NDNts API Design

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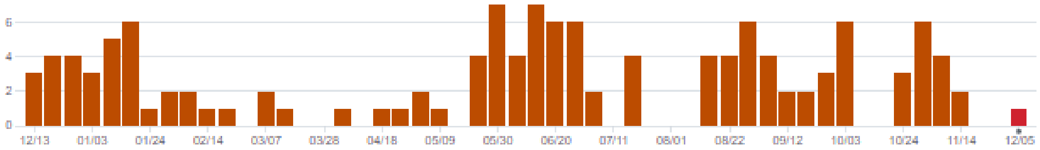
(NDNts is a personal project; this talk reflects personal opinions)

https://yoursunny.com/p/NDNts/

NDNts: NDN Libraries for the Modern Web

- Modern JavaScript libraries.
- Works in Node.js and browsers.
  - >90% test coverage.
  - Automated & manual browser tests on desktop / Android / iOS.
- Standalone without forwarder.
  - Or connect to NFD / NDN-DPDK.
- Actively maintained.



  - New features added regularly.
  - Support latest NDN specs.

What this talk is about

- My personal thoughts on NDN **low-level** API design.
  - ✓ Low-level: packet decoding, fragmentation, "face", retransmission logic, etc.
  - o Not low-level: "data centric toolkit", "common name library", etc.

- The unique challenges in building an NDN library for the web.
  - Code size is a primary concern.
  - The browser is like an OS, but it differs from a traditional OS.

Low-Level API is boring?

- Probably true.
  - Application developers are encouraged to use the high-level APIs, which abstracts NDN complexity away from the applications.
- Interacting with low-level API is unavoidable.
  - Developers who build high-level APIs would have to use low-level API.
  - High-level APIs do not cover all possible application needs.
- Therefore, it's still important to design a good low-level API.

Opportunities of NDNts

- NDNts is not the first library. I'm rarely the first to implement a feature. Instead, I prefer to:
    1. Write applications with the existing libraries.
    2. Look at how other developers are using the existing libraries.
    3. Feel the pain points of the existing libraries.
        - Which APIs are cumbersome to use?
        - Which code snippets are copy-pasted in multiple places because it's not in the library?
    4. Improve those areas in NDNts.
- NDNts is a personal project, so I can have the freedom.
    - I don't promise backwards compatibility.
    - I take my time to refactor, without worrying about deadlines.
    - I ask people to watch my push-ups over NDN testbed and collect metrics to improve NDNts congestion control implementation.

TLV Decoding

with TLV evolvability considerations

Example: NLSR LsaInfo structure

```
LsaInfo = LSA-TYPE TLV-LENGTH
          Name
          SequenceNumber
          ExpirationTime
```

NDN spec: **considerations for evolvability of TLV-based encoding**

- If the decoder encounters an unrecognized or out-of-order element, the behavior should be as follows:

TLV-TYPE number	expected behavior
0~31	abort decoding and report error
least significant bit is 1	abort decoding and report error
least significant bit is 0	ignore TLV element and continue decoding

NDNts: semi-declarative

```
const EVD = new EvDecoder<Lsa>("LsaInfo", 0x80)
  .add(TT.Name, (t, { value }) => t.originRouter = new Name(value))
  .add(0x82, (t, { value }) => t.sequenceNum = NNI.decode(value, { big: true }))
  .add(0x8B, (t, { text }) => t.expirationTime = text);
```

Evolvability-aware TLV decoder (EvDecoder)

1. Declare each sub-TLV via `.add()` function.
2. Decode each sub-TLV with a lambda function.
   - It may include extra logic, such as saving signed portion boundary.
3. EvDecoder automatically handles evolvability considerations.

ndn-cxx: procedural

```
m_originRouter.clear();
m_seqNo = 0;

ndn::Block baseWire = wire;
baseWire.parse();

auto val = baseWire.elements_begin();

if (val != baseWire.elements_end() &&
    val->type() == tlv::Name) {
  m_originRouter.wireDecode(*val++);
} else {
  throw Error("OriginRouter: Missing required Name field");
}
```

```
if (val != baseWire.elements_end() &&
    val->type() == tlv::SequenceNumber) {
  m_seqNo = readNonNegativeInteger(*val++);
} else {
  throw Error("Missing required SequenceNumber field");
}

if (val != baseWire.elements_end() &&
    val->type() == tlv::ExpirationTime) {
  m_expirationTimePoint =
    time::fromString(readString(*val++));
} else {
  throw Error("Missing required ExpirationTime field");
}
```

