

Embargoed for release at 10 a.m. October 9, 2014

October 9, 2014

Digital Life in 2025

Killer Apps in the Gigabit Age

Experts foresee changes across all aspects of life as connectivity advances. They predict hyper-personalized interactions with information and our surroundings, 3D holograms and teleconferencing, and immersive virtual reality environments. They anticipate a deepening human dependency upon machines and the vast stores of information people tap into as they navigate their lives. They expect new applications may have a significant impact on healthcare and education.

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About This Report

This report is the latest in a sustained effort throughout 2014 by the Pew Research Center's Internet Project to mark the 25th anniversary of the creation of the World Wide Web by Sir Tim Berners-Lee ([The Web at 25](#)).

The report covers experts' views about what much faster bandwidth speeds might produce as new Internet activities. . Over the past few decades people have been sharing and accessing magnitudes more information online annually. Network speeds are dependent upon many factors, but local Internet architecture is a lynchpin for the kind of efficient service that can handle cutting edge activities that could involve high-definition video encounters or massive amounts of data flowing between devices tied to the Internet of Things. In fact, former Federal Communications Commission Chairman Julius Genachowski issued a "Gigabit City Challenge" in 2013, urging that all 50 US states have at least one community with gigabit Internet access by 2015 so "innovators can develop next-generation applications and services that will drive economic growth and competitiveness."¹

Gigabit connectivity (1,000 Mbps) is still quite limited in the United States; while average speeds vary greatly, gigabit connections are 50-100 times faster than the average fixed high-speed connection.² The expectation of most of the more than 1,400 people who participated in this canvassing of experts by the Pew Research Center and Elon University's Imagining the Internet Center is that as this connectivity becomes more common, online life will be significantly changed, though the precise contours of the change are not fully clear. Indeed, the *New York Times* recently reported that people in two US communities with gigabit systems are finding "[it's hard to know what to do with it.](#)"

William Schrader, the co-founder and CEO of PSINet Inc., the first commercial ISP, said, "As gigabit bandwidth becomes widespread later this decade, applications will emerge which exploit the combination of big data, GPS location, weather, personal-health monitoring devices, industrial production, and much more ... Gigabit bandwidth is one of the few real 'build it and they will come' moments for new killer apps. The fact that no one had imagined the other killer apps prior to seeing them grow rapidly implies that no one can imagine these new ones—including me. But I am confident they will come."

¹ See *FCC Chairman Julius Genachowski Issues Gigabit City Challenge to Providers, Local, and State Governments*. January 18, 2013. <http://www.fcc.gov/document/fcc-chairman-genachowski-issues-gigabit-city-challenge>

² See *Measuring Broadband America 2014: FCC Report on Consumer Wireline Broadband Performance in the US* <http://www.fcc.gov/reports/measuring-broadband-america-2014>

Most participants in this canvassing said people will always find a way to use more “bandwidth.” As **Bob Harootyan**, manager of research for a national nonprofit organization, said, “The technological imperative will continue wherever advances promise to do one or more of the following: provide more efficient or effective outcomes, increase demand for a product or service, create new applications or uses, solve previously unsolvable problems, improve everyday life at a reasonable cost, promote well-being, respond to consumer needs or desires, provide entertainment, make a person or enterprise more competitive, etc. For the private sector, profit will be a driving force. For the nonprofit and government sectors, improved service and general well-being is the driving force.”

The findings we describe in this report emerge in the context of other reports:

- A February 2014 report from the Pew Research Center’s Internet Project tied to the Web’s anniversary looking at the strikingly fast adoption of the Internet and the generally positive attitudes users have about its role in their social environment.
- A March 2014 *Digital Life in 2025* report issued by the Internet Project in association with Elon University’s Imagining the Internet Center focusing on the Internet’s future more broadly. Some 1,867 experts and stakeholders responded to an open-ended question about the future of the Internet by 2025.
- A May 2014 *Digital Life in 2025* report on the Internet of Things from Pew Research and Elon University examining the likely impacts of the Internet of Things and wearable and embedded networked devices. A majority of the more than 1,600 respondents said they expect significant expansion of the Internet of Things, including connected devices, appliances, vehicles, wearables, and sensor-laden aspects of the environment.
- A July 2014 *Digital Life in 2025* report on “Net Threats” (challenges to the open Internet) from Pew Research and Elon University canvassing a number of experts and other stakeholders on what they see as the major threats to the free flow of information online. A majority of these experts expect the Internet to remain quite open to sharing but they see many potential threats to this freedom.
- An August 2014 *Digital Life in 2025* report on “AI, Robotics, and the Future of Jobs” from Pew Research and Elon University about the degree to which technology advances might destroy more jobs than they created. The expert respondents were split on the verdict.

This report is a collaborative effort based on the input and analysis of the following individuals.

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About the Imagining the Internet Center at Elon University

The Imagining the Internet Center's mission is to explore and provide insights into emerging network innovations, global development, dynamics, diffusion and governance. Its research holds a mirror to humanity's use of communications technologies, informs policy development, exposes potential futures and provides a historic record. It works to illuminate issues in order to serve the greater good, making its work public, free and open. The center is a network of Elon University faculty, students, staff, alumni, advisers, and friends working to identify, explore and engage with the challenges and opportunities of evolving communications forms and issues. They investigate the tangible and potential pros and cons of new-media channels through active research. The Imagining the Internet Center sponsors work that brings people together to share their visions for the future of communications and the future of the world.

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Summary

The age of gigabit connectivity is dawning and will advance in coming years. The only question is how quickly it might become widespread. A gigabit connection can deliver 1,000 megabits of information per second (Mbps). Globally, cloud service provider Akamai reports that the average global connection speed in quarter one of 2014 was 3.9 Mbps, with South Korea reporting the highest average connection speed, 23.6 Mbps and the US at 10.5 Mbps.³

In some respects, gigabit connectivity is not a new development. The US scientific community has been using hyper-fast networks for several years, changing the pace of data sharing and enabling levels of collaboration in scientific disciplines that were unimaginable a generation ago.

Gigabit speeds for the “average Internet user” are just arriving in select areas of the world. In the US, Google ran a competition in 2010 for communities to pitch themselves for the construction of the first Google Fiber network running at 1 gigabit per second—Internet speeds 50-100 times faster than the majority of Americans now enjoy. Kansas City was chosen among 1,100 entrants and residents are now signing up for the service. The firm has announced plans to build a gigabit network in Austin, Texas, and perhaps 34 other communities. In response, AT&T has said it expects to begin building gigabit networks in up to 100 US cities.⁴ The cities of Chattanooga, Tennessee; Lafayette, Louisiana; and Bristol, Virginia, have super speedy networks, and pockets of gigabit connectivity are in use in parts of Las Vegas, Omaha, Santa Monica, and several Vermont communities.⁵ There are also other regional efforts: Falcon Broadband in Colorado Springs, Colorado; Brooklyn Fiber in New York; Monkey Brains in San Francisco; MINET Fiber in Oregon; Wicked Fiber in Lawrence, Kansas; and Sonic.net in California, among others.⁶ NewWave expects to launch gigabit connections in 2015 in Poplar Bluff, Missouri Monroe, Rayville, Delhi; and Tallulah, Louisiana, and Suddenlink Communications has launched Operation GigaSpeed.⁷

In 2014, Google and Verizon were among the innovators announcing that they are testing the capabilities for currently installed fiber networks to carry data even more efficiently—at 10 gigabits per second—to businesses that handle large amounts of Internet traffic.

To explore the possibilities of the next leap in connectivity we asked thousands of experts and Internet builders to share their thoughts about likely new Internet activities and applications that might emerge in the gigabit age. We call this a canvassing because it is not a representative, randomized survey. Its findings emerge from an “opt in” invitation to experts, many of whom play

³ See <http://www.akamai.com/dl/akamai/akamai-soti-q114-infographic.pdf>

⁴ See http://about.att.com/story/att_eyes_100_u_s_cities_and_municipalities_for_its_ultra_fast_fiber_network.html

⁵ See <http://www.pcmag.com/slideshow/story/310861/if-you-want-gigabit-internet-move-here>

⁶ See <http://motherboard.vice.com/read/why-its-so-hard-to-bring-gigabit-internet-to-the-us>

⁷ See <http://www.multichannel.com/news/technology/newwave-sets-stage-1-gig/383411>

active roles in Internet evolution as technology builders, researchers, managers, policymakers, marketers, and analysts. We also invited comments from those who have made insightful predictions to our previous queries about the future of the Internet. (For more details, please see the section “About this Canvassing of Experts.”)

How could people benefit from a gigabit network? One expert in this study, **David Weinberger**, a senior researcher at Harvard's Berkman Center for Internet & Society, predicted, “There will be full, always-on, 360-degree environmental awareness, a semantic overlay on the real world, and full-presence massive open online courses. Plus Skype won't break up nearly as much.”

There are experiments progressing in some developing countries to produce gigabit-or-better wireless networks that will surpass the reach and speed of wireless connectivity in the industrially developed world.⁸

There are disputes about just how quickly and how broadly the move toward gigabit networks will spread. In the US, some experts on telecommunications policy say a lack of competition is stopping firms from investing in the infrastructure improvements that would enable a more widespread rollout of higher speeds.⁹ Some telecommunications leaders say the current speeds are sufficient for what most Internet users expect to be able to do online.¹⁰

There is less contention over what expanded capabilities will mean when they evolve. Historically, every major advance in bandwidth has facilitated innovation that has brought new services and applications to digital life. In the Internet's early days, slow modems facilitated email; faster dial-up modems helped websites become useable; early broadband rollout allowed for quicker sharing of relatively big files such as the MP3 music files that were shared on the first peer-to-peer services like Napster; later broadband advances allowed for streaming activities that have given rise to services like YouTube, Amazon Prime, and Netflix; and advances in wireless speeds have enabled everything from massive adoption of social networking sites to location-based sharing services on smartphones. The respondents to this canvassing foresee similar changes as gigabit connectivity emerges.

⁸ See <http://netpolicynews.com/index.php/reporting/49-kenya-s-100-mhz-gigabit-lte-by-2015-potentially-the-most-advanced-network-in-the-world>

⁹ See Susan Crawford's book, *Captive Audience*

¹⁰ See the op-ed piece in the *Philadelphia Inquirer* by Comcast Corp. Executive Vice President David Cohen, “[US the leader on broadband](#)”

Overall, 1,464 expert respondents weighed in on the following question:

New killer apps in the gigabit age: Will there be new, distinctive, and uniquely compelling technology applications that capitalize upon significant increases in bandwidth in the US between now and 2025?

Please elaborate on your answer: If you answered “no,” explain why you think there will be incremental change, or hardly any change at all. If you answered “yes,” describe what the killer apps might be as gigabit connectivity becomes available. Explain what new tools and applications will excite people in the next decade and envision the kinds of personal connectivity and immersive media experiences that will seize the public imagination.

Some 86% of the respondents to this non-probability survey said “yes,” they believe major new applications will accompany a rise of bandwidth speeds in the US by 2025, and 14% of the respondents said “no.” There were a number of broad themes threaded through their answers.

Killer Apps in a Gigabit Age: Themes

1. People’s basic interactions and their ability to ‘be together’ and collaborate will change in the age of vivid telepresence—enabling people to instantly ‘meet face-to-face’ in cyberspace with no travel necessary.
 2. Augmented reality will extend people’s sense and understanding of their real-life surroundings and virtual reality will make some spaces, such as gaming worlds and other simulated environments, even more compelling places to hang out.
 3. The connection between humans and technology will tighten as machines gather, assess, and display real-time personalized information in an ‘always-on’ environment. This integration will affect many activities—including thinking, the documentation of life events (‘life-logging’), and coordination of daily schedules.
 4. Specific economic and social sectors will be especially impacted; health/medicine and education were mentioned often.
 5. New digital divides may open as people gain opportunities on different timelines and with different tools.
 6. Who knows? ‘I have no idea due to rapid change.’ ‘The best Internet apps are yet to emerge.’ ‘If I knew, I wouldn’t tell you, I would invest in it!’
 7. Advances will be gradual for various reasons: Bandwidth is not the issue. The US will lag because a widespread gigabit network is not easily achieved.
-

Many of the respondents expanded the frame of the question and discussed advances that are generally tied to the Internet of Things—the spread of connected devices, artifacts, sensors, and wearables—and other technology trends.

Marti Hearst, a professor at the University of California-Berkeley, wrote, “These ideas aren't new, but they will finally work well enough if given high enough bandwidth. Entertainment: you play sports and music virtually, distributed, across the globe. Co-living: You have virtual Thanksgiving dinner with the other side of the family. Work: finally, we greatly reduce flying around for meetings because virtual conferencing feels real. Healthcare: remote assessment, treatment, and surgery. More generally, more interaction will be done with others remotely. For example, your golf lesson could be done with a coach remotely, in real time, while he or she watches your swing at the tee and has you make corrections and adjust your grip.”

A similarly expansive summary of possible effects came from **Jason Hong**, an associate professor in the School of Computer Science at Carnegie Mellon University. “Odds are high that there will be breakthroughs,” he replied. “My best guesses would be: a) far better telepresence, in terms of video quality, audio quality, robotic control, and time (for example: open all the time rather than just a short time for video conferencing); b) a few people starting to use life-logging technologies to capture everything in their lives (with some people choosing to share those); c) higher adoption of telesurgery and remote medical support; d) some new kind of entertainment, possibly including new kinds of social media; e) more sensor data being continuously captured and stored, including those embedded in the city (for bridges and buildings), cars, smart phones, portable home medical devices, and toys; f) better search for multimedia, especially videos; g) more cloud-based apps, offering far richer software-as-a-service than we can do today. Examples might include more thin-client netbooks with all of the backend stored in the cloud, or full apps that are currently desktop apps offered as a cloud service (think Adobe Creative Suite, games, or Microsoft Office fully in the cloud).”

Following is a selection of respondent answers that speak to each of the themes.

Theme 1) People’s basic interactions and their ability to ‘be together’ and collaborate will change in the age of vivid telepresence—enabling people to instantly ‘meet face-to-face’ in cyberspace with no travel necessary.

As the boundary between being “here” and being “there” shrinks, respondents predict that people will be able to experience faraway places, sounds, and smells without actually being there.

