Empowered by Innovation NEC

HydraICN

Scalable Content Exchange in Challenged ICNs

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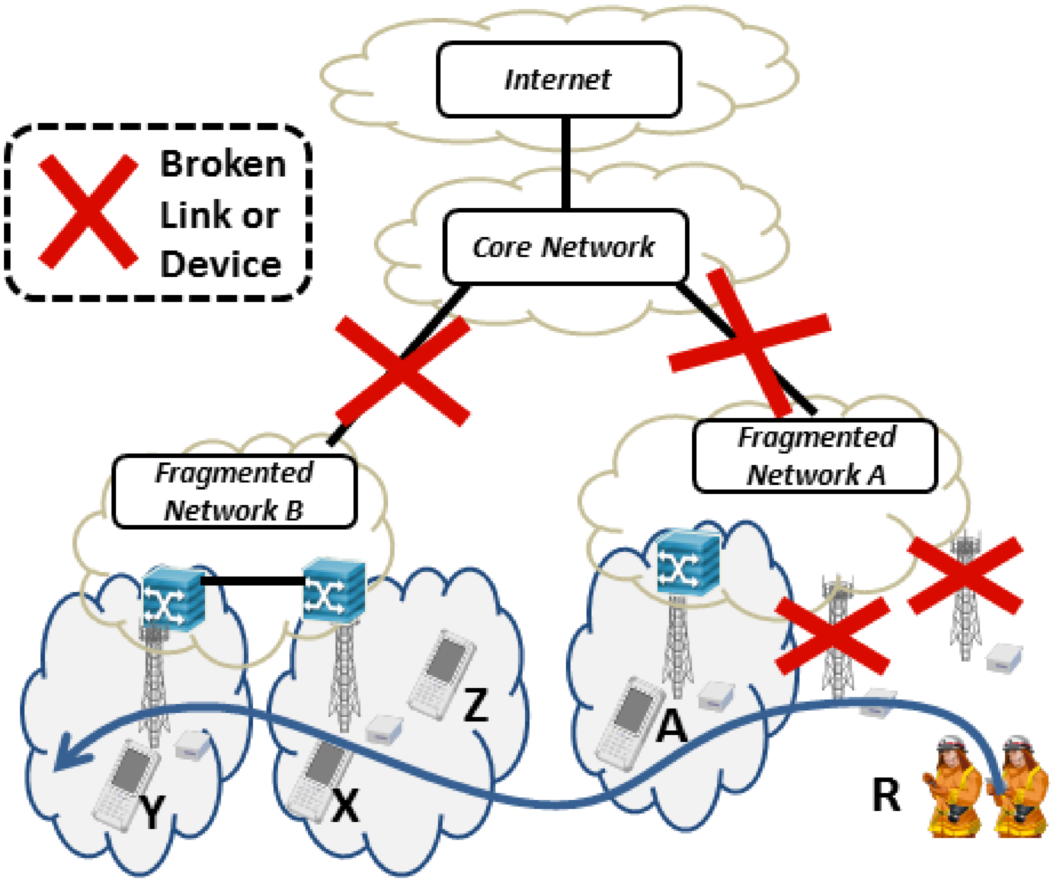
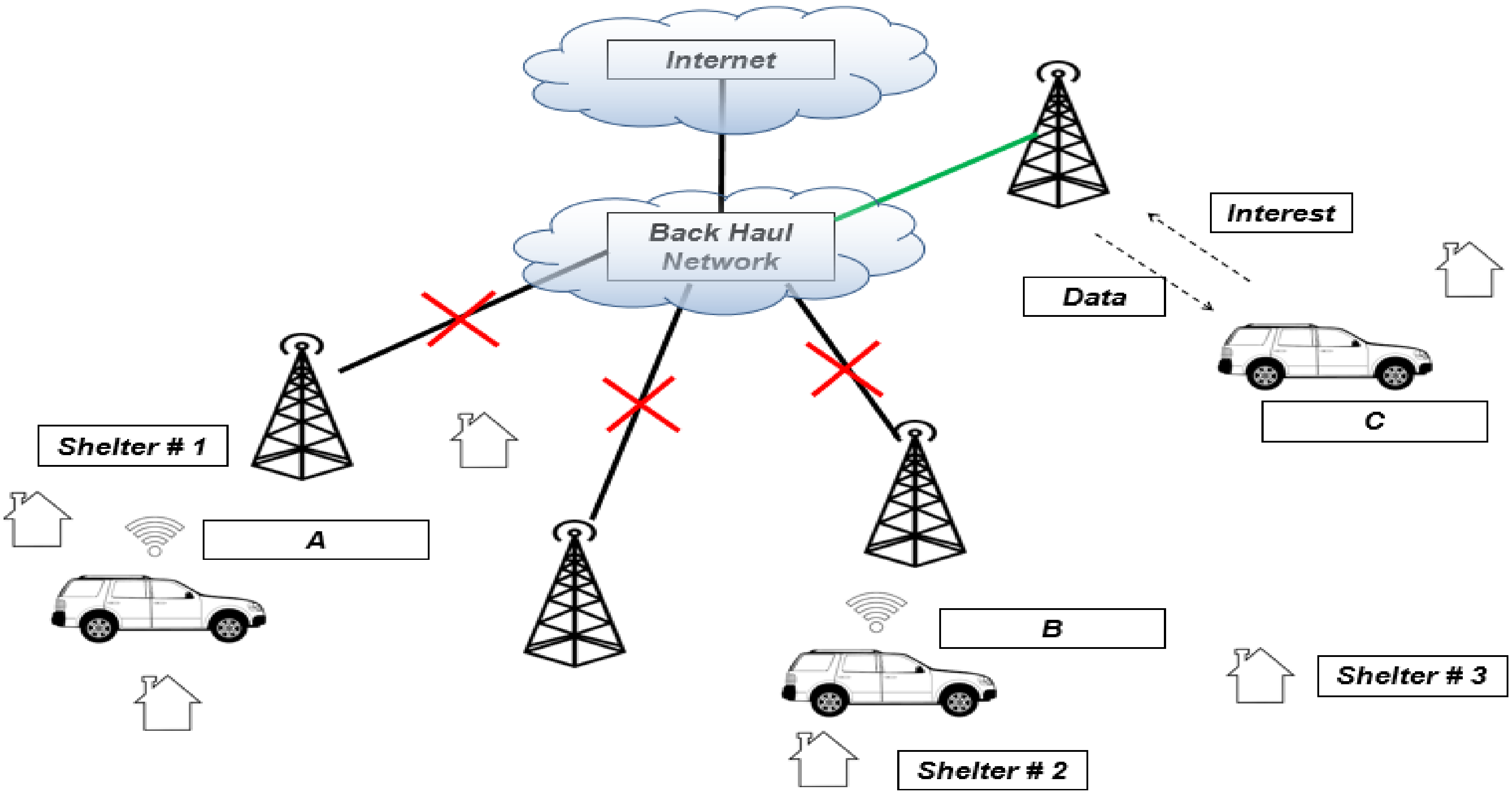
Supported by GreenICN Project

ICN Information Availability in Fragmented Networks



ICN nodes: store-and-forward mode

Data Mules Between Fragmented Communities



Challenges

- Achieving **„optimal" data availability** in fragmented ICNs with intermittent, unpredictable connectivity
- **Allocating storage and networking resources** accordingly
- **Leveraging knowledge about data popularity/relevance** to optimize resource usage
- **No global view on popularity**: need good enough decentralized estimation
- **Estimation algorithm**: balance effectiveness and complexity

Objectives

Distributed counting/aggregating of interests

- Interests serve as popularity counters
- Aggregating interest information without losing too much information

Robust protocol

- Scalable with respect to network size and network lifetimes
- Loop-free to accomodate random, unpredictable movements of ICN nodes

Naïve Approach: Counting Interests

- **Append nonce to each unique Interest message** and accumulate nonces in the network
  - Interest + nonce == unique interest

- **Advantage: can lead to accurate representation** of popularity per Interest at many nodes

- **Disadvantage: Scalability problem**
  - Need to store all nonces per Interest
  - Also: need to exchange complete nonce list when two nodes meet

Our Approach

- Idea: **Aggregate [nonce:count] tuples**
  - Approximate content popularity

- Append nonce to each unique Interest message and **count nonces as a popularity counter**: **[nonce:count]** tuples

- **Data mules maintain sorted list of [nonce:count]** per interest for scalability

- When two data mules meet, they **exchange their Interests**
  - Interests & Popularity estimation gets distributed in network

