US Ignite Testbeds

Advanced Testbeds Enable Next-Generation Applications

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Abstract—**US Ignite is organizing what will eventually become 200 testbeds for next-generation applications in the United States. Twenty-eight testbeds are currently in various stages of operation. Most testbeds have gigabit to the end user capability including homes and small businesses. Both wired (fiber) and wireless cities are represented. The three salient advantages of these testbeds are their (1) applicability for big data (and big video) applications upstream and downstream, (2) ability to provide low-latency access to edge or local cloud (*locavore*) infrastructure for ultra-responsive and powerful applications, and (3) capacity for enough physical bandwidth to allow for virtualized channels carrying new services under new business models.**

Keywords—gigabit; big data; locavore infrastructure; virtual networks; applications; edge computing

I. Introduction

US Ignite [1] is an ambitious public-private government initiative and non-profit organization encouraging the development of 60 transformational next-generation network applications during the years 2012-2017. US Ignite was launched by the White House Office of Science and Technology Policy in June 2012 and many US Ignite applications are developed with support from the National Science Foundation as the lead federal agency [2]. US Ignite is also supported by major industry players such as Juniper, Cisco, Verizon, Comcast, HP, Big Switch, and Extreme Networks. Twenty-eight communities with advanced network infrastructures have joined US Ignite to develop and test next-generation network applications and services [3].

A US Ignite next-generation network application meets two tests: (1) It provides a compelling public benefit in areas such as transportation, education, healthcare, public safety, clean energy, and advanced manufacturing. (2) It is not feasible to implement on the broadband infrastructure commonly available to most Americans. Hence, it requires new network speeds and/or services which are today predominately only available in education and research networks and US Ignite testbed communities.

Examples of advanced network services that will support US Ignite applications include: (1) Software defined networking [4], (2) Gigabit-class symmetrical speeds to the end user, and (3) Neighborhood cloud locavore infrastructure that delivers services more responsively than far-off clouds.

II. Testbed Properties and Implementations

US Ignite testbed cities are capable of providing one or more of the following services which give them an ability to run applications not otherwise feasible over widely-available commercial infrastructure:

A. Gigabit Capacity

Gigabit capacity is most often obtained in wired metropolitan networks by the use of optical fiber in either a GPON [5] or Active Eithernet [6] configuration in the US Ignite testbed cities. Appropriate ONTs are provided with copper gigabit Ethernet connections in the home or small business. In some cases, there are multiple ports provided on separate VLANs to allow for several individualized channels into the home. For example, in Chattanooga, TN, a separate channel provides for a hardwired link to the power meter because the connectivity is provided by the municipal power company [7]. In Blacksburg, Virginia, a group powered by TechPad [8] and assisted by Virginia Polytechnic is providing wireless gigabit 802.11ac WiFi over the entire downtown area. A typical characteristic of US Ignite cities is that the bandwidth is symmetrical, allowing for homes and small businesses to originate high bandwidth traffic in addition to sinking it.

B. Software-Defined Networking and Virtual Networks

Many of the current US Ignite testbeds are running multiple virtual networks on a single fiber or WiFi connection. Typically, VLANs are used to separate the handling of video and phone and plain old Internet connections. This can be viewed as a simple type of Software-Defined Networking because there are separate virtual channels and application-specific network handling for different testbed applications. Another possibility, not yet seen deployed to the end user, is MPLS [9]. Although familiar to many carriers and in use in their backbones, the cost and configuration complexity of terminating equipment has limited the use of MPLS to provide virtualized channels to small business and home users. The author expects that OpenFlow-style SDN [10,11] will also appear to allow for additional virtual network channels into homes and small businesses, although none are currently (as of May 2014) in use in US Ignite testbed cities. Efficient multiple streams on a fiber also will be important when a single physical

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fiber serves a multiple dwelling unit (MDU) and each subscriber can individually choose services.

