CHAPTER 1.2

The Internet of Everything: How the Network Unleashes the Benefits of Big Data

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Exabytes (10^{18}) of new data are created every single day. Much of this information is transported over Internet protocol (IP) networks. First described by Clive Humby as the "new oil,"[1] this data growth is fueling knowledge economies, sparking innovation, and unleashing waves of creative destruction. But most of these data are unstructured and underutilized, flowing at a volume and velocity that is often too large and too fast to analyze. If data do, in fact, comprise the new raw material of business, on par with economic inputs such as capital and labor,[2] then deriving insight and added value from this new input will require targeted transmission, processing, and analysis.

A rising share of this data growth is flowing over IP networks as more people, places, and things connect to this Internet of Everything (IoE). Proprietary networks, built on industry-siloed standards such as those in manufacturing or electric utilities, are increasingly migrating to IP networks, facilitating the growth of big data, and fast becoming the key link among data generation, processing, analysis, and utilization.

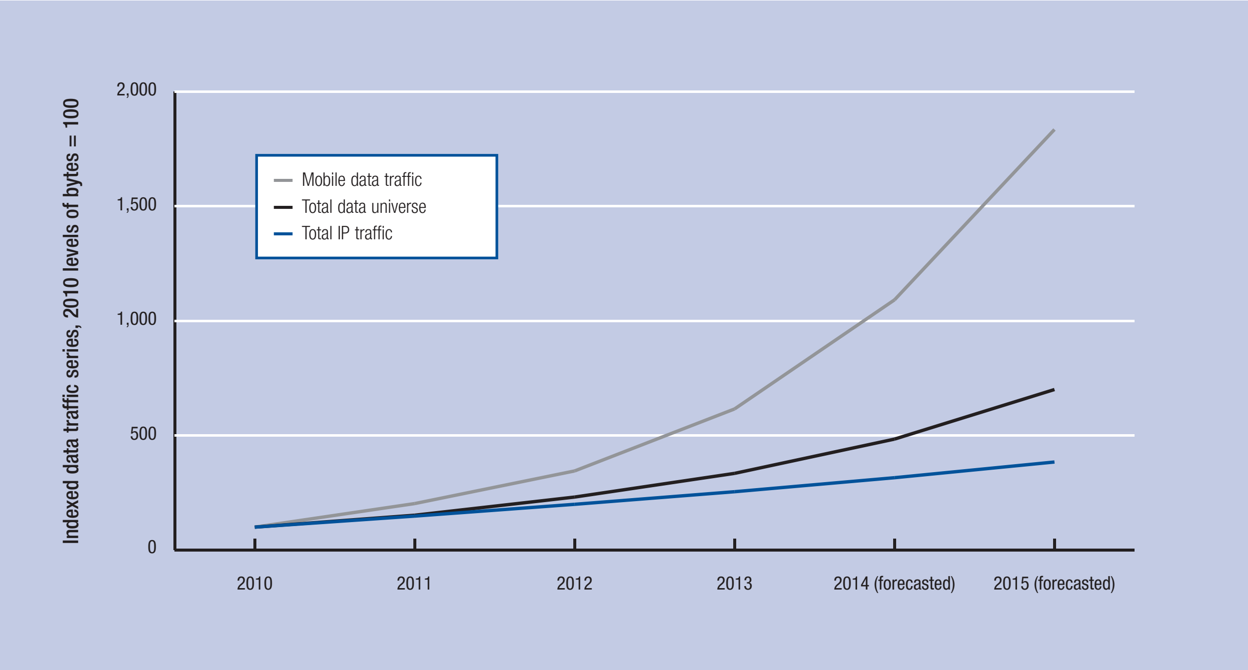
How can we effectively maximize value from this data explosion and avoid the pitfall of diminishing marginal data value? This chapter details how IP networks underpin the IoE and can accelerate big data's transformational impact on individuals, businesses, and governments around the world. After first highlighting four major trends driving data growth over IP networks and detailing how networks are central to maximizing analytical value from the data deluge, the chapter identifies critical technology and public policy challenges that could either accelerate or encumber the full impact of big data and the IoE.