Our Approach

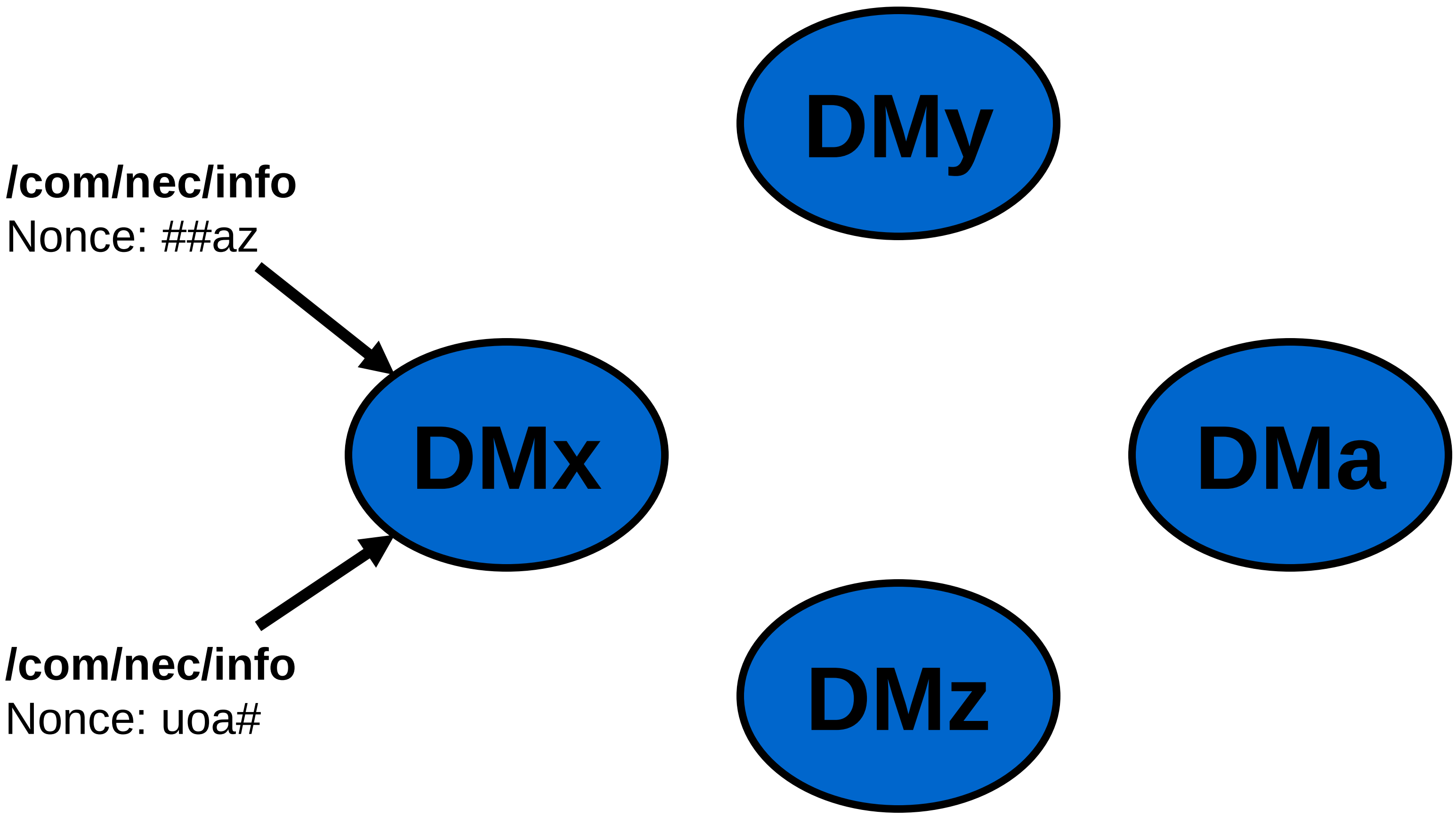
- For each Interest, aggregate **[nonce:count]** tuples as follows:

- **Compare([nonce1, count1] , [nonce2, count2])**

- **IF nonce1 == nonce2**
  - **new_count = MAX(count1, count2) (at both nodes)**

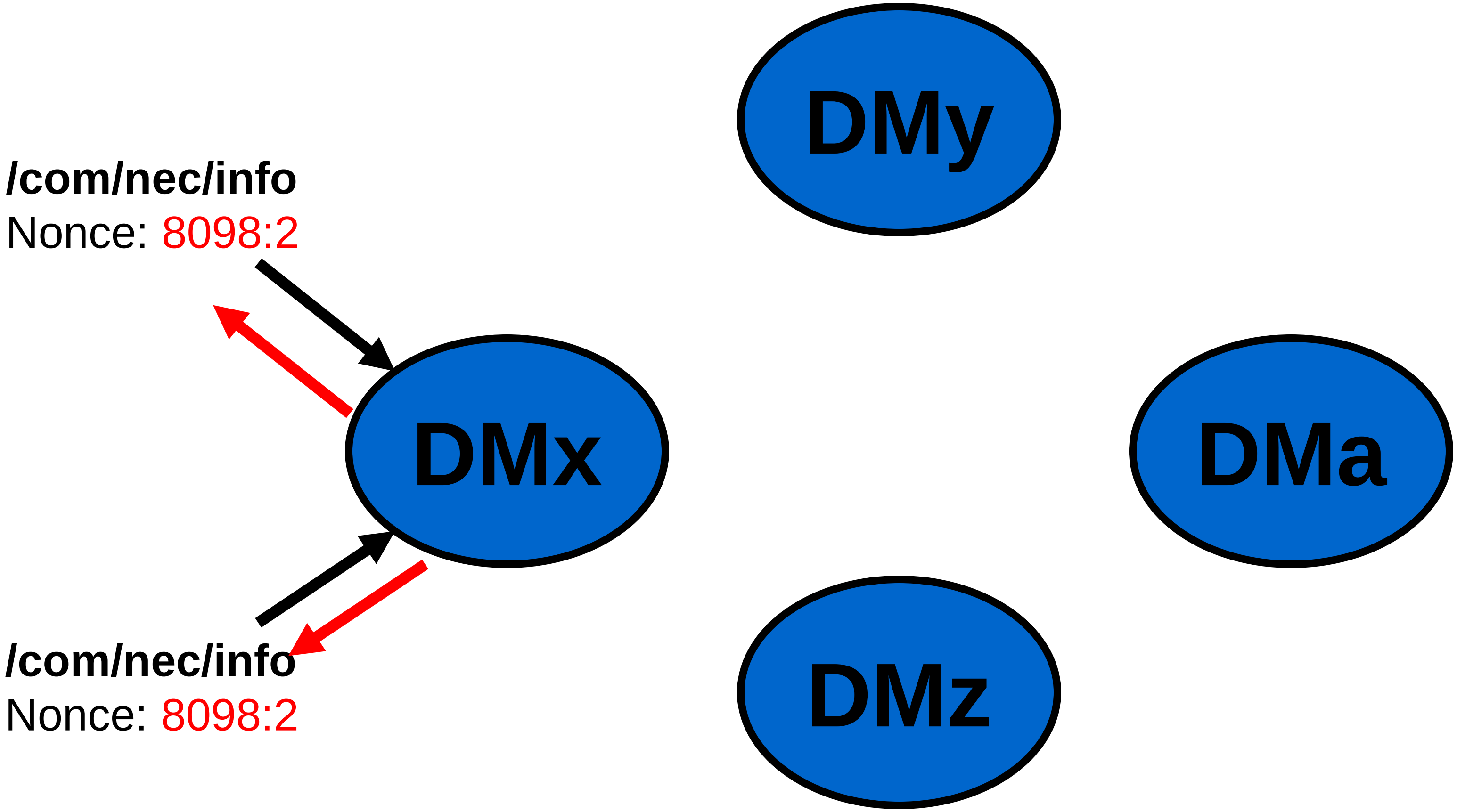
- **IF nonce1 != nonce2**
  - **New_nonce = nonce with largest counter([nonce1, count1], [nonce2, count2])**
  - **New_count = count1 + count2**

