ITU Kaleidoscope 2016
ICTs for a Sustainable World

A Popularity-based Caching Strategy for the Future Internet

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Presentation Outline

Overview & Motivation

Information/Content Centric Internet

Content Caching in Future Internet

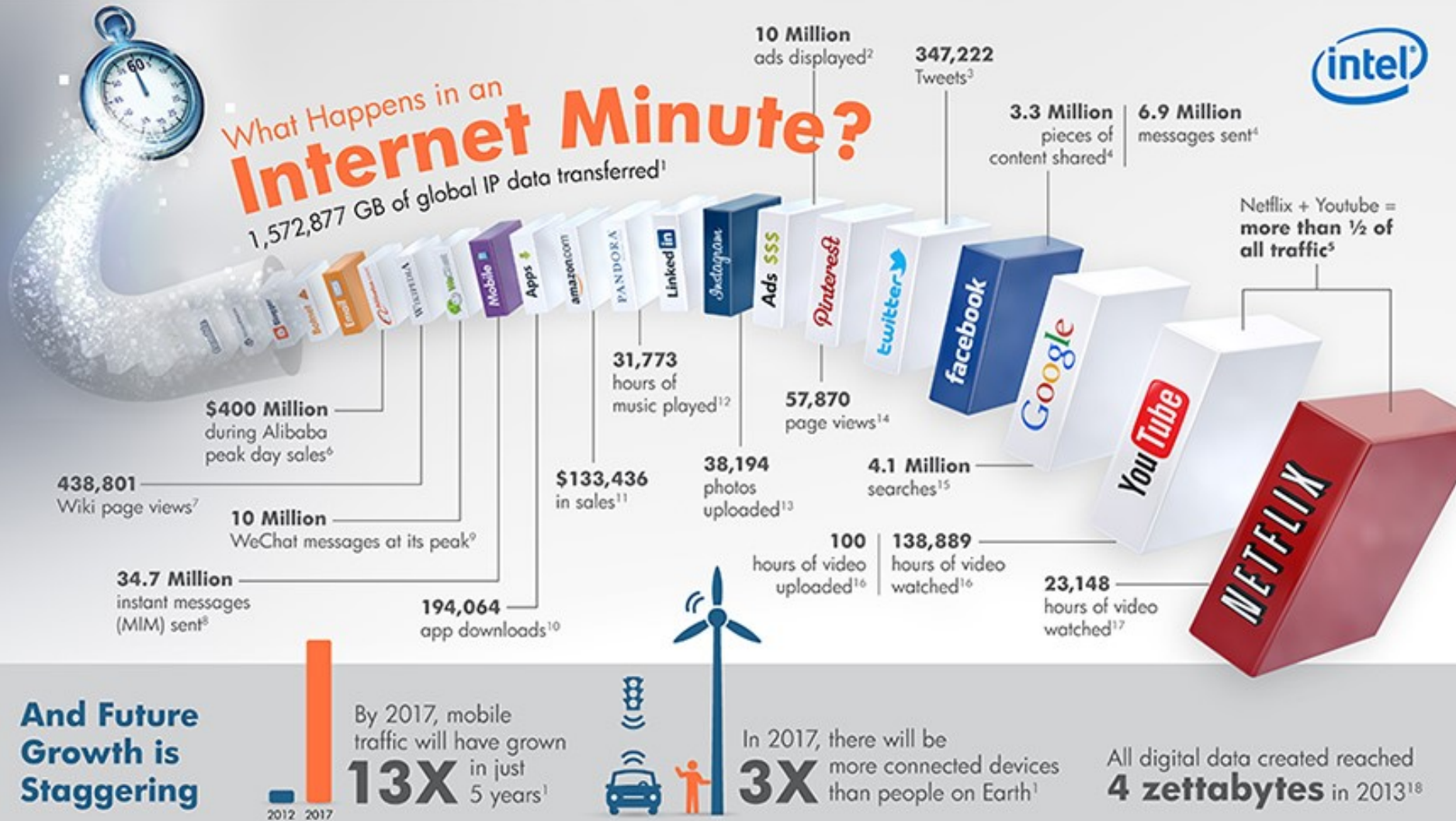CPCE: The Proposed Caching Strategy

CPCE Evaluation

Contribution

Conclusion

Internet Content Traffic Prediction

What Happens in an Internet Minute?

1,572,877 GB of global IP data transferred[1]

10 Million ads displayed[2]

347,222 Tweets[3]

3.3 Million pieces of content shared[4]

6.9 Million messages sent[4]

Netflix + Youtube = more than ½ of all traffic[5]

$400 Million during Alibaba peak day sales[6]

438,801 Wiki page views[7]

10 Million WeChat messages at its peak[9]

34.7 Million instant messages (MIM) sent[8]

31,773 hours of music played[12]

57,870 page views[14]

$133,436 in sales[11]

38,194 photos uploaded[13]

4.1 Million searches[15]

194,064 app downloads[10]

100 hours of video uploaded[16]

138,889 hours of video watched[16]

23,148 hours of video watched[17]

And Future Growth is Staggering

2012 2017

By 2017, mobile traffic will have grown **13X** in just 5 years[1]

In 2017, there will be **3X** more connected devices than people on Earth[1]

All digital data created reached **4 zettabytes** in 2013[18]

