Written statement

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Thank you very much for the opportunity to present some observations as a part of this workshop. There are four points that I would like to make that bear on the FCC mandate to prepare a broadband plan for the United States. In summary, they are:

- Broadband deployment is not a one-time objective, but a continuing process. I will argue that the goal of the FCC plan should be *sustainable broadband.*
- Over the lifetime of any such plan, the nature of the Internet may change greatly. I will catalog some of the driving forces for change, and describe some of the possible outcomes.
- Not only may the Internet change, but the structure of the industries that implement it may change as well. While some actors such as facilities owners seem to have a somewhat static form, the Internet value chain is highly fluid. This fact has implications for any plan that attempts to influence the future by shaping the incentives and obligations of specific actors.
- As we finish the job of getting some form of broadband available to all households, we will need to shift our attention to the question of why almost one in four citizens report that they do not use the Internet. This fact, and not just the unserved population, is and certainly will be the ultimate limit to broadband uptake.

Broadband deployment is a process

The task of the FCC is to develop a national broadband plan "to ensure that all people of the United States have access to broadband capability and [to] establish benchmarks for meeting that goal." While this text can be taken with more or less specificity, the reference to a *goal* might suggest that this objective is a one-time event: a finish line to be crossed after which success can be declared. Nothing could be further from what is actually needed. The deployment of broadband must be seen as an ongoing process, not a one-time conversion.

Broadband service is part of the computing *milieu*, which (at least until Moore's law stalls) advances at an exponential rate that gives us a factor of ten in performance about very five years. Broadband, if it is not to be the sea anchor for Moore's law, must match that rate of advance, and it must *keep on* doing it. So far, residential broadband has done a reasonable job of matching that pace: around the turn of the century broadband seemed to be a megabit or so, and now high-end products easily exceed ten megabits per second, if they have not (at least in the U.S.) reached 100 mb/s. An effective broadband plan must ensure that this sort of improvement continues appropriately. (And speed is not the only measure of progress—only the

most obvious). Broadband deployment is capital intensive, so the future of broadband depends on business models, incentives to invest, and the like.

I would like to suggest a term to describe the goal of the U.S. plan: *sustainable broadband* or *broadband sustainability*. In the larger context of economic planning and development, the goal of sustainability is now seen as a core objective. One-time infusions of money are often not effective—ventures launch but falter once the money is used up. We could see the same sort of failure if broadband deployment becomes a one-time event.

In 2002, the Computer Science and Telecommunications Board of our National Academies released a report on residential broadband titled "Bringing Home the Bits". In this report, for which I was one of the authors, we drew two relevant conclusions. First, we found that there will be substantial geographical variation in the nature of competition, and concluded that policy makers should anticipate that facilities-based competition will not occur in all places and should therefore fashion appropriate policies to address these gaps. Second, we proposed a dynamic definition of broadband that is consistent with the idea of sustainability. We offered two definitions:

Definition 1: Local access link performance should not be the limiting factor in a user's capability for running today's applications.

Definition 2: Broadband services should provide sufficient performance—and wide enough penetration of services reaching that performance level—to encourage the development of new applications.

At any given moment, these two definitions could be mapped to specific technical parameters, but those numbers would change over time.

According to these definitions, a broadband plan, to be sustainable, should strive to meet definition 2, not just definition 1. A plan that achieves only definition 1 but not definition 2 will stifle innovation, and stall the larger milieu of innovation and advancement.

Implications for the FCC broadband plan

Because broadband will take different shapes in different locations (factors such as penetration, competition, and improvements over time), any effective plan must deal with the uncertainties and disagreements about these issues that have marked our past telecoms planning. For example, is promoting competition and reducing regulation, as stated in the preamble of the Telecoms Act of 1996, always the right approach to sustainable broadband? Is this true for rural areas and tribal lands? The stimulus plan is certainly not free of regulation, as it imposes network neutrality obligations on the grant recipient. Perhaps in rural areas, regulation is replacing competition as the tool of choice. Is this a good plan? Will this lead to sustainable broadband in rural areas? I ask these questions honestly. I am not confident about the answers. However, the FCC will have to take some sort of

position as part of their planning. I will offer the tentative conclusion, echoing the CSTB report I mention, that the goal of sustainable broadband will require different approaches in different contexts.

Because sustainable broadband is a process, a plan should not just be based on one-time metrics such as "percent unserved", but should look at rates of change and other dynamic measures of progress. Progress can be assessed using measures such as rates of increasing peak capacity, shifts in the landscape of competition , costs to consumers and rates of capital expenditure, as well as counts of homes passed.

The Internet is not a fixed and finished technology

By one measure, the Internet is perhaps 35 years old—young by the standards of the "old" telecommunications industry but very old by the standards of almost any other part of the IT sector. While the Internet has been a great success, we can catalog a number of forces that might trigger change, perhaps rapid and dramatic.

