Advance Computer Networks (CS G525)

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First Semester 2018-2019
Lecture: 5-6 [17-20 Aug 2018]

Agenda

- Future Internet Architecture Design Projects
  - Compulsory Reading
    - A Survey of the Research on Future Internet Architectures [Jianli Pan 2011]

Enough Patchwork for Internet…?

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- Original simplicity is changing …
  - Hourglass approach
- Why…?
  - New class of applications
    - Real time, multimedia, content distribution, 3D immersive, cloud services etc.
  - Operational and management requirements
  - Variety of business models
  - Security mechanisms
    - Firewalls, NAT (to come up from IPv4 address crunch!)
  - Scalability enablers gives rise to Adhoc solutions
- Patching can affect the performance …

Problems with Current Internet [1]

- Security
  - Control, Management and Data planes are intermixed
  - Control messages are piggybacked with data packets
- Mobility
  - Identity and location in one (IP Address) makes mobility complex
- Energy
  - Assumes live and awake end systems
  - Communication can happen only when both ends are awake
- No Explicit Support for Client-Server Traffic and Distributed Services
  - e.g. connecting to Google

Problems with Current Internet [2]

- One to one communication
  - No support for multicast and multipath
- Symmetric protocols
  - No difference between a PDA and a big server
- Stateless
  - QoS is difficult
  - Some applications require guarantee about the delay and throughput of their flows
- Location Independent Addressing
  - Most services requires nearest server

Leading to New Internet Architecture

- Innovations in various aspects of the Internet
  - Security, mobility, energy, QoS etc.
- Collaborative projects putting multiple innovations into an overall networking architecture
- Testbeds for real-scale experimentation

Key Research Topics for Future Internet Design [.1]

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- Content or data oriented paradigms
  - **Motivation**: Primary usage of today's Internet has changed from host-to-host communication to **content distribution**
  - **Challenges**: Data and content security and privacy, scalability of naming and aggregation, compatibility and co-working with IP
- Mobility and ubiquitous access to networks
  - **Motivation**: Shift from PC-based computing to mobile computing.
  - **Challenges**: Trade-off with **mobility and scalability**, **security, and privacy protection** of mobile users, mobile endpoint **resource usage optimization**

Key Research Topics for Future Internet Design [..2]

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- Cloud computing centric architectures
  - **Motivation**: Computing becomes Utility Computing
  - **Challenges**: Needs to create secure, trustworthy, extensible, and robust architecture to interconnect **data**, **control**, and **management** planes of data centers

- Security
  - **Motivation:** In current Internet Security works as an Overlay not an integral part of it
  - **Challenges:**
    - **Technical aspects**→ encryption, authentication, authorization
    - **Non-Technical aspects**→ to provide trustworthy interface among the participants

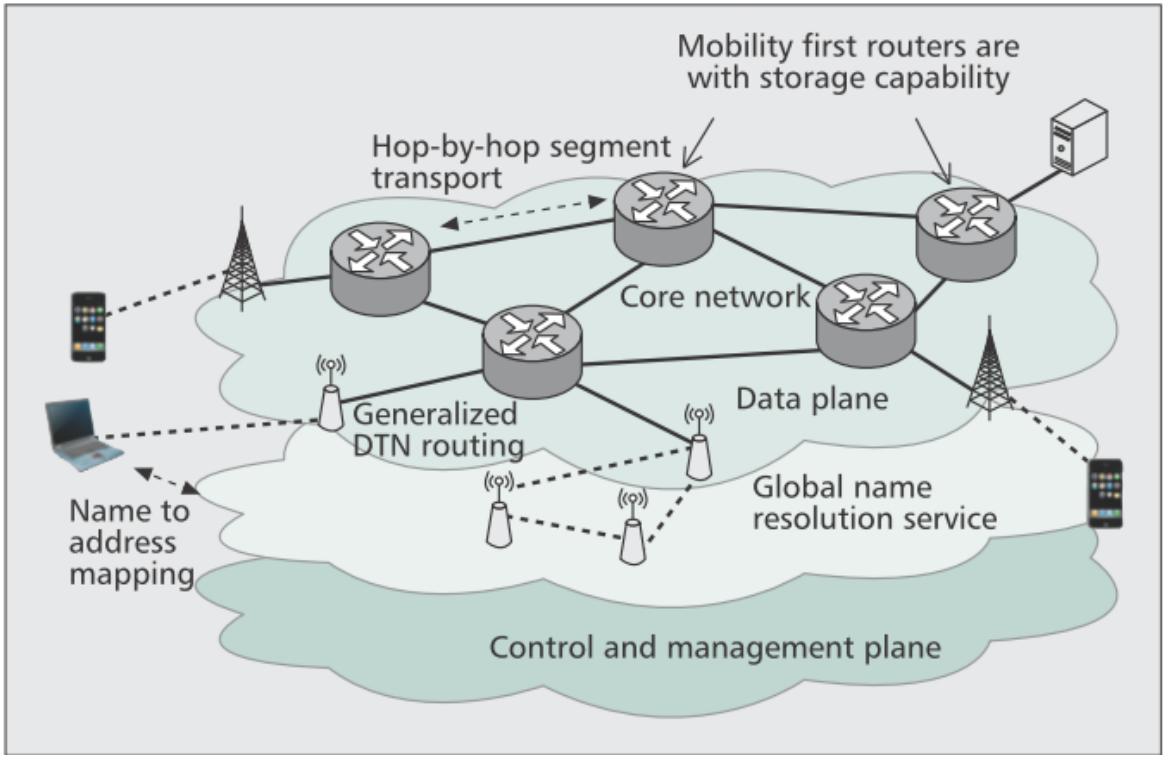
Key Research Topics for Future Internet Design [...3]