- **IP traffic in North America will reach 40.5 exabytes per month by 2018.**
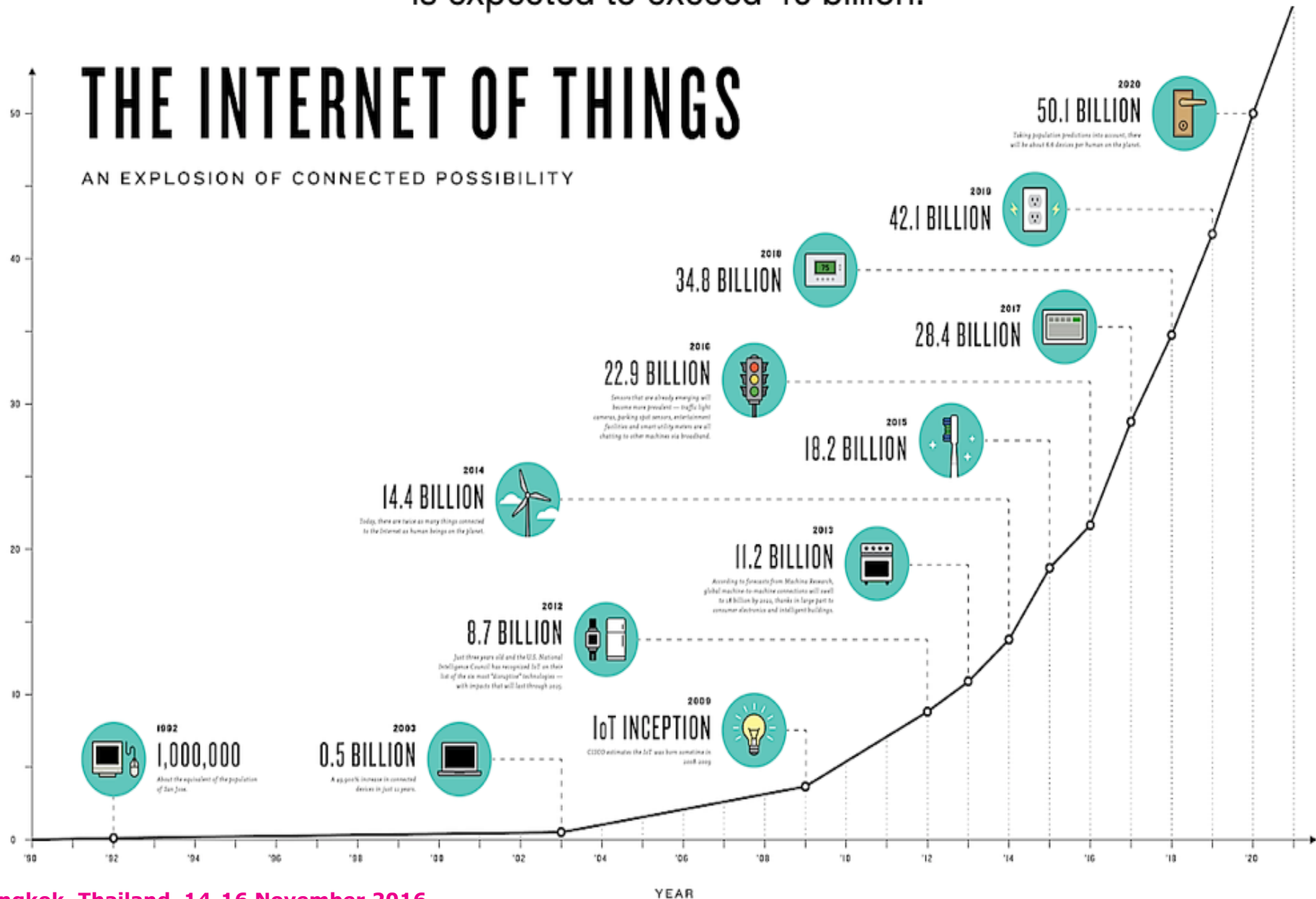- **IP traffic in Asia Pacific will reach 47.3 exabytes per month by 2018.**

Source: Cisco VNI 2015

By 2020, the number of devices connected to the Internet is expected to exceed 40 billion.

THE INTERNET OF THINGS

AN EXPLOSION OF CONNECTED POSSIBILITY

www.theconnectivist.com

Big data—a growing torrent

$600 to buy a disk drive that can store all of the world's music

5 billion mobile phones in use in 2010

30 billion pieces of content shared on Facebook every month

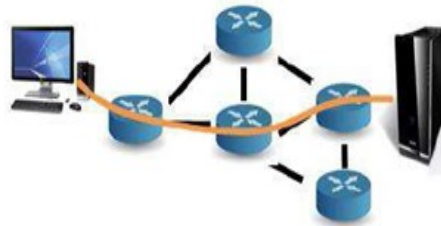**40%** projected growth in global data generated per year vs. **5%** growth in global IT spending

235 terabytes data collected by the US Library of Congress in April 2011

The Evolution of Modern Communication

Past → **Present** → **Not-so-far Future**

Telephony

Internet
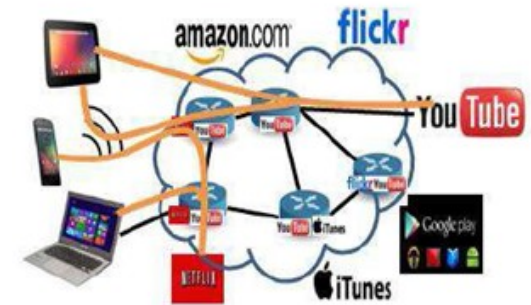
Content-centric Internet
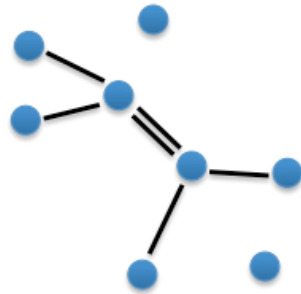
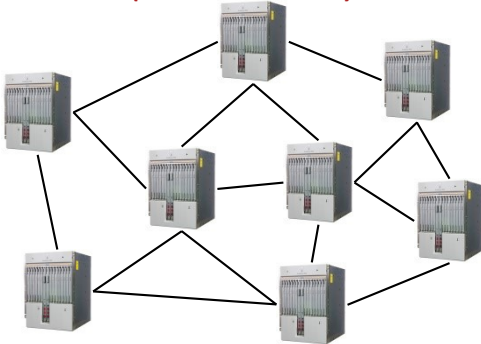Circuit Switching
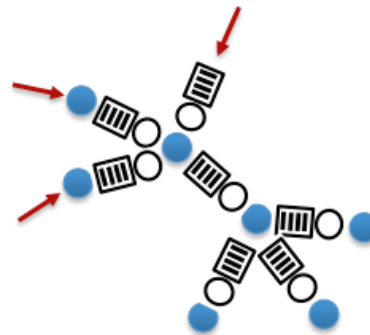
Packet Switching
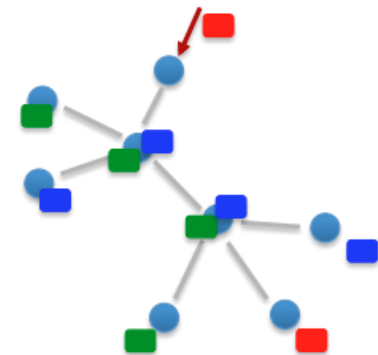
Content Caching

Information/Content Centric Networking

Today's Internet

Focus on
*Nodes
(host-centric)*

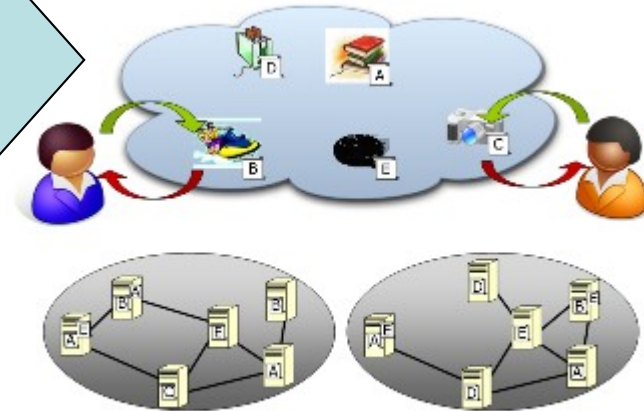In today's Internet, accessing information is the dominating use case!

