“Second Generation” NDN Applications:
Design Patterns, Libraries, and Architectural Support

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NDN Video **Rough Cut**
(from before the talk)

https://vimeo.com/265806508

Tutorial objectives

- Share architectural concepts that the NDN team is exploring in recent applications
- Expand on previous tutorials' overview of NDN open-source tools to cover more application needs (e.g., retrieving real time data, mobility support)
- Discuss interactions between different parts of the platform (e.g., forwarding strategy and library behavior)
- Discuss opportunities for community involvement

Organization

9:00A - **Welcome and Introduction**

9:45A - **NDN Thinking: App Components & Design Considerations**

10:15A - **Low-Latency Media over NDN**

11:00A - Break

11:15A - **Publisher Mobility**

11:45A - **New Library Directions**

12:15P - **Concluding Discussion**

12:30P – Finish, head to lunch

5:00P – *Opportunity for extended discussion*

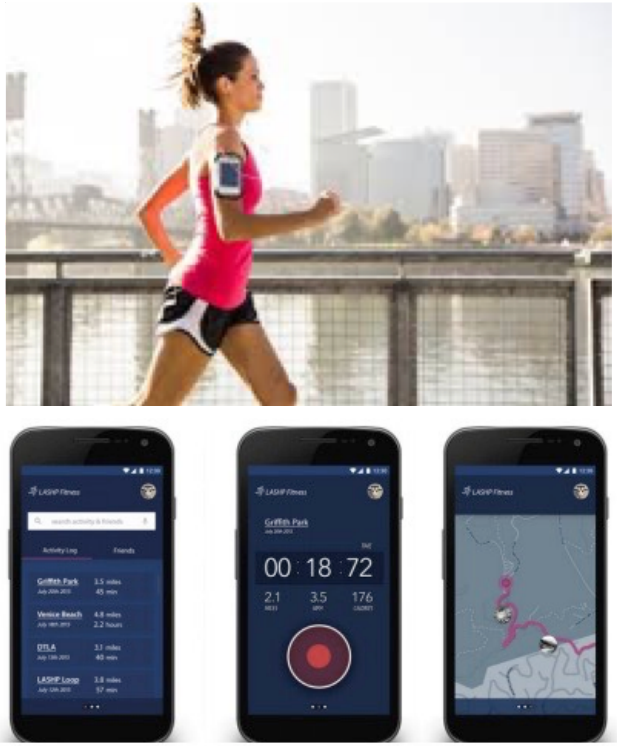
Introduction

Lan Wang

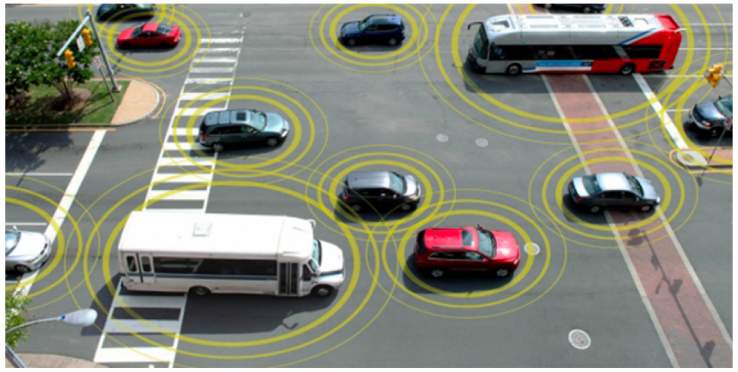
Section objectives

- Introduce basic concepts in NDN architecture
- Outline support for application development
- Give an example

