Thinking of Architecture for Future Internet

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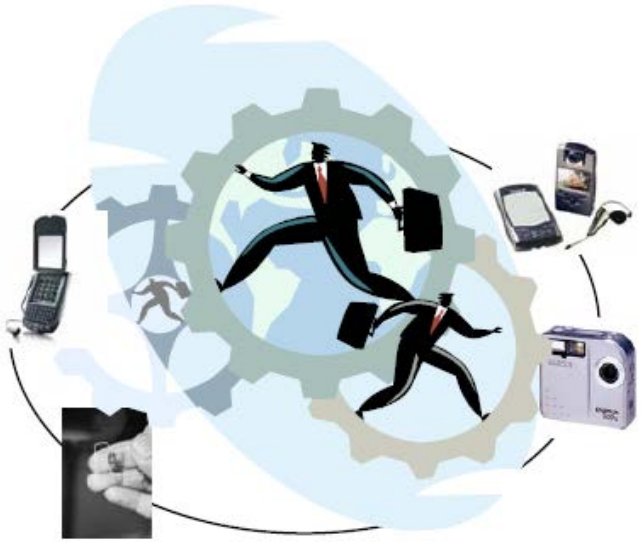
Recall of Internet ('74)

- Design Goals
  - (0) To connect existing networks
  - (1) Survivability
  - (2) To support multiple types of services
  - (3) To accommodates a variety of physical networks
  - (4) To allow distribute network management
  - (5) To be cost effective
  - (6) To allow host attachment with a low level of effort
  - (7) To allow resource accountability
- Design Principles
  - Layering (design goal – 0, 3)
  - Packet Switching (design goal – 5)
  - A network of collaborating networks (design goal – 1, 4)
  - Intelligent end-system / end-to-end arguments (design goal – 1, 5)
  - DHCP (design goal – 6), SNMP (design goal – 7)

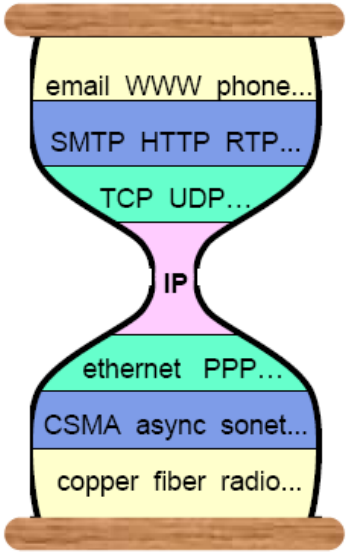
Changes of Networking

- Environment
  - *Trusted => Untrusted*
- Users
  - *Researchers => Customers*
- Operators
  - *Nonprofits => Commercial*
- Usages
  - *Host-oriented => Data-centric*
- Connectivity
  - *E2E IP => Intermittent Connection*



Internet Architecture (Hourglass model)

- IP over Everything
- Everything over IP
- The dummy network provides minimal functions while enabling the upper application on END SYSTEM evolution and competition. (end system matches PC age)

