Application Support

NDNComm 2014 – ICN Tutorial Dry Run

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Motivation

"The NDN project's approach is to design and build a variety of applications on NDN to **drive the development and deployment of the architecture and its supporting modules, to test prototype implementations**, and to encourage community use, experimentation, and feedback into the design.

"Application-driven development also allows **verification and validation of performance and functional advantages of NDN**, such as how routing on names promotes efficient authoring of sophisticated distributed applications, by reducing complexity, opportunities for error, and **time and expense of design and deployment**."

- Afanasyev et al., "Named Data Networking," CCR July 2014.

Outline of talk

- **Application library introduction**
- **Library security features**
- **Naming conventions**
- **Repository**
- **The NDN Platform - Software Distribution**

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Evolution of the libraries

- All libraries now reflect fundamental architectural abstractions directly in objects, and wire format manipulation is abstracted.
  - Name
  - Interest
  - Data
  - Face
  - KeyChain

- Two library efforts available to community
  - NDN-CXX: “C++ for eXtended eXperimentation”
  - NDN-CCL: “Common Client Libraries”
  - *Enables diversity of coding choice*
  - *Drives us towards specification (and not just implementation)*

ndn-cxx: **NDN C**++ library for e**X**tended e**X**perimentation

- Application-driven iterative library extension and evolution
  - Stable but evolving API based on application needs
    - New and extended APIs to support application patterns
  - Playground for experimental features
- Prioritizing developer productivity for experimentation
  - encouragement and extensive use of Boost libraries and modern application patterns
    - leveraging > 7000 person years of high-quality code*
  - multiple utility classes and helpers to simplify common operations
- Purity
  - Pure C++ implementation, adherent to OOP principles
  - Simplified maintenance and extensibility

* http://www.boost.org/development/index.html

ndn-cxx: Available Functionality

- Base
  - Fully asynchronous communication model based on Boost.Asio
  - Single-threaded, but thread-safe Face operations
  - Explicit time management based on Boost.Chrono
  - Test-driven development with continuous integration
- Security library with latest extensions and experimental features
  - Security primitives to simplify development of NDN applications
  - Flexible trust model for packet validation
    - set of built-in trust models
    - policy-based custom trust model definition
- Utility classes
  - Scheduler, NDN regular expressions, NFD management protocols helpers, random number generator, digest calculation, routines to work with time, NFD management support, security credentials IO, security library, etc
- Miscellaneous tools
  - ndnsec tools to manage security, tlvdump to visualize NDN-TLV

ndn-cxx: Usage Cases

- The library is currently being used as part of the following projects:
  - NFD - NDN Forwarding Daemon
  - NLSR - Named-data Link-State Routing protocol
  - repo-ng - Next generation of NDN repository
  - ChronoChat - Multi-user NDN chat application
  - ChronoSync - Sync library for multiuser realtime applications for NDN
  - ndn-tlv-ping - Ping Application For NDN
  - ndn-traffic-generator - Traffic Generator For NDN

NDN-CCL “Common Client Library”

- Encourage development and experimentation with NDN for a large audience of developers
- Reasonably consistent, stable API across multiple platforms and languages, plus language-specific syntax (typically more concise)
- Minimal dependencies or assumptions about threading/memory management for easier integration with applications
- Track updates to message protocols and the TLV wire format
- Incorporate advances from NDN research projects as library modules to speed adoption by applications (Security, Sync, etc.)
- Provide install packages where possible so applications can deploy easily

Features

- Languages
  - C++ with C core
  - Python (2 and 3),
  - JavaScript (browser and Node.js)
  - Java (preliminary)

- Helper functions
  - Basic interaction with NFD including Signed Interests
  - Protobuf+TLV based cross-platform message description
  - MemoryContent Cache

- Port of security library developed for ndn-cxx (Y. Yu)
  - Full support in C++ and Python
  - Preliminary support in other languages

- Port of ChronoSync 2013 (experimental feature)
  - Full support in C++ and Javascript

WireEncoding

- NDN-CCL *somewhat* wire format independent
- expressInterest, etc. take optional WireEncoding argument
- WireEncoding processes abstract Interest, Data to wire format
- Defaults to new TLV support.
- Supports both NFD and ndnd-tlv

- Why do this?
  - Application group desire for continuity and portability (cf, Architecture group desire for clarity)
  - Compile-time application portability (ndnrtc use case)
  - Comparison purposes
  - Provoke conversation: Wire-format vs. architecture

