Low-Latency Media over NDN

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Section Outline

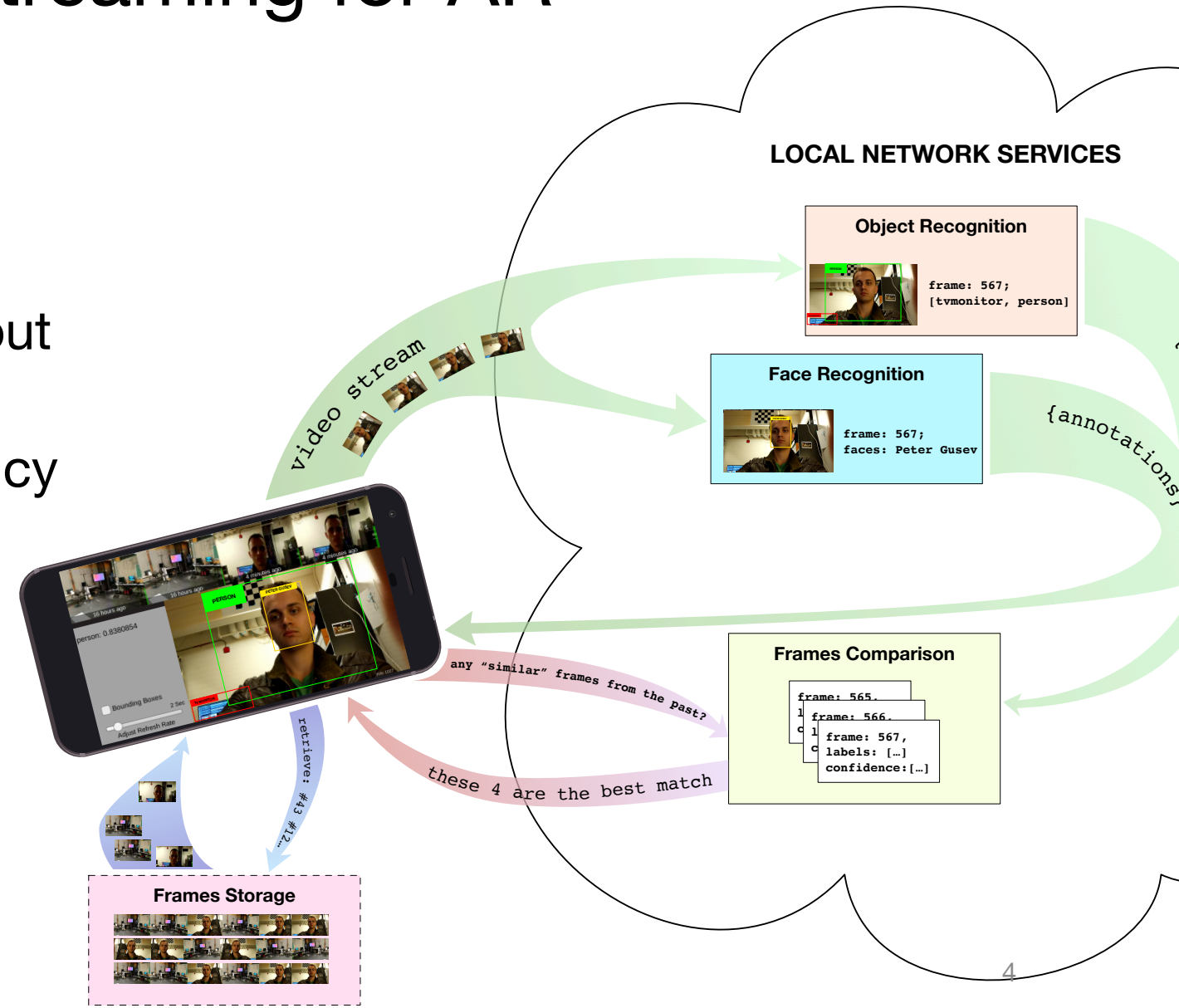
- NDN Real-Time Communication library (NDN-RTC):
  - architecture & hands-on session
- “Low-latency media”-friendly forwarding strategies
- Congestion control
- Real-time Data Retrieval (RDR) protocol

NDN-RTC

Low-Latency Media Streaming for AR

AR Browser “under the hood”:

- NDN communication throughout
- **NDN-RTC** library for low-latency media delivery
- C++ library & tools:
  - **github.com/remap/ndnrtc**