ACCELERATING DATA PRODUCTION AND DATA TRAFFIC

Data growth is skyrocketing. Over 2.5 quintillion bytes of data are created each day; 90 percent of the world's stored data was created in the last two years alone.[3] To put this into context, one hour of customer transaction data at Wal-Mart (2.5 petabytes) provides 167 times the amount of data housed by the Library of Congress. The research consultancy IDC estimates that the digital universe—all digital data created, replicated, or consumed—is growing by a factor of 30 from 2005 to 2020, doubling every two years. By 2020, there will be over 40 trillion gigabytes (or 40 yottabytes) of digital data—or 5,200 gigabytes for every person on earth.[4]

Much of this data growth is traversing IP networks. Cisco's Visual Networking Index estimates that, from 2012 to 2017, total traffic over IP networks will grow threefold, rising at a compound annual growth rate (CAGR) of 23 percent. Mobile data traffic, however, is growing at an even faster pace: over the same period, mobile data will grow 13-fold, with a CAGR of 66 percent, capturing a greater share of all data created and transmitted (Figure 1).[5]

Figure 1: Growth rates and rising share of mobile data



Sources: Cisco 2013b; EMC² 2013; authors' calculations.

Despite the rapid growth in data production and transmission, however, only a small fraction of all physical objects in the world are currently connected to IP networks. Cisco estimates that less than 1 percent of physical objects are connected to IP networks.[6] But the IoE is expanding as more devices and users are connecting to IP networks every day, conducting more transactions and processes online.

For individuals, the impacts of the IoE are felt daily. Sensors embedded in shoes, for example, track the distances that fitness enthusiasts run and automatically upload information to social media profiles to immediately compare athletic achievements with those of friends. Internet-enabled alarm clocks gather data on weather and traffic, combining that information with a user's schedule, determining the optimal time to wake local residents. And applications on smart phones can control home electronic devices, adjusting heating and cooling levels as well as arming (or disarming) security settings remotely.

At an industrial level, applications using sensor technologies are capturing vast amounts of data to improve decision-making. Sensors embedded in agricultural fields monitor temperature and moisture levels, controlling irrigation systems. Devices in oil fields and deep well rigs track all aspects of drilling and fuel delivery, increasing production efficiency. And sensors in vehicles are able to monitor usage, informing decisions around refueling and repair as well as vehicle design.

For governments, IoE and big data applications are helping to monitor pandemics and environmental conditions, improve public safety and security, and increase efficiency in the delivery of public services such as municipal traffic systems that incorporate real-time remote monitoring to streamline traffic flows.

As more people, places, and things connect to the IoE, the data universe will continue to grow rapidly. The IoE will not only fuel the expansion of big data and data transmission, but can also provide targeted, automatic, data-driven analysis for our day-to-day lives.

CRITICAL DRIVERS OF DATA GROWTH

In 1944, the first digital computer, the Colossus, was deployed in the United Kingdom to decipher codes during World War II. The Colossus was able to process data at 5,000 characters per second (~25 Kb/s).[7] Currently the world's fastest supercomputer, the MilkyWay-2, can process 54,902 × 10^{12} operations per second (54,902 TFlop/s).[8] This intensive growth in data processing power continues today, coupled with extensive growth in data production. This data growth also supports four major trends that lead to a rising share of data transmission over IP networks in the world of the IoE, as described below.

- **Internet protocol (IP) is becoming the common language for most data communication.** Proprietary industrial networks are migrating to IP, bringing previously isolated data onto public and managed IP networks. The Internet's history is built on the migration of proprietary networks to IP. Proprietary data networks such as AppleTalk and IBM Systems Network Architecture (SNA) have migrated to IP over time, and traditional time-division multiplexing (TDM) voice networks are migrating to

Voice over Internet Protocol (VoIP). Today electricity grids, building systems, industrial manufacturing, oil systems, and a multitude of other sectors with networks that were previously built with proprietary protocols are increasingly migrating to IP as industries and enterprises recognize the value of interoperability and scale. Each migration shifts a large amount of data production and transmission onto IP networks (see Box 1).