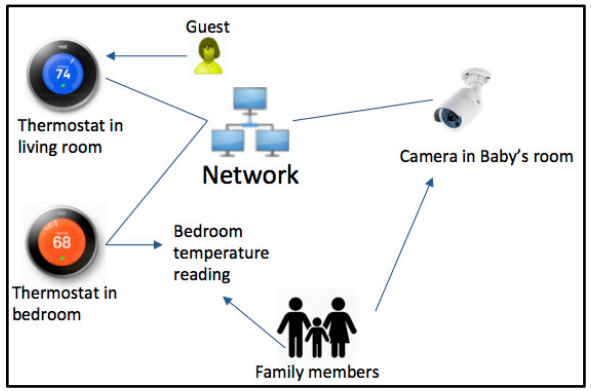
Future: Smart and Connected Communities



Mobile Health

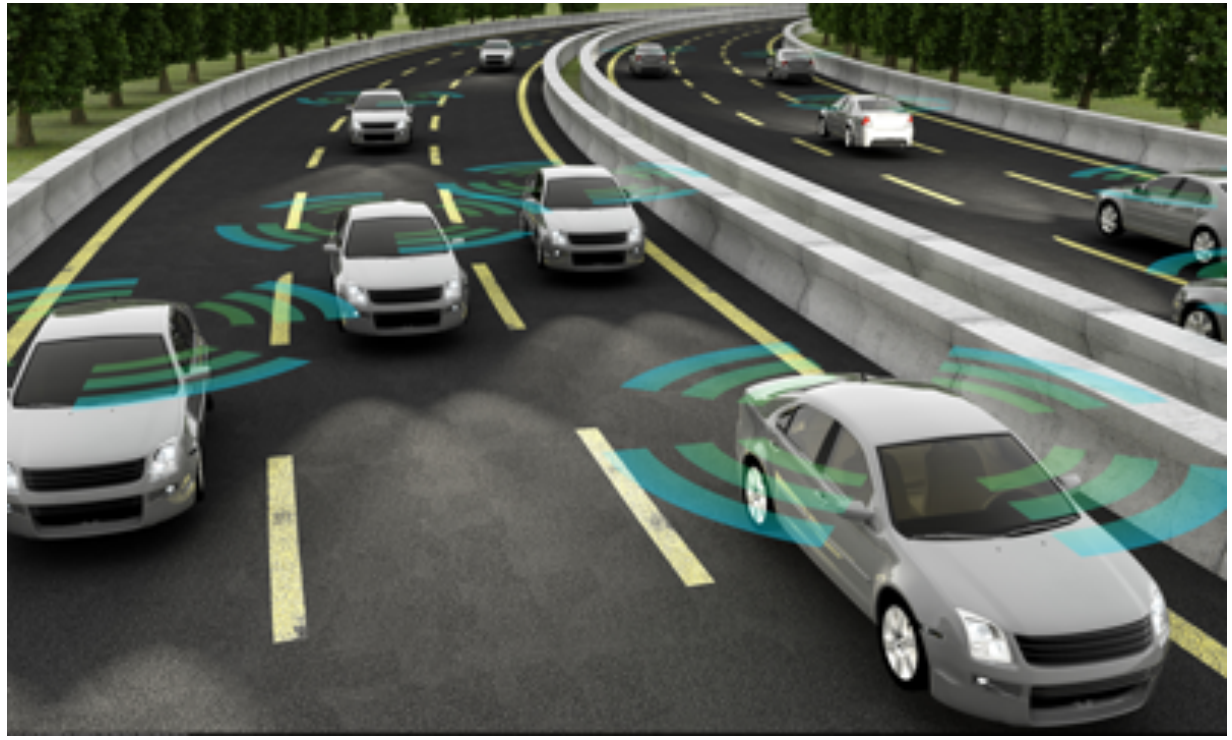


Connected & Autonomous Vehicles



Smart Buildings & Homes

Mobility Support: a challenge!



Connection time between neighboring vehicles is on the order of seconds.

Security remains a major challenge!

www.wired.com/2015/07/hackers-remotely-kill-jeep-highway/

Hackers Remotely Kill a Jeep on the Highway—With Me in It

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Miller attempts to rescue the Jeep after its brakes were remotely disabled, sending it into a ditch. ANDY GREENBERG/WIRED

NEWS

Researchers hack Philips Hue smart bulbs from the sky

Send in the drones.

RSAC17: More ransomware and IoT-enabled attacks on the way, warns expert

Smart light bulbs hacked for DDOS attacks

University attacked by its own vending machines, smart light bulbs & 5,000 IoT devices

A university, attacked by its own malware-laced soda machines and other botnet-controlled IoT devices, was locked out of 5,000 systems.

Network World | FEB 12, 2017 8:15 AM PT

Smart thermostat device got hacked with spyware

Why Named Data Networking?

Problems

- Incompatible communication models between application and network layer
- Difficult to support
  - mobility
  - multicast
  - multipath forwarding
- Complex & inadequate security mechanisms
- App vision (e.g., for IoT, AR) outstrips network capabilities

Causes

- host-centric packet delivery
- channel-based security

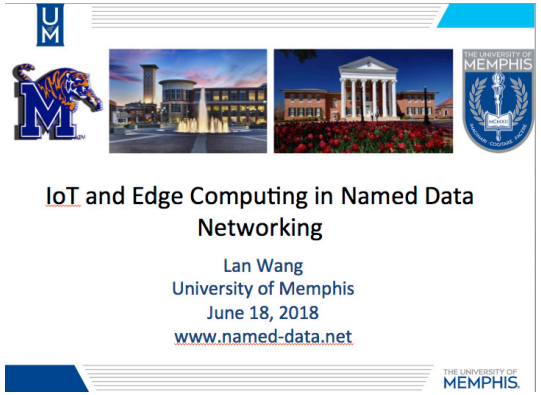
NDN Solutions

- Name data directly
- Use same name and data unit at both application layer and network layer
- Stateful forwarding with opportunistic caching
- Secure data, not channels

Name-based Data Retrieval

1. **Name data, not the container**
2. tell the network what you want..
3. let the network find it for you