- Experimental test beds
  - Explore challenges related to large-scale hardware, software, distributed system test and maintenance, security and robustness, coordination, openness, and extensibility.

Research Projects on Future Internet Design

- US National Foundation (2005)
  - Working on project Future INternet Design (FIND)
    - *More info: www.nets-find.net/*
- European Union
  - 7th Framework program
- Future Internet Architecture (FIA) (2010)
  - NDN, NEBULA, Mobility First, XIA (Project collaboration)
    - *More info: www.nets-fia.net/*
- Global Environment For Network Innovations (GENI)
  - To provide a global large-scale experimental test-bed for future Internet architecture test and validation.

Mobility First Project (Rutgers Univ.)

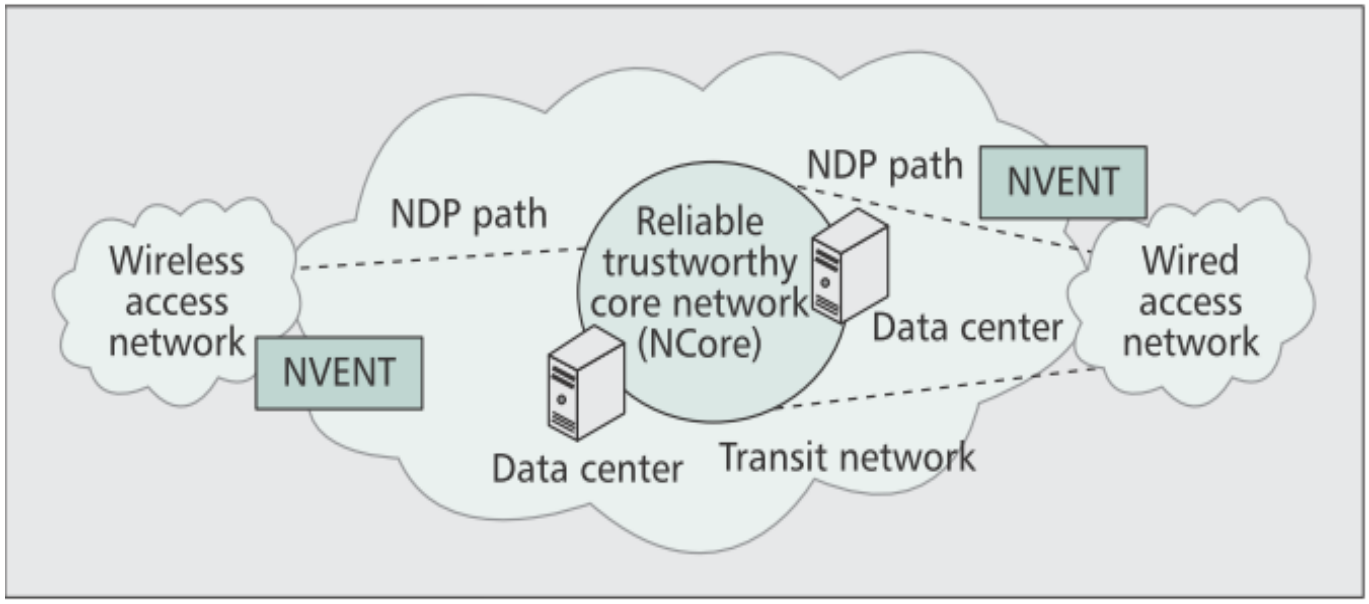


Challenges addressed by Mobility First

- Stronger security and trust requirements due to open wireless access
- Dynamic association, privacy concerns, and greater chance of network failure
- Content caching

