CHAPTER

BUSINESS RAMIFICATIONS 14

The fact that the very definition of SDN is vague confounds any attempt to assess its full business impact. If we narrow our focus to Open SDN, the business impact so far is minimal. The largest financial transactions to date, however, have revolved around technologies that only fall under broader definitions of SDN. This larger SDN umbrella encompasses any attempt to perform networking in a novel way that involves separation of control and data planes, unlike classical layers 2 and 3 switching. It also includes the creative use of existing protocols and platforms to provide solutions equally relevant and nearly as flexible as their Open SDN counterparts. By casting this wider net, we include companies and technologies that are often totally proprietary and whose solution is tightly focused on a specific network problem, such as network virtualization in the data center. But, as the saying goes, this has been where the money has gone, so this is where the greatest business impact has been.

There seems to be a growing consensus in the networking business community that SDN is here to stay and that its impact will be significant. This is supported by the sheer number of venture capital companies that have invested in SDN startups over the past 9 years, the magnitude of those investments, as well as the size of the acquisitions that have occurred since 2012 in this space. Unusually in the networking field, this particular paradigm-shift does not hinge on any breakthroughs in hardware technology. In general SDN is a software-based solution. This means that technical hurdles are more easily overcome than having to pass some gate-density or bits-per-second threshold. Customers generally view the advent of SDN with excitement and the hope of more capable networking equipment for lower costs. At first, entrenched NEMs may view it with trepidation as it is a disruptive force, and then usually find a way to jump on the SDN bandwagon by incorporating some form of the technology into their product offering. We will look at the dynamics of these various trends in the following sections.

In Sections 14.1–14.6 we review forecasts and trends related to the transition to SDN. When the data is historical, the reader is assured that it is not conjecture. With respect to the future, however, these remain just that—*forecasts*—and we encourage the reader to consider them accordingly. The SDN marketplace is in near constant flux. A sensible forecast one year can easily be proven folly just a couple of years hence.

14.1 EVERYTHING AS A SERVICE

In Fig. 14.1 we show that the ratio of *capital expenditures* (CAPEX) to *operational expenditures* (OPEX) on network equipment will *decrease* as we move through the first few years of SDN deployments. This is because the growth of SDN coincides with a fundamental shift in the way

Software Defined Networks. http://dx.doi.org/10.1016/B978-0-12-804555-8.00014-4

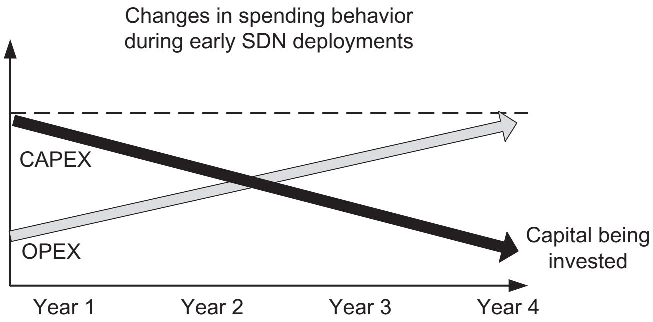

FIG. 14.1

CAPEX on network equipment migrates to OPEX.

that data centers and other large IT consumers will pay for their network equipment and services. New licensing models, subscription-based models and even usage-based models are all becoming increasingly common. The rapid expansion of new service delivery models such as *Software as a Service* (SaaS) and *Infrastructure as a Service* (IaaS) is testimony to this shift. The old model of enterprises purchasing network boxes from NEMs, amortizing them as a capital expense and then repeating the cycle with fork-lift upgrades every few years was a great business model for the NEMs but is gradually disappearing. These new models, where virtually every aspect of the networking business is available as a service and treated as an operational expense, will likely continue to displace the traditional network spending patterns. How quickly this process will unfold is a topic of hot debate.

14.2 MARKET SIZING

The net impact of a move to SDN technology will be influenced more than anything by the *total available market* (TAM) for SDN. At this early stage, forecasts are notoriously unreliable, but some effort has been expended to try to quantify what the total opportunity may be. Based on the studies reflected in [1], while SDN revenues in 2012 were less than 200 million dollars, they are likely to grow to more than 35 billion dollars by 2018. This is forecast to derive 60% from layers 2 and 3 SDN equipment sales and 40% from services equipment (layers 4–7). This growth will be primarily driven by a growth in network virtualization. It does not represent new growth in networking expenditures due to SDN, but rather the displacement of other network spending on SDN technology. Another study [2] predicts the SDN market to grow sixfold between 2014 and 2018, with SDN-enabled switches and appliances comprising the bulk of that revenue. Considering the SDN and NFV markets as a whole, more recent forecasts show the combined SDN and NFV market value ranging from $11 billion by 2018 [3] to $105 billion by 2020 [4].

14.3 CLASSIFYING SDN VENDORS

Network virtualization is happening and the term SDN is being blurred with this, for better or worse. What kind of company dominates network virtualization remains an open question, though. Certainly, there are at least three major classes of companies that are well positioned to make this transition. First, the NEMs themselves as by definition, already dominate the network equipment business. Secondly, since the server virtualization companies like VMware and Citrix already have a firm grasp on compute and storage virtualization, it is possible for them to make a horizontal move into network virtualization. Finally, since success in this area will likely depend on being successful at an SaaS business model, it would be wrong to discount the possibility of a software giant such as Microsoft dominating here. At this time, though, it appears that the battle for network virtualization will be fought between the titans of the network equipment industry and those of server virtualization. We take a deeper look at the impact of SDN on incumbent NEMs in Section 14.4. We first look at the server virtualization companies most likely to be impacted by SDN.

14.3.1 SERVER VIRTUALIZATION INCUMBENTS AND SDN

Since so much of the focus on SDN has been related to network virtualization in the data center, it is probable that incumbents that have traditionally been involved in compute and server virtualization will be drawn to extend their offerings to include network virtualization. The most salient example, VMware, has already surfaced many times earlier in this book. Already the world leader in server virtualization, VMware extended its reach into network virtualization with the acquisition of Nicira. Other companies that could follow suit include HP's server division, NEC and Citrix, among others. Not unusually, HP is a wild card here. HP is already both a major server manufacturer as well as a leading network equipment manufacturer. Of the larger incumbent NEMs, HP seems to be embracing Open SDN more enthusiastically than some of its competitors. Since HP's server division is already a powerful force in compute and storage servers, it would seem that HP was particularly well positioned to bring these two divisions together in a comprehensive networking-compute-storage virtualization story. HP will have to execute on this better than it has on most of its recent major initiatives, so it is impossible to predict what the outcome will be here.

14.3.2 VALUE-ADDED RESELLERS

One class of vendor that must not be neglected in this discussion is the *Value-Added Reseller* (VAR). Such companies, including well-known examples such as Presidio and Compucom, as well as numerous smaller companies, have long played a critical role in providing the customer face for the NEM. From a revenue perspective, this was possible because the network equipment sold had sufficient margins that the VAR could run a viable business based on their share of those margins. As illustrated in Fig. 14.1, part of the premise of SDN is that the hardware boxes become a smaller percentage of the overall network expenditure. Also, the *box sale* will not involve as much customer touch as it has traditionally and, therefore, the traditional value added by the VAR is not available to be added. It thus seems likely that in order to survive in an increasingly SDN world, these VARs will have to evolve into a service model of business. Indeed, their value was always in the service that they provided to their customers, but now this will not be at the box level but at the network or service level. This problem will be exacerbated as the NEMs like Cisco, due to the thinner margins, increasingly sell their boxes directly to the customers. SingleDigits and SpotOnNetworks are classic examples of companies that will need to shift with this change in business model. With SDN, such VARs will have the opportunity to innovate in specific markets of interest to their customer base, not merely sell the features that are provided to them by the NEMs.

