

# What is Future Internet?

[cshong@khu.ac.kr](mailto:cshong@khu.ac.kr), Choong Seon Hong, KHU

# Outline

2

- Why Future Internet?
- What is Future Internet?
- Status of Current Internet
  - ▣ History of Internet Growth
  - ▣ Merits and Demerits of Future Internet
- Summary of research effort of Future Internet
  - ▣ FIND, GENI, FIRE, JGNx, AsiaFi, etc
- Concluding Remarks

# Why Future Internet?

3

- A growing and changing demand
  - ▣ For increasing user control of networks/devices/services/applications
  - ▣ For interconnecting 'things'-TV/PC/smart phone/sensor/Dron...
  - ▣ For convergence: networks/devices/services
    - : Intelligent Transportation System(ITS), Smart Grid, Smart-City, ....
  - ▣ Mobility / Security
- Current technologies can be, and need to be improved significantly
  - ▣ For scaling up and more flexibility
  - ▣ For better security
  - ▣ For higher performance and more functionality

# What is Future Internet? (1)

4

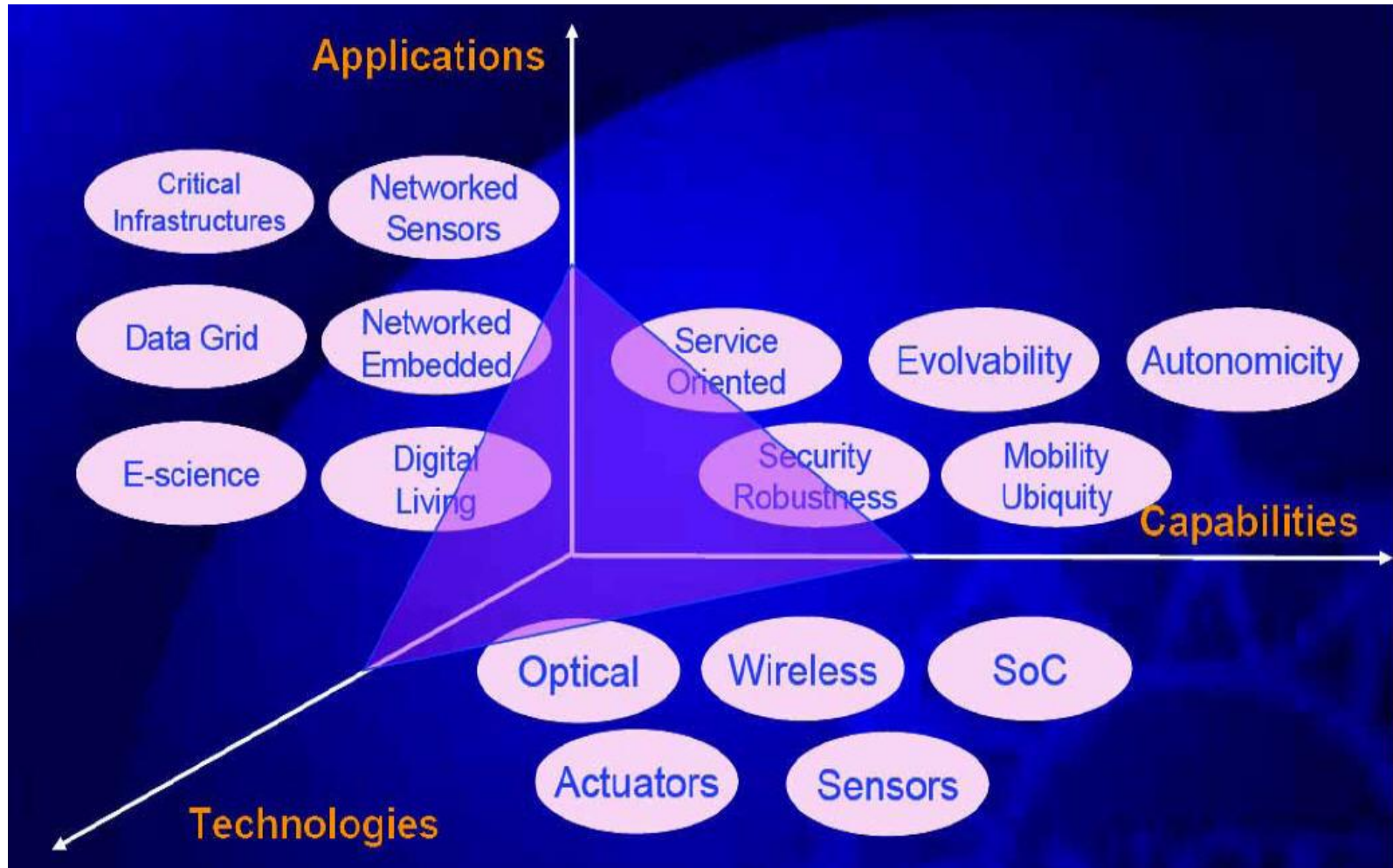
- Need to resolve the challenges facing today's Internet by rethinking the fundamental assumptions and design decisions underlying its current architecture
- Two principal ways in which to evolve or change a system
  - ▣ **Evolutionary approach (Incremental)**
    - A system is moved from one state to another with incremental patches
  - ▣ **Revolutionary approach (Clean-slate)**
    - The system is redesigned from scratch to offer improved abstractions and/or performance, while providing similar functionality based on new core principles
- It is time to explore a clean-slate approach
  - ▣ In the past 30 years, the Internet has been very successful using an incremental approach
  - ▣ Reaching a point where people are unwilling or unable to experiment on the current architecture

# What is Future Internet? (2)

- Future Internet?
  - **Clean Slate** design of the Internet's architecture to satisfy the growing demands
  - Management issues of Future Internet also need to be considered from the stage of design
  
- Research Goal for Future Internet
  - Performing research for Future Internet and designing new network architectures
  - Building an experimental facility

# What is Future Internet? (3)

6



Need a 'clean-slate' approach

# History of Internet Growth (1)

7

- Stage One: **Research and Academic Focus** (1980-1991)
  - Debate about which protocols will be used (TCP/IP)
  - The National Science Foundation (NSF) took a leading role in research networking
    - NSFNet1: “supercomputer net”
    - NSFNet2: a generalized Internet (thousands of Internet nodes on U.S campus)
  - The Internet Engineering Task Force (IETF) created open standards for the use of the Internet
    - Request for Comments (RFC) standards documents

# History of Internet Growth (2)

- Stage Two: **Early Public Internet** (1992-1997)
  - Federal Networking Council (FNC) made a decision to allow ISP to interconnect with federally supported Internets
  - The National Center for Supercomputing Applications (NCSA) adopted Tim Berners-Lee's work on the World Wide Web
  - Mosaic, Netscape started us down the path to the browser environment today
    - It was watershed development that shifted the Internet from a command-line, e-mail, and file-transfer in the kind of user interface to the browser world of full-screen applications
  - In the fall of 1996, a group of more than thirty University Corporation for Advanced Internet Development (UCAID)
    - Subsequently become known as Internet2



# History of Internet Growth (3)

- Stage Three: **International Public Internet** (1998-2005)
  - ▣ The Internet achieved both domestic and international critical mass of growth
  - ▣ Fueled by giant bubble in Internet stocks that peaked in 2000 and then collapsed
  - ▣ Fiber-optic bandwidth Improvements to gigabit-per-second levels, and price-performance improvements in personal computers
    - xDSL, FTTH, etc.
  - ▣ The “bubble” years laid the foundation for broadband Internet applications and integration of voice, data, and video services on one network base

# History of Internet Growth (4)

10

- Stage Four: **Challenges for the Future Internet (2006-?)**
  - ▣ The Internet has become a maturing, worldwide, universal network
  - ▣ Recently debated policy issues: net neutrality
    - Two of the few surviving U.S. telcos intended to levy special surcharges on broadband Internet traffic based on the application and on the company
    - Millions of Internet users
      - Growth in functionality and value of the net could never happened if there had been discrimination in managing packet flow
  - ▣ If the telco's well funded campaign succeeds
    - Then Progress toward universal and affordable broadband access would be further delayed