Evolution

| Web | CDN | P2P |

Information-Centric Internet

Focus on
*information objects
(content-centric)*

Source: www.irtf.org

Note: ICN variants exist, (with some differences):
- Content-centric networking (CCN)
- Named Data Networking (NDN)
- Data Oriented Network Architecture (DONA)
- Publish-Subscribe Internet (PSI)
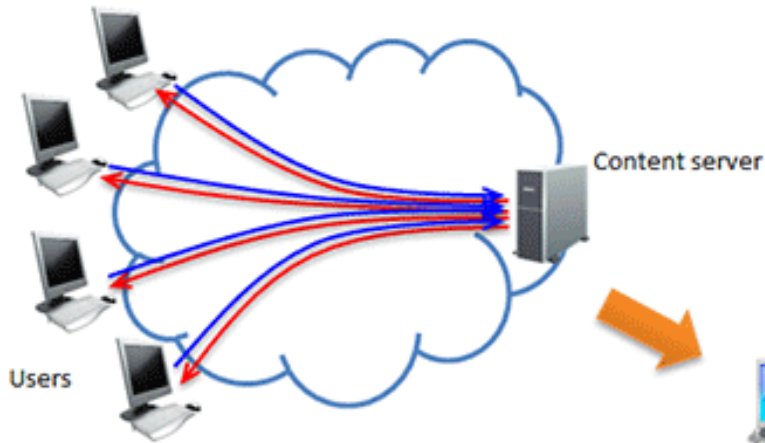- Content Oriented Networking (CONET)

In-network Caches in Future Internet
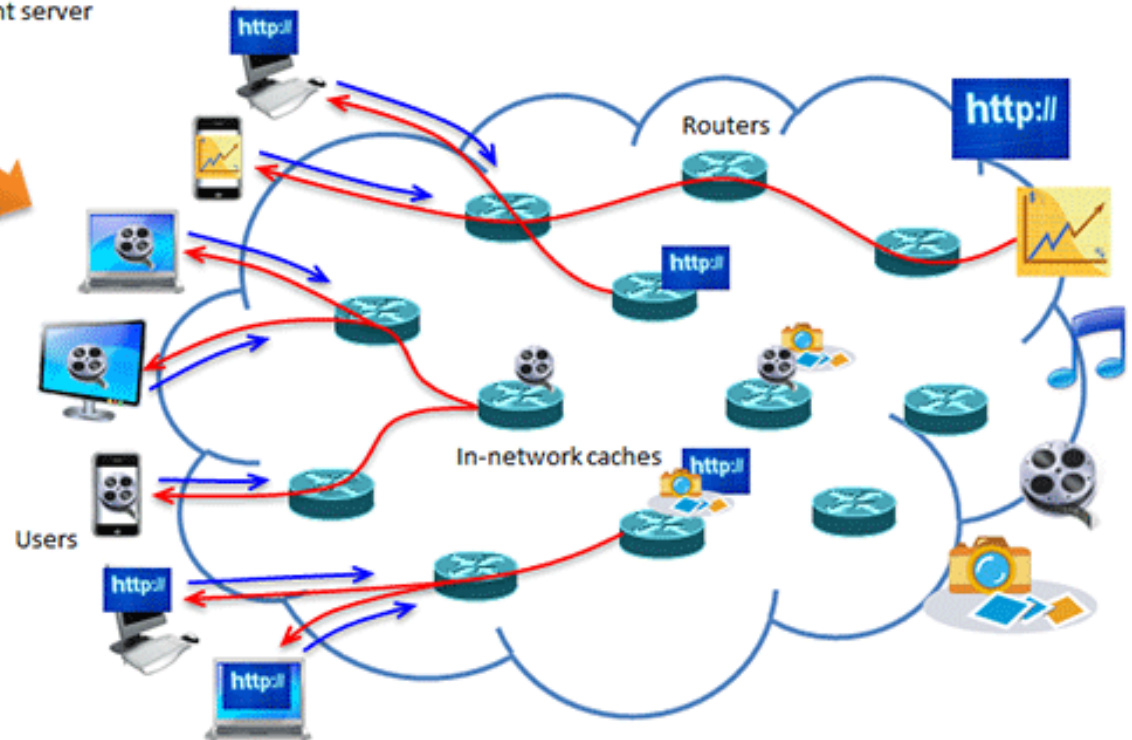## (Rec. ITU-T Y.3033)

Content request packets (blue solid arrows)

