ICE-AR Applications Research Update
Towards Evaluation/Comparison with TCP/IP

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Talk Outline

1. Recap of this year's application work
   via discussion of how to evaluate NDN v. TCP/IP for AR+MR

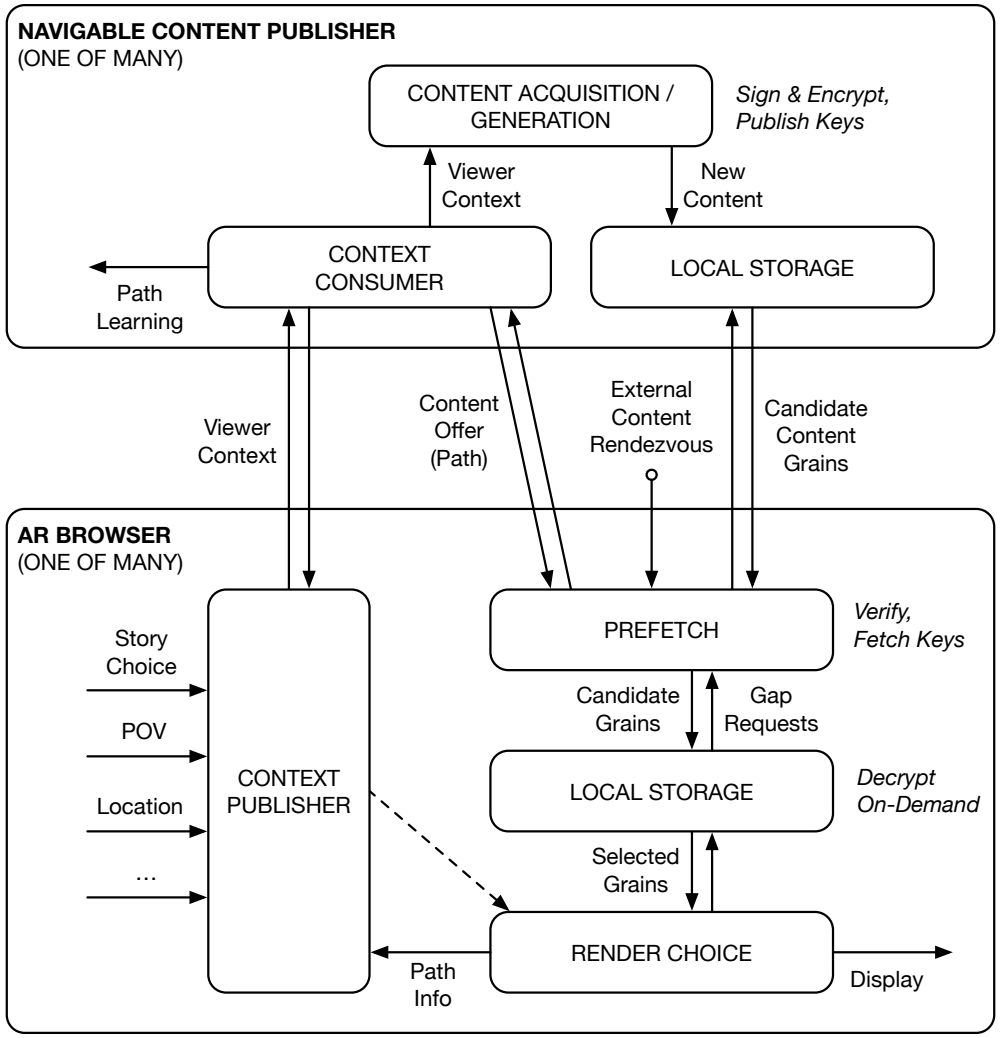
2. Plans for next year

Not in this talk:

- How app requirements drive other research – covered by others.
- Deep dives into app concepts – covered in previous talks + papers.
- Sorrows regarding implementation complexity of full-stack apps.

Recall - AR as a Web of Decentralized Content

- Vision of a (decentralized) data web integrated with physical world, supported by edge-fog-cloud components.
- UI Metaphor: “Lens” instead of “Tab”
- AppKernel instead of “Page”
- Multi-party context-content exchange w/many entry (rendezvous) points into content navigation – brand, location, etc.
- Video is both *context* and *content.*
- *What is the TCP/IP point of comparison?*



Integrations

	AR demo app (17-18)	AR workshop w/IP (July)	MR workshop w/NDN (Dec)	Project objective
Type	Tech demo	Experience demo	Experience creation	Technology + Demonstration
Audience	Intel mtg	35 crew, 85 audience	16 crew and guests	TBD
Platforms	Unity	Unity, Touchdesigner	Touchdesigner	Chromium or Unity, Touchdesigner
Context (Raw)	Camera, ARCore odometry	Camera, ARCore odometry, Game state	Camera, Show state, User feedback	Camera, odometry, state, user input
Context (Deep)	Scene contents	N/A	Scene contents	Scene semantics
Content	3D Game assets	3D Game assets / effects	Matching scenes (video recall)	TBD
L2	No	No	Yes	Yes
Wireless	Yes	Yes	Dev/orchestration only	Yes
Multicast	L3 NDN only	No	Yes, L2 broadcast + L3 NDN	Yes

	First Prototype (17-18)	AR workshop w/IP (July)	MR workshop w/NDN (Dec)	Project objective
RTC	Live only	N/A	Live and Historical; new bootstrap	Live and Historical
Naming	Rudimentary	N/A	More extensive	Generalized
App API / Library	CCL (Python), CNL	N/A	CNL (added C++), CCL	CNL, CCL
NDN for media	Yes	No	Yes	Yes
Reverse CDN	No	No	Yes	Yes
Storage	No	In-Game	NDN Fast Repo (rocksdb), sqlite	TBD
Edge	Face, Object, (Pose?)	Coordination only	ML: Face, Object x 2; Scene segmentation; Playback detection	ML: Face, Object, Pose + Coordination and recall
Cloud	No	Limited (AR Core Cloud Anchor)	Video post-processing (not integrated)	Integrated on-demand post-processing
Provisioning	Static	Static	Static	Dynamic
Security		N/A	Annotations manifest signing; Video capable but turned off for perf.	Trust management, Access control
Media granularity / addressability	Frame,	Asset (3D)	Frame	Video region, 3D asset