NDN-CCL Applications

- **CCNx Federated Wiki**, an NDN port of the Smallest Federated wiki (NDN-JS)
- **Chronochat-js**, a javascript implementation of the ChronoChat demonstration application (NDN-JS)
- **Matryoshka**, an experimental multi-player online game using NDN and the Unity3D game engine. (jndn as the basis of the .NET port of CCL used in this project.)
- **ndn-bms**, a building management system prototype being developed as part of the NDN-NP project (PyNDN, NDN-JS)
- **ndn-lighting**, lighting control application using NDN (PyNDN, NDN-JS)
- **ndn-protocol**, a firefox browser plug-in supporting an ndn:/ retrieval scheme (NDN-JS)
- **ndnfs** and **ChronoShare**, NDN file sharing platforms (PyNDN, NDN-JS – with ndn-cxx)
- **NDNoT**, the Named Data Network of Things toolkit for the Raspberry PI (PyNDN, NDN-JS)
- **ndnrjs**, a javascript implementation of an NDN repository (NDN-JS)
- **ndnrtc**, a peer-to-peer multiparty audio, video, and chat application over NDN. (NDN-CPP, NDN-JS)
- **ndnstatus**, the NDN routing status web page (PyNDN, NDN-JS)
- **NDNVideo**, a video playout application for NDN (PyNDN)

Coming:

- **NDNEx**, an NDN-based mobile health application being developed as part of the NDN-NP research project. (jndn)
- **OpenPTrack-NDN** an open source person tracking system that will add NDN support in Fall 2014. (NDN-CPP)

New Protocols + Advanced APIs

- Consumer / Producer API

  Moiseenko & Zhang. NDN Technical report #17, 2014.

- SYNC: Efficient synchronization of namespaces

  Zhu & Afanasyev. "Let's ChronoSync: Decentralized dataset state synchronization in Named Data Networking." ICNP, 2013.

ChronoSync

- Synchronization protocol for multi-user real-time application for NDN
- Users synchronize their knowledge about a data set
  - knowledge: names of data in the set
    - effectively represented by a crypto digest
  - users with different digests: one of them is missing some knowledge
    - one sends its digest in interest
      - "This is what I have known, any new updates?"
    - others, if can tell the difference, may reply some missing knowledge in data packet
      - "I guess this information may help us to get to the same page."
  - replies effectively utilize NDN multicast forwarding feature
    - in most cases, users express interests with the same digest
    - reply to a interest multicast to the senders with the same digest.
- User fetches data separately when discovering a new name
  - allow flexible data fetching strategy
  - allow flexible trust model to validate actual data
- 2013 version supported in NDN-CCL as experimental API; new ones coming.

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- Naming conventions
- Repository
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Security approach

- Consistent across ndn-cxx and NDN-CCL
- Reference implementation is ndn-cxx security components
- Data packets typically signed and verified with a default key of RSA 2048-bit. ECDSA also supported. (Probably other more efficient verification techniques in the future.)
- Most flexibility, power, and challenges in how trust is managed – still an open area of research.

Support for Interest Signing & Verification

- http://redmine.named-data.net/projects/ndn-cxx/wiki/SignedInterest
- /command/params/<timestamp>/<random-value>/<SignatureInfo>/<SignatureValue>
  - params may be TLV-encoded data
- The signature covers name components through SignatureInfo
- SignatureInfo and SignatureValue the same as a Data packet
- Example: Register
  - /localhost/nfd/rib/register/<control-parameters>/<timestamp>…
  - ControlParameters ::= CONTROL-PARAMETERS-TYPE TLV-LENGTH Name? FaceId? Uri? LocalControlFeature? Origin? Cost? Flags? Strategy? ExpirationPeriod?

ndn-cxx Security Library

- http://named-data.net/doc/ndn-cxx/current/tutorials/security-library.html

- Security abstractions
  - Certificate (same as signing certificate or identity certificate)
    - identified by NDN identity certificate name
    - carries "real-word" identity and other meta information
    - associated with the private key
  - Key (same as signing key)
    - identified by a "logical" name of a private key
    - "container" for the public (derived from the private) key certificates
  - Identity
    - defines signing namespace and is identified by this namespace
    - container for one or multiple keys

```
* /self/cawka
 +->* /self/cawka/ksk-1409527265871
     +->* /KEY/self/cawka/ksk-1409527265871/ID-CERT/%00%00%01H.%60%B7%7C
     +->  /self/cawka/KEY/ksk-1409527265871/ID-CERT/%00%00%01H._%3A%C6
 +->  /self/cawka/ksk-1409527205621
     +->* /self/cawka/KEY/ksk-1409527205621/ID-CERT/%00%00%01H.%5EOa
```