Parts of the Internet do change rapidly. New applications like Napster, Facebook or Twitter emerge in months. The Web was first conceived in 1990, and established its position as the application of the future in perhaps 5 years. On the other hand, some things happen slowly. The initial deployment of residential broadband is probably more than a decade project (starting perhaps around 2000), and we may argue forever about the transition from IPv4 to IPv6. Games (and the game industry generally) took off like a rocket, but VoIP has been over a decade in its growth.

These stories (and the reasons behind them), taken collectively, illustrate an important point. If we try to imagine the Internet of 10 years from today, we can extrapolate certain aspects and be somewhat confident about the prediction. Residential wireline broadband is not likely to undergo a revolutionary transformation, because there is not enough capital to sustain such a revolution. Wireless in some forms may have a low enough cost of deployment to allow for a major transformation. At the other extreme, it is really hard to guess what the application landscape will look like in ten years. Futurists dream, but not consistently.

Drivers of change

Better security: The requirement for better security is well recognized, but how this requirement will be met is not clear at all: there are many paths to the future. The government may choose to play a more active or more passive role, some event may heighten even further the calls for action, and so on. Further, the range of issues that are lumped under security are diverse—indeed there is actually no agreed definition of what "better security" might be, even though there are loud calls to implement it. Objectives include the elimination of nuisances such as spam, improved availability, prevention of espionage, protection of user privacy and identity, and protection of the network itself from attack.

While the path forward is not clear, examination of current research suggests at least some of the ways in which the Internet might change in response to these objectives:

- A greater emphasis on identity, and requirements or expectations that various sorts of service providers track these identities and take on some aspects of a policing role.
- A change in the way route computation is done, to make the infrastructure more stable, diverse and resilient.
- An increased use of *Virtual Internets*, which will break the current open world into more closed communities of trust, with limited modes of interaction among these different communities.
- Changes to the current end-node protocols such as IP and TCP to give the end-nodes greater abilities to detect failures and attacks and to trigger a response to them.
- An increased emphasis on the security and assurance of *information*, as opposed to simple communication.
- Redesign of the Domain Name System (the DNS) to improve availability and resistance to attack.

Better and easier network management: The problem of network management may seem like one that is restricted to large service providers, but anyone who has struggled to configure and debug a home network will agree that even small networks are hard to manage. Again, the path forward is hard to predict, but we can see the outline of possible changes:

- Redesign of the automatic host configuration tools to include auto-configuration of management.
- Redesign of existing transport protocols to include better tools to diagnose problems.

New sorts of computing devices: Today, the focus for network access has been on higher speeds, which (along with a bundle of related features such as "always-on") are referred to as "broadband". The goal of broadband is driven by higher-speed end-nodes (e.g. PCs), and more demanding applications, including video and audio as well as "the Web". This trend will continue. But at the same time, we will see the emergence of devices that are smaller and cheaper: sensors and monitors, actuators, and the like. The emergence of *sensor networks* will create a new set of requirements for access, characterized not by speed, but by high ubiquity, high availablity and very low cost. It is unclear today what industry will emerge to deliver this sort of access: the user himself (operating a home sensor network), a descendent of a cellular provider, a descendent of an Internet Service Provider, or some totally new industrial actor.

An examination of application areas such as health care or energy conservation will illustrate that speed is not the only dimension of access. The ability to deliver health monitoring to a rural patient may be a key component in allowing that person to

continue to live where they choose. This sort of sensing may not require higher speeds over time, but will stress other dimensions of the access service, such as ubiquity, cost and reliability.

Mobility and wireless: The emerging importance of mobility and wireless is so well-recognized that it might be taken as a given. However, it is important to catalog the ways that the Internet might evolve in support of mobility.

- Improved "Internet roaming", which will require a redesign of how the Internet does addressing and forwarding.
- An increased emphasis on application design that can deal with intermittent connectivity, rather than an "always-on" modality.

New applications and their implications: Applications such as Facebook signal a major transformation of the Internet: the online embedding of the social context. They incorporate into the online experience the social context of the users, and allow that context to shape that experience. The modalities of the Internet will morph from simple *communication* among users to a rich, heterogeneous shared experience. This will have two sorts of implications. First, as the online social context emerges as a platform for further application development, there will be arguments about what policies, if any, should be applied to this platform: issues like privacy, openness, or international harmonization. Second, the nature of the social interaction may change the lower layers, if perhaps only in subtle ways such as the movement away from *communications* to *dissemination.*

Implications for the FCC broadband plan

If the broadband plan narrowly focuses on deployment of high-speed access to the citizen, it may be adequate to offer guidance for a small number of years, but that focus will run the risk that it is rendered obsolete by changes in what broadband is. The broadband plan must be positioned within the context of a larger conception of where the Internet is going. Almost all of the changes mentioned above might change the nature of what broadband access is, and how that service is provided. Future debates about "neutrality", for example, might revolve around whether the consumer should have equal access to competing management service providers or security service providers. If route computation is no longer the exclusive responsibility of the facilities owner, should the consumer have equal access to all "route computation providers"? To what extent will policy and regulation have to concern itself with other advanced services such as mobility? Access networks for sensors will raise the same issues of ubiquitous coverage in rural areas, and as well potential requirements for sorts of neutrality we do not even understand yet.

