STANFORD UNIVERSITY
SCHOOL OF ENGINEERING
CASEPUBLISHER

2012-204-1

DRAFT Rev. May 21, 2012

NICIRA NETWORKS: DISRUPTIVE NETWORK VIRTUALIZATION

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Professors Micah Siegel (Stanford University) and Fred Gibbons (Stanford University) guided the development of this case using the CasePublisher service as the basis for class discussion rather than to illustrate either effective or ineffective handling of a business situation.

Introduction

Virtualization is one of the most powerful concepts in Computer Systems. Even though virtualization has existed as a concept for decades, it was only when VMware delivered the benefits of virtualization to industry-standard x86-based platforms that the computing community recognized its true commercial and technology value. The term virtualization broadly describes the separation of a resource or request for a service from the underlying physical delivery of that service. With virtual memory, for example, computer software gains access to more memory than is physically installed, via the background swapping of data to disk storage. Today, virtualization can apply to a range of system layers, including hardware-level virtualization, operating system-level virtualization, and high-level language virtual machines. 2)

With Nicira, it's network virtualization. Nicira helps create a virtual network - a network that can be controlled by the software, independently of the physical devices beneath it, as easily as a computer is programmed. Such an approach is called Software-Defined Networking (SDN) and this is the new direction the networking community is heading.

The founders of Nicira Networks: Martin Casado, Nick McKeown, and Scott Shenker state that their mission is to virtualize the network. Their ultimate goal is to control the network with software as opposed to hardware. Nicira's co-founder Martin Casado believes that:

> "...In 10 years, you're not going to have highly-skilled, highly-paid people working with networking hardware...."

Hence, in the current market scenario, much of the power would be taken out of the hands of companies such as Cisco, Juniper, and HP. John Engates, Rackspace's CTO and current Nicira customer, sums it up best:

> "...They put the power in the hands of the cloud architect rather than the network architect...."

Various network companies may have different strategies, but all agree that SDN is the future networking technology. For this reason, Nicira's products are received with both excitement (by network device customers) and disquiet (by network device providers). Now one wonders if Nicira's technology will be strong enough to disrupt the current network market. If so, will it sustain when major players with deep pockets join the virtualization game? Will potential adopters embrace the technology, and if so, when? Is Nicara's vision premature, and does Nicira have the right product for this market?

NICIRA'S BUSINESS

As the seminal article, Marketing Myopia by Theodore Levitt, points out, it is essential for any organization to precisely define the breadth of their business model and answer the question "what business are we in?" 1) Nicira is very clear in stating that it is in the business of network virtualization 2) According to Alan Cohen, this is a completely new business category which distinguishes it from other networking companies and hence provides distinct challenges for Nicira by breaking new ground. A big challenge Nicira will face is helping potential adopters understand network virtualization. To many users networks already embody a type of virtualization, not really understanding how they work or why. Marketing this disruptive technology is key to educating potential adopters.

Similarly, as indicated by the MIT Technology Review, Nicira makes the control of the existing physical network infrastructure easier by shifting the network control intelligence to software, 3)"to make all kinds of Internet services smarter, faster, and cheaper."

These are incredibly broad claims and begs the question "what business is Nicira really in?" So, an essential question remains: is Nicira biting off more than it can chew with this sweeping new technology? Or do they have the ability to completely disrupt the entire Internet services market? Nicira will need to define the breadth of their business model to clearly define their future objectives and ensure the proper scope of their capabilities. After all the network is really big place, and it may be naive to think one provider can satisfy market demand. This will only invite new entrants with competing virtual schemes that may in the end render implementation infeasible.

PROBLEM STATEMENT

Nicira is disrupting the traditional networking industry by shifting network control from the physical network to the server (software), thus facilitating more scalability, flexibility and efficiency. However, it is competing in a highly consolidated network management market against established players like Cisco and Juniper Networks. These companies have ample financial resources and experience in the industry to launch their own virtualization software. Cisco has, in fact, already launched a startup to contribute to the open-source project for network virtualization (OpenStack, see "Current Competitors" Section).

Nicira has the potential to become a disruptive force for the next generation of networking. Its products are rated very highly in the networks community, but is Nicira's technology strong enough to disrupt the current network market? Can it successfully change the way network management has been done for more than two decades?

If so, should Nicira find a viable way to gain a footing in the network management market and sustain its position when major players with deep pockets join in? Should it go heads up against the giants, or forge alliances with them? Can it compete in the market with a software-only solution? Will it find the right product/market fit? Althought the product appears to be excellent, will the market quickly adopt the new technology giving Nicira first-mover advantage? Or will slow adoption give established network providers ample time to develop their own indigenous capabilities and squeeze Nicira out?

Overview of Network Communications Industry

For the past two decades, development in the network communication industry was mostly centered around creating faster, cheaper, and better customized hardware. Networking hardware (e.g., routers, switches, gateways, hubs, etc.) connect all computers on the network and act as intermediate points that enable end-to-end transmission and reception of messages. The Internet technology is extremely fault-tolerant. Thus, the Internet is highly decentralized and infrastructural changes require significant hardware re-configurations.

Now the dominance of hardware technology in the network communications industry declines, and there is a shift towards Software Defined Networking (SDN). This is largely due to the transition from static client-server computing to the dynamic computing and storage needs of today's enterprise datacenters, campuses and carrier environments. With applications moving to the cloud, the ability to control the flow of network traffic through software is becoming indispensable.

Cloud computing[1]) refers to the provision of computing services via a remote machine. For example, traditionally, when a user converts a Word document to a PDF file, the entire process occurs on the user's machine, where the CPU receives the command to create and locally store the PDF file. In the case of cloud computing, the entire process takes place on a server that could be halfway across the world. The Word document is uploaded to the server from the user's machine via the Internet. The server creates the PDF, which is then downloaded by the user's machine. If the user wants to use the cloud for storage, the PDF file will also be stored on a server. Whenever the user wants to access the PDF file, he/she links his/her machine to the cloud and downloads the file from the server or servers. The cloud concept presents a disruptive technology for data processing and storage. This is a market at its infancy, and explosive growth is predicted (See Exhibit 11).

Even though cloud computing, now, might be a household term, it hasn't lived up to its hype—and as things now stand and it can't. It was supposed to turn computing power into a cheap utility, like electricity after the advent of power stations and a national grid. A relatively small number of companies would offer computing resources by running software in

vast, efficient data centers and piping the results over the Internet to anyone, anywhere. That would push down the price of services that rely on computing and allow them to become more sophisticated. Yet today, even with seemingly cost-effective cloud services available from the likes of Amazon, most companies still choose to operate their own computing resources—whether for corporate e-mail or financial trading—as if they were homeowners relying on generators for electricity. One reason they resist cloud computing, Casado says, is that network architecture is too decentralized to reconfigure easily, which leaves the cloud insecure and unreliable. computing providers tend to run entire data centers on one shared network. If, for example, Coke and Pepsi both entrusted their computer systems to one of today's public cloud services, they might share a network connection, even though their data stores would be carefully kept separate. That could pose a security risk: a hacker who accessed one company's data could see the other's. It would also mean that a busy day for Coke would cause Pepsi's data transfers to slow down. While the former problem is solved with server virtualization solutions like one from VMware, the latter is solved when Nicira's software is installed on the servers in a data center.

Background

Nicira, Inc., founded in 2007 is based on Martin Casado's research work as a Computer Science Ph.D. student at Stanford University. In his research, Casado proposed a theoretical network architecture SANE, and subsequently designed and implemented an incrementally deployable alternative Ethane to create simpler yet more secure networks. 1)2) Co-founders include his two advisors, Nick McKeown at Stanford University and Scott Schenker at the University of California at Berkeley. Nicira's technology provides a working framework for next-generation networks: Software-Defined Networking (SDN)3).

As a researcher at Lawrence Livermore National Laboratory, Casado was approached by a U.S. intelligence agency to solve a difficult problem. The agency (Casado won't say which one) told him it wanted to keep its large network but reserve the ability to temporarily close off parts of it for crucial transmissions, creating a data equivalent of the dedicated telephone hotline that used to link the White House and the Kremlin. 4) The distributed, decentralized nature of computer networks allowed easy sharing of information, but also carried security vulnerabilities that could not be trivially addressed. As a result, networks created by the existing technologies could not be used by government-based organizations. As Casado described, "The government, which has incredibly deep pockets, couldn't go out and buy what it wanted. It was extremely difficult to make these networks secure, and once you did, you had a really horrible management nightmare on your hands. Moving just one computer, for example, meant you had to make eight different configuration changes. You couldn't move anything — you couldn't touch anything — unless you put a tremendous number of

people to work." 5). Haunted by the problem, he soon left Livermore and entered grad school at Stanford University to search for an answer. He presented one in his 2007 PhD thesis, which proposed a radical new way for computer networks to operate. Now he's co-founded a company called Nicira, which is poised to use that idea to make the Internet more powerful than ever before. Nicira's technology won't just help intelligence agencies keep secrets. It should also improve the security, lower the price, and increase the power of any technology that uses the Internet, unlocking innovation that is too expensive or technically impossible to achieve today. Nicira's technology addresses this issue by virtualizing the network and enables modifying the network as conveniently as changing a piece of software. By using virtual computer networks rather than hardwired systems to connect cloud servers, Nicira could make the cloud more secure and reliable, hence the company's name "Nicira", meaning "vigilant" in Sanskirt.

