A SURVEY OF THE RESEARCH ON FUTURE INTERNET ARCHITECTURES

Jianli Pan et al. IEEE Communications Magazine, July 2011 p. 26-36

Steps for a FIA

1. Innovations in various aspects of the Internet
2. Collaborative projects putting multiple innovations into an overall networking architecture
3. Testbeds for real-scale experimentation

- It may take a few rounds or spirals to work out a future Internet architecture that can fit all the requirements.

Key Research Topics

- Content- or data-oriented paradigms:
  - It is desirable to change the architecture's narrow waist from IP to the data or content distribution.
  - Several research projects are based on this idea.
  - Challenges:
    - In data and content security and privacy,
    - Scalability of naming and aggregation,
    - Compatibility and co-working with IP, and
    - Efficiency of the new paradigm.

Key Research Topics

- Mobility and ubiquitous access to networks:
  - mobility as the norm instead of an exception of the architecture
  - Challenges:
    - how to trade off mobility with scalability,
    - security, and privacy protection of mobile users,
    - mobile endpoint resource usage optimization,
    - and so on.

Key Research Topics

- Cloud-computing-centric architectures
  - It is important to create secure, trustworthy, extensible, and robust architecture to interconnect data, control, and management planes of data centers.
  - Challenge:
    - how to guarantee the trustworthiness of users while maintaining persistent service availability.

Key Research Topics

- Security:
  - Technical context:
    - it has to provide multiple granularities (encryption, authentication, authorization, etc.) for any potential use case.
    - it needs to be open and extensible to future new security related solutions.
  - Economic and public policy context:
    - it should ensure a trustworthy interface among the participants (e.g., users, infrastructure providers, and content providers).

Key Research Topics

- Experimental testbeds
  - testbed research includes:
    - multiple testbeds with different virtualization technologies, and
    - the federation and coordination among these testbeds.

Research Projects from the US

Research Projects from the US

Categories	Project or cluster names (selected)
FIA	NDN, MobilityFirst, NEBULA, XIA, etc.
FIND	CABO, DAMS, Maestro, NetSerV, RNA, SISS, etc. (more than 47 total)
GENI	Spiral1: (5 clusters totally): DETER (1 project), PlanetLab (7 projects), ProtoGENI (5 projects), ORCA (4 projects), ORBIT (2 projects; 8 not classified; 2 analysis projects
	Spiral2: over 60 active projects as of 2009*
	Spiral3: about 100 active projects as of 2011*