C. Wireless

Gigabit wireless is an important new testbed technology because of the increasing importance of mobile devices and tablet / phone access into important future Internet services. In the US Ignite testbeds, we are seeing three directions: (a) Blanketing the city with public 802.11ac (as in Blacksburg, Virginia, USA). (b) Providing a public access or private extra access channel on privately-owned ultra-fast broadband connections so that a common WiFi SSID is available for people to roam among WiFi hotspots installed by the local ultra-high bandwidth provider. (c) Turning up ultra-high bandwidth on cellular systems as Sprint is doing in the United States with its LTE-Advanced service called SPARK capable of 80 Mbps. Of these, perhaps the most interesting from a testbed perspective is the middle one – roaming seamlessly from WiFi hotspot to WiFI hotspot. Because of the finite limit on cellular frequencies, the best way to grow a wireless system is to re-use frequencies through more closely-spaced towers or access points. Taken to its logical conclusion, one might find a femptocell in most every home and small business, connected to the local fiber. WiFi roaming among a set of hotspots in most every home and small business is therefore a possible end-game for frequency re-use, and a possible disruption point for current cellular carriers in densely populated areas [12].

D. Locavore Infrastructure

Once there is gigabit capacity, SDN and virtual network capability, and ubiquitous wireless, the only missing component required to provide ultra-responsive network-delivered applications is having the server(s) close enough that transmission hops and latency can be avoided. For example, the typical web page served from a national datacenter takes 20-30 hops from the end-user to and from the servers providing portions of the page. Add to that the speed of light latency between the hops, and you potentially have hundreds of milliseconds of latency. Applications that react to what the user is doing or observing in real-time must provide closed-loop feedback in less than 50 msec. to be perceived as instantaneous. The best solution is to provide public edge or local cloud computing and storage – or locavore infrastructure – at or very near (in latency terms) the head-end of the community testbed. This locavore infrastructure capability may be a generic virtual processor / storage / networking arrangement like the rentable cloud computing capabilities but localized so that they can implement services with imperceptible response times. Many US Ignite testbeds have implemented GENI [13] racks at or very near their head-ends to provide a dynamically-allocatable locavore infrastructure.

III. Types of Applications Enabled

Depending on the specific capabilities of a given testbed, the advantages accruing to the community include the ability to run applications that need one or more of the following properties:

- Big Data or Video Downstream. For example, in the Chattanooga testbed, a radiologist at home downloads 6 GB emergency imaging in less than a minute, saving previous time for the patient involved.
- Big Data or Video Upstream. For example, in an assisted living facility in Missouri, high quality video of a patient's psychotic episode can be uploaded quickly to hospital staff for analysis and recommendation of appropriate interventions by caregivers.
- Low-latency (Ultra-responsive). For example, in Kansas City, the public library is experimenting with "loaning" software with high visual requirements (e.g., video editing software) by running it on a locavore server and providing very high bandwidth to the end user. The gigabit bandwidth confers a 100:1 latency advantage in the last mile compared to 10 Mbps broadband.
- Virtualized Applications. Service providers can sell additional virtual channels per application using the same physical fiber (or wireless) over and over again. Rather than hope the end-user has bought "enough" Internet bandwidth to allow the network-delivered applications to run properly, the service provider can arrange for the use of an appropriately sized and configured virtual channel that will provide for a consistent and high quality experience of that service. New business models are possible where the cost of virtual channels is included in the price of services delivered over them. The incremental revenue will be welcomed by last-mile carriers which are today trapped into the expectation of delivering higher and higher utilization on their pipe for the same flat price.

IV. Sample Testbed Applications

The US Ignite community is still discovering interesting public benefit uses of the network services described earlier. This paper will discuss a few of them which are underway or which seem to have significant promise.