We believe that these arguments will likely dictate the long-term direction of the VARs' business, but this process may unfold slowly. The NEMs will justifiably attempt to keep such companies selling their products via the old model. Because of the fact that they are so entrenched, incumbent NEMs have many tools at their disposal. These include aggressive, targeted pricing designed to keep big deals from swinging toward the new paradigm. Also, in order to switch to the service model described previously, the VAR needs to sell future flexibility to the customer *today*. This is never an easy sale. Whatever the timing of this process turns out to be, the companies most likely to be heavily impacted by a major transition to SDN are the incumbent NEMs.

DISCUSSION QUESTION

There is much talk about *Everything as a Service*. IaaS and SaaS are examples of this. Why does this present a challenge to the business models of the established NEMs?

14.4 IMPACT ON INCUMBENT NEMs

Incumbent NEMs are extremely astute marketing organizations. When they intuit that a tectonic shift in network purchasing patterns is about to occur, they generally will find a way to redefine themselves or the problem set so that their current solutions are in lockstep with the paradigm shift. In some cases, this will be just an instance of slide-ware and, in many other cases, there will be genuine shifts within the NEMs to align themselves in *some* way with the new paradigm.

This transition will not come without pain. There are already signs within some NEMs of belt-tightening attributed to market shifts related to SDN. For example, in early 2013, Cisco laid off 500 employees in part in an effort to realign with the advent of SDN [5]. The growth of SDN, along with network virtualization, will reduce the demand for legacy *purpose-built* routers and switches that have been the mainstay of the large NEMs' revenues for many years.

14.4.1 PROTECT MARKET SHARE

Large, entrenched NEMs, such as Cisco and Juniper, have to walk a fine line between protecting their market share and missing out on a new wave of innovation. For example, the high valuation given Nicira by VMware shown in Table 14.2 later in this chapter can clearly put Cisco, Juniper, and their ilk on the defensive. The NEMs are extremely competent in both technical and marketing terms and they have the financial resources to make sure they have a competitive answer to the network virtualization offering from VMware.

When an incumbent has a large war chest of cash, one defensive answer to a new, competing technology is to simply purchase one of the startups offering it and incorporate that product into its solutions. However, if this is not done carefully, this can actually *erode* market share. While the startup has the luxury of being able to tout disruptive technology as a boon to consumers, the incumbent must somehow portray that technology as complementary to its existing offerings. Failing to respond in this way, the company runs the risk of reducing sales of the traditional product line while the nascent technology is still gaining a foothold.

14.4.2 INNOVATE A LITTLE

While an established NEM can readily incorporate *adjacent* technologies into its product line and even gain market share as a result, doing so with a directly confrontational, paradigm-shifting technology like SDN is a much more delicate proposition. In order to avoid getting left behind, the incumbent will need to ostensibly adopt the new technology, especially in name. An incumbent can provide a solution that is competitive to the paradigm shift by adhering to the following model:

- purport to solve the same problem (e.g., network virtualization);
- remain based on the incumbent's then-current technology;
- innovate by layering some aspects of the new technology on top of the existing technology;
- employ widespread use of the buzz-words of the new technology in all marketing materials (e.g., SDN washing).

The SDN via APIs approach, which we discussed in detail in Section 6.2, epitomizes the layering of the new approach on top of legacy technology. We recall that the underlying switching hardware of the leading NEMs has been optimized by custom hardware designs over many years. These hardware platforms may have inherent performance advantages over low-cost, *white-box* switches. If the incumbent provides a veneer of SDN over their already-superior switching hardware, this may present formidable competition to a new SDN paradigm of a separate and sophisticated control plane controlling low-cost commodity switches. Indeed, it is possible that from a pure performance metric such as packets switched per second, the pure SDN model may suffer when compared to high-end legacy switches. This veneer of SDN need not be just a stop-gap measure. As this evolves over time it can have the very positive effect of providing technologies that help their customers evolve to SDN. This can provide many of the benefits of SDN, albeit on proprietary technology. Most customers simply will not tolerate a fork-lift upgrade being imposed on them.

Following the model mentioned previously is a virtual necessity for large, established NEMs. This model provides them with margin preservation during a time of possibly great transition. If the new paradigm truly does become dominant, they are able to ride the coattails of its success, while slowing down the transition such that they are able to maintain robust margins without interruption. As we mentioned previously, they have the technical and marketing know-how to manage favorably this kind of transition. They also have something else, which may be even more important: *the bulk of the enterprise customers*. Such customers do not shift their mission-critical compute, storage or networking vendors willy-nilly, unless there are drastic technical shortcomings in their product offerings. By managing their customers' expectations carefully and innovating just enough, the advantage of owning the customer may be unbeatable.

A recent example of an NEM doing just this very successfully is Cisco's support of the BGP-LS/PCE-P plugin for OpenDaylight that we described in Section 7.2. Through this creative reuse of existing protocols and platforms, associated with an open source SDN controller project, Cisco has managed to create an offering that addresses many of the same needs purported to be solvable by Open SDN. While not as open or flexible as a comparable Open SDN solution, this plugin avoids the disadvantage of too much change too quickly, one of the potential pitfalls of Open SDN discussed in Section 6.1.1.

14.5 IMPACT ON ENTERPRISE CONSUMERS

Inevitably some of this book may read like a sort of SDN evangelist. The vast potential benefits of SDN have been inventoried and explained. It is easy to underestimate the risks that enterprises will run by severing their historic umbilical cords with the NEMs. These umbilical cords have been unwieldy and expensive, to be sure, but the security that comes with this safety net has undoubtedly provided countless IT managers with many a good night's sleep. We, the authors, are in fact SDN evangelists and believe that, at least in certain parts of networking infrastructure, SDN's power to innovate and to mitigate costs will indeed be a historically positive force. Nonetheless, it would be naive to trivialize the birthing pains of a major paradigm shift in such a highly visible area. In this section we will present an overview of both the positive business ramifications of this new technology paradigm (e.g., reduced costs, faster innovation) and also the downside of diluted responsibility when the network goes down.

The most prevalent solution described in the SDN context is network virtualization, which we have discussed at length throughout this book. While many of the solutions for network virtualization are not based on Open SDN, network virtualization via the varied flavors of SDN is a hot area of growth. According to [4], the portion of network purchases influenced by network virtualization is anticipated to increase from 16% in 2015 to almost 80% by 2020.

One challenge is that while these same customers understand compute and storage virtualization, for many, network virtualization remains a snappy catch phrase. Customers need considerable sophistication to understand how network virtualization will work for them.