Casado's vision of network virtualization is widely compared to VMware's server virtualization. Whether viewed as a network revolution or simply a good business opportunity, Nicira is considered a promising company as is evident by the more than $50 million it has raised so far in funding by venture capital firms, such as Andreessen Horowitz , Lightspeed Venture Partners, and New Enterprise Associates, as well as individual investors such as Andy Rachleff and Diane Greene (co-founder and for many years CEO of VMware). By 2011 Nicira was already enjoying some success, making Technology Review's 50 most innovative companies alongside technology giants Google, Apple, Samsung, and Facebook. 6)

In February, 2012, Nicira publicly unveiled its Network Virtualization Platform (NVP). NVP is a software-based system that creates a distributed virtual network infrastructure in cloud datacenters that is completely decoupled to and independent from physical network hardware.

NVP was designed to address the shortcomings of traditional networks by offering a platform that provides the operational model of a virtual machine. Until now, virtualized datacenters faced limits on what applications they could support and where the workloads can be placed. In fact, Nicira estimates that in datacenters without NVP 20%-30% of server capacity is under utilized and networking costs are several times more expensive. 7)

"Network virtualization is the biggest change to networking in 25 years," said Stephen Mullaney, Chief Executive Officer of Nicira. "NVP provides the final pivotal piece to cloud computing, the most transformational change to IT in a generation. And the largest most forward-thinking cloud providers are laser focused on operations and economics, the two benefits Nicira delivers." For example, global market leaders such as AT&T, Calligo, eBay, Fidelity Investments, NTT, and Rackspace have already benefited, seeing their service de-

livery time reduced from weeks to minutes, and realizing dramatic cost reductions of data-center deployments on the level of tens of millions of dollars.

"Virtualization and the cloud are the most profound changes in information technology since client-server and the web overtook mainframes and mini computers. We believe that the full promise of virtualization and the cloud can only be fully realized when the network enables rather than hinders this movement. That is why it needs to be virtualized..." states Alan Cohen on his personal blog regarding the reason for his joining Nicira as the VP of Marketing.8)

In addition to improving commercial services, Nicira's technology may have also piqued the interest of international government agencies. In mid 2011, someone broke into the company's headquarter in Palo Alto, California and took a particularly valuable laptop containing a significant amount of Nicira's intellectual property. Due to the manner in which the crime was carried out, some people speculated that the thief was an agent of a foreign government. Nicira's CEO Stephen Mullaney would only acknowledge the loss, which he dismissed as "very early stuff, nothing like what we've got now." 9) 10)

Led by an experienced management team (Exhibit 7), Nicira has about 100 employees in 2012 and is continuing to hire, claiming a revenue rate already in the millions.

Technology

After virtual servers and virtual storage, virtual networking is the newest arrival in the computing world. Virtualization, in simple terms, means that another layer of abstraction is introduced in the system to provide an illusion of service provision. For example, in the case of virtual servers, the illusion of having multiple pieces of hardware is created while running just one piece of hardware. Virtual servers and networks are so related that after VMware unlocked the power of running multiple virtual servers on a physical server ten years ago, the networking community thought of seeking a way to similarly virtualize networks. See Exhibit 3 for the seven properties of network virtualization. In Nicira's case, the majority of the company's R&D staff are system experts 1) working towards establishing networks controlled wholly by software. This type of networking technology is called Software-Defined Networking (SDN).

SOFTWARE-DEFINED NETWORKING (SDN)

SDN brings modularity to network control and uses software abstractions to decouple the control and data layers of the network, so that the underlying infrastructure is separated from the applications and the network becomes a logical entity. The firmware of network

switches and routers (control plane) has traditionally remained proprietary, locked and under the control of the companies that manufactured the equipment. When purchased, network hardware (e.g. Cisco switches and routers) ships with manufacturer-supplied device-specific control programs. Hence, to control the network, consumers have no choice but to use the manufacturer-provided firmware. In order to modify the network, one may have to reprogram all individual devices. In contrast, in an SDN environment, one can create a high-level control program for the network, using a well-defined general instruction set and following the supported communication protocol specifications.

The way SDN controllers work may be illustrated using the analogy of a postal service. For any given street location, all the letters from all the tenants would first be aggregated by a local post office–in SDN's case, by an SDN edge. This edge function would examine the current location for each of the letter-destinations using a global non-autonomous lookup mechanism. Based on that global lookup and on other globally defined and globally measured considerations (such as access control or remote location load conditions) the SDN edge places single or multiple of the original letters in an additional envelop designated to each of the current street locations of the destinations. It then uses the normal postal service which works like traditional IP to get these outer envelopes to the remote locations. This is done based on the existing and scalable hop-by-hop forwarding country.state.zip.street postal service. The outer letters are then opened by the remote SDN edge and the original envelopes are delivered to the destinations 2). The global software defined control also keep tabs on flow specific contexts based on source and destination identity aspects. Using the analogy example this service will differentiate between a remote chess game carried over small, non-urgent yet lossless postcards versus a massive transfer of consecutive legal documents that need to be rushed one after the other to the remote destination. A mechanism for driving network hardware has been added and adopted by network gear manufacturers for the purpose of sharing edge driving between software defined edge and vendor specific bridging and routing.

The first standard communications interface defined for an SDN architecture was OpenFlow, developed by Nick McKeown and his colleagues at Nicira while the company was still in stealth mode. 3),4),5). The OpenFlow protocol enables globally aware centralized or distributed software controllers to drive the network edge hardware in order to create an easily programable identity based overlay on top of the traditional IP core.

Also the SDN development models variants, including Symmetric vs Asymmetric, Flood-Less Vs FloodBased, HostBased Vs NetworkCentric. Some of the lines between these design models may not be completely sharp. For example in data-centers using compute fabrics "Big" hosts with lots of CPU cards perform also some of the TopOfRack access functions

and can concentrate SDN Edge functions on behalf of all the CPU cards in a chassis. This would be both HostBased and NetworkCentric design. There may also be dependency between these design variants, for example a HostBased implementation will typically mandate an Asymmetric centralized Lookup or Orchestration service to help organize a large distribution. Symmetric and FloodLess implementation model would typically mandate in-network SDN aggregation to enable lookup distribution to a reasonable amount of Edge points. Such concentration relies on local OpenFlow interfaces in order to sustain traffic encapsulation pressures.

OPENFLOW

OpenFlow (Exhibit 2) is an open-source firmware that enables users to reconfigure hardware externally. The original firmware of the routers and switches of the networks is locked down, meaning they are intellectual properties of hardware companies like Cisco and Hewlett-Packard, and not accessible externally. Once installed on the hardware, OpenFlow will allow engineers to command the switches and routers how to direct the network traffic6). This way, they can develop new methods to increase the network speed and then test them on a large-scale networks, which were not available due to the proprietary firmware of hardware manufacturers. OpenFlow is a pragmatic compromise. On one hand, it allows researchers to run experiments on heterogeneous switches in a uniform way at line-rate and with high port-density; on the other hand, vendors do not expose the internal workings of their switches.

OpenFlow was well received by computer industry giants (e.g. Google, VMWare and Microsoft) because it is modular and can immediately be incorporated into the current network stack, leaving the rest undisturbed. However, OpenFlow needs support from the network hardware. Some of the traditional networking vendors are currently working on gear that use OpenFlow, but others are building network controllers that use the technology. However, Martin Casado — one of the driving forces behind the creation of the technology — believes that in the grand scheme of things, OpenFlow is not that important. Nicira has created a network controller that lets users build virtual networks (i.e., networking that operates independently of and over the network hardware). To do that, Nicira created Open vSwitch (a new type of virtual switch) and Stateless Transport Tunneling (STT), which is a "tunneling protocol". A tunneling protocol allows for running a network protocol over a network that is built for a different protocol. STT enables transporting Ethernet data inside packets that use the Internet Protocol (IP, the protocol used to connect machines on the Internet).

OPEN VSWITCH

Open vSwitch is a virtual switch (Exhibit 13) used as the network switching component in the hypervisor. Open vSwitch maintains the logical state of a virtual machine's network connection across physical hosts when a virtual machine is migrated. It can be managed and monitored by standard protocols such as OpenFlow, NetFlow, sFlow, SPAN, RSPAN. It can run as both a standalone hypervisor switch and as a distributed switch across multiple physical servers (e.g., XenServer DVS). It integrates total physical platforms to provide enterprise-level functions such as virtual local area network (VLAN), Quality of Service (QoS), tracking and hardware acceleration support.

NETWORK VIRTUALIZATION PLATFORM (NVP)

NVP is a scalable software system deployed at the network edge and managed by distributed architecture of cluster controllerse. The system forms a thin software network abstraction layer between end hosts and the physical network, treating the physical network as an IP backplane. Virtual networks, containing the same properties and services as physical networks, can be created dynamically to support VM mobility anywhere within or between datacenters without service disruption or address changes. The logical network is completely built with software, while the underlying physical network is merely used to forward packets 8). Hence NVP is compatible with any datacenter network hardware and can be deployed on any existing network. Consequently, it allows for future changes to the network hardware without disrupting the operation of the virtual network platform.

