solution
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-: Not applicable or absent.

Key criteria serve to differentiate solutions, identifying the primary criteria to be considered when evaluating network operating systems. Indicating each vendor's strengths and weaknesses, they help organizations create a shortlist, engage with the vendor, and make informed decisions on which solution to adopt for their particular needs. Attributes and capabilities will vary and should be carefully evaluate based on each organization's needs and use cases.

Table 3: Evaluation Metrics Comparison

	EVALUATION METRICS						
	Feature Set	Scalability	Flexibility	Usability	Solution/Partner Ecosystem	Total Cost of Ownership (TCO)	Vision/ Roadmap
ADVA	+++	++	++	++	+	++	+
Arista	+++	++	+++	+++	+++	+	++
Arrcus	+	+++	+++	+++	+++	++	+++
DriveNets	+	+++	+++	++	++	++	+++
Exaware	++	+++	+++	++	++	++	++
Infinera	++	+++	+++	++	+++	++	++
IP Infusion	+++	+++	+++	++	+++	++	++
Kaloom	++	++	+++	++	++	++	++
Linux Foundation	++	++	++	++	++	++	+
Nokia	+	+++	+++	++	+	++	+++
NoviFlow	++	++	+++	+++	+++	++	+++
NVIDIA	++	+++	+++	++	+++	++	+++
Open Compute Project	++	+++	+++	++	+++	+	++
Pica8	++	++	+++	+++	++	+++	+
Pluribus Networks	++	++	+++	+++	+++	+++	++
RtBrick	++	+++	++	++	+	+++	+
Stateless	+	++	+++	+++	+	++	+
Volta Networks	++	+++	++	++	+	+++	+
VyOS	++	++	++	++	+	++	+

+++: strong focus and perfect fit of the solution
++: The solution is good in this area, but there is still room for improvement
+: The solution has limitations and a narrow set of use cases
-: Not applicable or absent.

By combining the information provided in **Tables 1, 2**, and **3** the reader should develop a clear understanding of the market and the technical solutions available in it.

4. GigaOm Radar

This report synthesizes the analysis of key criteria and their impact on evaluation metrics to inform the GigaOm Radar graphic in **Figure 1**. The resulting chart is a forward-looking perspective on all the vendors in this report, based on their products' technical capabilities and feature sets.

