Future Internet Architecture

IERG5090, April 2017

Outline

- Internet ossification
  - Call for virtualization of Internet
- Start from scratch
  - The new arch movement
  - Example: Named Data Networking
  - Example: the Scion Architecture
- Internet Evolution
- Evolutionary trends
  - Cloud/SDN/Virtualization
  - Internet of Things

Internet's success

- Internet's success is beyond everyone's expectations
  - Not only achieve data communication, but also absorbed voice communication and multi-media (e.g. TV) platforms.
  - It has disrupted many existing businesses, e.g. shopping, newspapers, and is poised to change more businesses, e.g. banking
  - It has created new services and businesses, e.g. social networks, sharing economy…
- Can the original design of the Internet meet the need of all these creative uses of the Internet?
- What are the biggest problems?
  - Some things people complain a lot are: QoE, availability, security, efficiency for content distribution, privacy…
- Can we update the Internet design? How?
  - Can we evolve the Internet gracefully?

Internet ossification

- By early 2000, networking researchers became frustrated in how difficult it is innovate
  - Lots of work on QoS, all failed
  - Lots work on IP multicast, but difficult to deploy
  - Lots of proposals to optimize routing, but hard to introduce new routing
  - A must-fix problem, addresses running out, but transition to IPv6 very slow
- People started to use “ossification” to describe the Internet
  - And asked how to innovate

Virtualizing the net

- One significant project is to "virtualize" the network
  - Adding a layer belong the routing layer
  - That allow links, routers, hosts to be virtualized
  - Hence a physical network can be used to run different virtual networks
  - Make a playground for innovation

http://home.ie.cuhk.edu.hk/~dmchiu/ossification.pdf

- Jonathan Turner
  - University of Washington
- Larry Peterson
  - Princeton University
  - PlanetLab
- Scott Shenker
  - UC Berkeley

New Arch project

- Almost the same time, a different project led by prominent networking researchers called for “clean slate” new network architecture

http://home.ie.cuhk.edu.hk/~dmchiu/newarch.ppt

http://www.isi.edu/newarch/

- Internet itself was a “new arch” in the age of circuit switched networks

Internet architect
Affiliated with MIT for many years

Research on Future Internet Architecture

- In 2008-09, US NSF funded a few large projects to do “Future Internet Design” (FIND)
  - Calling for clean slate Internet research
  - Later become Future Internet Architecture program

  http://www.nets-fia.net/

- NSF funded projects:
  - Content-centric networking (CCN)
  - MobilityFirst
  - Nebula (Latin word for “Cloud”)
  - eXpressive Internet Architecture (XIA)
  - ChoiceNet (added in 2nd round)

- In China, large Internet projects focus on “evolutionary” approach:
  - IPv6
  - SDN, IoT etc

Two of the “Clean Slate” projects

- Content Centric Networking (Named data networking)

Van Jacobson
A physicist by training, worked in Lawrence Berkeley Labs, Cisco and Xerox PARC
Architected and implemented the TCP congestion control mechanism

- Scion architecture

Adrian Perrig
CMU
Now at ETH in Zurich
Rising star in Internet security

Content centric networking

- The idea of Content Centric Networking has more novel and innovative ideas:
  - A more concrete proposal for CCN is "Named Data Network"

https://named-data.net/project/archoverview/

  - It has a significant following, the original ICN workshop became a ACM conference; many smaller workshops