The NVP software suite consists of three key components 9):

1. Controller cluster: a distributed control system
2. Management software: an operations console
3. RESTful API: integrated into a range of Cloud Management Systems (CMS)

NVP provides the following technical advantages 10):

- Fewer limitations of physical network
- Programmatic control of network infrastructure
- Network security model
- Strict tenant isolation and granular usage accounting
- Scalability (to hundreds of thousands of virtual ports)
- API into the network for rapid service creation

- Physical-to-virtual integration and migration
- Network services support including broadcast and multicast

An Illustration of the structure of Nicira's NVP are available in Exhibit 1, Exhibit 4 and Exhibit 5.

Value Proposition

Nicira's customers gain several significant benefits such as reduced time to revenue, increased operational efficiency, reduction of operational and capital cost:

Reduced time-to-revenue

NVP minimizes the time to deployment with a fast "click to reconfigure" cloud model. Consequently, public cloud providers can now differentiate at the infrastructure level and achieve faster time-to-revenue. Enterprise private clouds also gain the competitive advantage of accelerated new product and service introduction.

> " ... customers can reduce provisioning time for new services from weeks or days to minutes or seconds, which can translate to significant time-to-revenue reductions ..."1)

Increased operational efficiency

Traditional networks required manual reconfiguration of multiple network elements (one at a time) to provision a new service onto the network. These operations are fragile and prone to human error, with effects from changes to a single node propagating widely throughout the network. By abstracting network services from the physical network, NVP allows network reconfiguration and management to be simpler and free from human intervention, in turn reducing associated operational costs and downtime 2).

Reduced operational and capital cost

Network deployments become more cost-efficient. Legacy approaches only achieve server utilization of 20-30% in datacenters, translating to a several-fold increase in networking costs. Removing network bottlenecks allows for servers to be more fully loaded. That also eliminates the need for backup capacity, thus delivering overall better server utilization of existing equipment. In addition, NVP extends the lifetime of existing network hardware and providing choices for new deployment or upgrades. Its hardware-independence allows customers to choose the network architecture, technology and vendors that provide the best price performance solution for their businesses.3) In fact, Nicira claims that NVP can

recover $20-37 million in capital and operational costs for a large data center of 40,000 services 4). However there is no independent data to corroborate this claim.

Better server utilization

As mentioned in the previous paragraph, legacy approaches can leave as much as 20%-30% of the server capacity in data centers under-utilized. NVP can create virtual networks dynamically to support VM load and mobility. This allows better utilization of the datacenter servers in the same way virtual machine technology allowed better utilization over running applications on bare hardware.

Management

The management team of Nicira comes from strong engineering and networking backgrounds, including Cisco, Juniper, SynOptics, Fore Systems, Palo Alto Networks, Airespace, and Force 10 (Exhibit 7). Nicira's founders are Martin Casado (also the CTO), Nick McKeown and Scott Shenker. Steve Mullaney joined the company as the founding CEO in 2009. The VP of Engineering, Rob Enns, was recruited from Jupier.1) Their VP of Marketing, Cohen knows how to talk. He spent six years as a marketing executive at Cisco, the company that sells more networking hardware than anyone else in the world, and now, he's plugging Nicira, a company that wants to make Cisco irrelevant, taking the brains out of network hardware and moving them into software. 2).

> "We've created a new category: we're a network virtualization company" — Cohen's elevator pitch3)

The engineering team comes from the distributed systems world (VMware, Google, Yahoo) and a large percentage of them hold PhDs in systems design and computer science from leading universities including Stanford, UC Berkeley, MIT and Cornell.4)

> "Martin Casado is...amazing," who has worked closely with Casado for the past several years on the networking problems Nicira is trying to solve. "I've known a lot of smart people in my life, and on any dimension you care to mention, he's off the scale." - Scott Shenker, physics PhD, UC Berkeley computer science professor, and former Xerox PARC researcher5)

Ecosystem

Nicira's products need to be incorporated by enterprises that run datacenters and provide cloud services. Additionally, the ecosystem must be prepared on a number of fronts for the full-scale switch from a hardware-based network to a software-based one. Like most disruptive innovations, Nicira's Network Virtualization Platform provides greater convenience than the technology it seeks to substitute. While disruptive innovations are generally viewed as simpler or less capable products, this paradigm does not fit the Nicira model. Their service cannot come in as a less capable product. Network reliability and interruption of service considerations require the absolute correctness of Nicira's technology.

Three major players in the industry are helping to move the idea of cloud computing to the mainstream for the end user. They include digital media and service providers (e.g., Apple, Amazon, Google), digital media access and sharing providers (e,g., DropBox), and information storage providers (e.g., eBay). Apple's iCloud and Amazon cloud services are clearing the way for expansion of digital media into the cloud, which is providing widespread user-support for a transition from hardware into a virtual world. Apple's iCloud provides easy and automatic access to all user content on any device and provides this free with iOS5. Apple tends to wait for a mature ecosystem before launching their products, which indicates that cloud services are quickly maturing and there is support for this move. Amazon is offering similar cloud services, and the size of Amazon alone can push this service to the forefront of the industry. Other companies like DropBox, which allows users to upload and share documents across multiple computers and via internet-access, have started to make the concept of anywhere-anytime access an increasingly common concept, especially for sharing among users. Similarly, companies like eBay have long-standing relationships with customers looking for cheaper and faster ways to access and store information. As eBay is a current customer of Nicira, this speaks volumes of the large-scale end-user needs of cloud services and a maturing ecosystem.

The market demand for cloud computing is increasing. After the Great East Japan Earthquake in March 11, 2011, the demand for cloud technologies that enable undisrupted services, even when datacenters incur damage, through construction of backup offices and Disaster Recovery (DR) sites has greatly increased. Furthermore, the growth of multinational companies that require access to the most up-to-date shared data, both between divisions and between countries, is driving the need for cloud computing. Thanks to the increased take-up of its cloud offerings, the United Kingdom (UK) firm Interoute announced positive financials on Monday. The company revealed profits of €7.8m during 2011, led by revenue growth of 24 per cent on the previous year to hit €366m. Such growth demonstrates that beyond the hype at the high-end, smaller firms are seeing genuine growth from cloud tech-

nology, proving the cloud is becoming an established part of firms' IT estates. According to Interoute CEO Gareth Williams, the firm saw many customers move to the cloud during 2011 as they realised the benefits of the offer 1).

In terms of the initiative risk, interdependence risk, and integration risk of the ecosystem:2)3)

1. Ecosystem initiative risk is high - Today's networks require near-perfect reliability. Established network providers invest significant amounts of R&D money into ensuring network reliability. Transition to a new network architecture will be viewed with caution, and transition to this new paradigm will be slow. This slow transition will give established network providers time to develop their own virtual networks, whereby, they can leverage their existing networks and customer base. Nicera will find it very difficult to be first to market and may not be able to enjoy first mover advantages.

2. Ecosystem interdependence risk is low - SDN is based on software. Technical breakthroughs in hardware are not required to advance this technology. Nicira's NVP requires the complementary products of cheap, standard x86 servers. Since the physical network simply forwards packets, there is no hardware or vendor dependency. NVP requires only IP connectivity.

3. Ecosystem integration risk is high - The adoption of this technology will be transparent to end users. The end user will not ultimately create the market for this technology, but the market demand must come from established network providers such as Cisco. Given established providers significant investment in networking, they are unlikely to view Nicera in favorable terms. Established providers will likely develop virtual networks on their own because they can capitalize on their exiting customer base. That iss a high barrier to entry for Nicera.

The Market

COMPETITORS

Nicira has proved that there is customer demand for network virtualization. The company provides a software-only network virtualization solution, which intrinsically has performance penalties due to the latency in configuring the network as the workloads change dynamically. It must be acknowledged that performance as measured by throughput and latency will be inferior with a software-based network virtualization solution. Cisco and other big networking companies, such as Juniper, market their routers and switches on the

strength of the intelligence built into the chips inside, which is difficult to modify. This 'intelligence' translates to more complex ASIC's and thus higher cost to deploy the network. The Nicira offering renders much of this 'intelligence' disabled, but today the cost is still pushed onto the customer. Nicira hopes that the physical network infrastructure becomes simplified, cheaper, and commodity-like, but it has to recognize that substitute offerings from Cisco and Juniper are likely to provide a solution that preserves its existing physical network solution with network virtualization additions to its ASICs to address the performance issues.

CURRENT COMPETITORS

Startups such as ConteXtream, Embrane, Big Switch and others are also seeking to play a role in developing distributed-virtual networks1). There is also the risk of the virtualized, software-defined network feature being integrated within an existing vendor's product.

CONTEXTREAM

ConteXtream 2), founded in 2007, provides cloud-based network virtualization by running software on top of a server. ConteXtream delivering the cloud-based network virtualization framework for carriers, cloud service providers, and private cloud operators. Leveraging the power of proven virtualization and grid technologies, ConteXtream's market-ready products help extract more value and profitability from networks through higher performance, greater scalability, and lower operating and capital expenditures. ConteXtream has raised $23.6 million and is backed by Benhamou Global Ventures, Gemini Israel Funds, Norwest Venture Partners, Sofinnova Ventures, Comcast Interactive Capital and Verizon Investments.