- **Previously unconnected places, people, things, and processes are connecting to networks for the first time.** Billions of people and devices will come online in the next five years, adding heavily to the endpoints collecting data and to the devices consuming information. Cisco's Visual Networking Index estimates that, between 2012 and 2017, 7 billion more devices will connect to the Internet, reaching a total of 19 billion connected devices. These figures are conservative projections; other estimates of the total number of connected devices range from around 20 billion to 50 billion by 2020.[9] By 2017, nearly half of the world's population (3.6 billion out of 7.6 billion people) will be connected to the Internet. Of the world's total inhabited areas, mobile network coverage will increase to 85 percent in 2017, up from 79 percent in 2012.[10] In addition, a diversity of processes are migrating online. These include transactional activities (such as payments and requests), environmental monitoring (such as environmental sensors and remote monitoring), and government interactions (including census taking, tax collections, and benefit distributions).
- **Existing physically stored information is being digitized in order to record and share previously analogue material.** Over the last decade, the digital share of the world's stored information has increased from 25 percent to over 98 percent.[11] Information previously stored on other media—such as paper, film, and other analogue formats—is being digitized, along with meta-information about the data itself (e.g., descriptive statistics, frequency, distribution, dispersion, etc.). This digitization of information is leading to greater exchange of stored media and data over the Internet.
- **The introduction of Internet protocol version 6 (IPv6) allows for trillions of trillions (10^{38}) of devices to connect to the Internet.** IPv6 is the latest update to the protocol that underpins the Internet. It defines the system for routing traffic on the Internet by giving identification and location to all points connected to the global IP network. The previous version of the protocol, IPv4, enabled only approximately 4 billion IP addresses. But IPv6 provides more than 340 trillion, trillion, trillion, addresses,[12] ensuring no immediate exhaustion of IP

Box 1: Big data: Huge and growing data volume from industrial applications

Industrial applications of the Internet of Everything (IoE) generate immense data flows, which are increasingly shifting over to Internet protocol (IP) networks. One reason for the shift is that IP networks have increased reliability. Industrial networks have traditionally been concerned with uptime and latency, and IP networks have evolved to be able to handle industrial demands and the data flows that come with them.

In the oil and gas industry, for example, data are utilized across the entire value chain, from exploration, production, refining, and distribution to marketing and retail. Sensors and computing are used to capture and monitor seismic data, borehole activity, environmental readings, weather, production utilization, storage capacity, spot pricing (trading), transportation, inventory levels, demand and forecasts, and location data. In seismic exploration, the cost, size, and speed of data are all rising as exploration moves to 3D imaging. Data capture amounted to around 300 megabytes per square kilometer in the 1990s. By 2006, data per square kilometer amounted to 25 gigabytes, while today the amount per square kilometer is in the petabytes.[1] According to Chevron and industry-wide estimates, a "fully optimized" digital oil field based on data utilization results in 8 percent higher production rates and 6 percent higher overall recovery.[2]

In electric utility grids, data utilization also improves efficiency. Current grids monitor data to control electricity flows (both to and from the grid) based on real-time demand, thus improving generator efficiency and ensuring more-sustainable energy sources. Upgrading standard electric meters to "smart meters" allows information to be communicated over a network back to a control center and increases the amount of data captured. While traditional meters are read once a month, some smart meters can report usage rates in 15-minute intervals. For every million meters, this leads to 96 million measurements per day, an estimated 3,000-fold increase in data collection.[3] Conservative estimates of the total amount of data that will be generated by smart meters by 2019 in the United States alone (assuming only two readings per day, and below full deployment) yields measurements in the order of hundreds of petabytes per year.[4]

In an example from another industry, aircraft manufacture and operation, sensors on General Electric (GE)'s jet plane turbines illustrate the vast amount of data generated daily. GE estimates that each sensor on a GE turbine generates approximately 500 gigabytes of data every day. Each turbine has 20 sensors, and globally GE owns approximately 12,000 turbines. This aggregates to petabytes of data daily.[5]

