The New IP Economy: Software Innovation drives the Economy’s Evolution to Software-Defined Infrastructure

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Robert B. Cohen, Senior Fellow, Economic Strategy Institute, May 23, 2016

Summary

This review analyzes enterprises’ and service providers’ spending in the New IP economy. If focuses on the spending required to create cloud services for internal use in the enterprise and to offer cloud services, in the case cloud service providers and telcos. The review is based on our previous study of the demand for cloud services. Here, we examine the software, services, servers and other inputs needed to develop cloud services within the firm or to purchase them from external cloud service providers, both cloud service providers such as Amazon, Microsoft, IBM and Google, as well as telcos that will offer cloud services to their customers.

1. Introduction: Software is creating a New IP Economy based on the Transition to a Software Defined Communications and Compute Infrastructure. Software innovations are creating a new communications and computing infrastructure that is transforming the economy. They are changing the infrastructure enterprises use for computing and communications from traditional infrastructure to one that is software defined (see the comparison between the Old IP and the New IP in the table below). The latter infrastructure is more agile, scalable and capable of offering integrated services across many locations. This report analyzes how the new, software defined infrastructure is likely to evolve over the next ten years.

These software innovations mark a major shift away from traditional hardware infrastructure to more sophisticated software-defined infrastructure that can orchestrate or optimize, manage and deploy services.

Software Innovations Change Proprietary Hardware to Open, Software-based Ecosystems. Software innovations are changing computing and networking. Prof. Nick McKeown of Stanford has noted that infrastructure is shifting from a “vertically integrated closed proprietary system to a horizontal open interface based ecosystem that facilitates rapid innovation.” The move to horizontal open-interface based ecosystems means that:

1. “Networking applications will become modular and independent. These applications can be licensed and monetized individually or as a solution offering with a bundle of applications.

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2. Similar to server virtualization, with network virtualization multiple control planes (decision engines) for specific markets can be developed and monetized as virtual appliances independent of the physical network and hardware. [A mobile] operator ... would like to pool all the control software in mobile networks in one place (mobile computing) instead of distributing the intelligence in the different network elements. This will not only help reduce infrastructure cost and make management of network easy but bring together mobile analytics and big data mining technologies to enable new business models.

3. [It will be possible to] license and monetize different capacities in the physical network in an on-demand pay-as-you-grow electronic licensing model. This enables better service elasticity and better utilization of network resources.3 Viewed in the light of these changes, the New IP lets enterprises move beyond the initial benefits they achieve from Software Defined Networking. Gap and a few financial firms have used the new ecosystem to establish branch offices more rapidly. The next table summarizes what the New IP provides for enterprises.

<table>
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<th>Characterizing the Old IP and the New IP</th>
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<tr>
<td><strong>Old IP</strong></td>
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<td>Provisioning of Network Resources</td>
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<td>Who is at center of ecosystem</td>
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McKeown underscores the centrality of software in the transition to open network ecosystems. The figure below summarizes his vision of how proprietary systems will change from closed systems to horizontal, open-interface based systems.

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3 Ripin Checker, “Software Defined Networking ...”
Conclusion 1: Networks are becoming software-based, not hardware based. They are also becoming more interoperable, agile and scalable. Enterprises will need to develop new skills to manage these software based infrastructures and identify applications that they can run on them. The rapid shift to new infrastructure will set off a surge in spending on software defined infrastructure. Service providers will need to provide cloud services that permit enterprises to easily deploy crucial applications.

2. An analysis of Spending on the Inputs needed to create Cloud Services. For this analysis, we re-estimated the previous spending data by industries on cloud services, so that we could forecast the inputs needed to create cloud services. Once we have data formulated in this way, it should provide us with better insights into where spending is likely to be focused during the transition between traditional infrastructure and a more software defined New IP architecture.
We estimated that $819 billion would be spent over the 2015 to 2025 period to create cloud services. We forecast the largest spending will go for IT services and cloud service providers ($240 billion), labor ($214 billion) and software ($190 billion).