Joe Kochan, the chief operating officer for US Ignite, a company developing gigabit-ready digital experiences and applications responded, “Widely-available gigabit broadband connections will usher in the Internet of two-way, persistent, high-quality video to replace today's Internet of

images, text, and recorded video. Your interactions with doctors, educators, merchants, and others will consist not of emailed forms or pre-recorded messages, but instead of instantaneous, life-like video interaction that requires no setup or configuration.”

Bob Briscoe, chief researcher in networking and infrastructure for British Telecom, wrote, “Telepresence will be available in business environments. By 2025 it is unlikely to be realistic and natural, although sufficiently realistic to be usable. It will also be becoming available in personal and residential settings. It may become possible for an individual to project into more than one presence at once, given that young people have learned to cope with partial attention on multiple threads of interaction.”

Jim Hendler, a professor of Computer Science at Rensselaer Polytechnic Institute and Semantic Web engineer, wrote, “I believe ‘telepresence’ will be a driving application in the workforce, and thus the ability to have multi-person meetings without travel will be enhanced significantly.”

Peter Janca, the managed services development lead at MCNC, the nonprofit regional network operator serving North Carolina, wrote, “Increased bandwidth will enable true ‘you-are-there’ feelings in human-to-human interactions—maybe a holographic representation of the other parties sitting in the room with me. This becomes a ‘killer app’ for human interaction, but bad news for the travel and transportation industry. One application of the above will be in education: We use video conferencing today, but there are still impediments to it being an equivalent to the physical in-class experience. Higher bandwidth, coupled with higher-horsepower computing, will make today's virtual classroom work as if it were a real classroom.”

Alex Halavais, an associate professor of social and behavioral sciences at Arizona State University, predicted, “Yahoo aside, we'll see increased use of telepresence in workspaces and in family life. I suspect this will include a lot of ‘always-on,’ very-high-resolution video. I imagine a lot of offices doing something akin to what Thomas Keller does for his restaurants in New York and Napa, and installing video walls in the hall. Much of this may be in game space.”

Kathryn Campbell, a partner with Primitive Spark, Inc., an interactive marketing firm based in Los Angeles, responded, “No question, bandwidth will play the same kind of transformational role in reshaping society that railroads and freeways played in our past. I am most excited about the potential for truly immersive entertainment and communications as bandwidth continues to explode. On the entertainment front, something like the Holodeck concept first shown in the old *Star Trek* series is actually within our grasp by 2025. Games, films, shopping for cars and vacations, and (of course) porn will all become immersive 3D experiences. So will the 2025 version of that primitive tool that we call Skype today. Catching up with my sister in Papua, New Guinea, will be almost like being there in a decade (or at least I earnestly hope so!).”

Theme 2) Augmented reality will extend people’s sense and understanding of their real-life surroundings and virtual reality will make some spaces, such as gaming worlds and other simulated environments, even more compelling places to hang out.

David P. Collier-Brown, a system programmer and author, predicted, “Avatars to go to meetings for me in Texas, rather than me flying down. Bus tours of Istanbul on Saturday afternoon from the comfort of my living room. Playing a game of football with my cousin in Ulan Bator from the gym downtown.”

David J. Wierz, a strategic analytics professional for OCI, commented, “Virtual reality becomes the reality. The current 'fad' emulates effects such as that with [the 2013 movie] ‘*Her*.’ More practical applications become in creating fully interactive, personalized touring as well as visitation with family and friends. There is further the means to engage in 'live' sports and 'play' the game with a team set in one location or composed across multiple geographies. I'll also note the potential with medical care, personal engagement for care management, and the means to create a fully interactive 'environment' in the home or group area for individuals support health, wellness, mental participation, and care.”

Tim Bray, an active participant in the IETF and technology industry veteran, wrote, “I have particular hope for advances in locative augmented-reality applications, for art, entertainment, tourism, and other surprising things.”

Alison Alexander, a professor at the Grady College of Journalism and Mass Communication at the University of Georgia, wrote, “One killer app that could take off is a virtual reality environment. Forget reality, live in your selected world. Visit wherever and whenever. Also, this is not a killer app, but the global nature of connectivity could foster an integrated world economy, breaking down the importance of nations and governments. Foolish optimism, but perhaps we will even be able to make bureaucracy operate more effectively. I am very excited about the power of connectivity to solve research problems. It is happening already, but how wonderful when barriers of time and place no longer hinder collaboration.”

Bryan Alexander, a technology consultant and senior fellow at the National Institute for Technology in Liberal Education, responded, “Gaming has become a planetary culture industry, and it often relies on Internet connections for downloads, socialization, P2P gaming, security, etc. Game designers constantly push the resolution and display envelope; more bandwidth encourages this. We should expect new forms of gaming to emerge, such as ones integrating daily life with games (think Kinect or Alternate Reality Games) or more-immersive forms (play with that video wall).”

An optimistic but more measured response came from **Paul M.A. Baker**, associate director of the Center for 21st Century Universities at the Georgia Institute of Technology, who predicted, “There will be steady, incremental change. It will be more related to interface design and enhanced AI [artificial intelligence] and information processing applications than to bandwidth increase, per se.”

Theme 3) The connection between humans and technology will tighten as machines gather, assess, and display real-time personalized information in an ‘always-on’ environment. This integration will affect many activities—including thinking, the documentation of life events (‘life-logging’), and coordination of daily schedules.

Laurel Papworth, a social media educator, responded, “We are looking at full video lifestreaming in the near future. The Lost Generation had to manually document their lives. The Eternity Generations (from now on) face a future where the tapestry of life has ceased to unravel. Lifestreaming from ultrasound to final illness (and beyond if we add intelligent bots to the life data) will be the killer app. The challenge going forward is to live a full life. No one will be able to sit around in their underwear watching TV if their lives are being streamed for current and future generations. There is a small possibility that by 2025 behavior will have normalized (back to passive, not caring of opinion of watchers) but more likely that will take more time.”

Robert Cannon, Internet law and policy expert, wrote, “We are moving into an era anticipated by [Internet pioneers] [J.C.R.] Licklider and Doug Engelbart where the smart device becomes the assistant to the knowledge worker and to, frankly, everyone doing everything. But, as the Internet of Things anticipates, we move beyond network humans to networked devices, where sensors and monitors and databases constantly interact creating information ... Will there be a killer app in the future that changes everything? Maybe—but certainly what will change is that everything will be networked and everything will be providing information and interacting.”

Fred Baker, Internet pioneer, longtime leader in the IETF, and Cisco Systems Fellow, responded, “The current exponential growth of the network seems to show that connectivity is its own reward, and is more valuable than any individual application such as mail or the World-Wide Web. Today we use massive bandwidth for Map/Reduce and related applications, as well as communication at a distance. Obvious uses for communication capability at a distance include high-resolution hologram-like displays. But the biggest growth will be in machine-to-machine communications.”

David Orban, the CEO of Dotsub, wrote, “High-bandwidth and high-definition communication will allow the emergence of what we’ll call emotional computing. Remote group collaboration will gain a fundamental new dimension in being able to record, transmit, analyze, and understand the full gamut of human emotions. Facial expressions, subtle changes in voice stresses, gestures, will

all be part of how we will communicate among each other for work and fun across any distance, with computers and software platforms understanding these components and being able to adapt to them, facilitating the efficient reaching of goals and objectives.”

K.G. Schneider, a university librarian, wrote, “I see amazing potential of wearable computing to contribute a near-harmonious information-seeking environment where the analog world is enhanced and opened by the digital world. There are probably implications for sexual environments, but I'd prefer not to dwell on that. Instead, I'll make a haimish comment about how useful it would be to ‘see’ my recipes in a wearable heads-up display while I'm cooking, rather than interact manually with a paper book or worse, a tablet or other device.”

Marina Gorbis, executive director at the Institute for the Future, a nonprofit research organization, commented, “We will make significant advances in delivering context-aware applications of all kinds, i.e., providing information and resources that are relevant to the needs and context of the situation. These applications will automatically read the environment (location, mood, social and physical settings, intentions, etc.) and provide highly customized information that is relevant to a particular context.”

Hal Varian, chief economist for Google, commented, “The Internet of Things is real. Internet-enabled devices that interact with the physical world will be the norm. They will learn on their own, with some verbal instruction by their users. The big story here is continuous health monitoring... It will be much cheaper and more convenient to have that monitoring take place outside the hospital. You will be able to purchase health-monitoring systems just like you purchase home-security systems. Indeed, the home-security system will include health monitoring as a matter of course. Robotic and remote surgery will become commonplace. Lasik is just the beginning. Tools for artistic creation such as animated videos and interactive games will become much more powerful and enable collaborative creation.”

Theme 4) Specific economic and social sectors will be especially impacted; health/medicine and education were mentioned often.

JP Rangaswami, chief scientist for Salesforce.com, commented, “It will be classic William-Gibson-future's-here stuff. The focus will shift from just thinking about live, very high-quality, video-based apps to [experiences] that create lots of data to be moved around, sometimes synchronously, sometimes asynchronously. Having a personal healthpod you strap yourself into daily will become normal; wearing clothes that are tailor-made for you every day, 3D-printed at home, will also become normal, with the previous day's clothes recycled efficiently; the school day will disaggregate into a number of learning sessions, some at home, some in the neighborhood, some in pairs, some in larger groups, with different kinds of facilitators.”

Judith Donath, a fellow at Harvard University’s Berkman Center for Internet and Society, responded, “Telemedicine will be an enormous change in how we think of health care. Some will be from home—chronically ill or elderly patients will be released from hospitals with a kit of sensors that a home nurse can use. For others, drugstores (or private clinic chains—fast meds, analogous to fast foods) will have booths that function as remote examining, treatment, and simple surgery rooms. The next big food fad, after hipster locavores, will be individualized scientific diets, based on the theory that each person’s unique genetics, locations, and activities mean that she requires a specific diet, specially formulated each day. Augmented reality is another big future application that, for complex shared images, will require gigabit connectivity and very accurate sensing.”

Ed Lyell, a college professor of business and economics and early Internet policy consultant dating back to ARPANET, commented, “Just-in-time learning will continue to expand, permitting people of all ages to find the information they need when needed. It will permit the human mind to focus on creativity and critical thinking with known information being available as needed. Time in school will need to radically change since the talking-head, expert teacher is less and less valuable. The role of teacher-coach will be even more important yet require a different emotional and intellectual skill set than that which most educators now possess.”

Breanne Thomlison, founder and president of BTx2 Communications, a marketing and strategies firm, wrote, “Gigabit killer apps will be related to health and wellness and education. Tools will monitor us from birth and predict sickness and heal us faster. Genetics will be patented and evolve to have cures to current and new disease that will arise. All of this will happen rapidly. People will be able to connect with others who share similar DNA and experience a personal connection to focus on prevention versus treatment. When it comes to education, there will be an app for every child’s learning ability or disability... Children will be learning and tracking 24/7, while sharing their experience with selected-in peers and networks. Everyone will be the media and a newsmaker. Journalism will be more personal and targeted.”

Theme 5) New digital divides may open as people gain opportunities on different timelines and with different tools.

Danny Gillane, an information science professional, commented, “If there is a digital divide now, it will still exist in 2025. The divide’s existence will be magnified by the new killer apps—who has access and who does not, beneficiaries and those left out. Increased bandwidth and new compression technologies will just allow for more of the same as we have today—more entertainment, more commercial activities, more and better communications.”

Clifford Lynch, executive director for the Coalition for Networked Information (CNI), wrote, “Where very high bandwidth environments exist (for example, the upper end of the research and

higher education sectors) we are seeing a lot of innovation in science and scholarship that is dependent on very fast networks, advanced high-performance computing, and data-intensive practices. Our understanding of what gigabit connectivity can bring to consumers or small businesses (entertainment, games, education, commerce, social media) is much more limited. I worry greatly that most of these applications could be stillborn because affordable high-performance network connectivity to the general public in the United States is not very good and doesn't seem to be getting much better quickly (witness the steady drop in the US rankings in global surveys of national Internet connectivity), due to a whole series of public policy and economic choices that have been made. The good news is that we are seeing some 'labs' established as Google, for example, wires a few cities for very high bandwidth. There are other areas to watch carefully as well: mobile devices are still very bandwidth-constrained, and the combination of very high bandwidth and mobile may yield some interesting new apps. Also many of the most interesting bandwidth-dependent apps seem to involve new sensors and I/O devices, and as we see new developments there (Kinect, etc.) these could point towards new apps. Think about the implications of a new generation of sensors that can be controlled by thinking here. Also some of these can use local Wi-Fi type technology to get fairly high bandwidth and then compress or abstract data streams that travel across the wide-area network, circumventing some of the bandwidth constraints."

Rex Troumbley, a graduate research assistant at the University of Hawaii at Manoa commented, "We should not expect these bandwidth increases to be evenly distributed, and many who cannot afford access to increased bandwidth will be left with low-bandwidth options. We may see a new class divergence between those able to access immersive media, online telepathy, human consciousness uploads, and remote computing while the poor will be left with the low-bandwidth experiences we typically use today."

George Lessard, information curator and communications and media specialist at MediaMentor.ca, wrote, "Yes and the digital divide's gap between the US 'have' and 'have-nots' will grow even larger."

Theme 6) Who knows? 'I have no idea due to rapid change.' 'The best Internet apps are yet to emerge.' 'If I knew, I wouldn't tell you, I would invest in it!'

danah boyd, a research scientist for Microsoft, responded, "Moore's law predicts that the answer is yes. If I knew what it was, I'd be building that instead of filling out this survey."

Joel Halpern, a distinguished engineer at Ericsson, responded, "Changes in capability (such as bandwidth, computation, storage, etc.) by several orders of magnitude are inevitable over the stated time frame. Such changes will produce completely new and exciting applications. To pretend we know what those applications will be is a mistake. Each time such things have

emerged, they have largely been in spaces that were not anticipated. It is also worth remembering that many of the most pervasive effects will likely be in ways that are not directly visible, but make a dramatic difference indirectly.”

Howard Rheingold, a pioneering Internet sociologist and self-employed writer, consultant, and educator, responded, ‘Who has ever been able to predict the most significant results of increased bandwidth? Many, starting with Taylor and Licklider in 1968, have been able to see that networked computers would give rise to new communication media. But who could have foreseen YouTube?’”