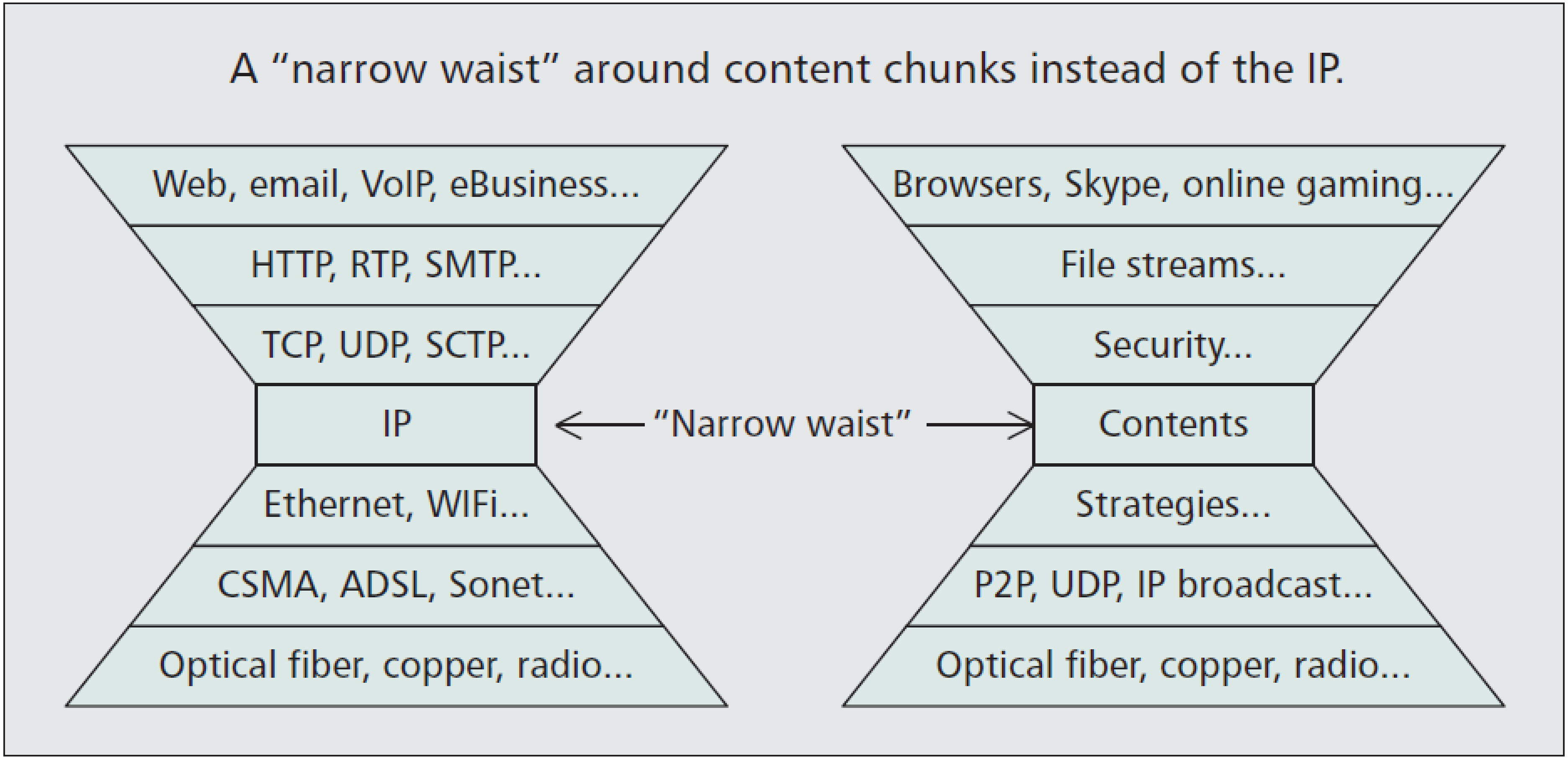
* GENI design and prototyping projects can last for more than one spiral.

Spiral4: outono 2011.
Spiral5: teve início no outono 2012.

NDN – Named Data Networking

- UCLA + 10 universities and research institutes
- Content Centric Model:
  - The data are named instead of their location (IP addresses)
  - Data become the first-class entities in NDN
  - Instead of trying to secure the transmission channel or data path through encryption, NDN tries to secure the content by naming the data through a security-enhanced method.
    - Separates trust in data from trust between hosts and servers.

NDN – Named Data Networking



NDN Key Research Issues

- How to find the data? Or How the data are named and organized to ensure fast data lookup and delivery?
  - Name the content by a hierarchical "name tree" which is scalable and easy to retrieve
- Data security and trustworthiness:
  - The contents are signed by public keys
- Scaling
  - Names are longer than IP addresses, but the hierarchical structure helps the efficency of lookup and global accessibility of the data.

NDN – Other challenges

- Routing scalability
- Security and trust models
- Fast data forwarding and delivery
- Content protection and privacy
- Underlying theory supporting the design

MobilityFirst

- Rutgers + 7 universities
- Basic Motivation:
  - The current Internet fails to address the trend of dramatically increasing demands of mobile devices and services.
- Short term goals:
  - Addressing the cellular convergence
  - Providing mobile p2p and infostation (DTN) application services.
- Long term: V2V and V2I modes
  - Location services, georouting, and reliable multicast.