# Merits & Demerits of Current Internet

11

## □ Merits

- The original Internet design goal of robustness
  - Network architecture must not mandate recovery from multiple failures, but provide the service for those users who require it
- Openness: low barrier to entry, freedom of expression, and ubiquitous access

## □ Demerits

- “Nothing wrong – just not enough right”
- Pervasive and diversified nature of network applications require many functionalities
  - Current network architecture doesn’t support
- E.g., TCP variants for high bandwidth delay product networks, earlier work on TCP over wireless networks, and current effort towards cross-layer optimization

## □ US NSF

- ▣ Future Internet Design (**FIND**)
- ▣ Global Environment for Networking Innovations (**GENI**)
- ▣ Platforms for Advanced Wireless Research (**PAWR**)

## □ European Commission

- ▣ Future Internet Research and Experimentation (**FIRE**)
- ▣ EIFFEL's Future Internet Initiative
- ▣ FP7 Projects : <http://www.future-internet.eu/activities/fp7-projects.html#c47>
- ▣ Goto the EU Future Internet Portal (<http://www.future-internet.eu/>)
- ▣ Horizon 2020  
(<http://ec.europa.eu/programmes/horizon2020/>)

- AsiaFI by CJK
- China : NSFC & MOST
  - ▣ 973 Fundamental Research Project
  - ▣ MOST 863 High-tech Project
  - ▣ CNGI Project
- JAPAN
  - ▣ NICT's NeW Generation Network (NWGN)
  - ▣ Japan Gigabit Network II (JGN2)
  - ▣ AKARI Project
- KOREA
  - ▣ Future Internet Forum (FIF)

## □ National Science Foundation (NSF)

- An independent federal agency created by Congress in 1950
- Supports for all fields of fundamental science and engineering
- With an annual budget of about \$5.92 billion

## □ Networking Technology and Systems (NeTS)

- A program in NSF
- Covers all properties of information networks including network architecture, protocols, algorithms, and proof of concept implementation of hardware and software
- Funding: approximately \$40 million per year
- Four areas of networking research
  - Future Internet Design (FIND)
  - Wireless Networks (WN)
  - Networks of Sensor Systems (NOSS)
  - Networking Broadly Defined (NBD)

# US NSF – CISE

15

- Computer Information Science and Engineering (CISE)
- The Directorate for CISE has three goals:
  - ▣ To enable the U.S. to uphold a position of world leadership in computing, communications, and information science & engineering
  - ▣ To promote understanding of the principles and uses of advanced computing, communications and information systems in service to society
  - ▣ To contribute to universal, transparent and affordable participation in an information-based society
- CISE is organized in three divisions:
  - ▣ the Division of Computing & Communication Foundations (CCF)
  - ▣ the Division of Computer and Network Systems (CNS)
  - ▣ the Division of Information and Intelligent Systems (IIS)
- Supports GENI project

# FIND (1)

16

- What is FIND?
  - ▣ Major new long-term initiative of NSF NeTS research program
  - ▣ Created in 2006
  - ▣ Funded project seeking to design a next-generation Internet called the 'Future Internet'
- Research goal
  - ▣ About end to end network architecture & design as well as implications of emerging technologies on Future Internet
  - ▣ Invites the research community to consider
    - What the requirements should be for a global network of 15 years from now
    - How we could build such a network if we are not constrained by the current Internet - if we could design it from scratch



# FIND (2) - Status

17

- Three phases
  - ▣ Each phase will last about three years
  - ▣ **Phase 1** (2006~2008): focuses on components or parts of an architecture such as new schemes for security, naming, or routing
    - 2006: Funded 26 projects
    - July, 2007: Proposals are evaluated
    - Three FIND research meetings/year
  - ▣ **Phase 2** (Current Phase: 2009~2011): proposes overarching network architectures using research and knowledge gained from the 1<sup>st</sup> phase
  - ▣ **Phase 3** (2012~2014): demonstrates ideas on experimental infrastructure (GENI)

- What is GENI?
  - ▣ A planning effort initiated by the NSF CISE Directorate
  - ▣ Experimental facility to validate research (infrastructure to demonstrate research)
  - ▣ A nationwide programmable facility for research into Future Internet technologies
  - ▣ Launched in August 2005
- Consists of two components
  - ▣ GENI research program(s): will continue CISE's long-term support for basic research and experimentation in networking and related topics
  - ▣ GENI research facility: will be a state-of-the-art, global experimental facility that will foster exploration and evaluation of new networking architectures (at scale) under realistic conditions

# Core Concepts of GENI

19

- Programmability :
  - May download software into GENI-compatible nodes to control how those nodes behave
- Virtualization and Other Forms of Resource Sharing
- Federation:
  - Forming a part of the overall “ecosystem” by the NSF portion of the GENI
- Slice-based Experimentation
  - Experiments of an interconnected set of reserved resources on platforms in diverse locations

# GENI Clusters

20

- “PlanetLab” framework, based on the PlanetLab system from Princeton Univ.
- “ProtoGENI” control framework, based on the Emulab system from the University of Utah.
- “ORCA” control framework from Duke University and RENCI.
- “OMF” control framework from Rutgers University.

# GENI – Status (1)

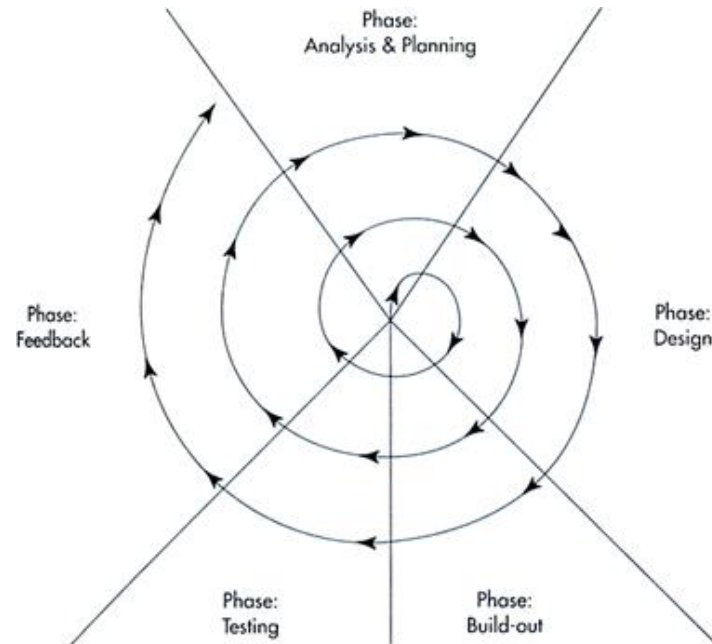
21

<b>YEAR</b>	<b>Activity</b>
<b>1970s~today</b>	Funding of networking research and infrastructure
<b>2002</b>	Network Research Testbeds Program Experimental Infrastructure Networks Program
<b>2003</b>	Network simulation, emulation, and experimental facilities funded (~\$20M)
<b>2004</b>	Consolidation of networking research programs into a larger new program NeTS with emphasis on next generation networks that go beyond Internet (~\$40M/yr)
<b>2005</b>	CISE GENI team formed Five GENI facility planning grants
<b>2006</b>	Facility Conceptual Design Creation of the Computing Community Consortium (CCC)
<b>2007</b>	The formative stages 'GENI Science Plan' revision GENI Facility 'Conceptual Design' almost completed
<b>2008 - 2014</b>	Beginning of construction and Making the testbed

# GENI – Status (2)

22

## □ Spiral development



Year 1 (2009-2010)

- GENI-enabled backbone deployments
- OpenFlow Campus deployments
- Early WiMax Deployments

Year 2 (2010-2011)

- Some early experiments
- Some production traffic on GENI
- Complete WiMax Deployments

Year (2011- 2014)

- More Experiments
- More Production Use
- Some Educational Use

- Enabler for experimental exploration of robust new wireless devices, communication techniques, networks, systems, and services
- The [PAWR Project Office](#) is managing this \$100 million public-private partnership to deploy and manage up to 4 city-scale research testbeds.
- PAWR is funded by [NSF](#) and a [wireless Industry Consortium](#) of 28 companies and associations.
- Accelerating research and commercialization of wireless technologies.