14.5.1 REDUCED EQUIPMENT COSTS

In the situation of an existing data center, the hoped-for reduction in equipment costs by migrating to SDN may prove elusive or at least delayed. A solution like VMware's NSX touts the fact that its separate control plane can achieve network virtualization without switching out the legacy networking equipment. While this is desirable in the sense that it produces less equipment churn in the data center racks, it does nothing to lower the money being spent on the switching equipment itself. Under this scenario, the customer continues to pay for highly capable and costly layers 2 and 3 switches but only uses them as dumb switches. It is hard to see a fast path to reduced equipment costs in this scenario. Over the longer term and as the legacy switching equipment becomes fully amortized, the opportunity will arise to replace that legacy underlay network with lower cost OpenFlow-enabled switches.

In a greenfield environment, the Open SDN model prescribes intelligent software control of low-cost, OpenFlow-enabled switches. While this scenario is conceivable, that division of the control and data plane brings with it a concomitant dilution of responsibilities. In the past, when your data center network went down, the IT department could usually point their finger at their primary NEM, whether it be Cisco, Juniper, HP, or another. In a perfect, pure SDN world, the white-box switches are just hardware devices that perform flawlessly according to the programming received from their SDN controller. No one with operational experience with a big network would believe that things will actually play out according to that script. The customer will still want *one throat to choke*, as the colloquial saying goes. Getting one company to offer up that single throat to choke may be difficult when the network is instantiated on virtual and physical switches as well as a controller, all running on hardware purchased from three different vendors.

14.5.2 AVOIDING CHAOS

Who ya gonna call…(when the network goes down)? When it boils down to a CIO or IT manager making the decision to migrate any major part of the network from the legacy gear to SDN, the hype about greater ease and granularity of control, higher equipment utilization rate and the other pro-SDN arguments will run into a brick wall if that decision maker fears that network reliability may be jeopardized by making the transition. Because of this, it is a virtual certainty that any migration to SDN in typical enterprise customers will be a slow and cautious one. NEMs may incorporate fully integrated SDN-based solutions into their product portfolio, much like what has occurred with Linux in the world of servers. This will still provide the proverbial throat to choke while using SDN to meet specific customer needs.

We note that certain immense enterprises like Google and Yahoo! are outliers here in that they may have as much networking expertise as the large NEMs themselves. This explains why these organizations have been at the forefront of OpenFlow innovation along with selected research universities. As we explained in Section 11.9, this is evidenced by the composition of the board of the ONF. There are no NEMs on that board, but Yahoo! and Google are represented. For the more typical enterprise, however, this transition to SDN will be viewed with much more caution. Experiments will be done carefully with nonmission-critical parts of the network.

While these pro-SDN rationales are all cogent, a web search on *SDN Purchases* in 2016 yielded a list of acquisitions of SDN startups rather than major investments in the technology by users. In other words, there is more hype about companies buying SDN companies than about customers buying SDN products. This indicates that the process described previously is still in its very early stages. In general we should assume that large-scale transition to SDN will take much longer than most pundits have claimed. This will provide more time for incumbent NEMs to adapt in order to avoid a real shake-up in the networking industry.

DISCUSSION QUESTION

There are some signs that large NEMs like Cisco are transforming themselves and the very definition of SDN to protect their market position. There are examples of this strategy succeeding as well as failing. Give one example of each.

14.6 TURMOIL IN THE NETWORKING INDUSTRY

14.6.1 FEWER AND FEWER LARGE NEMs

One of the advantages of an ecosystem where a small number of NEMs make large profits off of a market they dominate was that the super-sized profits did in fact drive continued innovation. Each NEM tried to use the next generation of features to garner market share from its competitors. Generally, this next generation of features addressed real problems that their customers faced and innovation proceeded apace. A precept of Open SDN is that since users, via the open source community, will be able to *directly* drive this innovation, the innovation will be both more pertinent and less expensive. This thesis has yet to be proven in practice, though. That is, will the creativity of the open source community be able to match the self-serving creativity of the NEMs themselves? The NEMs' ability to maintain margins through innovation has resulted in much of the progress in data networking that our society has enjoyed over the past two decades, so the answer to this question is not an obvious one. We forecast that the NEMs will strive to perform a balancing act between innovating sufficiently to retain their market control and their desire to maintain the status quo.

14.6.2 MIGRATION TO CLOUD COMPUTING

If we take as a given that the need for network virtualization in large data centers is the prime driver behind SDN, then we must acknowledge that the growth of cloud computing is one of the major factors that has forced those data centers to grow ever larger and more complex. From the end user's perspective, cloud computing has grown more relevant due to transitions in a number of related elements:

- Usage-based payment models
- Digital media and service providers
- Digital media access and sharing providers
- Online marketplaces
- Mobile phone network providers
- Web hosting

More and more enterprises avail themselves of the cloud computing capabilities of Google and Amazon for a variety of applications. Apple's *iCloud* takes local management of your smartphone, tablets, and laptops and handles it in the cloud. Sharing services like *DropBox* and *GoogleDocs* offer media sharing via the cloud. Google offers a plethora of business applications via the cloud. Amazon Web Services offers web hosting on an unprecedented scale. As more users depend on the cloud for an ever-increasing percentage of their applications' needs, both the quantity and reliability of data centers are under constant pressure to increase. This force creates the pressure on the data center providers and the vendors that supply equipment to them to innovate to keep up with this relentless growth. The nature of the networks in these data centers is virgin soil for a new networking paradigm in network virtualization if it can help manage this growth in a controlled fashion [4].

IaaS provides networking capacity via the OPEX payment model. The growing popularity of this model in itself contributes to the turmoil in the networking industry where networking capacity has traditionally been obtained by purchasing equipment. Many of the SDN startups discussed in this chapter hope to displace incumbent technology by offering their solutions via some kind of subscription model.

14.6.3 CHANNEL DYNAMICS

Among the consequences of the migration to cloud computing are radical changes to the way that customers purchase networking capabilities and to the companies that traditionally had the direct customer touch in those sales. Networking operating systems and applications will be bundled with a mix of private and public cloud offerings. A new set of vendors skilled at cloud-based orchestration solutions will customize, deploy, and manage compute, storage, and networking virtualization functions. Based on the enterprise's migration to cloud services, network solution providers will migrate from selling networking boxes to offering networking services [6]. The VARs that now focus on reselling and supporting network hardware design and implementation will likely consolidate into larger and more comprehensive IT services companies. IT services companies will hire, train, and acquire skilled resources that understand how to design, implement, and manage *Web Operations Functions* (WebOps) and *Development and Operations* (DevOps) specialists on behalf of enterprise customers.

14.7 VENTURE CAPITAL

It is no coincidence that a significant amount of *venture capital* (VC) investments have been placed in SDN startups in the past 7 years. It is the nature of venture capital firms to seek out groups of bright and ambitious entrepreneurs who have aspirations in a space that is likely to see rapid growth within a well-bounded time horizon. Depending on the field, the distance to that time horizon can vary greatly. In the field of medical startups, this horizon may be more than 10 years after the initial investments. In data networking, however, the time horizons tend to be shorter, between 3 and 5 years. SDN technology is the perfect contemporary fit for the VC firm with a history of investing in networking startups. The market, at least in the data center, is clamoring for solutions that help them break what is perceived as a stranglehold by the large incumbent NEMs. The amount of money available to be spent on upgrades of data center networks in the next few years is enormous. SDN's time horizon and the corresponding TAM is like a perfect storm for VCs. SDN may be the largest transformation in the networking world in the past three decades [7]. This is not merely a US-based phenomenon, either. Some other countries, notably Japan and China, see SDN as a means to thwart the multidecade long hegemony that US NEMs have had on switching innovation. In these countries, both adoption by customers as well as offerings by local NEMs are likely to heavily influence the uptake of SDN in the coming years. In Table 14.1 we list VC firms that have been the earliest and most prominent investors in SDN startups.