Our forecast identifies the sources of the spending to create cloud services according to the source creating the services. We have split the services in three ways, according to whether enterprises are supporting internal software development, or if cloud service providers or telcos are developing cloud services to offer to enterprises. Appendix 1 explains the connection between this analysis and the previous one that focused on industry spending on industry purchases of cloud services.

As can be seen from the table below, the largest spenders that create cloud services are cloud service providers, such as Amazon, Microsoft, Google, and IBM. They are followed by enterprises that spending funds on internal software development and by telcos acting as cloud service providers.

<table>
<thead>
<tr>
<th>SPENDING ON INPUTS TO CREATE CLOUD SERVICES IN BILLIONS OF DOLLARS</th>
<th>INTERNAL SOFTWARE DEVELOPMENT</th>
<th>CLOUD SERVICE PROVIDERS</th>
<th>TELCOS ACTING AS CLOUD SERVICE PROVIDERS</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>LABOR</td>
<td>28.48</td>
<td>54.04</td>
<td>40.58</td>
<td>59.97</td>
</tr>
<tr>
<td>SERVERS WITHOUT STORAGE</td>
<td>11.85</td>
<td>20.46</td>
<td>17.47</td>
<td>23.43</td>
</tr>
<tr>
<td>SOFTWARE</td>
<td>1.32</td>
<td>2.35</td>
<td>1.94</td>
<td>2.69</td>
</tr>
<tr>
<td>IT SERVICES AND CLOUD SERVICE PROVIDERS</td>
<td>16.24</td>
<td>55.83</td>
<td>23.95</td>
<td>63.96</td>
</tr>
<tr>
<td>NETWORKING EQUIP/COMMUNICATIONS</td>
<td>6.84</td>
<td>14.22</td>
<td>10.08</td>
<td>16.29</td>
</tr>
<tr>
<td>POWER DISTRIBUTION AND COOLING</td>
<td>1.66</td>
<td>2.96</td>
<td>2.45</td>
<td>3.39</td>
</tr>
<tr>
<td>POWER</td>
<td>1.66</td>
<td>2.96</td>
<td>2.45</td>
<td>3.39</td>
</tr>
<tr>
<td>TOTAL</td>
<td>97.06</td>
<td>214.87</td>
<td>141.69</td>
<td>244.20</td>
</tr>
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</table>

Although telcos lag behind cloud service providers, we forecast that they are more likely to experience a large uptick in spending on cloud services in the 2020 to 2025 time period. Of the three groups we analyzed, telcos have the biggest percentage change in spending of the three categories of spending we identified above. The biggest percentage changes in telco spending occur in software (699%), IT services and cloud service providers (397%) and networking equipment and communications (384%) (See below).
We created graphs to depict the spending in each of the categories identified above to provide a better picture of how spending on the inputs for cloud services changes over time for internal enterprise software development, cloud service providers and telcos acting as cloud service providers.

For enterprise spending on inputs to create cloud services, we see a large increase in spending on IT services and cloud service providers, software, and labor between the two periods of time we examined.

For cloud service providers, the pattern of spending changes is different. The largest areas for spending are networking equipment and communications, servers without including storage, and IT services and cloud service providers. The latter category suggests that cloud service providers, such as Amazon, Microsoft, Google and IBM, would rely upon each other to develop cloud services. It’s also notable that spending on servers accounts for a great deal of overall spending, but spending on software is not very substantial.
We found a similar pattern for spending among telcos that are creating cloud services. Here, the largest categories for spending are networking equipment and communications, services, and IT services and cloud service providers.

What do these figures suggest about the three groups we analyzed that are doing the spending on inputs to create cloud services? First, they indicate that telcos acting as cloud service providers are likely to see the largest growth in spending between 2015 to 2019 and 2020 and 2025. We expect that this spending represents an effort to implement the shift from traditional infrastructure to the New IP and its software-defined ecosystem. Second, the figures suggest that for the cloud service providers and telcos that provide outsourced cloud services to enterprises, there will be a great deal of spending on servers, networking equipment and communications, and IT services and cloud service providers. This focus for spending...
seems to conform to the points made by Prof. McKeown in pointing out the transition to a new, service defined infrastructure.