Panel discussion at ACM ICN 2016:
http://home.ie.cuhk.edu.hk/~dmchiu/icn16.pdf

is a good summary of current status

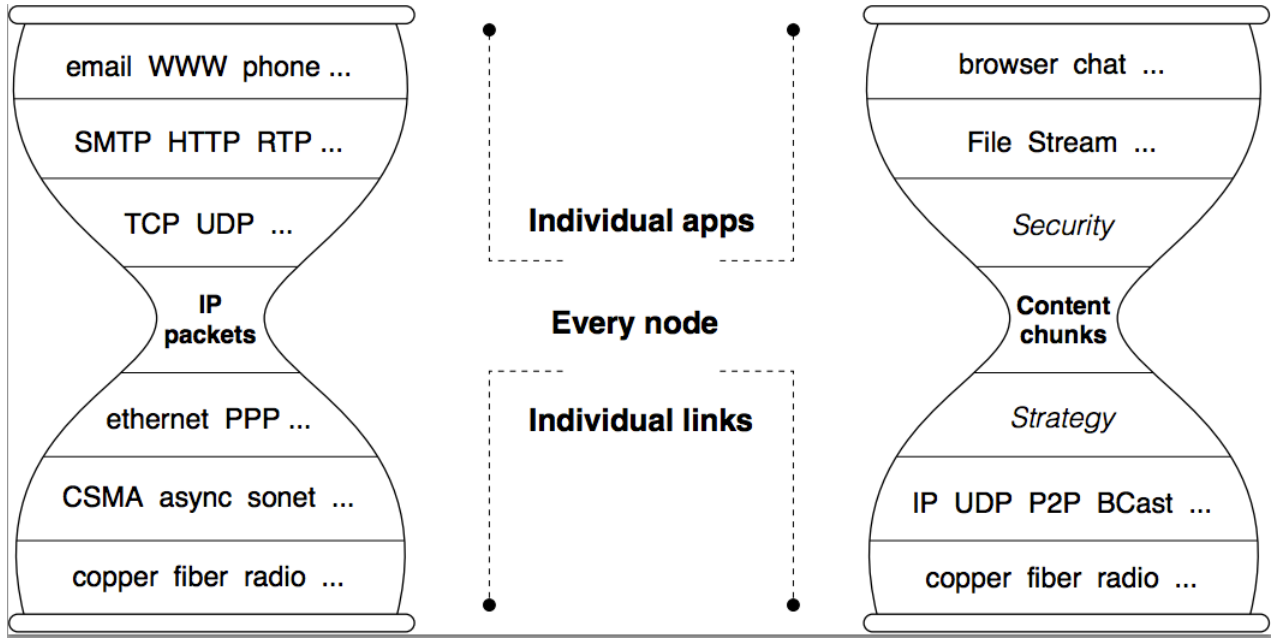
Why reference content by name rather than address?

- At the time when Internet was designed, important purpose is to access resources: a particular computer, printer, etc.
- Today's internet mostly deal with data distribution and sharing, in great volume, and to mobile devices
- Current content distribution methods, because of IP, depend on lots of middleware, unnecessarily complex
- Current internet tries to secure container and channel; rather than data/content directly

- People working on CCN believe IP should be replaced by a new infrastructure
- They have proposed some mechanisms:
  - Use hierarchical names
  - Use a "publish-subscribe" paradigm to meet need of publishers and subscribers

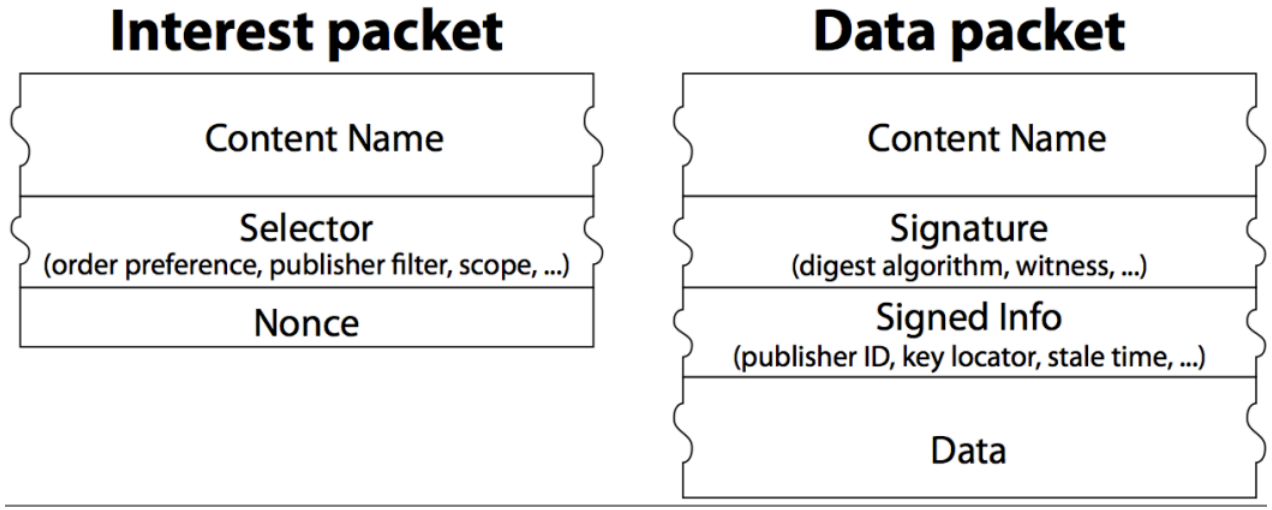
Good architecture leads to hour-glass system