A. Low-cost high-quality video

Much of the high price for high-quality video conferencing devices comes from the compression / decompression hardware used to reduce the video bandwidth. A color HD video signal uncompressed is about 1.5 Gbps. A high-quality video conferencing device can reduce that to several megabits. However, the price of high-quality low-latency compression limits the places such devices can be feasibly placed. To provide for home healthcare, for example, the cost must be much lower than the thousands of dollars of cost for the big-name commercial devices. We can trade-off bandwidth for device price in this particular application. By using gigabit-class bandwidth for a limited period of time, the hardware support needed drops to that which can be provided by a laptop with a gigabit Ethernet connection.

Home healthcare provided by low-cost high-quality video is a perfect example of a US Ignite application. Gigabit-class bandwidth is required. In addition, it is required only for a limited period of time. That's exactly the kind of dynamic network service which can be provided on demand by software-defined networking. The video and associated audio can be exchanged over a virtualized network dedicated to the healthcare audio and video. By separating this traffic from ordinary Internet traffic, the audio and video gains a layer of protection from interception, providing privacy.

A video application using this approach [14] is currently under development with funding from the National Science Foundation..

B. *Low-cost 3D model video transmision*

Like the preceding example, costs are minimized by using gigabit-class bandwidth provisioned only when needed by a software-defined network. To collect 3D video data, an inexpensive Microsoft Kinect box is used. The depth information is represented by a point cloud [15]. Processing this point cloud into a surface onto which the video is mapped is compute-intensive and needs more processing power than is typically available in a laptop. However, with symmetric gigabit upstream and downstream bandwidth, the video and point cloud information can be uploaded to a neighborhood cloud server at gigabit speeds. The neighborhood cloud server performs the point cloud computations and maps the video onto it. The results are sent to the recipient of the 3D model stream who can re-project the model at the recipient's chosen point of view.

Low-cost 3D videoconferencing appears to be useful for healthcare and education applications.

C. *Online study sections*

Students learn best when they have an opportunity to use and practice the material they are learning. This is an important reason for the discussion sections accompanying large lecture courses. Many non-traditional learners, however, find it difficult logistically to attend the discussion section. For them, the video application discussed above can be extended to provide low-cost multi-point video conferencing [14]. Software-defined networking (SDN) can be used to directly distribute video from each participant to each of the other participants. For example, the OpenFlow SDN protocol provides for duplicating packets at the optimal points in the network to minimize backbone traffic. This can be performed for each of the participants in the online study section, providing n optimized flows for each of the n participants.

The video and audio for these US Ignite applications has very low latency – lower than for traditional videoconferencing – because there are minimal compression delays, there is no multi-point control unit (MCU), and the video and audio are delivered over optimized SDN paths.

D. *Public safety communications and reverse 911*

Public safety notifications via radio and television are less effective as fewer people listen to radio and much television is recorded for later viewing. One US Ignite application uses a software-defined networking channel to the home to carry public safety messages. This virtual connection is unaffected by other traffic (e.g. movie viewing or gaming) to ensure the delivery of important public safety messages.

This application is being developed in Idaho and Utah with support from the National Science Foundation.

E. *Immersive education simulations*

The Louisiana Immersive Technology Enterprise (LITE) uses high-end compute clusters and graphics rendering to train flagmen for the Department of Transportation by immersing them in a visual and audio simulation that realistically shows the consequences of their actions. Today this training is done on-site at LITE. However, using gigabit-class networks and SDN, this training could be brought to the flagmen in training. The gigabit-class networks are needed to bring the realistic high-definition images in real time, and SDN can be asked to provide the smooth, low-jitter delivery over that fast network.

V. Conclusion

Advanced network services will enable a new generation of network applications. US Ignite is encouraging the creation of 60 such applications during 2012-2017.

This paper has presented the types and characteristics of advanced networking testbeds that will make these new applications viable. US Ignite intends to use compelling applications to foster 200 such testbeds by 2017. This is made a bit less difficult thanks to the recently announced expansion plans of Google Fiber to 34 communities [16] and AT&T's recent announcement of another 100 cities to be added to its GigaPower program [17]. Sprint SPARK [18] and Comcast's use of XFINITY common SSIDs [12] are also helping to power additional wireless testbed cities.

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