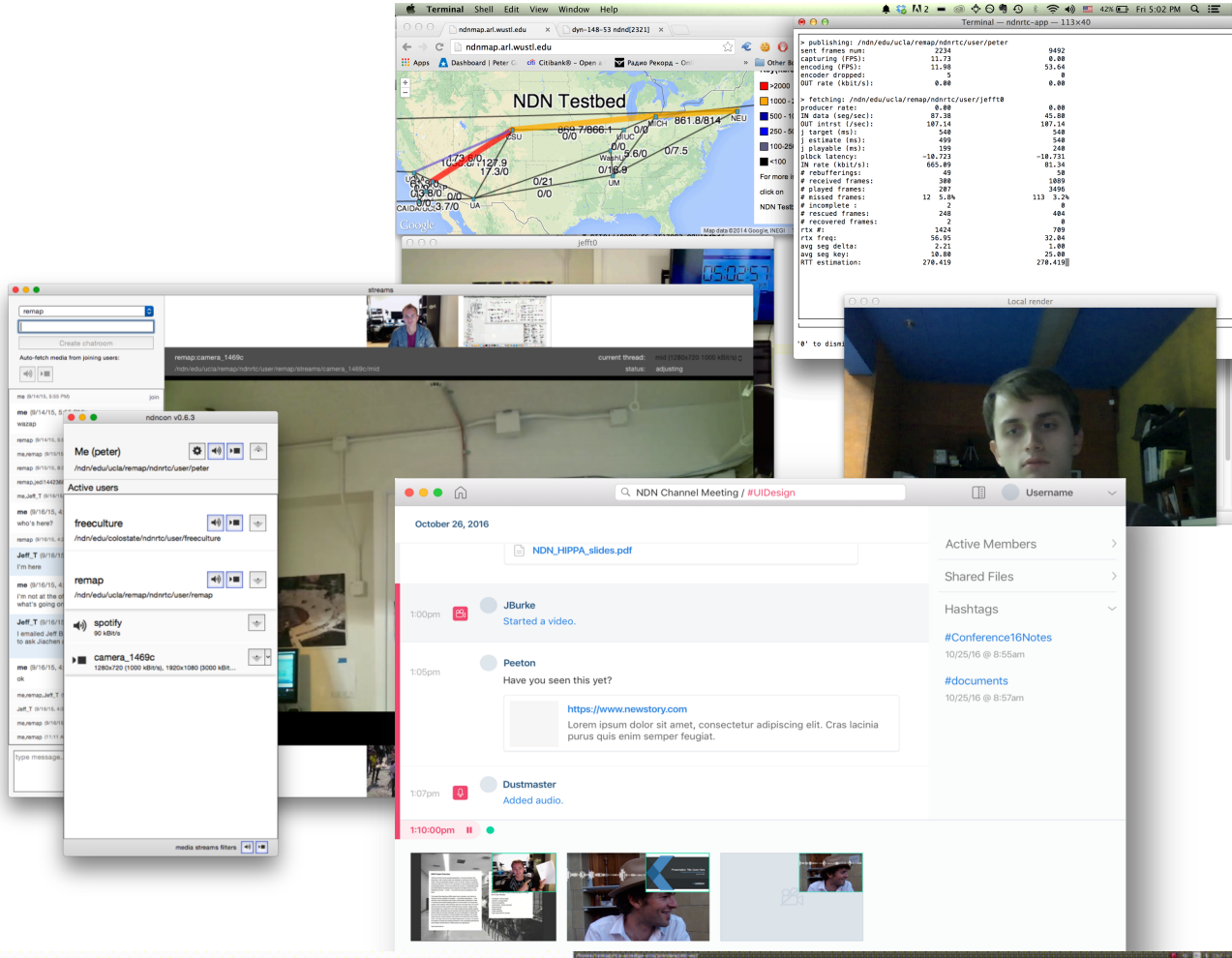
Hands-on with NDN-RTC

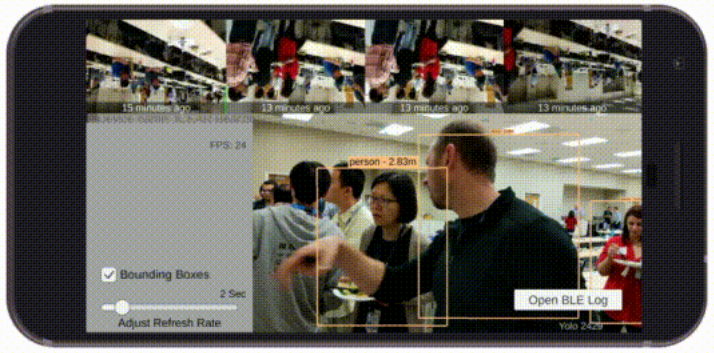
- Prerequisites:
  - macOS >= 10.12
  - NDN platform
  - Homebrew
- Install:
  - `brew update`
  - `brew tap` **`remap/ndnrtc`**
  - `brew install` **`ndnrtc ndnrtc-stream`**
- Run:
  - `ndnsec-keygen /hello-ndn | ndnsec-install-cert -`
  - `ndnrtc-stream publish /hello-ndn`
  - `ndnrtc-stream fetch /hello-ndn/rtc-stream`

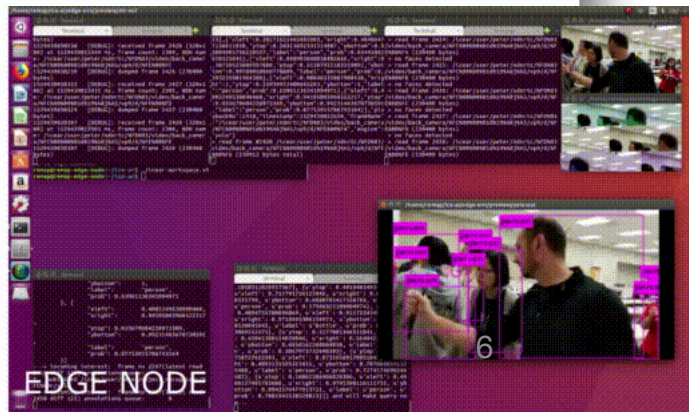
NDN-RTC C++ Library

Low-latency audio/video streaming over NDN

- First prototype in fall 2013
- Peer-to-peer approach, host-independent
- HD-capable video streaming
- Multiple bitrate streaming
- Audio streaming (echo cancellation)
- NDN-RTC-based NDN apps
  - 2013 - **ndnrtc-demo,** command-line
  - 2014 - **ndncon,** desktop conferencing app
  - 2015 - **ndnrtc-client,** headless client
  - 2017 - **Docker** containers
  - 2017 - **Flume** (prototype)
  - 2018 - **AR Browser**