Jeff Jarvis, director of the Tow-Knight Center for Entrepreneurial Journalism at the City University of New York Graduate School of Journalism, wrote, “I could not have predicted Google, Facebook, Blogger, or certainly Twitter. So there's no way I can predict what ubiquitous gigabit bandwidth will bring. I only know I want it.”

Tiffany Shlain, filmmaker, host of the AOL series *The Future Starts Here*, and founder of The Webby Awards, commented, “We have no idea what new apps will exist when every human on the planet is online. We could have never predicted Google or Twitter. I can't wait to see what 2025 will bring.”

Seth Finkelstein, a programmer, consultant and EFF Pioneer of the Electronic Frontier Award winner, commented, “Historically, every new technological capability generates new applications which take advantage of that capability. However, if I knew exactly beforehand what those new killer apps would be, I'd be contacting a venture capital fund, not putting it in this survey.”

Rob Atkinson, president of the Information Technology and Innovation Foundation, responded, “It's certainly possible there will be ‘killer apps’ but it's hard to see what they will be. Even super HD video does not require anything near one gigabyte.”

Theme 7) Advances will be gradual for various reasons: Bandwidth is not the issue. The US will continue to lag by 2025 because a widespread gigabit network is not easily achieved.

David Clark, a senior research scientist at MIT’s Computer Science and Artificial Intelligence Laboratory, wrote, “Video will continue to be the major driver of bandwidth demand. Video is not new or distinctive. There will be new apps, but I doubt that they will be enabled by increases in bandwidth. The exception may be mobile apps, which are highly constrained by cellular capacity.”

Mike Roberts, Internet pioneer and longtime leader with ICANN and the Internet Society, responded, “I’ve been involved professionally with this issue for years. It suffers from the usual problems of hype and misunderstanding. At least three major forces are at work in what is called

gigabit networks. 1) The economic issue of fair and equitable access to the Internet; 2) The economic structure in which bandwidth and applications and content generally are provided with Internet technology; and 3) The opportunities for new applications development which are possible when gigabit-style bandwidth is available to citizens. Generally, we are still stuck in the situation with Internet technology where success is being measured by comparison to the way things used to be done. Yes, there eventually will be killer apps dependent on gigabit-style bandwidth, but the path to them will be longer and more tortuous than advocates like to admit.”

Robert E. McGrath, an Internet pioneer and software engineer who participated in developing the World Wide Web and advanced interfaces, commented, “First, there will not be ‘significant increases in bandwidth’ in the United States. Increases yes, but not significant. Second, I’ll take a chance here and say that there will be no ‘killer app,’ at least not of the magnitude of the Internet. Lots of cool stuff will roll out, some people will get rich, but nothing really ground-breaking. I note that there haven’t been any ‘killer apps’ for quite a while. All the recent candidates (social media) are minor permutations of Internet messaging. Third, it would take massive investment in basic research now to get anything game changing by 2025. Investment is going down, which makes me say there will be no great results, since we aren’t doing the work to get them.”

Leah Lievrouw, a professor of information studies at the University of California-Los Angeles, responded, “I tend to agree with economists like Tyler Cowen and Robert Gordon that much of the innovativeness in the last couple of decades has been incremental, refining and building and elaborating on more fundamental infrastructural changes that are now decades old, like TCP/IP and other key features of Internet architecture, optical and satellite data transmission, petrochemicals and transportation, and so on. Over the last couple of decades, especially with the commercialization of publicly-funded infrastructure projects like the Internet and the ‘mean world’ perceptions of the post-9/11 age, the pressures to lock down, ‘stabilize,’ and render disruptive digital technologies ‘safe’ and predictable have dominated political discourse and popular culture, which has in many respects limited the emergence of truly disruptive innovations that would destabilize existing markets, products, and infrastructures. So we might well increase digital bandwidth, but use it to deliver and meter familiar, trusted (and ‘safe’) products and services, or variations on them: media content, college lectures, voice telephony, security services, public utilities, financial information and services, health care advice, and so on.”

Andre Brock, a survey participant who shared no additional identifying details, wrote, “I am unwilling to believe that there will be ‘significant’ increases in bandwidth before 2025. My concern lies with the unwillingness of telecom providers to upgrade their backbones to accommodate gigabit bandwidth and their continued litigation strategies to prohibit municipal Internet service providers willing to install their own fiber. Without significant federal intervention on the lines of the ‘universal service’ provision of the 1996 Telecom Act, we will continue to see incremental

increases in bandwidth (wired and wireless), overcharges for '4G' access, and increased telecom lobbying against net neutrality in order to profit from 'tiered service' throttled access.”

David Bollier, a long-time scholar and activist focused on the commons, responded, “The question contains embedded assumptions that may or may not hold true: 1) that the Internet will necessarily remain open and nondiscriminatory (net neutrality); 2) that telecom providers will indeed build out Internet bandwidth in significant and roughly ubiquitous ways; and 3) that killer apps are the necessarily the biggest, most desirable outcome imaginable. The social capacity to use and diffuse new apps, and to innovate ‘on top’ of them, is at least as important. The most promising avenues involve social collaboration, especially in nonmarket, commons-based contexts—but most business models today presume some monetization imperative that can limit or poison collaborative possibilities, and bottom-up, self-organized financing and governance remain rudimentary and under-theorized.”

Doc Searls, director of Project VRM at Harvard’s Berkman Center for Internet and Society, agreed that resistance by entrenched interests may not stop the eventual development of the gigabit Internet. He wrote, “For apps to be truly killer we will need symmetrical high-speed (gigabit+) connectivity, so the speed of the network—in both directions—approaches or equals that of our machines and our home networks. I believe that will happen. The examples we already see in Chattanooga and Kansas City will go viral in other cities, despite political opposition by the incumbent carriers, which seem hell-bent on keeping old TV consumption and business models alive for as long as possible. Once symmetrical gigabit connectivity happens, offsite storage and computation in clouds, for everybody, will become a norm. So will personal control over how that is done. Once everybody can keep and manipulate their own data in their own clouds, the Internet of Things will be included as well.”

And some said innovation will occur regardless of bandwidth. **Glenn Edens**, a director of research in networking, security, and distributed systems within the Computer Science Laboratory at PARC, a Xerox Company, replied, “The new and distinctive applications will occur with or without increased bandwidth. Our current progress in increased bandwidth is pretty miserable; my home bandwidth has been stuck at 24 megabits (on a good day) for many years now. Mobile bandwidth is getting better but usage increases are still outpacing gains. Application developers find new and interesting things to do all the time—a lot new will occur even if bandwidth gains stall.”

Big-Picture Responses: Part 1

Some of the most evocative future scenarios are expressed by these big thinkers' imaginings of what may be by 2025.

Massive change is likely to impact cities, and 3D video and printing will advance

Vint Cerf, vice president and chief Internet evangelist for Google, responded, "Entertainment appliances, environmental control systems, and security alarm systems will all benefit from third-party service providers managing these systems on our behalf. Smart cities will amass substantial information in real time to deal with traffic, power generation, and distribution. High-speed connectivity means streaming will be replaced by download/playback except for real-time events. Group interaction and perhaps 3D video will become a reality. Already we see a lot of the former in Google's Hangouts. 3D printing will lead to completely new supply chains including for raw materials. Designs will be transferred on the Net and devices created at the end points with 3D printing and manual or automatic assembly."

Sensors will be everywhere, contributing to information visualizations

Jonathan Grudin, a principal researcher at Microsoft Research, commented, "I expect that the management of networks of embedded sensors and effectors will be the largest change between now and 2025, sensors everywhere—on property, on our clothes, on (and perhaps in) our bodies, all of it feeding digital information to be processed on servers or filtered and passed to the cloud. By 2025 small devices might be powered by harvested energy, in which case the possibilities expand dramatically. On the receiving end of this massive information flow will be large displays at work and in many homes through which vast quantities of information can be rapidly visualized. We have lagged in exploiting this because it is more difficult to model or demo than a simple application, but it will come."

'Cloud immigrants' will appear as holograms and compete for jobs

Marcel Bullinga, a technology futures speaker, trend watcher, and futurist, replied, "No doubt the killer app will be real-life holograms operating in real time: for instance, as doctors, as surgeons, as coworkers. It will change the workplace. Not only will it diminish the need for business travel, it will also increase competition in the labor market immensely. Whereas before you had to compete with fellow humans in the same physical area, immigrants for example, in the future you have to compete with 'cloud immigrants'—coworkers appearing in their work as a hologram."

People will learn more about themselves and 'avoid coercive marketing'

Patrick Tucker, author of *The Naked Future: What Happens in a World That Anticipates Your Every Move?* observed, "Today, large organizations, including corporations and government

agencies, use personal data to make predictions about the behavior of individuals. In the next 10 years, users will have access to a variety of apps that constantly collect and analyze data to output personalized predictions that will better enable users to avoid coercive marketing and learn more about themselves. Big data will shrink to become personalized data in app form as every individual user develops a much better understanding of how her behavior influences her rapidly-evolving future.”

Bye-bye phones: Devices will manage things machine-to-machine

Paul Saffo, managing director at Discern Analytics and consulting associate professor at Stanford University, wrote, “Never underestimate the transformative power of Moore's law. The fastest growth will be communications options aimed at machines as data consumers. Your devices will subscribe to content and apps on your behalf. Smartphones will disappear rapidly.”

And **Mark Johnson**, CTO and vice president for architecture at MCNC, wrote, “We are approaching the post-bandwidth era where we are not constantly limited by the capabilities of our connections. We'll expect to be able to access and control everything we own that uses electricity all the time from any location using a device we always have with us. We won't think about ‘phones’ and ‘television’ as distinct things or even as services any more.”

‘Apps’ will be so over by 2025

Stephen Abram, a self-employed consultant with Lighthouse Consulting Inc. and CEO of the Federation of Ontario Public Libraries, wrote, “We haven't begun to see the big stuff yet. So far we are seeing traditional face-to-face and 20th century stuff being turned into apps. The real change will come with convergence of the total experience as smart card, phones, and appliances as well as smart wall and augmented reality really start to invent new modes on the backs of old ones. Just one small example—fiction and non-fiction e-books are merely the Gutenberg product wrapped in a digital wrapper. Where they'll be when they truly try to entertain or support pedagogy beggars the imagination. The year 2025 will be a much different place and 'apps' actually will have gone by the wayside as the need to bind them disappears into the social-cultural and workplace eco-system.”

Katie Derthick, a PhD candidate in human-centered design and engineering at the University of Washington, responded, “Applications are the wrong scale and quality of technological innovation and solution. In 22 years, I *hope* we are no longer churning out application after application for problems that require solutions at the institutional, social, family, or individual (as in, choices about daily life) levels. Innovation will persist at the application scale for a while, but a backlash against technologizing everything, at the cost of time, health, relationships, social skills, spirituality, presence, attention, and cultural and class divides is coming. Finally, rather than apps, the innovation with technology will be at the device and environment level, meaning

communication between devices (in ways that don't require apps), in the places we live (first) and work (later).”

Think bigger about ‘apps’ and the change becomes impressive

Bruce Mehلمان, Co-Chair & Co-Founder, Internet Innovation Alliance, wrote, “The App Economy spawned by mobile broadband innovations is already changing every aspect of Americans’ lives, with exponentially more ahead of us. A health care revolution will save lives, save money and meaningfully enhance patients’ quality of life, with wearable monitoring devices barely scratching the surface of what’s to come. Transformative educational apps promise a future free from the one-size-fits-all broadcasting-from-the-front-of-the-room teaching model that disservices so many learners who assimilate information differently. Real-time sensor networks will do for traffic congestion and fuel consumption what millions of dollars in public transportation advertising has failed to accomplish, with even late-adopting governments leveraging citizen-facing apps for better constituent service and internally-focused apps for less waste, fraud and abuse. And evolving apps will give citizens more privacy and security as consumers increasingly vote with their feet for differentiated solutions that return control and choice to the user. In short, we have only just begun to witness a revolutionary transformation as profound as the Internet itself.”

Machines will have ‘more-complex intelligence’ and decision-making capability

Susan Etlinger, an industry analyst for the Altimeter Group predicted, “In the next 10 years, we’ll see tremendous advances in the fields of automation (robotics) and information (data). We’re already seeing the emergence of drones for simple commercial use; in time, these devices will be invested with more-complex intelligence and a more sophisticated range of uses and decision-making capability. We’ll also continue to see blurring of the lines between physical and virtual reality, as well as an infusion of social, linguistic, and neuro-scientific research into technology development. New and more complex big data streams—images, sensor data, sound files, video, natural language—will continue to challenge us, however, as there is a limit to the ability of algorithms to account for human language and behavior. As a result, we’ll need to see dramatic advances in machine-learning capability. This will invest machines with a kind of sentience, although one far removed from the dystopian vision of a William Gibson. Our struggles with privacy, identity, and ethics will continue as technology advancements exceed our capacity to understand their implications.”

The Snowcrash Metaverse arises

Stowe Boyd, lead researcher for GigaOM Research, predicted, “High-fidelity meeting tools will decrease the need for business travel. These will present participants with artificially constructed online places to meet, and create high-fidelity renderings of people’s real-time actions based on cameras and other devices. For example, I could be writing on a ‘whiteboard’ with others, as well

as seeing them standing next to me. In fact, I would be in my office in Beacon, New York, wearing an Oculus-ish headset and writing on my wall, while meeting with people from London and San Francisco. The culmination of that meeting trend will be the true online conference, where I might be sitting in my office, again, but sensing that I am in a large conference hall with hundreds of others, hearing a lecture, and being able to chat with the people on either side of me. I sneeze, and five people say 'Gesundheit.' Basically, it is the Metaverse from *Snowcrash*.”

How will automated sensing and human decision-making mesh in this future?

Marjory Blumenthal, a science and technology policy analyst, replied, “The evolution of the ‘Internet of things’ and the associated proliferation of sensors will feed new applications; how automated sensing and human decision-making will mesh is what is most uncertain.”

