Next-Generation Internet Projects

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Abstract. The paper gives an introduction to some projects and initiatives that are connected with the new-generation Internet. US-Ignite partnerships, the European commission Future Internet Program, the European Fire projects, the Global Environment for Network Innovation (GENI), and WiMAX, are presented. New technologies and protocols, such as Software-defined networking (SDN), OpenFlow, a route configuration mechanism and the constituent protocols to add redundant packet forwarding capabilities that will provide high reliability communication for critical applications, are described. The goal of the paper is to understand intricacies, and nuances of some of these techniques and show some of the possibilities of next-generation high-speed networking and their possible applications in the field of the Internet and the applications to education, libraries and museums.

Keywords: US-Ignite initiatives · The European commission Future Internet Program · The European Fire projects · Internet of things · Software-defined networking · OpenFlow · The Global Environment for Network Innovation (GENI) · WiMAX

1 Introduction

The Digital Agenda for Europa states [1]: "The Internet is called on to perform increasingly many tasks - from online banking to tsunami monitoring. The Internet of tomorrow needs to be more powerful, connected and intuitive responding to our needs at home, work or on the go." In Sect. 2, we give an introduction to some projects and initiative connected with the new-generation Internet and the technologies that are linked with them. In Sect. 3, we study new technologies and protocols. In Sect. 4, we show some of the possibilities of next-generation high-speed networking and their possible applications in the field of the Internet of Things and the applications to education, libraries and museums. Our previous analysis of this issue can be found in [2,3].

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2 Next-Generation Internet Projects and Initiatives

2.1 US Ignite Partnership

US Ignite is a public-private nonprofit partnership of nationwide scope initiated by White House Office of Science and Technology Policy to "accelerate the development of applications that can take advantage of ultra-high-speed programmable broadband to bring innovative new products and services to the American people." The primary goal of the US Ignite Partnership is to catalyze approximately 60 advanced, next-gen applications over the next five years in six areas of national priority: education and workforce development, advanced manufacturing, health, transportation, public safety, and clean energy. Responsibilities of the Partnership include connecting, convening, and supporting startups, local and state government, universities, industry leaders, federal agencies, foundations, and community and carrier initiatives in conceptualizing and building new applications. The resulting new applications should have a significant impact on the U.S. economy, including providing a broad range of job and investment opportunities.

US Ignite is seeking applications with high societal impact using next generation, high-speed networking. It includes the "programmable broadband", high-speed Internet (1 Gbs+), a networking infrastructure to research, develop, test, prototype, and deploy, next-generation Software Defined Networking applications; a consortium of potential diverse partners. The four most important technical parts of the US Ignite technology include [4]:

- High symmetric bandwidth allows for uncompressed high definition video transmission, which has huge advantages over the IP-based transmission because it minimizes delays in video conferencing. For truly interactive experiences, uncompressed video with its high bandwidth requirements is best, and a number of Ignite applications use uncompressed video particularly in multiple areas, such as healthcare and education.
- The next-generation Internet will take advantage of Software Defined Networks (SDN), which takes the "intelligence" of routing data out of the switches and routers on shelves, and puts more of it into the cloud. SDN tricks servers into thinking that they have the network gear all to themselves, configured exactly the way they like it, when they are really sharing that gear with other servers. More servers can share less network gear, and they can also be moved around easier a big plus for applications such as cloud computing.
- Distributed Cloud Resources (e.g., US Ignite racks) are a kind of cloud computing in which the cloud is itself distributed throughout the network. This has distinct advantages, including pre-staging information where it is needed, processing data traffic more locally, and dramatically improving responsiveness while reducing latency.
- Virtual Networks are tailored to match specific advanced applications, as well as provide unique Access to Advanced Resources, such as advanced computational, sensor, storage and data resources provided by the owners and operators of new technology. The collection of network, distributed, and advanced

resources available in a virtual network to an application is called a "slice." Slices are an important concept because they can be thought of as the delivery mechanism for an application.

2.2 The European Commission Future Internet Program

The European Commission has launched the Future Internet Public-Private Partnership Program [5].