Sample Exchange 1



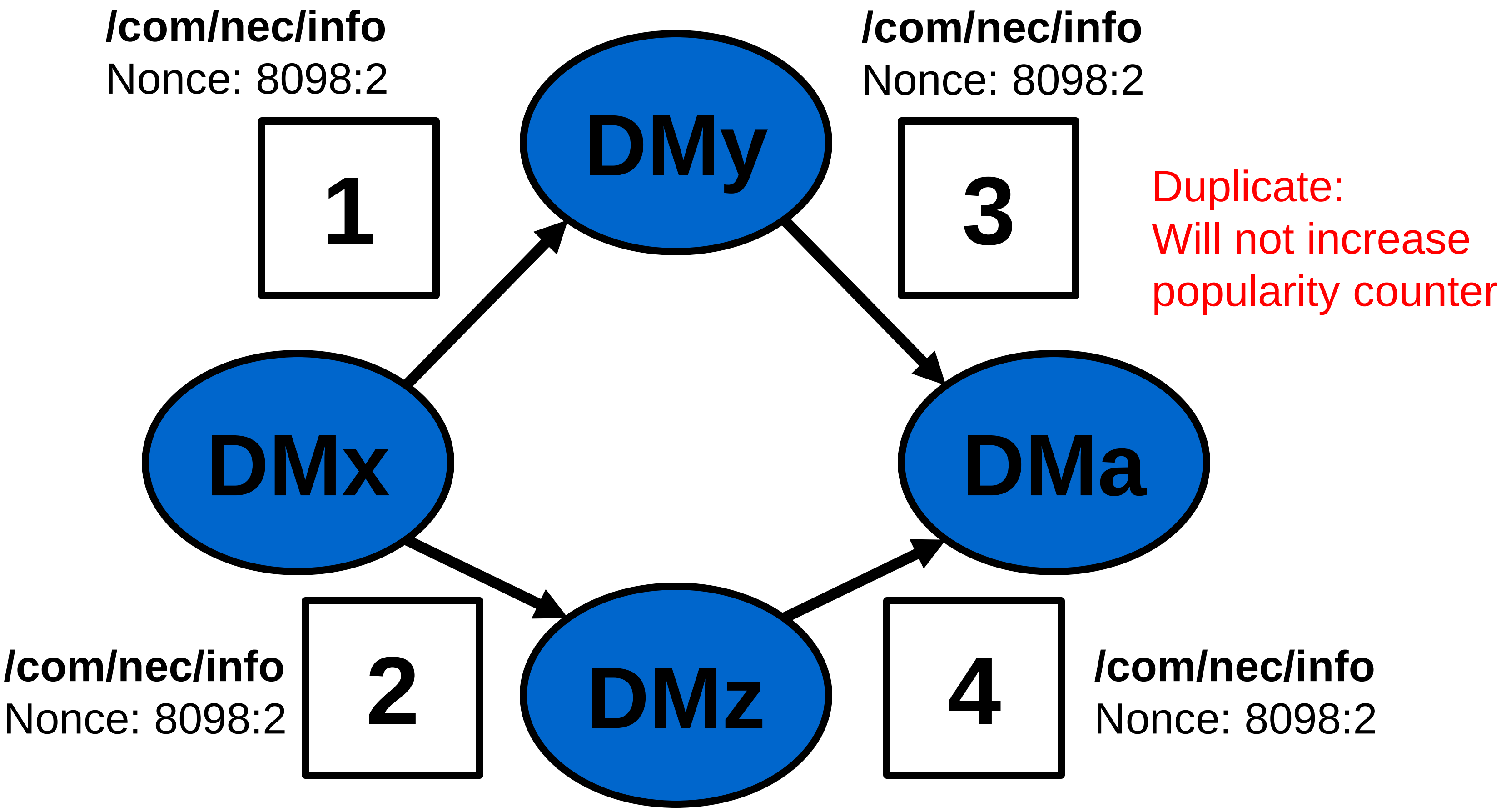
Two end users request the same name from DMx

Sample Exchange 2



End users are assigned a new nonce with count 2 for the same prefix

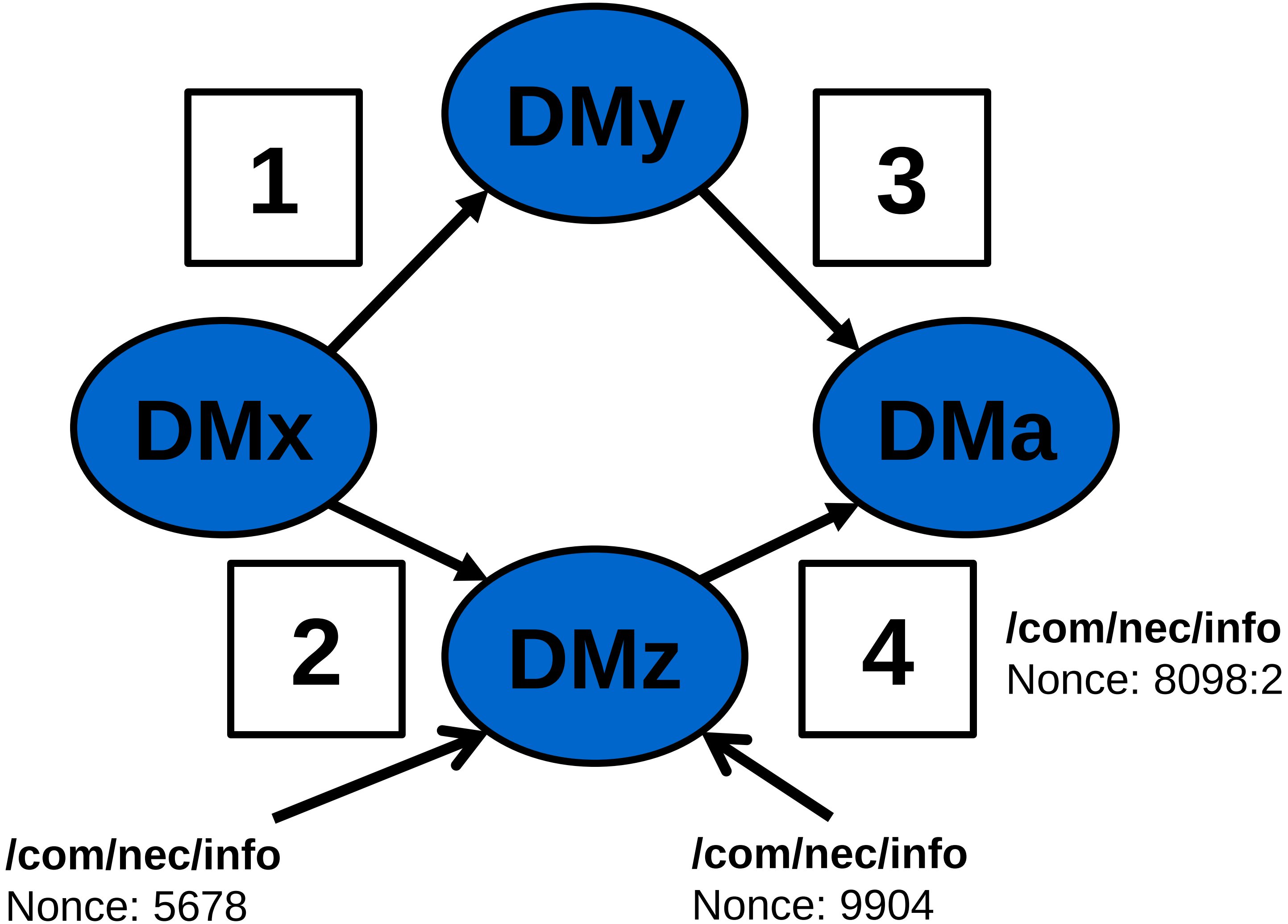
Sample Exchange 3



DMa receives duplicate query (loop) from DMz, thus drops the message (loop detection)