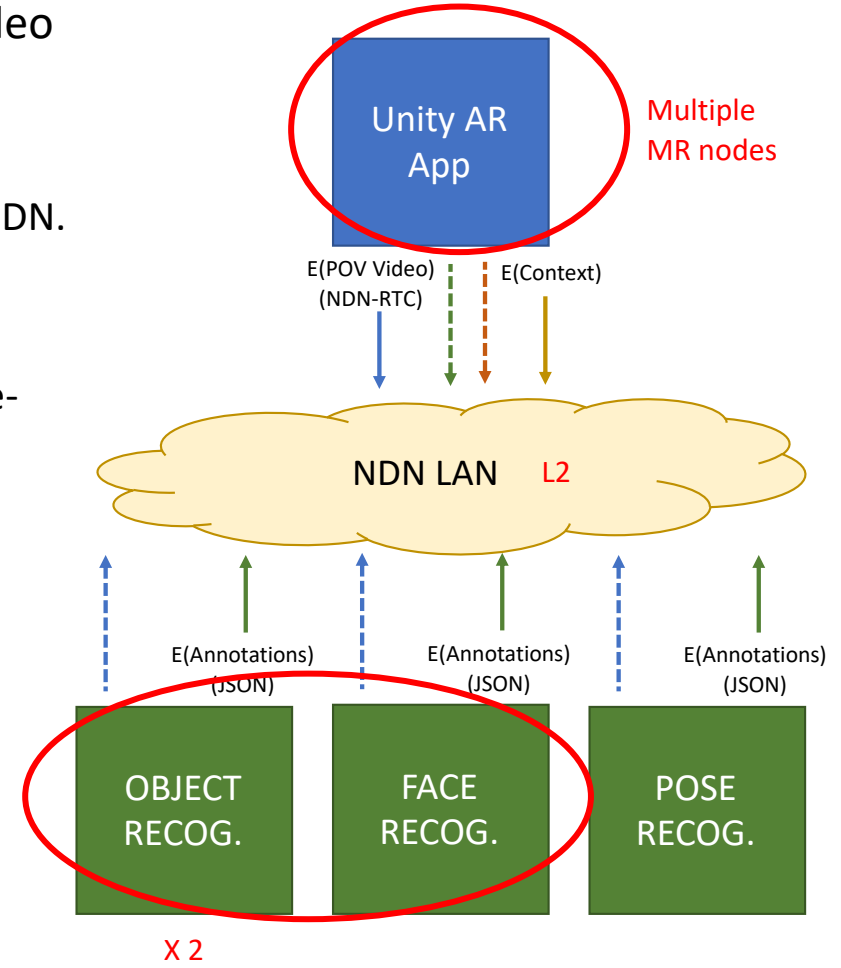
AR Case Study w/IP (July ‘18)

- Objective: Learn what’s involved in developing, deploying and running large-scale group AR experiences.
- What was built:
  - 45-minute immersive theatre demo using networked AR/VR world with 14+ simult. clients.
  - 85 audience members; ~30 team members. Daily builds used by team - iterative development with cloud build, over-the-air provisioning, etc.
- Networking takeaway
  - LAN v. Cloud divide in IP world adds significant complexity
  - Can’t just focus on *development*, have to consider *deployment*
  - Lack of effective multicast on IP is missed opportunity
  - Latency is critical for media components of AR
  - Multiplayer game networking framework (Photon Bolt) problematic
    - Assumes both local IP rendezvous and cloud dependency
    - Many-to-many comm. relies on local broker / behavior opaque
    - NDN would do well if deployment was straightforward
- https://vimeo.com/315600478 (6 minutes)

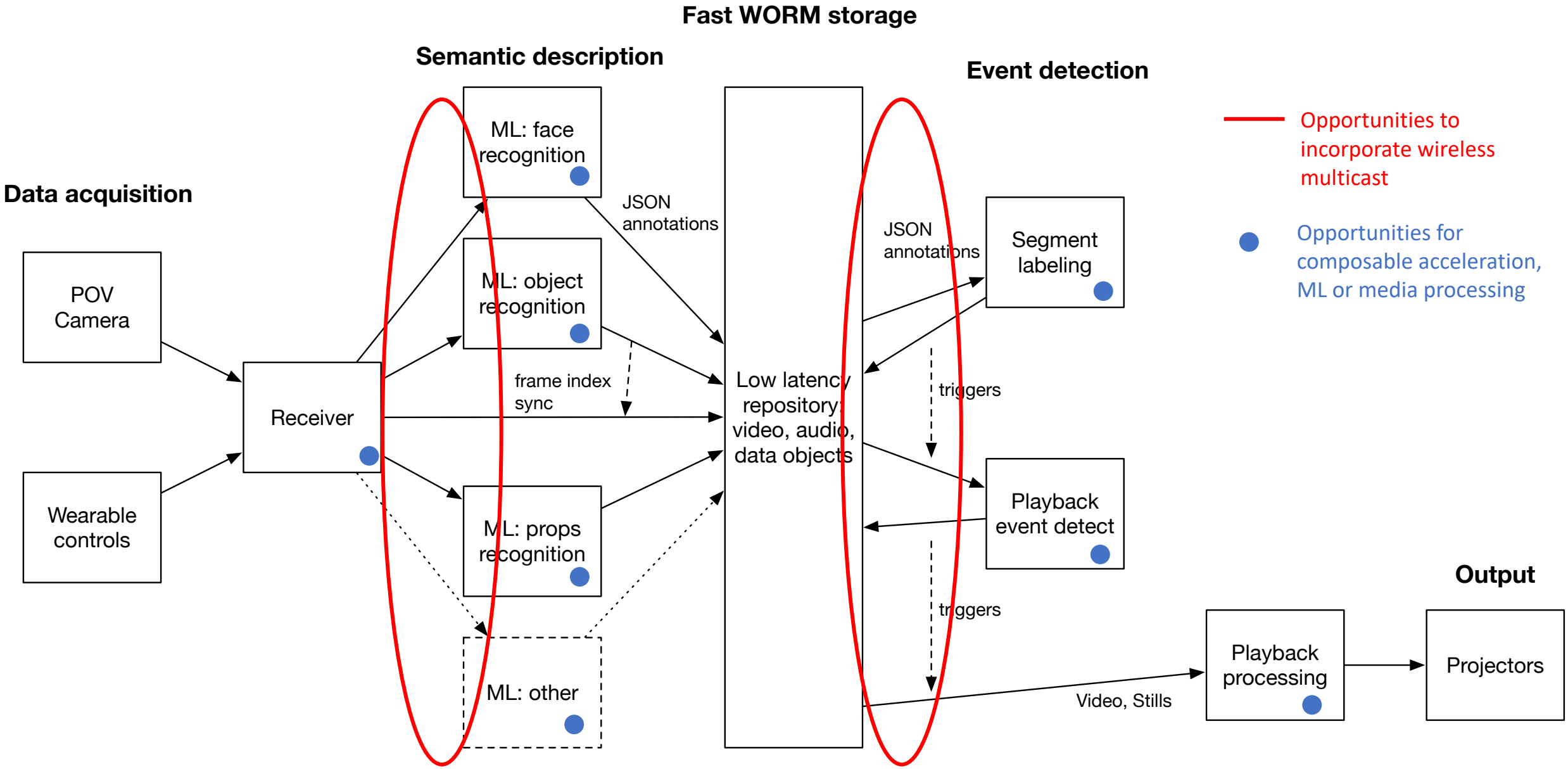
Primary support from the UCLA TFT Skoll Center for Social Impact Entertainment and UCLA REMAP.