- Named Data Networking: Lixia Zhang(UCLA)
  - Technical challenges: Routing scalability, fast forwarding, trust model, network security, content protection and privacy, and communication theory
- Mobility First: Dipankar Raychaudhuri (Rutgers University)
  - Using GDTN, tradeoffs between mobility and scalability and on opportunistic use of network resources to achieve effective communications among mobile endpoints
- NEBULA: Jonathan Smith (University of Pennsylvania)
  - The technical challenges in creating a cloud-computing-centric architecture
- eXpressive Internet Architecture: Peter Steenkiste (CMU)
  - Refine the interface between the network and users; analyzing the relationship between technical design decisions and public policy



- **ChoiceNet : Tilman Wolf, University of Massachusetts**
  - The ChoiceNet project aims to develop a new architectural design for the Internet of the near future to enable sustained innovation in the core of the network, using economic principles. The core idea of this new network architecture is to support choice as the central aspect of the architecture.

# Research in EU (1)

26

- The Seventh Framework Programme for research & technology development (FP7)
  - The main financial tools through which the European Union supports research and development activities covering almost all scientific disciplines
  - FPs have been implemented since 1984 and generally cover a period of five years with the last year of one FP and the first year of the following FP overlapping
  - FP7: 2007 ~ 2013 (7 years)
  - FP2014 ~2022 : Horizon 2020
- Information and Communication Technologies (ICT)
  - One of the major research themes in FP7
  - Critical to improve the competitiveness of European industry and to meet the demands of its society and economy

# Research in EU (2)

27

- FP6/IST (Information Society Technologies)/FET (Future Emerging Technologies)/FIRE → FP7/ICT/FIRE
- **EIFFEL** (Evolved Internet Future for European Leadership)
  - Launched by the EU Commission (J. Da Silva, **July 2006**) as a support action (SA) for FP7
  - Group of **technical experts** acting as an individual
  - Forms Future Internet Initiative (<http://www.future-internet.eu>)
  - Released a white paper in December 2006
  - Structure: 4 working groups
    - Evolution scenarios, technological and socio-economic drivers
    - Technical challenges
    - Policy challenges
    - Planning and coordination group

- **Horizon 2020 : ICT Research & Innovation**
  - ▣ Information and Communication Technologies
  - ▣ Leadership in Enabling and Industrial Technologies
  - ▣ Health, Demographic Change and Wellbeing
  - ▣ Secure, Clean and Efficient Energy
  - ▣ Smart, Green and Integrated Transport
  - ▣ Climate Action, Environment, Resource Efficiency and Raw Materials
  - ▣ Europe in a changing world - Inclusive, innovative and reflective societies
  - ▣ Secure societies – Protecting freedom and security of Europe and its citizens

## □ Horizon 2020 : ICT **Projects about Future Internet**

### ■ Technologies for Digitizing EU Industry

- Computing technologies and engineering methods for cyber-physical systems of systems
- Flexible and Wearable Electronics
- Photonics Manufacturing Pilot Lines for Photonic Components and Devices
- Photonics based manufacturing, access to photonics, datacom photonics and connected lighting
- Application driven Photonics components
- Unconventional Nanoelectronics
- Electronic Smart Systems (ESS)
- Security and resilience for collaborative manufacturing environments
- Robotics in Application Areas
- Robotics Core Technology

- **Horizon 2020 : ICT Projects about Future Internet**
  - **European Data Infrastructure: HPC, Big Data and Cloud technologies**
    - HPC and Big Data enabled Large-scale Test-beds and Applications
    - Big Data technologies and extreme-scale analytics
    - Supporting the emergence of data markets and the data economy
    - Cloud Computing
    - Software Technologies (such as virtualization, SDN, etc., for HPC, IoT, Big Data, Cloud, Artificial Intelligence)

## □ Horizon 2020 : ICT **Projects about Future Internet**

### ▣ **5G**

- 5G End to End Facility to Meet 5G PPP network KPIs
- 5G for cooperative, connected and automated mobility
  - V2X
- Advanced 5G validation trials across multiple vertical industries
  - addressing the 3 classes of ITU requirements (eMBB, mMTC, URLLC use cases)
- 5G Long Term Evolution

## ▣ **Next Generation Internet (NGI)**

- **Next Generation Internet - An Open Internet Initiative**
  - More human-centric Internet supporting values of openness, cooperation across borders, decentralization, inclusiveness and protection of privacy;
- **Interactive Technologies**
  - Interactive technologies such as Augmented (AR) and Virtual Reality (VR)
- **Artificial Intelligence**
  - European AI-on-demand platform mobilising the European AI community to support businesses and sectors in accessing expertise, knowledge, algorithms and tools to successfully apply AI thereby generating market impact.
- **Internet of Things**
- **Future Hyper-connected Sociality**
- **A multilingual Next Generation Internet**
- **An empowering, inclusive Next Generation Internet**



# FIRE (1)

33

- What is FIRE?
  - ▣ An activity or initiative aims to scope and consolidate the European work in networking testbeds
- Goal
  - ▣ Aims at providing a research environment for investigating and experimentally validating highly innovative and revolutionary ideas on future Internet
- FIRE Status
  - ▣ *January 2007*: Preliminary meeting between Panlab and OneLab
  - ▣ *14-15 Feb 2007*: First FIRE expert group meeting, Brussels
    - Expert groups to define a long-term vision, and to build a multidisciplinary constituency
  - ▣ *6-7 March 2007*: FIRE workshop, Zurich
    - *June*: Publication of the final report of the FIRE expert groups
  - ▣ *Sept. 10, 2008*, FIRE LAUNCH - Event and Workshop (GENI-FIRE workshop)