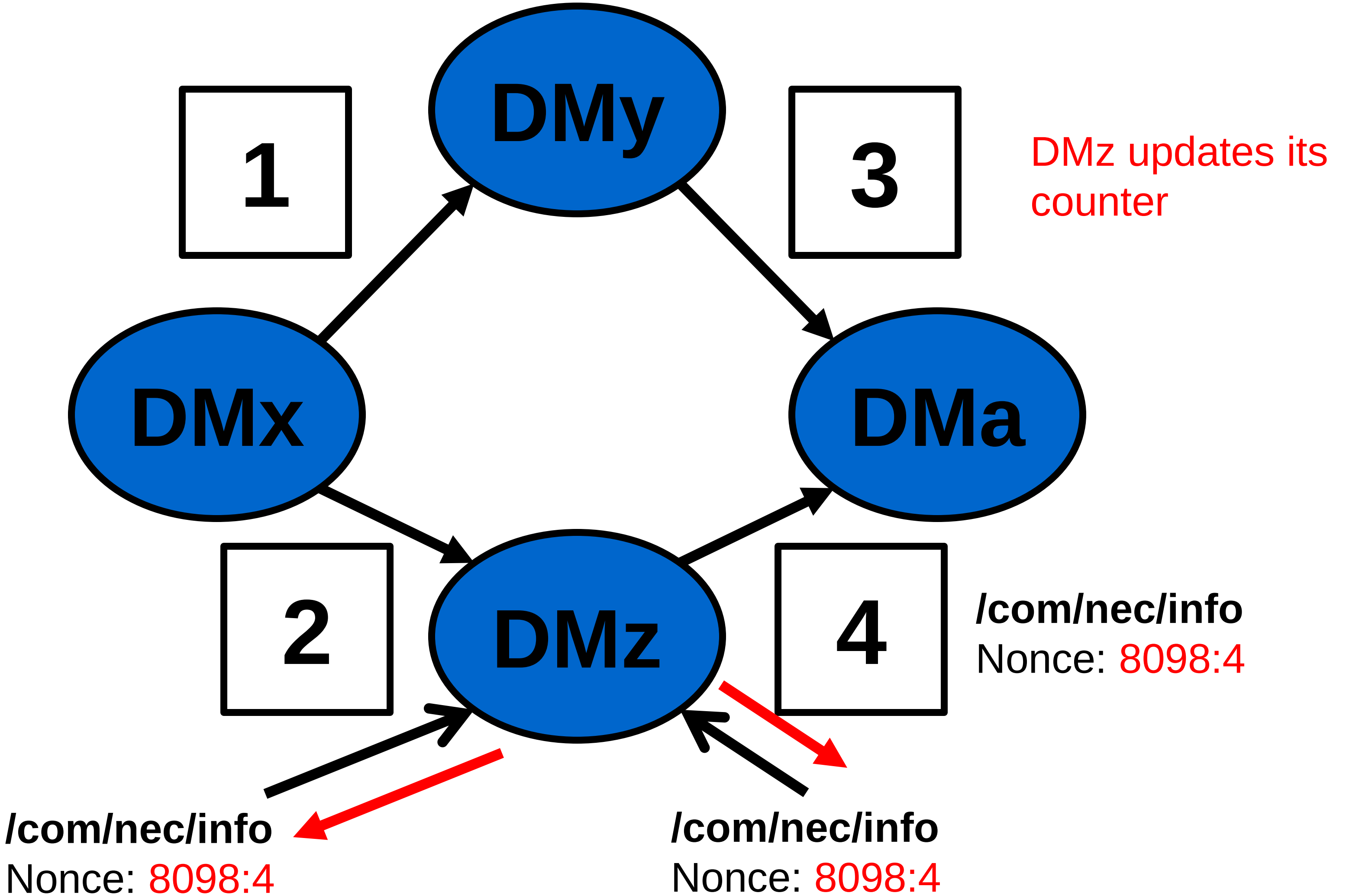
Sample Exchange 4

Two new user requests with same prefix from DMz

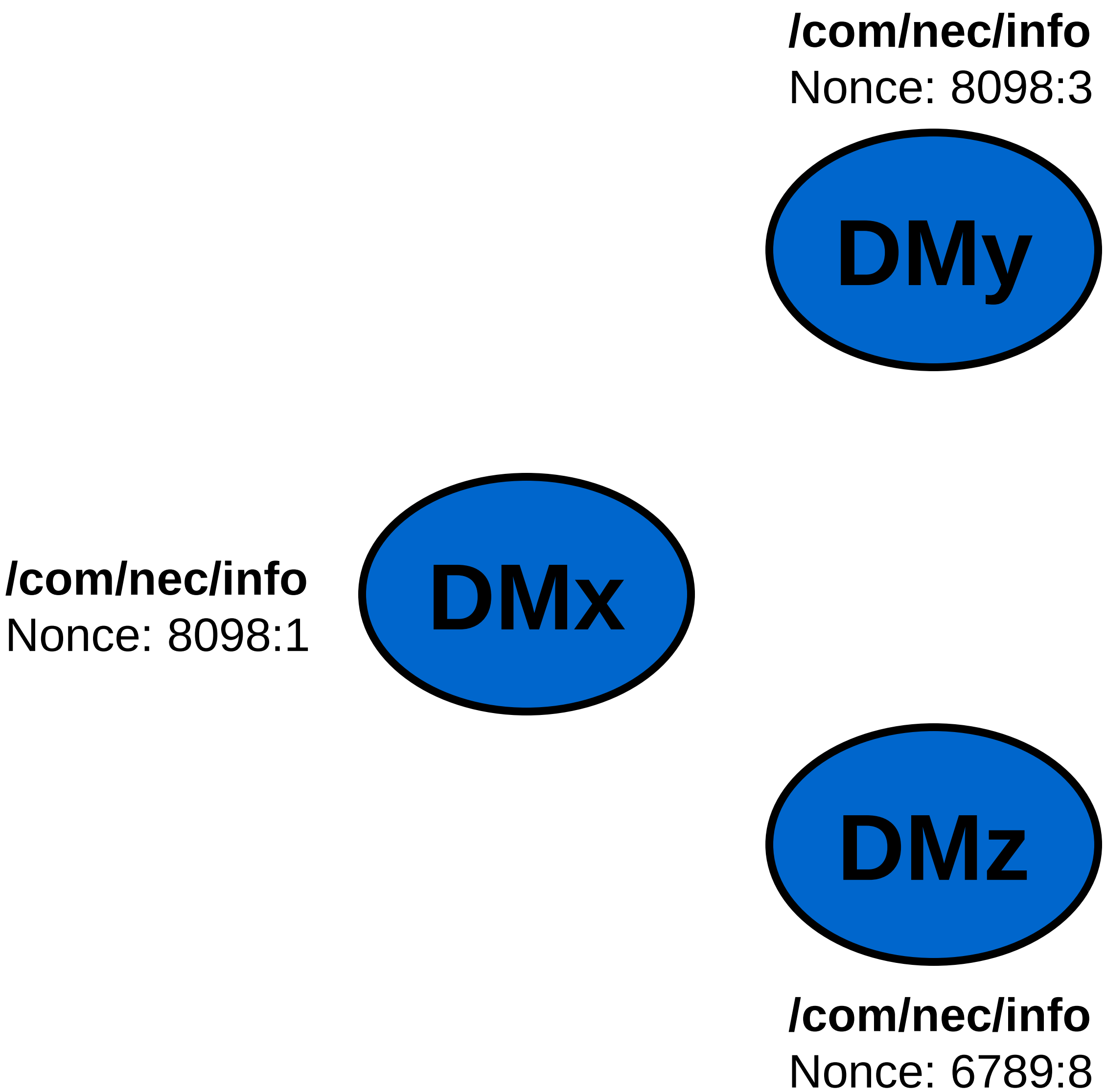


Sample Exchange 5

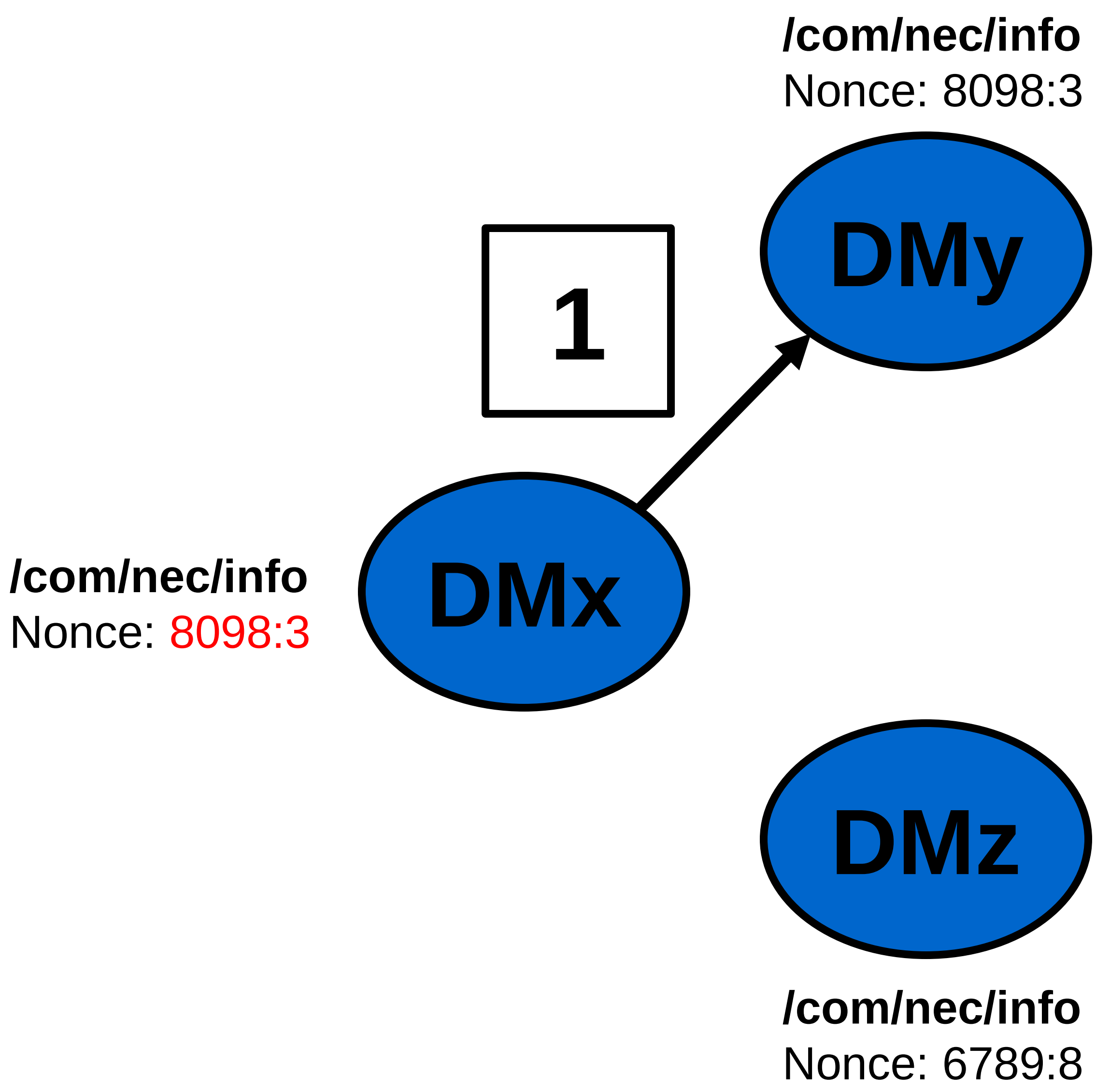
DMz updates its count and sends new once to the end user



