Over the past 30 years, the Internet has proven to be a revolutionary technology, so much so that it has run far beyond its original scope. The original Internet was designed as a network to connect academic researchers. From these humble beginnings, it grew into a global communications network as integral to our lives as roads, telephones, and public utilities. Increasingly, it’s taking on roles formerly performed by other infrastructures, such as mail (email), phones (voice over IP), television, and movies (streaming video). Simply put, it’s the global network of the 21st century.

Multiple rising demands are pushing the limits of Internet architecture and capacity—mobile devices are proliferating, applications are scaling at astronomical speeds, and computing has become ubiquitous. Simultaneously, we’re witnessing an explosion of data from Web 2.0, machine-to-machine and peer-to-peer communications, and devices diversifying into forms such as RFID, sensors, and more.

But with all of this progress come numerous hurdles to leap as well. An immediate challenge is IP and addressing. The current Internet largely rests on IPv4, which allows for 4.3 billion unique addresses. Once upon a time, this number seemed adequate, but with only 1 billion addresses left and more people and devices coming online every minute, it could represent a major crisis in a relatively short amount of time. Its successor, IPv6, has enough address space for every atom on Earth’s surface—plus 100 more Earths—but so far, there’s no consensus on a plan or timeline for migrating to this new protocol. Traffic continues to grow and place ever-greater demands on the network. According to estimates by Minnesota Internet Traffic Studies (MINTs), Internet traffic increases by roughly half each year, which amounts to a 100-fold increase every decade (www.dtc.umn.edu/mints/home.php). As one group of experts observed in the report Future Internet 2020, “The truth is, the Internet was never designed for how it is now being used and is creaking at the seams” (www.future-internet.eu/fileadmin/documents/reports/FI_Panel_Report_v3.1_Final.pdf).

For years, experts have argued that the current Internet would break at any moment, yet it has been much more robust than could be imagined (www.computer.org/portal/web/internet/extras/Bob-Metcalf). Will this still hold for the future Internet? In this article, we briefly review US and European approaches to addressing the future Internet’s core infrastructure problems. We believe these differences are worth exploring, both to determine their respective strengths and weaknesses and, perhaps most importantly, to spur discussion and increase public awareness of the future Internet.

Europe
The future Internet isn’t just a question of infrastructure—it will be the basis of a new service economy. Increasingly complex business processes will become commodities bought and sold via the Internet. Cloud computing is an early example of this trend.

In Europe, technology companies, government, and academics have allied together to build the infrastructure for a new service economy that ties all facets of our personal and professional lives into one end-to-end system. The general European consensus is that the future Internet must meet a wide array of challenges and opportunities. The 5th International Research Forum (www.sap.com/about/company/research/irf/2010/index.epx), a think tank of experts from academia, industry, and governments, addressed this idea at a conference sponsored by SAP Research in Westerburg, Germany.

“If we build it, we’re just going to unleash a new wave of innovation that’s probably unprecedented in the history of mankind,” Martin
Curley, director of Intel Labs Europe said at the conference (see www.international-research-forum.com/WIKI_2010/index.php/The_Future_Internet for some of the presentations). “We have the opportunity globally to create a new platform for knowledge-driven entrepreneurship, which will allow both business and mankind to progress at a rate faster than we’ve ever done before.”

One key theme that emerged from this discussion was the difference between the US and Europe when it comes to envisioning the future Internet. Europe regards the future Internet as a matter of public policy; consequently, government, academia, and businesses have banded together in a collaborative research agenda. In the US, prominent academic research programs are exploring architectural aspects for the Internet, but government has generally taken a laissez faire approach and left the private sector largely to its own devices.

Europeans speak in terms of a “digital agenda,” a vision of a single online marketplace that unites the whole continent. This agenda is one of the pillars of the EU 2020 vision of a new economy espoused by EU President Jose Manuel Barroso. At the IRF2010, the European vision was articulated by Mario Campolargo, director of the Emerging Technologies and Infrastructures Directorate of the European Union Directorate General for Information Society and Media. He described the future Internet as a key component of this digital agenda.