# FIRE (2)

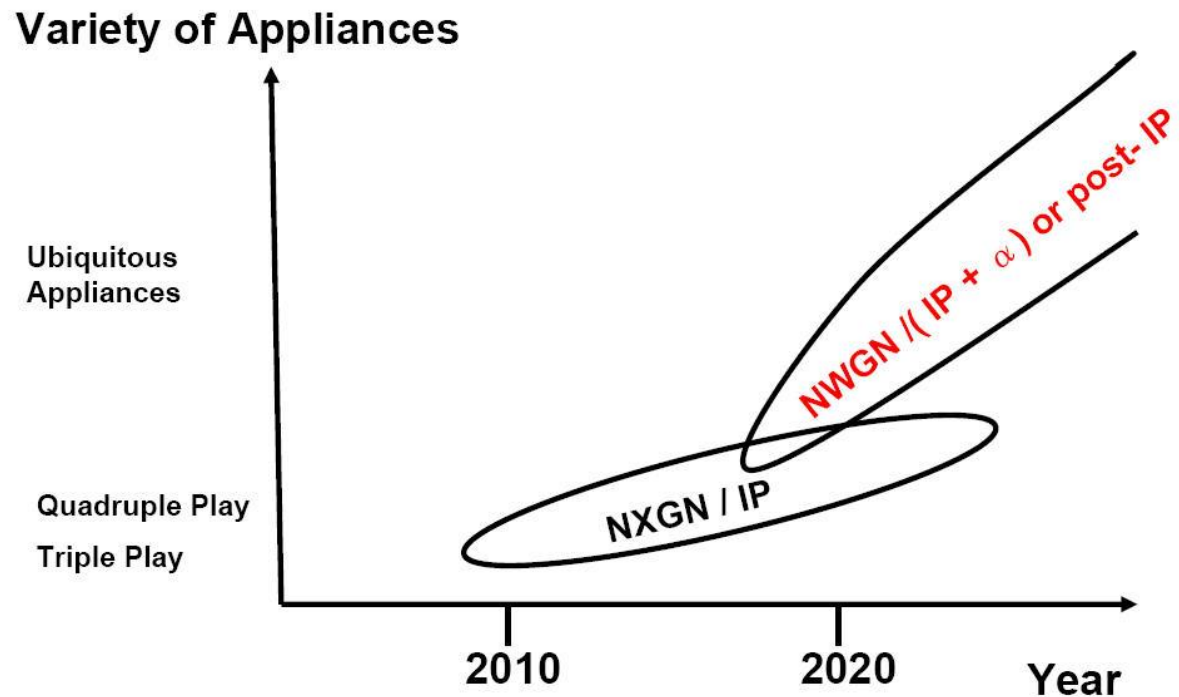
34

- Two related dimensions
  - Promoting experimentally-driven *long-term research* on new paradigms and networking concepts & architectures for the future Internet
  - Building a sustainable, dynamic, large scale *experimentation facility* by gradually *federating* existing and new testbeds for emerging or future internet technologies
- The expected impact is :
  - Strengthened European position in the development of the Future Internet
  - Global consensus towards standards and strengthened international co-operation through interconnected test beds and interconnection capabilities offered to third countries
  - Higher confidence in the secure use of the Internet through test beds enabling trusted access to e-Services

# JAPAN – NWGN (1)

35

- NeXt Generation Network (NXGN)
  - ▣ Improvement of IP networking to provide Triple-/Quadruple-play services
- NeW Generation Network (NWGN)
  - ▣ Network architectures and main protocols are different from IP networks



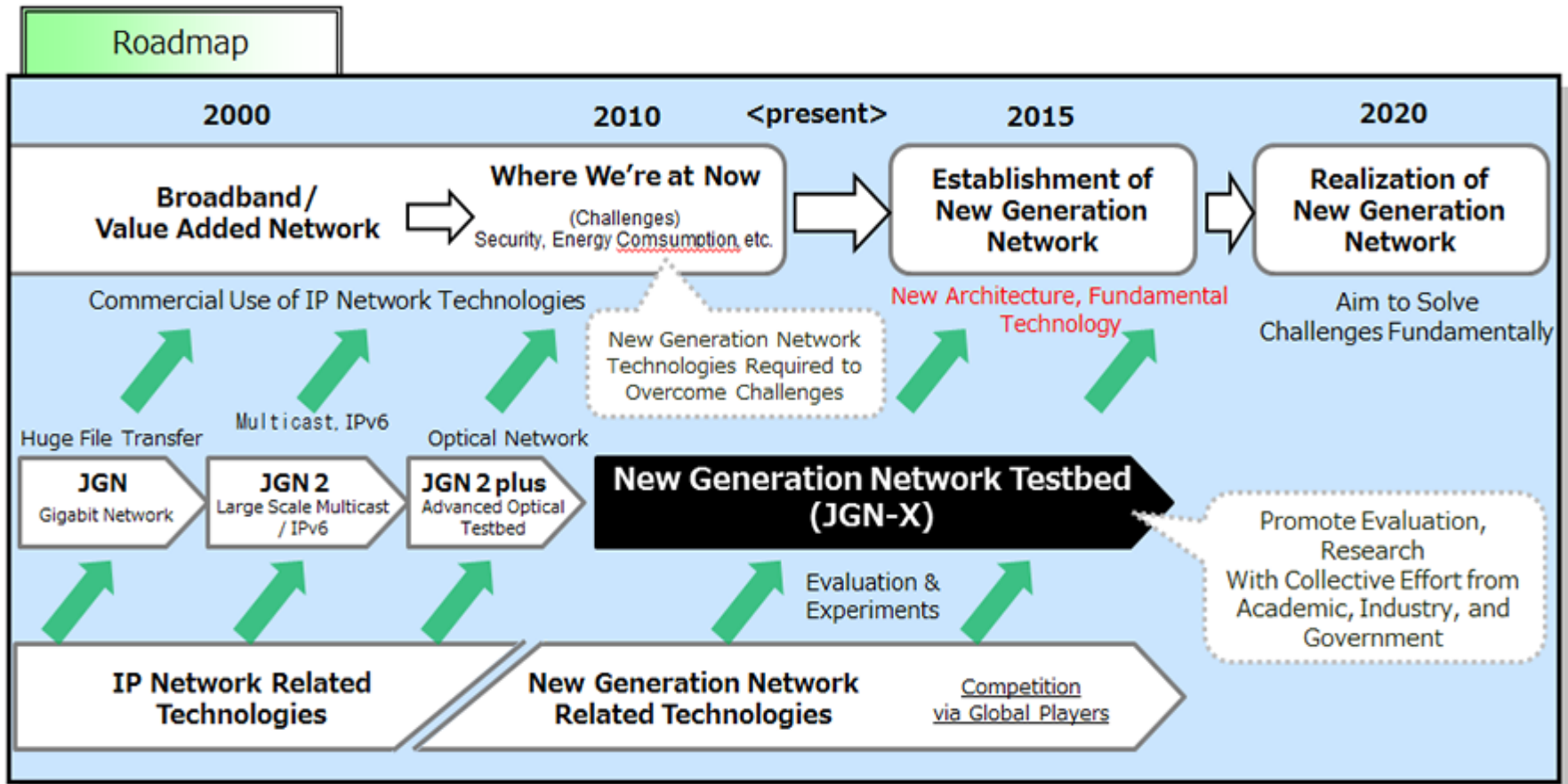
# JAPAN – NWGN (2)

36

- NXGN is now being deployed, standardized, and invested toward the service start in 2007
- NWGN is in the research phase
  - Various projects funded by NICT (National Institute of Information & Communications Technology) from underlay networking to applications
  - MIC is making a new report on a policy for future network research projects which Japanese Government should support

- NICT has launched the JGN2 project with an open testbed network
  - Aims to realize the research and development for Information Communication Technology
  - Since April 2004 following the project of JGN (Japan Gigabit Network) from April 1999 to March 2004
  - In collaboration with the industry, the academia, the government and regional organizations
  - Supports activities from the basic or fundamental research and development to the demonstrative experimental testing towards practicalities
  - Fosters the research of network-related technologies with diverse ranged applications for the next generation
  - Can be utilized by any user if its utilization purpose is research and development

## □ Milestone of JGN-X



- Found in 2007.7 ([www.asiafi.net](http://www.asiafi.net))
  - Asia Future Internet Forum (AsiaFI) was founded to coordinate research and development on Future Internet among countries in Asia as well as with other continents. In order to coordinate the research and development, AsiaFI carries the following activities among others;
    - WGs :
      - [Architecture & Building Blocks Working Group](#)
      - [Mobile & Wireless Working Group](#)
    - BoF : Education, Named Data Network, Network Science, Recursive Network
    - AsiaFI Schools

# KOREA - FIF

40

- Future Internet Forum (FIF)
- 1<sup>st</sup> BOF
  - ▣ Several researchers started an informal meeting in April, 2006
  - ▣ Several monthly BOF meetings followed
- First forum meeting –September, 2006
  - ▣ First stage: to June, 2007
    - Review prior activities related to future Internet research
  - ▣ Second stage (till now)
    - Propose areas that we can contribute most
- WGs
  - ▣ WGs: Architecture/Security, Wireless/Service, Testbed
- International Conference on Future Internet (CFI2018)
- FI Summit 2018