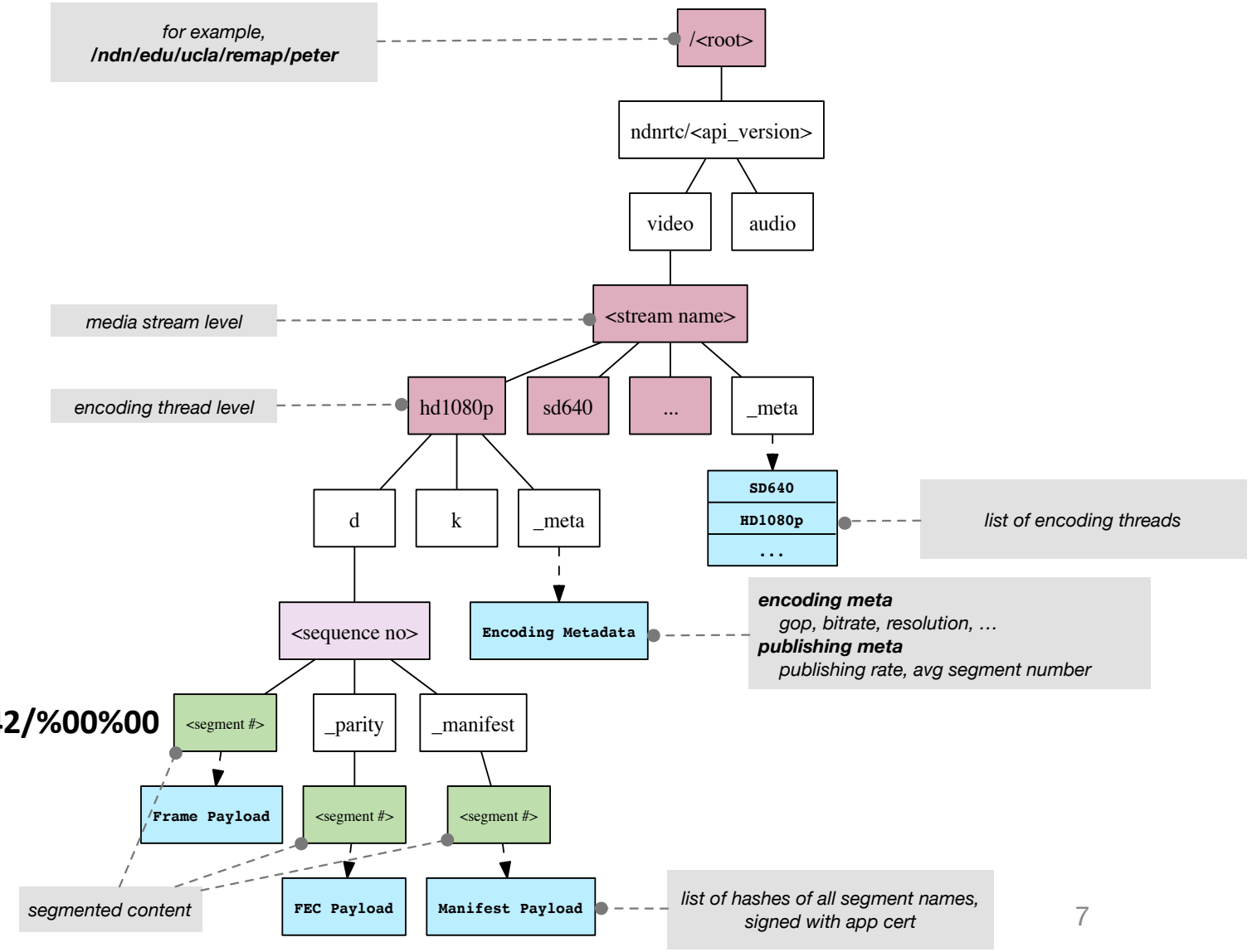


Library Namespace

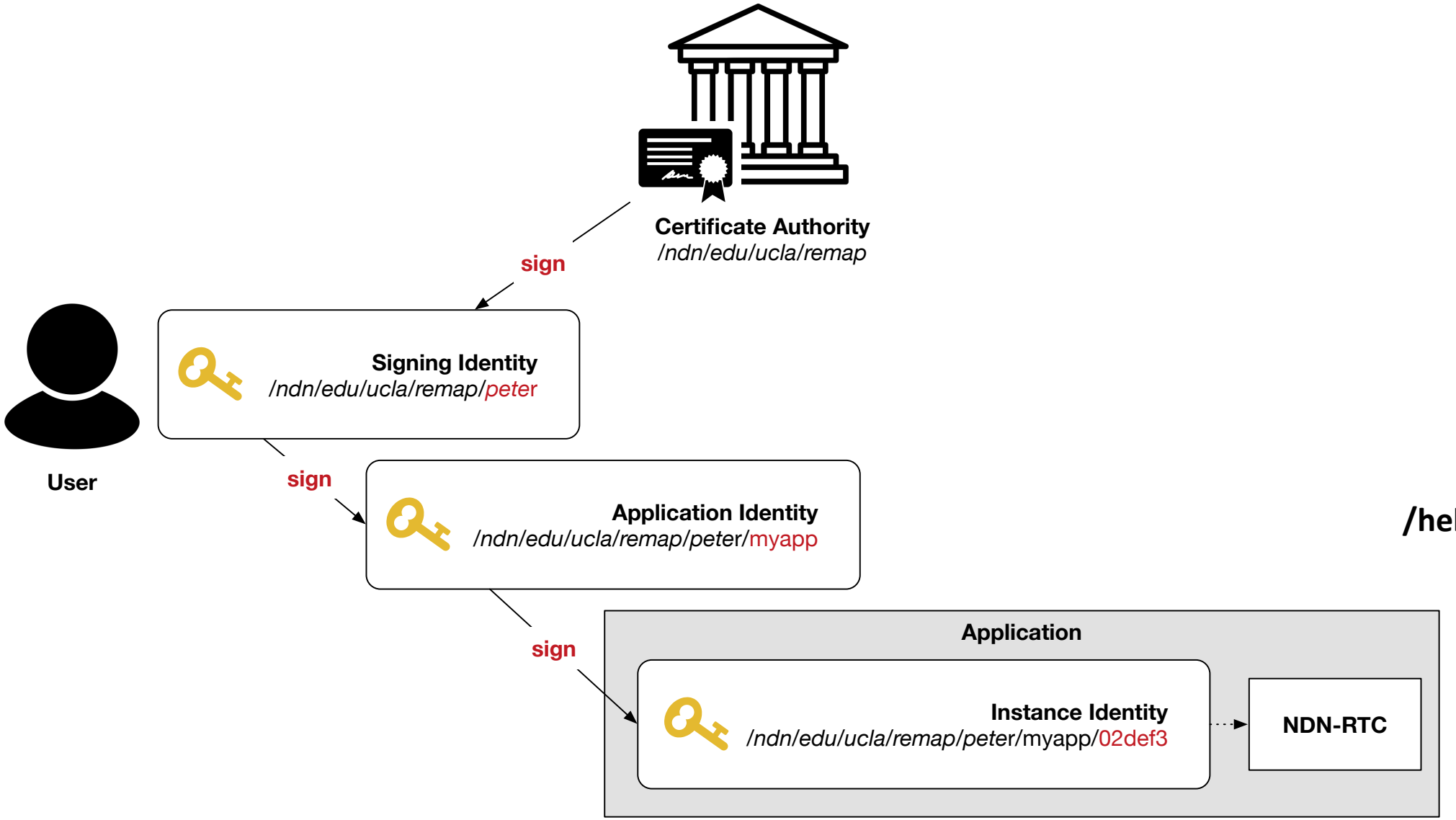
/hello-ndn/rtc-stream

/hello-ndn/rtc-stream/ndnrtc/3/video/camera

/hello-ndn/rtc-stream/ndnrtc/3/video/camera/720p/d/342/%00%00


for example,
/ndn/edu/ucla/remap/peter
/<root>
ndnrtc/<api_version>
video
audio
media stream level
<stream name>
encoding thread level
hd1080p
sd640
...
_meta
d
k
_meta
SD640
HD1080p
...
list of encoding threads
<sequence no>
Encoding Metadata
encoding meta
gop, bitrate, resolution, …
publishing meta
publishing rate, avg segment number