These investors have furnished the nest from which many companies have been hatched. Some of these companies are still in startup mode and others have been acquired. As of the time of writing of this work, none of the investments listed in Table 14.1 have resulted in *initial public offerings* (IPOs). In the next sections we examine what has happened both with the major acquisitions that have resulted from these investments as well as those companies still striving to determine their future.

14.8 MAJOR SDN ACQUISITIONS

One of the most visible signs of major transformations in a given market is a sudden spate of large acquisitions of startups all purporting to offer the same new technology. Certainly 2012 was such a year for SDN startups. The size of the acquisitions and the concentration of so many in such a relatively short calendar period was an extraordinary indicator of the momentum that SDN had gathered by 2012. In Table 14.2 we provide a listing of the largest SDN-related acquisitions that took place in 2012–15.

Table 14.1 Major VCs Investing in SDN Startups as of 2015

Venture Capital Company	Invested in
Khosla Ventures	Big Switch
Redpoint Ventures	Big Switch
Goldman Sachs	Big Switch
Intel Capital	Big Switch
Benhamou Global Ventures	ConteXtream
Gemini Israel Funds	ConteXtream
Norwest Venture Partners	ConteXtream, Pertino
Sofinnova Ventures	ConteXtream
Comcast Interactive Capital	ConteXtream
Verizon Investments	ConteXtream
Lightspeed Venture Partners	Embrane, Pertino, Plexxi
NEA	Embrane
North Bridge Venture Partners	Embrane, Plexxi
Innovation Network Corporation of Japan	Midokura
NTT Group's DOCOMO Innovations	Midokura
Innovative Ventures Fund Investment (NEC)	Midokura
Jafco Ventures	Pertino
Hummer Winblad	Plumgrid
US Venture Partners	Plumgrid
Vantage Point Capital	Pica8
Battery Ventures	Cumulus
Matrix Partners	Plexxi
SEB Capital	Tail-f
Presidio Ventures	Embrane
New Enterprise Associates	Embrane
Sequoia Capital	Viptela

It is rare to see so many acquisitions in one field of technology of such large dollar value concentrated in so short a period of time. If SDN did not already serve as the honey to attract investors, it surely did by 2012–13. Most of the companies listed in Table 14.2 were already either major players in the SDN landscape at the time of their acquisition or are now part of large companies that plan to become leaders in SDN as a result of their acquisition. In this section, we will attempt to explain the perceived synergies and market dynamics that led to the acquisition of each.

14.8.1 VMware

Nicira's technology and the success they have enjoyed with it has been a recurring theme in this book. Nicira's acquisition by VMware stands out as the largest dollar-value acquisition purporting to be primarily about SDN. VMware was already a dominant force in the business of compute and storage software in large data centers. Prior to the acquisition, VMware was largely leaving the networking part

Table 14.2 Major SDN Acquisitions in 2012–15

Company	Founded	Acquired by	Year	Price	Investors
Nicira	2007	VMware	2012	$1.26B	Andreessen Horowitz Lightspeed Ventures
Meraki	2006	Cisco	2012	$1.2B	Google Felicis Ventures Sequoia Capital DAG Ventures Northgate Capital
Contrail	2012	Juniper	2012	$176M	Khosla Ventures Juniper
Cariden	2001	Cisco	2012	$141M	Not available
Vyatta	2006	Brocade	2012	Undisclosed	JPMorgan Arrowpath Venture Partners Citrix Systems HighBAR Partners
Insieme	2012	Cisco	2013	$863M	Cisco
Tail-f	2005	Cisco	2014	$175M	SEB Capital
Embrane	2009	Cisco	2015	Undisclosed	Cisco Presidio Ventures New Enterprise Associates Lightspeed Venture Partners North Bridge Venture Partners
ConteXtream	2007	HP	2015	Undisclosed	Benhamou Global Ventures Gemini Israel Funds Norwest Venture Partners Sofinnova Ventures Comcast Interactive Capital Verizon Investments
Pertino	2011	Cradlepoint	2015	Undisclosed	Norwest Venture Partners Lightspeed Venture Partners Jafco Ventures
Cyan	2006	Ciena	2015	$400M	Norwest Venture Partners Azure Capital Partners

of the data center to the NEM incumbents, most notably Cisco [8], with whom they have partnered on certain data center technologies such as VXLAN. Since SDN and the growing acceptance of the need for network virtualization were demonstrating that a shift was forthcoming in data center networking, it made perfect sense for VMware to use this moment to make a major foray into the networking part of the data center. Nicira provided the perfect opportunity for that. The explosive growth of cloud computing has created challenges and opportunities for VMware as a leader in the compute and storage virtualization space [9]. VMware needed a strategy to deal with cloud networking alternatives, such as

OpenStack and Amazon Web Services, and Nicira provides that. This competitive landscape is fraught with fuzzy boundaries, though. While VMware and Cisco have worked closely together in the past, and Nicira and Cisco collaborated on OpenStack, it is hard not to imagine the battle for control of the network virtualization in the data center pitting VMware and Cisco against one another in the future.

14.8.2 JUNIPER

Juniper was an early investor in Contrail [10]. This falls into the *spin-in* category of acquisition. Juniper recognized that it needed to offer solutions to address the unique east-west traffic patterns common in the data center, but atypical for its traditional WAN networking customers. By acquiring Contrail, Juniper obtained network virtualization software as well as network-aware applications that help address these data center-specific problems. Juniper additionally gained the Contrail management team, which consisted of senior managers from Google and Aruba as well as others with outstanding pedigrees that are targeted to help Juniper bring SDN solutions to enterprise customers. We described the Contrail data center solution in Section 6.2.5.

Contrail also uses the OpenStack standard for network virtualization. Thus support for OpenStack is a common thread between Cisco, VMware, and now Juniper. It is difficult to predict at this time whether these companies will use this standard as a platform for collaboration and interoperability or look elsewhere to distinguish their network virtualization offerings from one another.

DISCUSSION QUESTION

Considering what we have said about Contrail here and in previous chapters, explain how their technology leverages Juniper's strengths with service provider WAN solutions to create a beachhead for Juniper in the network virtualization marketplace.

14.8.3 BROCADE

Brocade needed a virtual layer 3 switch in order to connect virtual network domains for cloud service providers [11]. Brocade believes it has found the solution to this missing link in its acquisition of Vyatta. Vyatta delivers a virtualized network infrastructure via its on-demand network operating system. The Vyatta operating system is able to connect separate groupings of storage and compute resources. Vyatta's solution works both with traditional network virtualization techniques like VLANs as well as newer SDN-based methods [11]. Like HP, Brocade remains more committed to Open SDN than most other incumbent NEMs.