MAIN GOAL: To advance a shared vision for harmonized European-scale technology platforms and their implementation, as well as the integration and harmonization of the relevant policy, legal, political and regulatory frameworks.

PROGRAME AIMS: Increase the effectiveness of business processes and infrastructures supporting applications in areas such as transport, health, and energy. Derive innovative business models that strengthen the competitive position of European industry in sectors such as telecommunication, mobile devices, software and services, and content provision and media.

PROGRAM APPROACH: The Future Internet Public-Private Partnership Program follows an industry-driven, holistic approach encompassing R&D on network and communication infrastructures, devices, software, service, and media technologies. It promotes their experimentation and validation in real application contexts, bringing together demand and supply and involving users early in the research lifecycle. The new platform will thus be used by range actors, in particular SMEs and Public Administrations, to validate the technologies in the context of smart applications and their ability to support user-driven innovation schemes.

2.3 The Global Environment for Network Innovations (GENI)

The Global Environment for Network Innovations [6] is a project sponsored by the USA National Science Foundation. It is open and broadly inclusive, providing collaborative and exploratory environments for academia, industry, and the public to catalyze groundbreaking discoveries and innovation in emerging global networks. GENI is a virtual laboratory at the frontiers of network science and engineering for exploring future internets at scale. GENI creates major opportunities to understand, innovate, and transform global networks and their interactions with society.

GENI, a virtual laboratory for exploring future internets at scale, creates major opportunities to understand, innovate, and transform global networks and their interactions with society. Dynamic and adaptive, GENI opens up new areas of research at the frontiers of network science and engineering, and increases the opportunity for significant socio-economic impact. GENI:

- supports at-scale experimentation on shared, heterogeneous, highly instrumented infrastructure;
- enables deep programmability throughout the network, promoting innovations in network science, security, technologies, services and applications;

- provides collaborative and exploratory environments for academia, industry and the public to catalyze groundbreaking discoveries and innovation.

2.4 Future Internet Research and Experimentation Initiative

The Future Internet Research and Experimentation Initiative (FIRE) [7] creates a multidisciplinary research environment for investigating and experimentally validating highly innovative and revolutionary ideas for new networking and service paradigms. FIRE is promoting the concept of experimentally-driven research, combining visionary academic research with the wide-scale testing and experimentation that is required for industry. FIRE also works to create a dynamic, sustainable, large scale European Experimental Facility, which is constructed by gradually connecting and federating existing and upcoming test beds for Future Internet technologies. Ultimately, FIRE aims to provide a framework in which European research on Future Internet can flourish and establish Europe as a key player in defining Future Internet concepts globally.

2.5 WiMAX

As the first 4G wireless technology, WiMAX [8] combines the performance of WiFi with the range and quality of service (QOS) of a carrier-grade cellular technology. WiMAX can provide broadband wireless access (BWA) up to 30 miles (50 km) for fixed stations, and 3–10 miles (5–15 km) for mobile stations. In contrast, the WiFi/802.11 wireless local area network standard is limited in most cases to only 100–300 ft (30 100 m).

In emerging markets and rural areas, WiMAX is being deployed as a fixed wireless technology to provide basic internet connectivity to residential and business users, without the cost and difficulty of deploying fiber or DSL. In this fixed capacity, the technology can provide backhaul connectivity for Wi-Fi hotspots and other IP enabled devices such as VoIP phones and video surveillance cameras. In more developed markets, WiMAX is being used as a mobile wireless technology by large carriers and operators. The GENI WiMAX projects are creating open, programmable, GENI enabled "cellular-like" infrastructure on university campuses. The WiMAX base station provides network researchers with wide-area coverage and the ability to support both mobile and fixed end users.

3 Next-Generation Internet Techniques and Protocols

3.1 Software-Defined Networking

The key architectural principle of the Internet is based on the TCP/IP protocol. Potential Internet roadblocks are: IP networks are based on Autonomous Systems (AS). An autonomous system is a contiguous set of networks and routers under control of one "administrative authority." The basic IP forwarding paradigm is that all traffic from a given source to a given destination always follows the same path. The forwarding table in a router only contains one entry for a given destination.