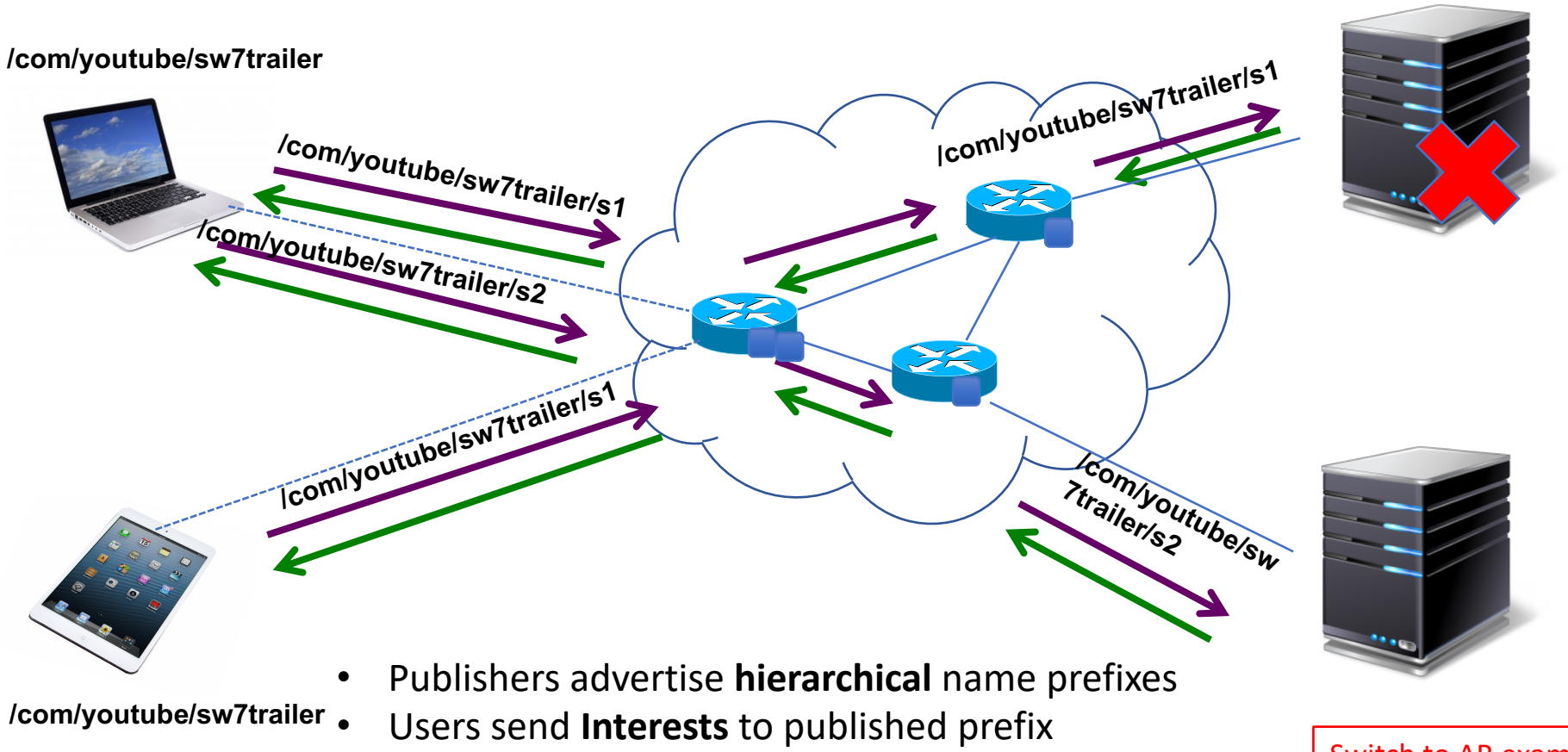
/edu/memphis/lanwang/talks/IoT-061818.pdf



/livingroom/thermostat1/status

Note: this is not Google Search!