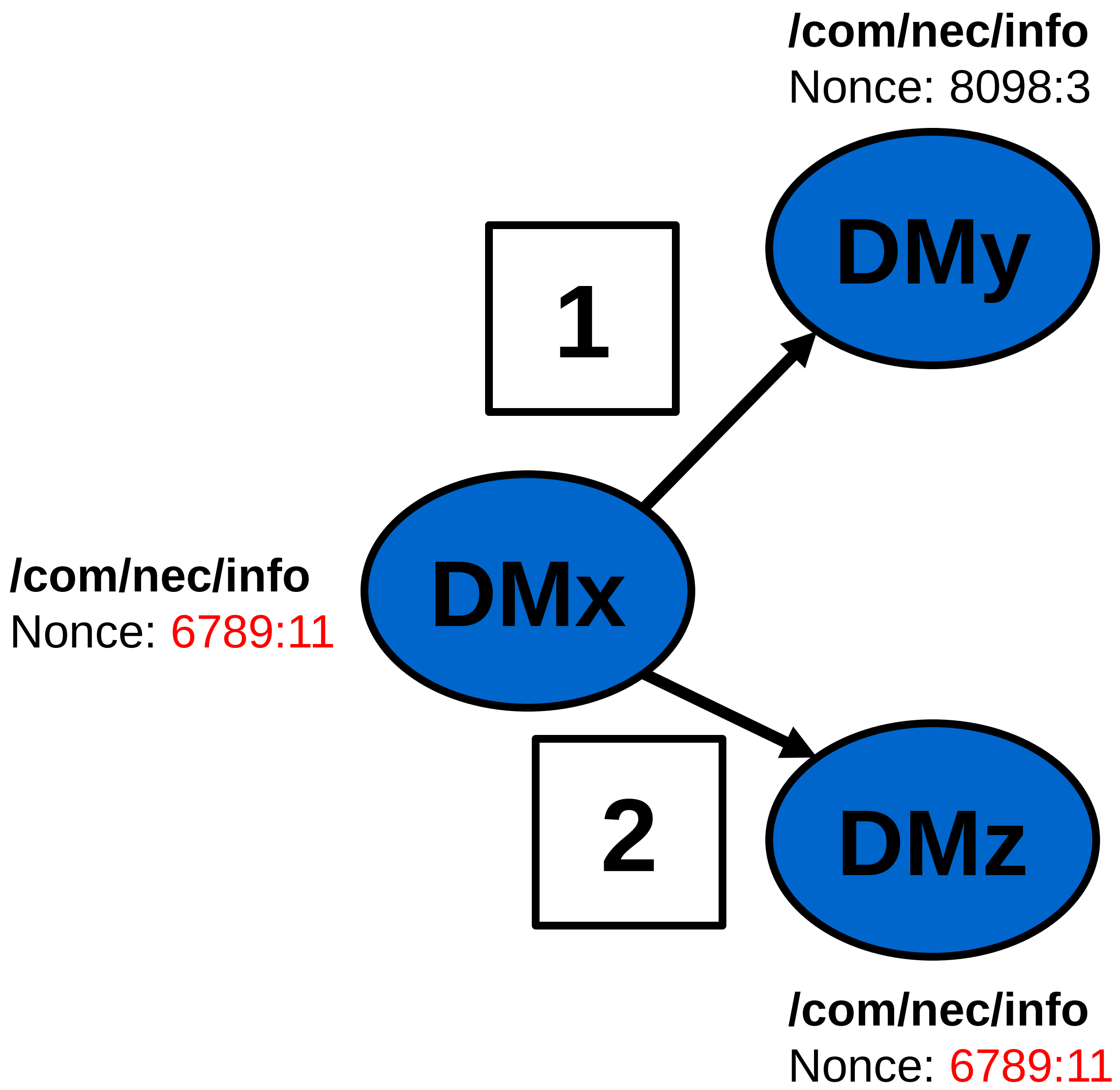
Loop Problem



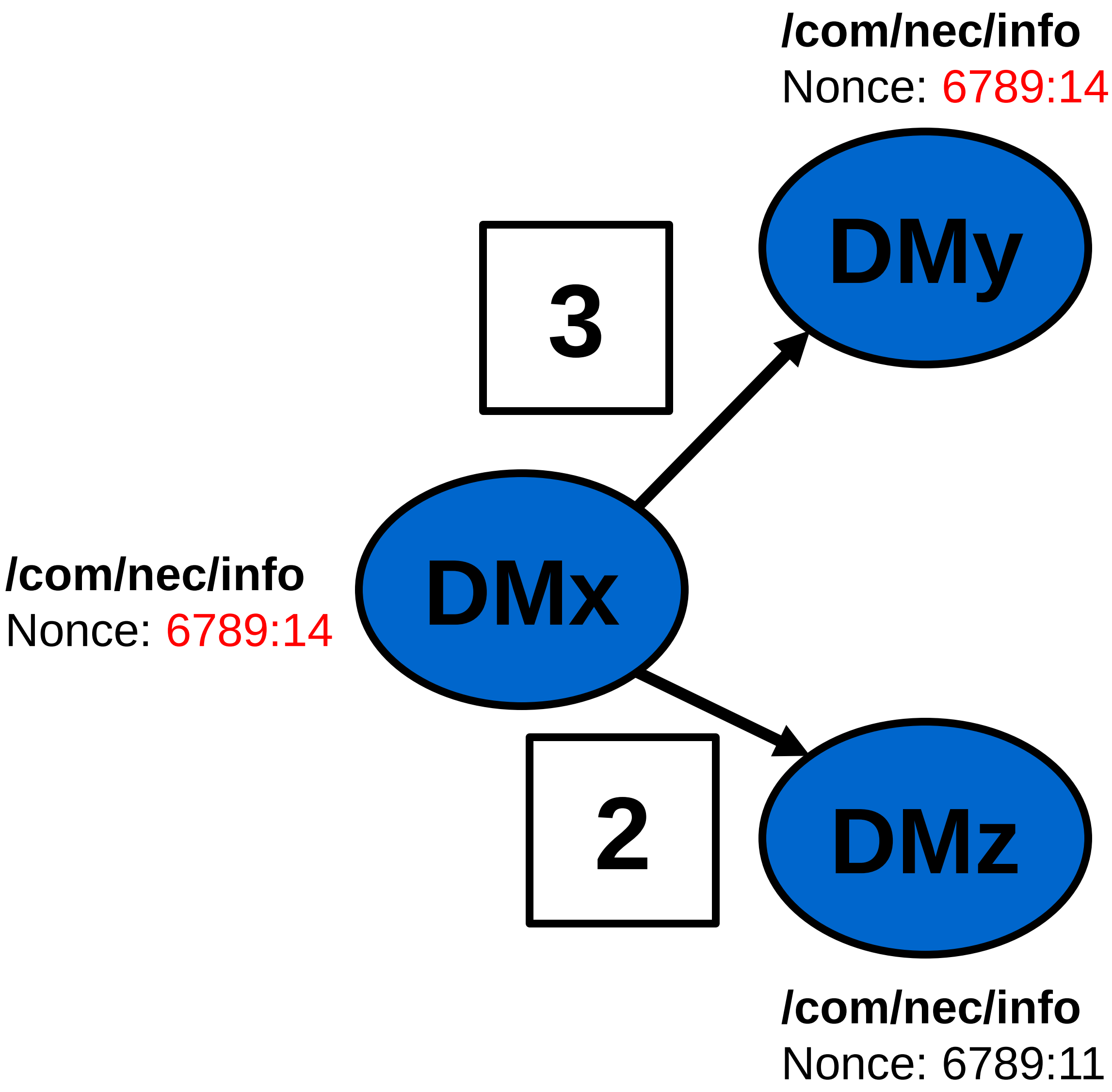
Loop Problem



Loop Problem



Loop Problem



Over-estimating Popularity!