In addition, there will be important impacts from moving to a more highly integrated infrastructure where enterprises can monitor events in real time and more easily use resources that are now difficult to integrate. What might this mean? It could speed up big data analysis and open up business models where traditional products that used to be sold with maintenance contracts are offered as services. One example of this is GE’s Power by the Hour and Rolls Royce’s Total Care programs to sell aircraft engines as a service. By obtaining data on engine performance from around the world and being able to analyze performance very rapidly, these firms have extended the product life cycle and supported innovation in engine design. IDC emphasized the ability of integrated systems to deliver IT efficiency, but also to support innovation and improved network management and troubleshooting when it analyzed the benefits of converged and integrated systems.

![Integrated Systems Deliver IT Efficiency](image)


Conclusion 2. Telcos will be the main group that begins to spend much larger sums on inputs for cloud services between the 2015 to 2019 and 2020 to 2025 periods. Much of its spending will for networking equipment and communications services, servers and IT services and cloud services providers. We forecast that the spending for cloud services on the part of enterprises will be greatest for IT services and cloud services providers, software and labor, while for cloud services providers spending on inputs will be greatest for the same areas, while cloud service providers will

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spend the most on the same areas as telcos. The move to a more integrated infrastructure will not only enhance the ability to manage and monitor networks but also result in greater innovation.

3. New types of Jobs to work with the New Infrastructure. What do the figures we provided above suggest about the type of jobs that are likely to be spurred by the leap in spending that is occurring as enterprises move away from traditional infrastructure? They indicate that cloud service providers and telcos will be making a similar transition to a service-based infrastructure that will require greater expertise in managing the new servers and networking equipment that will be deployed.

In addition, it is likely that both of these service providers will require more professionals to manage the software-defined infrastructure that will be built and to optimize its behavior. In addition, since the new infrastructure will need to respond to market demands rapidly, it is likely that the labor hired to work on the new infrastructure will be focused on software development that is more dynamic and responsive than before. So many of these employees are likely to be experts in DevOps and tools to handle big data, which will be a foundation for the Internet of Things at large corporations.

4. Software Defined Networking and Network Function Virtualization Power the New IP Architecture. Software defined networking is a central player in the transition to the New IP. It is an “emerging architecture that... decouples the network control and forwarding functions enabling the network control to become directly programmable and the underlying infrastructure to be abstracted for applications and network services.

The OpenFlow® protocol is a foundational element for building SDN solutions. The SDN architecture is:

1) Directly programmable;

2) Agile [because] control is ... [abstracted] from forwarding [so] administrators dynamically adjust network-wide traffic flow to meet changing needs;

3) centrally managed [since] network intelligence is (logically) centralized in software-based SDN controllers that maintain a global view of the network, which appears to applications and policy engines as a single, logical switch;

4) programmatically configured [because] SDN lets network managers configure, manage, secure, and optimize network resources very quickly via dynamic, automated SDN programs, which they can write themselves because the programs do not depend on proprietary software; [and]

5) Open standards-based and vendor-neutral: When implemented through open standards, SDN simplifies network design and operation because instructions are provided by SDN controllers instead of multiple, vendor-specific devices and protocols.\(^5\)

Closely related to the new network architecture is another software innovation, network function virtualization (NFV). It is “a network architecture concept that uses the technologies of IT virtualization to virtualize entire classes of network node functions into building blocks that may connect, or chain together, to create communication services. ....A virtualized network function, or VNF, may consist of one or more virtual machines running different software and processes, on top of standard high-volume

\(^5\) Open Networking Foundation, “Software-Defined Networking (SDN) Definition,”
https://www.opennetworking.org/sdn-resources/sdn-definition
servers, switches and storage, or even cloud computing infrastructure, instead of having custom hardware appliances for each network function. For example, a virtual session border controller could be deployed to protect a network without the typical cost and complexity of obtaining and installing physical units. Other examples of NFV include virtualized load balancers, firewalls, intrusion detection devices and WAN accelerators.\footnote{ETSI, “Network Functions Virtualization (NFV) Use Cases,” as cited in Wikipedia, “Network Function Virtualization,” https://en.wikipedia.org/wiki/Network_function_virtualization}