Mixed Reality Case Study w/NDN (Dec ‘18)

- Objective: Run an edge-supported capture-process-publish loop over NDN on Layer 2 for a real-world project. Unify live and historical low-latency video approaches.
- What was built:
  - Multinode real-time MR projection system with edge processing all over NDN.
  - AR-inspired used case with wireless POV camera processed by ML.
  - Generalized message publishing support (MQTT-replacement).
  - Supporting video + object-exchange protocols; new repo code; namespace-focused library.
- P. Gusev, J. Thompson, J. Burke.
  Data-centric video for mixed reality. ICCCN 2019.
- https://vimeo.com/322266085/159056bafb (7 minutes)



Primary support from a Google Focused Award.


Fast WORM storage
Semantic description
Event detection
Data acquisition
Output
POV Camera
Wearable controls
Receiver
ML: face recognition
ML: object recognition
ML: props recognition
ML: other
JSON annotations
frame index sync
Low latency repository: video, audio, data objects
JSON annotations
Segment labeling
triggers
Playback event detect
triggers
Playback processing
Video, Stills
Projectors
Opportunities to incorporate wireless multicast
Opportunities for composable acceleration, ML or media processing

Comparison

(Towards a…)

How to evaluate? What's the value proposition?

Dimensions

- Expressiveness
- Simplicity
- Best practices
- Security
- Performance

Limitations

- Competing with heavily engineered stacks and diverse incumbent toolsets.
- Research software platform doesn't yet make important things easy (connectivity, security, debugging).
- Biggest wins seem to be around apps that are designed for new data-centric paradigms. Apples v. oranges?

Performance

Performance benefit sources

Many-to-many comm leveraging broadcast media => reduced traffic

- Practical multicast
- Group encrypted data (incl ABE)
- Opportunistic communication

Indirection only when needed => lower latency

- Forward using names directly; avoid lookup
- Mobility can leverage network state

Receiver-driven selectivity + interest aggregation + caching => both

- Consumers only ask for what they need
- Links only carry what's needed
- Towards links w/1 copy per N requests

What needs to be shown here beyond early papers?

Simplicity

(Closeness of mapping, progressive evaluation)

New APIs / Envs: **NDN Common Name Library**

- *What if we integrate namespace design into app design?*
  - Abstraction: In-memory tree of Namespace nodes with associated handlers
  - Each node represents a name, has a parent (immediate prefix) and children (+ 1 component)
- Full name = packet.
- Prefix ≈ app data object.
  - **/foo/someimage is a mutable object** with a “latest version”
  - **/foo/someimage/v42 is an immutable version**
  - **/foo/someimage/v42/<tile> is a spatial segment** the app may or may not care about
- Consistent producer/consumer state machine.
- Well-suited for name sync protocols.
- Implemented in C++ and Python.

New APIs / Envs: **NDN Common Name Library**

Generalized Object Consumer

```
face = Face()
objectPrefix = Namespace("/ndn/eb/run/28/description")
objectPrefix.setFace(face)

def onGeneralizedObject(contentMetaInfo, objectNamespace):
    print("Got generalized object, content-type " +
          contentMetaInfo.contentType + ": " +
          str(objectNamespace.obj))

GeneralizedObjectHandler(objectPrefix, onGeneralizedObject)
objectPrefix.objectNeeded()
```