- The success of TCP/IP is attributed to the “hour glass” architecture:
  - Fix IP (and TCP) and keep it universal and simple
  - There can be many applications, and many innovations in layers below
- IP originally was “overlay” on top of telephone network
  - VoIP became overlay on top of IP



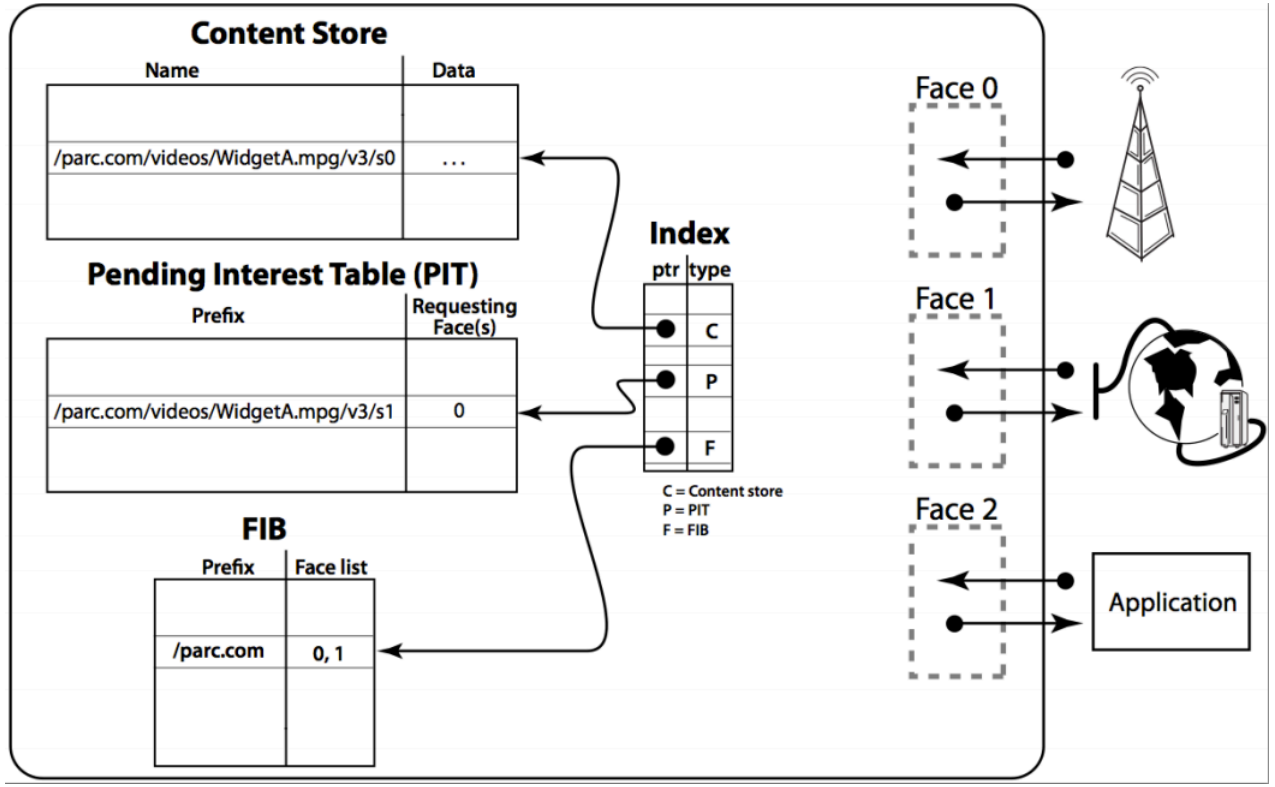
The “Request” and “Response” of NDN

- Consumer initiates communications by sending Interest packet:
  - It carries name instead of address, used to route the packet towards publisher
  - Nonce makes request unique: an Interest packet with different nonce is from different consumer
- The Interest packets leaves behind state info in NDN routers:
  - Pending Interest Table
  - Data replies on PIT to get back to consumer