Identifier: IP address of the server

Content server

Users

(a) IP address-based communication

Content request packets (blue solid arrows)
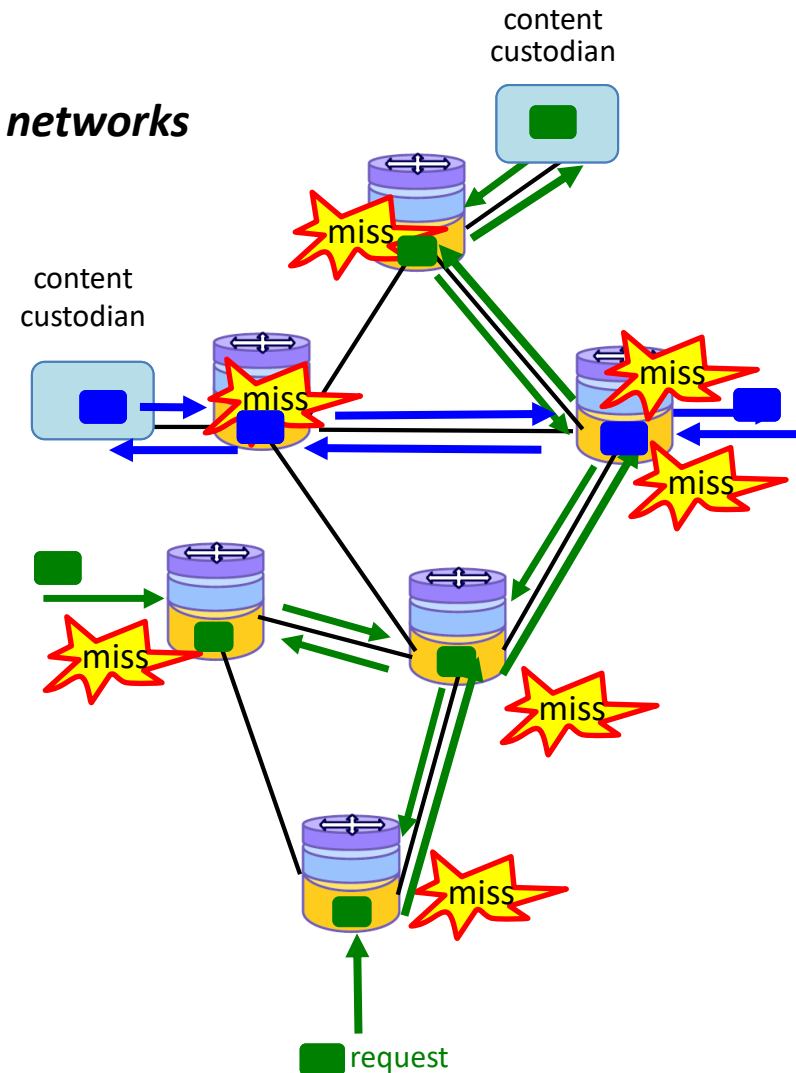
Identifier: content name

Routers

In-network caches

Users

(b) Information-centric network

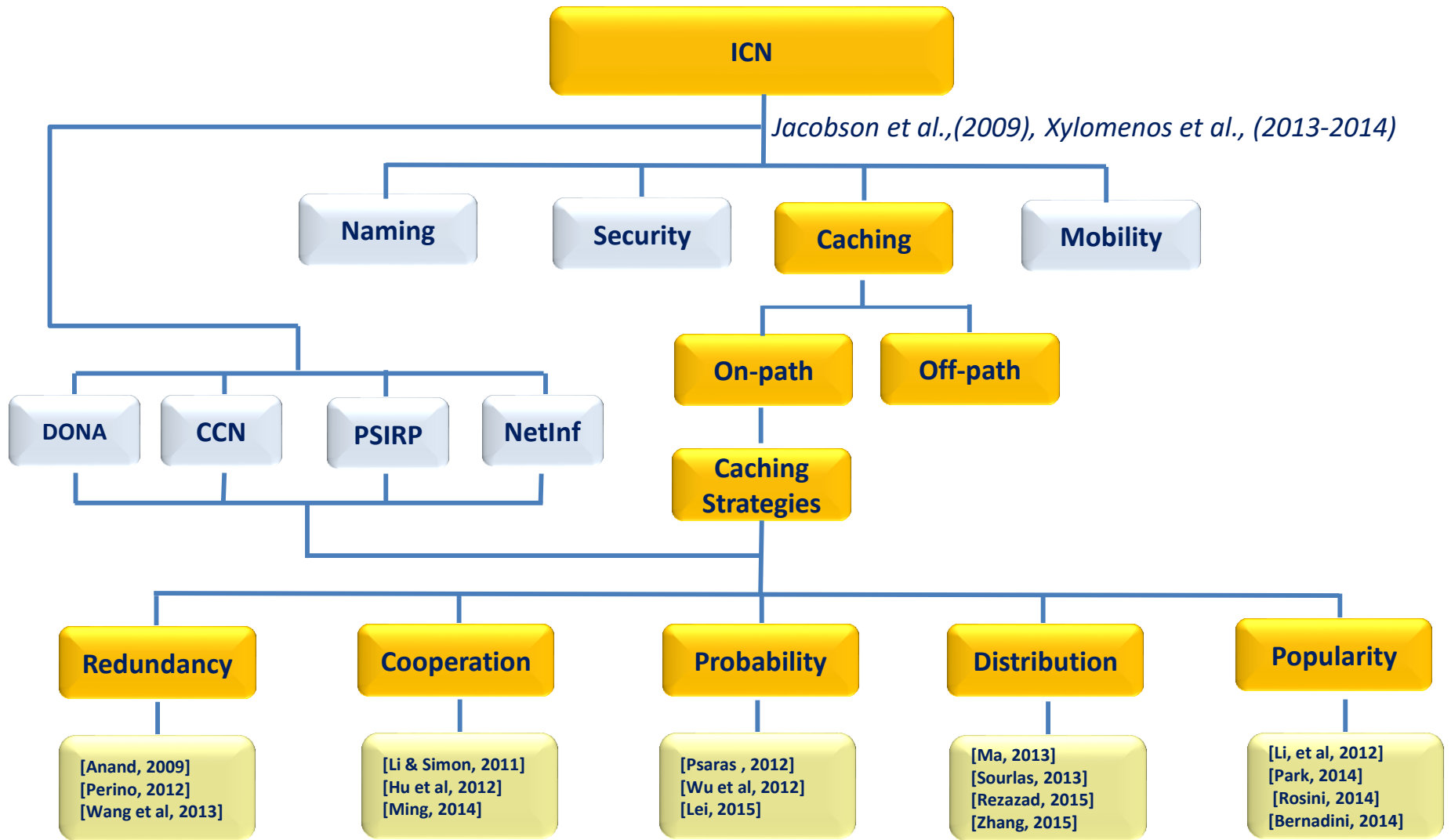# Content Caching in Future Internet

ITU-T Study Group 13: Recommendation Y.3033
Framework of data aware networking for future networks

- ❖ consumer *requests content*
- ❖ request *routed* (e.g., shortest path) to known *content custodian*
- ❖ en-route to custodian, *caches inspect* request
  - ▪ *hit:* return local copy
  - ▪ *miss:* forward request towards custodian
- ❖ during content download, *store* in caches along path

Source: Jim Kurose, SIGCOMM2013

Related Works

ICN

Jacobson et al.,(2009), Xylomenos et al., (2013-2014)

Naming · Security · Caching · Mobility

DONA · CCN · PSIRP · NetInf

On-path · Off-path

Caching Strategies

Redundancy
[Anand, 2009]
[Perino, 2012]
[Wang et al, 2013]

Cooperation
[Li & Simon, 2011]
[Hu et al, 2012]
[Ming, 2014]

Probability
[Psaras , 2012]
[Wu et al, 2012]
[Lei, 2015]

Distribution
[Ma, 2013]
[Sourlas, 2013]
[Rezazad, 2015]
[Zhang, 2015]

Popularity
[Li, et al, 2012]
[Park, 2014]
 [Rosini, 2014]
[Bernadini, 2014]

Caching Issues

What cache management strategies could be of effective benefits for ICN in mitigating the problems faced by the current practices?

i What is the best way of storing requested content items in content store in order to increase cache hit rate?