EMBRANE

Embrane 3) is in the cloud computing and IT-as-a-service business. Its Heleos delivers on-demand virtual network services such as server load balancing, network optimization, and security. Embrane's mission is to accelerate the adoption of cloud computing and IT-as-a-service by delivering the most dynamic platform for virtual network services. Embrane has created the industry's first multi-service, distributed software platform that powers virtual network services such as firewalls/VPNs, WAN optimization, etc. on-demand. Purposely built for those offering cloud infrastructure as a service, heleos delivers the agility, rapid provisioning and procurement, elasticity, multi-tenancy at scale and programmability, and cost savings users expect from the Cloud. Embrane has had $27 million in funding by New Enterprise Associates, Lightspeed Venture Partners and North Bridge Venture. It is pertinent to note that the funding is by the same Investors in Nicira.

CITRIX

Citrix 4), founded in 1989, is a multinational corporation with its Xen open-source products. The company is based in Fort Lauderdale, Florida, with operation offices in California and Massachusetts and development centers in Australia, India, and the United Kingdom. The company provides server and desktop virtualization, networking, software-as-a-service (SaaS), and cloud computing technologies. Citrix currently services around 230,000 organizations worldwide.

BIG SWITCH NETWORKS

Big Switch Networks 5), founded in 2010, provides a OpenFlow-based solution for network virtualization. The company raised $14 million from Index Ventures and Khosla Ventures. Compared to Nicira, Big Switch Networks takes a less-enterprise-focused approach.

NEC

NEC 6) is in the cloud computing market with their Hyper-V suite of cloud virtualization tools. NEC partners with Microsoft, which collaborates with Dell, Fujitsu, Hitachi, HP, IBM to deliver a broad choice of pre-defined, validated configurations for private cloud deployments.

HP

HP FlexFabric 7) is the next-generation, highly scalable data center fabric architecture of an HP Converged Infrastructure. FlexFabric provides efficient and securely network resources and deployment of virtualized workloads. With highly-scalable platforms and advanced networking and management technologies, FlexFabric network designs are simpler, flatter, and easier to manage and grow over time. This open architecture uses industry standards to simplify server and storage network connections while providing seamless interoperability with existing core data center networks. FlexFabric combines intelligence at the server edge with a focus on centrally-managed connection policy management to enable virtualization-aware networking and security, predictable performance, and rapid, business-driven provisioning of data center resources. FlexFabric enables building a wire-once data center that responds to application and workload mobility and provides resource elasticity. Network connections with workloads can be migrated across or between data centers. Also, the fabric can stretch and reclaim pools of resources to meet rapidly changing needs. High-

performance threat management tools unify physical and virtual security into a common, extensible framework. Dynamic provisioning capabilities fully exploit virtualized connections to achieve new levels of data center efficiency and accelerate time-to-service. The FlexFabric management and provisioning tools help align the fabric with governance policies and service-level agreements (SLAs), while reducing the cost of operations 8)

CISCO

Cisco has been contributing to an open-source virtual network tool, Openstack. VMware, a long time partner of Cisco, as well as some other existing networking competitors has been developing similar tools. However, Casado believes these hardware-based vendors will not fully commit to network virtualization technology. If it sells a product that allows one to work entirely without hardware, it will cannibalize all of its hardware-based products. He believes that Nicira is in a unique niche in the market.

PLEXXI

Plexxi's William Koss had this to say "In my view, SDN is not a tipping point. SDN is not obsoleting anyone. SDN is a starting point for a new network. It is an opportunity to ask: if I threw all the crap in my network in the trash and started over what would we build, how would we architect the network and how would it work? Is there a better way?"9)

SUBSTITUTE PRODUCTS

More players are bound to enter the network virtualization industry. However, Nicira's portfolio of patents is likely to keep others from directly copying its technology. Protection afforded by patents will not be sufficient to create barriers to entry for new players. Given this technology is software driven, new entrants can emerge overnight with different and potentially better virtual architectures. Competing standards will ultimately make the transition to virtual networks risky and may result in unreliable networks.

Cisco created Insieme 10), a "spin-in" to directly compete against Nicira, in 2012. Cisco is investing $100 million into Insieme, with the option to buy the startup back later for $750 million. Cisco is also working on its own network virtualization tool, OpenStack; this open source platform builds cloud infrastructure ala the tools offered by Rackspace and Amazon. In other words, it is an add-on to its existing hardware infrastructure and is still hardware-

dependent. Cisco has joined Nicira and others in building a networking virtualization framework for OpenStack, the open source platform for building infrastructure clouds along the lines of those offered by Rackspace and Amazon. "Cisco is a networking company, and we're increasingly looking at cloud services. We're not just switches and routers anymore," says Lew Tucker, who oversaw the development of Sun Microsystems' cloud service before it was sold to Oracle and now runs Cisco's OpenStack efforts. "We want to make sure this stuff works on Cisco gear."11)

It is worth mentioning that Nicira sees itself as the networking of VMware, which is not only partially owned by Cisco, but is also a partner of Cisco. In 2007, Cisco invested $150M to acquire 1.6% of VMware. The intention was to strengthen its strategic alliances. Not surprising, the collaboration is about the virtualization of networking. Hence, Cisco not only is working on its own network virtualization but also forming alliances even as back as 2007. 12)

CUSTOMER POWER

There is no direct switching cost because Nicira's NVP is compatible with any datacenter network hardware and can be deployed on any existing network, however, the switching cost might be hidden as other forms. For example, if a customer experienced networking problems, it might be non-trivial whether it is a hardware problem (i.e., call Cisco, Juniper, or...) or a software problem (i.e., call Nicira or internal software engineer). Another possible switching cost could be training engineers to operate Nicira's software itself.

Furthermore, transforming today's networks is not something that can happen overnight; companies have legacy applications and infrastructure that will take time to migrate and systems to rebuild. But, as demand grows, network technology has to progress to satisfy the network demands. Unfortunately if this demand comes from established network providers such as Cisco with an existing hardware and customer base, Nicera may find itself squeezed out when established providers develop their indigenous capability. Time is not on Nicera's side. Adoption of this technology will be slow due to the critical requirement for network reliability. This gives established providers ample time to develop its own virtual capabilities. 13)

Also, another type of switching cost is the future switching cost. If Nicira's product started to gain traction, could Cisco, Juniper, and/or HP start setting up new protocols that will require Nicira to redo their software? Or maybe even prohibit it? After all, Nicira's software still runs on a hardware that is not produced by Nicira. It is possible that there will be new hardware suppliers, but that is a switching cost the customers have to consider. Such actions

have been seen over and over again in different industries. The Wintel model essentially commoditized the PC hardware component industry. There is no reason to believe that the reverse cannot be done.

With Nicira's offering, buyers who want to create new network infrastructure for their datacenters have higher power than before. They can buy network hardware from any vendor- Cisco or HP or Juniper or some manufacturer in Taiwan most people have never heard of. With Nicira's platform, the hardware merely moves network packets to and fro, and the software does the thinking.

PARTNERS

Google built its own network hardware and sought help from Nicira on building network controllers, but this does not constitute a business partnership. Rather, it looks more like a specially close customer-provider relation. As part of its new-age system for moving traffic between its massive datacenters, Google is using a network controller built in tandem with Nicira, according to a Google presentation. During a speech in Santa Clara, California, Google's Urs Hölzle, who oversees the company's worldwide network of datacenters, revealed that the company is now using OpenFlow to completely overhaul the links between the computing facilities that drive its sweeping collection of web services. It indicated that Google is driving its OpenFlow-based network gear using a controller called Onix. Onix serves as the basis for the software offered by Nicira. According to a 2010 research paper, Onix was designed by four Nicira engineers, three Googlers, an NEC employee, and an academic who was among Nicira's co-founders. The top four contributors to the paper are Nicira employees, indicating the high level of cooperation between Nicira and Google. 1)

CUSTOMERS

According to Business Insider - "Nicira Networks has brand new technology that every enterprise is going to want."1). Nicira has an ever-growing list of elite service providers and enterprise customers. Its website claims, "Our customers are leaders in their industry segments and are building the largest cloud datacenters in the world." 2) These include:

1. Cloud Computing: Calligo[3)]
2. Telecommunications: AT&T, NTT [4)], Deutsche Telekom
3. Online Marketplace: eBay

4. Web Hosting: Rackspace Hosting, DreamHost
5. Finance: Fidelity Investments [5)]
6. Nicira and Google

CLOUD COMPUTING

Calligo, the Channel Island's only dedicated cloud computing specialist, announced on May 16,2012 that it was adopting Nicira's NVP to support customers in the offshore industries in the region. With NVP, Calligo operates two datacenters in two separate locations – one in Jersey and one in Guernsey – as a single facility, allowing Calligo to pool together its computing resources and operate giving Calligo greater operational resilience, flexibility and speed, while not compromising performance, security and application support. In general, Nicira's network virtualization resolves challenges faced by large-scale cloud operators by offering multi-tenant network scalability and security, flexibility of workload placement and mobility, and elimination of error-prone manual reconfiguration.

TELECOMMUNICATIONS

AT&T is spending $1 billion a year on its cloud. AT&T wants its software engineers to be able to quickly build new personalized features for 100 million or more mobile phone customers. By interacting with several parts of the AT&T cloud, it might be possible for customers to send automatic texts to their friends, for instance when they are stuck in traffic.