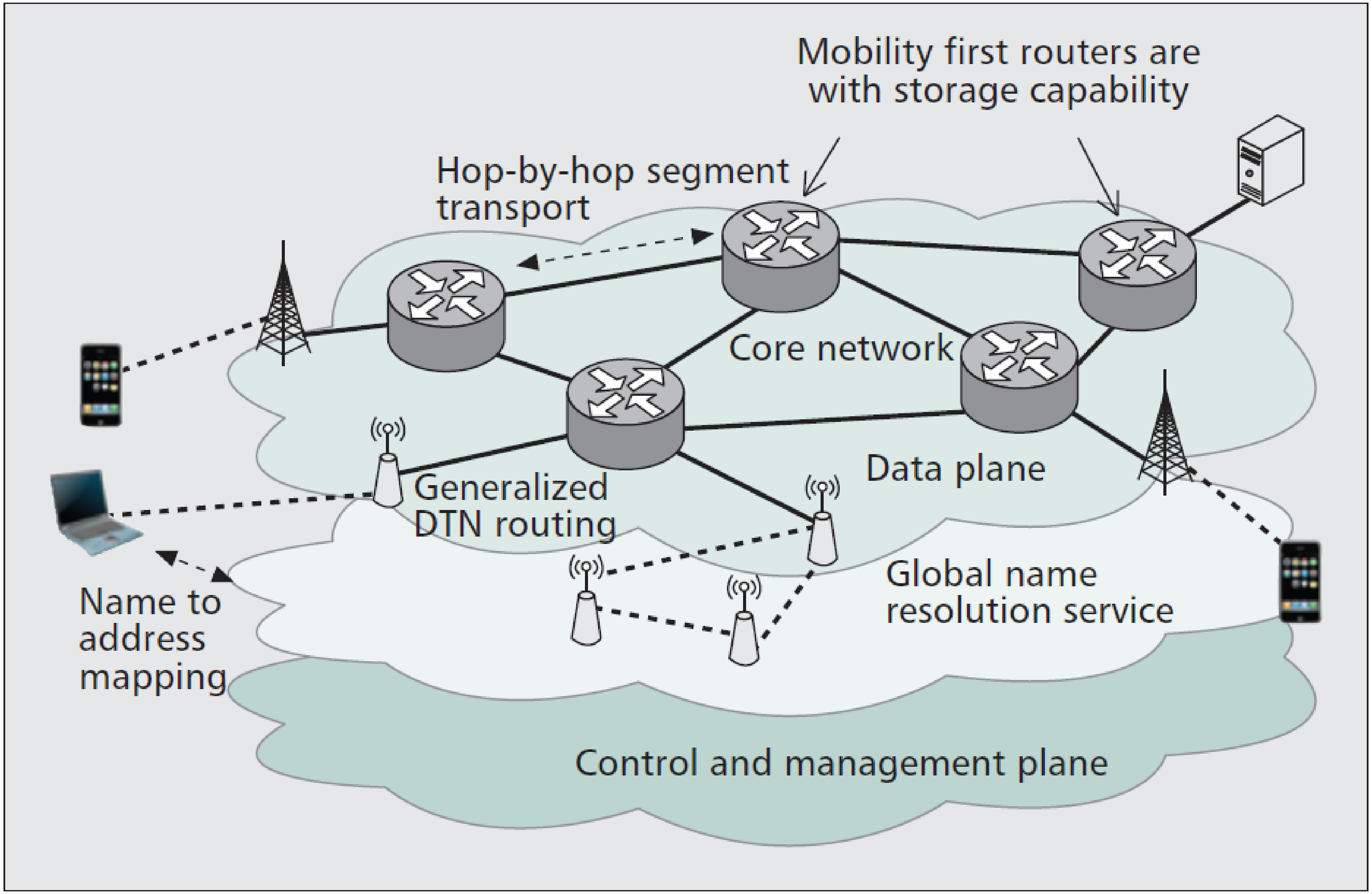
MobilityFirst

- Challenges:
  - Stronger security and trust requirements
- Targets a clean-slate design directly addressing mobility
  - The fixed Internet will be a special case of the general design
- "Narrow waist" around several protocols:
  - Global name resolution and routing service
  - Storage-aware (DTN-like) routing protocol
  - Hop-by-hop segmented transport
  - Service and Management APIs