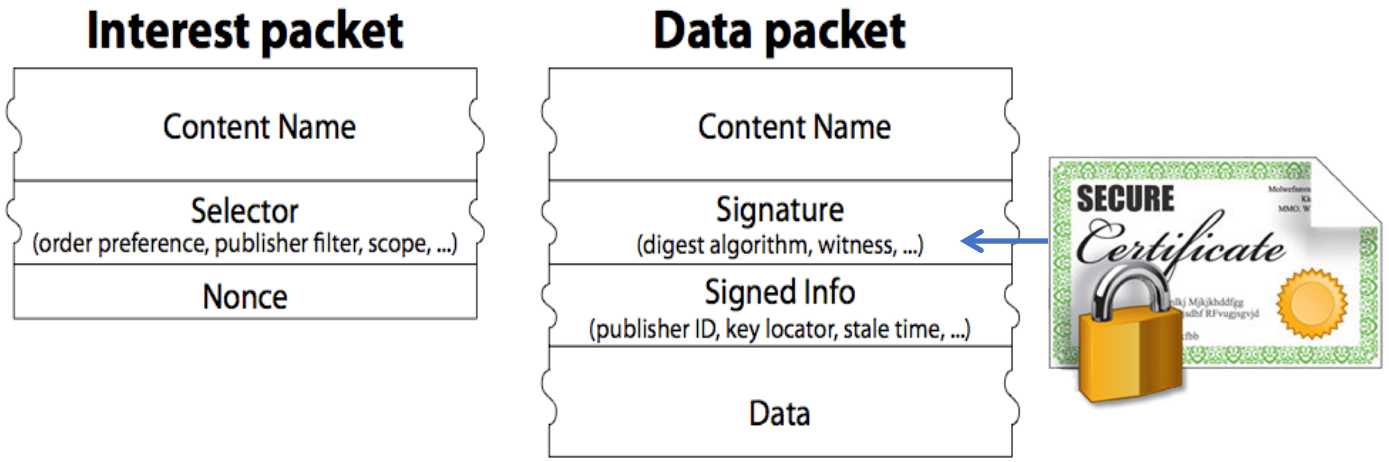
Named-based Routing and Forwarding



- Publishers advertise **hierarchical** name prefixes
- Users send **Interests** to published prefix
- "Breadcrumbs" direct **data** back to the user
- Data is **cached** into the network

Switch to AR example if time allows.

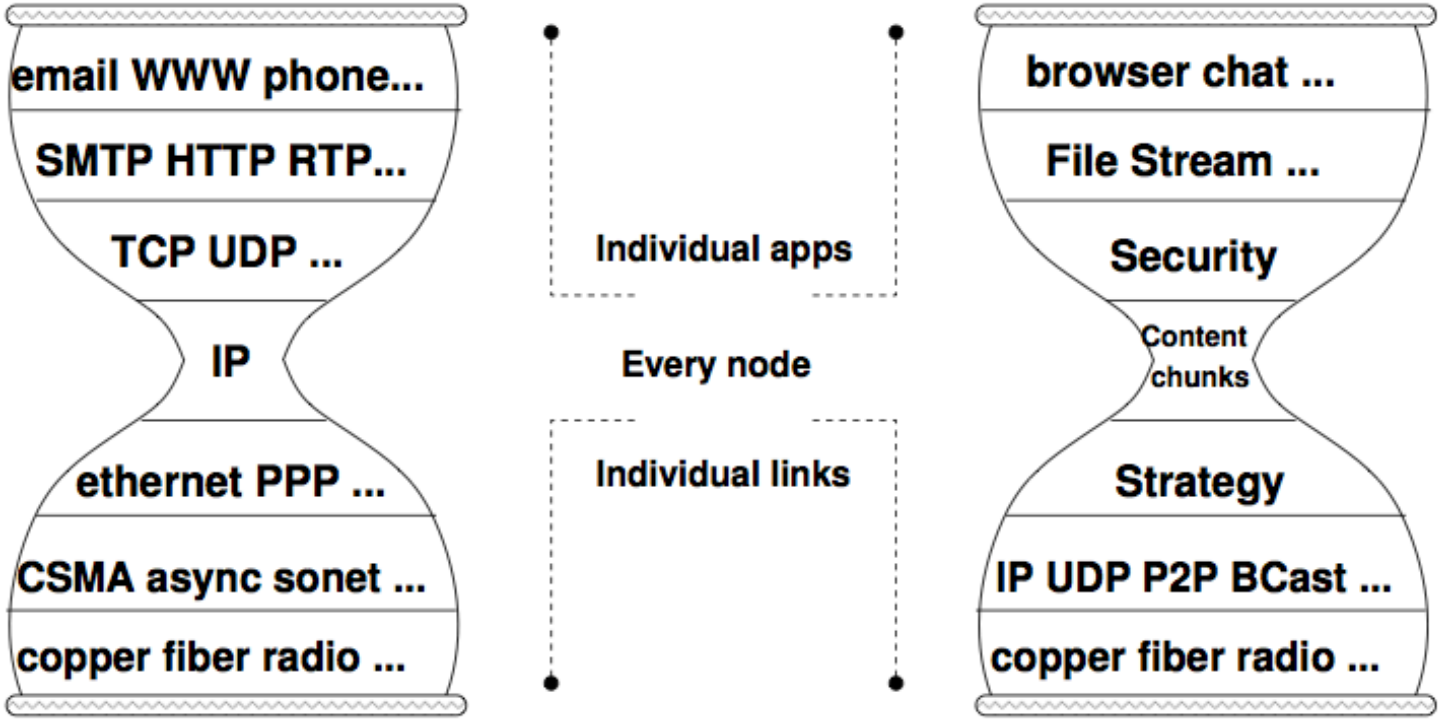
Data-Centric Security



- Data producer **signs** data with a **digital signature..**
- .. so the consumers know when they get bad data!
- .. so data can come from any node that has a copy.