NDN Identity Certificate

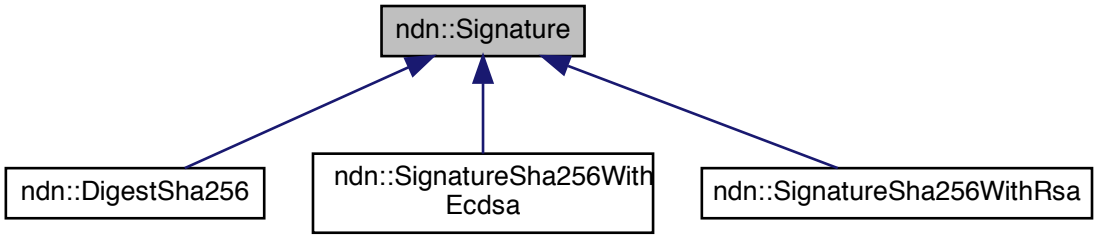
```
// NDN-TLV Encoding
Certificate ::= DATA-TLV TLV-LENGTH
            Name
            MetaInfo (=
CertificateMetaInfo)
            Content (= CertificateContent)
            Signature

CertificateMetaInfo ::= META-INFO-TYPE
                        TLV-LENGTH
            ContentType (= KEY)
            FreshnessPeriod (= ?)


CertificateContent ::= CONTENT-TYPE
                       TLV-LENGTH
            CertificateDerPayload
```

```
// DER Encoding
CertificateDerPayload ::= SEQUENCE {
    validity            Validity,
    subject             Name,
    subjectPubKeyInfo   SubjectPublicKeyInfo,
    extension           Extensions OPTIONAL   }

Validity ::= SEQUENCE {
    notBefore           Time,
    notAfter            Time   }

Time ::= CHOICE {
    GeneralizedTime   }

Name ::= CHOICE {
    RDNSequence   }

RDNSequence ::= SEQUENCE OF
                RelativeDistinguishedName

RelativeDistinguishedName ::=
    SET OF AttributeTypeAndValue

SubjectPublicKeyInfo ::= SEQUENCE {
    algorithm           AlgorithmIdentifier
    keybits             BIT STRING   }

Extensions ::= SEQUENCE SIZE (1..MAX) OF
               Extension
```

Implementation Abstractions

- Signing: KeyChain
  - manages identities, keys, certificates
  - signs Data and Interest packets
    - selects (requested) private key
    - assigns (requested) KeyLocator
  - consists of
    - TPM (Trusted Platform Module)
      - "Secure" storage for private keys
      - `SecTpmOsx, SecTpmFile`
    - PIB (Publickey Info Base)
      - Storage for public part of identities, keys, and certificates
      - `SecTpmSqlite3`
- Validation: Validator
  - Interface for Interest and Data packet validation
  - `ValidatorNull, ValidatorRegex, ValidatorConfig`

- Signature abstraction follow NDN-TLV definitions
  - Generic Signature
  - Specialized signature classes
    - RSA
    - ECDSA
    - SHA256
- When signing, signature type automatically selected
  - certificate name for RSA, ECDSA
  - special reserved name for SHA256
    - /localhost/signature/DigestSha256




```
Signature ::= SignatureInfo
              SignatureBits

SignatureInfo ::= SIGNATURE-INFO-TYPE TLV-LENGTH
                    SignatureType
                    KeyLocator?
                    ... (SignatureType-specific TLVs)

SignatureValue ::= SIGNATURE-VALUE-TYPE TLV-LENGTH
                    ... (SignatureType-specific TLVs and
                    BYTE+
```

Value	Reference	Description
0	*DigestSha256*	Integrity protection using SHA-256 digest
1	*SignatureSha256WithRsa*	Integrity and provenance protection using RSA signature over a SHA-256 digest
3	*SignatureSha256WithEcdsa*	Integrity and provenance protection using an ECDSA signature over a SHA-256 digest
2,4-200		reserved for future assignments
>200		unassigned

Signing

- http://named-data.net/doc/ndn-cxx/0.2.0/tutorials/security-library.html#signing
- Same process for Data and Interest* packets
- Differe

```
KeyChain keyChain;

// Application selects specific key/certificate
keyChain.sign(packet, signingCertificateName);
```