**ii** How to minimize stretch ratio during content placement and eviction?

iii How to determine the impact of the proposed strategy on cache hit rate and stretch ratio?

Position of Caches

Content Eviction

Content Placement
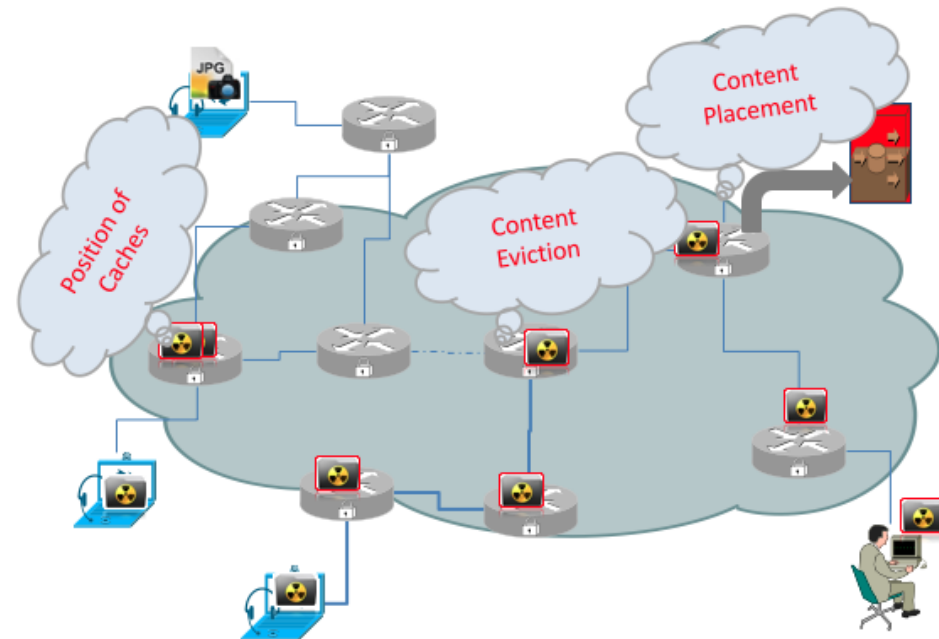
Cache Popular Content Everywhere (CPCE)

- Cache contents at all *on-path* routers once their popularity reaches specified threshold value (10).

- Use LRU policy to replace cached contents from each router if cache of all *on-path* routers overflows and a new content arrives

    - avoid maximum bandwidth utilization, as majority of the content requests pass through that router.

- Use LRU to evict cached contents accessed least recently. Evicted content is cached at underlying router.

- Use Random policy to accommodate the content coming from *R_max* if cache of underlying router is full
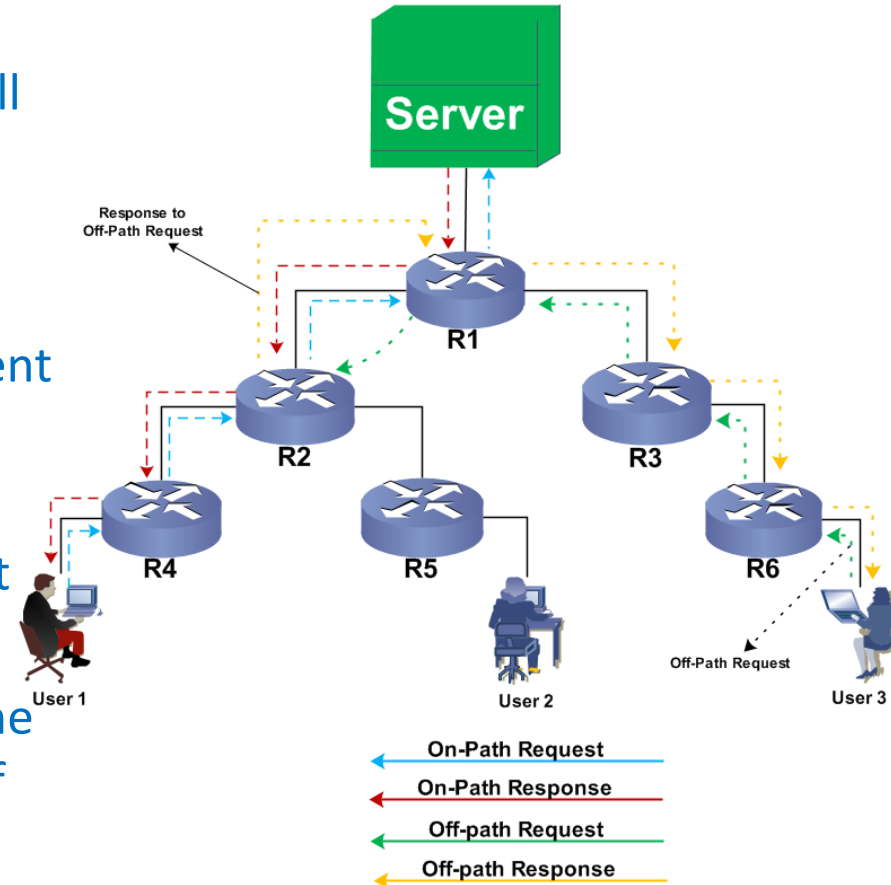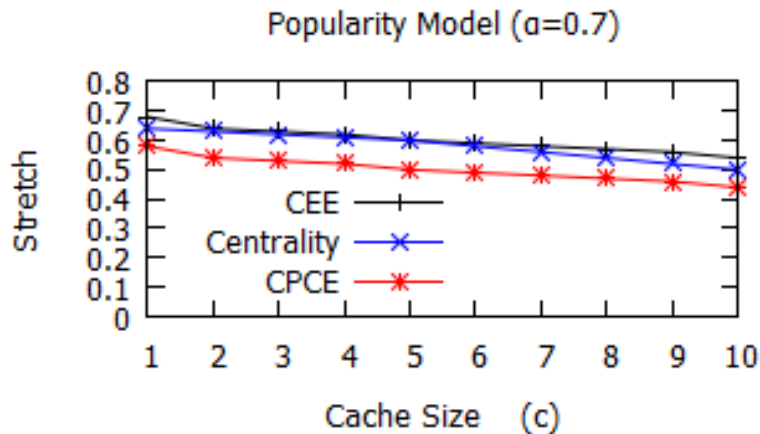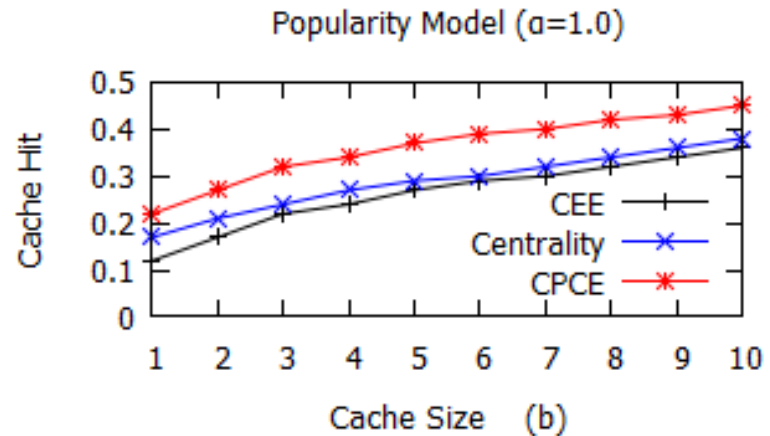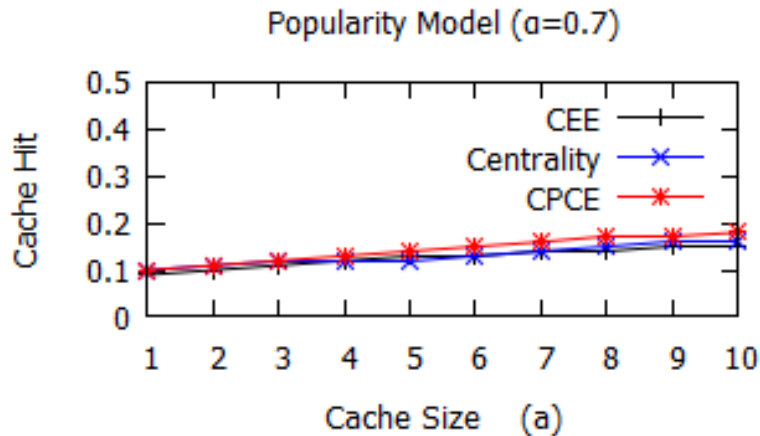
CPCE Evaluation Environment

