



# Research Trends in Future Internet

## Telefonica Open Research Day

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U. Carlos III and IMDEA Networks

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networks



# Global Research for the Future Internet (I)

## ◆ Internet2

- ❖ Infrastructure set by a group of universities (UCAID)
- ❖ Response to “commoditization” of US research internet
- ❖ Started in 1996 up to date

## ◆ Next Generation Internet

- ❖ US Government research program
- ❖ Funded through several Federal agencies (DARPA, NSF, DOE, NIH, and EPA)
- ❖ Started in 1997, ended in 2005
- ❖ Other national NGI programs (China’ IPv6, ...)

# Global Research for the Future Internet (II)

## ◆ Next Generation Network (NGN)

- ❖ Concept launched by ITU-T around 2000
- ❖ Evolution of the carriers' current hybrid circuit-packet infrastructure to a fully broadband packet-based infrastructure
- ❖ Requires: a) packet overlay at the core; b) voice ports at DSLAMs or direct VoIP home terminals; c) migration to CBR SIP-based VoIP systems in cable
- ❖ Standardized, including the “NGN Enabled” label

# Global Research for the Future Internet (III)

## ◆ Clean-Slate Internet

- ❖ Initiative launched by U. Stanford
- ❖ Started on 2005 up to date
- ❖ Directed by Nick McKeown
- ❖ *“Research on unconventional, bold, and long-term research that tries to break the network's ossification”*
- ❖ Focus on different topics (security, virtualization, ...)

## ◆ Other “clean-slates” (e.g. 100x100 Clean Slate Project)

# Global Research for the Future Internet (IV)

- ◆ **Future Internet Research and Experimentation (FIRE)**
  - ❖ **EU Research program – unit FET within VIIFP**
  - ❖ **Started around 2006 up to date**
  - ❖ **Research priorities under Challenge 1**
  - ❖ **15 projects funded so far**
  - ❖ **Various research topics (mesh, DTN, autonomic, virtualization, planetlab,...)**

# Global Research for the Future Internet (V)

- ◆ **Future Internet Design (FIND)**
  - ❖ **NSF Research program within NeTS**
  - ❖ **Started November 2006 up to date**
  - ❖ **Darleen Fisher chairing the initiative**
  - ❖ **Some activities already started in the US (WINLAB at Rutgers)**
  - ❖ **FIND/GENI are usually considered FIRE's USA counterpart**

# Global Research for the Future Internet (VI)

- ◆ **Global Environment for Network Innovations (GENI)**
  - ❖ **NSF Research program within NeSE**
  - ❖ **Started 2006 up to date**
  - ❖ **Darleen Fisher chairing the initiative, BBN holds the PO**
  - ❖ **Dave Clark, Scot Shenker and others are leading it**
  - ❖ **GENI Spiral 1 released on September 29th, 2008**
  - ❖ **Evolution of PlanetLab with emphasis in virtualization**
  - ❖ **Not focused on new physical systems and physical experimentation**

# Global Research for the Future Internet (VII)

## ◆ Future Internet Assembly

- ❖ EU Initiative – ICT wide (mainly Directorate D)
- ❖ Launched in 2007
- ❖ Coupled as a political and research policy action
- ❖ First main event in April 2008: Bled conference and Bled declaration
- ❖ Current research funds: 400 M€ and 63 projects
- ❖ Next event: Madrid Conference in Dec 2008



# Evolution vs. Revolution (I)

## EVOLUTION

- ◆ CIDR
- ◆ NAT
- ◆ BGP vX
- ◆ VoIP
- ◆ MPLS
- ◆ P2P
- ◆ ...

## REVOLUTION?

- ◆ ATM LANE
- ◆ 100 VG AnyLan
- ◆ DQDB
- ◆ SMDS
- ◆ ...

## Evolution vs. Revolution (II)

***Once a technology is mature, it is very unlikely to undergo a revolution.***

***Rather, it might be superseded by a new, different, technology.***

- ◆ **Background compatibility (in technology, service, know how, ...) with the installed base weights A LOT**
- ◆ **The phone system attempted “revolutions” with ISDN, CORBA, and ATM, ...**
- ◆ **Broadcast TV has done an evolution with color, cable TV, DVD-T, and now HD**

## Evolution vs. Revolution (III)

- ◆ ***A real revolution is not a “version 2” of the incumbent technology***
- ◆ ***A real revolution is not fostered by the guys that designed the incumbent technology***
- ◆ ***A real revolution never starts big***
- ◆ ***A real revolution usually comes from outsiders, is based on completely different principles, it starts small, and is heavily despised first, criticized later, by the community of the incumbent technology”***
- ◆ ***Would you call Internet “the future phone network”?***

[www.imdea.org/networks](http://www.imdea.org/networks)

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## What is going to be the revolution superseding Internet?

- ◆ ***If I knew, I would not tell you!!!!***
- ◆ ***However, I still have time left, so I have to continue talking...***

## Interesting Evolution topics (I)

- ◆ **Network and Service virtualization**
  - ❖ Strongly supported by Cisco, GENI, and others
  - ❖ Some promising proposals (X-bone, ...)
  - ❖ Could lead to a meta-network, supporting a wide variety of virtual networking services, tailored to customer's needs and preferences
- ◆ **Network mobility and vehicular networks**
  - ❖ Mobility with standard terminals
  - ❖ Interconnection of vehicle's sensors, actuators, PDAs, intelligent controllers, ...
  - ❖ Huge interest by manufacturers (car-2-car, EADS, ...)
  - ❖ Potential large impact in safety, security, energy consumption, ...