Cellular network providers are especially interested in this technology. Cellular networks heavily rely on expensive proprietary hardware and providers want to switch to Internet-based solutions allowing them to use more commoditized and low cost equipment7). The major obstacle in this movement is that the Internet networks do not provide the mobility and flexibility required by cellular networks. NVP removes these obstacles by providing a flexible software layer around the physical network. This in turn reduces the equipment costs of cellular providers.

Since October 2010, NTT Information Sharing Platform Laboratories has been conducting collaborative work on virtual networks with Nicira Networks.

ONLINE MARKETPLACES

"Nicira allows us to repurpose network infrastructure on-demand and move applications dynamically. This eliminates the operational constraints associated with the existing network environment, and reduces the time it takes us to deliver a service from days to minutes." JC Martin, Cloud Architect, and eBay.

WEB HOSTING

"Extremely powerful computing is going to get cheaper and cheaper and cheaper," said Lew Moorman, the president of Rackspace, a company with 161,000 customers using its cloud 8). He has been working with Nicira since 2009. Following in the footsteps of Amazon, Rackspace operates an "infrastructure cloud," offering instant access to virtual servers and storage. This service is used by thousands of developers and businesses across the globe, and Nicira provides the means for restricting each customer to its own virtual network — or multiple virtual networks. With Nicira, Rackspace can readily create multiple virtual networks for each customer — without creating separate physical networks. "Facebook and Google run their applications at a massive scale; we'll let tens of thousands of companies do whatever they want too, on the fly."

"What Nicira has done is take the intelligence that sits inside switches and routers and moved that up into software so that the switches don't need to know much," says John Engates, the chief technology officer of Rackspace, which has been working with Nicira since 2009 and is now using the Nicira platform to help drive a new beta version of its cloud service. "They've put the power in the hands of the cloud architect rather than the network architect."

Hosting provider DreamHost has also decided to deploy Nicira's Network Virtualization Platform to accelerate service delivery in its OpenStack data center environments. According to Carl Perry, Cloud Architect at DreamHost, "NVP decouples network services from hardware, providing unique flexibility for both DreamHost and our customers." 9)

FINANCE

"Network virtualization and software-defined networking enable us to provide an even more robust, responsive IT infrastructure for our firm. Nicira's commitment to open networking standards allows us to scale our infrastructure, while continuing to provide the highly flexible, agile and innovative IT services that help us meet our customers' needs." James Davis, Senior Vice President, Global Network Services, Fidelity Investments

NICIRA AND GOOGLE

During a speech in Santa Clara, California, Google's Urs Hölzle — the man who oversees the company's worldwide network of data centers — revealed that the company is now using an open source protocol known as OpenFlow to completely overhaul the links between the computing facilities that drive its sweeping collection of web services. It indicated that Google is driving its OpenFlow-based network gear using a controller called Onix. Onix

serves as the basis for the software offered by Nicira, an outfit that recently emerged from stealth mode touting a new breed of network that exists only as software. According to a 2010 research paper, Onix was designed by four Nicira engineers, three Googlers, an NEC employee, and an academic who was among Nicira's co-founders. The top four contributors to the paper are Nicira employees. A Google spokeswoman said: "We're not a customer of Nicira, but we have worked together with them (and others in the OpenFlow community) on the design and requirements of OpenFlow controllers." (Exhibit 12)

The Market

MARKET SIZE

The cloud computing market will represent $240 billion worth of revenue by 2016, up from $77 billion in 2011, according to Visiongain. Gartner researchers also believe that at the end of year 2016, more than 50 percent of Global 1000 companies will have stored customer-sensitive data in the public cloud (Exhibit 9 and Exhibit 11).

In 2011, network management systems (NMS) generated $4.7 billion in revenue worldwide. This was a 6% increase from $4.4 billion in 2010 and a 9% increase from $4.3 billion in 2009.2) 3) Ericsson, with 21% share of worldwide revenue, maintains leadership in the NMS market. The top six network equipment manufacturers (NEMs), which also include Alcatel-Lucent, Huawei, Nokia Siemens Networks, Cisco Systems (current market shares in Exhibit 10) and ZTE, account for 81% of this highly consolidated market.4)

Worldwide Server Systems factory revenue was $52 billion in 2011 (Exhibit 8). If customers use Nicira's NVP, Nicira will take a share from this market as cheap servers can be used instead of expensive ones. In Nicira's world, a network's intelligence resides in its control software, and any network hardware will do, the cheaper the better. "A few years out, if I'm buying network infrastructure I just want the price to be right," says Casado.5)

BUSINESS MODEL

Nicira provides a usage-based licensing model that allows customers to pay for only what they use. The monthly subscription is size-based, depending on the number of dedicated customer instances and the aggregate requirements of the customer 1). For example, the NVP software currently has a usage-based, monthly-subscription pricing model that scales per virtual network port.2).

This model has a track record of success. It is similar to the way in which Salesforce undercut established giant Oracle, by offering enterprise software to smaller customers at costs that are proportionately lower for smaller companies with less extravagant needs. Such a usage-based model is flexible in serving a wide range of market segments, from small independent businesses that only require a small virtual network to software giants that require large and complicated networks.

MARKETING

Nicira's current market has a high account concentration since their current customers are mainly large companies with large cloud data centers in the world.3) Nicira sells products directly to customers rather than through distributors. Besides its Palo Alto headquarter, Nicira has two other offices to reach out to their customers: one in Tokyo and the other in Singapore.4)

At the beginning of October 2011, Nicira appointed a new marketing VP Alan Cohen who has played a crucial role in Nicira's partnership with Offshore Cloud Specialist Calligo:

> "Nicira completely changes the economics for cloud providers, making it possible for companies like Calligo to run fast and efficient OpenStack and VMware based infrastructure at unprecedented levels of utilization while compromising nothing in terms of performance, security and application support," 5)

EMERGING MARKET

The emerging market in developing countries should not be ignored as the increasing demand for cost-efficient and reprogrammable data centers which could be used by telecommunication operators and large social networks. Fully utilizing the great opportunities in emerging market should be a long-term goal in Nicira.

For example, China is in the midst of expanding the capacity of data centers to support its rapidly growing on-line population with an estimation os 500 million 6). And China is heavily reliant today on outside firms for design expertise. In response to this huge data center booming, large oversea companies (eg. Cisco, IBM, HP) have invested heavily and is expanding in China's market, but none of them have yet introduced a flexible software distribution network (S.D.N) for the emerging data centers even though there is some competition in the U.S.. Therefore, due to the high entry barrier, low level of competition, and the high market demand, Nicira should take actions to pursue the emerging market as soon as possible.

What is more, the restricted political and regulatory in China, as opposed to prevent the development of a foreign company as usual, such as for the cases of Google and Apple, will help Nicira's market penetration in China. The reason is that as Nicira's Distributed Virtual Network Infrastructure (DVNI) can provided far more reliable security functions even more than "Chinese Wall".7) Chinese government would more than glad to be a partner with Nicira.

CAPITAL FUNDING

Nicira is a private company backed by well-known investors including venture firms Andreessen Horowitz, Lightspeed Venture Partners and New Enterprise Associates as well as individual investors including Diane Greene and Andy Rachleff. 1)

Nicira currently has funding of $89.5 million. Milestones in the company funding history include 2):

- $575,002: Series A, Jun. 2009
- $3,890,446: Series A, Dec. 2009
- $9,000,000: Series B, Jan. 2010
- $25,900,014: Series C, Feb. 2011
- $50,000,000: Venture Round, Feb. 2012

More details can be found in Exhibit 6.

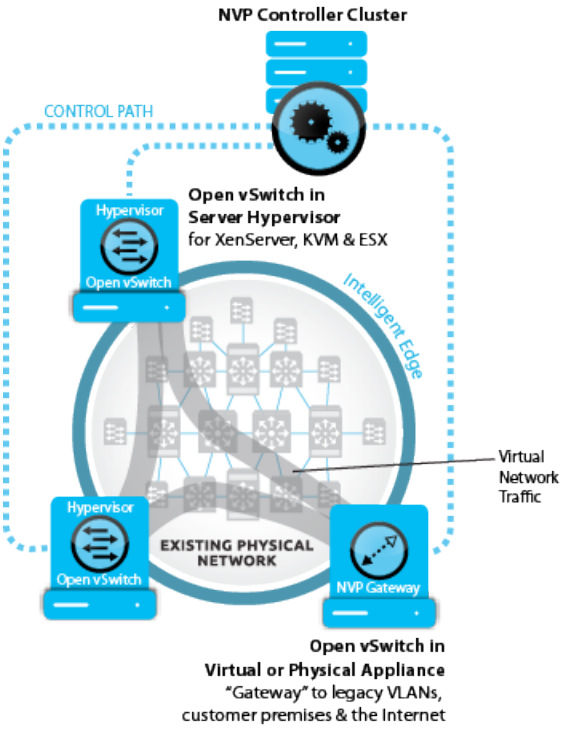
Discussion Questions

1. Respond, as Nicira, to the following questions:
   a. What business are you in?
   b. Do you provide attractive value to your customers?
   c. How big is the potential market?
   d. Can you expect to overcome Cisco's dominance in the computer networking industry and become a market leader?
2. Based on Marc Andreesen's product/market fit article, how good is the caliber of the startup team, how are the products' qualities compared to the competitors and how big is the size of the startup market?
3. As a venture capitalist, how do you assess the opportunity with Nicira? Consider timing, competition, opportunity, time to liquidity and magnitude of return.
4. What level of future investment will Nicira need to successfully introduce, deploy and integrate its product? Where will these funds come from?
5. Analyse the five competitive forces and ecosystem surrounding Nicira and the switch to virtualized networks. How can Nicira differentiate itself from its competitors? How compelling its its offering to alternative or existing products? Is Casado correct to not view the traditional vendors as serious competition because it would involve them cannibalizing their hardware-based sales?