European technology leaders hope that Europe can take the lead in developing this Internet and have pooled resources and pursued initiatives and tools toward achieving that goal. Europe offers a wide array of funding schemes: long- and short-term, academic, industrial, exploratory, experimental, fundamental, applied, innovation-oriented, product-oriented and so on. Initiatives and policies connect to the future Internet on many levels: EU-wide, national, regional, state, and local. In fact, major initiatives are already under way in counties such as Germany, France, Spain, Finland, Sweden, Belgium, Luxembourg, the Netherlands, Ireland, and Italy. These efforts address the full spectrum of the future Internet, from basic infrastructure to applications to business platforms.

“In Europe, we have a plan to focus on our key industries where we are leading and really can compete,” said Wolfgang Wahlster, director of DFKI, the German Research Center for Artificial Intelligence and professor of computer science at Saarland University, during a telephone interview. “We don’t work so much on Internet for consumers, which is typically a US domain.” He cites the example of the European auto industry, in which Internet research has spawned innovations such as the “all IP factory” and the “all IP car.” Such technological advances have helped the European auto industry remain a leader in building premium cars while the US auto sector has fallen behind.

Europe has a long tradition of collaboration between academia, industry, and government. Consequently, European industries rely on professors to deliver mission-critical parts of products. Wahlster, a former professor at the University of California, Berkeley, notes that US companies rarely do this. “From a societal point of view, if we switch off Facebook today, it would not hurt the world as
much as if we switched off our cars or medical technologies,” he said.

The European Commission (EC) funds more than 100 projects spanning the full range of Internet architecture. These efforts focus not only on components and hardware but also on software platform and application service layers as well as social and economic aspects of the future Internet. One milestone investment is the recently announced Future Internet Public-Private Partnership (FI PPP; http://ec.europa.eu/information _society/activities/foi/lead/fipp/p/ index2_en.htm), an initiative between the public sector and major Internet, communications, and technology companies. The EC will fund this initiative with 300 million Euros for 2011–2013, supplemented by an R&D budget of 200 million Euros.

The FI PPP is part of a much larger community activity that also incorporates the newly established Knowledge and Innovation Community (KIC) ICT Labs (http:// eit.europa.eu/kicslt/kics-call.html) of the European Institute of Innovation and Technology (EIT), as well as the newly established Future Internet Research Alliance (FIRA; www.future-internet.eu/fileadmin/ documents/2nd_FI_usage_area _workshop/documents/S0-5-Bohner_ pdf), an open group of technical experts who came together to ensure that the future Internet is guided by a group of stakeholders from all relevant sectors.

This sense of openness is shared widely in Europe, with the EC signaling that it might seek legislation to ensure a free market. Recently, EC Vice President Neelie Kroes suggested a European interoperability law to protect openness and prevent big companies from restricting consumer choice. As part of the digital agenda for Europe, Kroes said the commission would explore measures that require big market players to ensure interoperability. “The main challenge is that consumers need choice when it comes to software or hardware products,” she said. “Any kind of IT product should be able to communicate with any type of service in the future” (www. euractiv.com/en/infosociety/kroes -beef-scrutiny-eu-digital-industry -news-495527).

The US
The other side of the Atlantic has a different sensibility and is approaching the future on its own terms. For one thing, the term “future Internet” isn’t used as widely in the US as it is in Europe. Instead, discussions about the future tend to focus on specific concepts such as IPv6, Domain Name System Security Extensions (DNSSEC), and an internationalized domain name (IDN). In the US private sector, primary drivers of the discussion are network and host security, mobile phones, clouds, net neutrality, and broadband. According to Vint Cerf, one of the Internet’s founding fathers, the “future Internet is not too much in debate other than in academic circles in the US.”