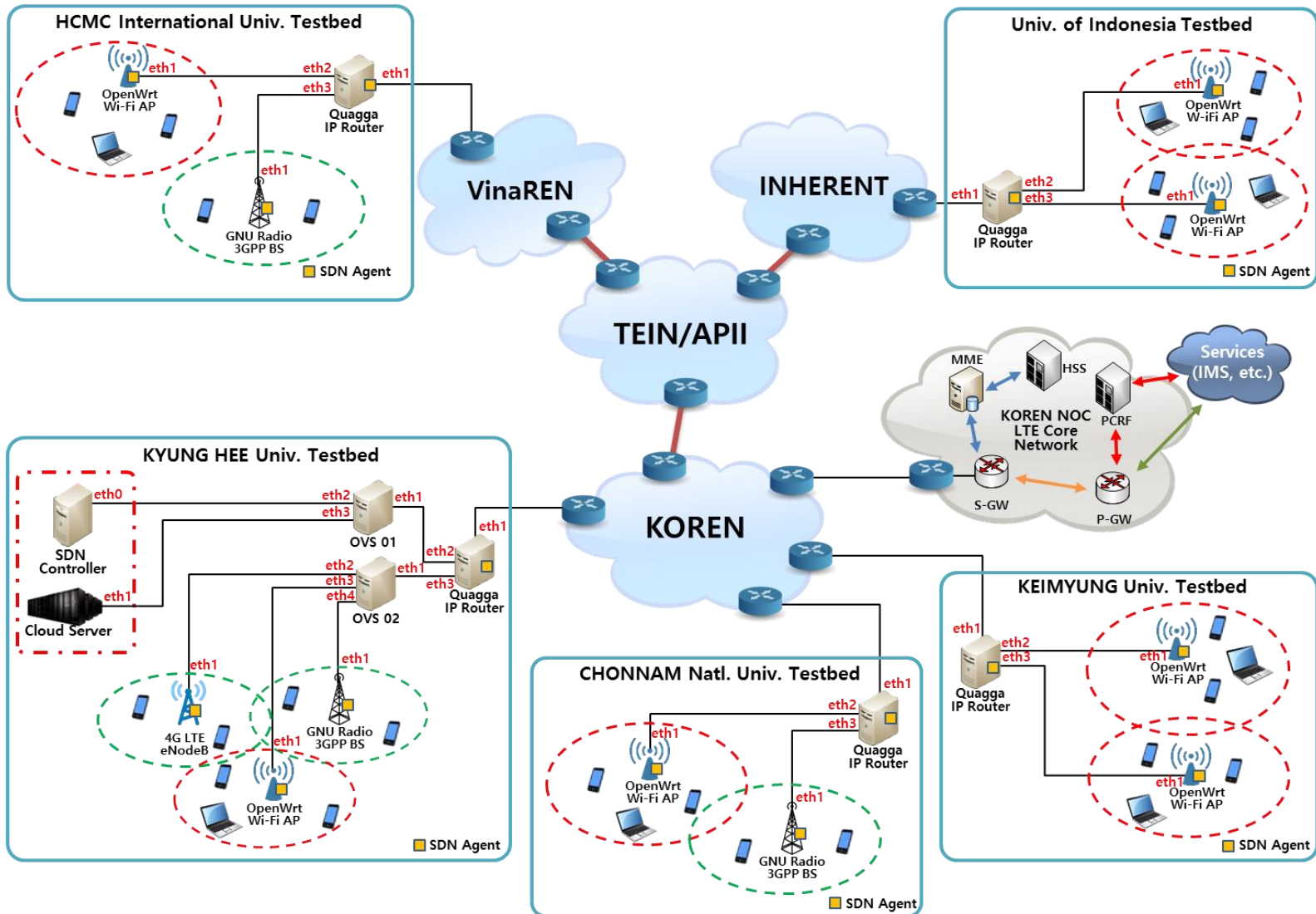
# FIF – Research activities

41

- Propose research projects to MIC (Ministry of Info. & Comm.):  
Fall, 2006
- Granted research funding
  - ▣ CCN, Service Traffic Measurement, Smart Node, SDN, Linked Data, etc.
- Existing testbed networks
  - ▣ KOREN, KREONET
  - ▣ Plan to extend to experiment FI protocols and ideas
  - ▣ Mobile Network Testbed Project using Open sources

# An Open Mobile Testbed

42



# Challenges of the Internet

43

- Security
  - Worrysome to everyone (user, application developers, operators)
- Mobility
  - Little support for mobile applications and services
- Reliability and Availability
  - ISPs face the task of providing a service which meets user expectations
- Problem analysis
  - Toolset for debugging the Internet is limited
- Scalability
  - E.g., routing system
- Quality of Service
  - It is unclear how and where to integrate different levels of QoS
- Economics
  - How network and service operators continue to make a profit

# Requirements of Future Internet

44

- ❑ Highly available information delivery
- ❑ Verifiably secure information delivery
- ❑ Support for mobility
- ❑ Interworking flexibility and extensibility
- ❑ Support for a scalable, unified network
- ❑ Explicit facilitation of cross-layer interactions
- ❑ Distribution of data and control

## □ Keywords

### □ Virtualization

- Virtualize network resources and provide customer-specific services

### □ Programmable

### □ Service-oriented architecture (SOA)

- Define layer's functions as services and converge the services to support the network operations
- Register services, discover services in repository and acquire necessary services