We add overlay and underlay networks to consider some of the new architecture that underpins the New IP. An overlay “is a virtual network that is built on top of an underlying network infrastructure (the underlay). ...An overlay [must have characteristics that are very similar to those of a Virtual Private Network. It must:] guarantee traffic segregation among users (tenants); support address space independence among those users; allow for dynamic end-station (server or VM) placement or migration independent of the underlay network’s addressing scheme [;] and support all of the above at large scale (millions of end-stations).”\footnote{Samer Salam, “Overlays, Underlays and the New World Order,” Cisco Blogs, Architects & DE Discussions, September 20, 2012. http://blogs.cisco.com/getyourbuildon/overlays-underlays-and-the-new-world-order} Overlays provide “a way to enable new services with a high degree of transparency and decoupling from the underlay network,” making them attractive to enterprises as well as cloud service providers, be they telcos or Amazon, Google, etc.

5. The New IP Architecture and how it changes the Total Market Picture. To measure the impact of the New IP on the total market picture, we estimated industry spending on cloud services and used it to estimate spending on software, storage and IT services related to cloud services. As part of our estimation of spending on each area, we evaluated how much enterprises as well as cloud service providers would spend on data centers. This permitted us to categorize the different types of spending that occurs as traditional infrastructure shifts over to the New IP.

We utilized this separation of costs to examine the likely timing of the shift in spending from proprietary hardware systems to more open software-based ecosystems.

The table below summarizes the spending on inputs needed not only for enterprises to develop cloud services internally but also for cloud service providers and telcos to develop them.
One trend we noted earlier is the significant shift in spending on inputs needed to offer cloud services between the 2015 to 2019 period and the 2020 to 2025 period. To show that these trends are not driven by a single group that is included in our calculations related to the move to the New IP, we disaggregated software spending\(^8\) into three categories in the chart on the bottom of page 4: 1) enterprises’ spending on internal staff to create cloud services; 2) cloud service providers’ spending to offer cloud services to enterprises; and 3) telcos acting as cloud service providers and dedicating spending to provide cloud services for enterprises.

We also created an overview of the evolution of virtualized infrastructure to frame our analysis of the spending reviewed above. This framework assumes that enterprises are likely to deal with three stages in the evolution of software defined networking.

\(^8\) Note, the spending estimates here represent only enterprise spending for cloud services that are developed internally or purchased externally. Therefore, the data we analyzed do not cover consumer purchases from cloud service providers or telcos.
We expect that the pattern of SDN adoption described here will influence how service providers, both cloud service providers, such as Amazon, Microsoft, and Google, and telcos will tailor their investments to succeed in offering cloud services.

We describe SDN's three evolutionary stages in the table that follows. We emphasize the role of underlay networks in this evolution.⁹

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Conclusion 3: We expect enterprises as well as cloud service providers to adopt SDN in three evolutionary steps. As SDN matures, we expect key advantages it will offer include full network controls, better network abstraction that simplifies complexity, and real-time network visibility. These will broaden the functions that enterprises and telcos will deploy and manage in software-defined networks.

Conclusion 4: Because spending on inputs to create cloud services will increase dramatically between 2015 to 2019 and 2020 to 2025, we find that this indicates that vendors should prepare to respond to changes in the marketplace earlier than assumed. In part, this will be motivated by a need to respond to enterprises that will act as a key driver in the shift to software-defined New IP networks from traditional infrastructure.

6. How SDN facilitates the move to the New IP. Using the forecast for spending we developed, we expect early adopter industries will significantly increase their SDN spending after 2020. Based upon this data, SDN maturity complements the conclusion we reached above that greater SDN functionality would power the shift to the New IP.

In our data, we identified “spending thresholds” that indicate when SDN became a critical driver of moving to the New IP. The thresholds indicate shifts in spending not only for enterprises, but also for telcos and cloud service providers.