MobilityFirst

- The DTN-like routing protocol is integrated with the use of self-certifying public key addresses for inherent trustworthiness.
- Context- and location-aware services fit into the architecture naturally

MobilityFirst Architecture



MobilityFirst

- Typical research challenges:
  - Trade-off between mobility and scalability
  - Content caching and opportunistic data delivery
  - Higher security and privacy requirements
  - Robusteness and fault tolerance

NEBULA

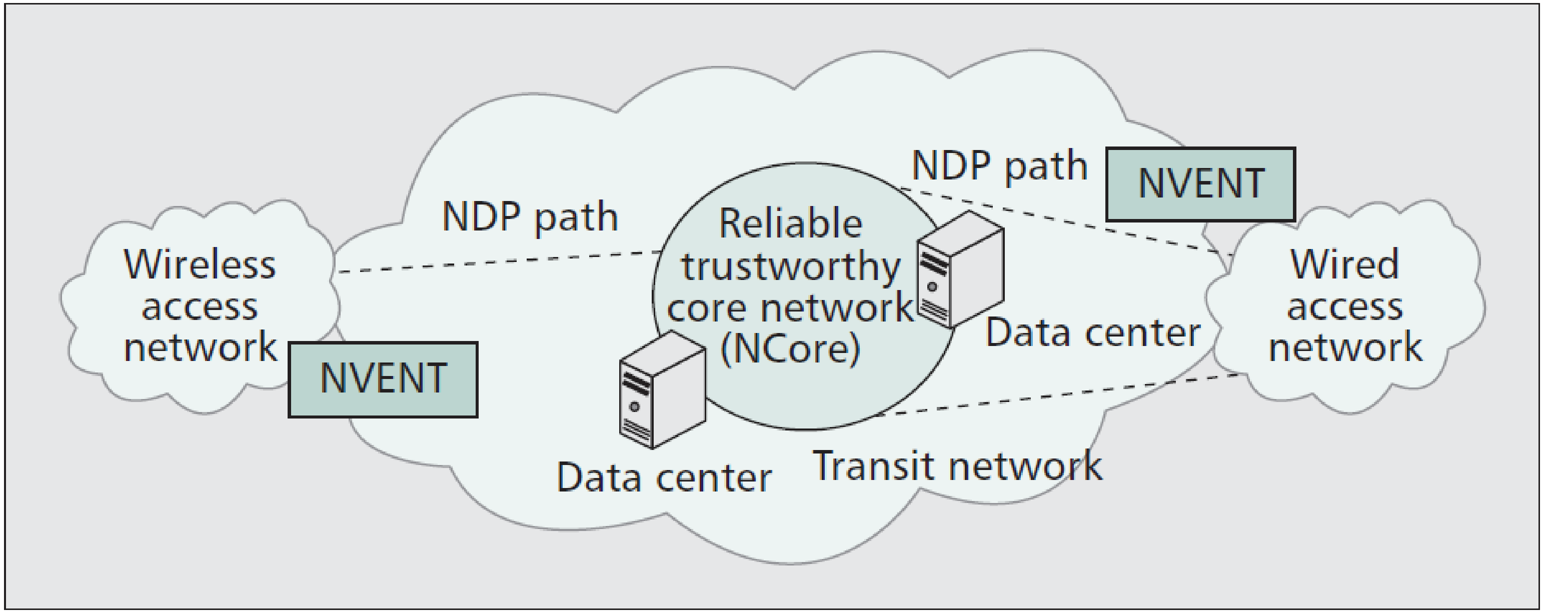
- University of Pennsylvania + 11 other universities
- Cloud-computing-centric architecture.
  - Highly available and extensible core network interconnecting data centers to provide utility-like services.
  - Multiple cloud providers can use replication by themselves
  - Mobile “roaming” users connect to the nearest data center with a variety of access mechanisms such as wired and wireless links.