<segment #>
_parity
_manifest
Frame Payload
<segment #>
<segment #>
segmented content
FEC Payload
Manifest Payload
list of hashes of all segment names,
signed with app cert

Schematized Trust

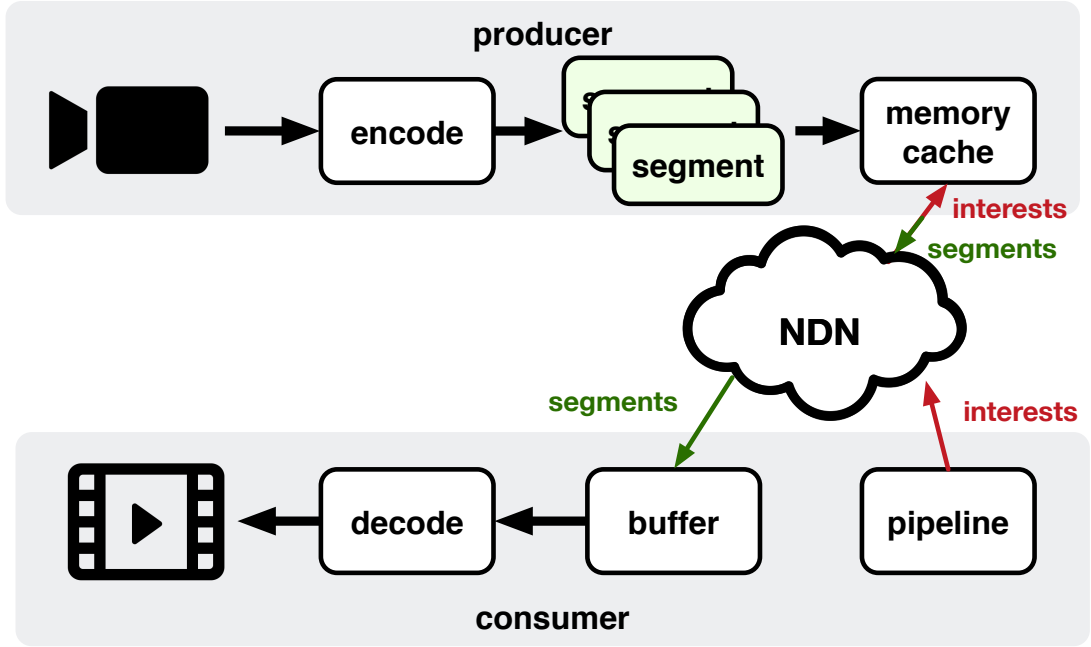


/hello-ndn

/hello-ndn/rtc-stream

Library Architecture

- Producer
  - slices encoded frame into segments
  - stores segments to the memory cache
- Consumer
  - ensures low-latency delivery using Interest pipeline
  - re-assembles segments into frames
  - queues frames in the buffer
  - decodes & plays back frames