LINK TO PRESENTATION ON THE CNL

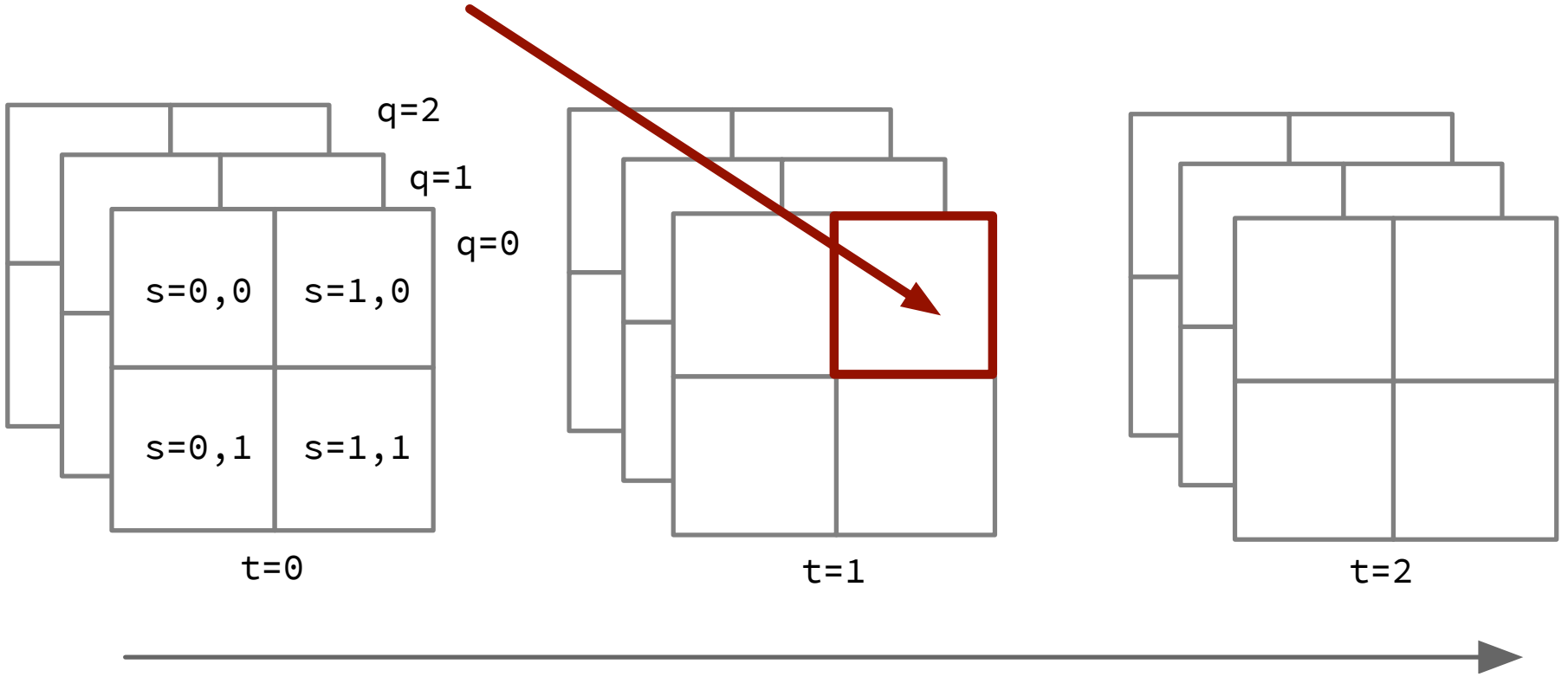
Paper in submission.

github.com/named-data/PyCNL

Example NDN video packet name format:

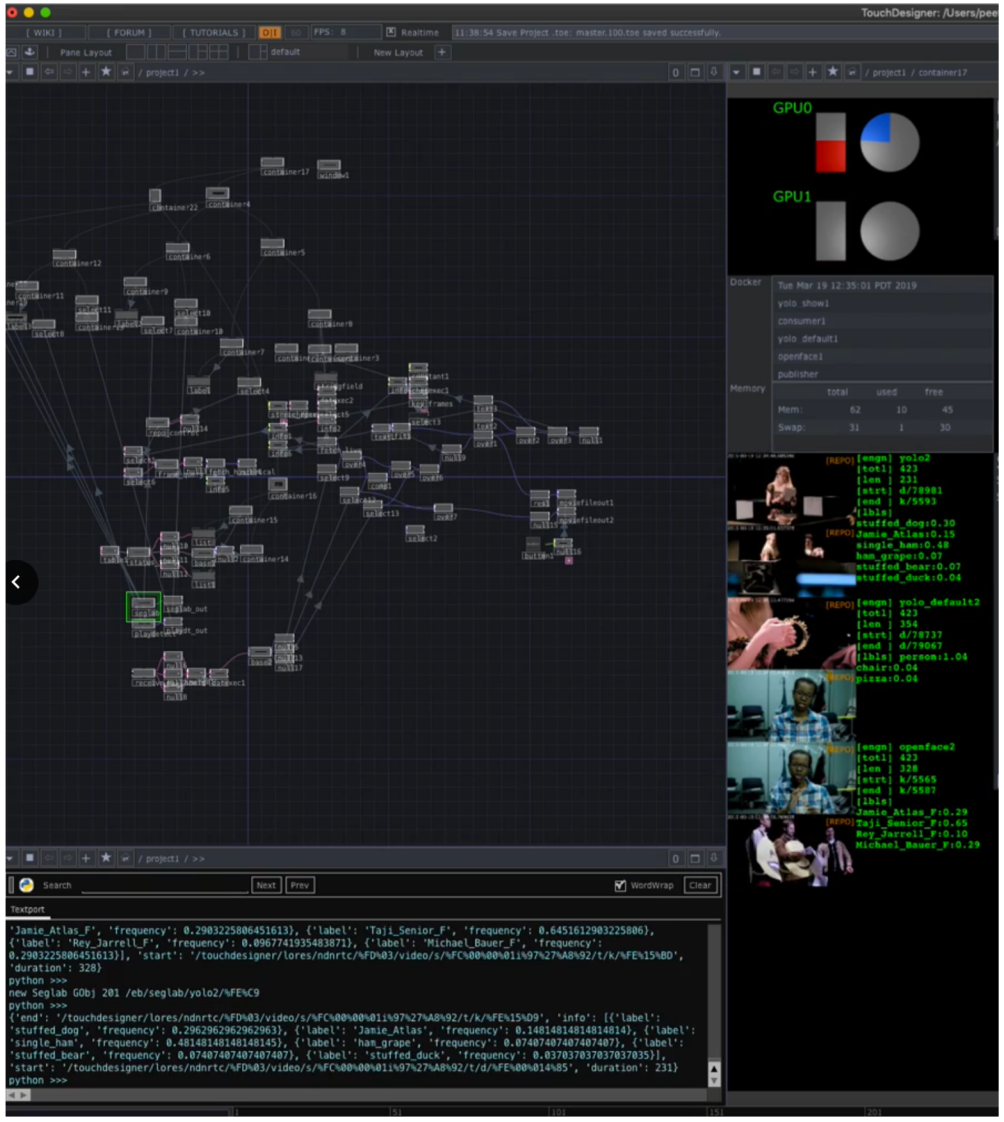
/<video-name>/<version>/**<time>**/**<space>**/**<quality>**/<chunk>