Software-defined networking (SDN) is an approach to building computer networking equipment and software that allows network administrators to have programmable central control of network traffic without requiring physical access to the network's hardware devices. Conceptually, a router or switch is divided into two parts: Control Plane: performs configuration and control and Data Plane: handles packet processing. Vendors tightly couple these two planes. SDN avoid using embedded routing protocols and specify how to handle specific critical cases.

In Fig. 1 from [9] shows the old and the new architecture of the networks devices.

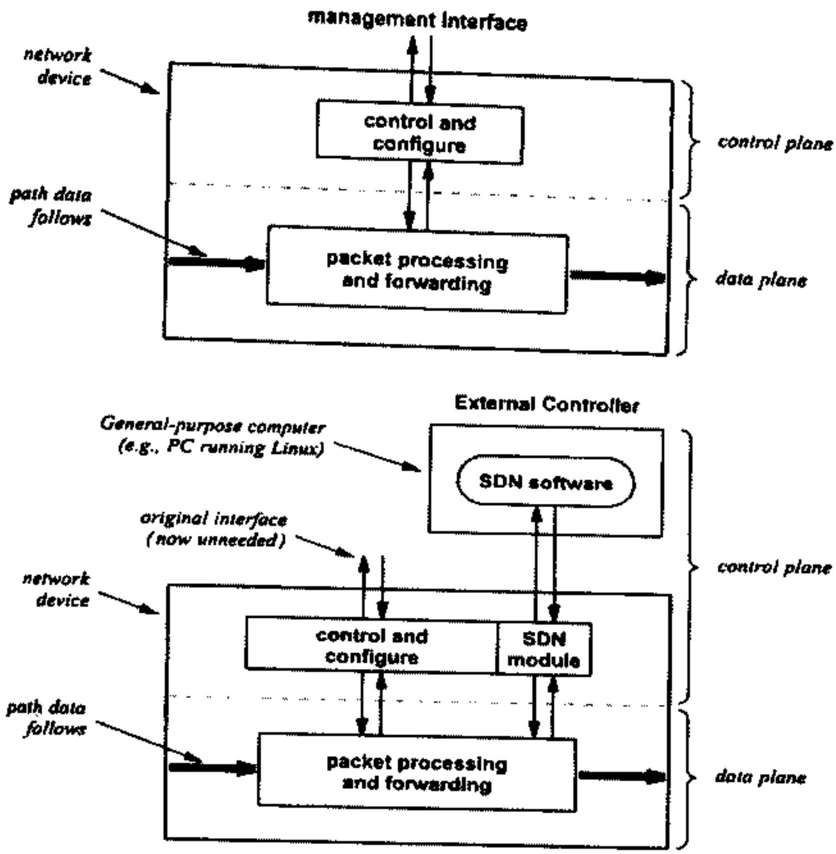

Fig. 1. a. Control and data plane, b. SDN architecture

3.2 OpenFlow Protocol

OpenFlow is a new protocol that is an instantiation of SDN. OpenFlow [10] enables networks to evolve by giving a remote controller the power to modify the behavior of network devices through a well-defined "forwarding instruction set". The growing OpenFlow ecosystem now includes routers, switches, virtual switches, and access points from a range of vendors. OpenFlow is based on an Ethernet switch, with an internal flow-table, and a standardized interface to add and remove flow entries. In Fig. 2 an example from [11] is given.

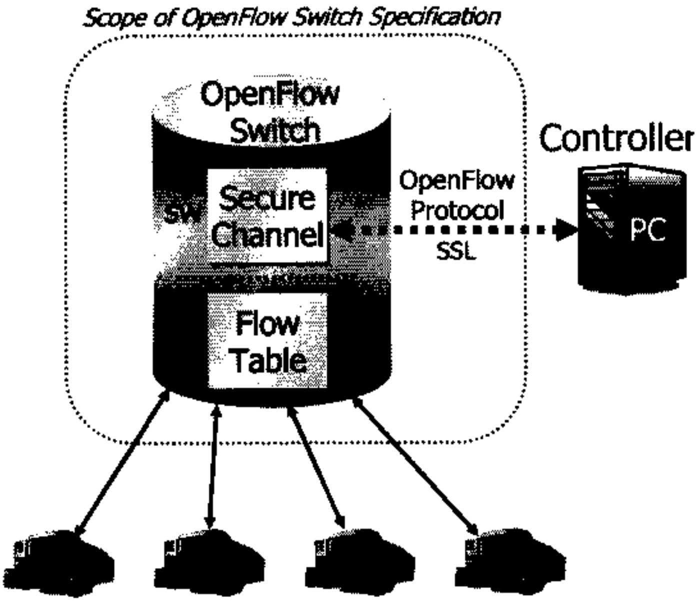

Fig. 2. Idealized OpenFlow switch. The flow table is controlled by a remote controller via the secure channel