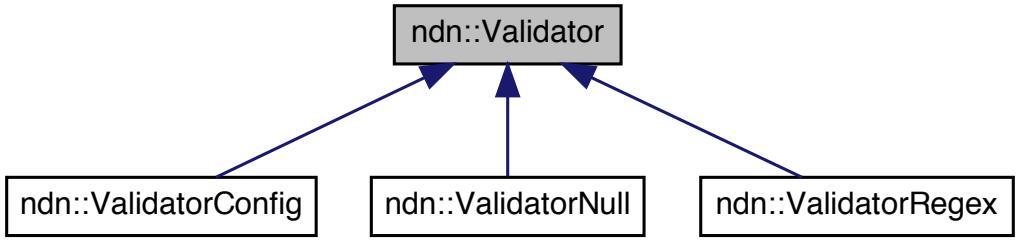
```
// Application selects specific identity
// Key/certificate for the identity is configured by user
keyChain.signByIdentity(packet, signingIdentity);
```

```
// Application uses user-configured key/certificate
keyChain.sign(packet);
```

*http://named-data.net/doc/ndn-cxx/current/tutorials/signed-interest.html

Data and Interest Validation

- http://named-data.net/doc/ndn-cxx/0.2.0/tutorials/security-library.html#validation
- Two-part Validation
  - Check if key is authorized to sign Data/Interest
    - name of the key matches Data/Interest name based on some rule
    - until reaching a trust anchor or step limit
  - Check signature validity
- Application defines when to do when packet is received
  - Either manually or using "Validator"-derived class



  - ValidatorNu
  - ValidatorRegex
    - compile-time defined "rules" and trust anchor
  - ValidatorConfig
    - run-time defined "rules" and trust anchors

ValidatorRegex

- http://named-data.net/doc/ndn-cxx/current/doxygen/dd/df5/classndn_1_1ValidatorRegex.html
- Compile-time configuration
  - Set of NDN regular expression rules
  - Set of trust anchors
  - Lifetime of trusted certificate cache
  - Limit on certification chain depth

```
Face face;
ValidatorRegex validator(face);

// Hierarchical Trust Anchor
IdentityCertificate anchor = ...;
validator.addTrustAnchor(anchor);

// Hierarchical Trust Rules
SecRuleRelative rule(
  // Extract authority namespace from data
name
  "(<>*)",
  "\\1",
  // Extract authority namespace from key
name
  "(<>*)<KEY><ksk-.*><ID-CERT><>$",
  "\\1",
  // Key's authority namespace must be
parent of data's namespace
  ">"));

validator.addRule(rule);
```

Configuration File Based Validator

- http://named-data.net/doc/ndn-cxx/0.2.0/tutorials/security-validator-config.html
- Compile-time configuration
  - Lifetime of trusted certificate cache
  - Limit on certification chain depth
- Run-time configuration (configuration file)
  - Set of NDN regular expression rules
  - Set of trust anchors

```
; One or more "rule"
rule
{
  id "<id>"
  for data ; or  "for interest"

  ; Apply the rule only for packet that
match the filter
  filter
  {
     ...
  }

  ; Make a decision of valid/invalid
based on the checker configuration
  checker
  {
     ...
  }
}

; One or more "trust-anchor"
trust-anchor
{
  ...
}
```

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Naming Conventions

- Namespace design is a critical component of application development.
- *"Where possible, put it in the name"* philosophy is expressing some packet requirements / features in the name.
- Three areas covered here
  - Scope control obeyed by NFD: /localhost, /localhop
  - Signed interest format
  - Versioning, segmenting, etc.

Scope Control

- http://redmine.named-data.net/projects/nfd/wiki/ScopeControl

- **`/localhost`**

  Limits propagation to the applications on the originating host.
  It is equivalent to Scope=1.

- **`/localhop`**

  The localhop scope limits propagation to no further than the next node.
  It is equivalent to Scope=2.

Versioning and Segmenting

- Technical Report #22, “Naming Conventions”
- **Marker** (Platform v0.3) vs. **Hierarchy**-based encoding (Platform v.0.4 targeted)
- Segmenting
  - Cut large data (e.g. video frame) into packet-sized pieces
  - Final segment indicated by MetaInfo FinalBlockID
  - appendSegment/toSegment, appendSegmentOffset/toSegmentOffset
- Versioning
  - Data packet is immutable: a new version needs a new name
  - Suggest millisecond time stamp but not required
  - appendVersion/toVersion
- Time-stamping
  - When data packet was produced
  - Microseconds since January 1, 1970
  - appendTimestamp/toTimestamp
- Sequencing
  - Sequential items in a collection
  - 0, 1, … X. Assume item X + 1 may be produced
  - appendSequenceNumber/toSequenceNumber

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Current research approach

- Storage in the network: a fundamental concept for NDN
- For now, particular app requirements may drive performance needs and features
- Explore diverse implementations
  - Expect 4-5 repo implementations this year
- Repo-ng is initial tool in platform, with protocol described here.