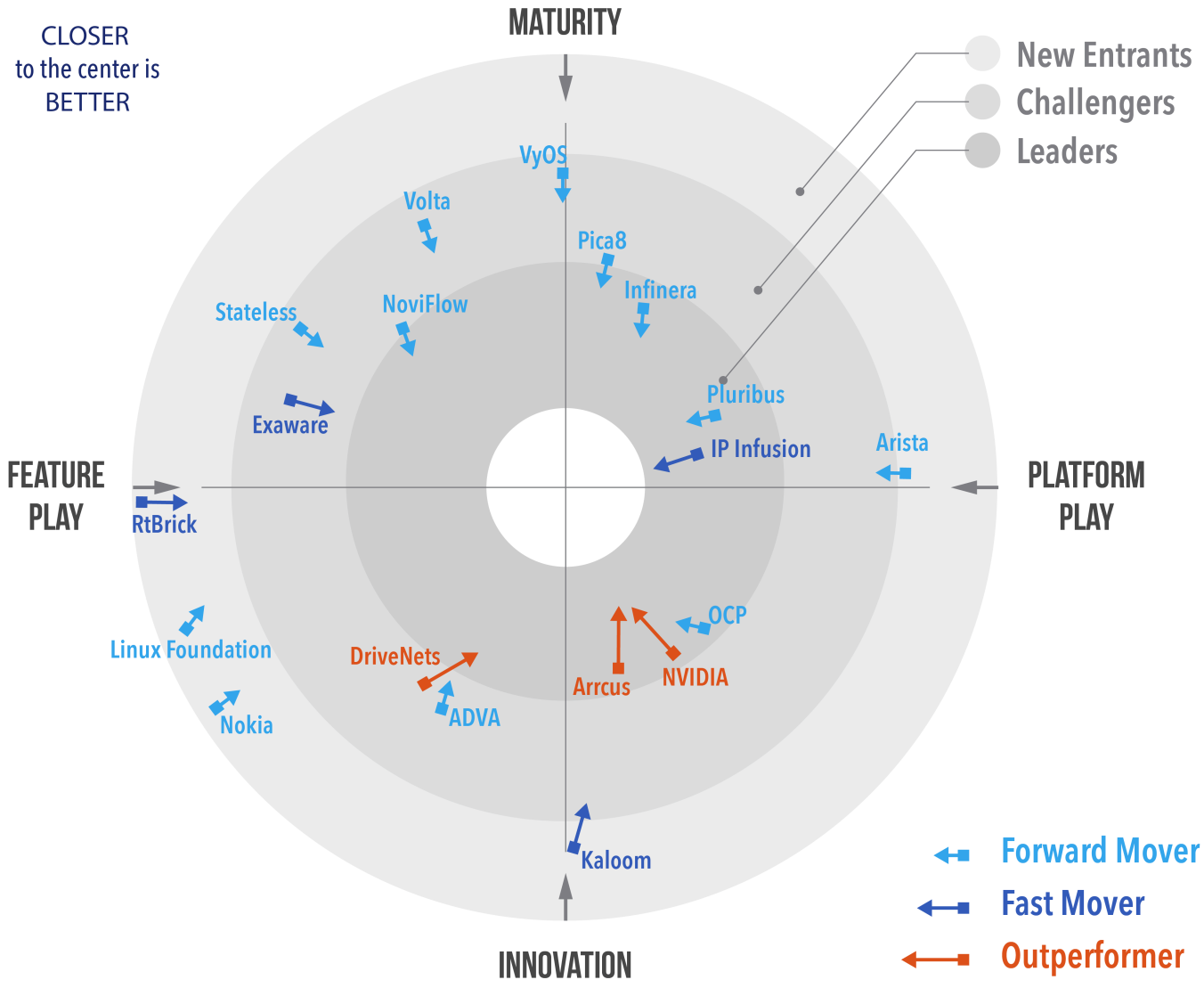

Figure 1: GigaOm Radar for Network Operating Systems

The GigaOm Radar plots vendor solutions across a series of concentric rings, with those set closer to the center judged to be of higher overall value. The chart characterizes each vendor on two axes—Maturity versus Innovation and Feature Play versus Platform Play—while providing an arrow that projects each solution's evolution over the coming 12 to 18 months.

As you can see in the Radar chart in **Figure 1**, there are six vendors (IPInfusion, Pluribus Networks, Arrcus, NVIDIA, Open Compute Project, and Infinera) in the leaders' ring and eight that are considered challengers, although it's worth noting that several are hugging that line on one side or the other. There are also five vendors categorized as new entrants, and we'll talk more about that shortly.

It is worth noting that every NOS could fairly be considered a "platform," and yet many (nine) fall on the feature-play half of the radar. This positioning is intentional in order to provide granularity for NOSs that are more use case-specific than those that fall on the platform-play side, which tend to have a broader set of potential applications. The scores in the tables above provide more specificity regarding applicable market segments, deployment models, and use cases.

Next, you'll find three outperformers identified with longer red arrows. Arrcus and DriveNets are gaining traction based on innovation, and we expect NVIDIA to leverage its acquisitions and the extensive Cumulus Linux intellectual property base to continue to expand its leadership position. Some of the other new entrants will expand through innovation, while most of the more established players will focus on satisfying the use cases of existing customers.

Finally, the reader may be surprised to see well-established networking names like Arista and Nokia in the new entrants' ring along with lesser-known (and much younger) companies. Though Arista and Nokia are not new entities, their primary focus has not been on disagreggation. We believe we will know more in the next 12-18 months about how committed each vendor is to supporting bare-metal infrastructure. Of the five new entrants, Kaloom and RtBrick are the fastest movers.

INSIDE THE GIGAOM RADAR

The GigaOm Radar weighs each vendor's execution, roadmap, and ability to innovate to plot solutions along two axes, each set as opposing pairs. On the Y axis, **Maturity** recognizes solution stability, strength of ecosystem, and a conservative stance, while **Innovation** highlights technical innovation and a more aggressive approach. On the X axis, **Feature Play** connotes a narrow focus on niche or cutting-edge functionality, while **Platform Play** displays a broader platform focus and commitment to a comprehensive feature set.

The closer to center a solution sits, the better its execution and value, with top performers occupying the inner Leaders circle. The centermost circle is almost always empty, reserved for highly mature and consolidated markets that lack space for further innovation.