3.3 Software-Defined Network Protocol

The ability to build a fault-tolerant and fixed latency communication path does not exist with todays TCP/IP Internet, but OpenFlow switches can establish an alternative proposal [12]. First, consider the GENI test bed with OpenFlow slice having two nodes (initially) with OnTimeMeasure Node Beacons setting. Between the nodes we can install switch flows using two different paths to demonstrate an application for remote control of a manufacturing process. The command line tools in OnTimeMeasure can be used to query the delay and loss measurements from Root Beacon and display the health of the two paths on a web page. Second, a preliminary version of the protocol running in a virtual environment on computers in a single lab is coded. Protocol experiments were carried out by team members at: Purdue, Ohio State, Kettering University, University of Missouri, and the Lit San Leandro gigabit metropolitan fiber project. With redundant paths, communication using the proposed protocol can tolerate faults increased transmission delay due to congestion of to hardware and, thus, reliable communication is achieved. In the event of congestion or failure of a path, the remaining path(s) support(s) communication between the access points while a replacement path is built to reestablish the desired level of fault tolerance.

4 New Internet Applications

Examples of these applications are: monitoring of medical procedures, control of Hazmat robots, monitoring and control of manufacturing robots, and remote unmanned vehicle operation. Remote Process Control - Reliable networks can provide new ways for controlling processes from afar, allowing engineers, artists, and experimenters to remotely control surgery robots, or advanced manufacturing processes, such as 3D printing, regardless of how close they are to the means of production. Such communication is needed for tasks including remote medical procedures, the control of robots used to clean up after a chemical or nuclear disaster, and the control of manufacturing processes.

4.1 Internet of Things

In 2010, Hans Vestberg, CEO of Ericsson group, predicted that by 2020, 50 billion devices would be connected to the internet. The Internet of Things (IoT) [13] is an emerging network superstructure that will connect physical resources and actual users. It will support an ecosystem of smart applications and services bringing hyper-connectivity to our society by using augmented and rich interfaces. Whereas in the beginning IoT referred to the advent of barcodes and Radio Frequency Identification (RFID), which helped to automate inventory, tracking and basic identification, today IoT is characterized by a dynamic trend toward connecting smart sensors, objects, devices, data, and applications. The main domains of IoT applications include the following.

- **Transport/Logistics.** By creating a connection between the two flows, an Internet of Things (IoT) for transport logistics may be created in which the logistics objects or "things" are capable of processing information, communicating with each other, and making their own decisions [14].
- **Smart Home**: The three main aspect of the smart home includes: (1) resource usage (water conservation and energy consumption), (2) security and (3) home comfort. Today, many of these products are still involved in small pilot programs. The security issues - complex security systems for detecting theft, fire or unauthorized entry. Do-it-yourself (DIY) kits are creating competition across previously separated home automation sectors. Most of them are cloud-based services. According to [15], custom-designed smart home systems will grow at only a 7-percent rate, compounded annually, to $2.2 billion in 2017. DIY kits will grow much faster but still only reach $200 million in annual sales by then. In contrast, connected home systems will explode from a $300-million base to $1.5 billion in 2017.