Notes

1 Beals 2013; see also note 4 at the end of this chapter.

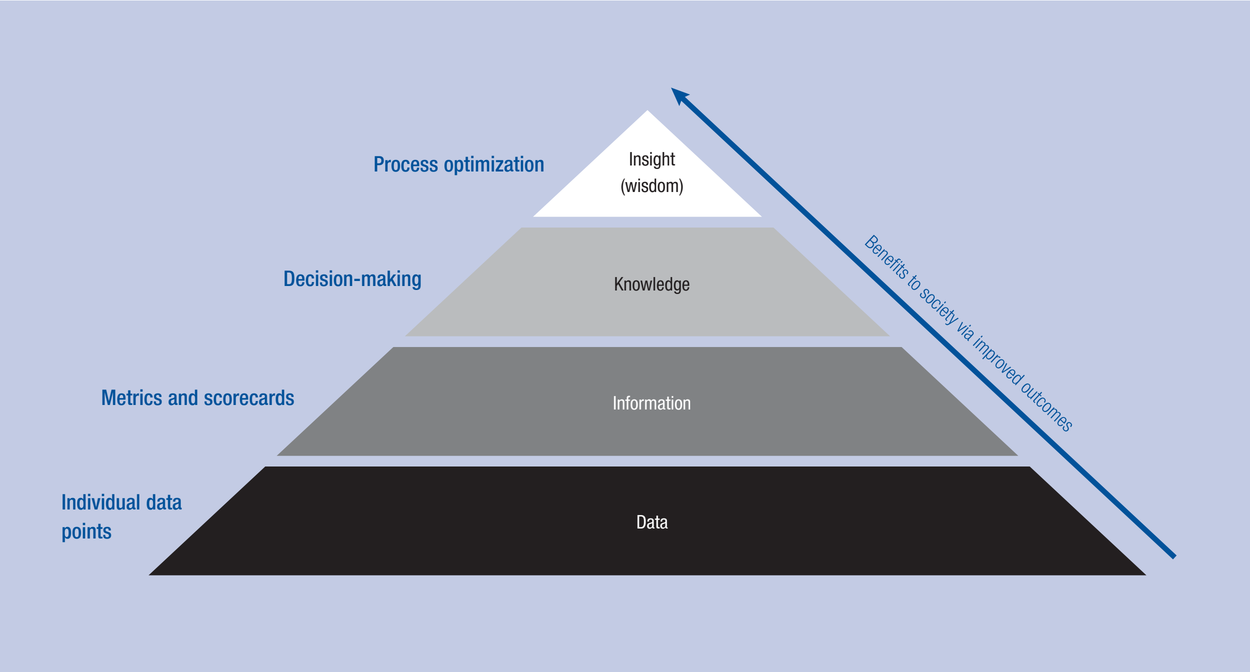
2 Leber 2012.

3 IBM Software 2012.

4 Danahy 2009; Fehrenbacher 2009.

5 Lopez 2013.

Figure 2: Turning data into insight



Sources: Ackoff 1989; authors' interpretation.

addresses or limits to the number of IP connections. The sheer number of available addresses allows for every single star in the known universe to have 4.8 trillion addresses.

THE GAP BETWEEN DATA GROWTH AND DATA VALUE

Current estimates suggest that only half a percent of all data is being analyzed for insights;[13] furthermore, the vast majority of existing data are unstructured and machine-generated.[14] Applying analytics to a greater share of all data can lead to productivity increases, economic growth, and societal development through the creation of actionable insights.

Data alone are not very interesting or useful. It is when data can be used and become actionable that they can change processes and have direct positive impact on people's lives. The IoE generates data, and adding analysis and analytics turns those data into actionable information. Building on the framework of the knowledge hierarchy,[15] aggregated data become information that, when analyzed, become knowledge. Knowledge can lead to insights and informed decision-making, which at the highest level is wisdom (Figure 2).