14.8.4 CISCO

Not surprisingly, in total dollar terms, the biggest SDN-acquirer in 2012 was Cisco. As seen in Table 14.2, Cisco acquired both Cariden and Meraki in 2012. Both of these acquisitions are considered in the networking literature [10,12] to be SDN-related acquisitions, though the Meraki case may be stretching the definition of SDN somewhat. Cariden was founded in 2001, well before the term SDN came into use. Cariden was respected as the developer of IP/MPLS planning and traffic engineering software. Cisco has used Cariden's software for managing networks to help achieve the industry-wide goal of being able to erect virtual networks with the same ease as instantiating a new virtual machine. Within Cisco, the Cariden platform has evolved into the *WAN Automation Engine* (WAE). As for Meraki, the value of the acquisition indicates the importance that Cisco places on this new member of the Cisco family. What distinguishes Meraki from Cisco's preacquisition technologies is that Meraki offers cloud-based control of the wireless APs and wired switches that it controls. This web-centric approach to device management fills a gap in Cisco's portfolio [12], providing it with a mid-market product in a space vulnerable to a competitive SDN-like offering. While we believe that Meraki is really an outlier in terms of the classical definition of an SDN company, the fact that their device control is separated from the data plane on the devices and implemented in the cloud supports their inclusion here as a major SDN acquisition.

Insieme was founded by Cisco in 2012 with plans to build *application-centric infrastructure* [13]. Insieme is a Cisco *spin-in* that received over $100 million in seed funding from Cisco. SDN is a game-changing technology that can be disconcerting to the largest incumbent in the field, Cisco. While Cisco brought to market a family of SDN-related products revolving around its commercial XNC controller, those actions had not convinced the market that Cisco had truly embraced SDN. The Insieme acquisition changed this. The high valuation given to the Insieme acquisition is affirmation of the importance Cisco is now giving to SDN. Understandably, the Insieme product offering attempts to pull potential SDN customers in a purely Cisco direction. While the new products may be configured to interoperate with other vendors' SDN products, they may also be configured in a Cisco-proprietary mode that purportedly works better. Significantly, the Insieme product line does represent a break with Cisco's legacy products. The new router and switch line from Insieme will not smoothly interoperate with legacy Cisco routers [14]. Cisco now emphasizes the Insieme controller, known as the *Application Policy Infrastructure Controller* (APIC), over the older XNC product. The company intends for the APIC to work with its installed base of legacy routers as well as the new equipment from Insieme [15].

Cisco acquired the Swedish-based Tail-f in 2014 to augment its capabilities for network configuration and orchestration. While Tail-f was founded in 2005, well before the hype around SDN and NFV began, it received a significant new round of funding in 2011 and repositioned itself as a provider of network orchestration tools tailored at bridging the gap between legacy *Operational Support Systems* (OSS) and the new SDN and NFV systems. Service providers see these new SDN and NFV technologies as a necessary step toward streamlining their operations and increasing their profitability. Being able to orchestrate the interoperation of these new tools without a radical departure from legacy systems is a significant challenge for service providers. Tail-f's solution is focused on this space. As Tail-f's customer base included more service providers than enterprise customers [16], this acquisition gives Cisco a wedge to drive itself further into the service provider market. The fact that AT&T is one of Tail-f's main customers is particularly significant, as this acquisition gives Cisco a more prominent place in AT&T's Domain 2.0 vendor program, where formerly it was relegated to a secondary role. The Tail-f solution allows a Cisco product to manage a variety of non-Cisco equipment. While it has not traditionally been Cisco's focus to work in a multivendor environment, this may be a requirement to advance its market share with service providers.

The managing of non-Cisco equipment with Cisco management tools is also a theme of another important Cisco acquisition, Embrane [17]. We describe Embranes's technology and business strategy as a stand-alone startup in Section 14.9.6. Embrane makes management software that facilitates the spin-up, shut down, and reconfiguration of NFVs. It has turned out that while NFVs are a formidable concept in and of themselves, the agility that they afford can only be readily harnessed via management systems tailored to this highly dynamic environment. In executing this acquisition in 2015, Cisco asserts that the Embrane technology dovetails well with the recently acquired Insieme product line.

14.8.5 HEWLETT-PACKARD

HP acquired ConteXtream in 2015 to strengthen its position in the NFV market [18]. We discuss ConteXstream's technology and business strategy as a stand-alone startup in Section 14.9.4. As part of its product lineup, ConteXstream offers an OpenDaylight-based controller. HP intends to increase its contributions to the OpenDaylight open source effort via this acquisition.

14.8.6 CIENA

Ciena added significantly to its SDN and NFV portfolio via its 2015 acquisition of Cyan. Through this acquisition, Ciena gains access to Cyan's SDN and NFV products as well as its optical networking hardware [19]. Cyan's product suite includes an NFV orchestration platform that Ciena plans to combine with its *Agility* software portfolio. It is noteworthy that Cyan does not appear in Table 14.3. The reason for this is that Cyan was founded as an optical chip designer long before the SDN movement began and thus was never a genuine SDN startup. More recently, Cyan made a major commitment to the SDN and NFV space which is why it is relevant in this discussion of major SDN acquisitions. Interestingly, Cyan actually had a moderately successful IPO in 2013, and thus Ciena's acquisition was of a publicly traded Cyan. Since we do not consider Cyan a genuine SDN startup, our earlier statement that none of our SDN startups in Table 14.1 have had a successful IPO remains true.

14.8.7 CRADLEPOINT

Pertino was acquired by Cradlepoint in late 2015. Cradlepoint will incorporate Pertino's SDN and cloud networking capabilities into Cradlepoint's 4G LTE offerings [20]. Pertino's SDN technology is expected to not only help Cradlepoint bolster their service provider business, but also to gain a stronger foothold with enterprise networks. In Section 14.9.4 we describe Pertino's strategy prior to this acquisition.

DISCUSSION QUESTION

NEMs with deep pockets often buy NFV and SDN startups to incorporate their innovative technology. Some believe that this slows down innovation from startups. Is there a way to prevent this from happening? If so, how?

14.9 SDN STARTUPS

The frenzy of customer interest in SDN combined with the willingness of investors to provide capital for new business ventures result in the unsurprisingly long yet inevitably incomplete list of SDN startups as of 2015 which we present in Table 14.3. SDN entrepreneurs are arriving so fast upon the scene that we cannot claim that this is an exhaustive list. Rather than attempting to cite every SDN startup, we hope to describe a succinct set of different markets that might be created or disrupted by SDN startups. For each of these, we will provide one or more examples of a new business venture approaching that market. The general categories we define are:

- OpenFlow stalwarts
- Network virtualization for the data center
- Network virtualization for the WAN
- Network functions virtualization
- Optical switching
- Mobility and SDN at the network edge

In deference to SDN purists, we begin with companies squarely focused on products compliant with the OpenFlow standard. Although this may represent to SDN purists the only true SDN, it has not had the financial impact that non-OpenFlow-focused network virtualization solutions have had. Indeed, network virtualization represents the bulk of investments and acquisition dollars expended thus far in SDN. For this reason, we will treat network virtualization in the two separate above-listed subcategories. We will conclude with some markets peripheral to the current foci in SDN that may have considerable future potential.