The GigaOm Radar offers a forward-looking assessment, plotting the current and projected position of each solution over a 12- to 18-month window. Arrows indicate travel based on strategy and pace of innovation, with vendors designated as Forward Movers, Fast Movers, or Outperformers based on their rate of progression.

Note that the Radar excludes vendor market share as a metric. The focus is on forward-looking analysis that emphasizes the value of innovation and differentiation over incumbent market position.

IP Infusion (DANOS-Vyatta Edition, OcNOS, and SONiC)

IP Infusion has an interesting history. Cofounded in 1999 by the developer of Zebra open source routing software (which ultimately evolved into Quagga), IP Infusion created ZebOS, a commercial-grade, hardware-independent, standards-based Layer 2, Layer 3, and MPLS/MPLS-TP network platform with a modular design that supports more than 200 standards-based network protocols. After selling ZebOS as an OEM product, the company created OcNOS, the industry's first enterprise and carrier-grade NOS running on bare-metal servers.

An active member of the TIP community, IP Infusion has contributed to numerous initiatives, including Cassini (open packet/optical transponder), DCSG, Phoenix (open white-box transponder), and others. In late 2019, AT&T released the code for the Disaggregated Network Operating System (DANOS)—an open source version of AT&T's Vyatta code hosted by the Linux Foundation and running on AT&T's production network at the time. AT&T also signed IP Infusion to be the value-added integrator with exclusive rights to sell the DANOS-Vyatta edition (DVe) as a commercial solution. In October 2020, IP Infusion announced it would also support SONiC, an open source NOS developed by Microsoft for data center network switch operations and management. (For details on SONiC, see the Open Compute Project section.)

As a result, IP Infusion supports DANOS-Vyatta (supporting telco use cases), OcNOS (supporting data center and NSP use cases), SONiC, and ZebOS running on Celestica, Dell, Delta, Edgecore, Quanta, Silicom, and UfiSpace bare-metal switches using Broadcom silicon (a hardware abstraction layer readily accommodates additional merchant silicon platforms as well). Installation is handled via ONIE and management through standard industry interfaces. OcNOS also supports P4-programmable Barefoot Tofino silicon.

DANOS-Vyatta Edition

TARGET MARKET	DEPLOYMENT MODEL
— Cloud Service Providers (CSP)	— Enterprise Data Center
✓ — Network Service Providers (NSP)	✓ — Wide Area Network (WAN)
— Managed Service Providers (MSP)	✓ — Campus / Extended Edge
— Enterprises (Large, Medium, Small)	

"A production-ready, carrier-grade, feature-rich network operating system (NOS)."
- IP Infusion

USE CASES

- Cell Site Gateway Router (CSGR)
- Virtual CPE (vCPE)

PRICING MODEL

Perpetual or subscription licenses with additional maintenance and support

An open, flexible, and cost-effective alternative to traditional networking operating systems, DANOS-Vyatta offers application awareness, automation, network visibility, and programmability for increased operational efficiency and service agility. DVe supports the Cell Site Gateway Router and uCPE use cases for 5G and Secure WAN Edge connectivity, respectively.

OcNOS

TARGET MARKET	DEPLOYMENT MODEL
✓ — Cloud Service Providers (CSP)	✓ — Enterprise Data Center
✓ — Network Service Providers (NSP)	✓ — Wide Area Network (WAN)
✓ — Managed Service Providers (MSP)	✓ — Campus / Extended Edge
✓ — Enterprises (Large, Medium, Small)	

"The industry's first enterprise- and carrier-grade network operating system."
- IP Infusion

USE CASES

- Cell Site Router (CSR)
- Data Center Layer 2 and Layer 3
- CLOS Topology – L3 eBGP
- EVPN-VXLAN Overlay with an L3 CLOS Design

PRICING MODEL

Perpetual or subscription licenses with additional maintenance and support.

Supporting both data center and network operator use cases, OcNOS has a sizable installed base spanning access, core, transport, and data center networking. Borrowing much of the rich feature set and robustness—including modular upgrades and process survivability—of ZebOS, OcNOS offers

consistent operations, workflow automation, and high availability while reducing operational expenses. OcNOS is certified with multiple TIP specifications, including DCSG (for Cell Site Router deployments during 5G rollouts), Cassini and Phoenix (for optical transport networks), and OpenSofthaul (for disaggregated wireless backhaul). Additionally, OcNOS provides an industry-standard CLI and support for REST APIs and NETCONF/YANG models for transaction-based configuration and device feature modeling, including checkpoints and rollback.