The ‘Internet of context’ could help us solve major social problems

Jerry Michalski, founder of REX, the Relationship Economy eXpedition, wrote, “If someone had told me in 2005 that there was room between blogging and instant messaging for an application I would like and use more than either, I would have said it was impossible. Yet I use Twitter all the time. So by 2025, a long time from now, I’m certain several innovations like that will have taken place. That said, I don’t think full-time, high-definition video, the obvious higher-bandwidth application, is the answer. Google Glass is facing backlash already, videoconferencing is interesting but not compelling. One possibility, if we turn back copyright laws (egregious at their current terms) and help people weave a context for their lives, is that we’ll have a rich Internet of content in context, representing many different points of view. This will allow us to dive deeper into conversations than the superficial modes of today’s discourse, where the same shallow ideas are repeated over and over. Context will give us depth, which will help us solve major social problems.”

The fundamental constraint is time

Joe Touch, director of the Information Sciences Institute’s Postel Center at the University of Southern California, responded, “Approaches and solutions change when a property shifts from being a constraint to being a resource, i.e., when it shifts from being part of the challenge to being part of the solution. We’ve seen that shift happen with CPU power, memory, and storage (disk) already, and we’ll soon start to see bandwidth in that light. The fundamental constraint is time—it’s fundamentally what we care about, and it’s the one thing we can’t speed up. We can trade bandwidth for latency; I explored this 25 years ago in my thesis, and the time is now becoming ready for that approach.”

Or none of the above Part I: Developments conspire against such progress

David Ellis, course director for the Department of Communication Studies at York University in Toronto, commented, “There’s a prior question: Will increases in bandwidth up to a gigabit materialize by 2025? A lot of developments continue to conspire against this outcome. One, the access business stays firmly on the path to concentration, especially on the cable side. Two, and despite the foregoing, the integrated ISPs in Canada and the United States have a vested interest in continuing to treat bandwidth as scarce and expensive. Three, a conservative school of thought continues to argue that the status of US (and Canadian) broadband is just fine, while invidious comparisons with other developed nations are irrelevant or misleading. Four, the progress in municipal Wi-Fi and fiber alternatives, and other carrier-neutral transmission platforms, is still not very encouraging, in part because of the extent to which the incumbents have convinced many US jurisdictions that publicly-funded connectivity should be outlawed. Five, the FCC’s pushback against further entrenchment by the incumbents on the content side (Open Internet Order) seems likely to get tossed by the DC Circuit this year.”

Or none of the above Part II: Intellectual property issues could squelch the whole thing

Jamais Cascio, a writer and futurist specializing in possible futures scenario outcomes commented, “The development of new killer apps for the gigabit age is, if not predetermined, highly likely simply as a consequence of greater numbers of people experimenting with the technology. The big potential roadblock—and the main reason I could just as easily have answered ‘no’—is the disturbingly high likelihood that intellectual property controls and the demise of network neutrality will undermine the end-to-end agnosticism of the Internet. If the gigabit future is essentially the modern wireless/cellular network writ large, then incremental innovation may even be difficult, let alone radical innovation.”

About this Canvassing of Experts

The expert predictions reported here about the impact of the Internet over the next 10 years came in response to one of eight questions asked by the Pew Research Center Internet Project and Elon University's Imagining the Internet Center in an online canvassing conducted between November 25, 2013, and January 13, 2014. This is the sixth Internet study the two organizations have conducted together since 2004. For this project, we invited more than 12,000 experts and members of the interested public to share their opinions on the likely future of the Internet and 2,551 responded to at least one of the questions we asked. Nearly 1,500 responded to this question about access and sharing online in 2025.

The Web-based instrument was fielded to three audiences. The first was a list of targeted experts identified and accumulated by Pew Research and Elon University during the five previous rounds of this study, as well as those identified across 12 years of studying the Internet realm during its formative years. The second wave of solicitation was targeted to prominent listservs of Internet analysts, including lists titled: Association of Internet Researchers, Internet Rights and Principles, Liberation Technology, American Political Science Association, Cybertelecom, and the Communication and Information Technologies section of the American Sociological Association. The third audience was the mailing list of the Pew Research Center Internet Project, which includes those who closely follow technology trends, data, and themselves are often builders of parts of the online world. While most people who responded live in North America, people from across the world were invited to participate.

Respondents gave their answers to the following prompts:

New killer apps in the gigabit age: Will there be new, distinctive, and uniquely compelling technology applications that capitalize upon significant increases in bandwidth in the US between now and 2025?

Please elaborate on your answer: (Begin with your name if you are willing to have your comments attributed to you.) If you answered "no," explain why you think there will be incremental change, or hardly any change at all. If you answered "yes," describe what the killer apps might be as gigabit connectivity becomes available. Explain what new tools and applications will excite people in the next decade and envision the kinds of personal connectivity and immersive media experiences that will seize the public imagination.

Since the data are based on a non-random sample, the results are not projectable to any population other than the individuals expressing their points of view in this sample. The respondents' remarks reflect their personal positions and are not the positions of their employers;

the descriptions of their leadership roles help identify their background and the locus of their expertise. About 84% of respondents identified themselves as being based in North America; the others hail from all corners of the world. When asked about their “primary area of Internet interest,” 19% identified themselves as research scientists; 9% said they were entrepreneurs or business leaders; 10% as authors, editors or journalists; 8% as technology developers or administrators; 8% as advocates or activist users; 7% said they were futurists or consultants; 2% as legislators, politicians or lawyers; 2% as pioneers or originators; and 33% specified their primary area of interest as “other.”

On this particular survey question a majority of the respondents elected to remain anonymous. Because people’s level of expertise is an important element of their participation in the conversation, anonymous respondents were given the opportunity to share a description of their Internet expertise or background.

Here are some of the key respondents in this report:

Miguel Alcaine, International Telecommunication Union area representative for Central America; **Francois-Dominique Armingaud**, formerly a computer engineer for IBM now teaching security; **danah boyd**, a social scientist for Microsoft; **Stowe Boyd**, lead at GigaOM Research; **Bob Briscoe**, chief researcher for British Telecom; **Robert Cannon**, Internet law and policy expert; **Vint Cerf**, vice president and chief Internet evangelist at Google; **David Clark**, senior scientist at MIT’s Computer Science and Artificial Intelligence Laboratory; **Glenn Edens**, research scientist at PARC and IETF area chair; **Jeremy Epstein**, a senior computer scientist at SRI International; **Susan Etlinger**, a technology industry analyst with the Altimeter Group; **Seth Finkelstein**, a programmer, consultant and EFF Pioneer of the Electronic Frontier Award winner; **Jonathan Grudin**, principal researcher for Microsoft; **Joel Halpern** a distinguished engineer at Ericsson; **Jim Hendler**, Semantic Web scientist and professor at Rensselaer Polytechnic Institute; **Jeff Jarvis**, director of the Tow-Knight Center at the City University of New York; **John Markoff**, senior writer for the Science section of the *New York Times*; **Jerry Michalski**, founder of REX, the Relationship Economy eXpedition; **Raymond Plzak**, former CEO of the American Registry for Internet Numbers, now a member of the board of ICANN; **Mike Roberts**, Internet Hall of Famer and longtime leader with ICANN; **Paul Saffo**, managing director of Discern Analytics and consulting associate professor at Stanford; **Doc Searls**, director of ProjectVRM at Harvard’s Berkman Center; **Hal Varian**, chief economist for Google; and **David Weinberger**, senior researcher at Harvard’s Berkman Center.

Here is a selection of other institutions at which respondents work or have affiliations:

Yahoo; Intel; IBM; Hewlett-Packard; Nokia; Amazon; Netflix; Verizon; PayPal; BBN; Comcast; US Congress; EFF; W3C; The Web Foundation; PIRG; NASA; Association of Internet Researchers;

Bloomberg News; World Future Society; ACM; the Aspen Institute; Magid; GigaOm; the Markle Foundation; The Altimeter Group; FactCheck.org; key offices of US and European Union governments; the Internet Engineering Task Force; the Internet Hall of Fame; ARIN; Nominet; Oxford Internet Institute; Princeton, Yale, Brown, Georgetown, Carnegie-Mellon, Duke, Purdue, Florida State and Columbia universities; the universities of Pennsylvania, California-Berkeley, Southern California, North Carolina-Chapel Hill, Kentucky, Maryland, Kansas, Texas-Austin, Illinois-Urbana-Champaign, the Georgia Institute of Technology, and Boston College.

Complete sets of credited and anonymous responses to this question, featuring many dozens of additional opinions, can be found on the Imagining the Internet site:

http://www.elon.edu/e-web/imagining/surveys/2014_survey/2025_Internet_Killer_Apps.xhtml

http://www.elon.edu/e-web/imagining/surveys/2014_survey/2025_Internet_Killer_Apps_credit.xhtml

http://www.elon.edu/e-web/imagining/surveys/2014_survey/2025_Internet_Killer_Apps_anon.xhtml

Elaborations: More Expert Responses

Each increment of growth in bandwidth has enabled new communication, new participation in communities, more effective outreach to broader social networks, more access to information, and more algorithmic interventions to sort and filter data. Most of the experts in this canvassing see all those trends being amplified in the decade to come as gigabit connectivity spreads. As **Jim Kennedy**, senior vice president for strategy for the Associated Press, put it, “The bandwidth revolution has driven the digital age from the start, and we are on the cusp of a day when connectivity will be like the air we breathe. At that stage, everything and everybody can be connected for a continuous flow of information and data exchange that can add a ‘meta’ layer to almost every human experience. The gadgets we have today are just the start. The killer apps of the future will take advantage of the ones that have already emerged: connectivity, search, sharing, touch, gestures, location awareness, and virtual reality, among others.”

Most—but not all—of the respondents believe the move toward gigabit connectivity will enrich personal encounters, create new kinds of personalized media experiences, and pack even more information into people’s lives, merging it with their surroundings and basing their individual experiences upon algorithms that estimate their personal preferences.

The power of those changes captivated many of the respondents. Among the most expansive analysts was **Barry Chudakov**, founder and principal of Sertain Research, who talked about how the merger of information and the physical environment could change people’s sense of reality:

“The most distinctive and uniquely compelling technology applications we will encounter between now and 2025 will take us into environments and surround us with information, navigation, and search capabilities. These apps will create *livingness* of information. We will enter any destination like diving into water. This new submersion, due to enhanced glasses or some evolved cognitive cum visual tool, will affect both the destination and those experiencing it. We will no longer go anywhere alone, as we will be connected to everyone and everything around us. We will not think of this as a media experience, but as reality immersion while we are walking down Fifth Avenue in New York or spending an afternoon at the Palazzo Vecchio. We will no longer think of a map as a representation of the territory; the map will become part of the territory, while at a gut level we will both be in the experience and we will be in the territory itself with constant readings of our responses to surroundings and live reporter/correspondents (us or other connected souls) providing a narrative of what is happening on the ground. In a flash, static documentation moves from two-dimensional estimate to detailed interactivity and monitoring; we move from passive observer to connected actor and commentator.”

Following are more answers that expand the broad themes of this report:

Theme 1) People’s basic interactions and their ability to ‘be together’ and collaborate will change in the age of vivid telepresence—enabling people to instantly ‘meet face-to-face’ in cyberspace with no travel necessary.

Daniel Miller, a professor at University College in London, responded, “I have been working on ‘always-on’ connectivity through webcam, and this issue is raised as ‘ambient awareness’ in Clive Thompson’s new book *Smarter Than You Think*, so one area that I expect to develop is different ways people can effectively live together even though they are apart. Given the increase in diaspora populations and migration for work this may be one of the most important consequences of increasing bandwidth. This is not the same as communication, since one of the main advantages of ‘always-on’ living together is you don’t have to be talking to each other all the time.”

Ray Schroeder, associate vice chancellor for online learning at the University of Illinois-Springfield, commented, “Holographic, immersive environments will emerge enabling us to fully engage others at a distance. This will have significant implications for education, training, recreation, and travel. Virtual opportunities will proliferate for people to engage one another in more than mere text chats; more than Skype; more than Google hangouts; instead they will be able to meet virtual face-to-face. These meetings can be in a wholly unique environment. For example a person in Norway may be with another person in Seattle. They will be represented in 3D to one another in a setting in Hawaii.”

A professor of communication at an international management institute wrote, “I will virtually kiss my wife in New York from New Delhi before I leave for work in the morning.”

The CEO for a company that builds intelligent machines wrote, “I am not sure if it will hit by 2025, but I would expect that one of the most sought-after forms of entertainment will be fully-immersive experiences that stimulate all the human senses. With the new human-computation interfaces and gigabit bandwidth connectivity available in 2025, we will have the first versions of tools able to record and play back a full human life, minus the boring parts, of course. We will be able to push our already considerable talent for make-believe on a large scale (the movies) to its natural end, and be able to craft dream-like narratives that will be so compelling that we’ll want to regularly check out of our daily lives for little burst of fantasy.”

Jane Adams, executive director of one of California’s state-based public organizations, replied, “Applications that broaden our sensory experiences while doing an activity will be created. For instance feeling that you are being at the top of Everest will be possible even if you aren’t there physically via apps. If you want the sights and smells of Paris or Istanbul there will be an app to bring that into our physical world. The world will seem smaller as we have the opportunity to ‘go’ to places without leaving our house. Perhaps we will have greater understanding of what it is like

to live under extreme conditions such as war, poverty, hunger, and illness and this may make us more benevolent towards others as it will expand our world view.”

Susan Keating, a self-employed digital consultant and instructor, predicted, “Telepresence for meetings and communicating; researching by computer for medical or research projects; perhaps remote medicine and surgeries; TV won't be a screen, but acted out in your room by holograms.”

Stuart Chittenden, the founder of the conversation consultancy Squishtalks, predicted, “Streaming of mass data, including holograms and shared sensory experiences of audience events, instant multi-person participation, etc.”

Some, like **John Lazzaro**, a research specialist and visiting lecturer in computer science at the University of California-Berkeley, focused not so much on advances in speed but on the shrinking “latency” of Internet-enabled encounters—the immediacy of online interactions without noticeable delay. He wrote, “By 2025, the network number of interest won't be bandwidth, but will be the geographic radius that supports interactions with others people in the 1-10 ms [millisecond, a thousandth of a second] range. For example, the latency between the Stanford and Berkeley campus has a median value of about 2 ms, which is about the acoustic latency between two people standing 2.5 feet apart. This latency supports applications like network musical performance, defined as musicians located in distant physical locations interacting as if they were in the same room, and many other telepresence applications... I think by 2025, enough people will have sufficiently low latency within their local metropolitan region... Once the network is there, attention will turn to getting the right product idea and executing it, and I believe one or more of them will take off and have the scale of success of a Facebook or a Twitter.”

