Internet Future Architectures for Network and Media Independent Services and Protocols

Jesus Alcober[*], Xavier Hesselbach[*], Antonio de la Oliva[+], Andres Garcia-Saavedra[+], David Roldan[×] and Carlos Bock[×]

[*] *Department of Telematics Engineering, Universitat Politecnica de Catalunya, Jordi Girona, 1 , Barcelona, Spain, {jesus.alcober, xavier.hesselbach}@upc.edu)*

[+] *Department of Telematics Engineering , Universidad Carlos III de Madrid Avda. Universidad, 30 28911 Leganes, Spain, {aoliva, agsaaved}@it.uc3m.esl}*

[×] *i2CAT Foundation, Gran Capità 2,4, 08034, Barcelona, Spain, {david.roldan, carlos.bock}@i2cat.net}*

ABSTRACT

Current Internet has become an essential communication infrastructure, not only for information transfer but also as a key component of social infrastructures, such as e-government, energy/traffic controls, finance, learning, health, *etc*. Even though the Internet has evolved towards high-bandwidth network architectures offering transparent transport services for fixed and mobile applications, its future depends on how it is going to cope with several concerns on different aspects such as scalability, ubiquity, security, robustness, mobility, heterogeneity, Quality of Service (QoS), re-configurability, context-awareness, manageability, data-centric, economics, *etc*.

This paper exposes the approaches proposed in the Spanish Government funded research project tin2010-20136-c03 to overcome identified drawbacks of the current internet, such as energy efficiency, network ossification, heterogeneity of information and coexistence of optical and wireless networks. In order to do so, two technologies have been identified as potential solutions to face some of these problems: i) Media Independence and ii) Virtualization. On the one hand, Media Independence enables the decoupling of the control plane from the physical technology specificities, by introducing an abstract control API to configure, monitor and command the physical interface. On the other hand, network virtualization strategies allow the partition of electrical and optical network infrastructures into multiple parallel, dedicated virtual networks for a physical infrastructure sharing purpose, and enables the creation of overlay networks spanning multiple technologies and realms, hence being a very useful tool for context-aware service composition.

Keywords: future internet, media independence, network virtualization.

1. INTRODUCTION

The Internet is facing an architectural crisis as the load and stress on the network increase with new users and applications. Current Internet architecture is becoming more and more ossified and complex; with lots of patches outside the core of the architecture, increasing its complexity and blurring the neat principles behind the original design of the Internet. Hence, today's Internet faces a number of considerable challenges which are not easy to overcome without significant changes to its architecture and protocols, such as resilience, traffic load, QoS, security and mobility. Furthermore, new services and computing paradigms require new modes of interaction, new features (identification, context-awareness, seamless service discovery and composition, *etc*.) and solutions to known issues (mobility, security, flexibility, *etc*.); but it is not clear how the current Internet architecture will be able to cope with all these new requirements. Fundamentally two approaches to solve these issues are possible. On one hand, revolutionary solutions, which imply a new architecture and paradigms for typical and novel functionalities to be redefined. On the other hand, an evolutionary solution built on top of current Internet architecture, modifying it to solve the upcoming limitations.

The aim of this paper is to summarize how media independence and virtualization become potential solutions to this challenge, aligned within the context of role-based architecture proposals.

Discussion on network architecture design, protocol modularization and redesign of the Internet has been around since the nineties, where one of the main outcomes was the Role-Based Architecture (RBA), a non-layered and modular architecture built around the concept of roles, which represents a communication building block that performs some specific function, such as "packet forwarding", "fragmentation", *etc*. RBA concept can be implemented in a revolutionary or evolutionary way. On one hand, it can be implemented with no layers at all and roles scope ranging from application all the way down to physical layers or perhaps just above a virtualized link layer (clean-slate approach). On the other hand, it can be deployed as an evolutionary enhancement on top of the network layer or even just at the application level.

This kind of micro-modularization, breaking existing protocols into small modules with a definite function, is common practice in most of clean slate proposals. Recently, some projects in the USA (NSF GENI /FIND), EU (FIRE /4WARD) and Japan (AKARI Project) have been issued to develop new network solutions from scratch. They share some common concepts in their design and objective, like micro-modularization and virtualization as a way to support multiple architectures simultaneously; although differing in scope and development. For