- This decoding function does not support TLV evolvability.

python-ndn: declarative, reflection-based

```
class LsaInfo(TlvModel):
    originRouter = NameField()
    sequenceNum = UintField(0x82)
    expirationTime = BytesField(0x8B, is_string=True)
```

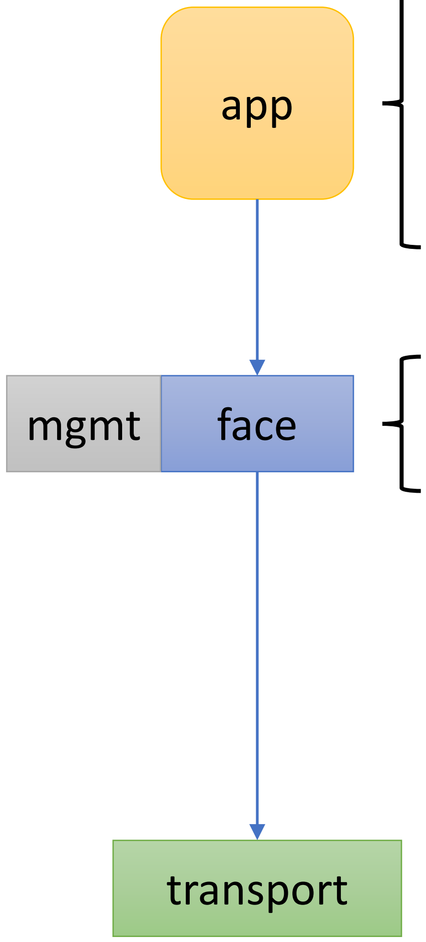
✓Shorter than NDNts.

- Less flexible: cannot easily add extra logic.
- Class structure must follow TLV structure:
  - Application is exposed to encoding details.

Not yet in NDNts, but it's a direction to explore.

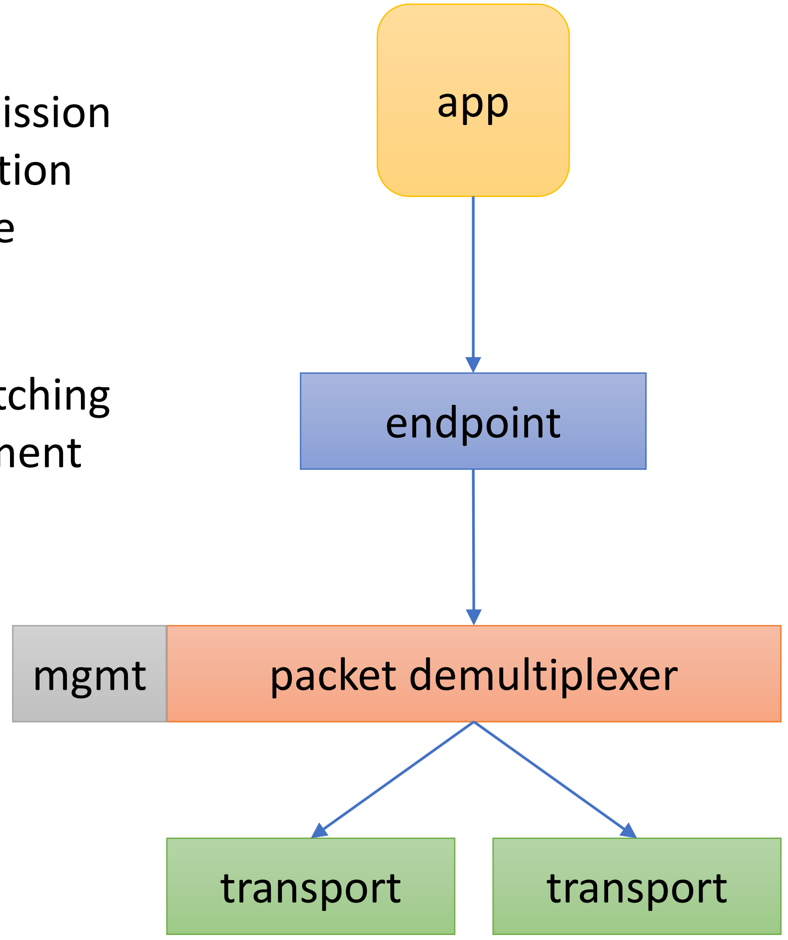
Endpoint, a better "face"