Lyman Chapin, co-founder and principal of Interisle Consulting Group, LLC, commented, “To first order, the only meaningful answer is yes,’ because ‘no’ has so often (almost uniformly) been proven wrong by history. Mobile bandwidth will almost certainly be the most significant instantiation of gigabit connectivity; I can imagine an app that continuously pre-fetches the data of everyday experience before the experiences have occurred, so that our progress through time becomes mediated by those data at least as much as by things that actually happen (which we might not even notice).”

Peng Hwa Ang, director of the Singapore Internet Research Center at Nanyang Technological University, wrote, “Video and location-based data could use the new technologies. Imagine moving anywhere (dark alley, battlefield) and being able to capture everything around. To be able to stream and record the data would be invaluable.”

Dave Kissoondoyal, CEO for KMP Global Ltd. and Internet consultant, commented, “By 2025, technology will have eased the everyday life of each individual. All communications will be on

video. The use of cloud computing and video applications will have greatly increased, requiring instant access to the various applications and data. Virtual meeting will not only include viewing and talking to the correspondent but also having the feel of shaking hands and meeting the correspondent virtually.”

Ian Peter, pioneer Internet activist and Internet rights advocate, wrote, “I suspect with mobile applications we will be able to look a few kilometers away to see how long it will be before the bus we are waiting for arrives, we will be able to check where our car is if other members of the family have it, where our children and pets are, how grandmother is in her nursing home, queues and traffic jams, items on supermarket shelves, and stock levels in online shops, etc.”

Lisa Dangutis, webmaster for The Sunshine Environment Link, responded, “More gigs please. People want faster, better media experiences that come with the capitalization of bandwidth. Experiences may include 3D-skype media, easier, faster relationships to visual graphing. High visual media plotting is also another possibility (3D graphing on mega-data projects or analytics). An app for tracking 3D change in the stock market could be feasible with more bandwidth and gigabit connectivity. For killer apps, the world is the oyster when it comes to gigabits. 3D GPS could be another killer app. The world is the oyster on such technology.”

David Allen, an academic and advocate engaged with the development of global Internet governance, responded, “When we look at media, the trajectory of change taken over the long view shows that the direction is toward greater and greater reality. That is, successive invention adds to the sense of ‘being there.’ That seems likely to continue. In time, we likely will have immersive holographic experience, both of entertainment and of our communications with those separated from us.”

John Wooten, the CEO and founder of ConsultED, wrote, “Human interconnectivity will become normalized by common, focal use of video conferencing as an ‘always-on,’ readily accessible, and cheaper way to communicate; the component of video will be complimented by add-on layers of data sharing to augment video as the primary vehicle for connectivity (text, image, and metadata sharing).”

Jon Lebkowsky, Web developer at Consumer’s Union, responded, “I expect refinement and extended use versus radically different tech. We’ll travel less, and use high-bandwidth, high-fidelity alternatives, especially since energy availability will have decreased significantly. I’m reminded that, despite higher-bandwidth alternatives, texting has become perhaps the most common form of communication, at least among digital natives.”

Liza Potts, assistant professor and senior researcher for writing in digital environments at Michigan State University, responded, “One can only hope that such amazing bandwidth would

improve our digital entertainment spectrum. Considering personal technologies like the ones created in our many science-fiction books, television shows, and movies, it would be amazing to have immersive systems become a reality. Holograms, holodecks, and other ways in which we could connect with each other over time and space.”

Adam Gismondi, PhD candidate in higher education at Boston College, responded, “Much as the decreasing cost of storage space and increases in bandwidth have resulted in apps that use these new capabilities to implement video (Vine, Instagram, FaceTime), future apps will likely follow a similar trend. By 2025, many of these tools and applications may take the video capability to the next level through immersive, interactive video. These sorts of applications can already be seen through revolutionary music videos recently produced (Arcade Fire, Bob Dylan, and others), but this will be enhanced to work seamlessly on mobile.”

Theme 2) Augmented reality will extend people’s sense and understanding of their real-life surroundings and virtual reality will make some spaces, such as gaming worlds and other simulated environments, even more compelling places to hang out.

David Bernstein, president at The Bernstein Agency, a marketing and research consultancy, commented, “Just as the cell phone and smartphone have made information and communications available nearly everywhere at any time, virtual reality communication could become technologically and economically reachable in the same manner. Virtual reality extensions of regular communications will likely start in the gaming industry, but could quickly move into the mainstream. Eventually it could change the way we preserve our past. In the same way that photography changed the way we could preserve our personal and collective history imagine the impact of being able to ‘walk into’ an old family photograph or video.”

John Markoff, a senior writer for the Science section of the *New York Times*, wrote, “Two words (not just ‘plastics’)—Augmented Reality.”

Daren C. Brabham, assistant professor at the Annenberg School for Communication and Journalism at the University of Southern California, wrote, “The arrival of Google Fiber in some US cities has already spurred a number of start-ups that envision new uses for increased bandwidth. Some of these applications of higher bandwidth include graphically intense multi-player online gaming on-the-go. With better bandwidth in more places, blockbuster game franchises (*Halo*, *Call of Duty*, etc.) will leave the game room and integrate seamlessly into people’s commuting time or other segments of down time. I also predict more educational uses for this bandwidth, including complex immersive learning simulations for medical and law students. With this higher level of intensive training, we will start to see online medical and legal degrees emerge. Finally, this level of bandwidth will mean that we will actually own less and less of our devices and will instead rent most of it (software-as-a-service) in real-time from remote servers.

This will put less of a focus on apps in mobile devices and more of a focus on the brute power of processors again.”

Evan Michelson, a researcher exploring the societal and policy implications of emerging technologies, predicted, “Augmented reality will expand in unimagined ways. Movies that you watch on your phone will be interactive. Want to buy the shirt that your favorite character is wearing? Click on it and buy it with currency, or in exchange for time (in your time bank account). Is the statue on the desk in the sitcom you are watching not available? Have it 3D printed on-demand and sent to you by drone messenger. While at work, perhaps you will be able to interact with virtual holograms at your desk—the distribution of telepresence to every knowledge worker.”

Jamie LaRue, a writer, speaker, and consultant on library, technology, and public sector issues wrote, “The likeliest result is an extrapolation of video games and 3D films. Something approaching full sensory environments should begin to be common; introduced to wearable (or physically embedded) technology this could result in a few richer interactions with remote sites. For instance, someone could be driving the Mars Rover in real time, or doing deep sea exploration. More likely, it will be used to meet up with one's friends and go virtual shopping.”

Sean Mead, the senior director of strategy and analytics for Interbrand, commented, “Immersive apps including olfactory and tactile sensations will divert large amounts of time, energy, and social activity to gaming and social worlds that appear and feel real, making people the stars of their own productions. Virtual relations will challenge real-world social relations.”

Scott McLeod, director of innovation for the Prairie Lakes Area Education Agency in Iowa, responded, “I see the possibility of 3D immersive simulations as incredibly promising opportunities. The ability to not just watch, but actually be immersed in different kinds of environments will come closer to reality with faster bandwidth.”

Todd Cotts, a business professional, wrote, “Moore's law would suggest that applications will be created that require less bandwidth to function at more than optimal levels of user experience, allowing for an even more all-encompassing interaction between user and technology. Cellular-based processing is likely to be behind these innovative leaps in bandwidth efficiency. Cellular-based functionality is likely to be behind technological features—which we will by then know as ‘experiences’—that will allow users to connect with tools and applications at a biological/neurological level, enabling an immersive experience—virtual reality—blurring the lines between reality and non-physical-reality in gaming, shopping, traveling, working (i.e., virtual surgery), and even dating, delivering to the user the experiences of ‘being there,’ accompanied by the smells, sights, sounds, perceptions, sensations, and emotions that would otherwise be experienced only on a physical plane.”

Aliza Sherman, a new media entrepreneur and author, predicted, “Immersive shopping experiences—virtual dressing rooms, virtual salons, getting the full picture or look before making the purchase. Immersive travel experiences for research and education or pleasure and entertainment.”

Yvette Wohn, a respondent who shared no other identifying details, commented, “I expect 3D projection (projecting three-dimensional synchronous images) will be the new form of video-conferencing. Virtual reality will become a household device (like the mobile phone) and be implemented first in entertainment form, such as massively multiplayer online games, and later be incorporated into communication devices. Moving beyond wearable computers, companies will be tinkering with prototypes of body-embedded technology that serves as communication device and personal-health tracking device.”

Janet Salmons, PhD and independent researcher and writer with Vision2Lead Inc., responded, “We’ll see more augmented reality apps that allow us to operate as ourselves or as avatars, and that those exchanges will be increasingly infused into everyday life. At the same time, we’ll start to see a different distinction emerge about what it means to be ‘in person.’ The loving touch, the expression of caring, the immediacy of personal presence will be more starkly contrasted with the options for immersive, any-time videoconference or virtual world exchanges that we have using communications technologies.”

Andrew Chen, associate professor of computer science at Minnesota State University Moorhead, responded, “Oculus Rift and similar technologies combined with 3D (stereoscopic) cameras and haptic-feedback gloves, clothing, and wearables will result in 3D ‘chat’ technologies that will come close to having people be able to ‘reach out and feel’ each other. This will get great popular press and many will choose to obtain this technology but this will not be commonly used because of how it will interfere with mobile usage—this will be a luxury for those who can stay at home, which most will be unable to.”

Miguel Alcaine, an International Telecommunication Union area representative for Central America, responded, “The next bandwidth hungry killer apps will be related to virtual reality and augmented reality, where other senses like taste, smell and touch can be more integrated with our experience with the digital world. I can easily foresee virtual reality games and training applications using virtual reality rooms and environments that supersede our wildest dreams. Bandwidth needs are proportional to our sense capabilities.”

Sharon Collingwood, a senior lecturer at Ohio State University, wrote, “Virtual worlds offer the possibility of real-time collaboration with no loss of worker time spent in traveling; reducing travel is also cost-effective and beneficial for the environment. As resources dwindle, business and education will look for ways to promote social cohesiveness in organizations, and virtual worlds

offer a rich set of resources for this purpose. The adoption of virtual worlds may be gradual, or it may be sparked by the appearance of a new interface, along the lines of Oculus Rift. Virtual worlds that dispense with the need for a special browser, like Cloud Party, may also play a role in adoption.”

Not everyone is excited about the prospects of limitless video. The CEO of an ISP wrote, “Imagery is generating most of the demand for bandwidth, and entertainment is currently the primary driver. We will soon exhaust the available microwave bandwidth unless we have a technology development that changes the model. What will drive this exhaustion is the ability of ordinary folks to transmit video in real time. The same people who revel in the ability to tweet meaningless drivel will want to do the same with their child doing something silly.”

Theme 3) The connection between humans and technology will tighten as machines gather, assess, and display real-time personalized information in an ‘always-on’ environment. This integration will affect many activities—including thinking, the documentation of life events (‘life-logging’), and coordination of daily schedules.

Mike Liebhold, senior researcher and distinguished fellow at the Institute for the Future, wrote, “Cloud-served supercomputing will enable any app or service to be fundamentally more powerful by the application analytics, sensemaking, and modeling.”

A lawyer wrote, “Video will continue to drive bandwidth growth, but it will be the vastly increased number of devices connected to the networks running machine-to-machine applications, rather than one or two new apps, that will drive the bandwidth needs.”

An Internet engineer and machine intelligence researcher responded, “Will there be new application technology that will pervade everyone’s day-to-day lives? Possibly. Machine intelligence will revolutionize the personalization of information access and management, most very likely impacting medicine, education, and public safety.”

Lee McKnight, a professor of entrepreneurship and innovation at the Syracuse University School of Information Studies, wrote, “Wireless grids edgeware—a new class of software applications for cloud-to-edge services including wiglets (open and non-proprietary) and gridlets will be pervasive as the cloud operating model supercedes the still semantic Web 2.0 business focus of 2013. Gigabit connectivity will permit a wide array of ‘over the virtual top’ applications which will require sophisticated virtual machines and software-defined networks for delivery, use, and creation. Meaning, gigabit home users may stand up their own physical networks for custom games-playing, seeking the ever-elusive technical edge in immersive virtual environments. Likewise immersive massive open online course-like learning will be more popular and powerful with greater bandwidth available. 80% of business services will be capable of being delivered as a

secure gigabit service, whether the worker is home, in the coffee shop, or, gasp, in an office. For home entertainment, ever-more-realistic immersive environments will permit a wide array of telepresent sports and entertainment options; think IMAX at home. Given the still-pervasive role of mobile in 2025, the key issue will be orchestrating enriching and engrossing applications and content that can be accessed and used across a wide array of devices and resources.”

Olivier Crepin-Leblond, managing director of Global Information Highway Ltd. in London, UK, predicted, “Internet Protocol Version 6 will allow for point-to-point, always-on access to each other's data streams—a bit like video mobile telephony, but always on and accessible to groups. The users will be able to turn on/off what services they'd like always on, but video will be the most widely used. How often have you gone ziplining and wanted to show all your friends in real time around the world what you are up to? The ‘status’ on social networking sites or a tweet you send will be replaced by real-time updating without needing to go through an intermediate site. That will cause a real bandwidth crunch at mobile data level.”

Clark Quinn, director of Quinnovation, wrote, “One of the areas I think is still to emerge is adaptive ubiquitous experiences, alternate reality games that capitalize on serendipity to foster emergent engagement. Systems will be much more aware of our context and commitments, and use this to surprise and challenge us via 'hard fun' in experiences that not just entertain us but transform us in important ways.”

John Saguto, an executive decision support analyst for geospatial information systems for large-scale disaster response, wrote, “We are already using gig-level bandwidth as we use HD on-demand video. Entertainment devices are routinely peak-capacity users of incredibly large datasets. These are virtual 3D-modeled worlds and interactive media. It will start slowly, much like video conferencing, but soon expand to user-controlled massive media that will (finally) eliminate keyboards for voice and gestures, thus expanding the market as well as opening up the technology to have real-time translators for expanding communications beyond the present-day thinking!”