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example, from the FIND program, the SILOS proposal uses micro-modularization, but do not avoid layering, in order to ease cross-layer interactions [1]. Another example is the Recursive Network Architecture (RNA) [2]. It does not avoid layering and proposes the use of a single, tunable “metaprotocol” for different layers of the protocol stack. Intimately related with the architecture is the way how these architectural approaches will be able to provide the existing and new services of the Future Internet; *i.e.* the service architecture. The classical way to tackle this is to define the process of the service composition, which can be defined as the composition of those activities required to combine and link existing services (atomic and composite services) to create new processes. A good deal of New Future Internet initiatives are based on SOA (Service Oriented Architecture) paradigm, which proposes to organize and to use distributed capabilities operating under the control of different ownership domains. In [3], architectural proposals for Internet of the Things have been presented to cope with different environments, such as people with disabilities, body sensors and underwater communications, but following the before-mentioned principles of role-based architectures; and, in [4], a clean-slate architecture specifically designed for VANETs has been introduced. The proposed non-layered context-aware ubiquitous architecture adapts dynamically to changes, is oriented to services (VANET applications) and has a flexible structure. The vehicle and environmental context-aware information as well as the VANET communication characteristics are designed for the proper operation of the applications.

The next Section explains how Network Virtualization enables to solve future Internet issues and the Section 3 describes the Media Independence as an additional useful approach to overcome them. Finally, some conclusions are drawn.

2. NETWORK VIRTUALIZATION

The deployment of new Internet services is being more and more difficult; the lack of cooperation among stakeholders does not facilitate radical changes to the Internet architecture. This tendency is called ossification. Network virtualization has been proposed as the alternative to face up this ossification [5], by allowing multiple heterogeneous networks to cohabit on a shared physical substrate. Each virtual network is composed of virtual routers interconnected by virtual links. Each virtual router or link is an instance that shares resources of one substrate network’s physical router or link respectively [6].

A virtual network is isolated from the protocols at a signaling point of view, keeping all the characteristics (routing, addressing, policing*, etc*.) of one physical network. Important properties of Virtual Networks are the level of participation of each resource and the clear separation of any virtual network to all others. Each resource can be sliced so that it can be part of multiple Virtual Networks, but on the other hand does virtualization guarantee the clear separation of each network, so that actions in one network do not affect the operation of any other network [7]. However, in the network community, Virtual Networks is a very broad term, ranging from running multiple wave lengths over a fiber, MPLS, virtual routers, to overlay systems. This leads to deployment of single technologies in parts of the Internet or other IP-based networks, but lacks a common understanding of what virtualized networks is causing to IP-based networks, or how Virtual Networks is applied in favorable way. This leads to the introduction of virtualization in an uncoordinated way between the various players, such as network operators, vendors, service providers and testbed providers (*e.g.* GENI, FEDERICA, *etc*.) without considerations about the overall impact on the system level.

When several virtual routers and links are deployed, the mechanism of bandwidth allocation must be taken into account as an important goal to provide fair utilization of the available resources. If no control is realized to allocate bandwidth, greedy applications crossing a virtual network might make use of big percentage of the total bandwidth (physical network’s bandwidth), leaving other virtual networks (bottlenecked networks) with not enough bandwidth to satisfy the demand of the flows crossing them. A framework to enhance network virtualization allocation in optical networks is presented, through a new layer above virtualized elements to take into account the demands of resources control and infrastructures below.

Application of network virtualization relies on algorithms that can instantiate virtualized networks on a substrate infrastructure, optimizing the layout for service-relevant metrics. This class of algorithms is commonly known as “Virtual Network Embedding (VNE)”. In [8], a classification scheme for VNE algorithms taxonomy of current approaches to the VNE problem is provided. VNE can be decomposed in two stages: Virtual node and virtual link mapping. In the first stage, each virtual node is mapped to a suitable node in the physical network whereas the second stage is in charge of mapping the links connecting virtual nodes to paths in the physical network that suit the virtual network demands through virtual link mapping stage.

Energy efficiency is also highly connected with virtualization. Waste of energy due to over-provisioning and over-dimensioning of network infrastructures has recently stimulated the interest on energy consumption reduction by Internet Service Providers (ISPs). By means of resource consolidation, network virtualization based architectures will enable energy saving. Virtual network embedding (VNE) allows energy awareness optimal energy efficient embeddings [9].

