Research Topics on Information-Centric Networking: Caching, Routing and Virtualization

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Bio

• 09/2014: JFLI, CNRS UMI 3527
  – Japanese-French Laboratory for Informatics
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• 09/2011: Associate Professor at University of Lorraine (Nancy)
  – LORIA, CNRS UMR 7503
  – Inria Nancy – Grand Est
• 2009-2011: Post-doc (JSPS) at University of Tokyo
• 2007: Ph.D. internship at University of Tokyo
  – CNRS/WIDE project
  – Prof. Esaki Laboratory

• Scienscope
  – http://www.sciencescope.org
  – French Researchers Association in Japan
    • French Research Day: 2015/11/13
Motivation

• Internet is mostly used to access content
  – Video: 86% of global consumer traffic by 2016
    • [Cisco Visual Networking Index 2014]
• Internet: host-to-host communication
  – TCP/IP
• Users are interested with content, not location
• Information Centric Networks
  – Content Centric Networks
    • *Networking Named Content*,
      V. Jacobson et al., ACM CoNEXT 2009
CCN Overview

- In-Network Caching
- Packet address refers to content not location
  - Named-Data Networking
- Two primitives
  - Interest, host requests content with Interest message
  - Data, a node answers with a Data message
- Data at the core of the communication
- New ‘Network Layer’ for Content Delivery
Host sends an **Interest** for /video.avi
CCN Overview

- CCN Node forwards *Interest* to the Network
  - Routing is still an open issue (Flooding)
CCN Overview

- Data is transmitted along the delivery Path
- CCN Node stores content and forward to the Host

Caching in CCN Nodes is an issue
CCN Overview

- Host sends an *Interest* for /video.avi
CCN Overview

- CCN node already has /video.avi in cache
CCN Overview

- Host sends an *Interest* for /video.avi
CCN Overview

- CCN node can forward the *Interest*
  - No flooding
Outline

1. Caching in CCN
   - Popularity-based Caching for CCN
     • Content: Most-Popular Caching Strategy [IEEE ICC 2013]
     • Users: Socially-Aware Caching Strategy [IFIP Networking 2014]

2. Routing in CCN
   - SDN-based Routing Scheme for CCN

3. Virtualization in CCN
   - ANR DOCTOR project
CCN Cache Management

• Caching along the delivery Path
  – In-Network caching
• Replacement Policies
  – Decide the element to be replaced
    • LRU, FIFO, MRU MFU etc.
    • Well-studied for OS, memory etc.
• Caching Strategy
  – Decide whether to cache content
    • Huge cache, Fricker et. al IEEE NOMEN 2012
    • Cache less, Chai et. al, IFIP Networking 2012
• Essential to design caching management for CCN
Content Popularity Caching Strategy

- **CCN in-network caching**
  - Always store the content at every nodes on the path
  - Overloading nodes and network resources

- **MPC: Most-Popular Caching Strategy [ICC 2013]**
  - Cache only *popular* content

- **Way of Working**
  - *Counts* locally #Interests for a *Content Name*
    - Information stored into a *Popularity Table*
  - #Content Interest > Popularity Threshold ➔ *Popular*
    - Content is cached
    - Pro-actively distributed 1-hop away
Case Study: MPC

/abc.flv - 0
/def.flv - 0

CCN Node X
Case Study: MPC
Case Study: MPC

/abc.flv is POPULAR

/def.flv is NOT POPULAR (not distributed)
MPC Evaluation

• ccnSim simulator [CRR13]
  – Chunk-level CCN simulator used by the community

• Comparison: MPC vs. CCN (LRU/Always)
  – Catalog: $10^8$ files
  – Popularity: Mzipf
  – Cache Size: 10GB
  – ccnSim topologies
  – Avg. Chunk by files: $10^3$
  – Metrics: Cache Hit / Cached Elements Ratio
MPC Evaluation

Cache Hit Ratio

Topologies

- Tree
- Abilene
- Tiger2
- Geant
- DTelkom
- Level3

CCN (LRU+Always) vs. MPC
MPC Evaluation

Ratio of Cached Elements

CCN (LRU+Always)
MPC

Topologies

Tree  Abilene  Tiger2  Geant  DTelekom  Level3
1. Caching in CCN
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User Popularity Caching Strategy

- Internet has become a «content network»
  - Video counts for 86% of traffic up to 2016
- Users' activity in the Internet: Online Social Network
  - OSN carry information about users and relationships
    - Facebook, Twitter, LinkedIn, etc.
    - Share video, messages, social features in website
- Internet has became a «social network»
- Use OSN information into ICN
  - Some users are «popular»
    - Many relationships

Caching Strategy for CCN based on OSN Information
SACS: Socially-Aware Caching Strategy

- CCN in-path caching
  - Whether the content comes from popular users or not
- Content produced by popular users are more likely to be ‘consumed’ by others
- Privilege content published by popular users
  - Pro-active caching in CCN nodes
  - Content from popular users will be cache in-path
    - No replication from non-popular user
- Popularity computation
  - Eigenvector and PageRank centrality measure
Case Study: SACS
Case Study: SACS