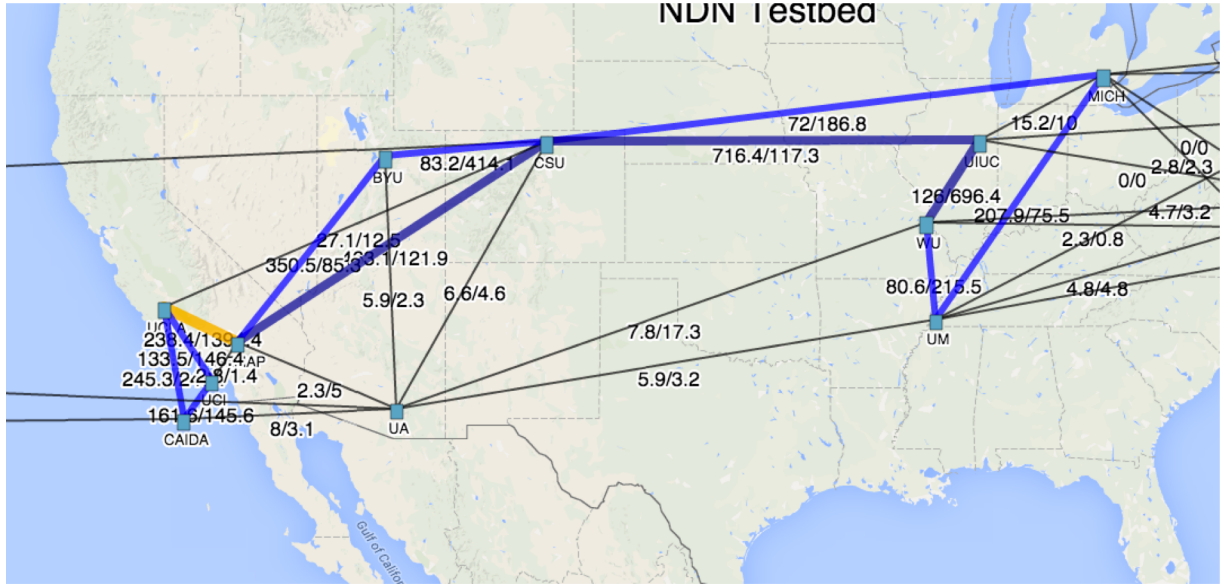


Peter Gusev, and Jeff Burke, “NDN-RTC: Real-Time Videoconferencing over Named Data Networking”, in Proceedings of the 2nd ACM Conference on Information-Centric Networking, September 2015

Link: http://conferences.sigcomm.org/acm-icn/2015/proceedings/p117-gusev.pdf

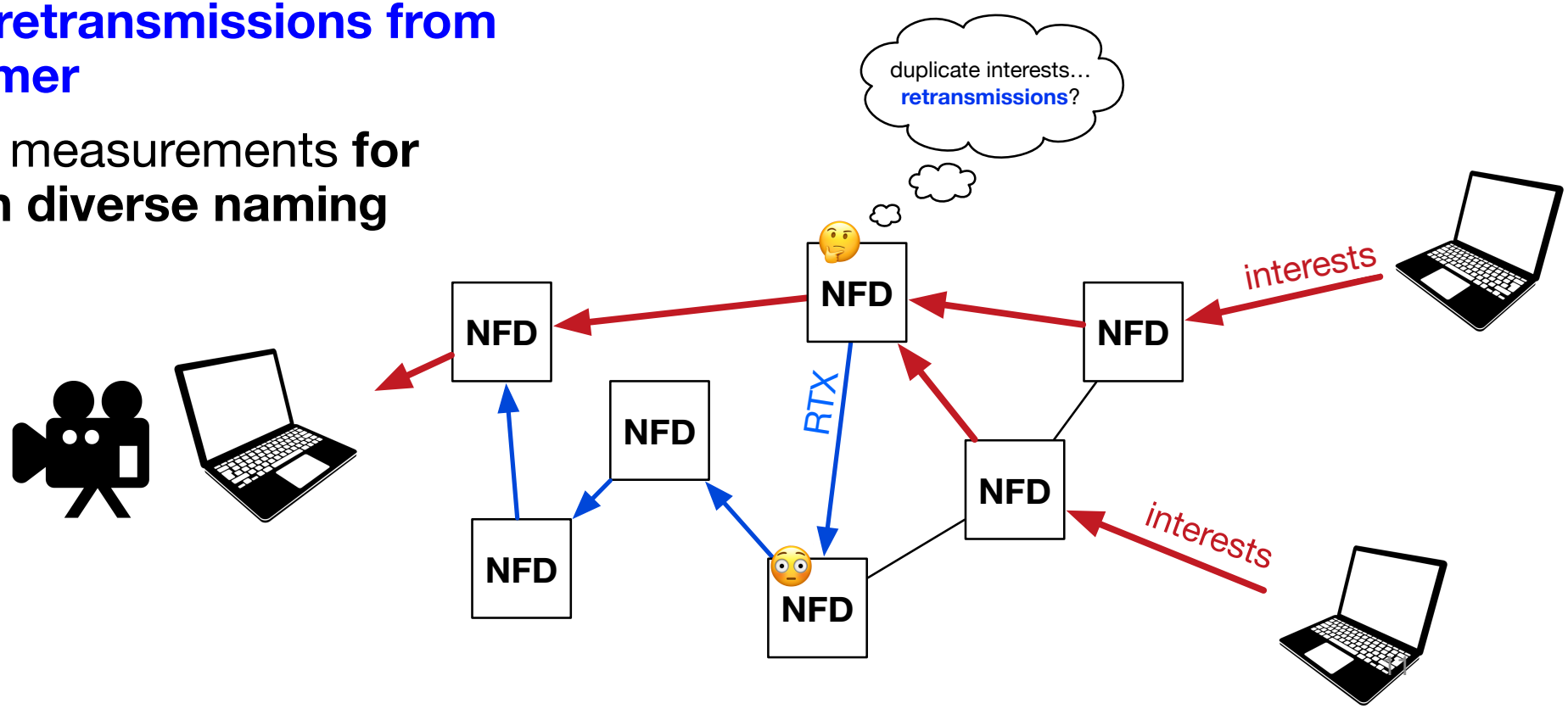
NDN-RTC Development. Experience and Goals