14.9.1 OpenFlow STALWARTS

One of the tenets of SDN is that by moving the intelligence out of the switching hardware into a general-purpose computer the switching hardware will become commoditized and thus low-cost. Part of the tension created by the emergence of SDN is that such a situation is not favorable to the incumbent NEMs, accustomed to high margins on their switches and routers. OpenFlow zealots generally respond that lower cost *original device manufacturers* (ODMs) will fill this space with inexpensive, OpenFlow-compatible, white-box switches. This, of course, opens the door for startups that view providing the white-box switches as a virgin soil opportunity.

As we described in Section 11.5, this is the basis of the strategy of Chinese-based startup Pica8 [21]. Pica8 provides a network operating system and reference architectures to help their customers build their SDN networks from low-cost switches, the Pica8 operating system and other vendors' OpenFlow-compatible products. Through its white-box ODM partners Accton and Quanta, Pica8 offers several Gigabit Ethernet switch platforms based on OVS that currently support OpenFlow 1.4 [22]. One wonders, though, if there is a way to turn this into a high margin business.

Big Switch also now has a business strategy centered on working with white-box switch ODMs. While Big Switch continues to put OpenFlow support at the cornerstone of their strategy, the company performed what they termed *a big pivot* in 2013 [23]. As one of the major players in the ecosystem, we described some of Big Switch's history in Section 11.4. They continue to offer the same set of commercial application, controller, and switch software products that they have all along. The pivot relates to selling them as bundles that white-box switches can download and self-configure. Their original product strategy included getting a number of switch vendors to become OpenFlow-compatible by facilitating this migration with the free switch code, thus creating a southbound ecosystem of switch vendors compatible with their controller. They also encouraged application partners to develop

Table 14.3 Startup Landscape in 2015

Company	Founded	Investors	Product Focus	Differentiator
Big Switch	2010	Khosla Ventures Redpoint Ventures Intel Capital Goldman Sachs	OpenFlow-based software	
ConteXtream[a]	2007	Benhamou Gbl Ventures Gemini Israel Funds Norwest Venture Ptr. Sofinnova Ventures Verizon Investments Comcast Interactive Cap.	Network virtualization in the data center	Grid computing
Cumulus	2010	Battery Ventures	White-box switch software	
Embrane[a]	2009	Lightspeed Venture Ptr. NEA North Bridge Venture Ptr.	Network virtualization in the data center	Network appliances via SDN
Midokura	2009	Innovation Network Corp. of Japan NTT Investment Ptr.	Network virtualization for Cloud Computing	IaaS
Nuage	2013	Alcatel-Lucent	Network virtualization	
Pertino[a]	2011	Norwest Venture Ptr. Lightspeed Venture Ptr. Jafco Ventures	Network virtualization for the WAN	
Pica8	2009	Vantage Point Cap.	White-box switch software	OpenFlow 1.2 OVS
Plexxi	2010	North Bridge Venture Ptr. Matrix Ptr. Lightspeed Venture Ptr.	Ethernet-Optical Switch Orchestration controller	SDN control of Optical Switches
Plumgrid	2011	Hummer Winblad US Venture Ptr.	Network virtualization	No Openflow
Pluribus	2010	Menlo Ventures New Enterprise Assoc. Mohr Davidow Ventures China Broadband Cap.	Physical switch	Integrated controller
Tallac	2012	–	Cloud-based SDN WiFi providing multitenant services	Open API to enable NFV services for vertical market applications

[a] *Has been acquired (see Table 14.2.)*

Table 14.3 Startup Landscape in 2015—Cont'd

Company	Founded	Investors	Product Focus	Differentiator
Vello	2009	–	Network Operating System (controller) Optical switches White-box Ethernet switches	OpenFlow support
Tail-f	2005	SEB Capital	Configuration and orchestration for SDN and NFV	
Viptela	2012	Sequoia Capital	SD-WAN	

applications to the northbound side of their controller. Such applications could be in the areas of firewalls, access control, monitoring, network virtualization, or any of a long list of other possibilities. The amount of investments they received [8,24] indicates that they were very successful at convincing others that their business model is viable.

After a rocky experience in trying to get production networks configured with different vendors' switches to interoperate with their controller and applications, they concluded that they needed to make the roll-out of the solution much easier than what they were experiencing with all but their most sophisticated customers. Big Switch concluded that by partnering instead with white-box ODMs, rather than established switch vendors like Juniper, Arista, and Brocade, they could better control the total user experience of the solution. This new approach, or pivot, has their customers purchasing white-box switches from Big Switch's ODM partners. These white-box switches are delivered with the *Open Network Install Environment* (ONIE) boot loader that can discover the controller and download Big Switch's *Switch Light* OpenFlow switch code [25]. Switch Light is based on the Indigo open source OpenFlow switch software. The notion is to sell the customer an entire bundle of switch, controller, and application code that is largely auto-configured, providing a particular solution to the customer.

There were two initial solution bundles offered at the time of the pivot, a network monitoring solution *Big Tap Monitoring Fabric*, and a cloud fabric for network virtualization. Significantly, the cloud fabric solution [26], called *Big Cloud Fabric*, is not based on an overlay strategy, but on replacing all of the physical switches with white-box switches running Big Switch's software. Big Switch is betting that by replacing the physical network with the low-cost white-box switches, and by having Big Switch stand behind the entire physical and virtual network as the sole provider, they will have created a compelling alternative to the many overlay alternatives being offered for network virtualization.

DISCUSSION QUESTION

The so-called *white-box strategy* is generally seen as a challenge to incumbent hardware-centric NEMs. While this strategy is symbiotic with Open SDN, can you identify possible weaknesses in the white-box strategy from a technical or business standpoint?

14.9.2 NON-OpenFlow WHITE-BOX VENTURES

Cumulus Networks takes the white-box boot loader concept and generalizes it one step further than Big Switch. As of this writing, Cumulus offers the product closest to the concept of *opening up the device* described in Section 6.4. As we pointed out in our discussion of white-box switches in Section 11.5, any switching code, OpenFlow or non-OpenFlow, controller-based or not, can be loaded into the Cumulus switches if written compatible with the Cumulus bootloader. Cumulus is a switch-centric company, and does offer the broad portfolio of controller and application software as does Big Switch.

14.9.3 AN OpenFlow ASIC?

Another OpenFlow hardware opportunity is to create a switching ASIC that is specifically designed to support OpenFlow 1.3 and beyond. Implementers have found it challenging to fully implement some parts of the advanced OpenFlow specifications in existing ASICs. One such challenge is supporting multiple, large flow tables. Since there is growing industry demand for the feature sets offered by OpenFlow 1.3, this creates an opportunity for semiconductor manufacturers to design an OpenFlow chip from scratch. Some of the incumbent switching chip manufacturers may be slow to displace their own advanced chips, but this is an inviting opportunity for a startup chip manufacturer. In Section 11.6 we described work being done at Mellanox that may be leading to such an advanced OpenFlow-capable ASIC. Intel has also announced switching silicon [27] that is explicitly designed to handle the multiple OpenFlow flow tables. This remains a technologically challenging area, however, and an active area of research [28].