EXHIBITS

Table of Exhibits

EXHIBIT 1: NICIRA NETWORK VIRTUALIZATION PLATFORM (NVP)



Source: http://nicira.com

EXHIBIT 2: OPENFLOW SWITCH SPECIFICATION

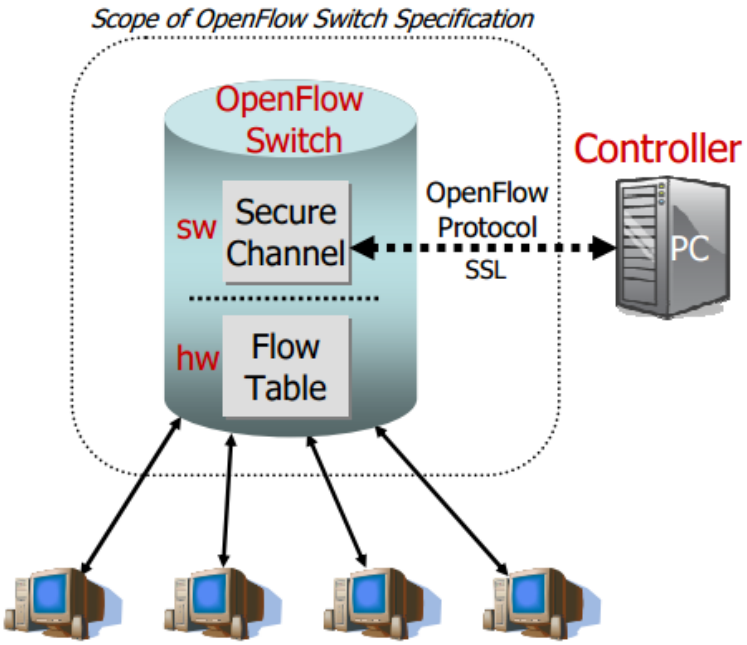


EXHIBIT 3: TUNEIN INTERFACE

The Seven Properties of Network Virtualization

1. Interdependence from network hardware
2. Faithful reproduction of the physical network service model
3. Follow operational model of compute virtualization
4. Compatible with any hypervisor platform
5. Secure isolation between virtual networks, the physical network and the control plane
6. Cloud performance and scale
7. Programmatic network provisioning and control

Source:
http://nicira.com/sites/default/files/docs/Nicira%20-%20The%20Seven%20Properties%20of%20Virtualization.pdf

EXHIBIT 4: NICIRA NETWORK VIRTUALIZATION PLATFORM (NVP) EXTENDED DETAIL

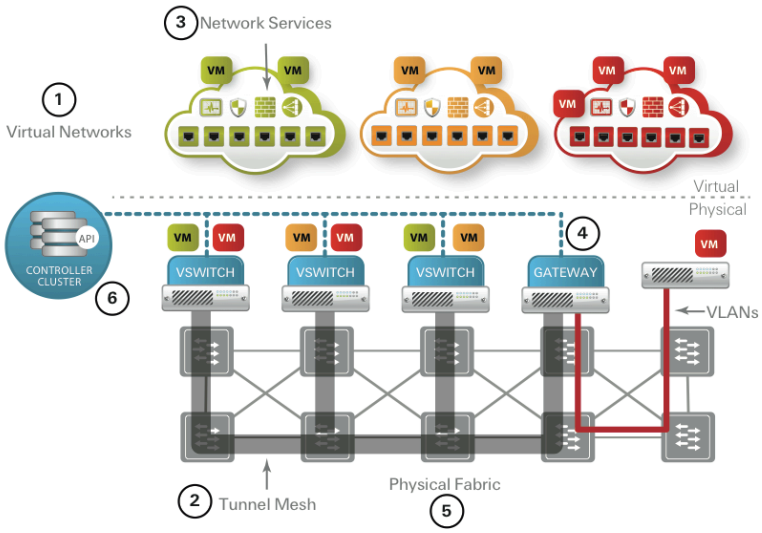


EXHIBIT 5:

Visualization of Network Virtualization

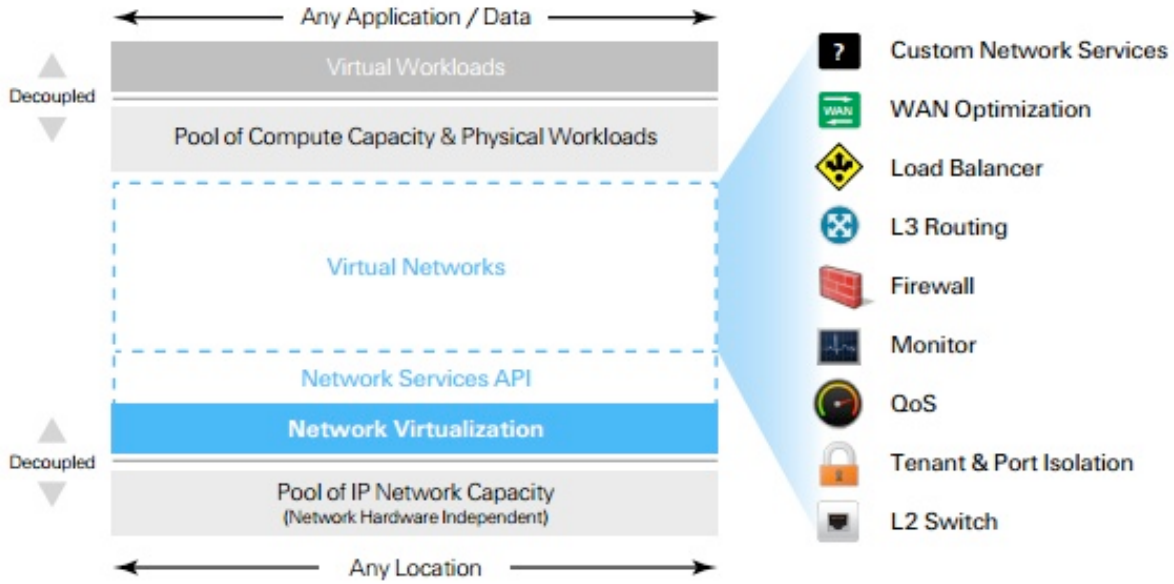


EXHIBIT 6:

History of Venture Capital Funding

Date	Series	Offering (USD)	Sold (USD)	To Be Sold (USD)	Investor	Type of Investor
2009-06-25	Series A Preferred Stock	2,213,878	575,002	1,638,876	Peter Thorpe	Person
2009-12-18	Series A Preferred Stock	4,023,321	3.89E+06	132,875	Undisclosed	N/A
2010-01-11	Series B Preferred Stock	10,999,999	9E+06	1,999,999	Ben Horowitz	Person
2011-02-03	Series C Preferred Stock	47,004,242	2.59E+07	21,104,228	Andreessen Horowitz Lightspeed Venture Partners New Enterprise Associates	Financial Organization
2012-02-05	Venture Round		5E+07		Andreessen Horowitz Lightspeed Venture Partners New Enterprise Associates	Financial Organization

EXHIBIT 7:

Nicira Management

Executive Team:

Steve Mullaney - CEO: Steve Mullaney has 25 years of marketing, product management, and engineering experience in network infrastructure and security. Prior to Nicira, Steve held executive positions at Palo Alto Networks, Blue Coat, Force10, Cisco, Growth Networks, ShoreTel, Bay Networks and SynOptics. Before SynOptics, he was a design engineer at GTE Government Systems. Steve holds a BSEE from University of Rhode Island.

Martin Casado - Co-Founder and CTO: Martin Casado received his PhD from Stanford University in 2007 where his dissertation work led to the technology on which Nicira is based. He received his Masters from Stanford University in 2005. While at Stanford, Martin co-founded Illuminics Systems, an IP analytics company, which was acquired by Quova Inc. in 2006. Prior to attending Stanford, Martin held a research position at Lawrence Livermore National Laboratory where he worked on network security in the information operations assurance center (IOAC).

Alan S. Cohen - Vice President, Marketing: Alan Cohen joins Nicira with over 20 years of marketing, product management, and business management experience in networking and software. Prior to Nicira, Alan held executive positions at Cisco, Airespace, Tahoe Networks, IBM, U S WEST, and Coopers & Lybrand. He served on the Board of Directors of GGP (NYSE: GGP). Alan holds graduate degrees from NYU and The American University School of International Service, and a BA from SUNY Buffalo.