We identified studies by IDC and Analysys Mason that suggest a similar increase in spending after 2018 to 2021/2. IDC expects there to be a rapid increase in the SD-WAN market size, with sales growing from $600
million in 2016 to $1.4 billion in 2017, $2.6 billion by 2018 and $6 billion in 2020.\textsuperscript{10} The following chart provides these estimates in five-year periods.

\begin{center}
\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{estimated_market_size_sd.png}
\caption{Estimated Market Size for SDN by Spending}
\end{figure}
\end{center}

Based upon spending estimates for early enterprise adopters on servers. This does not include spending from consumers and may only include part of the spending by cloud service providers and telcos to serve the consumer market.

We compared our own estimates based on enterprise spending to Analysys Mason’s\textsuperscript{11} study of cloud service providers’ spending. Analysys Mason forecasts that it will take “more than 5 years for communications service providers (CSPs) to spend more on network function virtualization (NFV) and software-defined networking (SDN) than on cloud computing.”\textsuperscript{12}

We have graphed the Analysys Mason estimates below. They appear to show a similar upswing to the one found in our own data, namely that spending on SDN as well as NFV is likely to increase after 2018. As the figure shows, cloud computing will continue to grow at slower 12 percent compound annual rate of growth and will be surpassed by spending on SDN and NFV in about 2020.

The graph identifies a “spending threshold” for SDN around 2020 and for NFV that is around 2019. We would expect that after these thresholds, there would be a notable shift in investment to the New IP infrastructure that is very software defined.


Analysys Mason’s studies also provide us with detailed estimates for the timing of SDN deployments. These estimates corroborate the results we developed from the data we have analyzed concerning spending on inputs to cloud services. The upswing we expect at the end of the 2015 to 2019 period and very certainly at the beginning of the 2020 to 2025 period is reinforced by Analysys Mason’s review of Software Controlled Networking (SCN) deployments over the 2013 to 2020 period.

For Analysys Mason, if CSP SDN matures by 2019, significant spending on SDN deployment would need to begin several years before this happens. In reviewing our data, the patterns of spending we see suggest that enterprises will make important demands on service providers over the next few years. This should spur a shift in investment to software-defined ecosystems during the 2016 to 2019 period, with refined ecosystems being available over the next few years.
We discovered other studies that identify a similar increase in spending on Software Defined Networking technologies (SDN, NFV and other next generation networking initiatives). According to SDxCentral, “it’s expected these technologies will influence almost 80% of the purchasing decisions associated with all networking revenue by the end of 2020, affecting virtually every customer segment within the networking space.....Cloud providers have been leading the charge into the new network paradigm and are expected to remain the largest consumer of new network technologies through 2020.”

SDxCentral’s estimates of spending on Software Defined Networking technologies between 2015 and 2020 illustrate a rapid upswing by 2020. SDxCentral also identifies a shift from hardware to software, saying “Our model shows potential SDxN revenues growing from less than $15B in 2015 to nearly $105B by 2020. This growth is driven primarily by the network (L2/3) and network functions (L4/7) categories....... In addition, a major portion of L2/L3 spend will migrate from HW spend to a new suite of software-only networking applications. We estimate that by 2020, the market for just L2-3 networking SW apps will be $14B. These will appear as applications running on controllers or integrated into provisioning or orchestration systems, or in some situations run partially as VNFs on NFV infrastructure (e.g. virtual route reflectors).”

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14 SDxN revenues include spending on SDN, NFV and other next generation networking initiatives.

**SDxCentral** also estimates that the crossover from spending on traditional networks to SDx Networks is likely to be after 2017, as shown in the chart below. This would indicate that many purchasers would be shifting from traditional networks so that they would have “applications running on controllers or integrated into provisioning or orchestration systems, or in some situations run partially as VNFs on NFV infrastructure (e.g. virtual route reflectors),” as noted above.

To achieve these changes will require new skills within enterprises as well as in service providers. We believe that Amazon, Microsoft, Apple and Google have made some of these changes and that AT&T and Verizon will be adjusting the skills in their workforces over the next few years to address the changes.