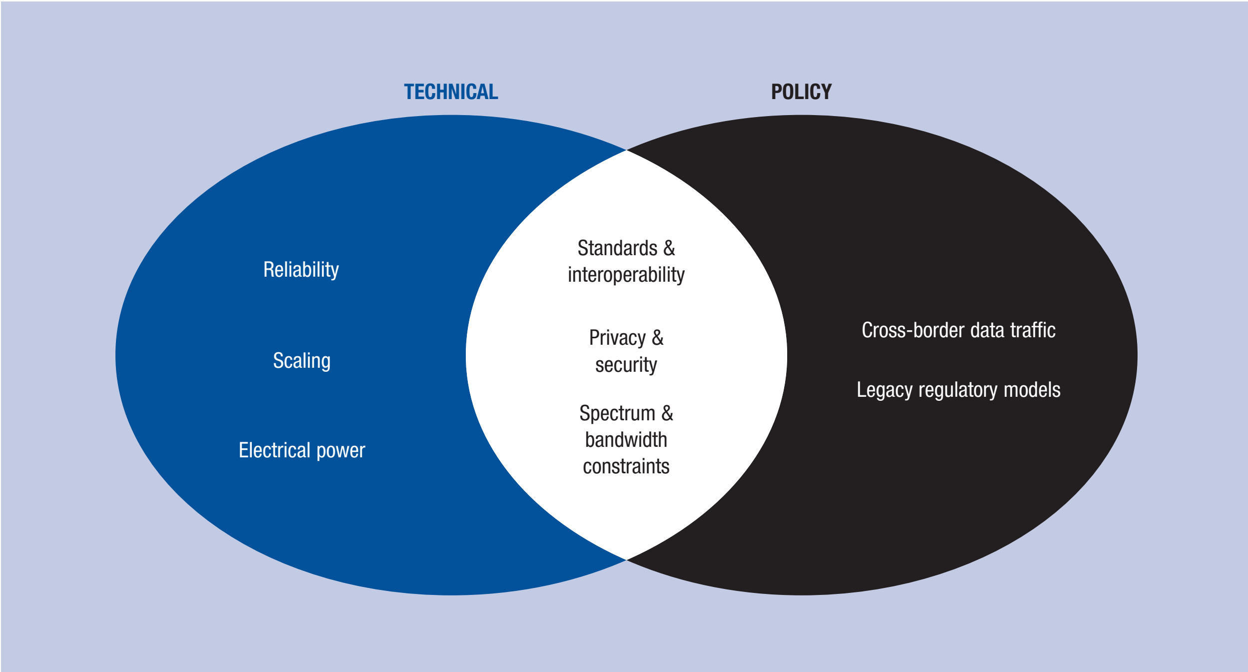
For example, society at large can benefit from tracking trends observed from metadata such as anonymized mobile phone data used to track population migration after the earthquake and cholera outbreaks in Port-au-Prince, Haiti.[16] Likewise, analyzing social media discussions can identify crises or flu outbreaks.

At an industrial level, big data analysis can yield very large benefits. For example, the value of modernizing the US electricity grid to be data-driven is estimated at US$210 billion. A reconstituted electricity grid would be based on an architecture driven by "technology selections to fully harness the convergence of data, controls and transactions."[17]

According to Bradley et al. in a recent Cisco White Paper, harvesting data for critical decision-making though the IoE can create approximately US$14.4 trillion dollars of added value in the commercial sector over the next 10 years across a wide range of industries.[18] This opportunity exists in the form of new value created by technology innovation, market share gains, and increasing competitive advantage. It translates into an opportunity to increase global corporate profits by approximately 21 percent, driven by improvements in asset utilization (reducing costs and improving capital efficiency), employee productivity (improved labor efficiency), supply chain logistics (eliminating waste and improving process efficiency), customer experience (adding more customers), and innovation (reducing time to market).