Traditional "face" vs NDNts Endpoint



handles manually:
- transport errors
- Interest retransmission
- signing & verification
- InMemoryStorage

✓ Interest-Data matching
✓ prefix announcement



❖ focus on application logic

Consumer:
✓ Interest retransmission
✓ Data verification

Producer:
✓ prefix announcement
✓ Data buffering
✓ Data signing

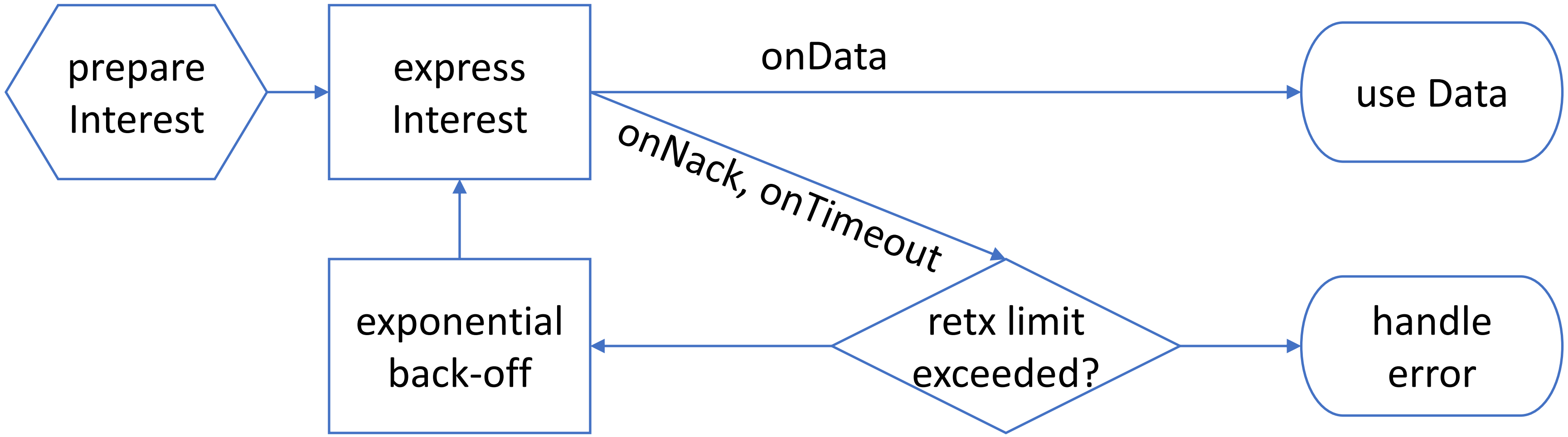
✓ multiple uplinks
✓ connect to other NDNts apps
✓ connect to forwarders
✓ connect to IoT gadgets
✓ automatic reconnecting

Consumer: Interest retransmissions

- NDNts: enable Interest retransmissions with one option.

```
try {
  const data = await endpoint.consume(interest, { retx: 2 });
  /* use retrieved Data */
} catch { /* handle retrieval error */ }
```

- Other libraries: developer implements this flowchart manually.



Producer: Data buffering

- Use case: prepare a multi-segment response to one Interest.
  - Example: NFD management protocol dataset publisher.
- NDNts: automatic Data buffering.
  - Insert multiple Data packets to the buffer.
  - Subsequent Interests are satisfied from the buffer automatically.

```
endpoint.produce("/prefix", async (interest, { dataBuffer }) {
  if (interest.name.at(-1).as(Segment) === 0) {
    /* generate all segments */
    await dataBuffer.insert(seg0, seg1, seg2);
  }
});
```

- Other libraries: developer queries InMemoryStorage for every Interest.

Data signing & verification

- NDNts: automatically sign outgoing Data and verify incoming Data.

```
const endpoint = new Endpoint({
  dataSigner: signer,
  verifier: verifier,
});
```

- Both signer and verifier can be either:
  - a fixed key, or
  - a trust schema that chooses a key based on Data packet name.

- Other libraries: developer calls KeyChain & Validator manually.

Code size is a primary concern on the Web

Every KB of code must be downloaded over the network.