Pro-active Caching

Influential publishes X

Wire, physical connection

Pro-active Caching

15
SACS Evaluation

- **Social Network Topology**
  - LastFM & Facebook data set
- **CCN Topology**
  - inet generator: ~3,000 nodes
- **Popularity**
  - PageRank, Eigenvector (centrality measure)
- **Caching Configuration**
  - Replacement Policies: LRU
  - Cache Size: 1..20
SACS Evaluation

![Graph showing Cache Hit Ratio vs Cache Size for different algorithms: CCN (Leave Copy Everywhere), SACS/Eigenvector, SACS/Pagerank. The graph illustrates how cache hit ratio increases with cache size for each algorithm, with CCN showing the highest hit ratio followed by SACS/Eigenvector and SACS/Pagerank.]
SACS Evaluation

- SACS implementation into CCNx
- Deployed in 14 PlanetLab nodes
Caching Summary

• Popularity-based Caching Strategies for CCN
  – Content Popularity [IEEE ICC 2013]
  – Users Popularity [IFIP Networking 2014]

• Improves CCN performances
  – MPC reduces also #Replications
    • Save network resources

• Perspectives
  – Routing in CCN
    • Software-Defined Networking
  – CCN Deployment
    • Network-Function Virtualization
Outline

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2. Routing in CCN
   - SDN-based Routing Scheme for CCN
     • Clean-slate approach [IEEE Netsoft 2015]

3. Virtualization in CCN
   - ANR DOCTOR project
Routing in CCN

• **Content Centric Networking**
  – Open Issues: Routing
    • Flooding wastes network resources

• **Software-Defined Networking**
  – Decoupled control/data plane
  – Network devices managed by Controller
  – Store (Push) forwarding decisions in the Controller (nodes)
  – Communication protocols (e.g.: Openflow)

• **Proposal**: Routing scheme for CCN based on SDN
SRSC: SDN-based Routing Scheme for CCN

- **SDN Controller**
  - Learns network topology
  - Store content locality in the network
  - Compute path (nodes->content)
- **SRSC: clean-slate approach**
  - Relies on CCN messages (*Interest/Data*)
  - Deployment without IP
SRSC: Bootstrapping Step

- Bind nodes to a controller
- Discover topology and border nodes
- Advertise content available
SRSC: Forwarding Step

- Compute Path up to content
- Push rules into nodes
SRSC: Forwarding Step

- Compute Path up to content
- Push rules into nodes
SRSC: Forwarding Step

![Diagram showing a network with two networks labeled Network1 and Network2. The diagram includes Controller nodes, CCN nodes, and a user. Arrows indicate the flow of control messages and data. The path from the user to the CCN node and then to the controller is shown, with the file '/movie.avi' circulating between nodes.]
• NS-3 with ndnSim module
• Reduce by 10 #Interests (reduce overhead)
• Cache Hit improvement
SRSC Summary

- A routing scheme for CCN based on SDN
  - Clean-slate approach
  - NS-3 (ndnSim)

- Reduce by 10 #Interest messages
  - Saves network resources / Still improves Cache Hit

- Perspectives
  - Compare with NLSR
    *Named-Data Link State Routing Protocol*, Houque et al. ACM ICN 2013
  - Implementation into testbed

- More Information
  *SRSC: SDN-based Routing Scheme for CCN*,
Outline

1. Caching in CCN
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2. Routing in CCN
   - SDN-based Routing Scheme for CCN [IEEE Netsoft 2015]

3. Virtualization in CCN
   - ANR DOCTOR Project
     Deployment and seCurisaTion of new functiOnalities in virtualized networking enviRonnements
     • Funded by ANR: French National Funding Agency
     • Partners: Orange, Thales, Montimage, CNRS/LORIA, UTT
Context and Problem statement

• Deploying new network equipment is costly
  – Deployment only if secure and manageable

• New networking architecture & solutions for better data delivery and optimal use of network resources
  – NDN: Named-based routing

• Cost Reduction, Hardware Mutualisation, Energy Consumption
  – Network Function Virtualization (NFV)
  – Software-Defined Networking (SDN)
Objectives of the project

- Deployment of new network functions and protocols in a virtualized networking environment (NDN Use case)
- Monitoring, managing and securing the virtually deployed networking architectures, using SDN for reconfiguration
Technical Locks & Methodology

• Co-existence of multiple network protocols in the same virtualized node
  – Design and implementation of virtualized NDN network, together with a IP-based one (migration step)

• Monitoring & Security of the virtualized NDN network
  – Monitoring flows & Collection of network and usage data
  – Analysis of attacks and definition of counter-measures

• Dependability over an entire managed domain
  – Management & control using SDN
  – Implementation of a management/security plane

• Deploying NDN for real use
  – Set up of a real testbed for end-users accessing Internet web sites
Project Organization

• **Task 1**: Architecture of the virtualized node for hosting network functions
• **Task 2**: Security analysis and monitoring of virtualized network architectures
• **Task 3**: Global network dependability
• **Task 4**: Testbed (real end-users, real services) and Demonstrator
## Tasks Scheduling

- **T0 = 01/12/2014**  
  **Today = 21/05/2015**  
  **36 months-long project**

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Monitoring architecture

- MMT probes distributed in each virtual machine.
- P2P communication, to share relevant information
- Centralized MMT Operator, for coordination and orchestration
Thank You!

ありがとうございます

Q & A