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# Management of Content-Centric Networking

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# Management of Content-Centric Networking

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RESCOM 2013

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# Plan

- 1 Key Challenges for the management of CCN
- 2 A firewall for CCN

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## CCN an old idea ?

A MOBICOM 2000 paper [IGE00] [AY05] "Directed Diffusion" describes the "Data-Centric" paradigm

- "Directed Diffusion is an important milestone in the data-centric routing research of sensor networks. The idea aims at diffusing data through sensor nodes by using a naming scheme for the data"
- "The main reason behind using such a scheme is to get rid of unnecessary operations of network layer routing"
- "In order to create a query, an interest is defined", "The interest is broadcast"
- "Each node receiving the data can do caching for later use"
- "Hence, by utilizing interest and gradients, paths are established between sink and sources. Several paths can be established"
- "all communication is neighbor-to-neighbor with no need for a node addressing mechanism"

## Why focusing on CCN ?

### Why is CCN so popular among ICN solutions ?

- Simple architecture based on simple ideas
- ACM CoNEXT 2009 paper [JST<sup>+</sup>09] : Good educational introduction, most architectural aspects covered
- Many research questions clearly highlighted (routing, key management, etc.)
- ... even if not all (scalability regarding number of contents or updates frequencies, enforcement of unique names at the Internet scale, mobility while providing content, etc.)
- CCNx implementation / community
- Lucky factor : right time / right research community ?

# Network management

## What is network management ?

- Wikipedia attempt : "Network management refers to the activities, methods, procedures, and tools that pertain to the operation, administration, maintenance, and provisioning of networked systems"
- NMRG functional areas : Fault management, Performance management, Security management, Configuration management, Accounting management, Service management, Event management
- Configure and control a set of resources that ensure the network is running well
- Means : monitoring (centralized, distributed, autonomous) coupled with control/optimization/economic/machine learning/stochastic theories

# Network management

## What is relevant for CCN ?

- Traffic management
- Cache management
- Content management
- Nodes management
- Security management



# Traffic Management

## Key challenges

- Traffic control for QoS [ORS12] [FRRS12]
  - Fair queuing, congestion avoidance (Interest discard, etc.)
- Traffic control for business/political purposes (easier filtering / censorship ?)
- Traffic differentiation : several hacks of the CCN architecture to handle specific traffic types
  - Private data [ACG<sup>+</sup>13]<sup>a</sup>
  - Ephemeral data [CPW11]<sup>b</sup>

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a. "Cache Privacy in Named-Data Networking" Acs & al.

b. "Content-based publish/subscribe networking and information-centric networking" Carzaniga & al.

# Cache Management

## Key challenges

- What types of contents should be cached ? Where ? With which priority ? [FRRS12]
  - Video on demand
  - Long lived multimedia contents (file sharing or user generated)
  - Web
- What types of contents should not be cached ?
  - Conversational (two parties)
  - Ephemeral events (notifications from IoT world, online games)
  - Private communications (email, VOIP, etc.)
- How to use cache efficiently : size, location, caching policy (LRU, LFU, popularity, etc.)

# Content Management

## Key challenges

- Accountability of content's access
- Monitoring of content (diffusion, replication)
- Revocation of deprecated contents
- Access control (restriction per country, per user, etc.)

# Nodes Management

## Key challenges

- Monitoring of CCN nodes : collect information and status of CCN nodes, detection of anomalies
  - Strategy layer needs information
  - Define relevant information to be monitored + right granularity (per prefix, per face)?
  - Define efficient architecture (CCN ready) for collection of information
- Design and implementation of new network tools (ping, traceroute, etc.)
- Design of new metrics (CCN/ICN flows, etc.)
- Remote configuration (no push mechanism)

# Security Management

## Key challenges

- Identification of new threats [WSV12]<sup>a</sup>
- DoS by resource exhaustion of stateful routers
  - On PIT : Interest flooding attack
  - On FIB : Announcing conflicting domains, non-existing content, non-aggregable names
  - On CS : Privacy issues (cache probing) [LLR<sup>+</sup>12]<sup>b</sup> [ACG<sup>+</sup>13], cache pollution
  - Cryptography attacks (long-lived content, many encryptions with the same key)

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a. "Threats to Stability and Security in Information-Centric Networking" Wahlisch & al.

b. "Privacy risks in named data networking : what is the cost of performance?" Lauinger & al.