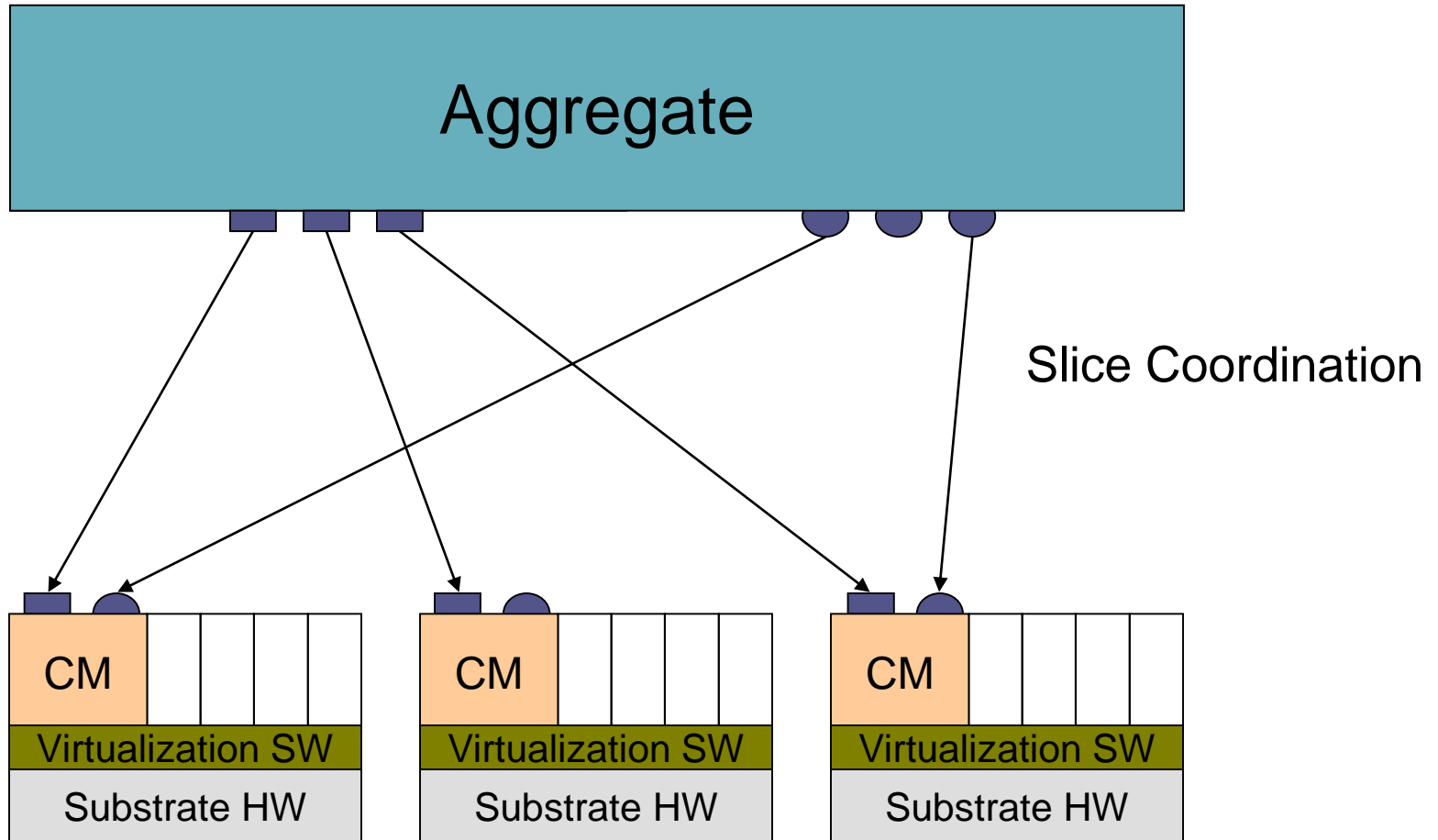
### □ Cross-layer design

- Divide network layers and support a cross-layer mechanism

# Virtualization - GENI

46

- Virtualize network resources and provide customer-specific services

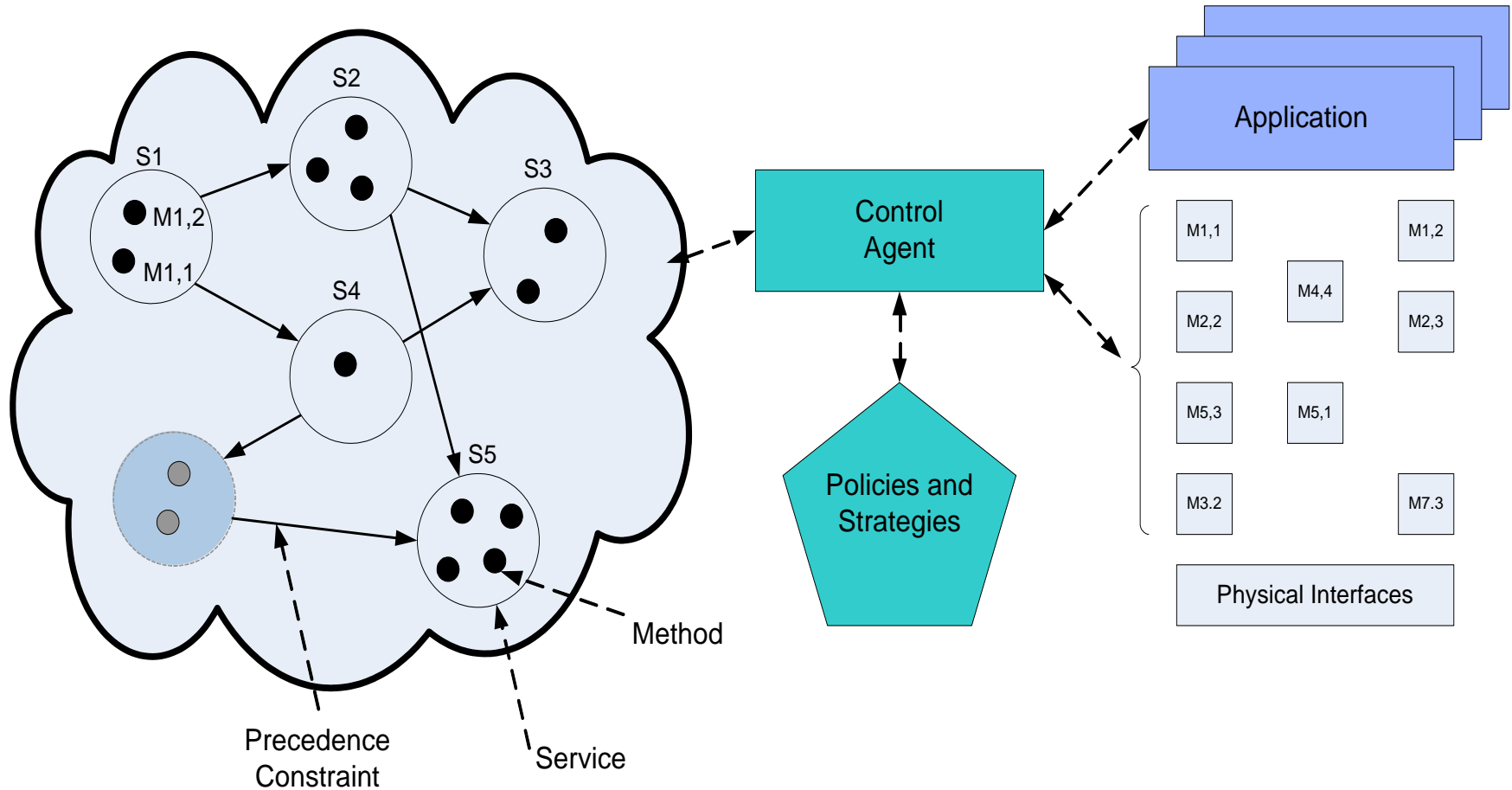


CM : Component Manager

# SOA (1) – FIND's SILOS

47

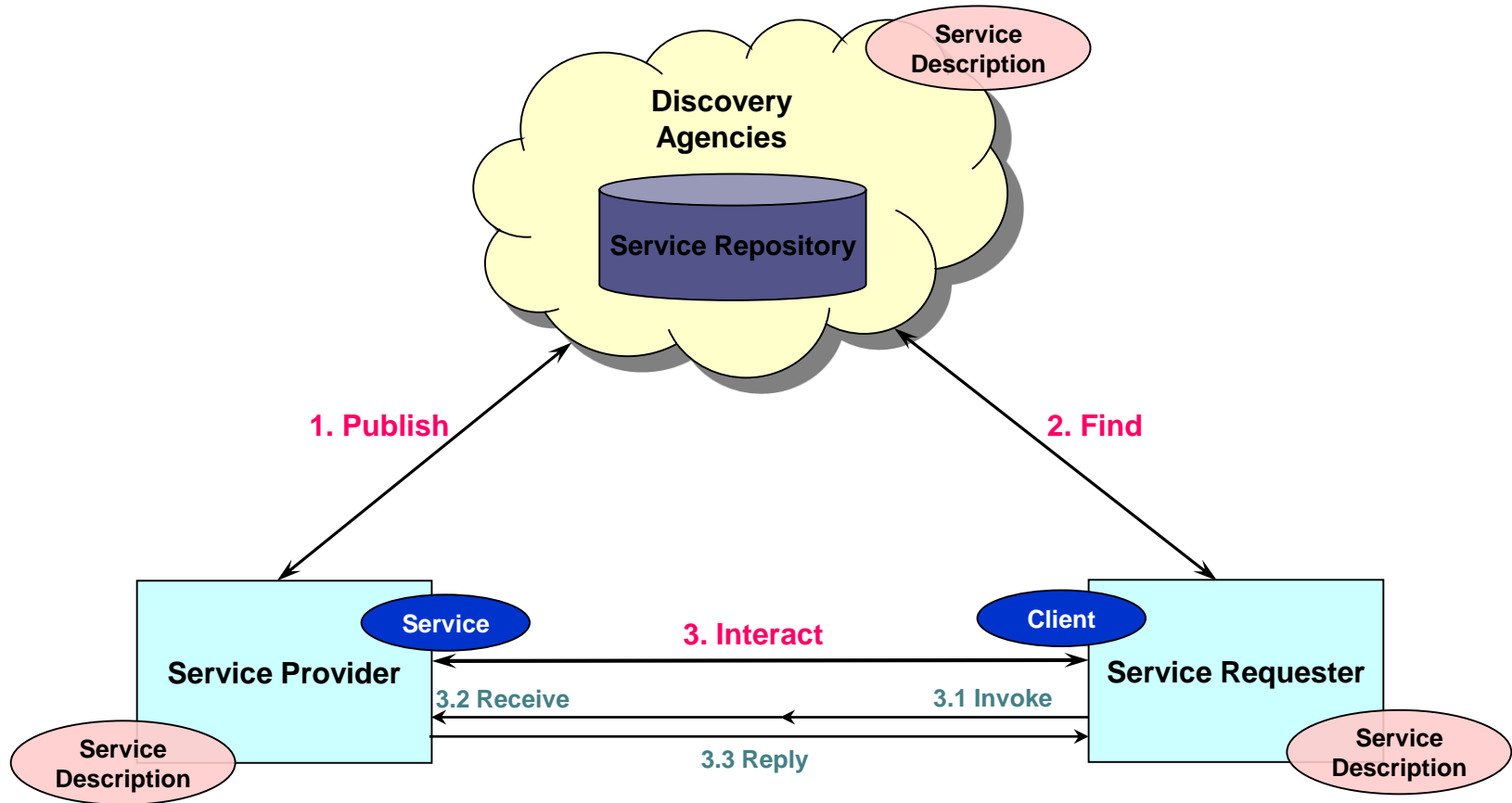
- Service Integration, control, and Optimization
- Define layer's functions as services and converge the services to support the network operations