Strengths: With over 20 years' experience providing NOS solutions, IP Infusion's rich pedigree guarantees you won't get fired for choosing this company. With the addition of DVe and SONiC to its portfolio, IP Infusion now has carrier-grade, open source solutions to meet the needs of customers looking for a low-cost NOS.

Challenges: As the company transitions from an OEM to consumer focus, it will be interesting to see how it positions its offerings and whether the investment in its only commercial NOS, OcNOS, and support for Barefoot Networks' P4-programmable Tofino ASIC will continue as before.

6. Analyst's Take

This battle of the NOSs has only just begun. With new entrants, acquisitions, and strategic alliances, 2020 was an eventful year, and we expect this trend to continue in 2021. Despite the arrival of the vaccine, post-COVID-19 strategies will need to accommodate the increase in remote working and the possibility of future disruption.

Enterprises will take a good hard look at their mobility support strategies, CSPs and MSPs will take the time to review the impact of COVID-19 on their scalability and QoS, while NSPs will look to ramp up their 5G initiatives. Across all scenarios, network operating systems will play an essential role in increasing agility and driving down costs.

Disruption also creates opportunity. While still targeting incumbent networking providers' installed base using proprietary, monolithic architectures, vendors will take advantage of any form of disruption. An example of this exploitation of opportunity is Pluribus Networks' aggressive targeting of the Cumulus Linux installed base following its acquisition by NVIDIA and Broadcom's decision to cut off access to its SDK—leaving Cumulus Linux 4.2 the last release to be supported on Broadcom silicon.

As new entrants like Arrcus, DriveNets, Kaloom, and RtBrick leverage high-performance merchant silicon, cost-effective bare-metal switches, and cloud-native architectures to re-engineer network functions for increased scalability and efficiency, we anticipate further waves of acquisitions and mergers in the next 18-36 months. In any case, open network architectures and operating systems present an opportunity to create agile, innovative, and scalable next-gen services with a low TCO.

As you set out to discover new opportunities based on open networking, we recommend using this report to create a shortlist of vendors who support your target market, deployment model, and use case before focusing on features and cost through vendor engagement.

7. About Chris Grundemann

Chris Grundemann is a passionate, creative technologist and a strong believer in technology's power to aid in the betterment of humankind. In his current role as VP, Strategy at Myriad360 he is expressing that passion by helping clients build bigger, faster, more efficient technology infrastructure that is both more secure and easier to operate and scale. Chris has well over a decade of experience as both a network engineer and solution architect designing, building, securing, and operating large IP, Ethernet, and Wireless Ethernet networks. His specialties include infrastructure design, protocol design, consensus building, technology evangelism, research and development (R&D), leading collaborative groups, communicating abstract ideas to diverse audiences, and generally getting stuff done!

Chris has given presentations in 34 countries and is often sought out to speak at conferences, NOGs, and NOFs the world over. He holds 8 patents in network technology and has written two books: *Day One: Exploring IPv6* and *Day One: Advanced IPv6 Configuration*; as well as an IETF RFC, various industry papers, a personal weblog, and several other publications, including contributions to GestaltIT, CircleID, Packet Pushers, and Forbes.

Chris is also a co-founder and Vice President of IX-Denver and Chair of the Open-IX BCOP committee. He has held previous positions with Markley Group, Internet Society, CableLabs, tw telecom, CO ISOC, ISOC-NY, ARIN, NANOG, AfPIF, CEA, UPnP, DLNA, RMv6TF, and several others.

Chris is currently based in Brooklyn, NY.

8. About GigaOm

GigaOm provides technical, operational, and business advice for IT's strategic digital enterprise and business initiatives. Enterprise business leaders, CIOs, and technology organizations partner with GigaOm for practical, actionable, strategic, and visionary advice for modernizing and transforming their business. GigaOm's advice empowers enterprises to successfully compete in an increasingly complicated business atmosphere that requires a solid understanding of constantly changing customer demands.

GigaOm works directly with enterprises both inside and outside of the IT organization to apply proven research and methodologies designed to avoid pitfalls and roadblocks while balancing risk and innovation. Research methodologies include but are not limited to adoption and benchmarking surveys, use cases, interviews, ROI/TCO, market landscapes, strategic trends, and technical benchmarks. Our analysts possess 20+ years of experience advising a spectrum of clients from early adopters to mainstream enterprises.

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