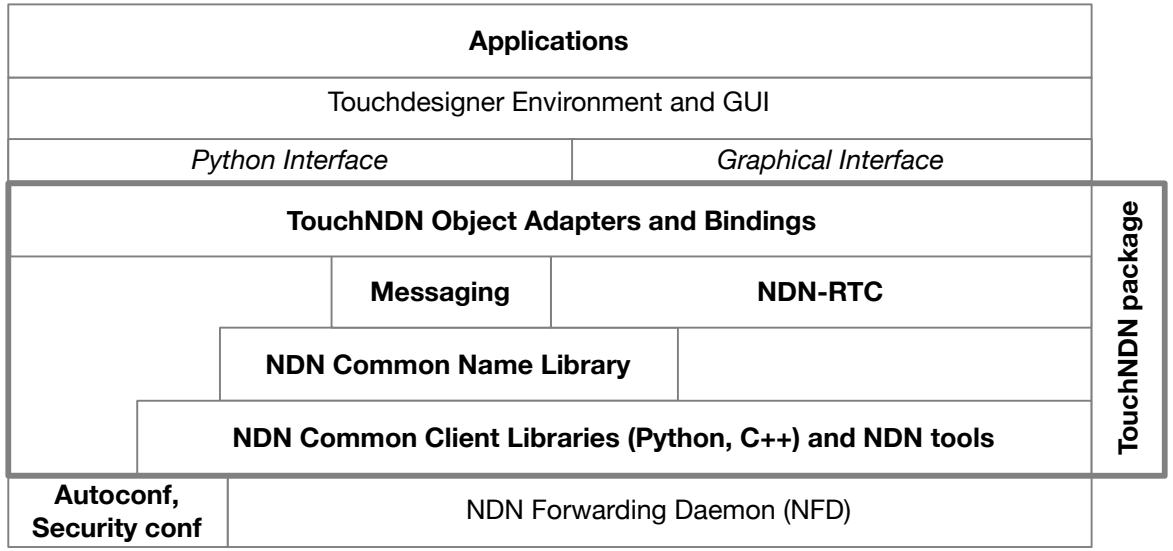
/video/v3/1/1,0/0/*



New APIs / Envs: **TouchNDN**

- *Can we expose data-centric video primitives visually for experimentation?*
- Sandbox for experimenting with NDN-based low-latency video: hierarchical, graph-based dev. env.
- Library for Derivative's TouchDesigner.
- Used for MR applications and this meeting's demo.
- To be shared in upcoming ACM ICN tutorial and side event.



