Economics of Information Centric Networks

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Today’s Challenges
The Internet today
Information Centric Network (ICN)
Technical Aspects of ICN’s
- Components of ICN
- Caching Strategies
- Performance & Cost
Economical Aspects of ICN’s
- Stakeholders & Incentives
- Tussles
Discussion
Today’s Challenges

- The IP/TCP was created for a **trustworthy** environment of **fixed** hosts that communicated over a **dedicated** network.
- Today: Content **dissemination** and mobility over unsecure multiple links (Internet).
  - Public dissemination
    (news agencies, movie studios, meteorological offices)
  - Between restricted groups of recipients
    (e.g. Facebook or LinkedIn groups)
Some numbers about traffic

- https://www.youtube.com/watch?v=OnBsAS sxnmw
The CDN model:

- Send a request for information
- Pass through DNS server
- The End-User connects to the IP address
  - An edge server
- The information reaches the requester
CDN VS ICN

Main differences:
- Information Is now the center of everything
- IP communication replaces by Named Data Communication
- Unique name
- Shift from where to what
The ICN model

- The End User sends a request (Unique Name)
- The request is processed
  - 1st request:
    - The path goes to the publisher
    - The publisher sends the information to one cache
    - The information will be spread through the next requests

Source: http://www.adcapnet.com/partners/akamai/
The ICN model

- The End User sends a request (Unique Name)
- The request is processed
  - 1\textsuperscript{st} request:
    - The path goes to the publisher
    - The publisher sends the information to one cache
    - The information will be spread through the next requests
  - Next requests:
    - Chunks are gathered from the different caches (in-network caching)

Source: http://www.adcapnet.com/partners/akamai/
Main components of ICN

- Persistent Named Data Object (NDO)
- Naming
- Application programming interface (API)
- Routing and Forwarding
- Caching
Named Data Objects (NDO’s)

- NDO’s are published at nodes by the publisher.
- Routing protocols are employed to distribute information about NDO location.
Naming

- Persistent & unique object names
- Human readable
- Hierarchically structured
- Versioning & Segmentation

Human Readable: /parc.com/videos/WidgetA.mpg/_v <timestamp>/_s3

Temporal evolution (Version)  Segmentation
API

- Is defined in terms of requesting & delivering
- Using object’s name as main parameter
- Location preferences as supplement parameter for scoping and filtering publications and requests. [4]
ICN can use existing, conventional routing protocols (e.g. IS-IS or OSPF).
But it depends on the Naming → protocol modifications!
New components for ICN routing protocol:
- Interests Packets & Data Packets
- Forwarding engine model
Routing and Forwarding (II)

- **Forwarding engine model:**
  - PIT = Pending Interest Table
  - FIB = Forwarding Information Base
  - Cache = Content Store

Source: Ahlgren et al.
Routing and Forwarding (III)

- Send Interest (1-3)
  - Request aggregation
- Data is routed back (4-6)
  - On-path caching
- New request are served from cache (7 + 8)

Source: Ahlgren et al.
Caching Aspects (I)

- Granularity: Chunk size is not defined yet
  - Experiments with 1 KB, 10 KB, 16 MB
- Decision: What content will be cached where?
  - LCE: Leave Copy Everywhere
  - Selective
  - Minimizing caching redundancy
Caching Aspects (II)

- **Replacement**: What content will be replaced?
  - Most considered replacements:
    - LRU: Least Recently Used
  - Less considered replacements:
    - MRU: Most Recently Used
    - MFU: Most Frequently Used
    - UNIF: Uniform Random Replacement
- **Topology**: tree, ring, star, etc.
- **Frequency of cash update**
Pervasive (LCE)

- Not possible to store the whole data on every router → high cache replacement error!
- Huge caching redundancy
Selective

- Betweenness centrality: caching only at more "important" nodes.
Decision strategies

- Probabilistic In-Network Caching: ProbCache
  - Minimizing caching redundancy.

![Diagram showing network nodes and their TSB values, with user requests and TSI values indicated.]