Dynamic industry structure

Changes in the Internet may exploit technical advances, but it is not primarily technology that drives change. The major drivers of change include economic and social factors, and innovation at the level of the user experience. Since economics

and investment are major drivers, we should expect that as the Internet itself evolves, the industry structure that creates the Internet will change as well. The concept of "Internet Service Provider" is only about 15 years old, and has mutated within that time, changing from pure overlay providers to providers that may own their own facilities. The layering of the industry—who owns physical facilities, who provides which services—is not stable and mature. While facilities ownership seems to imply a certain stability (due to the sunk capital), proposals such as virtual Internets (mentioned above in connection with security) have the potential to split the traditional facilities-based provider into two layers (somewhat similar in its implications to a virtual form of facilities unbundling) which will shift both the economic structure of the industry, and the ability of the facilities providers to implement various possible sorts of policy objectives. Above this capital-intensive layer, most parts of the Internet value chain are highly dynamic.

These dynamics are important to the extent that the FCC plan addresses any objectives other than simple deployment of facilities. For example, a broadband plan might be scoped to include national objectives for the broadband infrastructure, such as targets for service availability, lawful intercept or emergency preparedness. These objectives would bring in a larger set of industrial players, and a plan would then have to take into account the plasticity of this set of actors in trying to create suitable incentives and obligations that can be imposed on various of them.

The problem of implementing E911, and determining the set of players that should be required to provide E911 services, illustrates the complexity of the issues. All sorts of actors provide one or another Internet service that involves interactive communication. Some can be more easily defined as "telephone-like", since they interoperate with the PSTN. But more and more, people communicate using tools that do not quite resemble classic telephony. For example, some police departments are using Twitter today to send out real-time community alerts, similar to "reverse 911". Should a national broadband plan have an eventual objective that any citizen should have access to Twitter? Questions of this sort expand the scope of discussion to include actors not normally within the purview of the FCC, and raise questions about the future limits to national policy discussions.

Even if the FCC plan restricts itself to only the issues that surround physical build-out of broadband facilities, it is important to note that the rate of investment of facilities providers will depend on the overall health of these industries, and their overall health will depend on the range of commercial offerings they can make. With respect to the "classic" Internet Service Providers, a barrier to the commercial evolution of the Internet is the difficulty of working out new service offerings that have to span the various competing providers that make up the Internet. The Internet is locked in a simple service model (best-effort packet delivery) not because of technical limits or simple inertia but by the real difficulties in bringing advances to the market in a world of competing providers, limited by the drive for competitive advantage, concerns over anti-trust, and lack of a natural locus of leadership.

In this respect, different countries with different frameworks for investment, industry structure and regulation (different *plans)* will face different obstacles and observe different outcomes. For example, since competition is both a driver of innovation and a barrier to cooperative innovation, a more regulated, perhaps public-sector system will face fewer barriers to coordinated planning but have fewer incentives to innovate in the first place.

If facilities providers do bring new service offerings to the market, for example enhanced Quality of Service across the public Internet, this outcome will raise further policy debates about the necessity of addressing issues such as neutrality and open access to these services. If the services are brought to the market by other sorts of actors, the FCC should consider the ways in which this might change the answer to these questions.

Implications for the FCC broadband plan

My goal in making these points is not to expand the scope of the FCC broadband plan beyond the point where progress is possible. My goal is just to emphasize that few aspects of the Internet are fixed and immutable. Assuming that the future will resemble the past is a formula for a plan that rapidly becomes obsolete. The FCC, in their announcement of their intent to construct this plan, alluded to the fact that the Telecoms Act of 1994 hardly mentioned Internet at all, and largely assumed that the industry structure of the future would resemble the past, with (for example) healthy competition in long-distance telephony. Embedding this sort of assumption about industry structure and the nature of competition will doom a plan to quick obsolescence.

I do not suggest that the FCC should attempt to predict the future. I would just urge the FCC to construct a plan that is resilient to change.

Our focus must shift from buildout to uptake

While making broadband available in unserved areas is a valid social goal, only a small percentage of the population will benefit from the effort. Using various data from the Pew Internet & American Life project, I conclude that the uptake of broadband might increase about two percentage points as a result. So if the FCC plan looks only at completing an initial buildout in unserved areas, the needs of a very modest segment of the population will be addressed today today. Pew reports that 63% of adults have broadband at home. So a plan for sustainable broadband will affect this group—almost two thirds of the population today and growing over time. Finally, 22% of adults report that they do not use the Internet. A plan that addresses this issue would affect almost of quarter of the population. Additionally, bringing more citizens online will increase the revenues of the broadband providers, providing income that might go either to reducing costs or investing in improved services. In the long run, this last issue must be addressed if we want to see the use of broadband increase. With only 7% of adults using dialup today, most

of our existing residential users have already made the switch to broadband. It is the pool of non-users that will shape the future trajectory of broadband usage.