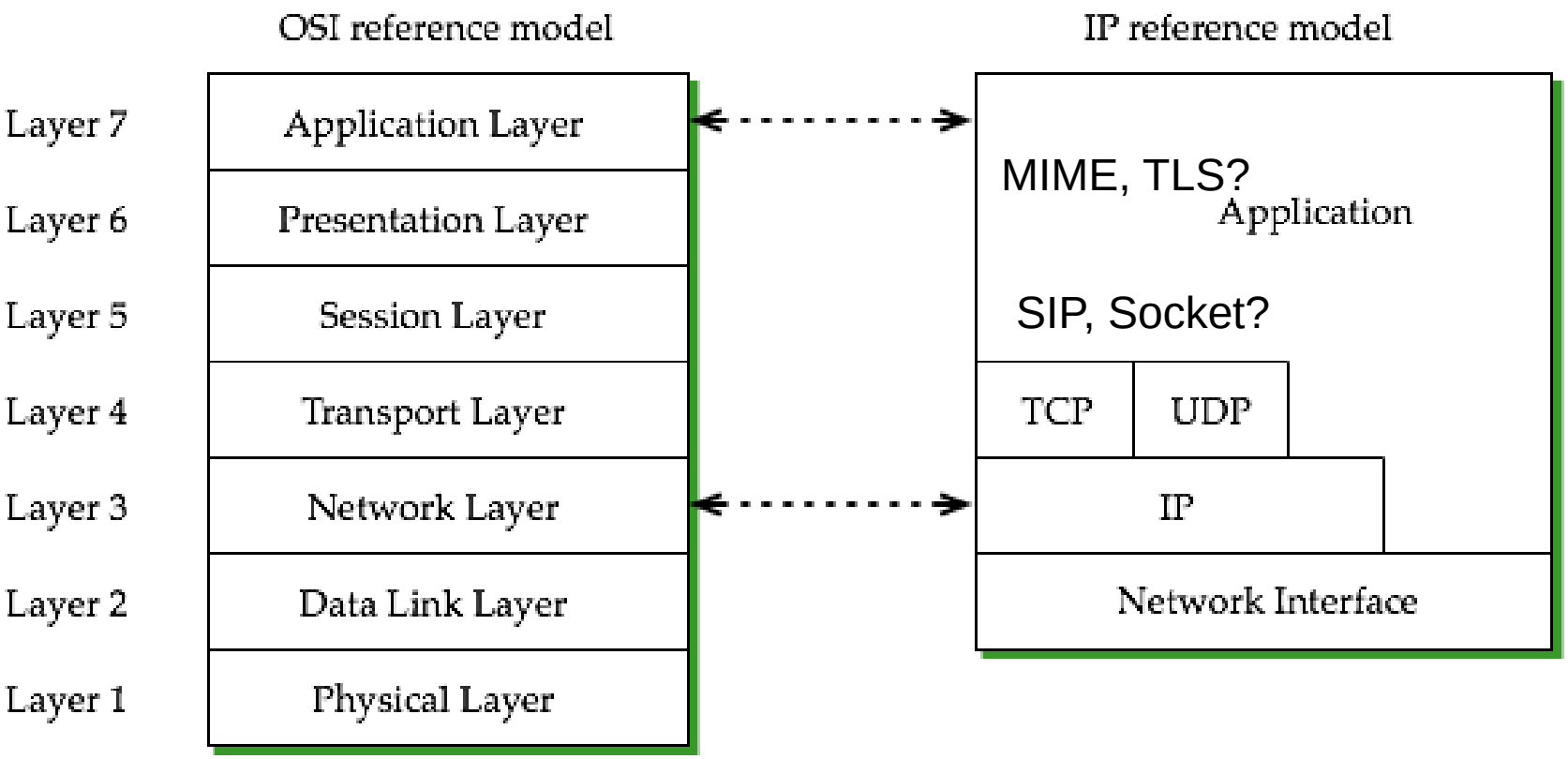


Narrow Waist for Internet Hourglass (Common Layer = IP)

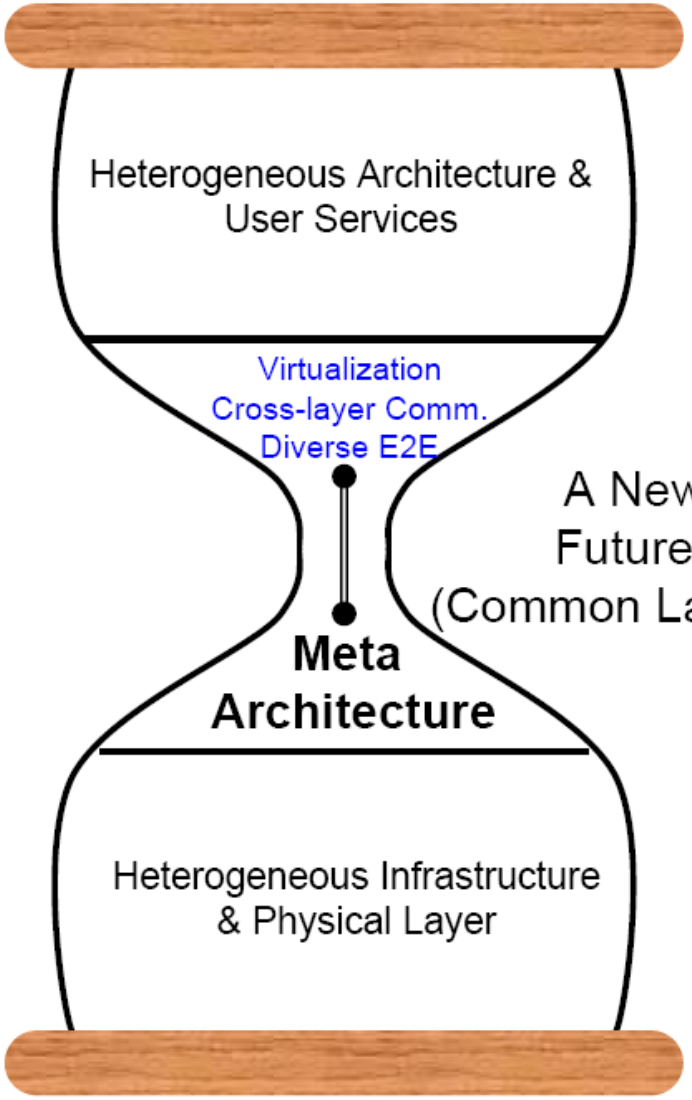
Source : Steve Deering, IPv6 :addressing the future