NDN Architecture: Preserving the Hourglass Shape

- The Narrow waist: common interface, the network layer
  - IP -- address format, IP packet forwarding
  - NDN – data name format, NDN Interest/Data forwarding

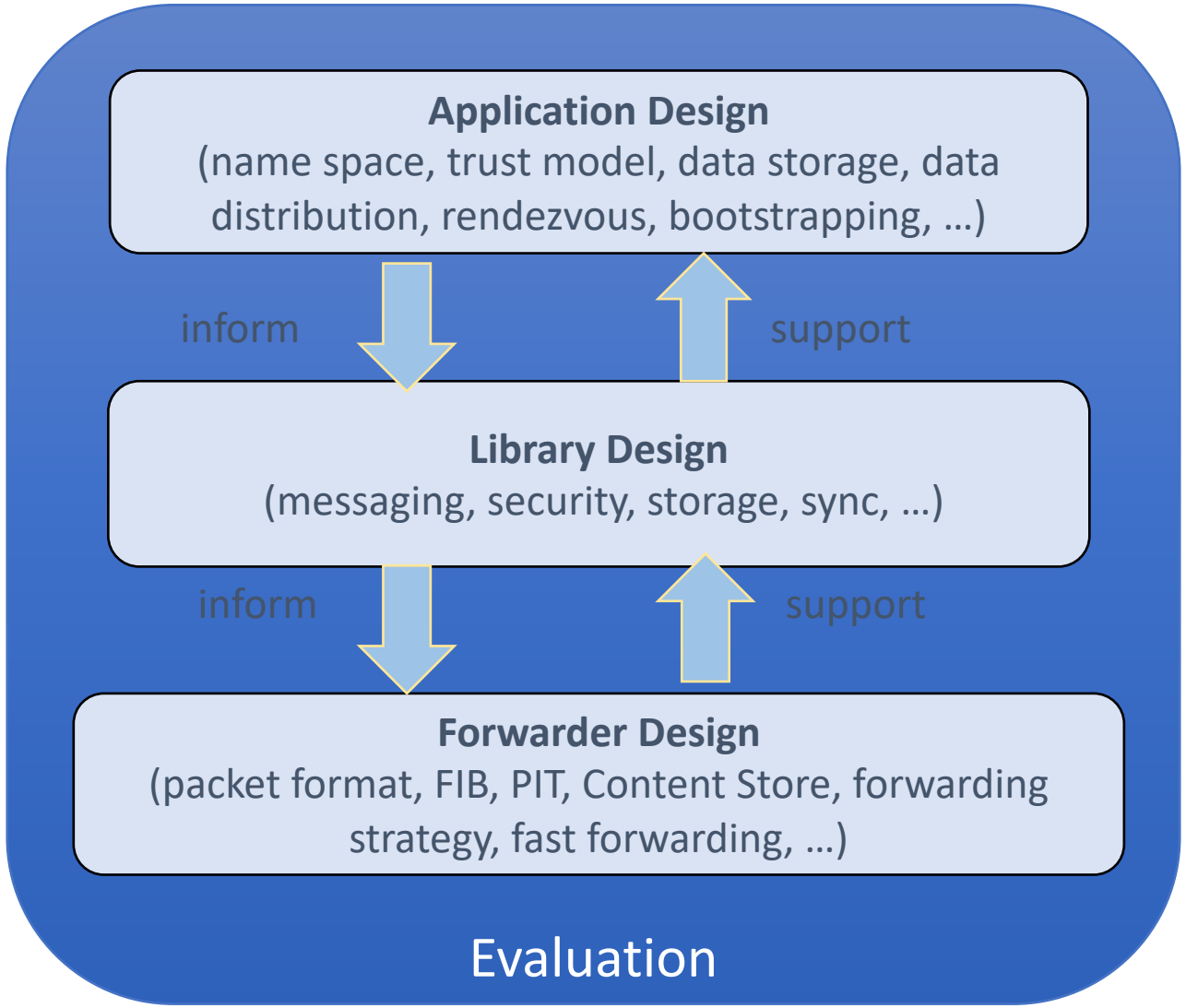


New capabilities…

- ***Interest/Data exchange retrieves named data from anywhere***
- ***Naming***: names facilitate key management and trust derivation.
- ***End-to-end security***: data is signed by producer and verified by consumers.
- ***Sync***: enable multiple parties of a distributed application to keep synchronized state
- ***Repo***: persistent storage helps producers store and publish data

… yield new design patterns – discussed in the next section.