- Visitors expect the webpage to load within 5 seconds "time to interactive".
- Code size budget: 170KB minified & gzipped.

How I'm solving this problem in NDNts?

- Reduce core features that are always loaded.
- If an app needs an extra feature, import the module and pay the cost:

```
const endpoint = new Endpoint({
  dataBuffer: new DataBuffer(new DataStore(memdown())),
});
```

- Trade-off between API simplicity and webpage performance.

Transport support matrix

- ● built-in
- * proxy or plugin
- ○ planned

libraries				protocol	forwarders and more			
ndn-cxx	python-ndn	NDNts (Node.js)	NDNts (browser)		NFD	YaNFD	NDN-DPDK	esp8266ndn (ESP32)
●	●	●		Unix socket	●	●		
		●		memif			●	
				Ethernet	●	●	●	●
		●		UDP	●	●	●	●
●	●	●		TCP	●	●		
		●	●	WebSocket	*	●		
	○		●	HTTP/3	*	○		
		○	○	WebRTC				
	*		●	Bluetooth				●

KeyChain & Crypto

KeyChain: Web Crypto & IndexedDB

```
const keyChain = KeyChain.open("homecam");

const [pvt, pub] = await generateSigningKey(keyChain, subjectName);

const cert = await requestCertificate({
  profile: caProfile,
  publicKey: pub,
  privateKey: pvt,
  validity: ValidityPeriod.MAX,
  challenges: [new ClientNopChallenge()],
});

await keyChain.insertCert(cert);
```

open IndexedDB for storing keys and certificates

generate non-extractable keys via Web Crypto API and store in IndexedDB

request a certificate from a remote certificate authority, using NDNCERT (NDN certificate management protocol)

save the received certificate

Web Crypto requires Secure Context

- Webpage must be delivered over HTTPS to use Web Crypto.
  - Required by Web Crypto spec.
  - Enforced in Chrome.
  - Not enforced in Firefox.
- Why bother with plain HTTP?
- "Coffee shop hotspots" are still popular in less developed countries.
  - The locals are sharing files and chatting over those hotspot networks.
  - No Internet, no DNS, cannot obtain trusted TLS certificates.
- NDNts security features will not work in this environment.

Web Crypto has limited algorithms

- ✓SHA-256
- ✓ECDSA, ECDH
- ✓RSA PKCS#1, RSA-OAEP
- ✓AES-CBC, AES-GCM
- ✓PBKDF2
- o BLAKE2b, required in Pollere DCT
- o EdDSA, required in Pollere DCT
- o AES-CCM, an option of FLIC rev03
- o ChaCha20-Poly1305, an option of ndn-ind

Despite being an option, if an existing application chooses an algorithm, NDNts needs to have the algorithm to be able to interoperate with that app.

Alternatives to Web Crypto

- asmcrypto.js and other JavaScript crypto libraries
- Rust crypto compiled as WebAssembly module

- Drawbacks:
  - Code size concerns.
  - Keys are unprotected (vs. non-extractable keys in Web Crypto).
  - No effective way to cleanse memory.
- Drawbacks, when delivered over plain HTTP:
  - Code can be modified by MITM attacker, completely compromising security.
  - Lack of secure random number generator.

- So far, NDNts is limited to Web Crypto only.

Naming a Browser

"Name is the secret sauce of NDN"

Naming a browser for anonymous users

```
await generateSigningKey(keyChain, subjectName);
```

Where does this name come from?

- My current webapps use random names:
  1. Generate a random identity name during the first visit.
  2. Request a certificate and store it in the KeyChain.
  3. Reuse the same identity name during subsequent visits.
  4. Start over if the certificate expires or the KeyChain is deleted.
- This only works for anonymous users.

Naming a browser with user authentication

- Username+password / "Email me a magic link".
  - Obtains a short-lived certificate from a server-controlled CA.
- OpenID / OAuth / WebAuthn, but do it over NDN.
  - Interacts with a downloadable or self-hosted "NDN authenticator" app, which contains a user-controlled CA.
- User experience must be streamlined.
  - Visitors do not care whether the webpage is using NDN.

Start Coding with NDNts

- NDNts homepage: https://yoursunny.com/p/NDNts/
- Getting Started tutorials on yoursunny.com blog
- API documentation available in Visual Studio Code IDE

- NDN Play https://play.ndn.today
  - Web simulator for NDN, built with NDNts