Loop Prevention

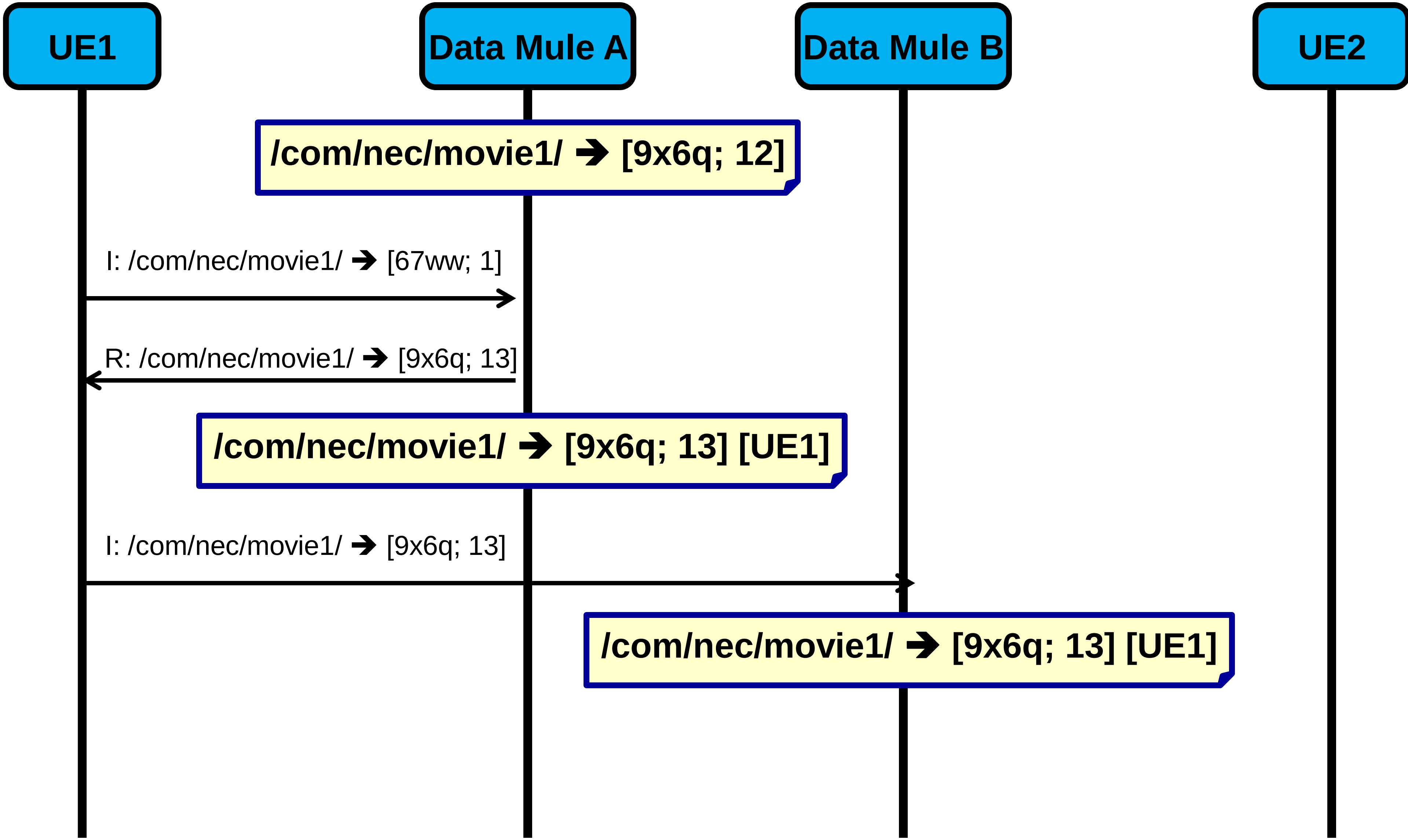
- Data mules keep list of recently encountered mules per Interest

- If a data mule is encountered shortly after the first encounter, counters are not added

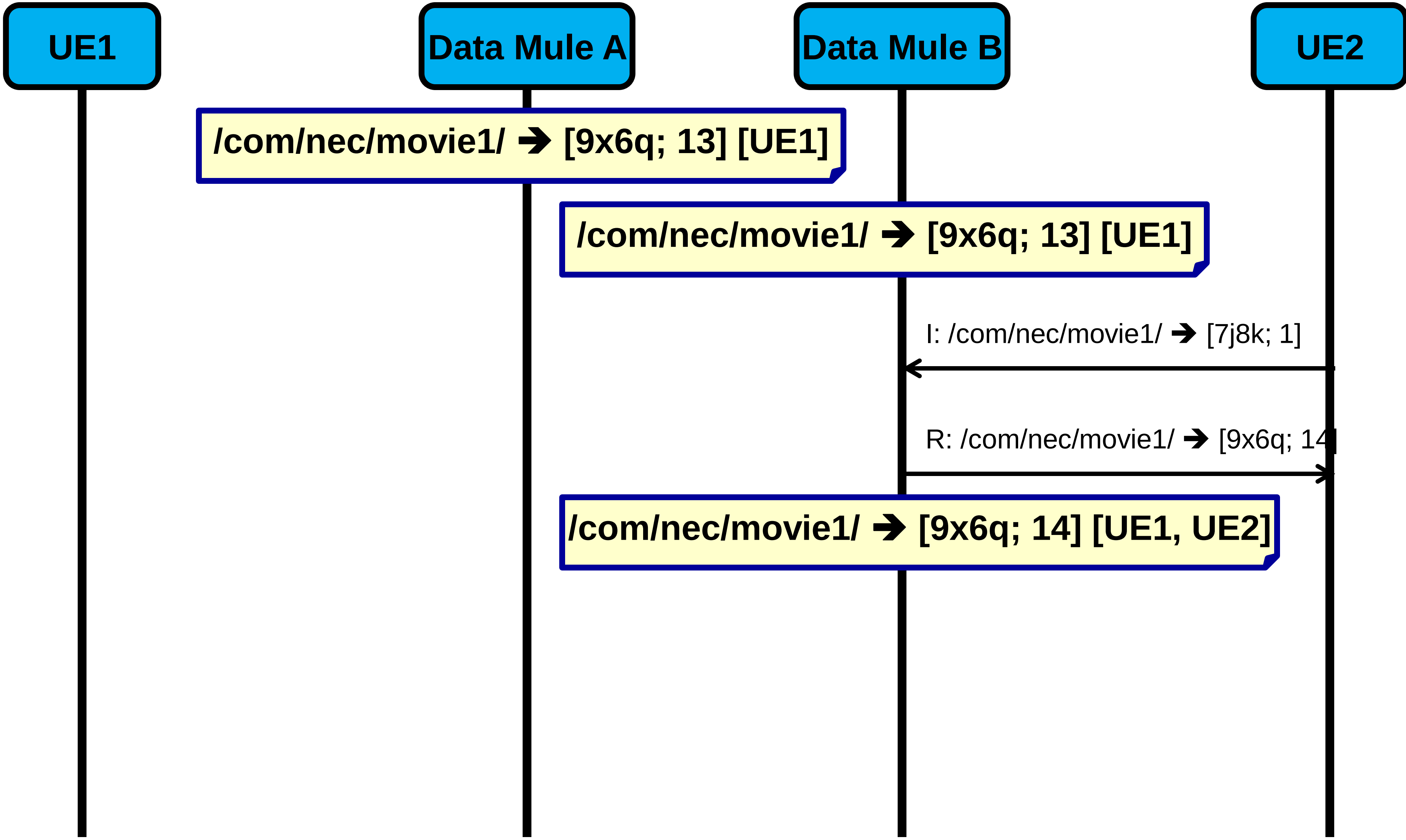
- Instead, max-counter rules is applied at both sides
  - **`nonce1 != nonce2 (AND recently met)`**
    - **`New_nonce = nonce with largest counter([nonce1, count1], [nonce2, count2])`**
    - **`New_count = MAX(count1, count2)`**

- Sliding approach: FIFO list of encountered nodes has limited (configurable) size
  - Can trade off acuracy against memory conservation

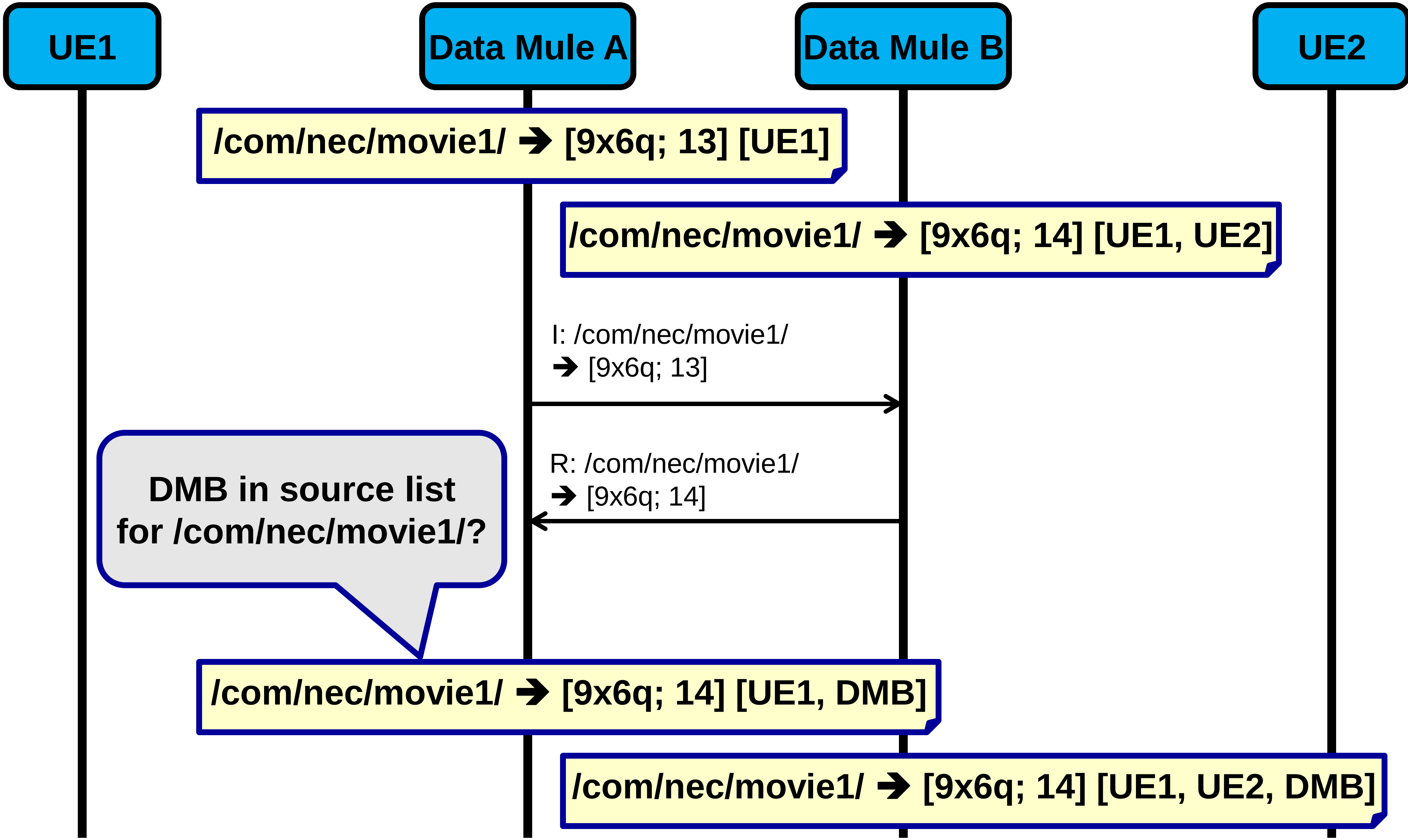
Exchange Scheme (1)