Bruce Davie - Chief Service Provider Architect: Bruce Davie has over 20 years of networking industry experience, and was a Cisco Fellow prior to joining Nicira. At Cisco, he led the team that developed the MPLS architecture and worked closely with leading service providers to enhance the capabilities of their networks. In addition to his work on MPLS, Bruce contributed to the standards on IP quality of service and has written over a dozen Internet RFCs. He currently chairs the ACM's Special Interest Group on Data Communications (SIGCOMM) and is an ACM Fellow. He is also the author of several networking texts and a visiting lecturer at MIT. Bruce received his Ph. D. in computer science from the University of Edinburgh in 1988.

Rob Enns - Vice President, Engineering: Rob Enns joins Nicira after eleven years at Juniper Networks. At Juniper, Rob held several executive leadership roles, including Vice President Engineering of Junos Core, and Vice President Engineering of the Edge & Aggregation Business Unit. In these roles Rob built multiple international engineering teams responsible for delivering a diverse portfolio of networking software and systems. Prior to Juniper Rob spent ten years as principal engineer at Berkeley Networks, Fore Systems, IBM, and Bell-Northern Research. Rob holds a masters degree in computer science from the University of Waterloo in Ontario, Canada.

Paul Fazzone - Vice President, Product Management: Paul Fazzone has over 13 years of experience with data center and virtualization networking products. He currently drives Nicira's product management efforts. Prior to joining Nicira, Paul was the Director of Product Management at Cisco responsible for the Nexus data center access and virtualization switching products and strategy including the Nexus 1000V. Paul holds a BA in computer science from Saint Anselm College.

John Jendricks - Vice President, Business Development and Operations: John Jendricks is responsible for Nicira's business operations. He has held similar positions over several decades at Adobe, Wellfleet, StrataCom, Cisco, Juniper and Force10. He graduated from California Polytechnic University.

Nick McKeown - Co-Founder: Nick McKeown is a Professor in the Electrical Engineering and Computer Science Department at Stanford University, and Faculty Director of the Stanford Clean Slate Design Program. He received his bachelor's degree from Leeds University (1986), his MS (1992) and PhD (1995) from the University of California, Berkeley. From 1986-1989 he worked for Hewlett-Packard Labs in Bristol, England. In 1995, he helped architect Cisco's GSR 12000 router. In 1997 Nick co-founded Abrizio Inc. (acquired by PMC-Sierra), where he was CTO. He was co-founder and CEO of Nemo ("Network Memory") , which is now part of Cisco. Nick is a Fellow of the Royal Academy of Engineering (UK), the IEEE and the ACM. In 2005, he was awarded the British Computer Society Lovelace Medal, and in 2009 the IEEE Kobayashi Computer and Communications Award.

Denis Murphy - VP, Worldwide Sales: Denis Murphy has over 20 years of technology sales and sales management experience. Prior to Nicira, Denis held executive positions at Riverbed, BlueArc, EMC and Mercury Interactive. Denis holds an MBA from Thunderbird School of Global Management and a BSEE from the University of Massachusetts at Amherst.

Scott Shenker - Co-Founder and Chief Scientist: Scott Shenker is a Professor in the Electrical Engineering and Computer Science Department at the University of California at Berkeley. He received his bachelor's degree from Brown University (1978), his PhD (1983) in theoretical physics from the University of Chicago, and spent a postdoctoral year at Cornell University. He became a member of the research staff at Xerox PARC in 1984, left to found and direct the AT&T Center for Internet Research at ICSI in 1999, and then joined the U. C. Berkeley faculty in 2004. Scott was awarded the ACM SIGCOMM award in 2002, the IEEE Internet Award in 2006, and an honorary doctorate by the University of Chicago in 2007. In terms of business experience, Scott has worked closely with AT&T and has been a consultant with Cisco.

BOARD OF DIRECTORS

1. **Steve Mullaney**
Chief Executive Officer

See bio above.

2. **Martin Casado**
Co-Founder and Chief Technology Officer

See bio above.

3. **Nick McKeown**
Co-Founder

See bio above.

4. **Ben Horowitz**
General Partner, Andreessen Horowitz

Ben Horowitz is a co-founder and general partner of Andreessen Horowitz, a venture capital firm that helps entrepreneurs become successful CEOs and build important and enduring companies. Andreessen Horowitz provides seed, venture and growth-stage funding to the best new technology companies, and the firm currently has $1.2 billion under management across two funds. Among its 80 investments are Airbnb, Facebook, Foursquare, Groupon, Jawbone, Lytro, Pinterest, Twitter and Zynga. Horowitz has a BA in Computer Science from Columbia University and an MS in Computer Science from UCLA. He serves on the board of many companies including Foursquare, Jawbone, Lytro, Magnet, Nicira and Tidemark. Horowitz also pens his own blog, Ben's Blog (www.bhorowitz.com), where he covers everything from how CEOs should hire executives to how to minimize politics in your company. He lives in Silicon Valley with his wife and three daughters.

5. **Andy Rachleff**
Member of the Board

Former General Partner of venture capital firm Benchmark Capital, Andy is on the faculty of the Stanford Graduate School of Business, where he teaches a variety of courses on technology entrepreneurship. He also serves on the Board of Trustees of the University of Pennsylvania and is the Vice Chairman of their endowment investment committee. Andy earned his BS from the University of Pennsylvania and his M.B.A. from Stanford Graduate School of Business.

EXHIBIT 8:

Top 5 Corporate Family, Worldwide Server Systems Factory Revenue, Full Year 2011 (Revenues are in Millions)

Vendor	2011 Revenue	Market Share	2010 Revenue	Market Share	2011/2010 Revenue Growth
1. IBM	$16,456	31.5%	$15,342	31.1%	7.3%
2. HP	$15,301	29.3%	$15,388	31.2%	-0.6%
3. Dell	$7,814	15.0%	$7,106	14.4%	10.0%
4. Oracle	$3,215	6.2%	$3,204	6.5%	0.3%
5. Fujitsu	$2,516	4.8%	$2,197	4.4%	14.5%
Others	$6,964	13.3%	$6,159	12.5%	13.1%
All Vendors	$52,266	100%	$49,395	100%	5.8%

http://www.idc.com/getdoc.jsp?containerId=prUS23347812&pageType=PRINTFRIENDLY

EXHIBIT 9: CLOUD COMPUTING

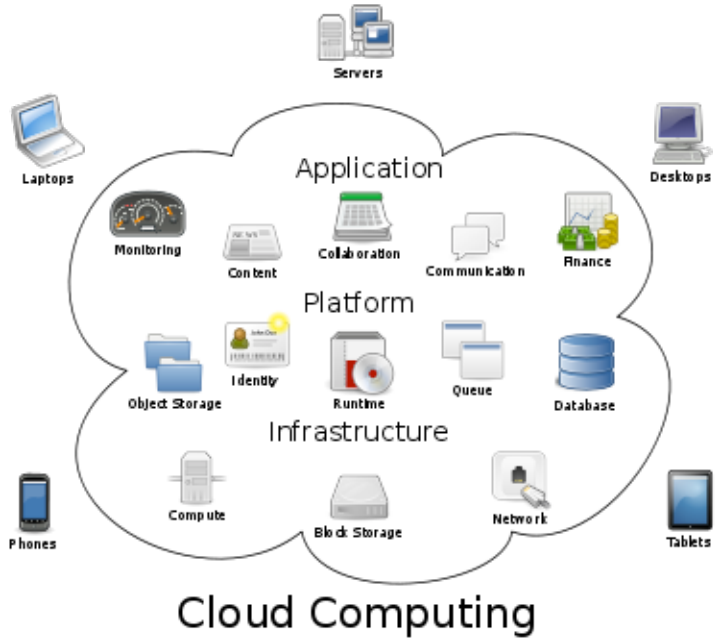


EXHIBIT 10:

Cisco Market Share by Segment, Q2 FY20121)