Similarly, research by the Economist Intelligence Unit and Capgemini indicates that big data analytics were responsible for a 26 percent improvement in business performance among a cohort of companies examined, and forecasts that the impact could increase to 41 percent in three years.[19] Capturing these gains, however, may require concurrent investment in resources to manage the rise in data. It is forecasted that by 2020, an average business will have to manage 50 times more information than it does today, while the average information technology (IT) staff is expected to rise only by 1.5 times.[20]

Figure 3: Policy and technical issues facing big data and the IoE



Source: Authors.

EQUIPPING IP NETWORKS TO DELIVER BIG DATA INSIGHTS

Moving up the knowledge pyramid from data to insights and informed decisions is a critical challenge facing businesses and governments. Equipping IP networks to better transmit data to processing centers as well as enabling the network to create, analyze, and act on data insights is one comprehensive approach. Building this capability will require improving network infrastructure, building analytical capabilities and "intelligence" into the network, and distributing computing and analytical capabilities throughout the network, particularly at the edge. Specifically, these are:

- *Network infrastructure improvements.* These improvements include connecting all things, including unintelligent ones (those that are capable only of transmitting data, not receiving them); securing infrastructure; improving inter and intra-data center traffic flows; and increasing the ability to manage private and public networks.
- *Building intelligence into the network.* This will require building in the ability to compute data in motion and host partner applications in an ecosystem where applications can be built to analyze data inflow, particularly enabling machine-to-machine (M2M) services.
- *Distributing computing and storage.* Efficient distribution will require moving the ability to analyze data only in the data center to add processing at the edge (or near the edge) of the network, to prevent delays in processing caused by latency as well as delays caused by network congestion.

TECHNICAL AND POLICY CHALLENGES

Building a network that will maximize the impact of big data requires powerful and seamless interactions among sensors, devices, computing, storage, analytics, and control systems.

But although IP networks are primed to support the expansion of big data and the IoE, technical and policy challenges exist in the ability of current IP networks to fully exploit big data expansion (Figure 3). An approach that tackles these issues concurrently will help to create the right ecosystem. The discussion below highlights specific issues that will need to be addressed thoughtfully.

Standards and *interoperability issues* span both the technical and policy domains. Agreement on standards is critical to develop economies of scale by encouraging product and service innovation around a common language, and generally accepted global standards allow for greater interoperability between devices. Requirements differ for closed critical networks (such as utilities) and open networks (for example, those that may monitor parking space availability), but common standards allow information to be exchanged within, and among, these networks when those needs arise.

Privacy issues arise with the growth of data, particularly with regard to data generated by or about individuals. Policymakers must identify the appropriate balance between protecting the privacy of individuals' data and allowing for innovation in service delivery and product development. New technologies and services, such as location-based services, are bringing these privacy issues to the forefront, offering users enhanced experiences while raising concerns of identity protection. Some policies—such as transparency in the use of data and effective mechanisms for consumer control of personal data—can help in this regard. The key *security issues* for big data include the reliable prevention of hacking and access by unauthorized and unwanted users to large databases and data flows. In order to ensure a healthy ecosystem where users, consumers, and businesses feel safe in engaging in big data activities, network security is essential.

Over the next five years, the growth of mobile data traffic will require greater radio spectrum to enable wireless M2M, as well as people-to-people (P2P) and people-to-machine (P2M), connectivity. Ensuring device connectivity and sufficient bandwidth for all of the uses of wireless sensors will require careful planning. The spectrum requirements are going to be heterogeneous and will include narrowband and broadband frequencies, short haul and long haul spectrum, continuous data transmission and short bursts of data transmission, and licensed spectrum in addition to license-exempt spectrum. *Bandwidth constraints* will also be an obstacle in transmitting data over existing networks. The examples cited in Box 1 reflect the volume of data being generated by proprietary networks, resulting in the need to move computing close to the network edge in a distributed intelligence architecture. Data loads will be lumpy across various applications of the IoE, and matching bandwidth needs to bandwidth availability will be a continuous challenge.