An emerging pattern at enterprises has been to build capabilities to meet key requirements. Macy’s has worked with Apache Cassandra to build internal as well as mobile customer support for catalog sales, expecting data growth at a rate of 30 percent per year. Macy’s had to move from relational technologies to support heavy reads during the day and heavy writes at night. This contrasts with firms that have built a big data analysis capability, such as Ford. There, the need to handle large data lakes has fueled the transition from traditional infrastructure to software defined data centers.

*Conclusion 5:* The emergence of SDx Networks shifts funds away from traditional networking very rapidly. We identified “spending thresholds” that indicate how the pace of funds devoted to cloud service creation will shift to speed the deployment of technologies that accelerate the shift to New IP. The new SDx networks support the growth of applications running on controllers or integrated into provisioning or orchestration systems. The upswing in SDN and NFV spending appears likely to begin after 2018 according to our analysis, with cloud service providers and telcos pressed by enterprises to move to more software-based infrastructure. This forecast is more optimistic than those from SDxCentral and Analysys Mason. They expect the upswing to occur in 2020. The integration of applications expected with SDN’s maturity should offer more efficient ways to distribute applications. It may also provide a vehicle to increase the reach of other application “packages,” such as containers.

7. The importance of Underlay Networks for Enterprises and Service Providers.

Overlay and underlay networks support innovations in software defined networking. We describe the role of these networks in the maturation of software defined networking in the table on page 11. They provide the network abstraction and real-time network visibility needed to offer cloud services and greater functionality for enterprises’ use of more advanced infrastructure.

Engineers involved in creating the infrastructure for Fifth Generation (5G) networks have also pointed to the importance of underlay networks in expanding the diversity of connections to the communications infrastructure.

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16 A Macy’s Case Study was presented at Cassandra Summit 2015. Peter Connolly and Andrew Santoro, Macy’s, and Ivan Ukolov, Grid Dynamics, “Changing Engines in Mid Flight,”
https://player.vimeo.com/video/141956134?autoplay=1
Geng Wu of Intel has noted that in moving to 5G there will be a change in the way the cloud links to edge devices, such as those used for the Internet of Things, i.e., sensor networks, and smart devices such as Google glass.
Several firms, such as Gap\textsuperscript{17} have deployed SDN in networks to help bring up branch offices on a network more rapidly than was possible in traditional networks. This is also happening in financial firms that are connecting branches to their networks. We have created a simple picture for these SDN ecosystems.

We expect that the architecture of future ecosystems will include greater functionality in the underlay network. We believe that several enterprises that operate large internal and, often, international networks as part of their operations, such as FedEx, Bank of America, Fidelity and Visa, have deployed early stages of SDN technology to connect branch offices and experiment with resource sharing among corporate computing locations.

Once SDN matures further, we expect to see greater coordination of common tasks, such as risk analysis, taking place at banks. We expect that firms such as FedEx could use better real time management of networks to provide a service that links designs for 3-D printed parts to the final customers and reduces the amount of airline shipments needed to provide the service.

\textit{Conclusion 6: Underlay networks will provide an important way to support the continued expansion of sensor networks and the integration of networks with major resources in many locations. Highly distributed enterprise networks, part of the Internet of Things, will increase the need for connectivity at the edge of networks, but edges will need to be connected to each other. In addition, having visibility into the network in real time may help exchange resources within an ecosystem, so servers and storage facing high demand in one location may be able to shift traffic to locations with available resources. These requirements will act as an additional driver speeding the adoption of SDN ecosystems.}

\textsuperscript{17} See the discussion of SD-WAN by Conrad Menezes, Bank of America and Snehal Patel, Gap, at ONUG 2016. \url{http://opennetworkingusergroup.com/agenda/}
8. Conclusions

Conclusion 1: Networks are becoming software-based, not hardware-based. They are also becoming more interoperable, agile and scalable. Enterprises will need to develop new skills to manage these software-based infrastructures and identify applications that they can run on them. The rapid shift to new infrastructure will set off a surge in spending on software defined infrastructure. Service providers will need to provide cloud services that permit enterprises to easily deploy crucial applications.