- Continuous development & improvements since 2013
- Multi-peer testing over the testbed
- Test out NDN with real apps
- Drive network architecture and NDN app development
- Build essentials: streaming over NDN
- Learning:
  - how to build NDN apps
  - how to design network
  - how to deal with congestions
  - how to retrieve latest data in the presence of caches



Challenges for forwarding strategy

- *"A forwarding strategy decides how to forward an Interest."**
- **How to distinguish multiple consumers** with **retransmissions from the same consumer**
- Forwarding plane measurements **for applications with diverse naming schemes**



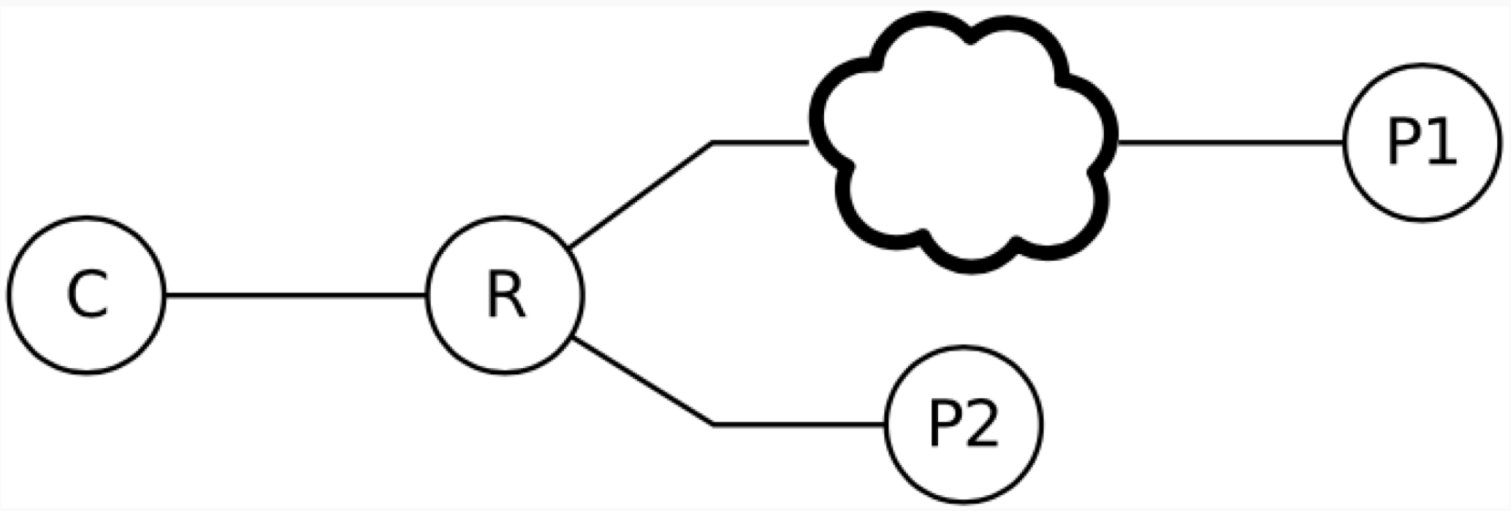
* NFD Developer's Guide

Lessons learned

- *Best route strategy*
  - Interest with same Name+Selectors coming from the same face → retransmission*
  - Interest with same Name+Selectors coming from a different face → another consumer is requesting the same Data, should be suppressed for the first time*
- Strategy measurements of forwarding plane performance:
  - Work with diverse application namespaces (not only “/prefix/segment-number”)

*Redmine issues
https://redmine.named-data.net/issues/3230
https://redmine.named-data.net/issues/3219
https://redmine.named-data.net/issues/3485

