Reflexive Forwarding Update

https://datatracker.ietf.org/doc/draft-oran-icnrg-reflexive-forwarding/05/

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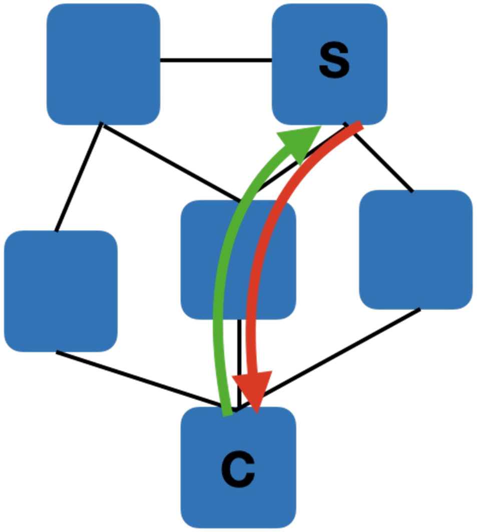
Recap: Motivation

- Many scenarios benefit from ICN's robust and secure two-way exchange through INTEREST/DATA
- There are other scenarios though where that is not sufficient
  - RESTful communication, e.g., Web over ICN
  - Remote Method Invocation
  - Phone-home scenarios
  - Peer state synchronization
- Desirable features
  - Pushing Data
  - RESTful-like session continuation
- Our goal: enable these scenarios in an ICN-idiomatic way
  - As a foundation for the scenarios above and more
  - Most relevant (probably): RESTful ICN



Design Overview - Recap

- Utilize forwarder state established by Interest sent from consumer to producer
  - Allow for not just a returning Data message, but a *Reflexive* Interest to flow from producer to the unique consumer who sent the original Interest
- Define a scheme for *Reflexive Name Prefixes*
  - Can only be seen and understood by already established consumer/producer pairing
  - Do not reveal consumer identity (temporary names within the RI context)
- Provide forwarder mechanism for routing these back to consumer from producer
- Couple state of the original Interest/Data exchange with the reflexive exchange(s)
  - Ensure state gets mapped correctly by both consumer and producer
  - And unwound properly at forwarders when Data message responding to original Interest is sent back

Current Status

- Version -05 just published
- Addresses comments, especially really helpful ones from Hitoshi Asaeda (see next slide for changes)
- Can review changes via issues recorded on Github (https://github.com/daveoran/draft-oran-icnrg-reflexive-forwarding/issues)

Changes in -05

- Cleaned up terminology
  - Fixed confusion about Reflexive name Component/Segment and Reflexive Name Prefix TLV
  - Added a terminology section
- Fixed the protocol ladder diagram labeling
- Fixed IANA Registry references and instructions
- Bunches of small editing changes for clarity of exposition

Next Steps?

- NICT has expressed interest in doing an implementation based on their *Cefore* CCNx forwarder.
- Adopt as ICNRG draft?
  - Need lots of eyes and opinions by ICNRG participants on this, as the chairs are the co-authors.

That’s about it. Questions & Comments?

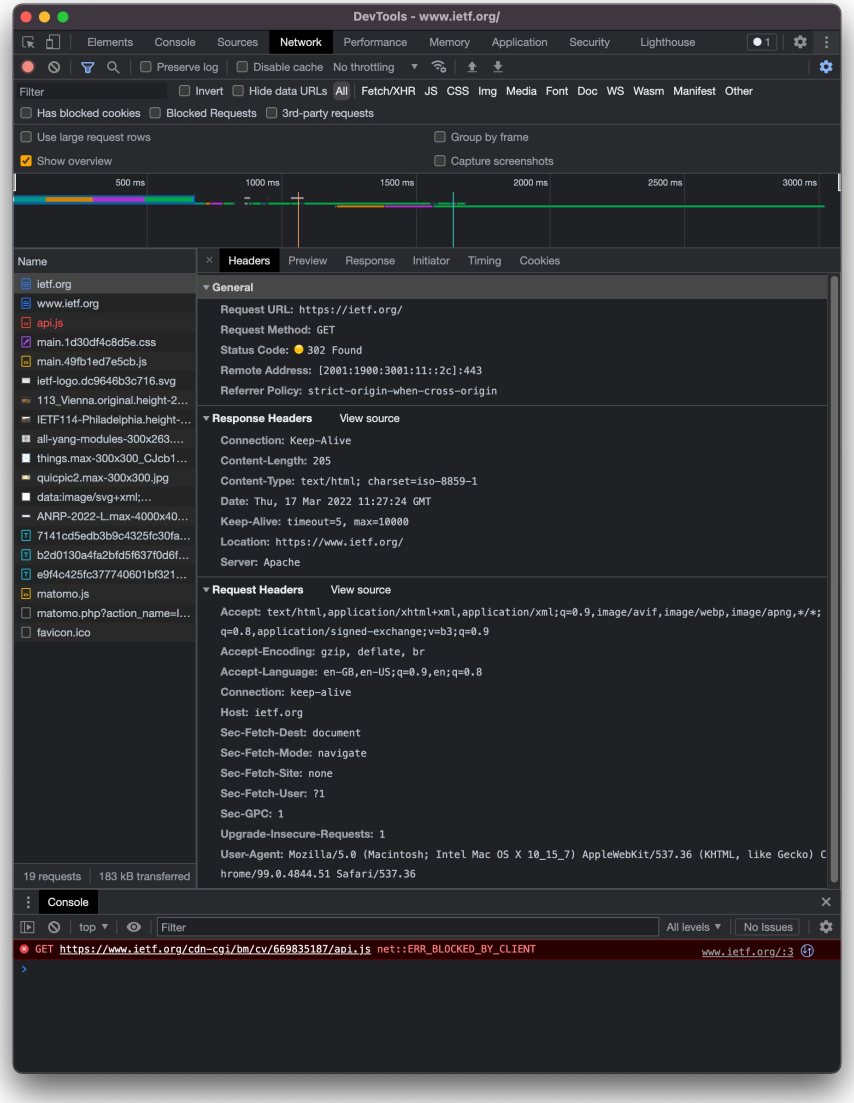
Please review and comment on the Latest draft!!!