Michael Wollowski, a study participant who did not share additional identifying details, wrote, “Going back to systems like IBM's Watson that can intelligently digest large amounts of information, if we pull this information from different sources we can provide intelligent information at a moment's notice. Imagine a digital assistant that is at once an attorney, a physician, a teacher, and many other things. It is going to be a paradise for the curious.”

Marc Prensky, a futurist, consultant, and speaker on technology and education wrote, “One innovation I very much hope will happen is the inclusion of cloud-connected text-to-voice scanners, and voice-to-text printers in all cell phones. If there happens there will be no more

excuse for illiteracy (in the reading and writing sense)—we will just have to distribute all inexpensive phones with these features.”

Bill Woodcock, executive director for the Packet Clearing House, responded, “The high end of communication, as used by adults at work, will continue to become more immersive, using more sophisticated, higher-resolution imaging and image reproduction to convey ever-more-subtle nuances of human facial expression and tone of voice. That may be coupled with agent technology to provide ‘coaching’ to users party to a conversation, side-channels by which users’ agents are providing additional communication beyond what the two users can convey by conversation: backing documents, machine-readable contracts, automatic bidding for goods and services mentioned in the conversation, and so forth, as well as behind-the-scenes analysis of the other conversant’s position, inflection, putative motivations, etc.”

Cliff Zukin, a professor at Rutgers University, wrote, “That would be a pretty simple evolution to imagine, like every three to five years, much less 12. Generations come more quickly in a digital world... And, as we enter the era of big data, there will be more data to sort with an increased bandwidth to do it. We’re headed for more fragmentation and personal targeting as consumers.”

Rebecca Lieb, an industry analyst for the Altimeter Group and author, replied, “One can only hope and pray for significantly increased bandwidth in the United States. It’s vitally needed and critical to the country’s economy. Assuming this does happen, two clear current trends, cloud computing and mobility, will accelerate even faster than they are now. Part of this assumption is that better, longer-lasting power supplies and batteries will create an even greater expectation of always-on, networked devices. Mobility will expand to include a real Internet of Things: household, office, and personal devices.”

Sonigitu Asibong Ekpe, a consultant with the AgeCare Foundation, a nonprofit organization, wrote, “The killer app is this: high-performance knowledge exchange. Gigabit networks can unleash our collective imagination and encourage all manner of ‘what if’ scenarios. The onset of advanced, communication-rich networks and the multilayered applications that run on them promise to break conventional boundaries and propel our world to a true Information Age. Big bandwidth gets us closer than we ever thought possible. It dramatically reduces the barriers to collaboration that distance erects. There will be new applications for digital strategies for market dominance. Tools that will harness the new forces that govern life and business in the digital age and in the gap created by the law of disruption, golden opportunities await those who move quickly.”

Frank Feather, a business futurist, CEO, and trend tracker based in Ontario, Canada, observed, “Bandwidth will become unlimited and basically free to operate. People and organizations will

increasingly operate in virtual space, for work, e-commerce, socializing, and entertainment, mostly using mobile devices and wireless systems.”

Bryan Padgett, a research systems manager for a major US entertainment company, replied, “While the emergence of full video (TV, online video, video calls, etc.) on mobile devices will become common, the well-established players will be the ones who bring that content to us. We will see a complete convergence of phone, mobile, television, Internet, security, and home automation since almost all will be delivered with data networks. We will become accustomed to paying for water, power, and data as ‘standard’ costs of living, dropping separate companies and eliminating the need to pay separate companies and services. I also think we will see more devices connected but not necessarily needing to send massive amounts of data. Home automation will be as common as air conditioning for most locations. For instance, my washing machine may need to communicate with my home automation system so it can run when I scheduled it, but it will not need gigabytes to do that.”

Mark Nall, a program manager for NASA, responded, "Opportunities for entertainment and family/friends connectivity will increase. I'll take a guess here and say that a person could be equipped with multiple (nearly) always-on, unobtrusive high-definition cameras and microphones, touring a city or skiing while streaming an Adobe Illustrator, edited (don't want anything embarrassing) feed to select friends and relatives. Call it Foursquare on steroids!"

Steve Jones, a distinguished professor of communications at the University of Illinois-Chicago commented, “My guesses are that a good deal of this will be related to increased streaming of high-density content (e.g., UHD and its successors) as well as wall-sized screens in homes. Management of personal digital assets will also require advances in storage and transmission as well as apps to curate content.”

Jack Hardy, principal at Niche Public Relations, commented, “Our interaction in this digital era will be through voice commands and motion control. 3D and holographic images and interaction will be the norm. The television, telephone, and Internet experience will be transformed to such a degree that it will be largely unrecognizable from its previous incarnation.”

Will Stuiwenga, information science professional in the state of Washington, commented, “One area sure to have significant advances will be apps that aid individuals in recording and making available (to themselves, and to others, if desired) every detail of their lives: full video recording capability for one's own life, for instance, and the ability to immediately and easily interface with this archival record, search it, replay it, share it, etc.”

Paul Jones, a professor at the University of North Carolina and founder of ibiblio.org, responded, “More visual information that can be scanned and reconfigured and customized for the

needs of the moment will be the hallmark of the next 10 years. Significant increases in bandwidth will remove some of the barriers to that end. Expect this information to be 3D and easily manipulated. Expect a new era of literacies more special than ever available to us.”

Mícheál Ó Foghlú, chief technology officer of FeedHenry, wrote, “Collecting one’s own video life history may become more mainstream rather than the geek sideline it is now. Much of the important usage will come from an ability to process and analyse the data collected, and not just the increasing capacity to capture it.”

Sunil Gunderia, a mobile strategist at an education start-up, commented, “The gigabit age will enable huge advances leveraging predictive analytics to determine what an individual is likely to want to do next. This ‘AI’ will allow personal agents to offer useful real-time information to help decide almost every aspect of your life.”

Patrick Stack, manager of the Digital Transformation Acquity Group, wrote, “The ‘killer apps’ will be less about increased bandwidth capability and more about increased short-range capabilities. Common data formats will be developed to allow phones, kiosks, displays, and other physical items to interact with each other and process experiences accordingly. It will be less about data-heavy applications and more about ever-present software and processing between the physical and digital worlds.”

Andrew D. Pritchard, a lawyer, PhD candidate, and researcher, wrote, “Increases in bandwidth and processing power also increase the number of different types of information an app can integrate into a single interaction, approaching the complexity of the pro-and-con balancing of human decision-making. Thus, it seems likely that the next 10 years will bring increasing numbers of apps that make decisions on behalf of their users rather than merely provide requested factual information.”

Richard James, an information science professional, predicted, “Personal security systems based on real-time monitoring of your vital statistics, location, environment, and visual input via Glass-like applications.”

Clark Sept, the co-founder and principal of Business Place Strategies, Inc., wrote, “One such killer app will be a ‘personal information assistant’—a digital agent that will filter incoming information (news, education, entertainment, lifestyle) in a way similar, but more relevant and successful, to online services such as Pandora or iTunes Genius do today for entertainment.”

Theme 4) Specific economic and social sectors will be especially impacted; health/medicine and education were mentioned often.

Robert Furberg, RTI International senior clinical informaticist, wrote, “As a public health technologist, the greatest area of interest for me is in how applications will facilitate 1) improved self-efficacy of chronic disease management; 2) online health community engagement for social support and higher levels of engagement with an individual's own care, or that of a family member. Major drivers include: the increase in connectivity between individuals via social technologies, passive data collection via wearables, and the Internet of things, the fluidity of information, and new means to analyze and visualize data.”

The CFO for a major Internet company responded, “Besides streaming video and delivery of digital goods (media like books, music, video), the next area of promise is telemedicine. The development of home digital appliances/diagnostics that allow a doctor to diagnose and virtually ‘see’ a patient should take care of most non-emergency medical situations.”

Francois-Dominique Armingaud, a retired computer engineer from IBM now teaching security at universities, wrote, “Whenever new possibilities appear, new ideas come with them to people thinking ‘out of the box.’ IBM succeeded because they understood that mainframe computers would sell by thousands, Microsoft because they understood that personal computers would sell by millions, Google because they understood that Internet users would be billions. However, as usual, perhaps 1% of the adventures around that will be successful. If I had the ideas that will be the successful ones, I guess I would work hard to be a millionaire instead of wasting time on Facebook. So I cannot predict these future ideas, but I am pretty sure that things like TEDx, Coursera and others will be successful. If all Internet providers allowed Internet protocol multicast, democracy could reach new heights, and individual lives as well. Just imagine giving a guitar course online to 18 people or more scattered anywhere at a time.”

Stewart Baker, a partner at Steptoe & Johnson, a Washington law firm, wrote, “The Internet of Things will use growing bandwidth to create a kind of sensory Web that knows where we are and what we are doing at all times. Big data will begin to tease surprising new social and medical innovations from that Web.”

Nick Wreden, a professor of social business at University Technology Malaysia, based in Kuala Lumpur, responded, “Health. Not only will there be 24/7 monitoring of body functions, but surgeons will be able to do operations only dreamed about today. The doctors won't even have to be in the operating room!”

Gary Kreps, director of the Center for Health and Risk Communication at George Mason University, wrote, “New applications will be more engaging and dramatic, incorporating vivid entertainment media for communicating with users. These applications will include vivid visuals, sound, and movement that capture user attention and promote attention and learning. This will be particularly valuable for entertainment, education, communication, and health promotion. These

applications will also enhance interpersonal and group communication by making interactions more vivid with rich multi-channel message systems.”

S. Craig Watkins, a professor and author based at the University of Texas-Austin, responded, “High-end, high-quality communication and video conferencing will change how we conduct meetings, collaborate, share ideas, and create. The real challenge will be if these new applications can transform how resource-poor schools and communities connect to the world, expertise, and knowledge.”

Chen Jiangong, an Internet business analyst in China commented, “Firstly, the new killer apps will be born in the medical field. I believe that distance surgery will become common. Secondly, the services based on emotion will rise because big data will be able to forecast the emotional needs of people.”

Sakari Taipale, a social policy and new technologies researcher in Finland, wrote, “New killer apps will emerge, most likely, in the medical and care work sectors. Domestic technologies that will assist aging people on a daily basis, providing them with interactive connectivity with nurses, physician, relatives, etc., will require more and more bandwidth.”

Brian Butler, a professor at the University of Maryland, responded, “Unless you get the system built right, the technology is more likely to be a chased fad than a true killer app. See, for example, genomics and personalized medicine. While we need to continue technical development the challenge at this point is to build the institutional, professional, and patient skills and practices needed to do something with it on more than a pilot testing level.”

Linda Neuhauser, clinical professor at the School of Public Health at the University of California-Berkeley, responded, “The ‘killer apps’ are likely to be those that ‘zone in’ on handling issues over which people want to have more control. Video is important to model how to make change. Other new tools will be those that are able to manage multiple variables of interest to people in managing their health. Those applications are already available to a very small percentage of people... Once people have discovered that by harnessing multiple personal health factors, it is empowering and those applications are eagerly adopted. Right now, wristbands and other practical ways to access this information are being used by an ‘informed 20% of the population.’ I think that will increase to half of the population by 2025. Wearable monitors will be extremely important by 2015.”

Brad Berens, a senior research fellow at the USC Annenberg Center for the Digital Future commented, “Ultrahigh bandwidth will expand the canvases for education, commerce, and entertainment even more in the near future than they already have. One common statistic, for example, is that only 6% of commerce in 2013 is ecommerce. By 2025 all commerce will have a

digital component, but it will be hybrid online/offline rather than just one or another. However, while bandwidth will be ever cheaper and ever plentiful, another technology to watch carefully for increased development and progress is battery technology. Google Glass, for example, will never be what it can be so long as it is tethered to a two-hour battery life and also dependent on an anchoring smartphone.”

Theme 5) New digital divides may open as people gain opportunities on different timelines and with different tools.

The International Telecommunication Union estimates that by the end of 2014 the number of Internet users globally will have reached nearly 3 billion. Two-thirds of the world’s current Internet users live in the developing world, still, Internet-user penetration is at 78% in developed countries and 32% in developing countries. Globally, there are 4 billion people not yet using the Internet, and more than 90% of them are in the developing world.¹¹

In every country there is a divide between those who have access to the best tools and network connections and those who do not. The US is no exception. Businesses and the public are generally being required to pay their Internet service providers a higher price to get better connectivity to information. A connection to the gigabit Internet can cost up to \$1,200 annually in fees, and the tools to take advantage of that access can add to that cost. Many respondents to this study said they expect a widening divide between those who are equipped to communicate at the premium level and those who do not.

Peter and Trudy Johnson-Lenz, founders of the online community Awakening Technology, based in Portland, Oregon, commented, “On the consumer side, ‘bandwidth to burn’ is usually thought to be most likely used for entertainment and sports ... On the side of corporate, government, science and technology, drug discovery, and other complex institutions, things like big data analysis, visualization, real-time dashboards, environmental monitoring and control (such as smart buildings, etc.), and so on are certainly important apps in the gigabit age. These applications in turn will only be in the common interest if enough people rise up nonviolently and demand public oversight and universal, affordable Internet access. For example, see the new *Community Informatics Declaration: An Internet for the Common Good—Engagement, Empowerment, and Justice for All.*”

Virginia Bird, director of New River Public Library Cooperative, wrote, “We are still waiting for gigabit connections in rural America. Companies don’t want to spend the money on infrastructure to serve few people. There might be killer apps but reach will be limited.”

¹¹ See *The World in 2014: ICT Facts and Figures* from the ITU <http://www.itu.int/en/ITU-D/Statistics/Documents/facts/ICTFactsFigures2014-e.pdf>

Some argued that if it is true that a gigabit network will greatly accelerate change in education and health, then Internet access and use will become more life-enhancing and that means that digital divides can be life-threatening. **David Hughes**, a retired US Army Colonel who, in 1972, pioneered individual to/from digital telecommunications, wrote, “Health and physical welfare monitoring of each and all living Americans, perhaps 350 million by 2025, will require vast amounts of bandwidth, wired and wireless, extending into all homes and places of work. At 85, I am already grateful for the Centronics heart monitoring device connected to my doctors via wireless and, within the house, to my defibrillator, but via the less-than-reliable telephone lines available to widowed me, living alone.”