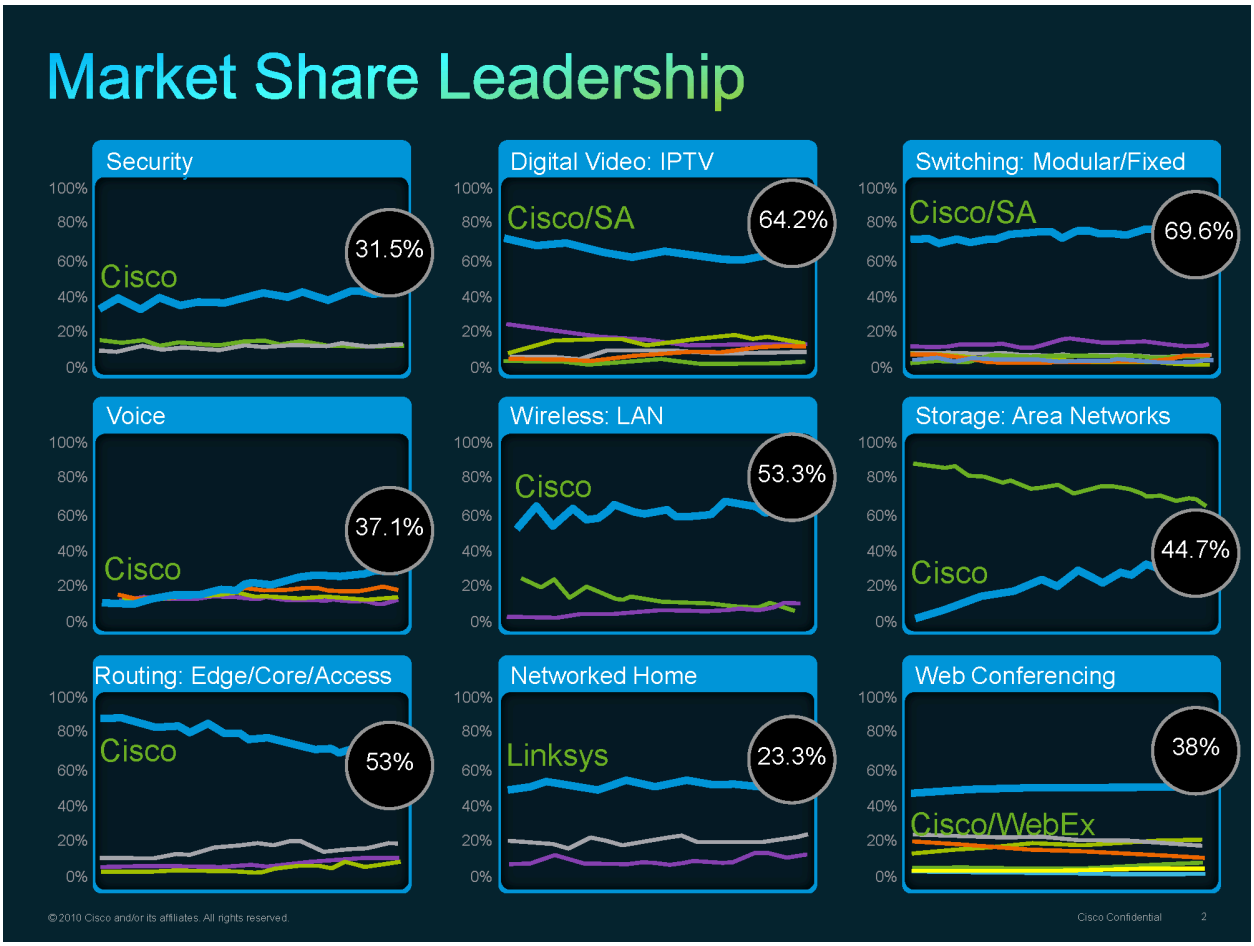


EXHIBIT 11:

Total Cloud Revenue Forecast

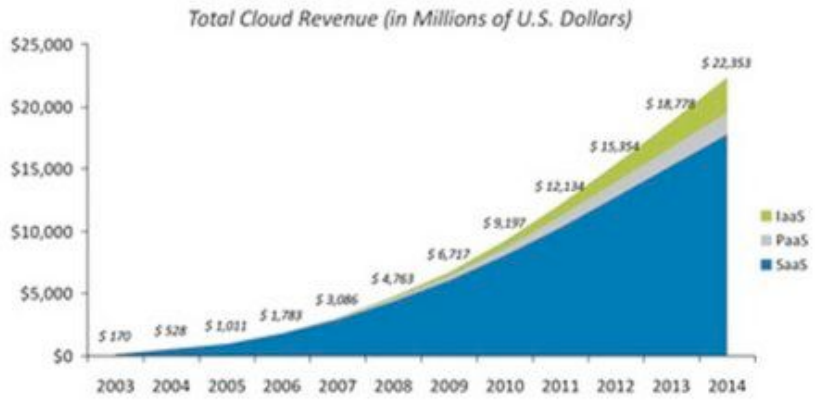


EXHIBIT 12:

Nicira and Google

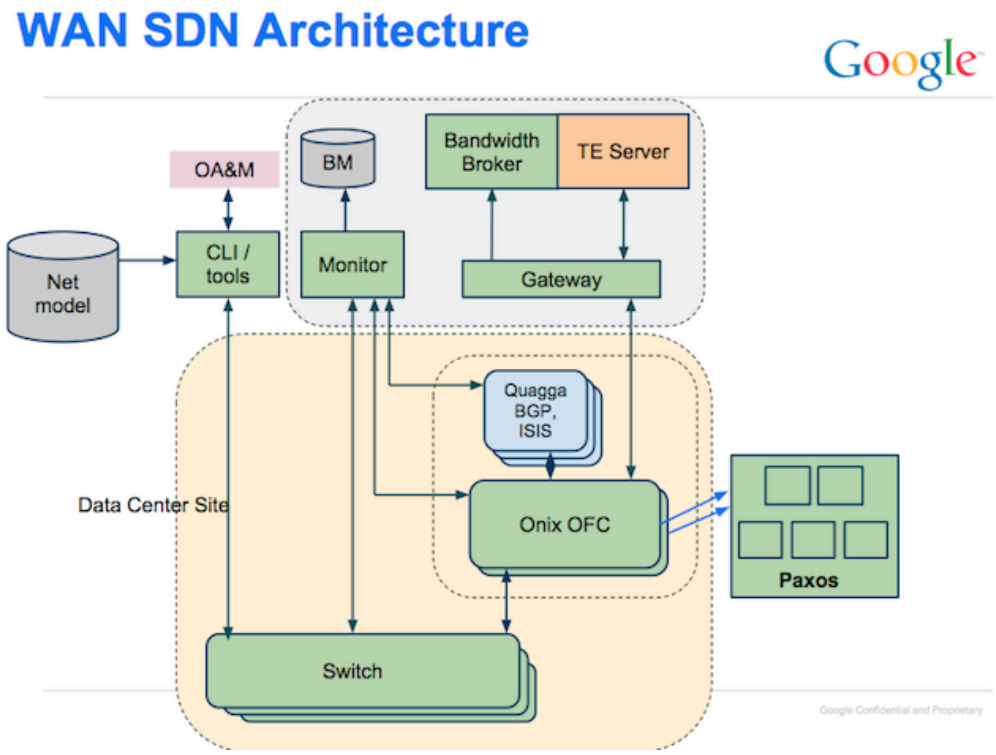


EXHIBIT 13:

The only proper way to decouple virtual and physical networks is to treat virtual networking like yet another application (like VoIP, iSCSI or any other "infrastructure" application). Virtual switches that can encapsulate L2 or L3 payloads in UDP (VXLAN) or GRE (NVGRE/Open vSwitch) envelopes appear as IP hosts to the network; you can use the time-tested large-scale network design techniques to build truly scalable data center networks.

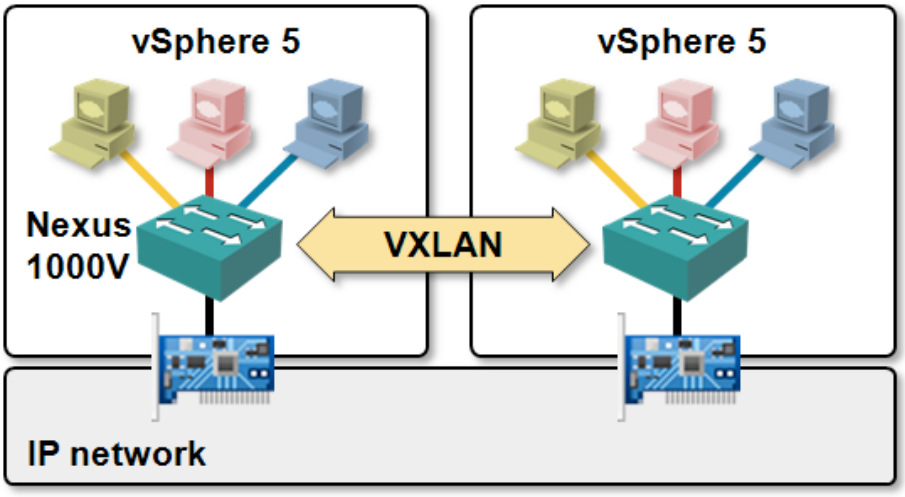
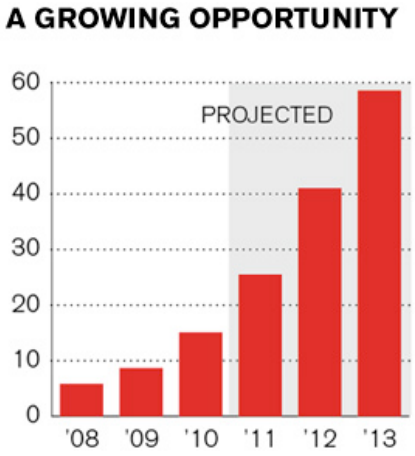


EXHIBIT 14:

Revenue from "public cloud" services, in billions of dollars. Source: Forrester Research



REFERENCES

INTRODUCTION

1. "Stack Overflow Careers." Stack Overflow Careers. Web. 17 May 2010. http://careers.stackoverflow.com/.
2. "About - Stack Overflow." Stack Overflow. Web. 17 May 2010. http://stackoverflow.com/about.

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Authors of 2012-204-1

Cite this paper:

xxx et al. “Nicira Networks - Disruptive Network Virtualization” Stanford CasePublisher 204-2012-1. 21 May 2012. **DRAFT**

SENIOR AUTHORS:
(CaseMaster)

AUTHORS (ALPHABETICAL):

Professors Micah Siegel (Stanford University) and Fred Gibbons (Stanford University) guided the development of this case using the CasePublisher service as the basis for class discussion rather than to illustrate either effective or ineffective handling of a business situation.