- Shortcoming : IP layer is toooo important to evolve (***"Narrow waist"***)

Internet Architecture

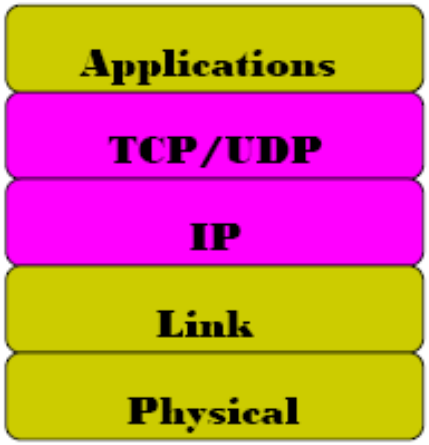


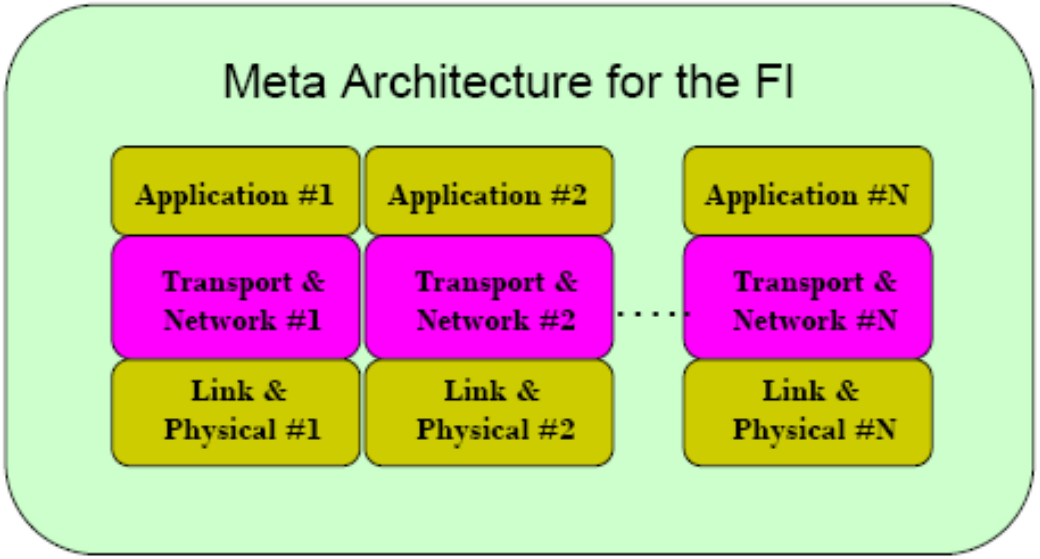
Future Internet



A New Narrow Waist for
Future Internet Hourglass
(Common Layer = Meta Architecture)

Internet vs. FI





Current Internet :
Architecture – TCP/IP (Narrow Arch.)
Mechanism – SNMP, IPsec …
Application – Web, E-mail …