While all the research results on future Internet architectures and technologies should be validated on large scale testbeds that provide realistic conditions, once they are validated and ready for production network operators have to deploy them in the real world. However, the cost of deploying new network technologies is difficult to be absorbed by traditional network operation models as return of investment is forecasted for periods larger than 20 years. Therefore, shared infrastructure projects are essential in order to find a viable network operation model. Once the network infrastructure is deployed, each operator sharing the network needs to control their resources independently of the other network operators participating in the network deployment. Infrastructure as a service (IaaS), initially introduced by the IT community to provide virtual machines on demand, can be applied to networks equipment and provide an elegant solution to this problem. An infrastructure provider can roll out the network and purchase the network equipment, and provide the management/control of the different devices as a service to one or more network operators. This way the cost of building a network is divided between several network operators, and they still can operate a network in an independent fashion. To date, existing research on infrastructure as a service models, architectures and tools for networks has either been focused on core optical networks, such as UCLPv2 [10] and Argia, IP Networks, as MANTICORE, or network infrastructures dedicated to future Internet research, such as FEDERICA, GENI, PlanetLab or OneLab. However, the IaaS framework has not yet been applied to the range of access networks, where it could bring a significant benefit in terms of CAPEX and OPEX reduction. Several proposals to design, develop and validate management and control solutions for heterogeneous access networks has been provided, such as innovative high-bandwidth access network architecture that offers transparent transport services for fixed and mobile applications. Key to this is the development of a high-functionality, low-energy active remote node (ARN) offering high-speed switching and statistical-multiplexing features for maximal exploitation of available network resources, together with radio, wavelength conversion and legacy systems compatibility. Although inherently future-proofed, the proposed network platform is also intrinsically compatible with existing PON and wireless access solutions: fixed fibre and radio access, LTE and beyond, and legacy services (CATV and DSL technologies) can all be delivered and managed in an open access environment. In addition, its low-energy and low-cost design offers an environmentally sustainable technology solution, whilst acting as a critical enabler for new smart services, e-society initiatives, and intelligent lifestyle management. Another approach to offer a convergent solution is to combine technologies at the physical layer to deploy multi-service networks. Several combined wired-wireless topologies offering Fiber-to-the-Home access and wireless connectivity on a unique access solution have been developed lately [11] , offering seamless integration, centralized bandwidth allocation and quality of service management in order to fulfil the requirements of the Future Internet.

3. MEDIA INDEPENDENCE

The heterogeneity of these access networks are not limited only to fixed, but also to wireless access, which importance will be higher in the next future. Given the diversity of wireless technologies and the complexity this implies for higher layers which need to interact with the different control interfaces, a natural approach is to design an interface to the upper layers that is common for all wireless technologies and hides the specificities of each one to the upper layers. However, if desired, features specific to a particular technology should still be accessible and exploitable. This project aims at providing this new media independent interface*, i.e.* a set of common primitives which allow the upper layers to use each technology in an abstract and common way. For each technology, a mapping of the common primitives to the specific primitives of the technology is then provided. The higher-layer network services which are ultimately enabled by this interface are referred to as Media Independent Layer.

Initially, Media Independence concept [12] was focused on supporting mobility since there is a commercial need to support user data continuity over networks comprising of multiple access technologies. Recent research projects, as CArrier gRade MEsh Networks (CARMEN), have proved how the a broader definition of a Media Independence Layer providing a set of abstract services can simplify network operations, such as bootstrapping, routing or network management and then it is acting as a horizontal layer. Within the standardization community, there is a trend within IEEE 802.21 [13] to broaden its scope by the study of other aspects where the concept of Media Independence can be applied, such as the Wireless Backhauls or Opportunistic spectrum sharing [14]. IEEE 802.21 Working Group has defined a Media Independent Handover Function (MIHF) as a collection of methods and procedures to support its goal. In order to provide an abstract interface between lower layers of different technology and mobility algorithms acting as users, this specification provides a set of media independent events, commands and information services. These services can be used by manufacturers to provide mobility aware applications (such connection manager applications, currently being used in smartphones of all major brands) that can work on different interfaces, without requiring specific tuning for each network technology. Within this work-in-progress, a first initiative is related to Management of Heterogeneous Wireless Networks, where the partners are currently analyzing the architectural limitations of IEEE 802.21 to support multiple Media Independent Services beyond handover. It is also worth to highlight the recent creation of the IEEE 802.21.1 (Media Independent Services) aiming at the extension of the media independent concepts to other use cases as the ones defined above.

4. CONCLUSIONS

This paper introduce different ways to overcome identified drawbacks of the current internet, such as energy efficiency, network ossification, heterogeneity of information and coexistence of optical and wireless networks, by using the technologies based on network virtualization and media independence. By means of virtualization, multiple heterogeneous networks are able to cohabit on a shared physical substrate while providing an emulated easy-managed service and permitting enhancement strategies, such as energy consumption optimization by consolidation of services, cost reduction for new deployed technologies, or protocol-independent network. From this point of view the users are not able to appreciate differences from a non-virtualized network. By means of media independence, a set of abstract services are defined to simplify network operations, in order to provide mobility aware applications.

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