# SOA (2)

48

- Register services, discover services in repository and acquire necessary services

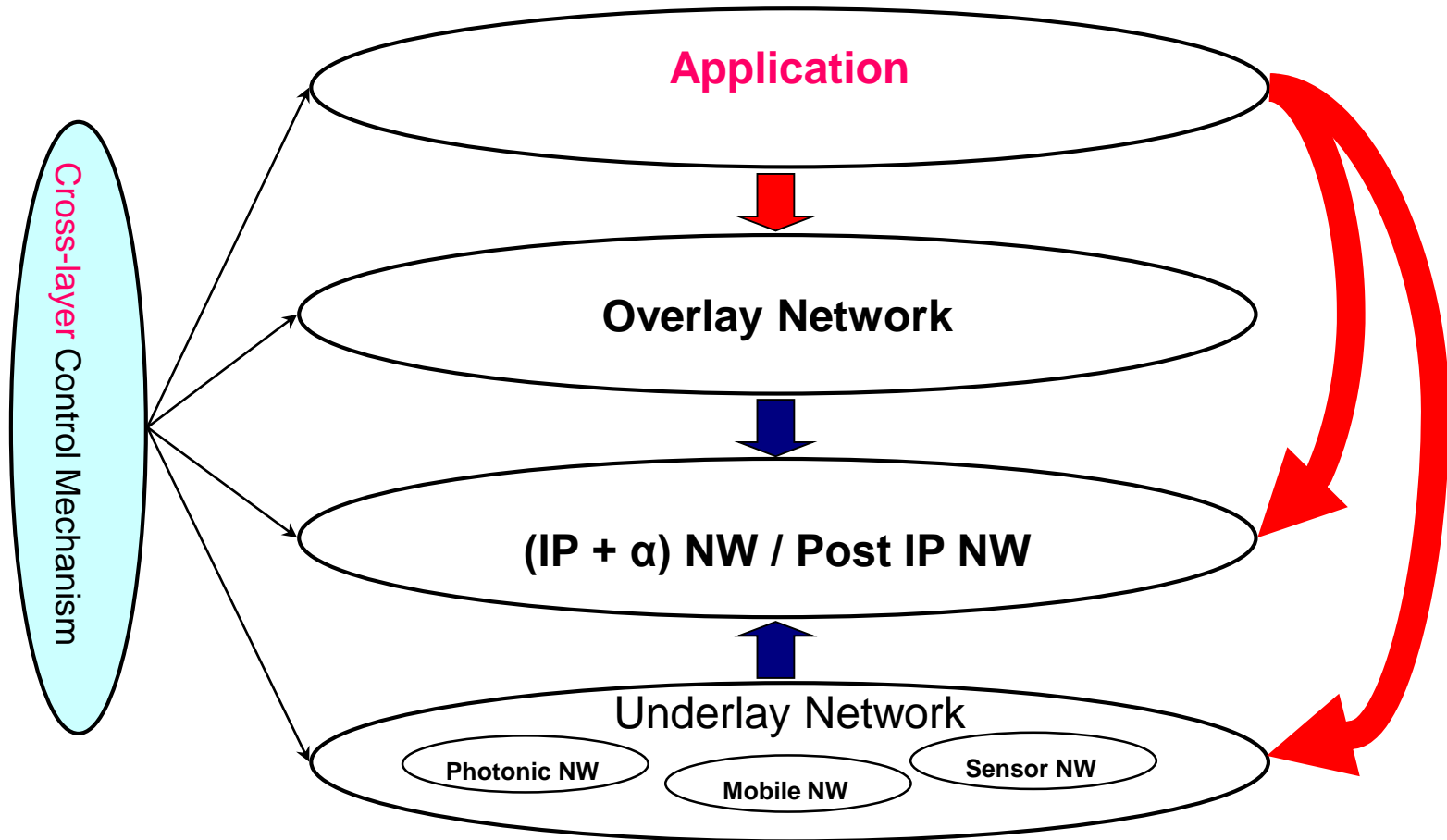




# Cross-Layer Design – JGN2

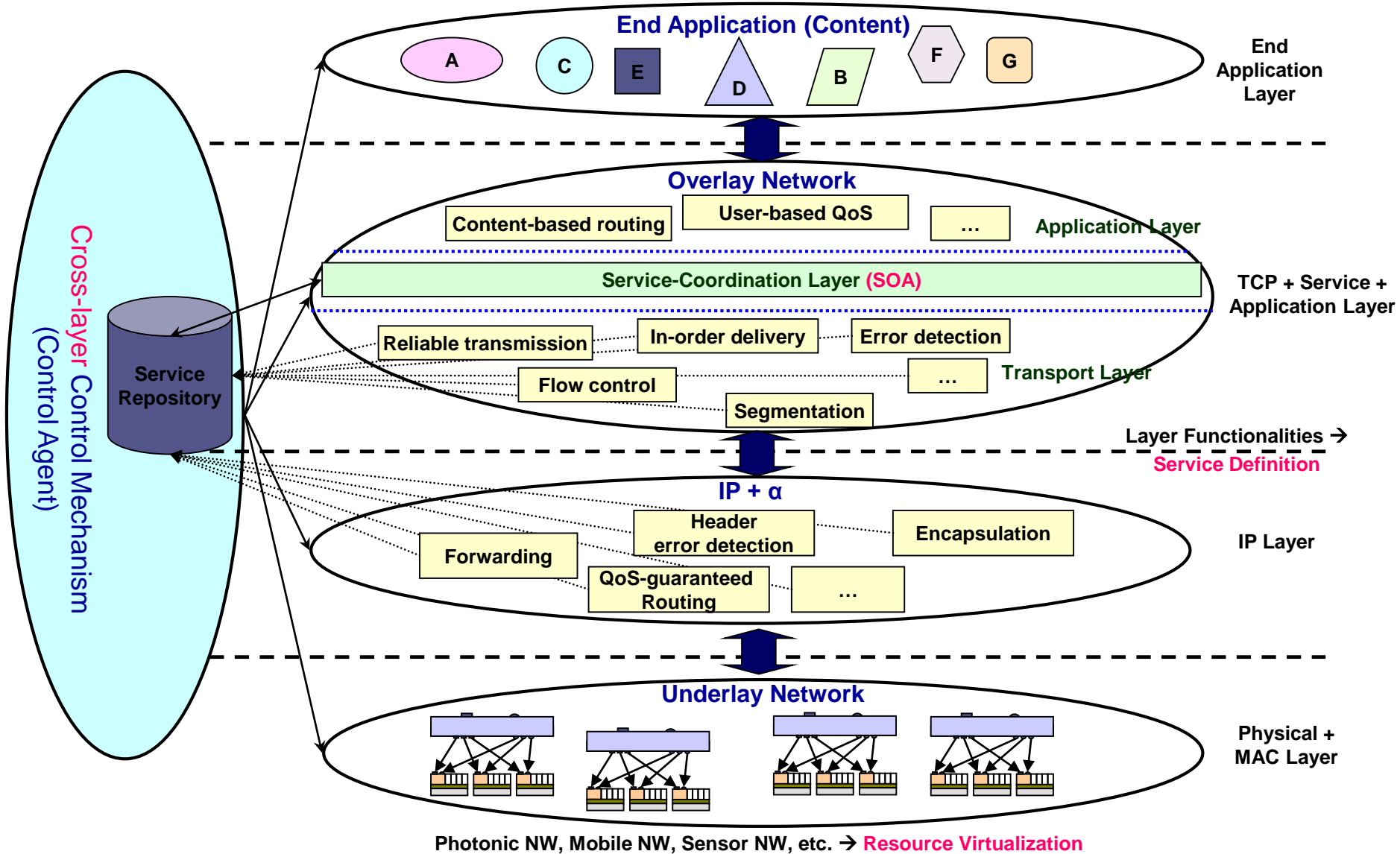
49

- Divide network layers and support a cross-layer mechanism



# Integrated Architecture

50



# A Trend for FI

51

- European Future Internet Initiative PPP (EFII PPP)

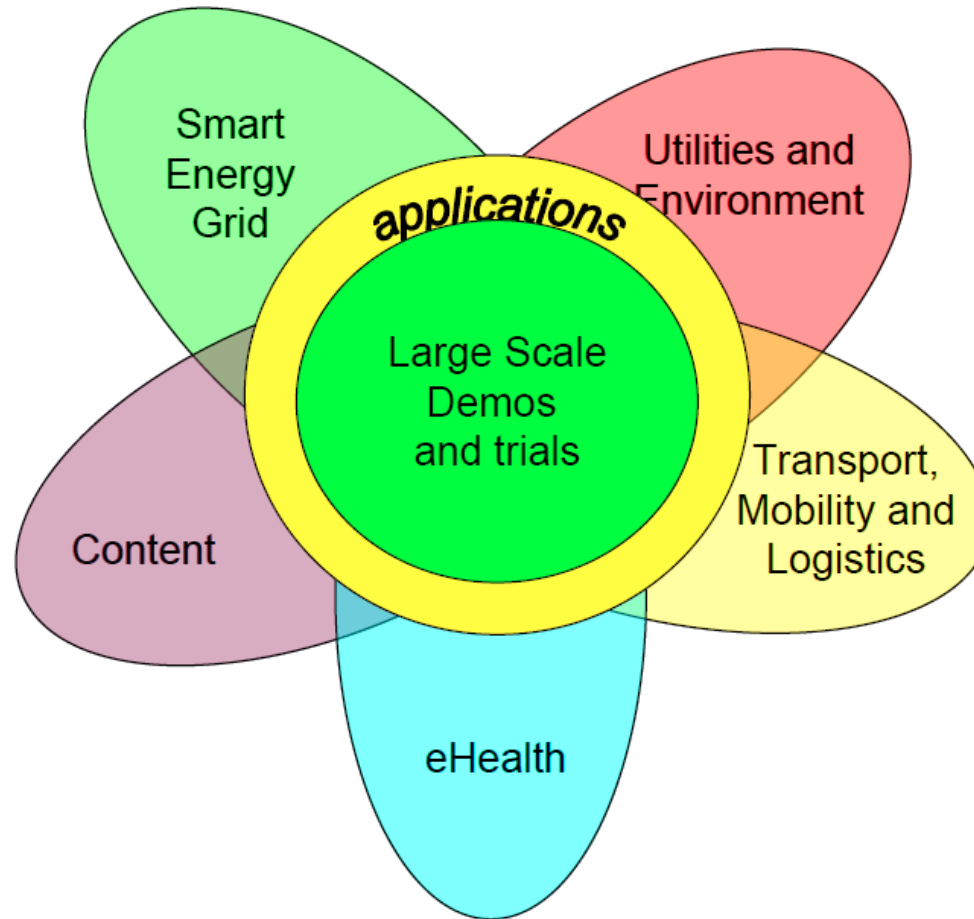
## Founders



Main Objectives : Creation of new European-scale markets for smart infrastructures with integrated ICT functionalities

# Application Services of EFlI

52



# EFII PPP Projects (1)

53

- The FI-PPP Programme is implemented via three phases:
  - [Phase 1](#), 2011-12, budget 90 million euros
    - ▣ Laying the technology foundation
    - ▣ Defining "use case scenarios" in different industry sectors
    - ▣ Making an inventory of available (public) infrastructures via capacity building
    - ▣ Programme support
  - [Phase 2](#), 2013-14, budget 80 million euros
    - ▣ Developing use case pilots and platforms
    - ▣ Setting up infrastructures
  - [Phase 3](#), 2014-16, budget 130 million euros
    - ▣ Expansion of use cases by developing applications and services
    - ▣ Extending the technology foundation

# The Future Internet platform FIWARE (1)

54

- An open source cloud platform with a collaborative and mature ecosystem of developers, innovation Hubs, accelerators, cities and more than 1000 Small and Medium Enterprises and startups.
- By 2020, businesses leveraging the FIWARE platform are expected to generate revenues of more than EUR 330 million
- [FIWARE](#) was born in Europe from the Future Internet Public Private Partnership (FI-PPP), which aimed at:
  - accelerating the development and adoption of Future Internet technologies in Europe,
  - advancing the European market for smart infrastructures, and
  - increasing the effectiveness of business processes through the Internet.