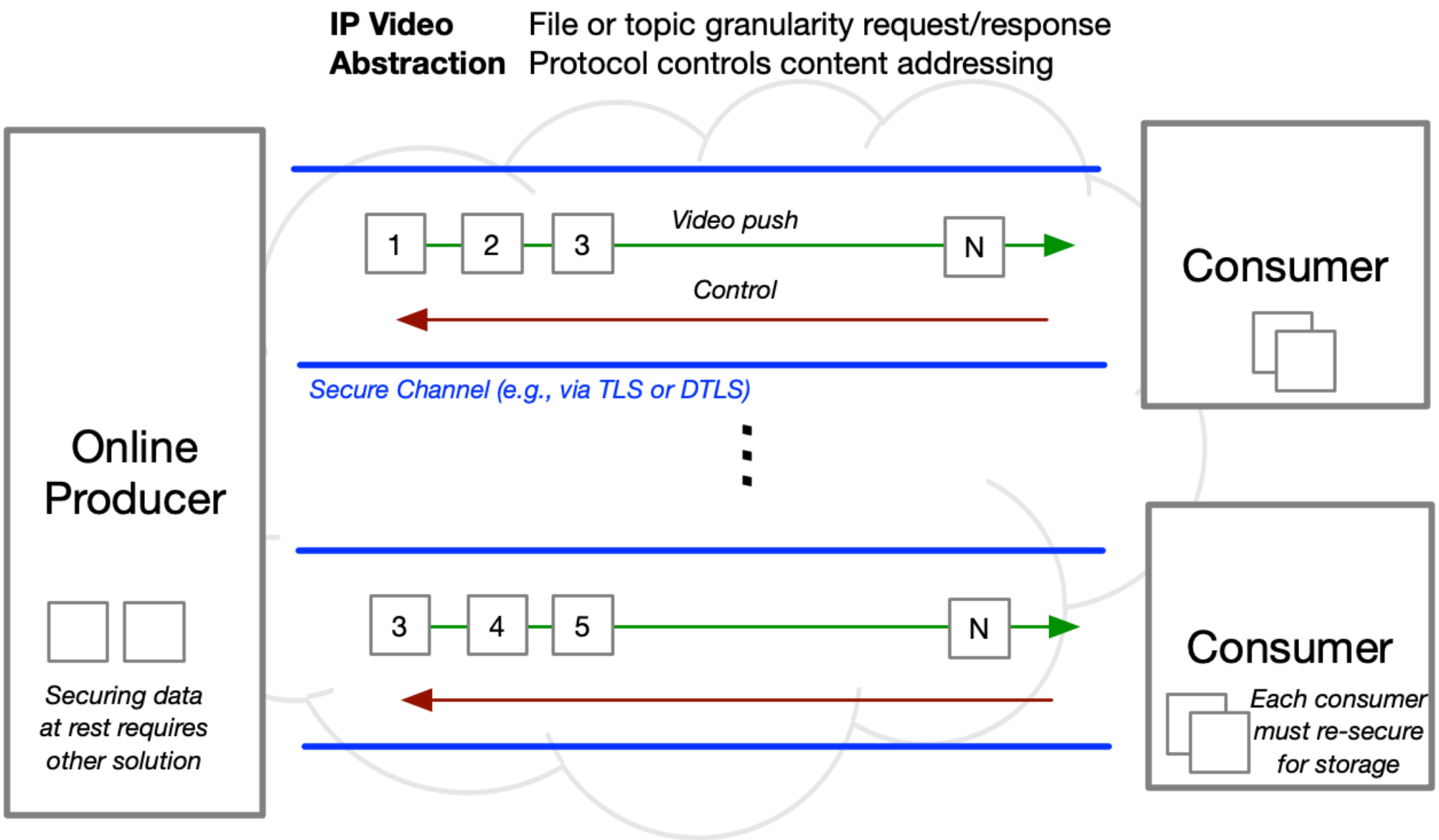


touchndn.com

Expressiveness

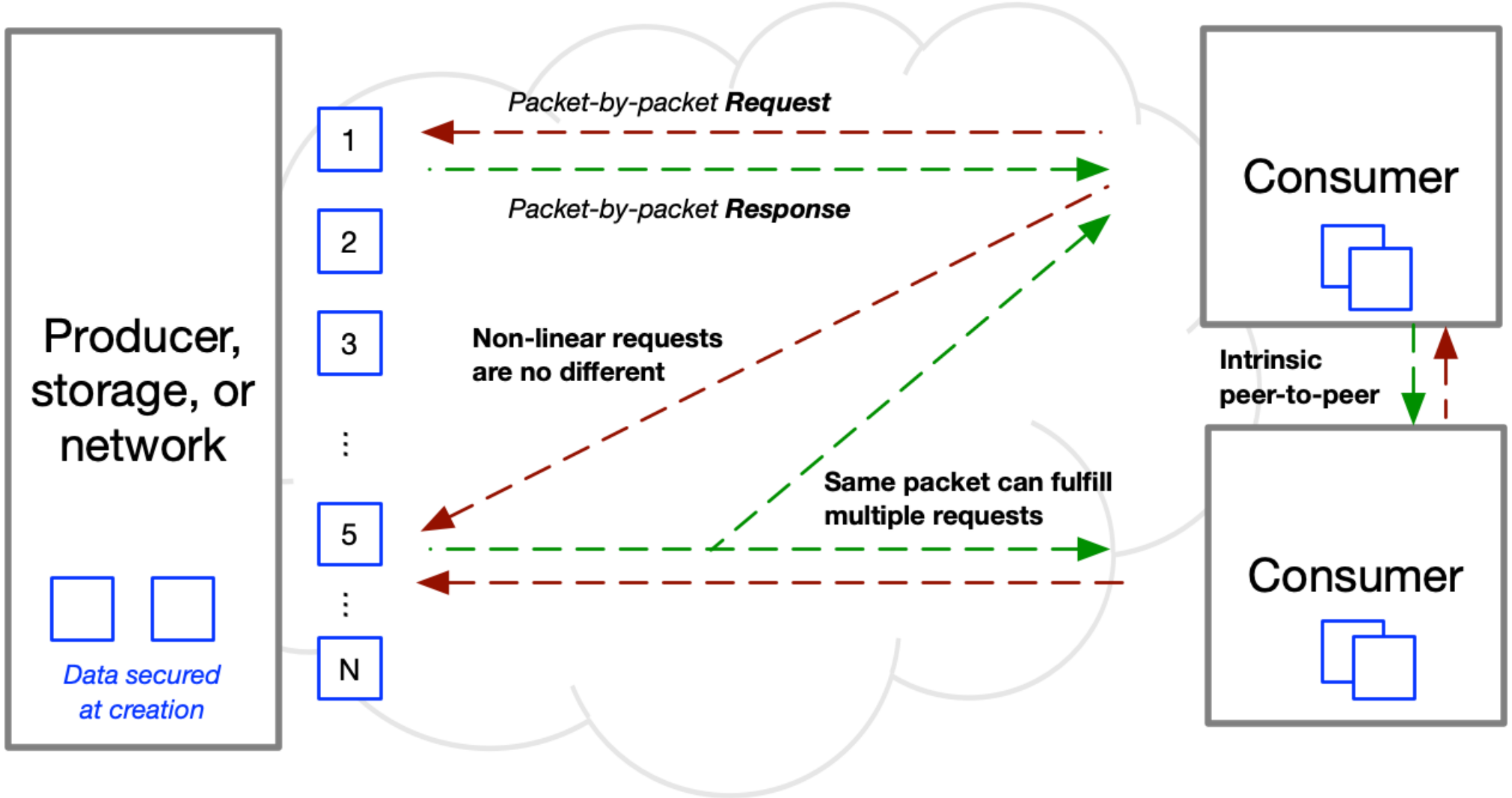
(+ Reduced hard mental operations and late binding)