NDN Development



Codebase

Apply NDN thinking:
ChronoChat, NdnCon, nTorrent, NDNFit, Repo-ng, NLSR, NDNoT, AR Browser…

Facilitate design patterns:
ndn-cxx, NDN-CCL,
ChronoSync, PSync, NDN-RTC, …

Embody the architecture:
NFD, NFD-android, NDN-RIOT, …

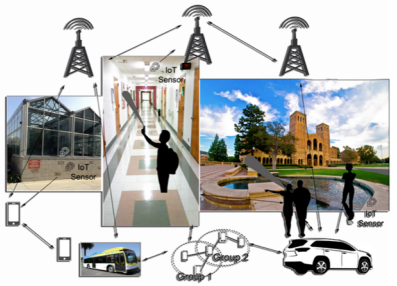
ndnSIM, Mini-NDN, NDN Testbed Tools, …

Edge-supported Mobile Augmented Reality Application

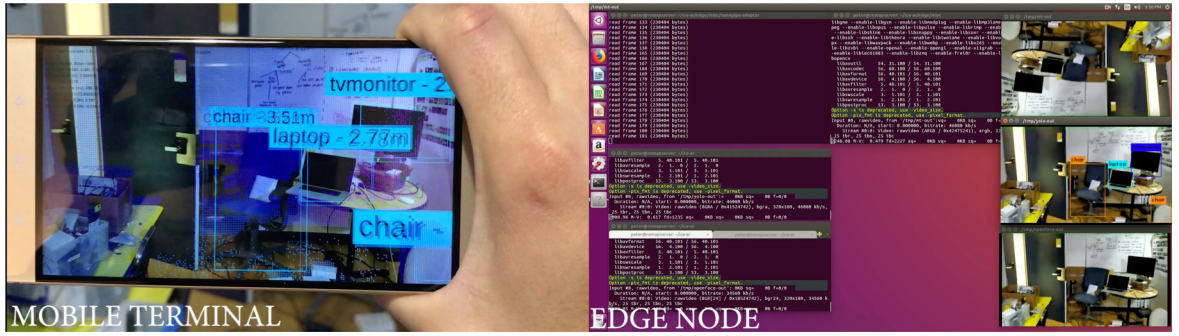
- Intel/NSF ICN-WEN Support
- App: Mobile AR browser
- Context-context exchange between many-to-many parties
- Demonstrate low-latency edge processing support using NDN-RTC as media transport.
- Acceleration-as-a-service providing low-latency semantic scene analysis support
- Data-centric security approach

ICN-Enabled Secure Edge Networking with Augmented Reality (ICE-AR)

Technological advances have moved society into an exciting era of mobile computing. Our daily lives can be further enriched by a new generation of mobile applications, such as augmented reality (AR) which broadens one's real-world perception by harmonizing sound, image, video, and sensors from multiple sources to aid comprehension and navigation. However, today's Internet operates with the address-based TCP/IP protocol architecture developed 40 years ago, which greatly limits the full promises of these new applications. Thus, current AR implementations face challenges in performance, scalability and availability upon disasters. This proposed research project (ICE-AR) aims to develop a new wireless network architecture to address these limitations and provide pervasive support for these emerging applications.