As more critical processes are conducted as part of the IoE, the need for *reliability* in IP networks increases. Healthcare applications that require instant communication between end users and medical professionals, safety and security applications, utility functions, and industrial uses are examples where continuous, uninterrupted, real-time communications require reliable and redundant connectivity. Low latency (the time required for round-trip data transmission) is already required for advanced cloud computing applications such as high-definition video conferencing and industrial collaboration. Any interruption to the transmission of data over networks negatively impacts these processes.

Constraints on the technological limits of electrical efficiency and on computer memory and processing already pose *limits to computing* and data analysis. Data centers, for example, exemplify the boundaries where electrical power, cooling resources, and space design are constantly redesigned and re-imagined to advance current capabilities. As the IoE expands into tens of billions of connected devices, the technological aspects of IP networks have to be able to manage the huge scale of device connectivity. One aspect of this expansion, Internet addressing, is being resolved with the migration from IPv4 to IPv6. Other challenges include determining how virtualized computing environments may support a reallocation of computing resources. And new sources of electrical power (advanced batteries, simple chemical reactions, etc.) will be needed to power the multitude of new devices that will emerge.

IoE applications that collect and handle data across sovereign jurisdictions could be negatively affected by policies restricting *cross-border data traffic and global trade* in IoE-related services. Emerging cross-border issues include national data protection rules and data transfers, data portability and interoperability standards, and liability costs for cloud service providers. Furthermore, trade in some IoE services may fall under existing international trade agreements, while others do not.

As the IoE permeates across business sectors, the application of IoE technology in traditional industries presents new challenges to *legacy regulatory models.* IoE technology is impacting business models, input/output markets, and end users in markets ranging from healthcare to utilities. The heavily regulated energy markets, in particular, face a range of issues from "connected energy" technologies. At the consumer level, smart meters may present privacy and security challenges. However, at the aggregation and distribution levels, utility companies face the new reality of a changing energy source mix and must adapt to transactional loads and markets along with existing grid control that needs to adapt to distributed intelligence as well as challenges to traditional regulated utility pricing.

THE CENTRALITY OF THE NETWORK

Since the beginning of our species, humans have been processing data. We have been our own primary data machines. But today, with the advent of vast arrays of computing power, we increasingly rely on data processed by others, and the IoE and the era of big data are transforming our lives.

Data flows and the ability to capture value from data are changing industries, creating new opportunities while impacting others. For example, the "app economy"—the business created by software applications running on smartphones—has created hundreds of thousands of jobs.[21] One recent study estimates that the marginal impact of data utilization in the IoE could raise US gross domestic product by 2 percent to 2.5 percent by 2025.[22]

The IoE—where more data are being captured by more devices, interacting with more people and changing the processes by which we live, learn, work, and play—is having a profound impact on the world. But the value derived from the IoE can be measurably increased if IP networks are able to facilitate the rise of big data and generate added positive impact for society.

NOTES

1 Palmer 2006.

2 The Economist 2010.

3 IBM 2013.

4 Gantz and Reinsel 2012. A useful reminder in the sequence of data storage and memory is that the measure increases by the thousands and the sequence is from byte, kilobyte, megabyte, gigabyte, terabyte, petabyte, exabyte, zettabyte and beyond.

5 Cisco 2013b

6 Cisco 2013a.

7 McLellan. 2013.

8 Top500.org 2013.

9 Biggs et al. 2012.

10 GSM Association 2012.

11 Cukier and Mayer-Schoenburger 2013.

12 More specifically, 340,282,366,920,938,463,463,374,607,431,768, 211,456 addresses, or roughly 3.4 times 1038.

13 Gantz and Reinsel 2012.

14 Canalys 2012.

15 Ackoff 1989.

16 Bengtsson et al. 2011.

17 De Martini and Von Prellwitz 2011; Taft et al. 2012, p. 2.

18 Bradley et al. 2013.

19 EIU 2012.

20 EMC^2 2013.

21 In the United States, according to Mandel and Scherer (2012), over 500,000 jobs have been created through application development since 2007; in the European Union, Vision Mobile and Plum (2013) found that nearly 800,000 jobs have been created this way.

22 Mandel 2013.

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