The most prominent publicly funded US research efforts tend to focus on networking infrastructure and architecture. The notion of a clean-slate approach (redesigning the Internet from scratch) animates much of the research in the US. FIND (Future Internet Design; www.nets -find.net/), a long-term initiative of the US National Science Foundation NeTS research program, examines the requirements for a global network 15 years in the future. Similarly, the Clean-Slate program (http:// cleanslate.stanford.edu) at Stanford University aims to reinvent the Internet by helping it overcome such challenges as scalability and mobility to integrate new technologies into applications and services. Another major US program is GENI, a virtual laboratory for exploring future Internets at scale.

GENI is similar to the European Future Internet Research & Experimentation (FIRE) program (http:// cordis.europa.eu/fp7/ict/fire/), one of the few areas where an apples-to-apples comparison between European and US-based future Internet programs is possible.

US research on the future Internet differs from European research in many ways. According to David Clark, a senior research scientist at the MIT Computer Science and Artificial Intelligence Laboratory, US government funding agencies tend to support research into long-term questions and put less emphasis on commercial applications. In contrast, European government agencies encourage more short-term, application-driven research.

“We should be out in front of industry, not doing the same thing they do,” Clark said of academic researchers, during a recent phone interview. “When the time comes for industry to make the big bets, they can find 10 times as much money as the US government can.”

Clark believes academics should look into the more distant future, hence the idea of the clean-slate approach. It frees them from being constrained by legacy systems or fear of migration. Consequently, researchers can focus on the most optimal solution, not the most feasible one. According to Clark, if the vision of the future is compelling enough, “smart people will figure out how to get there.” As an example, he points out that some features of IPv6, such as secure packet encryption, have actually been retrofitted into IPv4.

Some Europeans wonder why the US hasn’t addressed the future Internet in a broader way. Is it missing the boat? Or does it simply have confidence that the market will find the right solutions and government will be able to step in later to provide whatever regulation is necessary? Clark disputes any suggestion
that the US has been “asleep at the switch” with regard to the future Internet. He points to academic initiatives such as FIND as well as centers at universities like Harvard, Stanford, and Georgetown that are exploring social and economic questions around the future Internet.

In Europe, funding is often associated with ministries of trade or commerce and thus seeks commercial relevance. In the US, government-funded initiatives focus on architectural questions, and there’s less talk of a holistic model of the future Internet. Europeans tend to consider more regulatory questions up front. According to Clark, US researchers tend to leave short-term commercial applications to the private sector (indeed, some of the biggest US Internet successes such as Amazon, Facebook, and Google were the result of smart entrepreneurs) and let the government step in later to “clean up the mess.”

Fortunately, the Internet is a global phenomenon, so it’s not a matter of one approach versus the other. As Wolfgang Wahlster pointed out, “The world would be less interesting if we did not have both sides.”

Both Europe and the US want to build an Internet that protects freedom – but they define freedom in very different terms. Europeans talk about creating a free marketplace that prevents monopoly, lock-in, and discrimination and guarantees openness and fairness, which often means that government must set limits on company behavior. Americans often associate freedom with government getting out of the way and allowing businesses to operate with the least possible interference.

No doubt the future Internet will look very different in 10 or 15 years, but how much should it be guided, and how much should be left to the free market? What models should we follow? How can we create fair playing fields and prevent monopoly? Is a “Wild West” Internet the right environment for the evolving Web-based service industry?

We can’t answer all these questions, but we can conclude that failing to answer them risks disaster. We must take a holistic approach that embraces the full spectrum of the future Internet and addresses fundamental concerns like privacy, security, trust, and fair markets. Clean-slate approaches might inform the Internet’s development, but it will almost certainly continue to evolve incrementally due to incentives and pressures from both business and government. A more holistic approach can also bring people to the table from all over the globe. What is China’s role in the future Internet? How about other big emerging markets, such as Brazil and India? We must engage in constructive dialog together as soon as possible because the future Internet is right here, right now.

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