# Security Management

## Key challenges

- Security of contents (revocation, pollution [FMP10]<sup>a</sup>, etc.)
- Security of the naming space (malicious names, route poisoning ~BGP)
- Key management scheme : How to retrieve public keys quickly, efficiently, securely ?
- Collaboration for attack detection
- Enforcement of security policies within a network

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a. "Information ranking in content-centric networks" Fotiou & al.

# What is available in CCNx commands?

## Content management

- `ccngetfile` : retrieve a file published as CCNx content and save it to a local file
- `ccnputfile` : publish a file as CCNx content (local file filename or url to content with the `ccnxname`), manage segmentation, key signature, etc.
- `ccnrm` : mark as stale any locally cached content objects matching the given prefix (no further Interest response)
- `ccnls` : list name components available at the next level for a given CCNx name prefix
- `ccnlsrepo` : explore content stored under a given prefix (one or more repositories)

# CCNx commands

## Tools

- `ccn_ccnbtoxml` : convert ccn binary encoded data into XML form
- `ccn_xmltoccnb` : convert XML into ccn binary encoded data (ccnb)
- `ccndsmoketest` : testing of communications, send and receive data on sockets



# Monitoring of ccnd

## Monitoring commands

- `ccndstatus` : display the status a running ccnd (nb of active faces, stat of each face, etc)
- `ccnpeek` : generates an Interest, get one content item matching the name prefix and write it to stdout (eq to IP ping)
- `ccnponk` : read data from stdin, send it as a single ContentObject in response to an interest

## Web Interface

- `http ://localhost :9695/` , similar to `ccndstatus`
- Limitation : sliding time window (avg of last minute) provides inaccurate results

# Monitoring web interface

```
mailly ccnd[14550] local port 9695 api 6000 start 1338724361.760754 now 1338726149.399268
```

**Content items:** 23 accessioned, 23 stored, 11 stale, 0 sparse, 112 duplicate, 143 sent

**Interests:** 31 names, 2 pending, 2 propagating, 14 noted

**Interest totals:** 586 accepted, 447 dropped, 588 sent, 112 stuffed

## Faces

- **face:** 0 **flags:** 0xc **pending:** 0
- **face:** 1 **flags:** 0x400c **pending:** 0
- **face:** 2 **flags:** 0x5012 **pending:** 0 **local:** 0.0.0.0:9695
- **face:** 3 **flags:** 0x5010 **pending:** 0 **local:** 0.0.0.0:9695
- **face:** 4 **flags:** 0x4042 **pending:** 0 **local:** [::]:9695
- **face:** 5 **flags:** 0x4040 **pending:** 0 **local:** [::]:9695
- **face:** 7 **flags:** 0x81412 **pending:** 0 **remote:** 127.0.1.1:9695 **via:** 2
- **face:** 12 **flags:** 0x1014 **pending:** 2 **activity:** 13 **remote:** 127.0.0.1:38200
- **face:** 13 **flags:** 0x1014 **pending:** 0 **activity:** 7 **remote:** 127.0.0.1:38202
- **face:** 14 **flags:** 0x21012 **pending:** 0 **activity:** 7 **remote:** 127.0.0.1:9695 **via:** 2

## Face Activity Rates

	Bytes/sec In/Out	recv data/intr sent	sent data/intr recv
<b>face:</b> 0	259 / 31	0 / 0	0 / 0
<b>face:</b> 7	0 / 176	0 / 0	0 / 0
<b>face:</b> 12	128 / 0	0 / 0	0 / 0
<b>face:</b> 13	0 / 0	0 / 0	0 / 0
<b>face:</b> 14	440 / 263	0 / 0	0 / 0