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Conclusion 3: We expect enterprises as well as cloud service providers to adopt SDN in three evolutionary steps. As SDN matures, we expect key advantages it will offer include full network controls, better network abstraction that simplifies complexity, and real-time network visibility. These will broaden the functions that enterprises and telcos will deploy and manage in software-defined networks.

Conclusion 4: Because spending on inputs to create cloud services will increase dramatically between 2015 to 2019 and 2020 to 2025, we find that this indicates that vendors should prepare to respond to changes in the marketplace earlier than assumed. In part, this will be motivated by a need to respond to enterprises that will act as a key driver in the shift to software-defined New IP networks from traditional infrastructure.

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Appendix 1. Extending Earlier Estimates on Industry-Level Spending on Cloud Services to Estimates of the Inputs Required to Provide Cloud Services

We used previous estimates of enterprise spending for cloud services that we forecast for early adopter industries (see the previous report for these estimates) and divided them into spending on internal software development and outsourced cloud services from cloud services providers and telcos acting as cloud services providers (see the table below). This also provides a way to indicate significant milestones in the evolution of the New IP infrastructure.

With the inputs identified, we use industrial categories such as servers, storage and software, to estimate impacts on the US economy. The extended analysis begins with the profile of cloud services spending grouped around spending that we previously estimated for internal software development and outsourced software and services purchases. We divided the latter category into purchases from cloud service providers and from telcos acting as cloud service providers as noted in the table below.

Using estimates from these types of spending, we identified the cost of creating and deploying cloud services.

<table>
<thead>
<tr>
<th>DIMENSION 1: SPENDING ON INTERNAL AND OUTSOURCED CLOUD SERVICES</th>
</tr>
</thead>
<tbody>
<tr>
<td>INTERNAL SOFTWARE</td>
</tr>
<tr>
<td>$217 BILLION</td>
</tr>
<tr>
<td>↓</td>
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<tr>
<td>CLOUD SERVICE PROVIDERS</td>
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<tr>
<td>↓</td>
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<tr>
<td>$269 BILLION</td>
</tr>
</tbody>
</table>

INPUTS FOR DATA CENTERS

CLOUD SERVICES

IT SERVICES AND CLOUD SERVICE PROVIDERS

LABOR COSTS

COMMUNICATIONS COSTS

ESTIMATE DATA CENTER COSTS

USING SERVERS WITHOUT STORAGE

STORAGE

SOFTWARE

POWER DISTRIBUTION AND COOLING

POWER

NETWORKING EQUIPMENT AND COMMUNICATIONS EQUIPMENT
Appendix 2. Adjusting Actual Spending on Inputs for Cloud Services for Price Changes and Elasticity of Demand Effects

Several spending categories that we examined were characterized by large changes in prices. In some cases, these items also might be affected by the elasticity of demand. With elasticities of demand, if prices are elastic, there is an increase in demand with a change in prices.

IT Services and Cloud Service Providers — Adjustment for Cost declines and Demand Elasticity

Using published technology magazines that cite Google prices declining 62% from 2013 to 2015,
Computing the CAGR came to 27%
I used data from the AWS sales for Q2-2015 to Q2-2016 $1.864 bn to $2.57 bn to estimate a CAGR of 64%
This resulted in a PED of 2.37 or 64/27. I used 2.0 as the elasticity of demand although it could have been a big larger, perhaps up to 3.0.

I developed the correction to the figures for IT and Cloud Services spending by early adopter industries
The index assumed a price in 2015 that is the index price, I then applied a 30 price reduction to the index. I corrected this
by estimating that due to the Elasticity of Demand of 2.0 that there would be an increase of 60% in sales.
I repeated this estimate over a five year period to come up with an estimate of an index factor to apply to the
figures for IT and Cloud services spending to adjust them for price declines and offsetting demand elasticity impacts

<table>
<thead>
<tr>
<th>Index price adjustment</th>
<th>2015</th>
<th>2016</th>
<th>2017</th>
<th>2018</th>
<th>2019</th>
</tr>
</thead>
<tbody>
<tr>
<td>price</td>
<td>100</td>
<td>70</td>
<td>78.4</td>
<td>87.808</td>
<td>98.3446</td>
</tr>
<tr>
<td>elasticity of demand adjustment</td>
<td>42</td>
<td>47.04</td>
<td>52.6848</td>
<td>59.006976</td>
<td></td>
</tr>
<tr>
<td>adjusted price</td>
<td>112</td>
<td>125.44</td>
<td>140.4928</td>
<td>157.351936</td>
<td></td>
</tr>
</tbody>
</table>

To correct the original spending figures for IT and Cloud services, I used 157 as a correcting index factor.