## Interesting Evolution topics (II)

- ◆ **Multipath routing and transport**
  - ❖ **Increased service resilience and reliability**
  - ❖ **Potential high impact on congestion control**
  - ❖ **Benefits in load balancing and multihoming capabilities**
  - ❖ **Challenges in backward compatibility and deployment**
- ◆ **P2P and overlay networks**
  - ❖ **Evolution of active and programmable networks**
  - ❖ **Convergence trends with Autonomic and community networks**
  - ❖ **Large impact for network and service management**
  - ❖ **Enabler of new business models**

## Interesting Evolution topics (III)

### ◆ Alternatives to IPv6

- ❖ IPv6 first RFC in 1995
- ❖ IPv6 first RFC in 1998 (10 years old!!!!)
- ❖ IPv6 traffic is infinitesimal, despite quite widespread available network and OS support
- ❖ Main problem: it was designed for migration from, not for co-existence with, IPv4
- ❖ IPv64 internet-draft in 2001
- ❖ IPv4+4 in and Oxygen in 2004
- ❖ Current NAT64 work in IETF
- ❖ ...

# Two of my favorite Evolution topics (I)

## Future Media Internet

- ◆ Internet, without a doubt, will become the next mass-media technology
- ◆ Broadcast TV will not disappear (like TV did not kill radio), but TV will have to reinvent itself
- ◆ Internet is more flexible and versatile, and most important, is fully interactive, the user controls the contents to view, and individual users may produce and distribute content
- ◆ CONTENT NoE has produced relevant contributions in this direction

## Two of my favorite Evolution topics (II)

### Future Wireless Internet

- ◆ In the coming years, Internet will grow much more in wireless devices than in wired devices
- ◆ Our vision is an Internet with  $10^{12}$  heterogeneous interconnected wireless devices
- ◆ Pervasive, ubiquitous, and mobile networking service
- ◆ Wide heterogeneity of terminals: PDAs, smartphones, presentation, sensor, actuator, and other devices
- ◆ A new generation of applications and teleservices
- ◆ A new generation of networking facilities and protocols

# A possible Revolution topic????

## Quantum Networking

- ◆ The impact of quantum transmission, processing and storage may have a dramatic impact on network technologies
- ◆ Just to start, some algorithms currently unusable because of their exponential computational complexity may become feasible, as are rendered linear by quantum tech
- ◆ Seminar on Quantum networking to be held at IMDEA Networks next spring (Jon Crowcroft, Jim Kurose, Lixia Zhang, Hari Balakrishnan, Gonzalo Camarillo, Arturo Azcorra, David del Val, Ralf Steinmetz, Ioannis Stavrakakis, Zhi-Li Zhang, Huw Oliver, and others)

## Conclusions

- ◆ **All countries and regions are competing to get a stake in the Future Internet market**
- ◆ **Technology is the key factor to market**
- ◆ **Large private and public efforts to fund the necessary research**
- ◆ **Incredibly growing market (8 million new mobile subscribers a month in China, PDAs, google, ...)**
- ◆ **What will be the next Google? The next Nokia? the next Cisco? the next Skype? ...**

## References (I)

### ◆ Evolution vs. Revolution:

- ❖ “The Structure of Scientific Revolutions”, 1962, Thomas Kuhn
- ❖ “The Logic of Scientific Discovery”, 1959, Karl Popper

### ◆ Virtualization

- ❖ Yi Wang, Eric Keller, Brian Biskeborn, Jacobus van der Merwe, and Jennifer Rexford, “Virtual routers on the move: Live router migration as a network-management primitive,” in Proc. ACM SIGCOMM, August 2008

### ◆ IPv6 alternatives

- ❖ Internet Protocol, Version 64 (IPv64) Specification, A. Azcorra, A. García-Martínez, M. Bagnulo, Internet Draft, Internet Engineering Task Force, 8 May 2002

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### ◆ Vehicular Networks

- ❖ **VARON: Vehicular Ad Hoc Route Optimisation for NEMO**, C.J. Bernardos, I. Soto, M. Calderón, F. Boavida, A. Azcorra *Computer Communications* Vol. 30, pag 1765-1784. Elsevier Ed. ISSN 0140-3664. June 2007
- ❖ **A Stable Routing Protocol to Support ITS Services in VANET Networks**, Tarik Taleb, Ehssan Sakhaee, Abbas Jamalipour, Kazuo Hashimoto, Nei Kato, and Yoshiaki Nemoto

### ◆ Multipath

- ❖ **IPv6 Multihoming Support in the Mobile Internet**, M. Bagnulo, A. García, A. Azcorra *IEEE Wireless Communications Magazine*. ISSN 1536-1284. 2007
- ❖ **MIRO: Multi-path Interdomain ROuting**, Wen Xu, Jen Rexford, *ACM-SIGCOMM'06*, Pisa, Italy.

### ◆ Future Media Internet:

- ❖ **Elsevier Computer Networks. Special Issue on 'Content Distribution Infrastructures'** edited by Roberto Canonico, Andreas Mauthe and Carmen Guerrero, for immediate publication.

### ◆ Future Wireless Internet:

- ❖ **A. Azcorra, J. Touch, A. Zhang (editors), Selected Papers on Wireless and**



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  - ❖ <http://www.wpi.edu/Admin/IT/Internet2/history.html>
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- ◆ **Future Wireless Internet**
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