Exchange Scheme (2)



Exchange Scheme (3)



Implementation

- Interests are retransmitted whenever two nodes meet
- Application on top of CCN creates FIB entries for all the interests (names) we want to send to the next node
- The life time of an interest packet is set to infinite
  - Objective: don‘t expire interest
  - PITs can become large...
- Current exchange protocol implemented in TCP (not in CCNx protocol)
- Popularity count for all the prefixes in the PIT
  - Colon separates nonce and count

```
/com/nec/info          8098:4
```

Name/Popularity-Based Prioritization

- Contact time between two data mules could be short
  - Data prioritization scheme needed to optimize exchanges
  - Here: **Leverage popularity estimation for prioritization**

- ***Name-Based Prioritization*** **protocol (NBP)**

1. Node contact: nodes exchange meta data about cached objects
   - List of names, assessed popularity

2. Requesting node generates Interest packets, ordered by „priority“

- Different categorization schemes possible
  - GreenICN: prioritizing by name / prefix (disaster scenario)

Evaluation

- Objective: evaluate accuracy of distributed popularity estimation

- Two Fragmented Communities

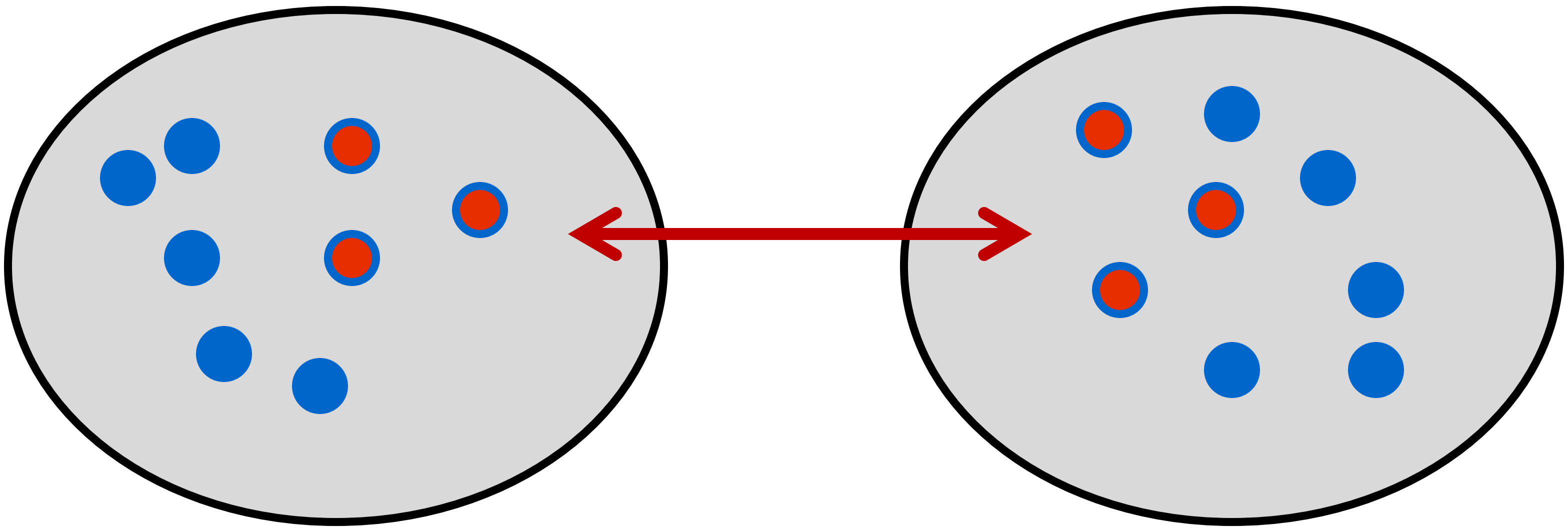
- 100 distinct data objects
  - Queried from three different DMs in each of the fragmented communities

- Data mules meet each other in a random manner and exchange interests

- Zipf distribution for Interests with 0.8 < alpha <0.9

Scenario Diagram

- **3 Nodes per FG which fetch interests from 600 end users**
- **Different sets of names (popular content) in FGs**



Fragmented Community 1 Fragmented Community 2

Measurement Setup

Areas with data mules

- Emulation: Mules meet randomly, no disruption during intermeeting times

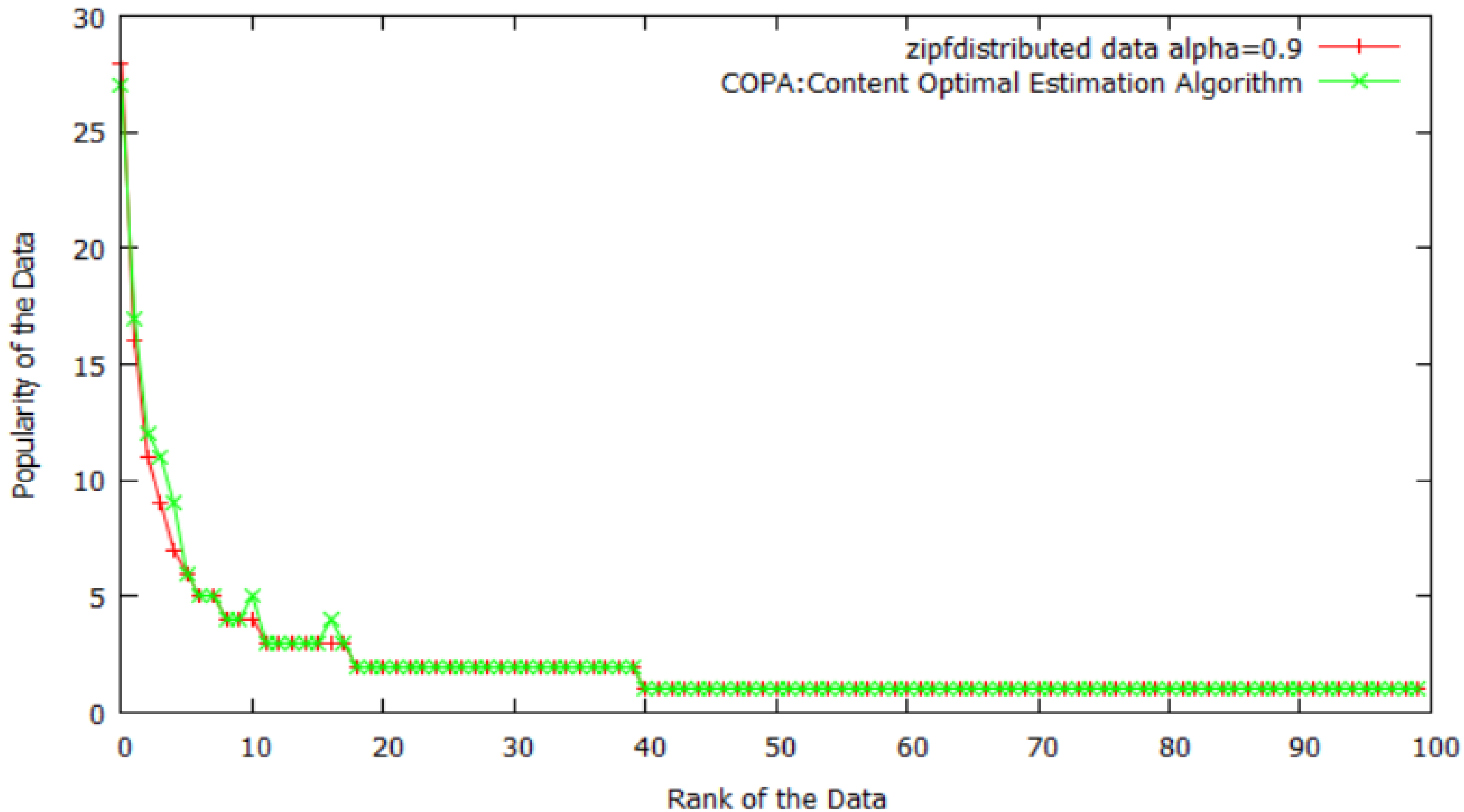
Details of the test setup

- 6 nodes, 2 Fragmented Communities with different set of names
- Three nodes in their respective FG fetch interest from end users
- Meet DM at random times
- 15 contacts between different DM at different times
- Object size: 8 KB
- Approx. 500 Interests issued by users