The head of a department in a state government agency wrote, “There are two digital divides: rural/urban and rich/poor. Rural areas do not yet have bandwidth because the investment is so high and economic returns are so low. Those who are poor are continually more and more neglected and left out of digital advances, especially those whose poverty is the result of poor education and lack of basic literacy skills. In many ways this disenfranchisement is getting worse as government agencies—even those who are supposed to serve the poor—ignore the lack of access and ability to access services.”

An information science professional based in Colorado wrote, “The infrastructure cost to push this connectivity to non-urban areas will be prohibitive and create an even greater digital divide between urban and rural communities. This leads to further inequality in education and job preparedness for rural communities—and, I am sure, added resentment from rural areas toward urban areas.”

Christopher Wilkinson, a retired European Union official, board member for EURid.eu, and Internet Society leader said, “The US is moving into an economic and demographic phase where inequalities result in the majority of the population not experiencing any 'progress' in terms of education, income, or other welfare. I doubt that those folk will be interested in, or able to afford, leading-edge, new killer apps.”

An information science professional who remained anonymous wrote, “My bandwidth concern is mostly that some places are being left behind ... Some rural areas have no Internet access at all. In others, it is too slow to handle all these wonderful new high-bandwidth apps. I’m thinking specifically of Arkansas and West Virginia.”

An entrepreneur and business leader said, “The gap between those whose know of and can afford to use the killer apps and the rest will be greater and greater over time. The knowledge of technology and the way of thinking about reality for those who are immersed in technology will be a second language—even a second culture—shared globally. I also see a gap opening between those who know how to create those killer apps and those who are only prepared to use them intuitively

without metaview of architecture and meaning—technological builders, technological users, and the rest. Multiple gaps between multiple cultures of relationship to technology.”

David Solomonoff, president of the New York Chapter of the Internet Society, wrote, “There is still a very uneven distribution of bandwidth—even in prosperous, technically advanced countries. We may see a lot more innovation in the developing world [outside the US] in the near future because they adapt to wireless mesh networks and leapfrog past countries that are hamstrung by incumbent service providers.”

Karen Riggs, a professor of media arts at Ohio University, responded, “Time and space have been, as we have known it, collapsed in the Internet age. More powerful networks of information flow and tools developed by creative individuals (many in the corporate sector) will create a far more directly networked planet. This does not suggest that power will become equally shared, because powerful corporate and governmental ‘digital haves’ will strive to dominate these channels. Power, however, will not be static and will create new opportunities, as we see now with the growing Internet capacities of China and Google. Positively, human relationships can be positively affected through advances, with the prospect of personal presence far exceeding the technical capacity of Skype and the social practice of Internet dating, for example. I am not a technologist, but it is obvious that ICT [information and communication technologies] advances are careening toward the immersive and transformative. As usual, creative tensions will be at work between those who introduce and initially control implementation of technologies and those who constitute the users, who historically have adapted technologies for their own purposes and in the result have altered design itself.”

Tim Kambitsch, an activist Internet user, spoke of a different sort of digital divide. He wrote, “Content access will be effortless if the content can be found. With the explosion of new content escalating at a rapid pace, the strategies for identifying what is worth viewing, reading, listening to, will be more important than any future increase in bandwidth. The digital divide will switch from those with or without bandwidth to those with or without the capacity to navigate and acquire the right content. The cost of content is an important part of the equation, so copyright and intellectual property rights may be the defining difference.”

If people work together, advancing technologies are likely be used in collaborative efforts to bridge some divides, some of these experts believe. **Stacey Higginbotham**, a Texas-based technology writer and frequent blogger for GigaOM, commented, “In terms of schooling and work, it could happen in your home, which could change the way homes are designed in order to offer privacy and minimize distractions. If you take gigabit networks and software-defined networks, you could parcel out elements of a home network to serve as a neighborhood-shared network that might aggregate video camera views and info outside people's homes or provide connectivity for ambulances and public safety when they are driving through. You could even view millions of

gigabit homes containing hundreds of computers (actual computers but also smart appliances or set top boxes) and run software that aggregates them, creating a neighborhood data center. Imagine everyone running the equivalent of a SETI@home program to provide compute capacity for a charity or even a corporation.”

Theme 6) Who knows? ‘I have no idea due to rapid change.’ ‘The best Internet apps are yet to emerge.’ ‘If I knew, I wouldn’t tell you, I would invest in it!’

Garland McCoy, president and founder of the Technology Education Institute, responded, "If I told you of my killer apps I would have to kill you—just kidding. Obviously the Internet of things, IPv6, etc., have not yet kicked in but when they do, look out. There will be machine-to-machine communications, radio frequency identification—all is possible. And if you can back haul with fiber quickly you free up spectrum, so there will be micro transponders everywhere.”

A top leader at the Internet Society wrote, “I don’t think we can predict innovation between now and 2025. No one could have predicted the similar advances in the past period.”

Robert Bell of IntelligentCommunity.org responded, “I have absolutely no idea what they will be. I was once consulted on the creation of a conference on gigabit applications and advised the organizers that no one would be able to address the topic because there are no gigabit applications. They didn't believe me until they checked and found out I was right. But leaps in bandwidth have triggered explosions of online creativity each time they have happened, and there is no reason to think it will not happen again.”

A computer science and security professor at Purdue University wrote, “If I knew what the technologies were I’d be investing and inventing them! Increased capacity always leads to new developments. However, issues of Internet protocol, security, and social stratification will all have an effect. Given the ossified business models of most Western telecom providers I would expect that some of the real innovation may come from other sources.”

Munir Mandviwalla, an associate professor and chair of the business school at Temple University commented, “My generation grew up with the screech of the telephone modem, we are 'genetically' limited in our thinking about how to use gobs of bandwidth. My son’s generation is the always on excess bandwidth generation. They will have ideas that we cannot think of.”

Micky Hingorani, program manager at AVAC, which does global advocacy for HIV prevention, wrote, “If I knew, I'd be working on it right now.”

Amy Crook, an assistant in the IT department of a large public accounting firm, responded, “I don't know what these tools will be, and can't imagine the new immersive experiences that await us. If I knew how to dream up the next big thing, wouldn't I be lucky?”

Justin Reich, a fellow at Harvard University's Berkman Center for Internet and Society, said, “If I knew, I wouldn't be telling you; I'd be making a killing! I'm not sure what creative new ideas people will come up with, but I suspect they will.”

Fredric Litto, a professor emeritus at the University of Sao Paulo in Brazil, responded, “Yes, but I cannot identify them at this time, for, if I could, I would be actively involved in setting up one or more startups to make them come about. But as long as there is money to be made in innovating products and services, society as a whole will be benefitted. Optimism in this sector is easily justified.”

Theme 7) Advances will be gradual for various reasons: Bandwidth is not the issue. The US will continue to lag by 2025 because a widespread gigabit network is not easily achieved.

A number of respondents to this study responded in various ways to indicate that they do not think it likely that a gigabit network will enable new, different, and wondrous things by 2025.

Dave Burstein, editor of Fast Net News, basically predicted that by 2025 more people will be connecting through mobile devices to goods and services “in the cloud.” He wrote, “One ‘app’ that already exists but is not pervasive is likely to become crucial to most people. I do most of my work on Google Drive in the ‘cloud.’ I'm starting to put my music there as well. I'm writing this 2,000 miles away from home and it's as smooth as though I'm on my own machine. Nearly all of us will carry Internet-connected ‘smartphones’ and it will be so convenient to access our stuff that we'll move much of our work and life to the ‘cloud’ as we have better connections.”

Ian Rumbles, a technology developer and administrator, said, “One of the challenges that still exists is access to reliable high-speed wherever you go. So possibly it is an infrastructure change that will really explode the use of technology and the new apps.” A pioneering academic computer scientist from Princeton University agreed, writing, “Currently access to reliable high bandwidth is spotty. Some people have it at home, but we can't rely on having good bandwidth everywhere at all times. The biggest change going forward is that we will have good bandwidth available more often. This will make new types of system architectures, which assume connectivity, possible.”

Thomas Lenzo, a self-employed consultant in the areas of training, technology, and security, wrote, “I don't see any killer apps. I do see modifications and improvements of the various apps we now have or that are in development.”

Jerome McDonough, an associate professor at the University of Illinois, responded, "A 'killer app' has traditionally been considered an application which was sufficiently compelling to drive the uptake of a new device in both the business and the personal markets. Killer apps are very hard to develop in the face of a massive installed base of devices, which is what we have now with personal computers and mobiles. And to date, most of those devices do not fully exploit even their existing bandwidth capacity. If there are killer apps to be found they will probably involve networking devices which are not currently employing network capabilities at all (e.g., cars and appliances), but significant advances necessary to develop a 'must-have' application in those domains also confronts the installed base problem as well as the need for standardization of communication protocols. I don't see that happening in a 12-year time frame. And I'm not sure any of those will really require significant bandwidth increases."

The vice president of research and consumer media for a research and analysis firm responded, "With the rapid digitization and delivery of high-quality video and large databases by 2025 we'll have reached the last of all current applications that have been moved to the Net. There are no kinds of information that are going to require large quantities of speedy bandwidth. Future applications will be relatively compact or about the size of current applications: imaging, 3D printer files, communications, virtual reality."

A browser engineer for Mozilla wrote, "Gigabit-per-second links are not going to enable anything significant. Telepresence will be better but not significantly so." An Internet pioneer who has been in the field since the 1970s wrote, "We have enough now!"

Thomas Haigh, an information technology historian and associate professor of information studies at the University of Wisconsin, responded, "Twelve years is not that long, and killer applications do not arrive very often. Recent popular applications like social networking and Twitter were not particularly related to advances in network bandwidth, though they did benefit from network ubiquity and personal devices. Streaming video has matured with higher bandwidth, and will continue to benefit from it, but that's hardly unique and compelling."

Manuel Landa, the CEO of Urban360, a Mexican start-up, wrote, "More bandwidth will create incremental improvements in certain areas, but overall it is going to be similar to digital photography, where the real improvement from an 8 megapixel camera and a 32 megapixel camera is irrelevant for most of the people."

Peter McCann, a senior staff engineer in the telecommunications industry, responded, "The bandwidth-intensive apps that exist today (media streaming, telepresence, etc.) will continue to be the primary consumers of Internet resources in 2025, although they will be packaged in easier-to-use formats and new rights-management frameworks will evolve."

Liam Pomfret, a PhD student in online consumer privacy at the University of Queensland, Australia, responded, "While I think it's likely that we'll continue to see great strides being made in mobile and wearable computing, I don't feel these will be anything but incremental advances of the technology already being presented with Google Glass."

Governments' goals, Internet service providers' motivations, and evolving standards were seen by some people as key hurdles to the evolution of better connectivity and new applications.

A post-doctoral researcher wrote, "The same actors who are fighting against Net Neutrality or peer-to-peer technologies will also be concerned about the increase in the bandwidth. Online piracy, for example, will be unstoppable and more the norm with increased bandwidth. Communication networks like AT&T and others will have reasons to fight change or at least negotiate it in their favor."

Vytautas Butrimas, chief adviser to a major government's ministry, with experience in ICT and defense policy, commented, "The big question mark is how far government-surveillance apps will go and at what cost to society."

Fernando Botelho, a social entrepreneur working to enhance the lives of people with disabilities wrote, "Speed can enable qualitative changes in the way the network is used, but real innovation requires widespread experimentation and the type of decentralized and thriving ecosystem that only factors such as network neutrality and truly open standards can enable."

Dominic Pinto, a trust and foundation manager active in the Internet Society and IEEE, commented, "It's unpredictable other than to say that people will continue to develop apps, Microsoft and others will continue to develop ever-bloated programs, services and apps, and governments and bureaucracies will want more and more online, and more and more monitored and controlled. And there's as much interest and demand in the private sector as well as the spooks."

John Anderson, director of broadcast journalism at Brooklyn College, wrote, "This question premises 'significant increases in bandwidth' between now and 2025. It bears remembering that, as a part of the Telecommunications Act of 1996, telecommunications companies promised to invest hundreds of billions to build out that 21st century communications infrastructure we say we need. But we're still waiting on that, and even today network development isn't really about investing in infrastructure: it's about maximizing profits on what there is, most notably through the notions of tiered access and data discrimination. Broadband isn't even ubiquitous yet; how long do you think it will be until gigabit is?"

The director of an entertainment media coalition wrote, “Innovation has almost always trumped bandwidth and spectrum scarcity, but this dynamic may not last forever. Take for example, the mobile space. Verizon and AT&T’s growing duopoly over the wireless market may drive up costs for consumers. Worse, these companies (as well as wireline ISPs like Comcast) are imposing caps, charging customers extra if they use more than a small amount of data per month. Of course, these companies would allow data delivered by their own applications and services (or those of their preferred partners) to not be held against caps. As Cardozo Law School professor Susan Crawford writes, ‘Data caps are excellent tools with which to make as much money as possible from an existing monopoly facility.’ That’s not good for competition, consumer pricing, or innovation. There’s also the issue of whether unlicensed spectrum is available to research and development that could usher in the next wave of networked innovation. Voluntary spectrum auctions and repackaging may create some opportunities, but that remains to be seen.”

Jonathan Sterne, a professor in the department of art history and communication studies at McGill University, responded, “This is an infrastructure question. Will new lines be put down that can accommodate massive increases in bandwidth for average users? The year 2025 is only 11 years away—that’s not enough time for a complete overhaul of the telecommunications infrastructure.”

Natascha Karlova, a PhD candidate at the University of Washington Information School, wrote “Significant increases in bandwidth—? US consumers pay more money for slower Internet than most industrialized nations. Besides, in 2025, bandwidth doesn’t matter—data service does. It’s all about mobile.”

Some said “bandwidth” isn’t the issue.

Fred Hapgood, a self-employed science and technology writer, responded, “Bandwidth is not a limiting resource. We have enough bandwidth right now to take care of the big applications in prospect, such as smart homes. The barrier is all in software and standards and the price of implementation. I don’t think holograms are going to prove to be a very big deal. 3D never has.”