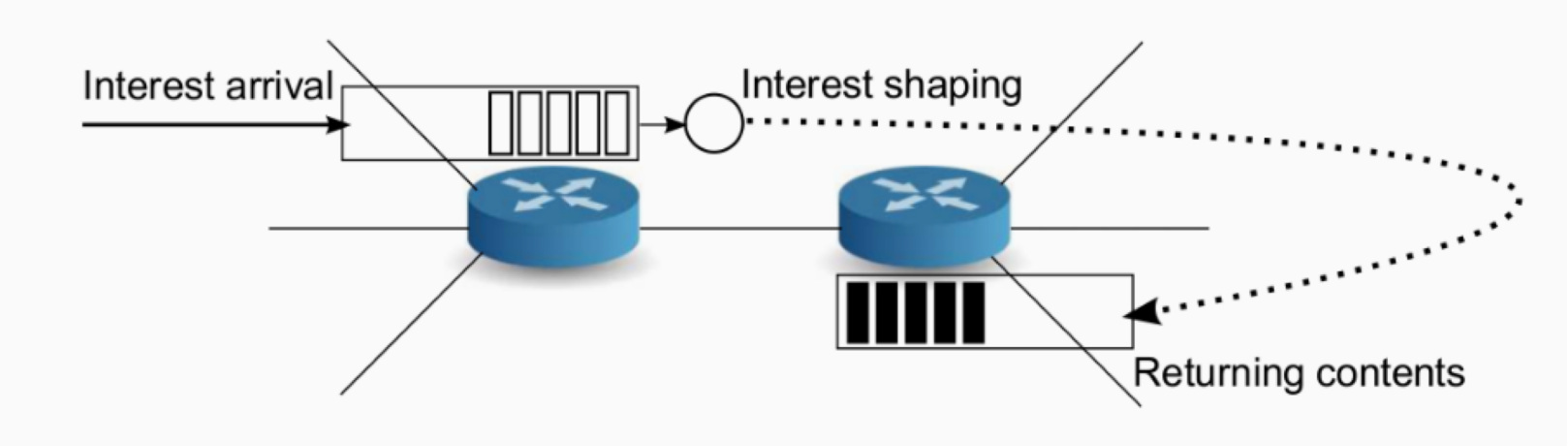
Congestion control for NDN



- Traditional congestion control does not work for NDN
- Congestion control in NDN is challenging:
  - pull-based approach
  - multiple paths and endpoints
  - diverse deployment scenarios (wired, IP tunnels, wireless, etc.)
  - hard to determine “per-content fairness“ with interest aggregation

Hop-by-Hop congestion control (PCON*)

- Design principles:
  - detect congestion at the bottleneck
  - signal congestion towards consumer
  - remove strong assumptions:
    - unknown link capacity & Data chunk size
    - no route-labels or data location predictions



Real-time Data Retrieval (RDR) protocol

Retrieval of Latest Real-time Data

- How to fetch the latest generated real-time data in a network with caching
- Segment numbers instead of application-level timestamps
- Need to know the exact data names to pipeline Interests to fetch multiple data segments
- Need to know the exact name of data that has not been produced yet