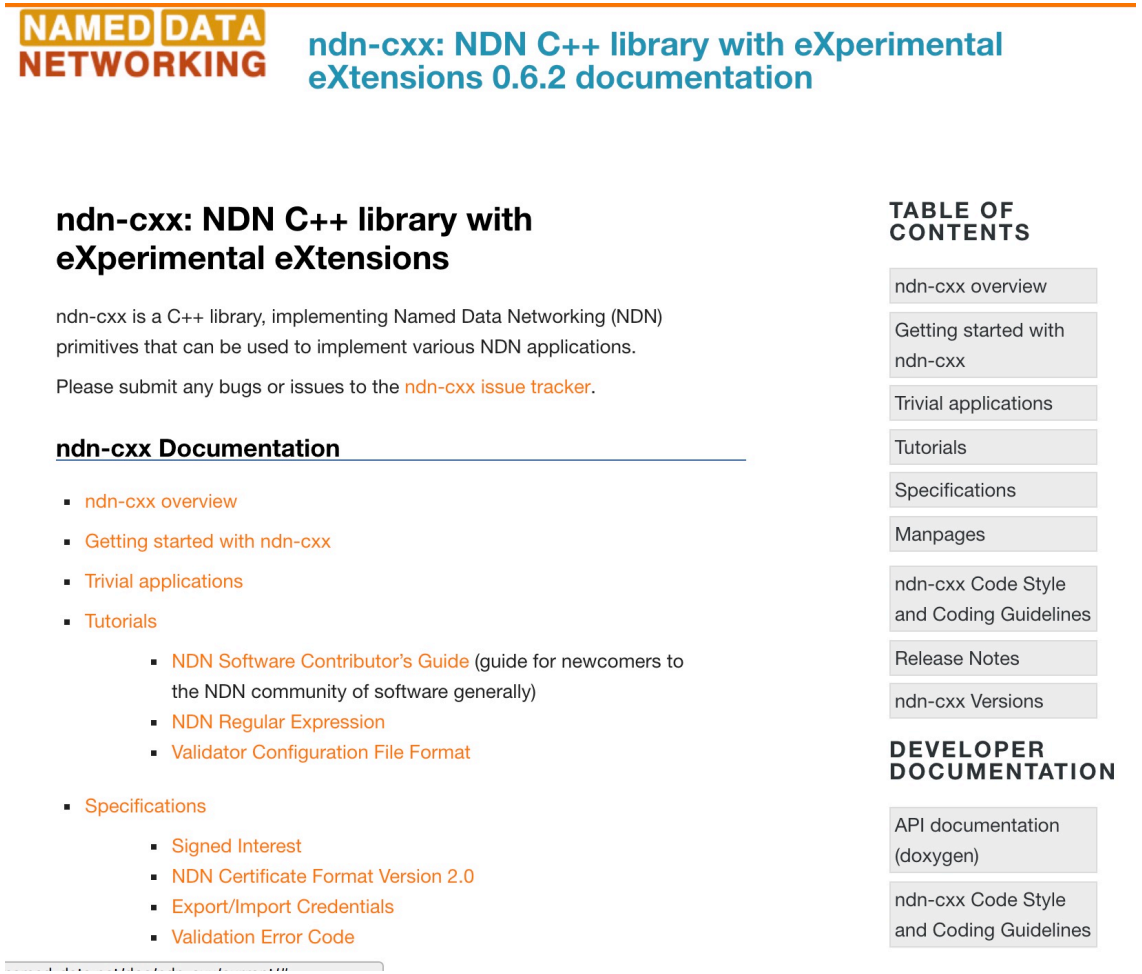


The ICE-AR project team will apply and extend seven years of research efforts on Named Data Networking (NDN), a realization of the Information Centric Networking (ICN) vision, to create this new architecture. The design will emphasize application-level data naming, data-centric security and computing, asynchronous publishing and consumption, and efficient use of local and proximate resources. The architecture will unify latest advances in wireless communication with domain-specific computing technologies to accelerate AR at the wireless edge and deliver robust performance, with or without the pre-deployed infrastructure support.



ndn-cxx Library

- NDN C++ library with eXperimental eXtensions
  - The reference library implementation
- Supports
  - sending interests
  - receiving data
  - fetching certificates
  - validating data
  - encrypting/decrypting data
  - Other functions
- Used in NFD, NLSR, ndn-tools, ChronoChat, repo-ng, etc.
- Code: https://named-data.net/doc/ndn-cxx



NDN Common Client Libraries (NDN CCL)

- NDN-CCL libraries provide a common API for client applications to use NDN
  - NDN-CPP (C++)
  - jNDN (Java)
  - PyNDN (Python)
  - NDN-JS (JavaScript)
  - NDN-DOT-NET (C#)
  - NDN-Squirrel (Squirrel)
- Follows the ndn-cxx reference implementation
- Used in NDN-RTC, NdnCon, NFD-Android, etc.
- https://named- data.net/codebase/platform/ndn-ccl/

Supported Features

Feature	NDN-CPP	PyNDN	NDN-JS	jNDN	NDN-DOT-NET
MemoryContentCache	✓	✓	✓	✓	✓
ChronoSync2013	✓	✓	✓	✓	✓
Name.Component from*	✓	✓	✓	✓	✓
Name.Component is*	✓	✓	✓	✓	✓
Name.Component to*	✓	✓	✓	✓	✓
typed name components	✓	✓	✓	✓	✓
ImplicitSha256DigestComponent	✓	✓	✓	✓	✓
ProtobufTlv	✓ API	✓ API	✓ API	✓ API	✓ API
SegmentFetcher	✓ API	✓ API	✓ API	✓ API	✓ API
ConfigPolicyManager	✓ API	✓ API	✓ API	✓ API	✓ API
ControlResponse	✓ API	✓ API	✓ API	✓ API	✓ API
Face.setInterestFilter	✓	✓	✓	✓	✓
Interest forwarding hint	✓	✓	✓	✓	✓
NDNLPv2 NetworkNack	✓	✓	✓	✓	✓
NDNLPv2 IncomingFaceId (Interest, Data)	✓	✓	✓	✓	✓
NDNLPv2 CongestionMark (Data)	✓	✓	✓	✓	✓
remote prefix registration	✓	✓	✓	✓	✓
FilePrivateKeyStorage	✓ API	✓ API	✓ API	✓ API	✓ API
BasicIdentityStorage	✓ API	✓ API	✓ API	✓ API	✓ API
encrypt/EncryptedContent	✓ API	✓ API	✓ API	✓ API	✓ API