FI :
Meta Architecture : Multiple Architectures Architecture
Architecture – TCP/IP, Intermittent X, ….
Mechanism – SNMP, IPsec, Cognitive, Cooperative,
Application – Web, E-mail, Sensor, Vehicle/aircraft, Satellite

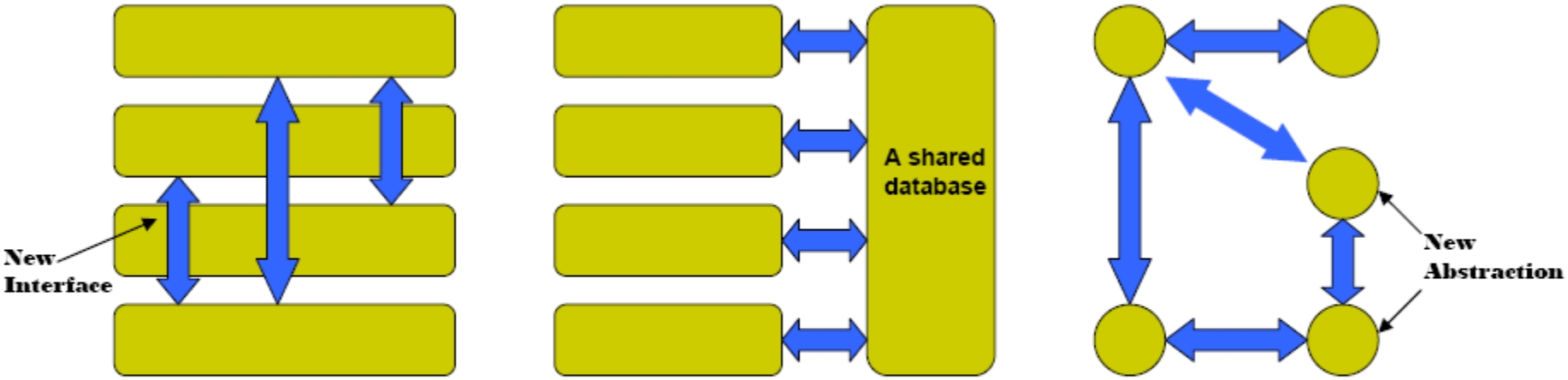
Meta Architecture

- Network virtualization
  - Realize virtual network with programmable network elements.
  - Multiple architectures architecture or no architecture
- Federation of different architecture regions
  - Heterogeneous networks with heterogeneous architectures connected with gateway
- New layered architecture
  - Violate strict layering abstraction
  - Instead, use other layers' functionalities (APIs) to do something efficiently
- Diverse models of the end-to-end principle

Network Virtualization

- *De-ossifying the current Internet*
  - Multiple *virtual networks* co-exist on top of a shared *substrate*.
  - Different virtual networks provide alternate end-to-end packet delivery systems and may use different protocols and packet formats.
  - Easily programmable
    - Can experiment on any level (optical to apps)
- E.g., GENI (Global Environment for Network Innovations)

Cross-Layer Design Proposals



a) Direct communication between the different layers

b) A shared database

c) Complete new abstraction (no more protocol layers)

Source : V. Srivastava et al., Cross-layer design, IEEE Comm. Magazine, 2005

Diverse E2E Communications

- Original E2E
  - Concerned with end-to-end services and protocols implemented in hosts, such as transport protocols and implementation architecture for high performance.
    - e.g., presentation layer design, application-layer framing, high performance host interfaces, and efficient protocol implementation techniques.
- EME (End-Middle-End)
  - While still end-to-end in many ways, connection establishment in the Internet today involves state and functionality in the middle in the form of NATs, firewalls, proxies and so on .
  - The current Internet architecture does not reflect this resulting in a mismatch between design and practice.
  - There are some signaling based solutions to connection establishment

Architecture Components

- Network addressing and naming
- Routing protocols
- Backbone design
- Circuit & Packet
- Heterogeneous physical layers
- Heterogeneous applications
- Security

Architecture (E.g.) (1/2)