NDN Router

- The Forwarding Information Base (FIB) could be created in a similar fashion as IP routing, but it is with hierarchical names
  - For names not found, the Interest packet may be forwarded to other routers
  - How to make it scalable?
  - For redundant request, it is not forwarded, but added to the PIT
- Content store is used to cache content



Various problems with address are solved

- four problems that addresses pose in the IP architecture:
  - address space exhaustion – name space is unlimited
  - NAT traversal – no address hence no need for translation
  - Mobility – no matter how far you move, name still the same
  - address management – no need to assign address to each node connected to NDN
- Some questions:
  - How to name data/content, so as to make routing easy?
  - How to deal with scalability – the name space is unlimited?
  - Although data integrity is easier, but how to do access control and support data privacy, if they get stored in content store?

Flow and congestion control

- Interest and Data packets are balanced
- Flow and congestion control can be done hop-by-hop, by the routers
- If lots of interest in the same data, it is handled more efficiently
- DoS attack to a host is avoided; DoS to a name is harder, as it needs to be launched from different places

- Some questions:
  - For certain pattern of naming, wouldn’t it generate unbalanced traffic load?

The Scion Architecture

- In today's Internet, one has little confidence in the various network elements handling your data.
- Main idea of Scion is to set up Internet based on Domains of Trust
  - The service in Domain of Trust are provided by elements you can trust; each DoT has its own PKI
  - Routing can be done more efficiently based on this structure, using Beacons, rather than based on distance vectors.

- Website for the project:
https://www.scion-architecture.net/

An old ppt about the basic idea:
http://home.ie.cuhk.edu.hk/~dmchiu/SCION.pdf

Internet evolution

- Probably more practical is for Internet to evolve
- I recently wrote an article, soon to appear in IEEE Internet Computing:

http://home.ie.cuhk.edu.hk/~dmchiu/IC-21-03-Standards.pdf

- Some points I make:
  - Evolution by standardization, like IPv4 to IPv6, very slow and complicated
  - Evolution=innovation+competition
  - Network as a Computer – a like of modularization
    - You are free to innovate how you implement the “computer”
    - A solution for the QoS problem
  - Implications for stakeholders – academia, engineers, IETF, government…