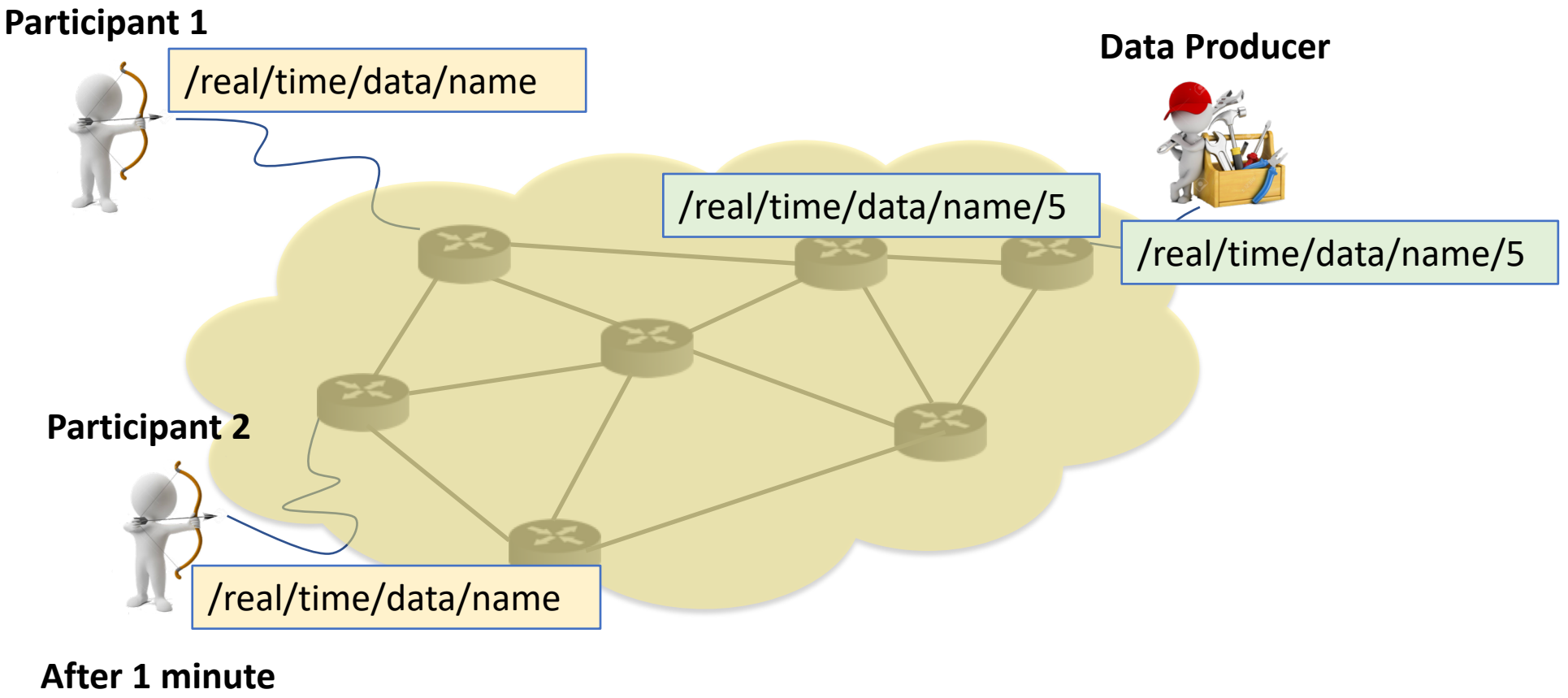
/real/time/data/name/0

/real/time/data/name/1

…

/real/time/data/name/N

Why bother?



Retrieved Data generated a minute ago!

Retrieve Latest Data by Making Use of Protocol Features

- Producers generate ***metadata*** for real-time sessions:
  - Determines for how long metadata stays fresh at each-hop CS (FreshnessPeriod)
  - Name of the latest data
  - (Optionally piggybacking) The latest generated segment

- Consumers fetch ***fresh metadata*** (MustBeFresh)
  - Bypass “non-fresh” cached metadata
  - Learn the exact name of the latest generated data (before ½ RTT)
  - Determine exact name of data to be produced in the future through naming conventions

Metadata for NDN-RTC Streaming

Name: /NDNcall/ndnrtc/user/Spyros/_metadata

MustBeFresh

CanBePrefix

Name: /NDNcall/ndnrtc/user/Spyros/_metadata/_v=10

Meta Info **FreshnessPeriod:** 10ms

Content

Latest Delta Frame Name:
/NDNcall/ndnrtc/user/Spyros/…/frames/delta/92

Latest Key Frame (First Segment)

Name: /NDNcall/ndnrtc/user/Spyros/…/frames/key/3/data/0

...

Signature

Can pipeline interests to fetch delta frame 93, 94, …

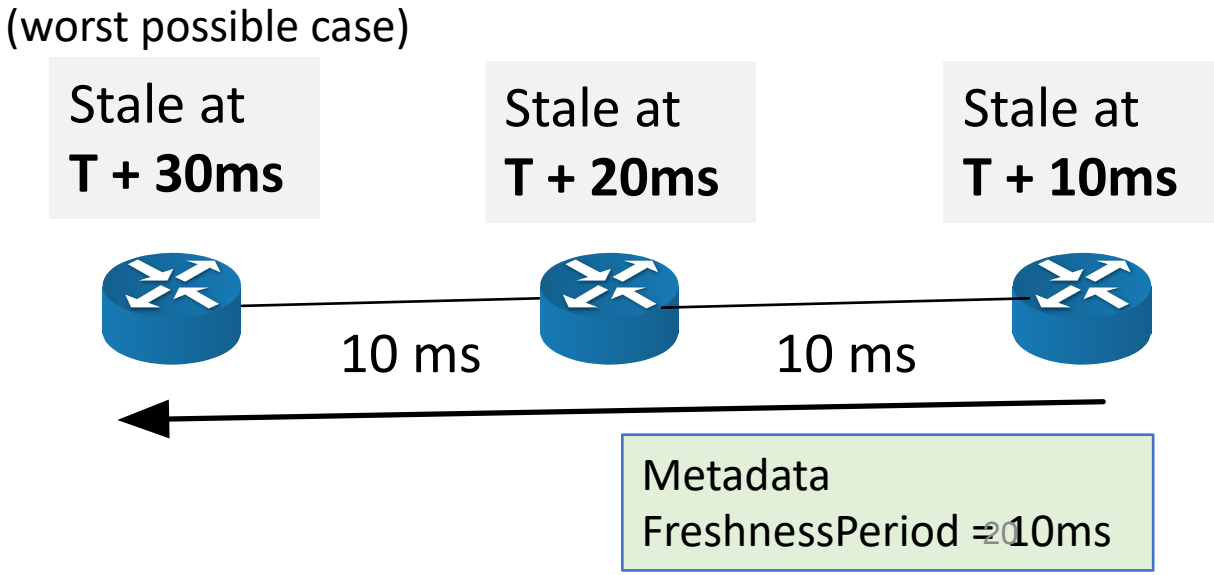
Can pipeline interests to fetch key frame 4, 5, …

FreshnessPeriod Considerations

- FreshnessPeriod is a per-hop relative metric

- Metadata *may* stay fresh for a longer (absolute) time further away from the producer (due to processing and propagation delays)

- FreshnessPeriod value:
  - ***Short enough***: Avoid stale metadata further away from the producer
  - ***Long enough***: protect producers from excessive requests



How to learn more

Spyridon Mastorakis, Peter Gusev, Alexander Afanasyev, and Lixia Zhang, "**Real-Time Data Retrieval in Named Data Networking**", in Proceedings of IEEE International Conference on Hot Information-Centric Networking (HotICN'2018), August 2018

Link: https://named-data.net/wp-content/uploads/2018/08/hoticn18realtime-retrieval.pdf

Peter Gusev, Jeff Burke, "**Ndn-rtc: Real-time videoconferencing over named data networking**", in Proceedings of the 2nd ACM Conference on Information-Centric Networking, September 2015

Link: *https://named-data.net/wp-content/uploads/2015/11/NDN-RTC_Real_Time_Videoconferencing.pdf*