Network video usually based on analog video thinking



Hybrid Abstraction: **Stream, bus, store**

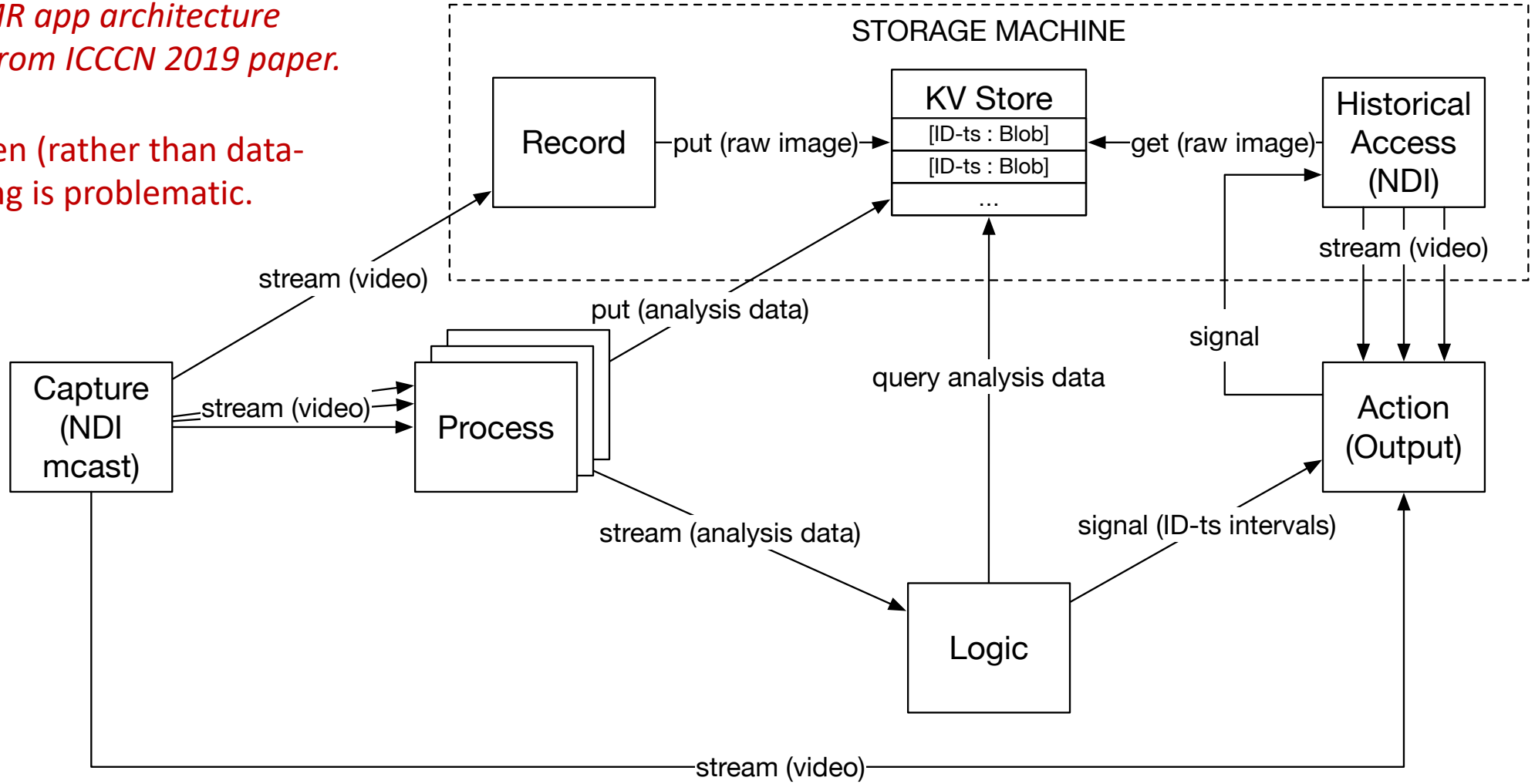
NDN Video Abstraction Packet granularity request/response
Application controls content addressing



How to unify live & recorded video approach over TCP/IP?

Comparison MR app architecture using TCP/IP, from ICCCN 2019 paper.

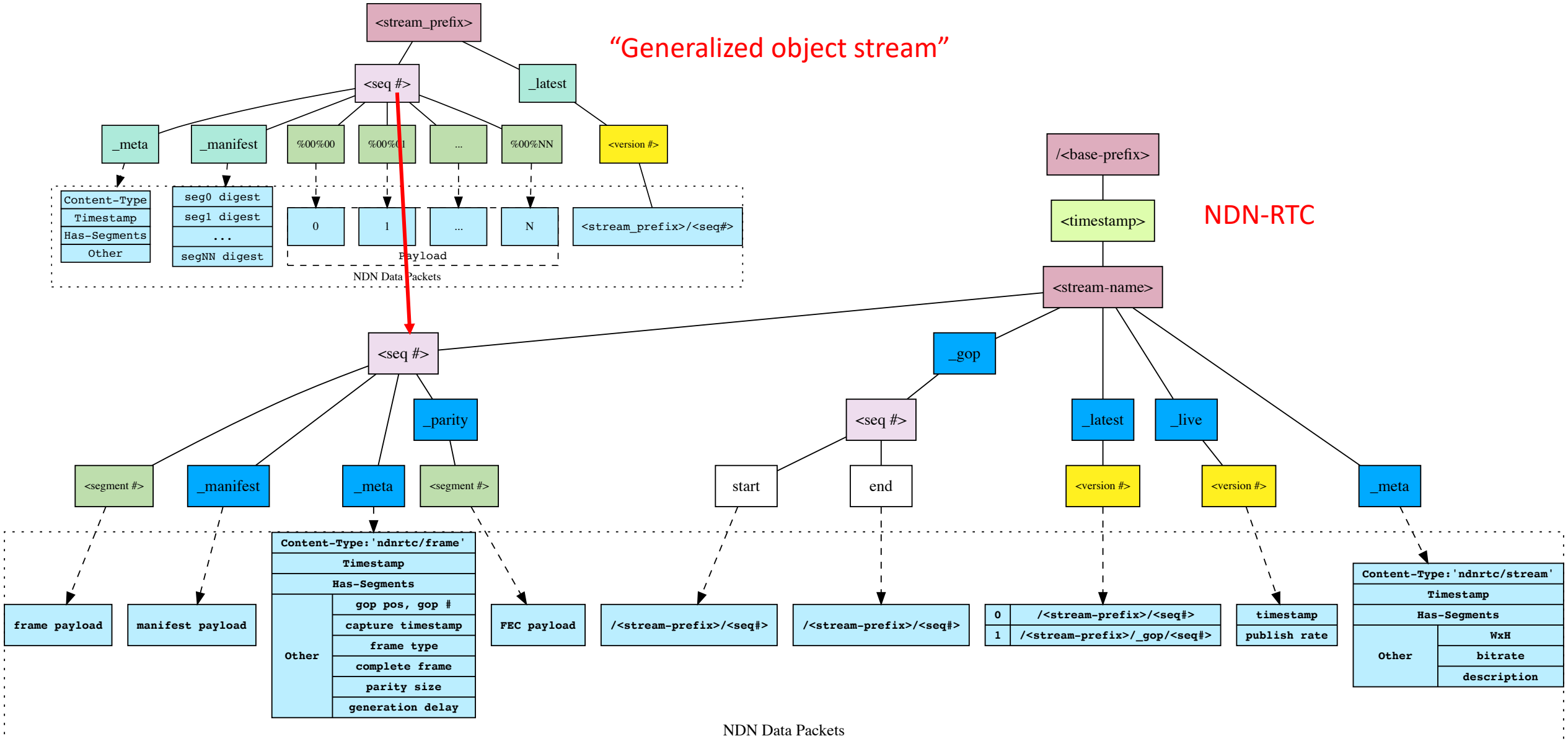
Endpoint-driven (rather than data-driven) thinking is problematic.