## Forwarding

- ccnx:/%C1.M.S.localhost/%C1.M.SRV/ccnd **face:** 0 **flags:** 0x3 **expires:** 2147481862
- ccnx:/ccnx/ping **face:** 0 **flags:** 0x3 **expires:** 2147481862
- ccnx:/ccntuto2 **face:** 7 **flags:** 0x3 **expires:** 2147482037
- ccnx:/%C1.M.S.neighborhood **face:** 0 **flags:** 0x3 **expires:** 2147481862
- ccnx:/%C1.M.S.localhost **face:** 0 **flags:** 0x23 **expires:** 2147481862
- ccnx:/ccnx/%1B%D20%5C%AD%86%99Z%1F%BE%94%609%06%FAy%12%F6%19%E4%8E%B6%F6o1%8B%17%A4%E5%A3.%05%DB **face:** 0 **flags:** 0x17 **expires:** 2147481862
- ccnx:/ccntuto **face:** 7 **flags:** 0x3 **expires:** 2147481922
- ccnx:/ccntuto2/test\_chat\_room/Users/tibs/Keys/%C1.M.K%00%9D%BA%9Cv%AC%DC%BE%DA%CE%80%21HAYG%1A%D1iZn%3A\_%2F8s%7F%FC%D1%E9%13cr/%FD%04%EXA **face:** 0 **flags:** 0x3 **expires:** 2147483637

# Experimentation for management activities

## Need of better tools

- More monitored parameters
- Better accuracy
- New metrics

## Need of a large scale testbed to support experiments

- Based on CCNx enabled nodes
- Solution 1 : federated testbed between academic partners (like the young Internet)
- Solution 2 : PlanetLab nodes (cf NEPI talk)

# IRTF Information-Centric Networking Research Group

## Main topics

- Naming schemes for ICN and scalable name resolution for flat names
- Scalable routing schemes
- Congestion control, QoS approaches, and caching strategies
- Metrics that make it possible to evaluate ICN implementations in a consistent manner
- Security and privacy, including scoping of information objects and access control to them
- Application/application-protocol design and APIs
- Business, legal and regulatory frameworks
- Deployment and interoperability (with BGP, OSPF)

# IRTF Information-Centric Networking Research Group

- Very active group, mailing list : [icnrg@irtf.org](mailto:icnrg@irtf.org), web : [irtf.org/icnrg](http://irtf.org/icnrg)
- Other related IRTF working groups : RRG (Routing Research Group), NMRG (Network Management Working Group)

# Plan

- 1 Key Challenges for the management of CCN
- 2 A firewall for CCN

# Motivation

## How to enforce security policies in CCN?

- Goal : prevent users from downloading malicious/forbidden contents
- Authentication of content possible (lower layers : simple verification) but real security tools missing
- Inheritance of IP firewalls limited : no filter on IP addresses or ports
- New security features enabled by the CCN paradigm

## Contribution

- Content firewall : considering content name and signature
- Use case analysis : Identification of security needs for CCN
- Design of a semantic CCN firewall : grammar definition, preprocessing for semantic enhancement
- Implementation in CCNx and performance evaluation

## IP firewall main use cases

- IP\_UC1 : Filtering based on the protocol (Example : http, smtp, etc.)
- IP\_UC2 : Filtering based on status of the connection (new, established, etc.)
- IP\_UC3 : Filtering based on a list of known blacklisted IP addresses
- IP\_UC4 : Filtering unusual inbound traffic pattern (from a denial of service attack attempt)

Some use cases do not make sense in CCN, others must be adapted.



## CCN-specific use cases

- CCN\_UC1 : Filtering on content provider (Example : known untrustworthy or banned)
- CCN\_UC2 : Filtering on bad signature
- CCN\_UC3 : Filtering on content name and semantic (Example : excluding contents named with a given keyword)
- CCN\_UC4 : Composition (content provider & content name)
- CCN\_UC5 : Filtering on content direction (Example : avoid leakage of certain documents)
- CCN\_UC6 : Filtering on heavy traffic (Preservation of QoS)
- CCN\_UC7 : Filtering of stored data (Example : caching only storing specific content)

## Comparison : IP vs CCN use cases

IP use cases	CCN use cases	Filtering on
IP_UC1	CCN_UC3	Protocol / Content name
IP_UC2	--	Status of the connection
IP_UC3	CCN_UC1	Listed IP / Content provider
IP_UC4	CCN_UC6	Unusual / Heavy traffic
--	CCN_UC2	Bad signature
--	CCN_UC4	Composition of filters
--	CCN_UC5	Content direction
--	CCN_UC7	Stored data

## Syntax definition

- Syntax based on iptables for ease of use and readability
- 3 different types of rules

```
rule = r_interest | r_data | r_face
```

```
r_interest = "interest" SP direction SP  
            match_interest SP "pit" SP action
```

```
r_data = "data" SP direction SP match_data  
        SP ["cs"|"pit"] SP action
```

```
r_face = "face" SP number
```