User 1
Request 1
TSI(y1) = 1

User 2
Request 2
TSI(y2) = 1

TSB(x*) = 1, 2, 3, 4, 5
TSB(x1) = 1, 4, 5
TSI(y1) = 5
TSI(y2) = 4

Node S to r1, r2, r3, r4, r5

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TSB(x) = Total Service Bandwidth, TSI = Total Service Index
Caching Performance Influencer

- Network topologies
  - Limited impact
- Caching replacement & decision policies
  - Simple policies perform almost as well as more complex ones.
  - Bigger impact
- Size of catalog and caches
  - Bigger impact
- Content Popularity
Costs from a technical perspective

- CCN can use existing Infrastructure by attaching CCN routers enhanced by caches (content storage)
- New ICN enabled Routers are roughly 1.5 to 2.5 times more expensive.
  - Edge Router:
    - Cisco 7505 Router with 1-TByte SSD for cache.
    - Cost: $ 24’000 (router) & $ 31’000 (enabling ICN) = 55 k
  - Backbone Router:
    - Cisco CRS 1 series router with 80-GByte DRAM for cache.
    - Cost: $ 200’000 (router) & $130’000 (enabling ICN) = 330 k
- Security Costs:
  - Publisher may have significant costs for signature generation or verification.
  - verifying Data on routers.
Advantages with the ICN model

- Low latency
- Low network congestion
- Scalable and Cost-Efficient Content Distribution
- Persistent and Unique Naming
- Security Model
- Mobility
- Multihoming
Performance vs. Costs

- Performance:
  - Low latency
  - Low bandwidth usage
  - Low traffic / network congestion

  → fast delivery

- Costs:
  - New routers with cache
  - Higher maintenance costs
  - Learning costs for adapting new technology
Economical Aspects of ICN’s
Stakeholders

- Publisher
- Content Distribution Network (CDN)
- Transit Network
- Internet Service Provider (ISP)
- End-users

Payment Flows

Connections
End-users incentives

- Low Latency
- Quality of Experience (QoE)
  - fast access to any information, up-to-dateness
- Quality of Service (QoS)
  - Phone and Video without interruptions
- Security & Privacy
- Low prices
Publisher

- Produces content for end-users
  - e.g. Google, CNN, eBay, Netflix, Facebook, Twitter

Benefits
- Increased revenues from improved end-user latency
- Resilience to flash crowd and DDoS
- Savings in network access charges
- Savings in processing costs

Costs
- Payments for content delivery
- Transaction costs
- Costs to modify content for delivery by third-party
- Potential loss of content access information
Primarily caches and delivers content on behalf of publishers for a fee.

- e.g. Akamai, Limelight

Benefits
- Revenue from publishers for content delivery

Costs
- Processing costs
- Storage costs
- Billing and accounting costs
- Co-location and traffic termination charges
Transit Network

- Primarily provides transport services to publishers and ISP to reach the Internet.
  - e.g. Level 3 Communications, Tata Communications

Benefits

- Bandwidth savings
- Revenue from publishers for content delivery

Costs

- Lost network access/transit revenue
- Processing and storage costs
- Billing and accounting costs
- Co-location and traffic termination charges
ISP

- Predominantly provides network access to end-users
  - e.g. Swisscom, British Telecom, Fastweb etc.

**Benefits**

- Bandwidth savings
- Revenue from end-users due to improved latency
- Revenue from publishers for content delivery
- Co-location and traffic termination charges

**Costs**

- Processing and storage costs
- Billing and accounting costs
Under what conditions will ISP’s deploy caches?

- ISP’s have benefits of deploying caches even without payments from the publishers.
  - bandwidth savings (cost & performance)
Under what conditions will ISP’s deploy caches?

- ISP deploys transparent caches

Source: Agyapong
Under what conditions will ISP’s deploy caches?

- ISP deploys commercial caches

Source: Agyapong
Who will deploy caches?

Source: Agyapong
Multiple contracts with several Content Providers.

→ CDN
Tussles

- Tussle: a conflict of interest between two or more stakeholders
- There are five different groups of tussles
Tussles

Security:
- Infrastructure Security
- Information Security
- Accountability

Trust:
- Trust in function
- Trust in information

Information:
- Information Governance
- Brokering Information

Infrastructure:
- Brokering topological capabilities
- Delivering bits
Tussles

Socio-Economic
Tussles

- Defining Functional boundaries
Tussles: Security

ISP  

Regulator

Publisher

End-User

Infrastructure Security

Accountability

Information Security
Tussles: Trust

Trust in Functions

Trust in Information

Trust in Publisher

ISP

Regulator

End-User

Publisher
Tussles: Information Governance

- ISP
- Regulator
- End-User
- Publisher

Information Governance

Brokering Information
Tussles: Infrastructure

ISP

Brokering Topological Capabilities

Regulator

End-User

Publisher

Delivering Bits
Tussles: Socio-Economic

Defining Functional Boundaries

ISP

Regulator

End-User

Publisher

Defining Functional Boundaries
Video
Question 1:

Do you think ICN is worth it? Why?
(Do you think ICN is a sustainable architecture?)
Discussion

- Question 2:

What about network neutrality?
Regulations for Transit / Cache
Question 3:

Do you think ICN is a sustainable architecture?
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