- The CPCE strategy was evaluated on the GEANT and DTelecom topologies

- The contents were downloaded from Facebook social network topology, which consists of 4,039 nodes

- The simulations were run for 10 times: each time 1 hour for every cache size (i.e., 1GB-10GB)

- The Cache Hit was calculated as: $H_c = \frac{\sum_{i=1}^{n} hiti}{\sum_{i=1}^{n}(hiti+missi)}$

- The Stretch was calculated as: $S = \frac{\sum_{i=1}^{n} H_c}{H_t}$

CPCE Evaluation Parameters

GEANT Topology

DTelekom Topology

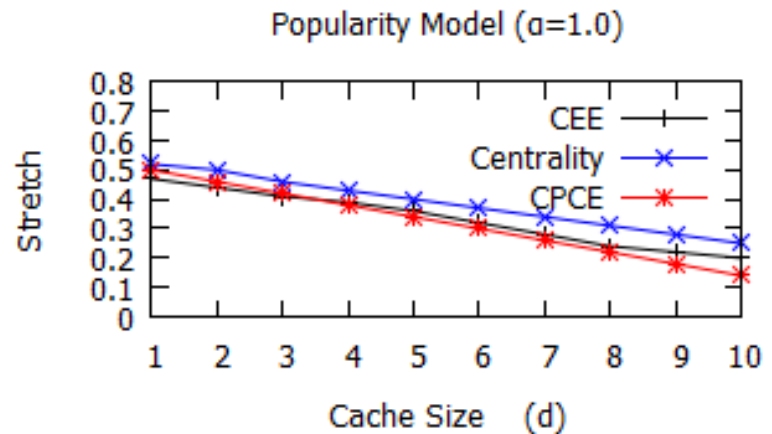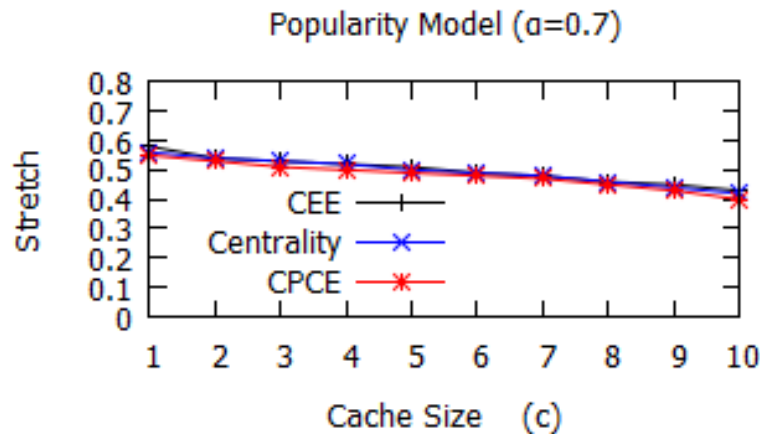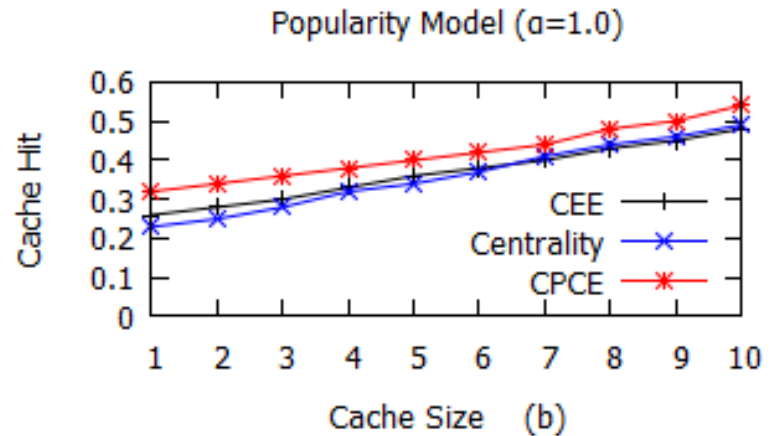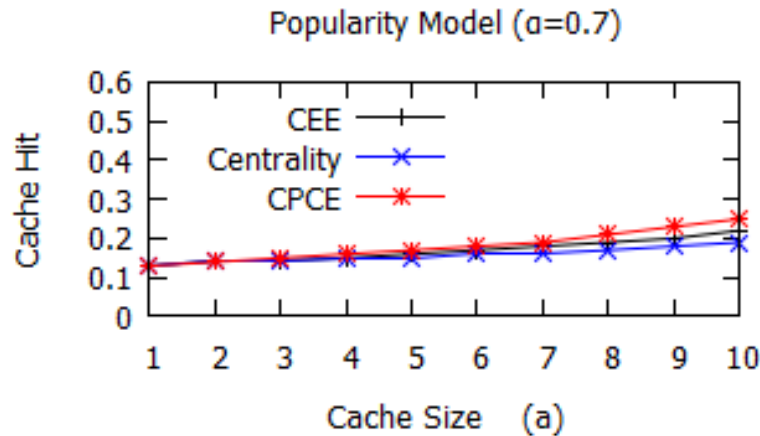| Zipf Categorization | $a = 0.7, 1.0$ |
Cache Size	1GB-10GB
Catalog Size	10^8
Topology	GEANT, DTelekom
Replacement Policy	LRU
Traffic	SONETOR
Simulator	SocialCCNSim
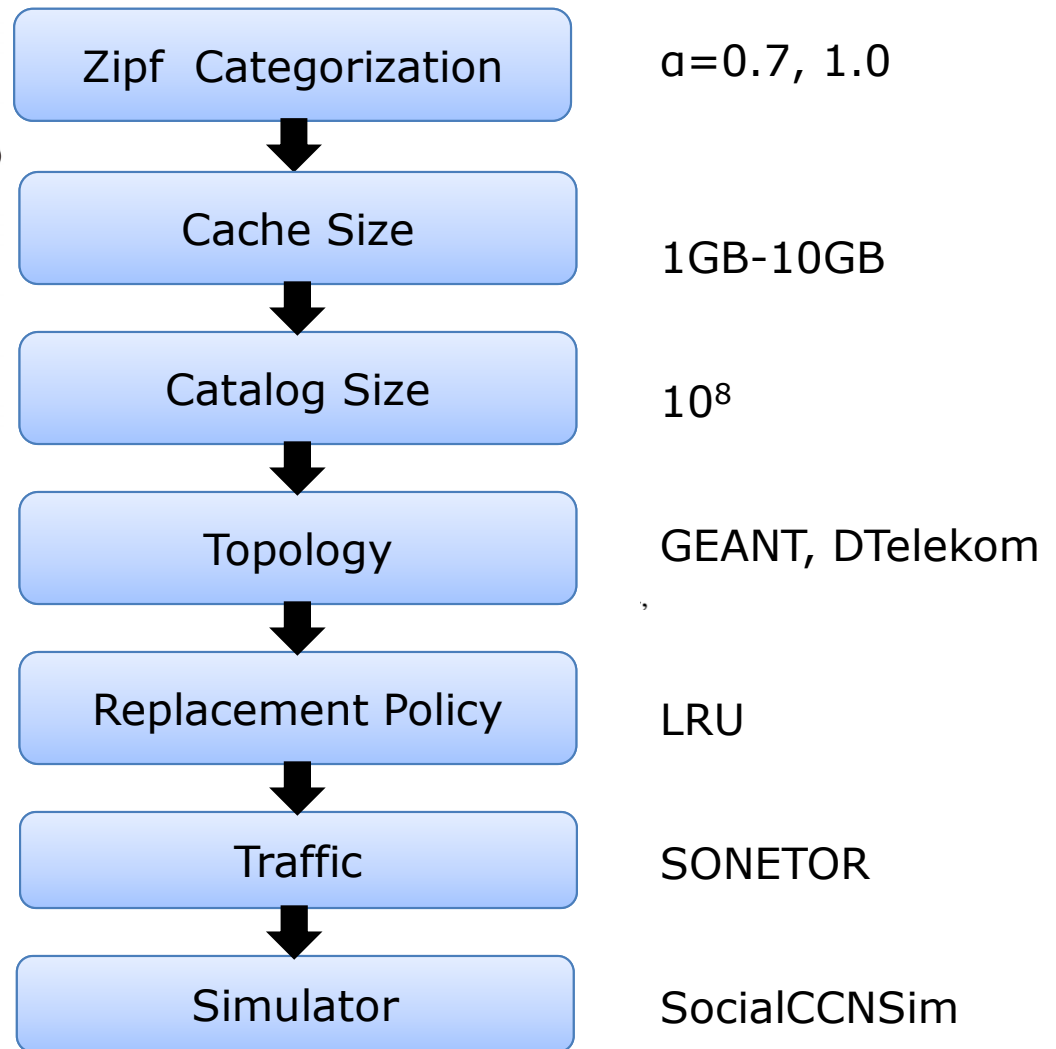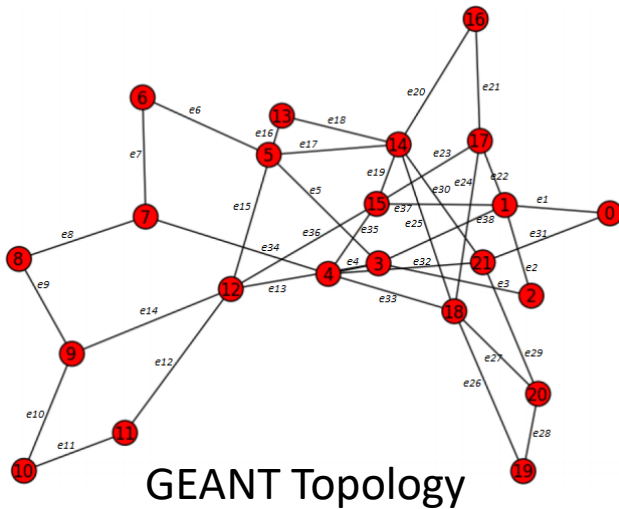
Evaluation Result (GEANT Topology)
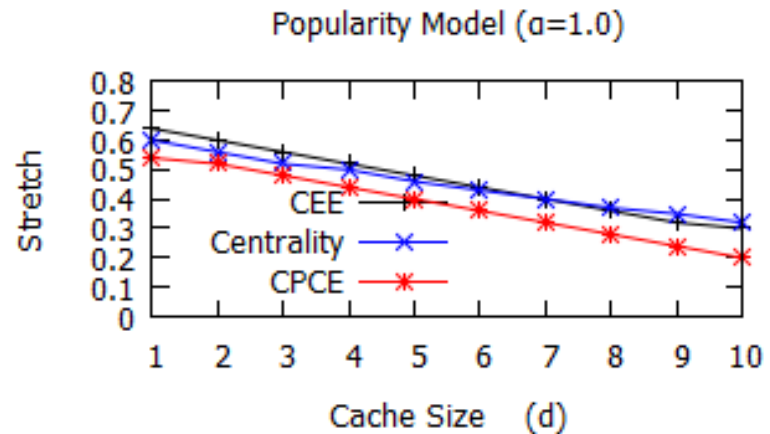
Observation: CPCE outperforms CEE and Betweenness-Centrality caching in both Cache Hit and Stretch ratio.