- **Smart Cities**: The term smart city is still not well defined. This is an urban area providing better quality of life. Mr. Rudolf Giffinger, professor at the Department of Spatial Planning, Centre of Regional Science, Vienna University of Technology et al.'s model [16] elucidates the characteristics of a smart city, encompassing economy, people, governance, mobility, environment and living. A smart city should not only be understood as an "intelligent" city but above all as an informed and needs-based city oriented towards the future. It will include smart metering, infrastructure for charging electric vehicles, and remote patient monitoring.
- **Smart Factory**: The industrial value chain, including product design, production planning, production engineering, production execution, and services were implemented separately. Today, new technologies are bringing these worlds together in exciting ways. Maintenance of machinery will be facilitated by connected sensors, allowing for real-time monitoring. Workers will be replaced by complex robots [17].
- **Retail**: Retailers realize both customer needs and business needs. M2M (Machine to Machine) Technology Building Blocks is described in [18]. Having information in real time helps enterprises to improve their business and to satisfy customer needs [19].
- **Smart Energy/Smart Grid**: The key issue is to detect ways to save energy and it is based on smart metering.

4.2 Applications in Education, Libraries and Museums

Holograms, lenticulars, and 3D television systems are the latest additions to high tech museum displays enabling the viewer to see museum artifacts in a whole new light. To bring these apps to life, developers leverage the unique capabilities of next-generation networks, including: High speed, multiple bi-directional streams of uncompressed video; Software-defined networks (e.g. OpenFlow), promising dramatically-improved control over network routing and optimization; Networks with capabilities such as virtual network slices matched to application requirements and distributed programmable resources throughout the network; Integrated wireless networks to facilitate, for example, sensor networks and continuous remote monitoring.

Some new-generation internet applications in education, libraries and museums are [20]:

- Cuyahoga County Public Library is partnering with Case Western Reserve University and One Community to bring a one-gigabit broadband connection to the new Warrensville Height branch, serving 20,000 residents from an economically disadvantaged community;
- Rutgers University Libraries is a lead partner on the Video Mosaic Collaborative (VMC), to create a portal to enable teachers and researchers to analyze and use over 20 years of classroom videos to transform mathematics research, teaching, and learning;

- San Francisco Public Library is developing a Teen Media Learning Lab in partnership with local education, museum, technology, and media organizations, to create a free, seven-day-per-week, interactive digital media learning space for youth;
- Graduate School of Library and Information Science at the University of Illinois Urbana-Champaign hold a series of four continuing education forums to enhance understanding of how libraries can adopt and use next-generation internet networks to address social inclusion through the organization US Ignite;
- High Quality Open Source Web Conferencing: Big Blue Button System will gives remote students multiple HD camera angles, high-quality audio and synchronized slides;
- Engage3D Conferencing: This in-browser application can bring the Aquarium's educational offerings live, interactive, and in 3D into these classrooms at no additional cost to the school. Unlike a simple video, this application allows students to interact with the content moving, seeing, exploring;
- Lynx Laboratories, Real-Time 3D Modeling Cameras. 3D Creation A camera for all your 3D creations that is as easy to use as a point-and-shoot (http://www.engadget.com/2013/02/02/lynx-a/);
- Hyperaudio Pad It is a transcript for audio and video based media, making them more accessible, searchable, navigable and index able. Hyperaudio Pad allows people to assemble and remix media as easily as they would a document (http://www.youtube.com/watch?v=Y-hZk4GI6a0);
- LITE Virtual Reality Workforce Development - Workforce development is based on virtual learning and interactive digital media technology. The use of advanced networking allows interactive training with several sites simultaneously;
- Luminosity - Easily creates interactive scientific visualizations in a web application focusing on simplicity. This web application enables a wider audience to participate in scientific research, data exploration and discovery.

5 Conclusions and Future Work

A vision of a new kind of global virtual museum of the future starts with exhibits anywhere, anytime. Example of such museums is the Vatican Museum. It provides visitors with the opportunity to take virtual tour of some of the dozen of museums and galleries from the Vatican collection. The visitors can view a three dimension video of the Sistine Chapel. We are trying to experiment some of the new techniques in the museum of Parzardjik. Historical Museum in Pazardjik is one of the most popular museum in Bulgaria. It is one of the first museums in the country. It is divided into several sections: Archaeology, History of Bulgaria XV-XIX century Ethnography, Modern History, Contemporary History, Foundations and scientific records. Archaeology will meet the moral culture of the region reflected in the pottery of the Stone Age, Middle and Western coins, weapons, ornaments, and has one of the most complete collection of the Thracian artifacts.

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