NEBULA Design Principles

- Reliabe and high-speed core interconnecting data centers
- Parallel paths between data centers and core routers
- Secure in both access and transit
- A policy-based path selection mechanism
- Authentication enforced during connection establishment

NEBULA FIA Key Parts

- The NEBULA data plane (NDP)
- NEBULA virtual and extensible networking techniques (NVENT)
- The NEBULA core (Ncore)



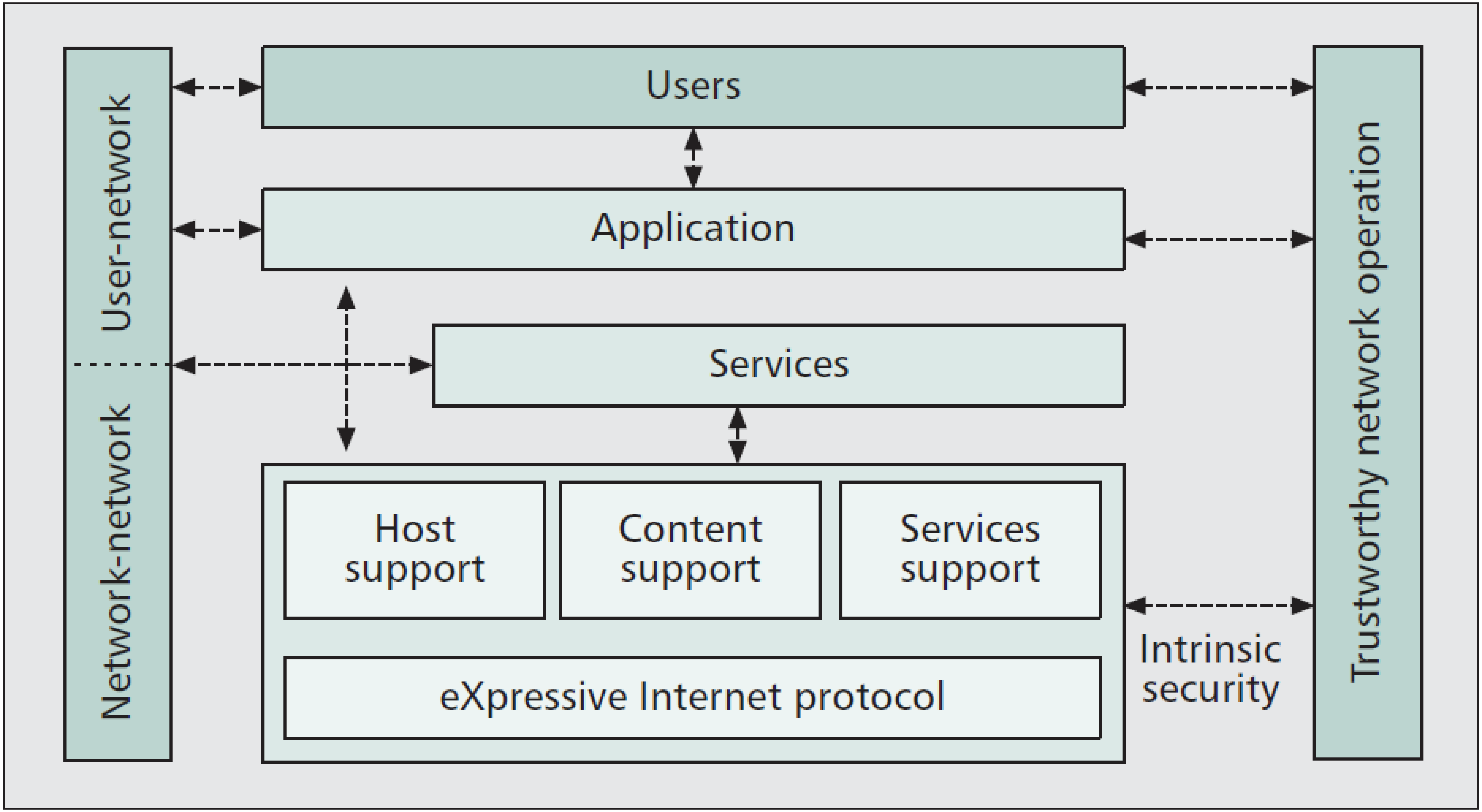
eXpressive Internet Architecture (XIA)