Evaluation Result (DTelekom Topology)

Observation: CPCE also produces better results than CEE and Betweenness-Centrality caching on the DTelecom topology

Comparing Analytical vs. Simulation Results
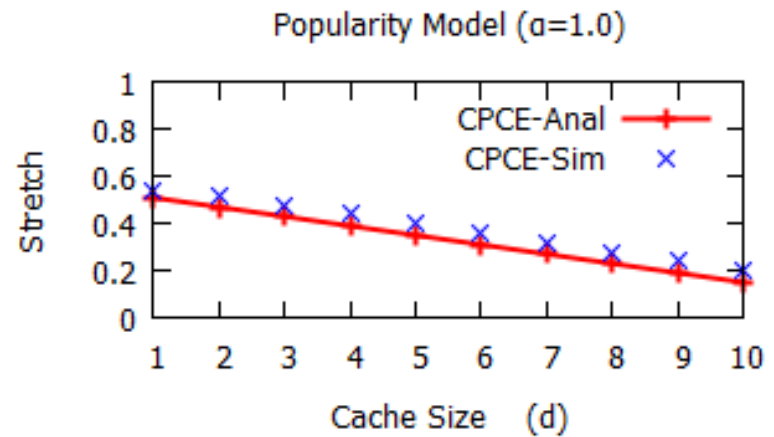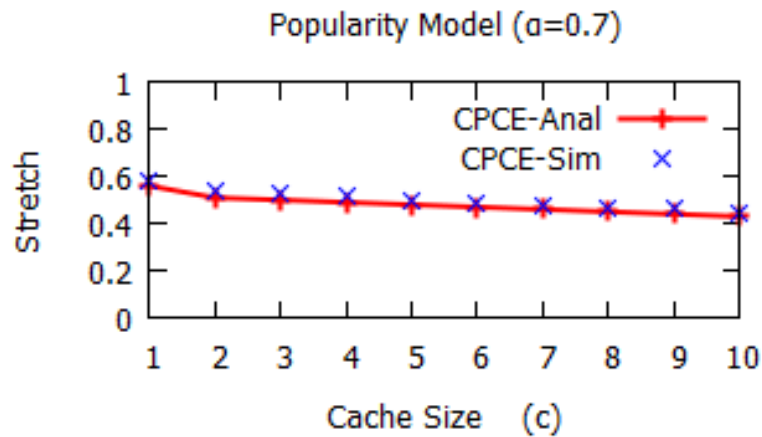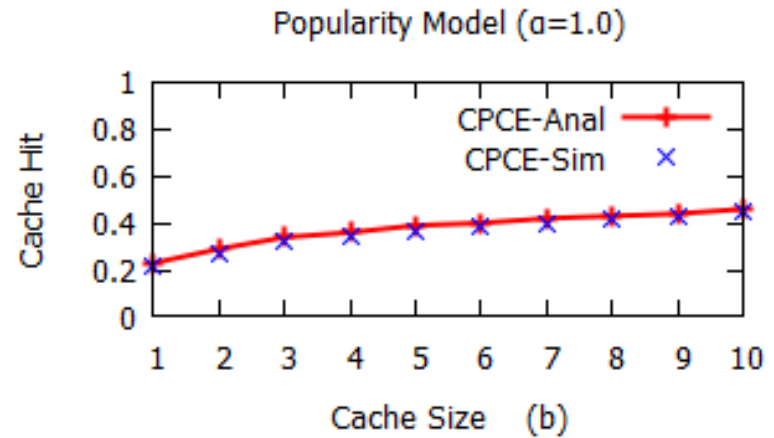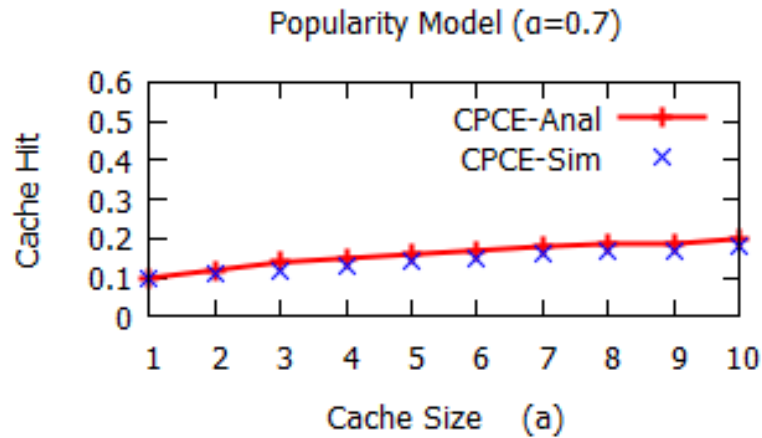
Average difference: ~ 1.7%;
Accuracy: ~ 98%

Contributions

CPCE Cache Management Strategy for ICN

Hypergraph Concept in ICN Caching

- Mathematical formulation for Path acquiring in ICN

Cache Management Model in ICN

- Framework design for Publisher-Subscriber Positions in ICN Caching

Extension of FlexPop to the SocialCCNSim Simulator

Conclusion

- ITU-T Recommendation Y.3033 (SG13): Every network segment in data aware networking (DAN) is recommended to support a caching component

- To support Recommendation Y.3033, we propose a caching strategy for caching popular contents to improve the performance of ICN caching in terms of *cache hit rate* and *stretch ratio*

- We evaluate performance of CPCE and compare with the default ICN strategies CEE, and Betweenness-Centrality

- We show that the proposed CPCE produced better results than the default ICN strategies CEE and Betweenness-Centrality

Future Work

- To evaluate CPCE against other ICN caching strategies

- To evaluate on different wireless networks, (e.g., VANET)

- To test for real-time applications

- To test for future network domains, e.g., 5G network and cloud infrastructure

Image Source: https://goo.gl/CgGXXD

THANK YOU
ขอขอบคุณ
khop khun khap