Correction for Communications Services spending

I used Internet Bandwidth estimates from an Internet Society Study "Growing Pains: Bandwidth on the Internet." It had data on Bandwidth Traffic for Japan during a rapid period of growth
This showed
Bandwidth traffic 2008 | 230
Bandwidth traffic 2010 | 380
CAGR | 28.50%

I also used Telegeography data from "Wholesale Bandwidth Pricing Database Service" to check price changes on the circuit from Frankfurt to London. This circuit had a price drop that was similar to others in Europe and to the US.

| Jan-13 | 4000 |
| 15-Jan | 1941 |
| CAGR   | -43.55% |

Correction for Communications Spending

I developed the correction to the figures for Communications spending by early adopter industries
The index assumed a price in 2015 that is the index price, I then applied a 40% price reduction to the index. I corrected this
by estimating that due to the Elasticity of Demand of 0.6. This meant there would be an increase of 0.6 times the price that was reduced 40%.
I repeated this estimate over a five year period to come up with an estimate of an index factor to apply to the
figures for Communications spending to adjust them for price declines and offsetting demand elasticity impacts

<table>
<thead>
<tr>
<th>Index price adjustment</th>
<th>2015</th>
<th>2016</th>
<th>2017</th>
<th>2018</th>
<th>2019</th>
</tr>
</thead>
<tbody>
<tr>
<td>price</td>
<td>100</td>
<td>60</td>
<td>44.64</td>
<td>33.21216</td>
<td>24.70984704</td>
</tr>
<tr>
<td>elasticity of demand adjustment</td>
<td>14.4</td>
<td>10.7136</td>
<td>7.9709184</td>
<td>5.93036329</td>
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</tr>
<tr>
<td>adjusted price</td>
<td>74.4</td>
<td>55.3536</td>
<td>41.1830784</td>
<td>30.64021033</td>
<td></td>
</tr>
</tbody>
</table>

So the adjustment factor for communications prices is 0.31.
1. Storage pricing and demand adjustment
by 15% to 20% over the last few years.

Storage quantity is changing by around 23% a year, from 1986 to 2007
http://www.techweekeurope.co.uk/workspace/worlds-data-storage-capacity-reaches-295-exabytes-20816

The Elasticity of Demand is 23/15 or 1.53.

I developed the correction to the figures for Data Storage spending by early adopter industries
The index assumed a price in 2015 that is the index price, I then applied a 15% price reduction to the index. I corrected this by estimating that due to the Elasticity of Demand of 1.53.

I repeated this estimate over a five year period to come up with an estimate of an index factor to apply to the figures for Communications spending to adjust them for price declines and offsetting demand elasticity impacts

<table>
<thead>
<tr>
<th></th>
<th>2015</th>
<th>2016</th>
<th>2017</th>
<th>2018</th>
<th>2019</th>
</tr>
</thead>
<tbody>
<tr>
<td>index price adjustment</td>
<td>100</td>
<td>85</td>
<td>88.8675</td>
<td>92.91097125</td>
<td>97.13842044</td>
</tr>
<tr>
<td>elasticity of demand adjustment</td>
<td>19.55</td>
<td>20.439525</td>
<td>21.36952339</td>
<td>22.3418367</td>
<td></td>
</tr>
<tr>
<td>adjusted priced</td>
<td>104.55</td>
<td>109.307025</td>
<td>114.2804946</td>
<td>119.4802571</td>
<td></td>
</tr>
</tbody>
</table>

So the adjustment here is 1.19.