Repo-ng

- http://redmine.named-data.net/projects/repo-ng/wiki/Repo_Protocol_Specification
- **Basic Repo Insertion Protocol**
  insertion of a single or collection of Data packets.
- **Watched Prefix Insertion Protocol**
  a protocol to insert continuously generated data for a given namespace
- **TCP Bulk Insert Repo Insertion Protocol**
  a simple TCP-based protocol to insert Data packets in bulk
  (e.g., from a producer on the same host)
- **Repo Deletion Protocol**
  deletion of a single or collection of Data packets under certain prefix
- Signed interest-based.

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NDN Platform Goals

- **Provide a coherent, usable, and well-documented "platform" for exploring NDN in practical applications – for the NDN project team and external users.**

- Use a release "heartbeat" to stimulate interoperability testing and discussion of how the various moving parts work together.

- Along the way, improve access to and consistency of various NDN code projects.

- Open and lightweight process, with no unrealistic centralization or over-management but clear ownership of each component project.

- Managed nodes on the testbed run the Platform.

NDN Platform 0.1 (Aug 2013)

- NDNx – Team fork of CCNx
  - C API support only, no Java, limited Android support
  - Include NDNLP
  - Break in API compatibility with CCNx
- NDN-CCL – Common Client Libraries
  - ndn-cpp, ndn-js, PyNDN
  - Naming conv change for Interest/ContentObject?
- NDN on Node
- ndnSIM v.5 – Simulator
- NDN Network Tools – ping, ndndump
- Package manager support – Macports

NDN Platform 0.3 (August 2014)

- **NFD** NDN Forwarding Daemon, version 0.2.0 (1)
- **ndn-cxx** library, version 0.2.0
  - The NDN C++ library with eXperimental eXtensions (CXX)
  - The ndnsec security tools to manage security identities and certificates
- **NDN-CCL** - NDN Common Client libraries suite, version 0.3
  - NDN-CPP C++ / C library
  - PyNDN2 Python library
  - NDN-JS JavaScript library (with Node.js support)
  - jNDN Java library (preliminary)
- **NLSR** - Named Data Link State Routing Protocol , version 0.1.0
- **repo-ng** - next generation of NDN repository , version 0.1.0
- **ndn-tlv-ping** - ping application for NDN , version 0.2.0
- **ndn-traffic-generator** - traffic generator for NDN , version 0.2.0
- **ndndump** - packet capture and analysis tool for NDN , version 0.5

- Partial binary package support on Ubuntu, MacOS X, others…

Supported platforms

- Required
  - Two most recent Ubuntu LTS releases with the gcc which comes with apt, both 32-bit* and 64-bit, 2GB memory
  - Latest three OS X releases with the clang which comes with XCode, 64-bit, 2GB memory
- Optional
  - Latest Ubuntu release (if not LTS) with the gcc which comes with apt, 64-bit, 2GB memory
  - Latest Windows with Visual Studio, 64 bit, 2GB
  - Latest FreeBSD "RELEASE" with the clang which comes with ports, 64 bit, 2GB memory

http://named-data.net/codebase/platform/documentation/ndn-platform-development-guidelines/#Build_support

Licensing

- GPLv3 applications (mostly)
- LGPLv3 libraries
- Open and cost-free

Community support

- One Github repo for all code
- Public redmine
- Per-component wiki
- Code review
- Continuous integration
- Technical reports (NFD, NDN-CCL, etc.)
- Mailing lists

Open to contributors and collaborators!

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- *Briefly, what's next?*
- *Where to find things*

What's next

"A few years of designing and developing prototype applications on NDN has revealed five key areas of application research that map to important features of the architecture:

(1) namespaces;

(2) trust models;

(3) in-network storage;

(4) data synchronization;

(5) rendezvous, discovery, and bootstrapping."

- NDN Tech Report #19, 2014

Also, see Tech Report #17 for ideas on API evolution.

Where to find things

http://named-data.net

http://github.com/named-data

http://named-data.net/doc/NFD/
http://named-data.net/doc/NLSR/
http://named-data.net/doc/ndn-cxx/
http://named-data.net/codebase/platform/ndn-ccl/

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