14.9.4 DATA CENTER NETWORK VIRTUALIZATION

The team at ConteXtream has used their grid-computing heritage as the basis for their distributed network virtualization solution [29]. Theirs is an overlay network consisting of L4–L7 virtual switches [30]. It is touted as an SDN product, since the routing of sessions in the data center is controlled by a distributed solution with global knowledge of the network. This solution is very different from the classical OpenFlow approach of centralizing the network routing decisions to a single controller with a small number of backup controllers. In the ConteXtream approach, the control is pushed down to the rack level. If a control element fails, only a single rack fails, not the entire network. This per-rack control element is added to the TOR server. Admittedly, this architecture deviates significantly from the more classical SDN approaches of Big Switch or Nicira. In fact, a distributed algorithm with global knowledge of the network sounds similar to the definition of OSPF or IS-IS. The ConteXtream solution does differ significantly from classical routing in that (1) it can perform switching at the session level, (2) network devices like firewalls and load balancers can be virtualized into their software, and (3) the network administrators have explicit control over the path of each session in the network. ConteXtream's offering also includes provisioning of NFVs, which was the primary motivation cited in Section 14.8.5 behind HP's 2015 acquisition of ConteXtream.

As shown in Table 14.3, PLUMgrid has also received a sizable investment to develop network virtualization solutions. PLUMgrid offers an SDN via Overlays solution that is designed for data centers and integrates with VMware ESX as well as with *Kernel-based Virtual Machine* (KVM). PLUMgrid does not use OpenFlow for directing traffic through its VXLAN tunnels, but instead uses a proprietary mechanism. It also uses a proprietary virtual switch implementation rather than using OVS or Indigo.

PLUMgrid indicates that OpenFlow might be supported in the future [31], whereas it does currently support OpenStack [32].

Midokura [33] is another well-funded startup attacking the network virtualization market. Midokura currently integrates with OpenStack [34] and the CloudStack cloud-software platform [35]. Like other network virtualization companies, their product, MidoNet, creates virtual switches, virtual load balancers, and virtual firewalls. MidoNet is an SDN via Overlays product that runs on existing hardware in the data center. MidoNet claims to allow data center operators to construct public or private cloud environments through the creation of thousands of virtual networks from a single physical network. Since managing this plethora of virtual networks using traditional configuration tools is a huge burden, MidoNet provides a unified network management capability that permits simple network and service configurations of this complex environment. As shown in Table 14.3, Midokura's lead investors are large Japanese institutions, and some of the senior management are battle-hardened data communications veterans. Midokura is further evidence of the enthusiasm in Japan for SDN as is reflected by the incumbents NTT and NEC's interest in this technology [36,37].

14.9.5 WAN NETWORK VIRTUALIZATION: SD-WAN

SDN for the WAN, or SD-WAN as it is commonly known, has attracted a number of startups in recent years. The general idea espoused by these startups is to use an overlay strategy of virtual connections, often via some tunneling mechanism across a set of WAN connections, usually including the Internet itself. The mapping of traffic from branch offices of enterprises over these virtual connections is orchestrated by a centralized controller. This market is forecast to reach $7.5 billion by 2020 [38]. In this section we will review the technology and business of some of the more prominent startups in this field. We will explore the details of SD-WAN technology in greater depth in Section 15.2.

Pertino's offering is very different from the aforementioned data center-focused companies. They believe that there is a large market for *SDN-via-cloud*. Pertino offers a cloud service that provides WAN or LAN connectivity to organizations that wish to dynamically create and tear down secure private networks for their organization [39]. The term SDN-via-cloud is another stretch from the original meaning of the term SDN but, indeed, this concept truly is a *software defined network* in the sense that software configuration changes in Pertino's cloud spin up and spin down their customers' private networks through simple configuration changes. The only technical requirement for the individual users of these virtual networks is that they have Internet connectivity. A handful of branch offices from a small enterprise can easily obtain a secure, private network via the Pertino service as long as each of those branch offices has Internet connectivity. Such a private network can be brought on-line or off-line very easily under the Pertino paradigm. Pertino also attempts to make this service easy to use from a business perspective. This is another IaaS proposition. Their business model is a usage-based service charge, where the service is free for up to three users and after that there is a fixed monthly fee per user. As mentioned in Section 14.8.7, Cradlepoint acquired Pertino in 2015.

Viptela was founded in 2012 as an SD-WAN company. The Viptela *Secure Extensible Network* solution [40] for architecture transformation includes five steps:

1. Enable transport independence
2. Enable security at routing scale
3. Enable network-wide segmentation

4. Centrally enforce policy and business logic
5. Insert layers 4–7 services on demand

Viptela's offering separates the service provided from the underlying physical network by building an overlay network on top of the physical connections that exist. This allows the network transport level to be provisioned and operate independently of the underlying physical WAN connections. The Viptela solution is comprised of three major components: (1) the centralized *vManage* Network Configuration and Monitoring System, (2) the *vSmart* controller, and (3) the *vEdge* router one of which is deployed at every site belonging to the enterprise customer.

Other SD-WAN startups [41] include Aryaka, CloudGenix, Talari, and VeloCloud. Some established vendors in the SD-WAN space include Citrix, FatPipe, Ipanema, Silver Peak, and Riverbed. Unsurprisingly, Cisco is also a major player in SD-WAN via its *Intelligent WAN* (IWAN) offering.

14.9.6 NETWORK FUNCTIONS VIRTUALIZATION

Embrane has a distributed software platform for NFV that runs on commodity server hardware. The company's focus is to virtualize load balancers, firewalls, VPNs, and WAN optimization through the use of *distributed virtual appliances* (DVAs) [42]. Considering that a typical physical server in a data center hosts multiple customers with a pair of firewalls for each customer, the number of physical devices that can be removed by deploying their product, called Heleos, is significant [43]. They emphasize that Heleos functions at network layers 4–7, unlike the OpenFlow focus on layers 2 and 3. While Heleos does work with OpenFlow, it is not required. Indeed, Heleos integrates virtualization technology from multiple hypervisor vendors. One of Embrane's goals is to allow Heleos to coexist with existing network appliances to permit a gradual migration to the virtualized appliance model. In keeping with the growth of IaaS, in addition to the standard annual subscription fee, they support a usage-based model that charges an hourly rate for a certain amount of available bandwidth. As we described in Section 14.8.4, Embrane was acquired by Cisco in 2015.

Pluribus' offering is based on their server-switch hardware platform along with their NetVisor network operating system. Their target market is network virtualization of public and private clouds. The Pluribus product, like that of others mentioned previously, provides services like load balancing and firewalls that formerly required independent devices in the data center [31]. The Pluribus SDN controller is integrated with its server-switches such that their solution is completely distributed across the Pluribus hardware. The Pluribus solution also provides interoperability with OpenFlow controllers and switches by interfacing with the integrated Pluribus SDN controller. It also is compatible with the VMware NSX controller. The combination of the NetVisor network operating system and their proprietary server-switches attempts to provide a complete fabric for handling the complex cloud environment that requires coordination between applications, hypervisors, and the compute virtualization layer [39].