## □ Sectors

- Smart Cities
- AgriFood
- eHealth
- Transport
- Energy & Environment
- Media & Content
- Manufacturing & Logistics
- Social & Learning
- Others

# Concluding Remarks

56

- Current Internet
  - ▣ Root cause of problem: tremendous pace of increase of its use
  - ▣ Merits: openness, freedom of expression and ubiquitous access
  - ▣ Challenges: mobility, scalability, security & privacy, addressing & identity, robustness, manageability, etc.
- Future Internet
  - ▣ **Clean slate design** of Internet architecture considering **security**, scalability, **mobility**, robustness, identity, **manageability**, etc.
- Research Goal
  - ▣ Performing research for Future Internet and designing new network architectures
  - ▣ Building an experimental facility
- Propose an integrated architecture of Future Internet
- Investigate possible research topics towards management of Future Internet
  - ▣ In a design phase, we can imagine all possible mechanisms to solve the drawbacks of current Internet
  - ▣ How can we validate our proposed architecture and management issues?
  - ▣ What topic can we focus on?



# References

57

- [www.asiafi.net](http://www.asiafi.net)
- [www.fif.net](http://www.fif.net)
- [www.geni.net](http://www.geni.net)
- [www.eurongi.net](http://www.eurongi.net)
- [www.ign2.jp](http://www.ign2.jp)
- <http://cordis.europa.eu/fp7/ict/fire/>
- [cfit.ucdavis.edu/internet\\_futures/](http://cfit.ucdavis.edu/internet_futures/)
- <http://net.educause.edu/ir/library/pdf/ERM0640.pdf>
- <http://www.panlab.net/>
- <http://www.fi-ppp.eu/projects/>
- <http://ec.europa.eu/programmes/horizon2020/>
- [http://ec.europa.eu/research/participants/data/ref/h2020/wp/2018-2020/main/h2020-wp1820-leit-ict\\_en.pdf](http://ec.europa.eu/research/participants/data/ref/h2020/wp/2018-2020/main/h2020-wp1820-leit-ict_en.pdf)
- <https://www.firmware.org/>

# Question and Discussion

58