Other Best Practices

(Abstraction gradient, reduced error, consistency, visibility)

Data Exchange Generalization

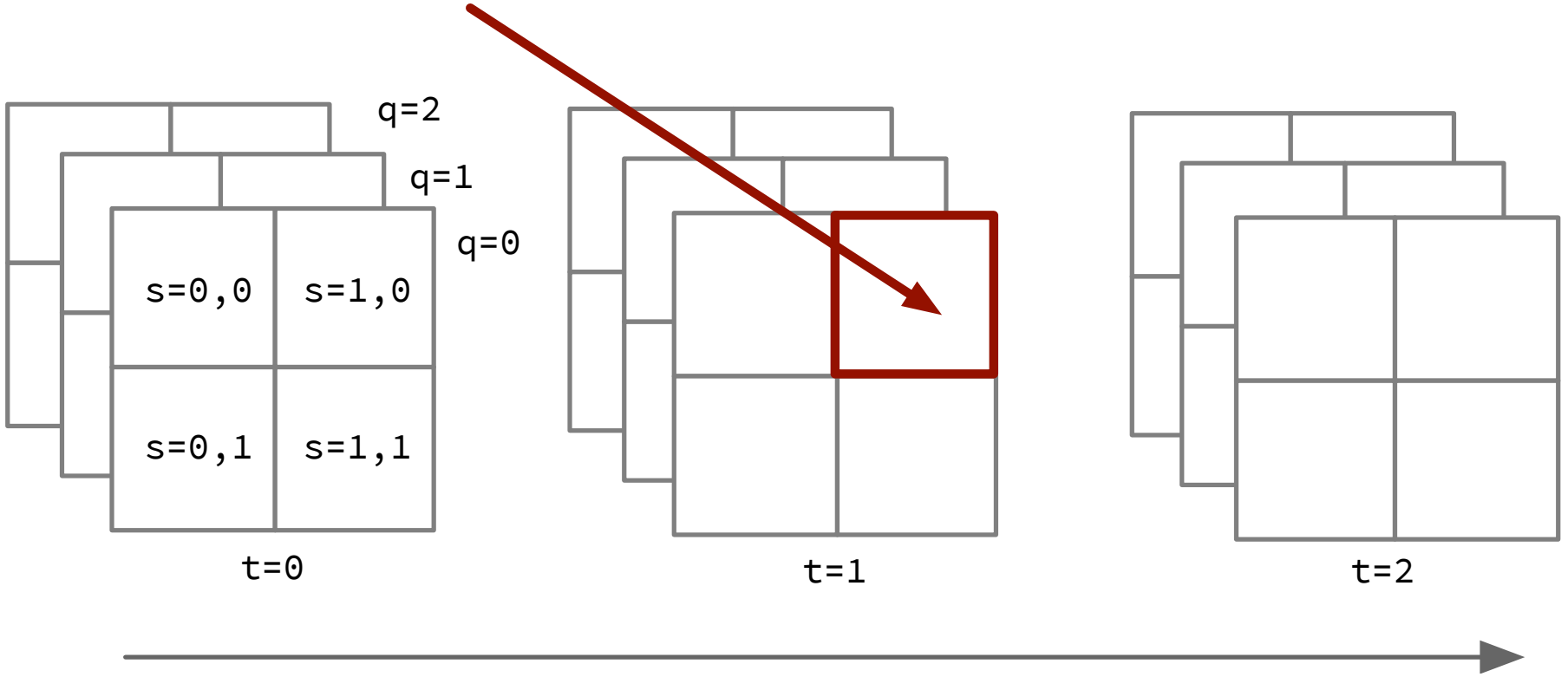

"Generalized object stream"
<stream_prefix>
<seq #>
_latest
_meta
_manifest
%00%00
%00%01
...
%00%NN
<version #>
Content-Type
Timestamp
Has-Segments
Other
seg0 digest
seg1 digest
...
segNN digest
0
1
...
N
<stream_prefix>/<seq#>
Payload
NDN Data Packets
/<base-prefix>
<timestamp>
NDN-RTC
<stream-name>
<seq #>
_gop
_parity
<seq #>
_latest
_live
<segment #>
_manifest
_meta
<segment #>
start
end
<version #>
<version #>
_meta
frame payload
manifest payload
Content-Type:'ndnrtc/frame'
Timestamp
Has-Segments
Other
gop pos, gop #
capture timestamp
frame type
complete frame
parity size
generation delay
FEC payload
/<stream-prefix>/<seq#>
/<stream-prefix>/<seq#>
0
/<stream-prefix>/<seq#>
1
/<stream-prefix>/_gop/<seq#>
timestamp
publish rate
Content-Type:'ndnrtc/stream'
Timestamp
Has-Segments
Other
WxH
bitrate
description
NDN Data Packets

Data-centric security opportunities

Example NDN video packet name format:

/<video-name>/<version>/**<time>**/**<space>**/**<quality>**/<chunk>

/video/v3/1/1,0/0/*



How to structure evaluation?

Idea: Adapt Cognitive Dimensions Framework

- CDs are “descriptions of the artifact-user relationship, intended to raise the level of discourse.” - T.R. Green, 1989
- CDs address **cognitive fit between mental and external representations**, critical to NDN’s named-based approach.

Abstraction gradient

Closeness of mapping

Consistency

Diffuseness

Error-proneness

Hidden dependencies

Premature commitment

Progressive evaluation

Role expressivenesss

Secondary notation

Viscosity

Visibility

Green & Petre, 1996

Plans for Next Year

Next steps

- Support other research groups in using new toolset
  - ICN Tutorial + Side event
  - Fall hackathon
- Continue requirements development and discussion
  - Composable edge accel., security, cross-layer opt, deployment/debugging support.
- Design/demonstrate granular media benefits
  - Spatial selectivity in video with AV1 codec
  - Possibly – describe volumetric video extensions
- Comparative evaluation (w/Lixia's group)
  - NDN-RPS v. pub-sub
- Summarize results
  - ICN Design book chapter
  - Complement performance evals of AR/MR impact with cognitive dimensions

Thank you!

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http://ice-ar.named-data.net