Source: A Survey of the Research on Future Internet Architectures [Pan 2011]

NEBULA Architecture



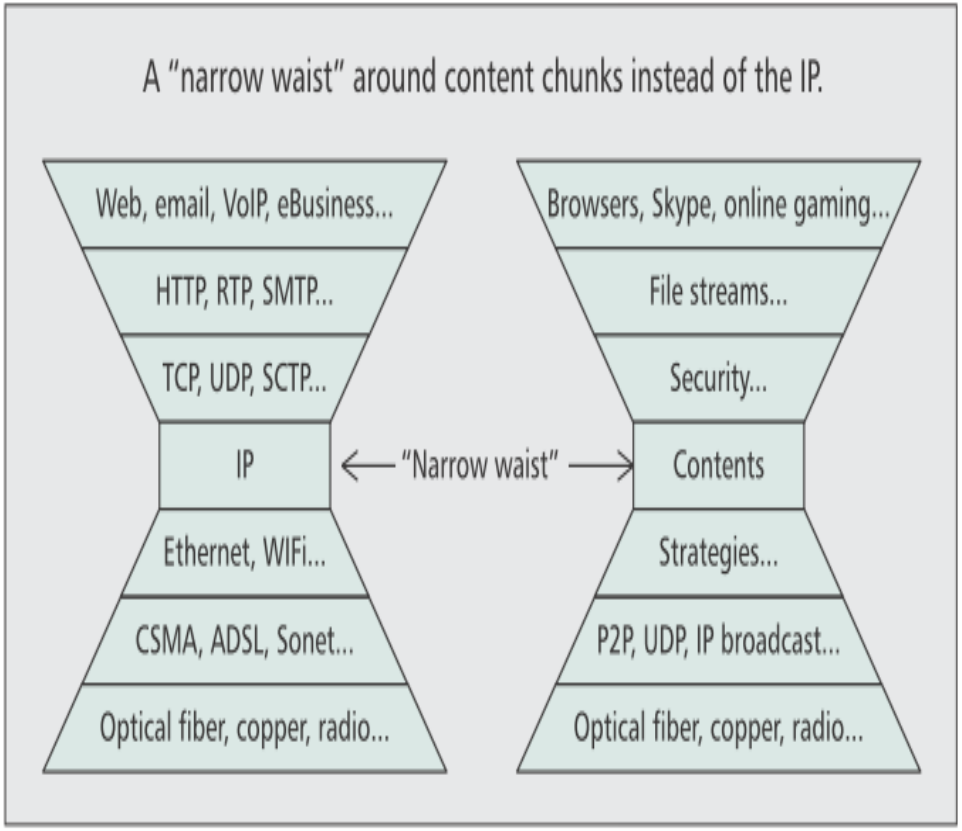
Source: A Survey of the Research on Future Internet Architectures [Pan 2012]

- Secure and high speed interconnection of Datacenters with parallel paths
- NDP-NEBULA Data Plane→ Establishes trustworthy paths among routers and provides **policy compliant** paths
- NVENT- Extensible Control Plane to provide **application selectable service**
- NCore- Redundantly connected High availability routers (Interconnecting DCs)

Named Data Networking Project (Univ of California)

- Moving from end to end packet delivery to Content Centric Model
  - Current client server model facing challenges in supporting **secure content oriented** functionality
    - Network is transparent and just forwarding the data
  - NDN focuses on ‘what’ (content) in place of ‘where’ (address)
  - Allows **content caching** on network side to optimize the traffic