Bob Frankston, Internet pioneer and technology innovator, responded, “Using ‘bandwidth’ is the wrong framing of the question. That’s like asking if more railroad tracks will ... oh never mind! This question is so retro that it’s stupid. It’s like asking about thicker dictionaries. This fixation on bandwidth misses the entire point of the Internet!”

Raymond Plzak, former CEO of the American Registry for Internet Numbers, and current member of the Board of Directors of ICANN, wrote, “Just as the envisioned killer apps of the 1990s did not appear in the form that the conventional wisdom of the 1990’s anticipated, to a certain extent that is still true. For example no one really predicted that television advertising

would, instead of being supplanted by Web-based advertising, surpass it and in fact become a major way of getting to the Web-based merchandisers. One can expect continual adaption and evolution in the way people live and conduct business and leisure to be the norm and not a true killer app despite what the promoters of popular social media sites might say to the contrary.”

Dave Rustin, a digital serial entrepreneur and former digital global corporate executive, responded, “Fiber optics is the enabler. The largest bankruptcy in telecommunications history is just a slight example of how picking up oceanic fiber optic capacity shifted economies, education, and learning. Having oceanic fiber strands bought for pennies on the dollar enabled off-shoring to occur. Off-shoring had less to do with trade agreements or policies as it had to do with cheap, available optical bandwidth. Only a fool or someone psychic can say what 2025 is or ‘killer applications’ will be—they have yet to be created. They will be created by better education systems, public/private collaborations in research and development with universities and corporations, and university start-ups. Advancements by way of technology applied in capital formation are desperately needed whereby the access to capital is not through the old angel, venture capitalist, and PE paradigms of today.”

Tim Mallory, information science professional, responded, “Just faster speeds will occur, possibly by multiplexing bandwidth paths. It will seem new, but it will all still be ones and zeroes. A real breakthrough would be to find a replacement for binary code. Experimental science and information theory, though, predict that one ‘bit’ is the smallest information quantum. This does apply to sequential media—but what about analog and quantum processes?”

Mike Caprio, software engineer for a consulting firm, responded, “There will be no significant increases in bandwidth in the United States between now and 2025 if the current state of affairs is not completely disrupted. The monopolistic corporate oligarchies of telecommunications providers will not allow it.”

Will enhanced interconnectedness lead mostly to video entertainment on steroids? **Rex Cornelius**, retired Information science professional, wrote, “Application development since the 1990s has been driven by use of devices for entertainment. I can imagine further development, but not a new distinctive use for bandwidth.”

Jim McQuaid, former chair of the Benchmarking Methodologies Working Group of the Internet Engineering Task Force, responded, “The idea of ‘killer apps’ is overrated. However, if we succeed in increasing bandwidth to the home sufficiently, television as we know it will end. Broadcast is likely to be overcome by Internet-based television and movies.”

Michael Maranda wrote, “I expect change to be incremental. Part of it is a failure of imagination and a desire for entertainment and escape. More video sharing and more gaming? These are not

impressive. We're not building the infrastructure in a creatively open way nor are we cultivating the technical skills to manipulate an open infrastructure. The absence of these keeps technological change beholden to old models of revenue generation and locked down networks.”

Ben Fuller, the dean of sustainable development at the International University of Management in Windhoek, Namibia, commented, “Gigabit connectivity will mean the ability to both collect and transmit a lot of data in real time. The key question will be whether or not apps will be able to take that incoming data from a large array of sources and put it all together in meaningful ways so it can be transmitted back to users. Or, will it be just multiple streams of *The Simpsons*? Associated with computing power will be the technologies that underlie immersive media experiences. If someone can get interactive 3D technology right, then a wide range of applications becomes possible. I can see major opportunities in many fields, like education and medicine.”

Big-Picture Responses: Part 2

A range of input by some responses covered ground not related to the themes highlighted above.

‘Information underload’ problems will be solved

Warren Yoder, executive director of the Public Policy Center of Mississippi, wrote, “There is now a significant information underload (as opposed to an overload.) We can't get our stuff to do what we want. We can't discover the people who could help us when we need the help. We can't get situated intelligence to refine our questions in a way that would relieve our situated ignorance. Our need-to-control reach is steadily outpacing our information grasp, and the gap is the greatest it has been since the beginning of the information age. The gap is felt as an ache that shiny cannot touch. What the killer app will be, I have no idea. Can we link our 3D printers to our brainwave scanners and produce a built environment for our deepest desires? Not by 2025. But a gap this big will call forth remarkable applications.”

The first war of nation states against corporations

Judith Perrolle, a professor at Northeastern University, based in Boston, wrote, “Texting and tweeting will be replaced by 3D video ‘face-to-face’ communications that are not limited to two participants. People will regain the use of their thumbs for other purposes, as they experience the electronic co-presence of their family, friends, co-workers, boss, merchants, advertisers, spammers, stalkers, and government surveillance personnel. Dissident groups will experiment with coded text messages in the scenery and musical backgrounds. The Internet of Things will take an ugly turn as hackers, cyber security SWAT teams, advertisers, and terrorists run amok through citizens' and nations' refrigerators, heating systems, power grids, and pacemakers. A sub-specialty of lawyers will arise to deal with Internet-connected objects' product liability, in turn giving rise to laws absolving manufacturers of fault. Problems with rogue nanobots and genetically engineered diseases will dwarf concerns about the Internet. The monopolization of the world's food and fresh water resources by a small group of countries will lead to the first war of nation states against corporations. Renewable energy resources will be nearly universal; sustainable manufacturing and lifestyles will be the norm.”

‘Precognition’ apps might emerge to help people make better choices

Annette Liska, director of design at a research/design firm, said, “Connectivity can be understood in different ways: that which is mediated by technology; that which is not; and a hybrid of the two. The best apps of the future will likely be a hybrid. One interesting area of cognitive research is pre-cognition, or things that lead to our responses or decisions before we act on them, even in the space of a nanosecond. A tool that intelligently and graciously recognizes our likely choices and behaviors (without overloading with information), then allows us to modify our choices based on a predictive outcome of those choices could play a key role in self-awareness,

self-development, empathy, creativity, and our fundamental desire to a) feel connection to others and b) to be wise more than impulsive. The feedback loop will likely be visual in nature. This tool will likely use sensors and be implanted, but only turned on when desired (full immersion in technology is, for the most part, not a healthy or desirable quality of being human). This concept speaks nothing of the potential for misuse or addictiveness.”

New forms of addiction and theft ... and people will ‘redefine what a “thought” is

Karen Landis, user experience team leader for Belk.com, a department store, wrote, “Implants and wearables will replace tools we carry or purchase. Technology will be biological in the sense that those who can afford it will ‘receive’ it as children. It will be part of our body and our minds will not function well without it. We will be dependent on it. There will probably be new forms of addiction and theft. It will also redefine what a ‘thought’ is, as we won't ‘think’ unassisted.”

‘The operating system will be integrated into the human body’

Anita Salem, a design research consultant, responded, “The operating system will be integrated into the human body. I predict killer apps that control objects through thought, drug implants, virus detectors, stimulants and narcotics, super powers (X-ray vision, super hearing, self-emitting light), instant communications, virtual reality games, privacy and identity hiding tools, virtual pornography, robotic pets, robotic personal helpers, virtual wars, forced sterilizations, or birth control.”

‘Personal pico power’ will arise

Rui Correia, the founding director of Netday Namibia, a nonprofit supporting information and communications technologies for education and development, predicted, “Wearable communication technologies—an effective convergence of the computer and the communication device, with significant attention to the use of personal pico power—the cost-effective *personal* use of renewable power generation to support such technologies.”

‘Big data will become user friendly’

Mary Joyce, an Internet researcher and digital activism consultant, commented, “Big data will become user friendly. Users will be able to track their health, social networks, and productivity using the data collected about them, though they'll likely be forced to buy it back or pay to access it. Companies that currently monetize social and productivity infrastructure in the cloud will monetize the data they have created about their users, but as retail consumer goods, not as business intelligence.”

Turning to the power grid to open avenues for Internet connectivity

Lillie Coney, a legislative director specializing in technology policy for a member of the US House of Representatives, commented, “There are two challenges: universal access to high-speed broadband and applications that are easier to access and use. Internet access should be treated like a utility. Municipalities should construct them and the Federal government should cover areas outside of large metropolitan areas. Moving across the country or world while using or accessing communication media should be seamless. Bandwidth and infrastructure are the challenge to high-speed digital communication systems. The largest potential high-speed bandwidth carrier already in place is the electric utility grid. Solving the problem of using it to send communication is not simple, but if solved would open up many avenues for broadband high-speed access for rural and some urban areas. It would also add value to electric utility infrastructure upgrades that are underway. This would create a new wave of innovation and a new class of technologies. The digital information age runs on power so another important step that must be overcome is energy retention. Storing power for indefinite periods would reduce dependence on a range of energy sources and allow greater reliance on renewable sources. A lot of power is lost because it cannot be stored so the architecture is to generate much more than is needed. Battery technology is much further behind than the innovation of new devices. Solve the battery problem and you can solve access, reliability, and stability issues with digital technology. One early indication of how digital technology is changing people or society is to ask ‘How well can young people engage with others in person? How comfortable are they in speaking publicly? How well can they articulate their feelings or beliefs to others even those they know very well?’”

‘Mind control’ might be the killer app

Mikey O’Connor, an elected representative to the GNSO Council, representing the ISP and connectivity provider constituency at ICANN, commented, “There will always be applications (new and old) that consume more bandwidth. Some of those will be completely nifty. But ‘distinctive, and uniquely compelling’ is a high bar. I have two words for you. Are you listening? Mind control. That’s the ticket—solve that one and you’ve got the world by the tail. It may be that it’s already been solved, but there will be loads of opportunity in making it ever more effective.”

‘Supplying the very data that will be controlling’ the future

An anonymous respondent wrote, “Unfortunately, I have to respond in the affirmative, which does not bode well for the citizens attempting to maintain/establish those controls they seek for their ‘private’ life. In the next 12 years the ignorant, uninformed, and uneducated will continue to view the so-called ‘apps’ as life benefits/enhancements. Little do they realize that by submitting to the interminable ‘rules’ these ‘apps’ contain, they are supplying the very data that will be controlling them into the future.”

Interfaces will change—‘air becomes our desktop’

Ken Elmore, audience research and development strategist, wrote, “By 2025 I can see physical devices, like tablets and phones, replaced by virtual floating displays produced by wearable media such as watches or headgear. The air becomes our desktop.”

‘It will be a social taboo to not be connected’

Pamela Wright, the chief innovation officer for the US National Archives, wrote, “Products like Google Glass will improve to the point where people will consider these kinds of wearable tools as necessary as wearing items such as shoes. It will be something of a social taboo to not be connected. Having to hold up something as clunky as a smart phone to take a picture will be unimaginable for the next generation.

When work takes place in alternate environments we could reach a tipping point

An anonymous survey participant responded, “Immersive environments will become even more compelling, and people will begin spending more and more of their time in these environments. A tipping point will be when a significant portion of our population begins not just to play in these environments but to work in them. As that happens, the need to interact with actual reality begins to diminish, which will have major impacts on its own. By 2025, we'll see that start to happen.”

Look for innovation in data storage and information processing

Oscar Gandy, an emeritus professor at the Annenberg School, University of Pennsylvania, wrote, “While it seems likely/necessary for increased bandwidth for transmission, problems of storage will arise, so we should expect more innovation in the area of information processing that reduces the need for bandwidth for many routine operations.”

Diversification of apps is more likely

Niels Ole Finnemann, a professor and director of Netlab DigHumLab in Denmark, replied, “The main developmental trend will be diversification. We will see many new apps, which will be popular in their area. An area of exception from this is entertainment, where some global players may create global events supported by new apps, as for instance related to the Olympics. Focus will increasingly be on the supportive role rather than the IT centric focus of today.”

A culture ‘primed to be sold and sold out’

A self-employed software designer and policy researcher wrote, “My answer depends what you mean by ‘apps’—a term that annoys me no end. Yes, I expect that a significant proportion of software development will continue to be indiscriminately resource-intensive, and increasingly so, without considering the economic or environmental costs, let alone the built-in exclusions. ‘New,

distinctive, and uniquely compelling’—whatever. Each new thing builds on what came before it, whether we're talking about Apple products, surgical tools, *Angry Birds*, Google Maps, or electric cars. Those adjectives describe not the products but how the products are marketed. You have developed a culture that has been primed to be sold to and sold out, and a ruling private industry that is phenomenally gifted at making the most of that and at continuing to perpetuate that. So, sure, Americans will likely think that they are encountering new, distinctive, uniquely compelling technologies that they can't resist and must have and that they must convince all of their friends to buy.”

Restructure communities as ‘peer-to-peer collaborations’

Marcus Cake, a network society content architect and strategist with WisdomNetworks.im, wrote, “Bandwidth is almost irrelevant. There is enough to achieve singularity or the ‘shift’ to the next stage of economic development. Bandwidth speeds up the status quo and exacerbates its flaws. Bandwidth may actually empower the status quo. The killer app between now and 2025 is to restructure society into peer-to-peer networks. The community (or crowd) has been building the foundation for distributed prosperity for decades—the first three elements data (Internet 30 years), information (World Wide Web 15 years), community (social networks 10 years)—the next three elements to be distributed are collaboration, knowledge, and wisdom. These will be achieved in less than five years with wisdom networks. In the Information Age, our technology allows point-to-point communication. Reach increased from near to far. Speed increased to instant. Our society developed tools based on point-to-point communication that included hierarchies and centralized knowledge and decision-making. The Internet has sped up the status quo with negligible productivity benefit. These tools don’t scale and are failing to deliver global prosperity, productivity, or equality. If we restructure communities from point-to-point communication and its centralized form in the physical world to peer-to-peer collaboration and distributed contribution over the Internet, then it solves huge problems resulting from Information Age structures and delivers a new era of productivity, growth, and distributed prosperity. Wisdom networks are an elective singularity and reshape the status quo using the peer-to-peer structure of the Internet and achieving a rapid jump in productivity, potential output (18.2% to 55%), productive work time (28% to 50-75%), and usher in the new era of prosperity. This is the overdue third revolution in economic development. I predict that distributed prosperity will be enabled in less than two years with less than thirty networks and 900 people and it will transform the world within five years. Citizens will demand societies are organized like Facebook.”