## r\_interest

### Main rule

```
r_interest = "interest" SP direction SP  
            match_interest SP "pit" SP action
```

### Syntactic elements

```
direction = "*"|"int"|"ext"  
action = "forward"|"drop"  
match_interest = content_name
```

### Example

```
interest * \@game|play|fun\@ 15 pit drop
```

## r\_data

### Main rule

```
r_data = "data" SP direction SP match_data  
        SP ["cs"|"pit"] SP action
```

### Syntactic elements

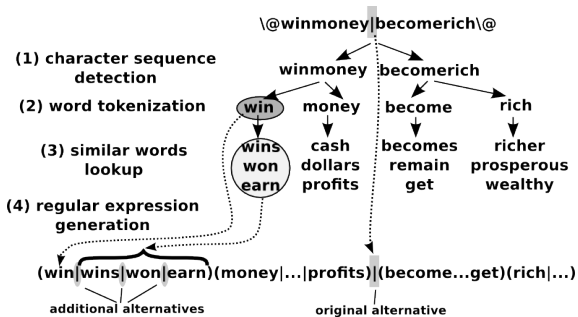
```
direction = "*"|"int"|"ext"  
action = "forward"|"drop"  
match_data = content_name SP provider  
content_name = "*"|reg_exp  
provider = sign_check SP provider_sign  
sign_check = "0" | "1"  
provider_sign = "*"|first_sign *next_signs
```

### Example

```
data * \@game|fun\@ 0 0 123456789A;FFFF0000AA pit drop
```

## Pre-processing with Disco

- Sequences of more than 3 characters are extracted
- Segmented as real human-readable words
- For each word, x semantically similar words are found...
- ... and included into an extended regular expression



# Implementation

## Integration within the CCN stack

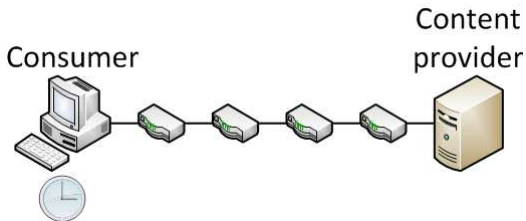
- Firewall directly processes content chunks : captures packets arriving on a face, applies rules on it, eventually calls standard CCN process



## Evaluation (1/3)

### CCN firewall evaluation setup

- 6 nodes
- Intermediate routers do not cache
- Consumer request single binary file
- Measurement of transmission time

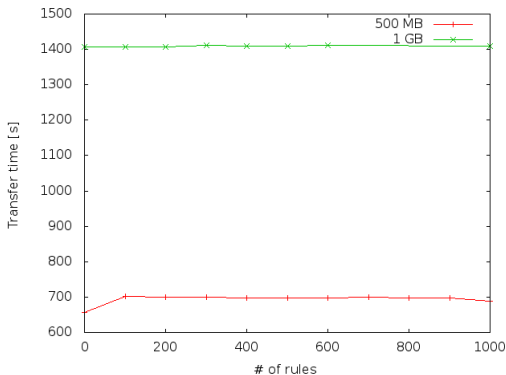




## Evaluation (2/3)

### Impact of the number of rules on the transfer time

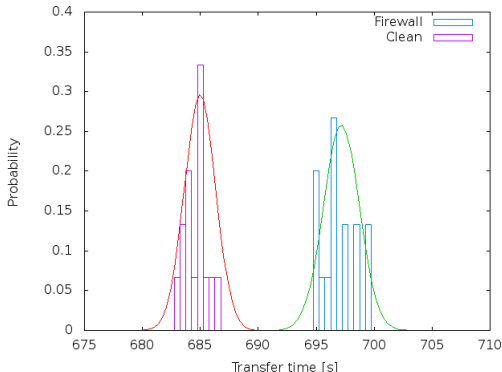
- Increasing step 100 MB
- Requested files size : 500 MB and 1 GB
- Shows small to no impact on transfer time



## Evaluation (3/3)

### Impact of a 1000-rules firewall on the transfer time

- Repeated experiment (500 MB file transfer) to obtain significant results
- Applied Chi-square and KS-test on obtain result
- Overhead of the firewall is insignificant



# Questions?



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