Sync

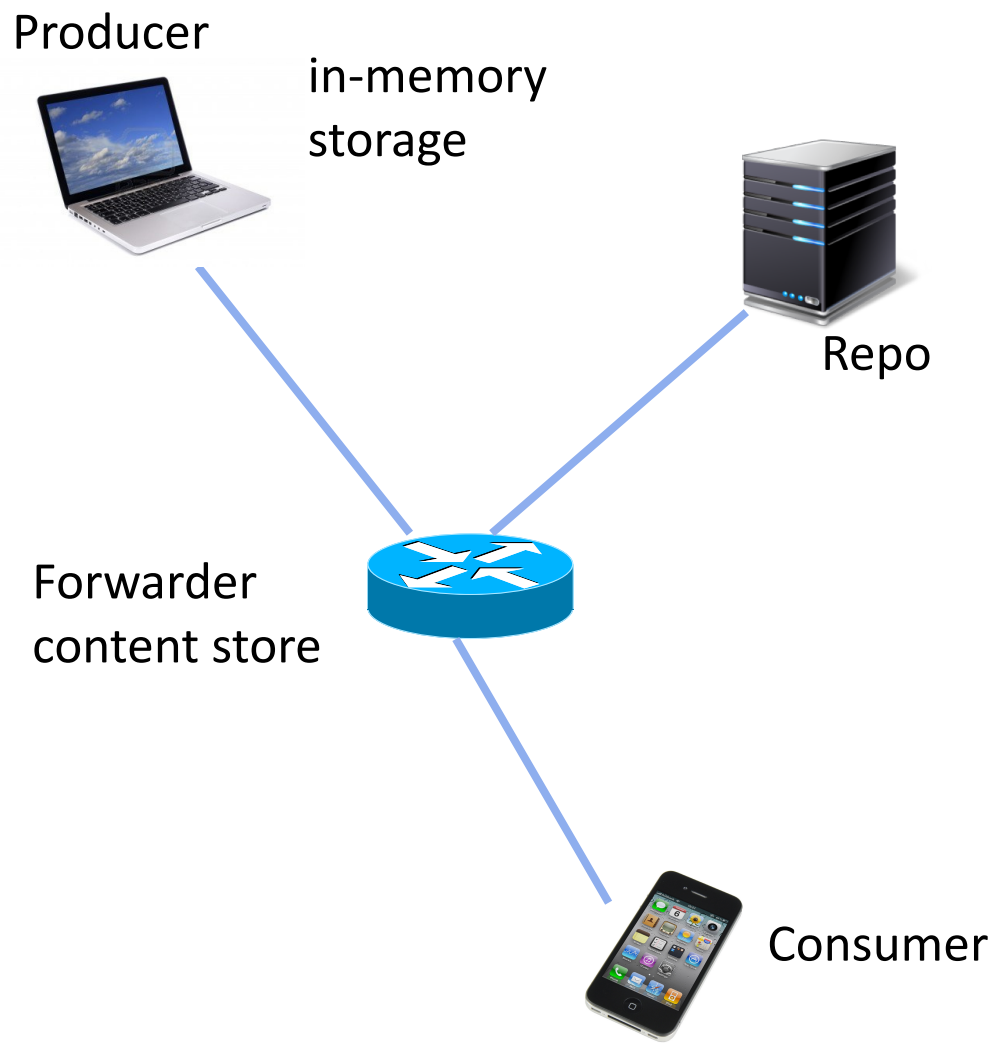
- Transport layer mechanism for NDN

- Set reconciliation between participants that sync data in a name space
  - Represent the data set using a compact “digest” over data name
    - Digest can be hash, IBF, or other format
  - Exchange digests to detect missing data names
  - Retrieve data using the data names

- Protocols: ChronoSync, iSync, PSync, Round Sync, VectorSync, DSSN, …
  - implemented in libraries

Storage

- Application in-memory storage
  - Allocated in memory
  - Managed by applications
- forwarder content store
  - Managed by routers
  - Opportunistic
- Repository
  - Managed by application users or third party
  - Long-term persistent storage



What do we mean by “second generation” app?

Several meanings:

1. Post NSF FIA/FIA-NP support: Research support not only for NDN architectural development.
2. Previous research outcomes now generalized (somewhat), e.g.:
   - AR Browser uses a first generation application (NDN-RTC) as a library.
   - NDN-CNL (Common Name Library) abstracts from Interest-Data exchange.
3. Addressing a number of more complex issues, e.g.:
   - Interaction between configurable aspects of forwarding plane and application design.
   - Cross-layer optimization for wireless (in ICE-AR research).
   - Granularity and usability of security.

How to learn more

- NDN project website: https://named-data.net
- NFD, core libraries, and other general use software: https://github.com/named-data
- NDN papers
  - Named Data Networking. Lixia Zhang, Alexander Afanasyev, Jeffrey Burke, Van Jacobson, kc claffy, Patrick Crowley, Christos Papadopoulos, Lan Wang, and Beichuan Zhang, ACM SIGCOMM Computer Communication Review (CCR), July 2014.
  - Schematizing Trust in Named Data Networking, Yingdi Yu, Alexander Afanasyev, David Clark, kc claffy, Van Jacobson, and Lixia Zhang. ACM ICN, September 2015.
  - A Survey of Distributed Dataset Synchronization in Named Data Networking. Wentao Shang, Yingdi Yu, Lijing Wang, Alexander Afanasyev, and Lixia Zhang. NDN Technical Report NDN-0053.. 2017.