- Carnegie Mellon + 2 other universities
- Directly and explicitly targets the security issue within its design

eXpressive Internet Architecture (XIA)

- Key ideas:
  - Define a rich set of building blocks or communication entities as network principals including hosts, services, contents, and future additional entities.
  - It is embedded with intrinsic security by using self-certifying identifiers for all principals for integrity and accountability properties.
  - A pervasive "narrow waist" (not limited to the host-based communication as in the current Internet) for all key functions, including access to principals, interaction among stakeholders, and trust management; it aims to provide interoperability at all levels in the system, not just packet forwarding.

XIA components and interactions



GENI

GENI Key Pieces

- Physical network substrates that are expandable building block components
- A global control and management framework that assembles the building blocks together into a coherent facility

GENI generic control framework

- Basic entities:
  - Aggregate and components
  - Clearinghouse
  - Research organizations, including researchers and experiment tools
  - Experiment support service
  - “Opt-in” end users
  - GENI operation and management

GENI Original Clusters

- Cluster A: TIED – Trial Integration Environment based on DETER
- Cluster B: CF based on PlanetLab
- Cluster C: ProtoGENI
- Cluster D: ORCA – Open Resource Control Architecture
- Cluster E: ORBIT – Open-Access Research Testbed for Next-Generation Wireless Networks

Research Projects from the EU

FP7 Projects

- Objective 1.1: Network of the Future
- Clusters:
  - "Future Internet Technologies (FI),"
  - "Converged and Optical Networks (CaON)," and
  - "Radio Access and Spectrum (RAS)."

Research Projects from the EU

Categories	Project names (selected)
Future Architectures and Technologies	4AWARD, TRILOGY, EIFFEL, SPARC, SENSEI, Socrates, CHANGE, PSIRP, etc.
Services, Software, and Virtualization	ALERT, FAST, PLAY, S-Cube, SLA@SOI, VISION Cloud, etc.
Network Media	3DLife, COAST, COMET, FutureNEM, nextMEDIA, P2P-Next, etc.
Internet of Things	ASPIRE, COIN, CuteLoop, SYNERGY, etc.
Trustworthiness	ABC4Trust, AVANTSSAR, ECRYPT II, MASTER, uTRUSTit, etc.
Testbeds	FIRE, N4C, OPNEX, OneLAB2, PII, WISEBED, G-Lab, etc.
Others	HYDRA, INSPIRE, SOCIALNETS, etc.

4WARD – Architecture and Design for the Future Internet

- Led by an industry consortium
- Design goals:
  - To create a new “network of information” paradigm in which information objects have their own identity and do not need to be bound to hosts
  - To design the network path to be an active unit that can control itself and provide resilience and failover, mobility, and secure data transmission
  - To devise “default-on” management capability that is an intrinsic part of the network itself
  - To provide dependable instantiation and interoperation of different networks on a single infrastructure.