Test specs

- 10 runs for each of the normalized results
- Each runs takes several minutes

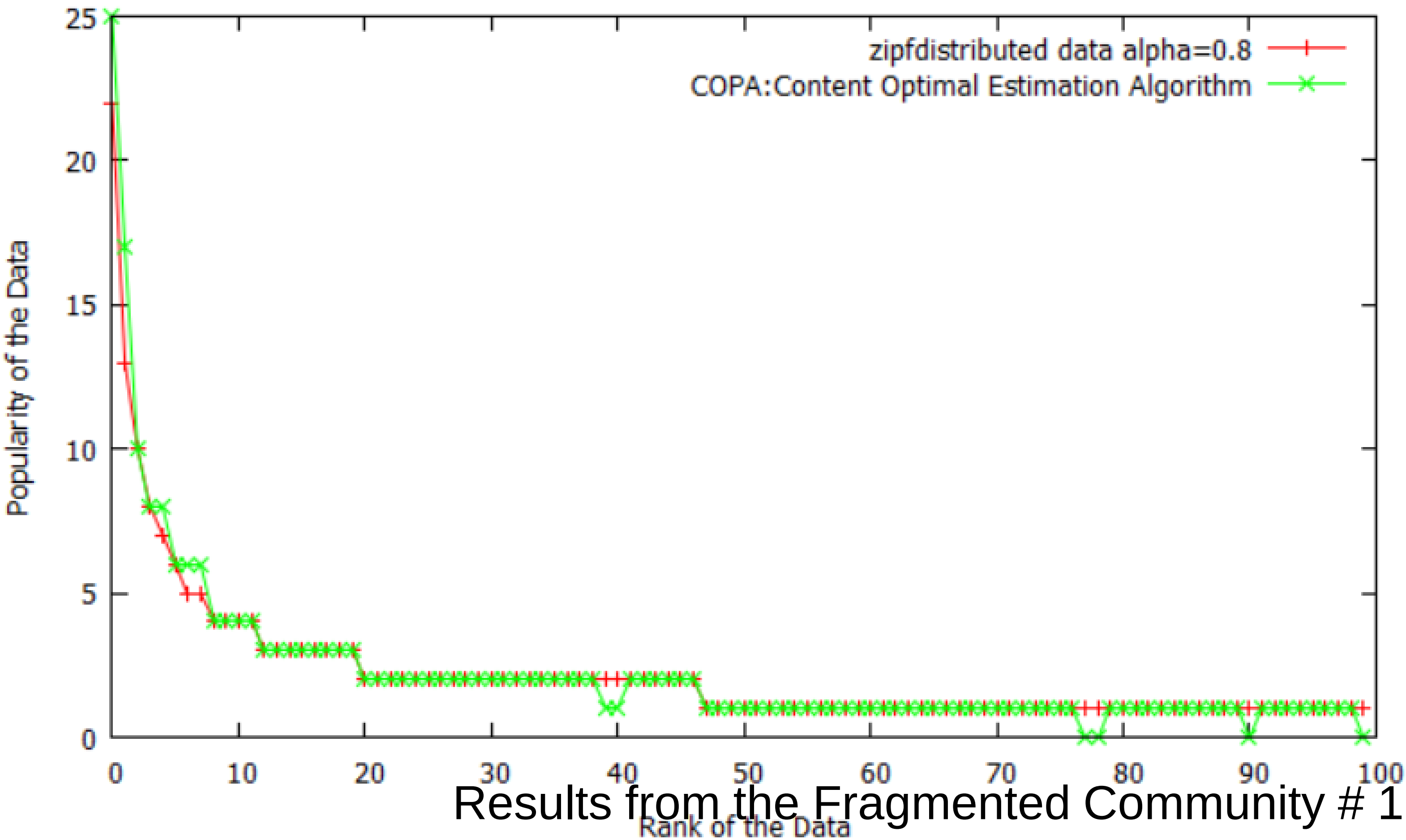
Evaluation (15 Contacts)



Results from the Fragmented Community # 1

Zipf, alpha=0.9
15 contacts

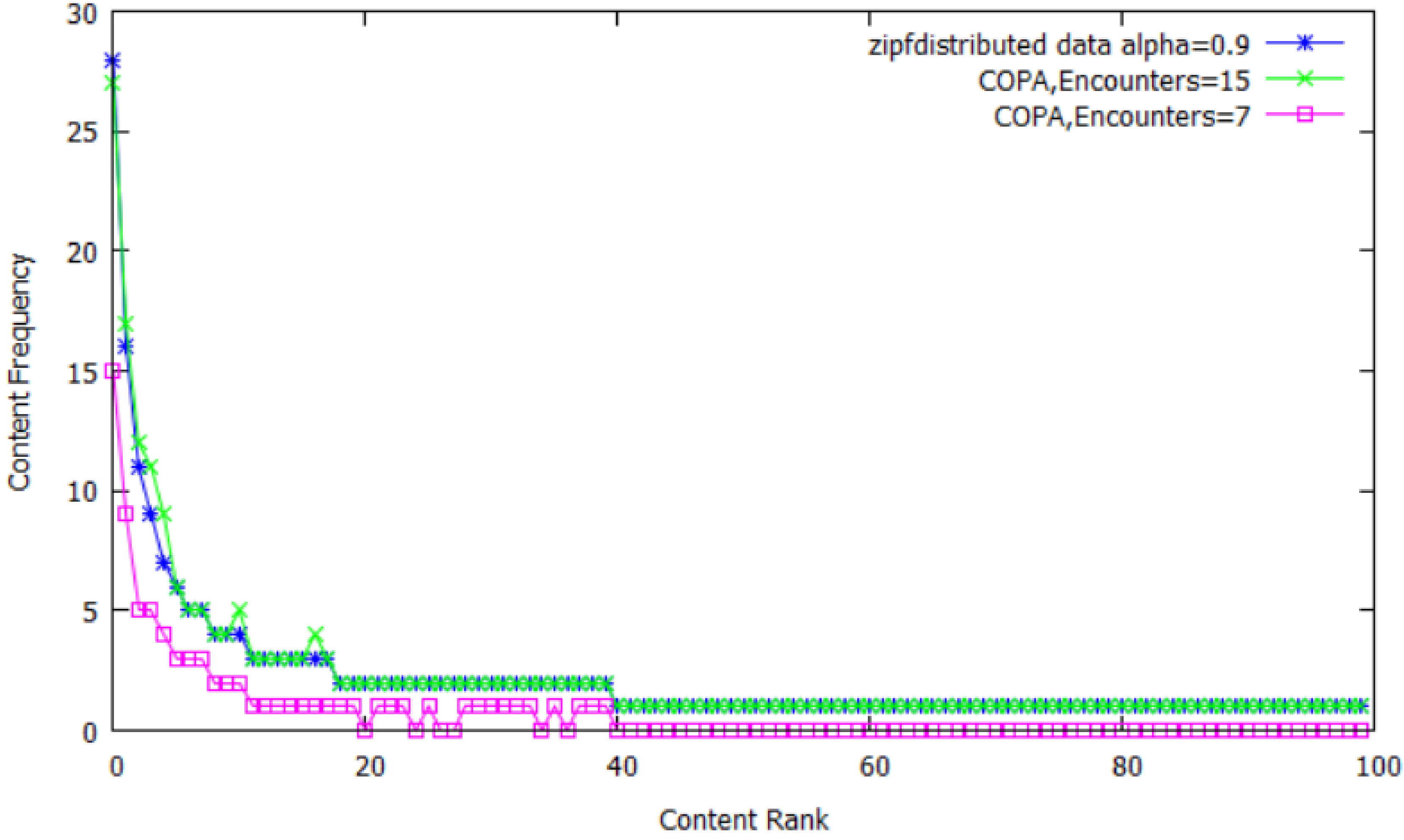
Zipf-Alpha=0.8



Results from the Fragmented Community # 1

Zipf, alpha=0.8
15 contacts

Better Estimation with more Contacts



Zipf, alpha=0.9
7 and 15 contacts

Observations

- More contacts: better accuracy
  - 15 contacts lead to quite good results
  - But: consistent underestimation (for all objects) – so may not be a real problem

- There can be more than one nonce per object name in the network
  - Can lead to slight overestimation

- PITs can become large

- Our approach significantly more memory-efficient than naive approach (thanks to aggregation)

Summary

- **Popularity estimation in ICN** for optimizing performance and availability (here: DTN scenario)
- **Leveraging ICN naming and storage features** – changing CCN semantics (store-carry-forward of interests for long time)
- **Simple scheme – intuitively scalable**
- First evaluations suggest **sufficient accuracy**
- Next Steps
  - Polish implementation, documentation, more experiments
  - Mobile GW implementation

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