- **Data Oriented Network Architecture**
  - Data dissemination rather than p2p conversation
  - DONA : The Data-Oriented Network Architecture
    - explores a clean-slate data-centric approach to Internet architecture. The key observation that motivates this design is that the vast majority of current Internet usage is data retrieval, where the user cares about content and is oblivious to its location.
  - CCN: Content Centric Network
- **Autonomic Communication**
  - Manageability
  - ANA: *Autonomic* Network Architectures
  - CASCADAS:Component-ware for Autonomic Situation-aware Communications, and Dynamically Adaptable Services
- **Bio-Inspired Network**
  - Use biological concept for network
  - Service generation with natural selection/ evolution
  - Security with immune system

Architecture (E.g.) (2/2)

- Opportunistic Communication
  - Send packet according to the link condition
  - Store & forward
  - DTN (Delay Tolerant Networking)
  - Haggle: A European Union funded project in Situated and Autonomic Communications

Mechanisms

- Wireless
  - Cognitive
  - Cooperative
  - Coopcom: http://www.coopcom.eu.org/
  - Viral network
- Optical
- P2p
  - DHT(Distributed Hash Table)
    - Pastry
- Security
  - Self-revealing content
  - Public key/ ECC
- Manageability
  - High level Abstraction
- Building Block
  - Lego like building blocks

Service/Applications

- Sensor
- Vehicle/aircraft
- Emergency
- Satellite
- Energy/power

NSF Future Internet Architecture Awards (**August 27, 2010**)

- Four projects, each worth up to $8 million over three years, as part of the Future Internet Architecture (FIA) program.
  - **Named Data Networking**
  - **MobilityFirst**
  - **NEBULA**
  - **eXpressive Internet Architecture**

Named Data Networking (NDN)

- **Principal Investigator**:
  - Lixia Zhang, UCLA
- **Collaborating Institutions**:
  - Colorado State University,
  - PARC, University of Arizona,
  - University of Illinois/Urbana-Champaign,
  - UC Irvine,
  - University of Memphis,
  - UC San Diego,
  - Washington University,
  - Yale University

NDN

- Allowing the decoupling of trust in data from trust in hosts and servers
- Enabling trustworthiness as well as several radically scalable communication mechanisms, for example, automatic caching to optimize bandwidth and the potential to move content along multiple paths to the destination.
- Addressing the technical challenges in creating NDN, including routing scalability, fast forwarding, trust models, network security, content protection and privacy, and a new fundamental communication theory enabling its design.

MobilityFirst

- **Principal Investigator**:
  - Dipankar Raychaudhuri, Rutgers University/New Brunswick
- **Collaborating Institutions**:
  - Duke University,
  - Massachusetts Institute of Technology,
  - University of Massachusetts/Amherst,
  - University of Massachusetts/Lowell,
  - University of Michigan,
  - University of Nebraska/Lincoln,
  - University of North Carolina/Chapel Hill

MobilityFirst

- Current Internet, originally designed to support communications between fixed end-points
- MobilityFirst project proposes an architecture centered on mobility as the norm, rather than the exception
- Generalized Delay-tolerant networking (GDTN) to provide robustness even in presence of link/network disconnections
- Tradeoffs between mobility and scalability
- Tradeoffs on opportunistic use of network resources to achieve effective communications among mobile endpoints.

NEBULA

- **Principal Investigator:**
  Jonathan Smith, University of Pennsylvania
- **Collaborating Institutions:**
  - Cornell University,
  - Massachusetts Institute of Technology,
  - Princeton University,
  - Purdue University,
  - Stanford University,
  - Stevens Institute of Technology,
  - University of California/Berkley,
  - University of Delaware,
  - University of Illinois/Urbana-Champaign,
  - University of Texas,
  - University of Washington

NEBULA

- "Cloud" creating opportunities for global-scale, network-centric computing infrastructure
  - Fast resource provisioning
  - Fast utility pricing
  - Fast consistent
  - easy management
- NEBULA is an architecture in which cloud computing data centers are
  - primary repositories of data
  - primary locus of computation
- The project focuses
  - developing new trustworthy data, control
  - core networking approaches to support the emerging cloud computing model of always-available network services.
- This project addresses the technical challenges in creating a cloud-computing-centric architecture

eXpressive Internet Architecture(XIA)

- **Principal Investigator:** Peter Steenkiste, Carnegie
  - Mellon University
- **Collaborating Institutions:**
  - Boston University,
  - University of Wisconsin/Madison

eXpressive Internet Architecture

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Question and Discussion