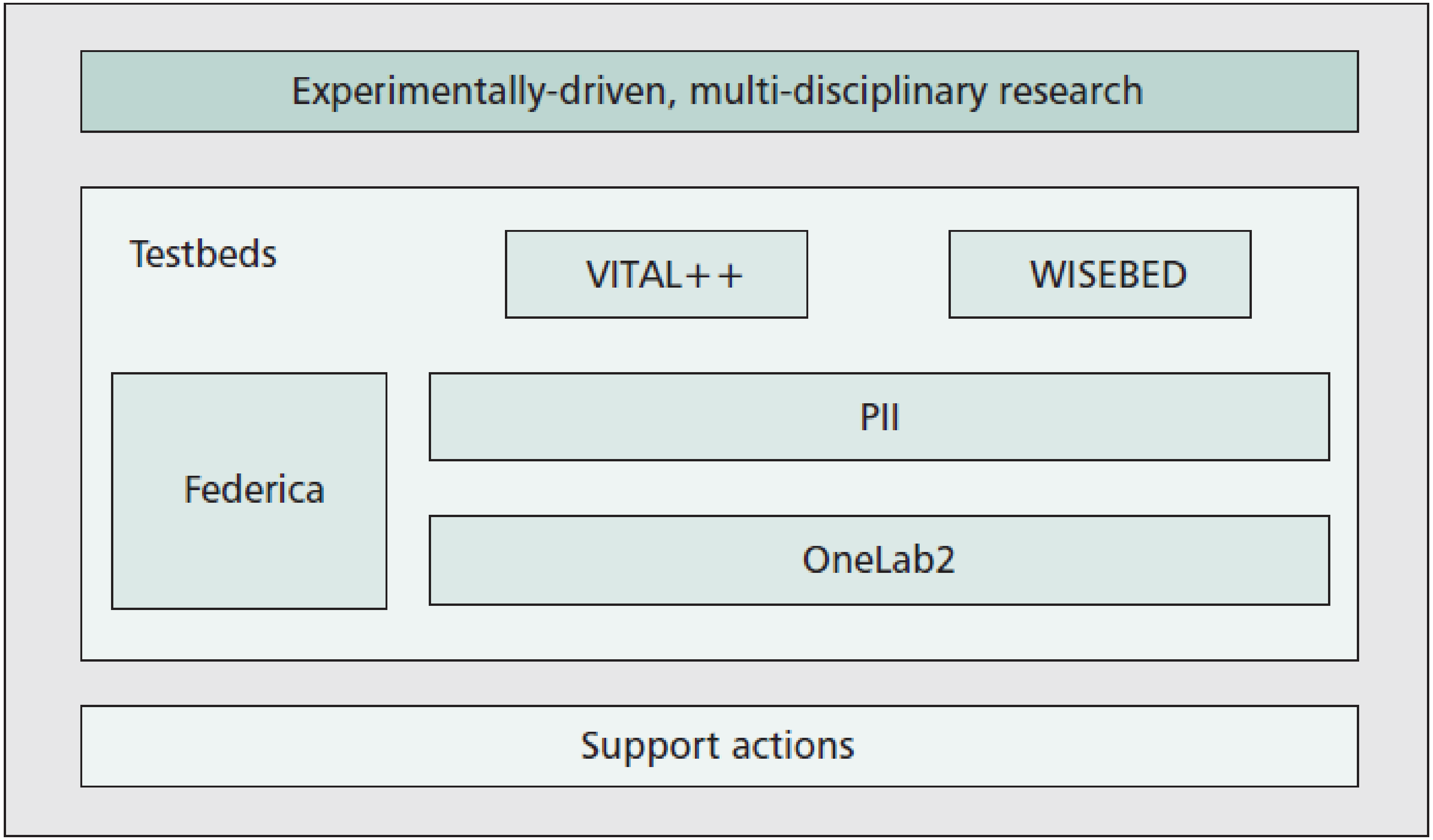
4WARD Task Components

- A general architecture and framework
- Dynamic mechanisms for securely sharing resources in virtual networks
- "Default-on" network management system; a communication path architecture with multipath and mobility support
- Architecture for information-oriented networks