Efforts that help evolve the Internet

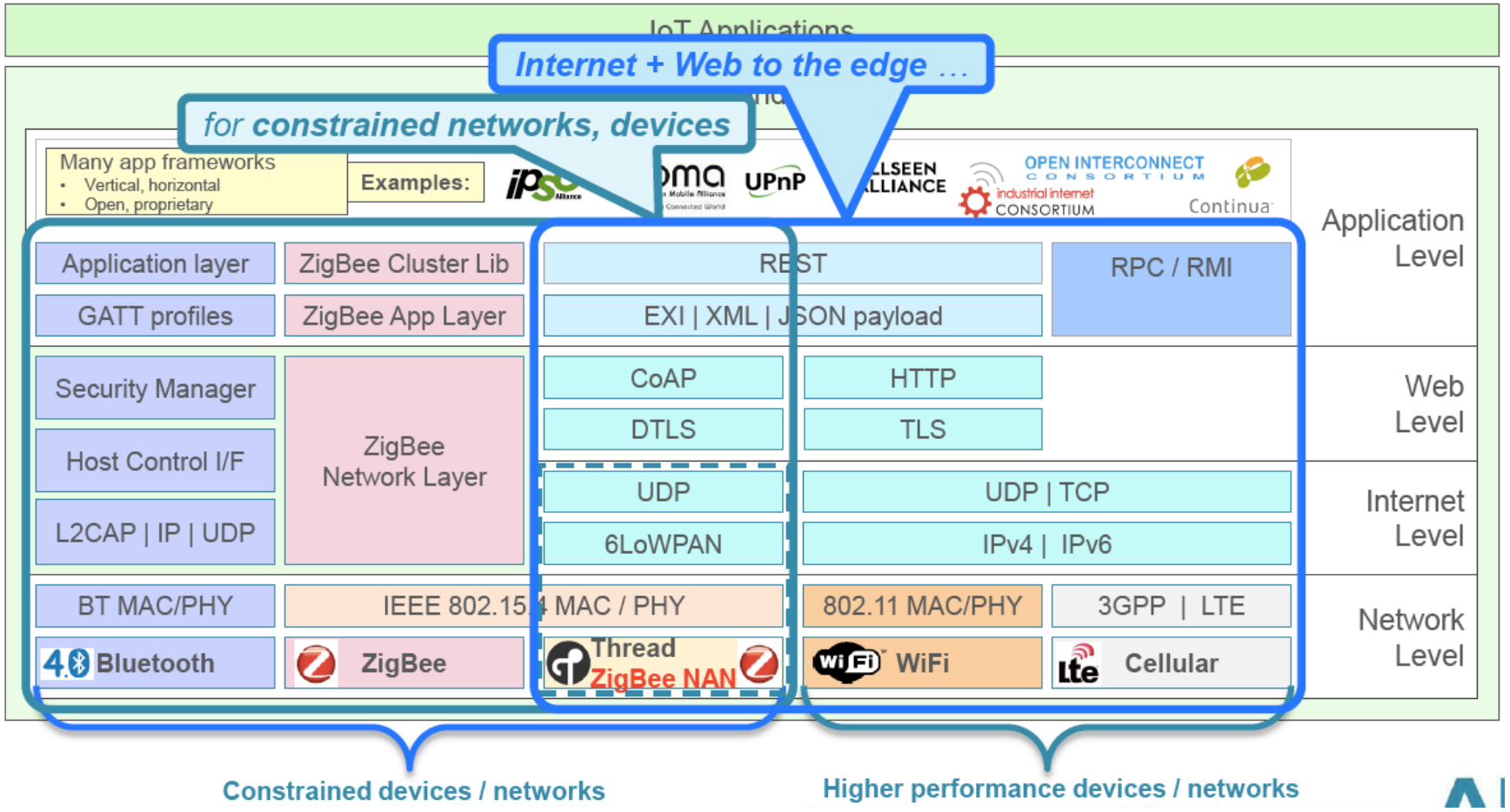
- Cloud computing, data center technology, network virtualization, SDN…
  - This is propelled by Internet services and businesses
- Internet-of-Things
  - This is propelled by connecting more “things” (sensors, devices…) to the Internet, at low power and low cost (e.g. w/o need for configuration)
  - Another community: Fog computing

- If you go to top networking conference (Sigcomm, NSDI), you see lots of people working on the first category of problems

- In industry, lots of players working on in IoT as well, it is closer to different applications.

Internet of Things – lots of systems, and standards

- It is not a new topic, but enjoys growing interest
- Early effort based on ZigBee (IEEE 802.15.4)
  - Low power
  - Low cost
  - Vertical stack
- Recent efforts aim more for general applications



Cyber Physical Systems

- This is a related area of research
  - Integrating physical systems, with Internet technology
  - We recently had a visitor who gave a seminar on various topics he works on, including:
    - Health related monitoring
    - Earthquake morning
- It is also related to:
  - Smart City
  - Smart Buildings (one of my PhD students work on this)
- Security is usually not figured into these systems – a good area of research

Summary

- Internet is successful, but difficult to upgrade/improve – why?
- Some argue for “clean-slate” architecture
  - Good ideas for research, but so far, not much to show practically
- Others argue for “evolution”
  - How to allow more innovation?
  - How to get innovative ideas work together? Merging many standards? Open source development?
  - How to allow more competition
- Besides working on the infrastructure, a lot of networking researchers are working on more application related things:
  - Internet-of-Things, Cyber-physical systems, Big data systems, Smart City, Smart Buildings, Health systems, Transport systems etc.