Architectural Principles of NDN: Key Points



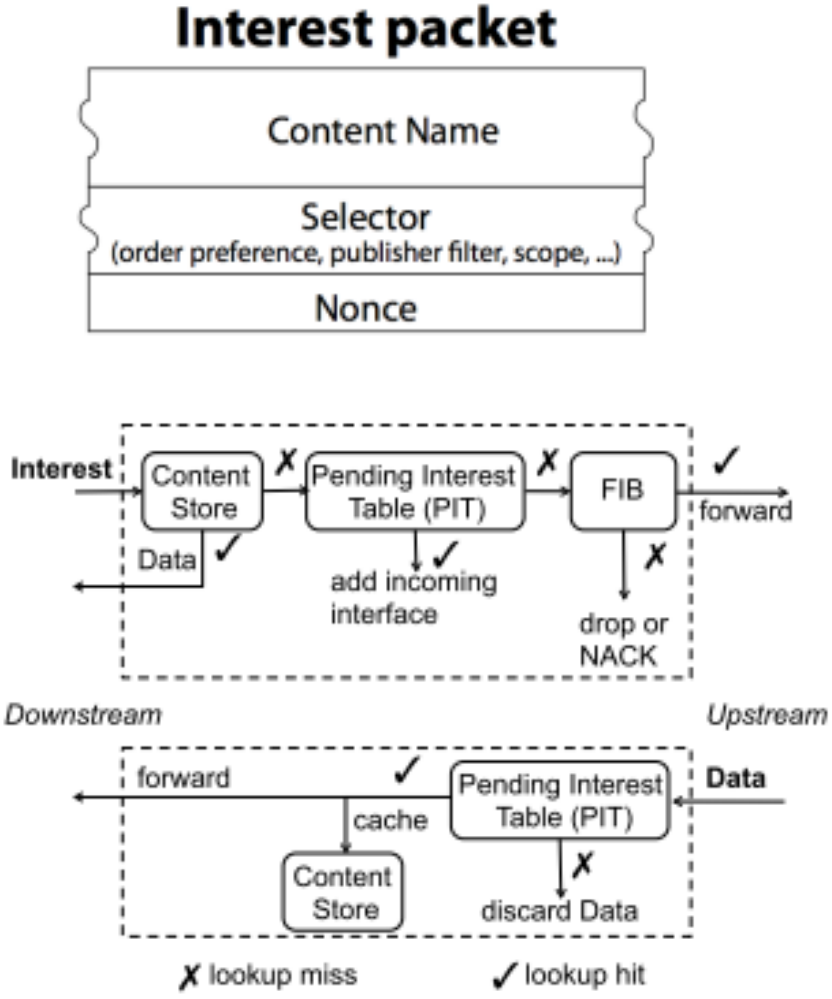
Next…

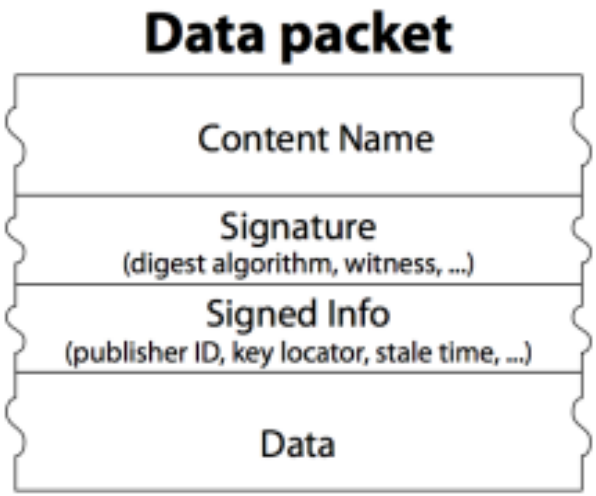
- NDN Architecture Details
  - Compulsory Reading
    - NDN Project Technical Report [L Zhang 2010]
  - Additional Reading for ndnSim
    - named-data.net/techreport/TR005-ndnsim.pdf

NDN Architecture [1]

- Communication is driven by the receiver (consumer)
  - Sends interest packet
    - e.g. /pilani/computerscience/courses/acn/lectures/lec1.pdf
- Router forwards **Interest packet** by looking up the name in its **FIB** (name based routing protocol)
- **Data packet** travels on the same path followed by the **Interest packet** in reverse direction
  - It carries both the name and the content of the data, together with a signature by the producer's key

NDN Architecture: Forwarding Process





NDN Architecture [2]

- NDN Supports following inherently
  - **Content Distribution** (many users are requesting the same data at different times)
  - **Multicast** (Many users are requesting same data at same time)
  - **Mobility** (users requesting data from different locations)
  - **Delay Tolerant Networking** (Users having intermittent connectivity)