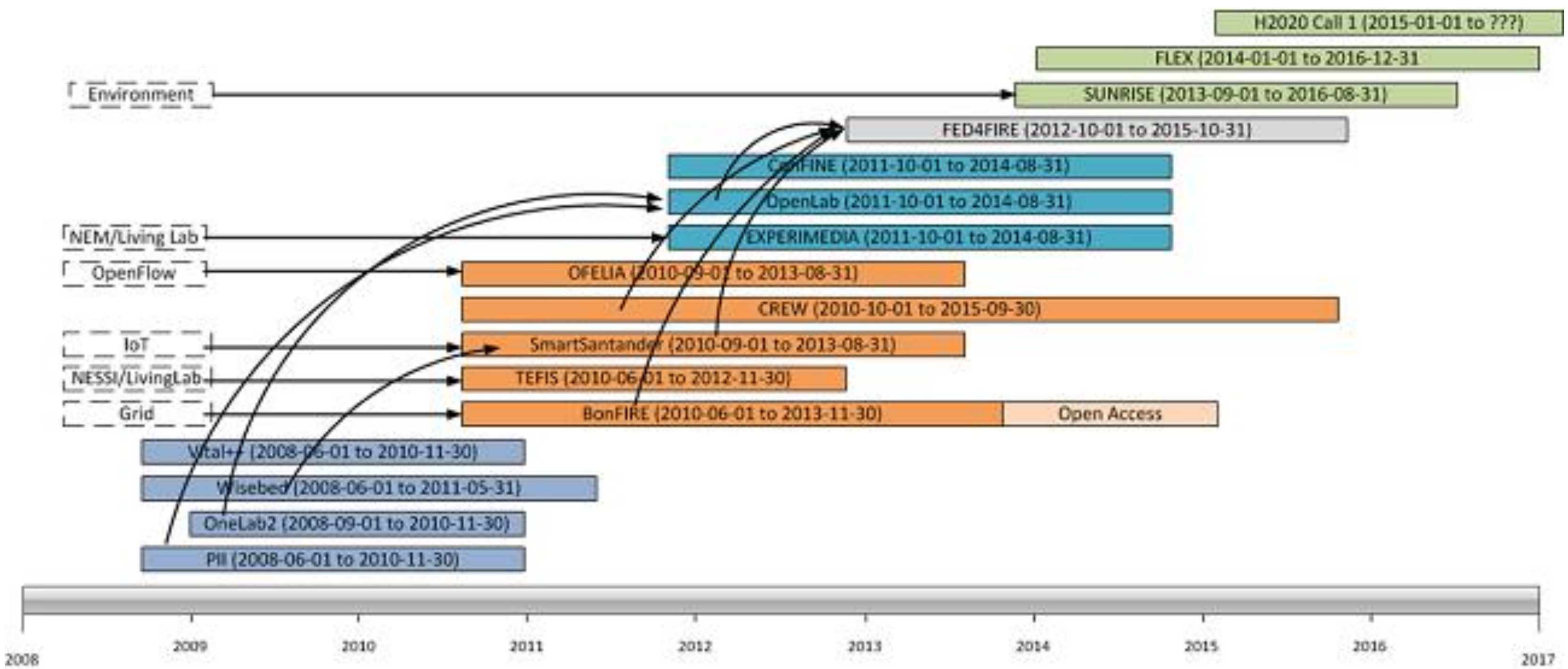
FIRE – Future Internet Research and Experimentation

- Started a 4th wave in 2012.
- Dimensions:
  - To support long-term experimentally driven research on new paradigms and concepts and architectures for the future Internet
  - To build a large-scale experimentation facility by gradually federating existing and future emerging testbeds
- A major goal of FIRE is federation.

FIRE clustering of projects



FIRE roadmap



Fonte: http://www.ict-fire.eu/home/fire-roadmap.html

Asia

Japan

- NWGN – New Generation Network
- Participates in PlanetLab and is federated with G-Lab
- AKARI – FI Architecture
- JGN2plus and JGN-X

AKARI

- AKARI = "a small light in the darkness"
- Clean-slate approach
- Key design principles:
  - "Crystal synthesis," which means to keep the architecture design simple even when integrating different functions
  - "Reality connected," which separates the physical and logical structures
  - "Sustainable and evolutional," which means it should embed the "self-*" properties (self-organizing, self-distributed, self-emergent, etc.), and be flexible and open to the future changes

China

- Research projects:
  - New Generation Trustworthy Networks (from 2007 to 2010)
  - New Generation Network Architectures (from 2009 to 2013)
  - Future Internet Architectures (from 2011 to 2015)
- Other projects:
  - China Next Generation Internet (CNGI)
  - IPv6 testbed

Discussions and Perspectives

Issues worth discussing

- Clean-slate vs. Evolutionary
  - While the architectures can be revolutionary, their implementation has to be evolutionary.
  - Any architecture that requires investment without immediate payoff is bound to fail.
- Integration of security, mobility, and other functionalities
- Architectures built around people instead of machines

Issues worth discussing

- Experimental facilities
- Service delivery networks