Nuage entered the SDN playing field with its *Virtualized Services Platform* (VSP) [44]. Alcatel-Lucent founded Nuage in 2013. Network operators can use VSP to set policies across the network, at tenant-level granularity. VSP is designed to control both virtualized and nonvirtualized infrastructures and, as such, can help service providers and enterprises implement cloud services. Nuage has also entered the NFV space, integrating with ETSI-standard MANO stacks. Nuage's future will undoubtedly be heavily influenced by the 2015 acquisition of Alcatel-Lucent by Nokia. The NFV and network virtualization talent in Nuage should nicely mesh with Nokia's efforts in those areas. As of this writing, Nuage remains an independent subsidiary under the Nokia-Alcatel-Lucent umbrella.

14.9.7 OPTICAL SWITCHING

Optical switches have been around for more than a decade now. They offer extremely high bandwidth circuit switching services, but have been comparatively unwieldy to reconfigure for dynamic networking environments. The SDN concept of moving the layers 2 and 3 control plane to a separate controller translates readily to the layer 1 control plane appropriate for optical switches. A couple of SDN startups, Plexxi and Vello, are attempting to leverage this natural SDN-optical synergy into successful business ventures. Plexxi has a dual mode switch that is both an Ethernet and an optical switch. The optical ports interconnect the Plexxi switches. The fact that each Plexxi switch is actually an optical switch allows extremely high bandwidth, low latency *direct* connections between many Plexxi switches in a data center. The Plexxi controller platform provides SDN-based network orchestration. This controller has been used to configure and control pure optical switches from other manufacturers such as Calient [45]. In this combined offering, the Plexxi switch's Ethernet ports are used for short, bursty flows and the Plexxi optical multiplexing layer is used for intermediate-sized flows. High volume, persistent flows (elephant flows) are shunted to the dedicated Calient optical switch.

Vello also offers Ethernet and optical switches. The Vello products are OpenFlow-enabled themselves and can interface to other vendors' OpenFlow-compatible switches [31]. While Vello, like most of the other startups discussed previously, addresses network virtualization, they focus on use cases and applications related to storage devices.

14.9.8 MOBILITY AND SDN AT THE NETWORK EDGE

Current SDN efforts have focused primarily on the data center and carrier WAN, but Tallac Networks is expanding that focus with an emphasis on managing services for the Campus LAN [6,46]. Tallac technology offers a new approach called *Software Defined Mobility* (SDM), which enables MSPs to connect users to the network services they demand. One powerful aspect of OpenFlow is the ability to virtualize a network so it can be easily shared by a diverse set of network services. In the context of *Network-as-a-Service* (NaaS), this means creating a multitenant WiFi environment. The fine-grained control of the OpenFlow protocol allows network connections and secure tunnels to be provisioned dynamically. Through a set of technologies combining OpenFlow, access to Network Functions, and standards-based Hotspot 2.0 (Passpoint), Tallac delivers an SDN-enabled, multitenant, service-oriented WiFi network for wireless LAN operators to centrally administer networks and services. Combined with NaaS business frameworks, Tallac's cloud service enables network operators to bring a multitude of applications, services, and network functions right to the users that need them.

14.10 CAREER DISRUPTIONS

Most of this chapter has focused on the potential disruption SDN is likely to cause to the incumbent NEMs and the opportunities it affords startup enterprises. We need to remember that the driving force inspiring this new technology was to simplify the tasks of the network administrators in the data center.

Most of the marketing materials for the startups discussed in this chapter declare that the current network administration environment in the ever-more-complex data center is spiraling out of control. One consequence of this complexity has been a seemingly endless demand for highly skilled network administrators capable of the black art of data center network management. If *any* of the SDN hype presented in this chapter proves to be real, one certain outcome is that there will be less of a need for highly skilled technology-focused network engineers to manually reconfigure network devices than there would be without the advent of SDN [43]. For example, consider that one of the highly sought-after professional certifications today is that of the *Cisco Certified Internetwork Expert* (CCIE). This sort of highly targeted, deep networking knowledge will become less and less necessary as SDN gains a larger foothold in the data center [4,42]. In [47], the author cites the VLAN provisioning technician as an example of a particularly vulnerable career as SDN proliferates.

There will, however, be a growing need in the data center for the kind of professional capable of the sort of agile network service planning depicted in Fig. 14.2. Much like the *Agile Development Methodology* that has turned the software development industry on its head in recent years, the network professionals in an SDN world will be required to rapidly move through the never-ending cycles of *plan*, *build*, *release*, and *run* shown in Fig. 14.2 in order to keep pace with customers' demands for IaaS. *DevOps* is a term now commonly used for this more programming-aware IT workforce that will displace the traditional IT network engineer. This new professional will possess a stronger development operations background than the traditional CLI-oriented network administrator [48]. Since SDN increases how much innovation IT professionals will be able to apply to the network, professionals working in this area today need to embrace that change and ensure that their skills evolve accordingly.

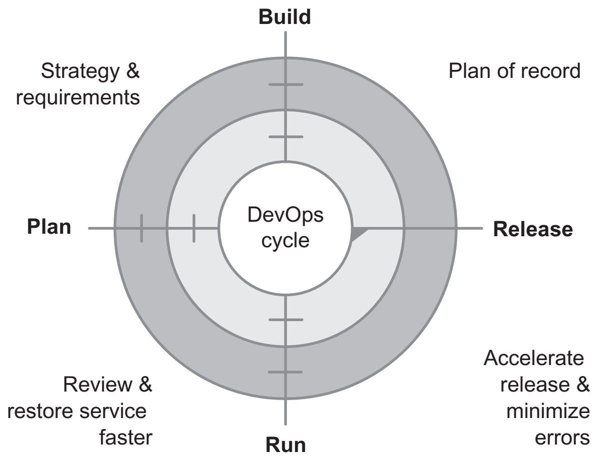

FIG. 14.2

Agile environment for network administrators.

DISCUSSION QUESTION

Describe how the job of a network administrator for a data center is likely to have changed between 2010 and 2020?

14.11 CONCLUSION

There is a historical pattern with new Internet technologies where the hype surrounding the possibilities and financial opportunities reaches a frenzy that is out of proportion to its actual impact. We have seen this happen numerous times over the past two decades. FDDI and WIMAX are but two examples of this trend. While it may be likely that the current hype surrounding SDN is probably near its peak [11], it does seem inevitable that some form of SDN will take root. In particular, de-embedding the control plane from the physical switch for data center products seems to be an unstoppable trend. The technical underpinnings of this idea are very sound and the amount of investment that has poured into this area in the past few years is ample evidence of the confidence in this technology. The big question from a business ramifications standpoint is whether or not there will be a sea-change in the relationship between vendors and customers, or will the degree of vendor-lock that the large NEMs enjoy today persist in a slightly modified form. Idealistic SDN proponents proselytize that the adoption of SDN will take the power from the NEMs and put it in the hands of customers. Whether or not this happens largely hinges on whether or not openness is truly a mandatory part of the SDN paradigm. In the business world today there is no consensus on that and we acknowledge that separation of control plane from data plane need not be performed in an open manner. It is entirely possible that proprietary incarnations of this concept end up dominating the market. This is still an open question and the answer to it will undoubtedly be the biggest determinant of the business ramifications of SDN.

In the next and final chapter we attempt to synthesize the current state of SDN research with current market forces to forecast where SDN is headed in the future.

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