Data Names

- How to find the data, or how the data are named and organized to ensure fast data lookup and delivery…?
  - Hierarchically structured names
    - /pilani/computerscience/courses/acn/lectures/lec1.mp4/1/2
  - Names are application specific and opaque to the network
  - Dynamic data can be retrieved by common agreement between consumer and producer
  - Not all the names need to be ***globally unique***
  - Name space management is not part of the NDN architecture, just as in IP networks

Data Centric Security

- NDN proposes to secure the data directly instead of securing the data "containers" such as files, hosts, and network connections.
- Each piece of data is signed (mandatory) together with its name, securely binding them.
- Trust of Host and servers → Trust in Data
- NDN's data-centric security can be extended to content access control and infrastructure security.

Routing & Forwarding…[1]

- Forwarding
  - Forwarding is based on names
  - Is there any benefit wrt IP Routing…?
- Routing
  - IP Prefixes→ Name Prefixes
  - Existing routing protocols can be used to construct FIB table
- Question..?
  - How to keep routing table sizes scalable for unbounded data names
    - NDN names are longer than IP addresses, but the hierarchical structure helps the efficiency of lookup and global accessibility of the data.

Routing & Forwarding…[2]

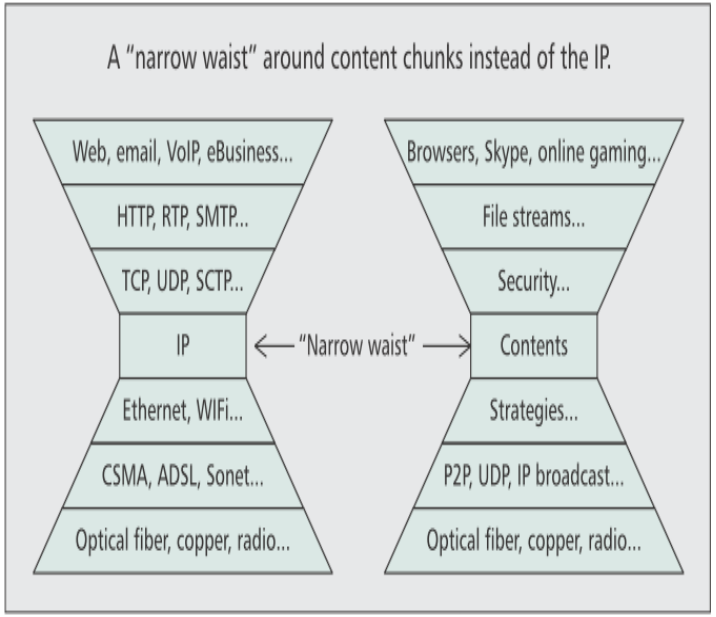
- NDN Inherently supports multipath routing
  - No chance of looping like IP routing… Why?
- It improves Routing security…How?
  - Every data is signed…including routing messages
  - Multipath routing mitigates prefix hijacking because routers may detect the anomaly caused by prefix hijacking and try other paths to retrieve the data.
  - Attacking to a particular target is difficult… Why??
- Privacy Protection
  - No information about who requested what data

No Transport Layer in NDN

- Transport Layer functions can be placed either in the application or NDN layer
  - Multiplexing and demultiplexing among application processes is done directly using names at the NDN layer
  - Data integrity and reliability are directly handled by application processes
  - NDN routers manage traffic load through managing the Interest forwarding rate on a hop-by-hop basis
    - NDN eliminates the dependency on end hosts to perform congestion control

Architectural Principles of NDN: Key Points

- Hourglass architecture is maintained surrounding the Data NOT IP
- Security is built-in into the architecture itself
- Retains the E2E for fast application development and caters network failures.
- Flow balanced data delivery ensures self regulating network traffic
- Routing and Forwarding planes separation
- Caters user choice and competition where ever possible



NDN Key Research Areas Evolved

- Development of NDN Applications
- Data Namespaces
  - e.g., Name Discovery, Name design
- Trust Models
- Routing and Forwarding Mechanisms
  - Forwarding Strategy Design (e.g., better path selection)
  - Forwarding Engine Design (e.g., fast lookup, efficient storage)
  - Routing Protocol Design (e.g., NLSR)
- In Network Storage
- Data Synchronization

Resources

- NDN Project URL
  - https://named-data.net/

Thank You!