Backup Slides

Application Layer Interactions

- Web
  - RESTful communications: series of requests in session context – through representational state transfer
  - Considerable request sizes: header fields, cookies, input data (GET, PUT, POST)

- Remote Method Invocation
  - Authentication/authorization info
  - Potentially really large input parameters – think “map-reduce”



☐ Preserve log ☐ Disable cache No throttling

☐ Invert ☐ Hide data URLs

☐ Has blocked cookies ☐ Blocked Requests ☐ 3rd-party requests

☐ Use large request rows ☐ Group by frame

☑ Show overview ☐ Capture screenshots

```
ietf.org
www.ietf.org
api.js
main.1d30df4c8d5e.css
main.49fb1ed7e5cb.js
ietf-logo.dc9646b3c716.svg
113_Vienna.original.height-2…
IETF114-Philadelphia.height-…
all-yang-modules-300x263.…
things.max-300x300_CJcb1…
quicpic2.max-300x300.jpg
data:image/svg+xml;…
ANRP-2022-L.max-4000x40…
7141cd5edb3b9c4325fc30fa…
b2d0130a4fa2bfd5f637f0d6f…
e9f4c425fc377740601bf321…
matomo.js
matomo.php?action_name=l…
favicon.ico

19 requests | 183 kB transferred
```

```
▼ General
  Request URL: https://ietf.org/
  Request Method: GET
  Status Code: ● 302 Found
  Remote Address: [2001:1900:3001:11::2c]:443
  Referrer Policy: strict-origin-when-cross-origin
▼ Response Headers     View source
  Connection: Keep-Alive
  Content-Length: 205
  Content-Type: text/html; charset=iso-8859-1
  Date: Thu, 17 Mar 2022 11:27:24 GMT
  Keep-Alive: timeout=5, max=10000
  Location: https://www.ietf.org/
  Server: Apache
▼ Request Headers     View source
  Accept: text/html,application/xhtml+xml,application/xml;q=0.9,image/avif,image/webp,image/apng,*/*;
  q=0.8,application/signed-exchange;v=b3;q=0.9
  Accept-Encoding: gzip, deflate, br
  Accept-Language: en-GB,en-US;q=0.9,en;q=0.8
  Connection: keep-alive
  Host: ietf.org
  Sec-Fetch-Dest: document
  Sec-Fetch-Mode: navigate
  Sec-Fetch-Site: none
  Sec-Fetch-User: ?1
  Sec-GPC: 1
  Upgrade-Insecure-Requests: 1
  User-Agent: Mozilla/5.0 (Macintosh; Intel Mac OS X 10_15_7) AppleWebKit/537.36 (KHTML, like Gecko) C
  hrome/99.0.4844.51 Safari/537.36
```

Console

top ▼ Filter All levels ▼ No Issues

```
✖ GET https://www.ietf.org/cdn-cgi/bm/cv/669835187/api.js net::ERR_BLOCKED_BY_CLIENT     www.ietf.org/:3
>
```

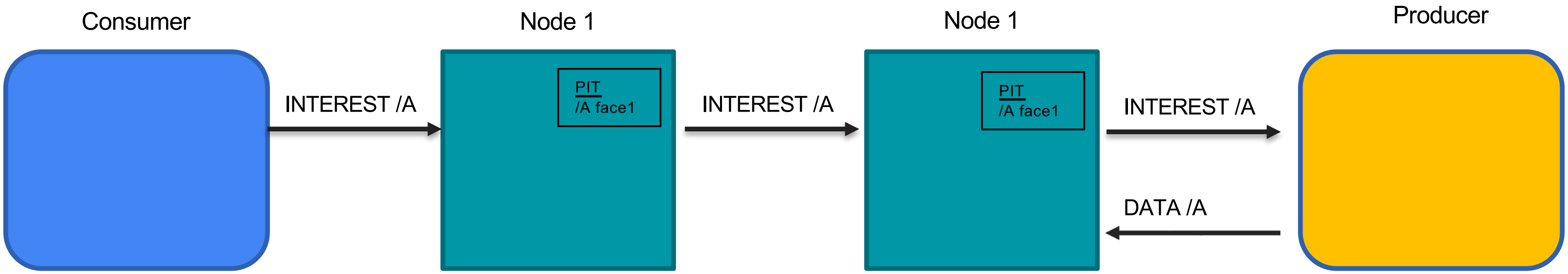
Motivations for multi-way Handshakes

- Remote Method Invocation (RMI, aka RPC)
  - Fetch arguments
  - Perform authorization
  - Separate invocation from results return

- Phone-home for sensor/actuators
  - Fetch from gateway rather than push from device
  - Eliminate polling

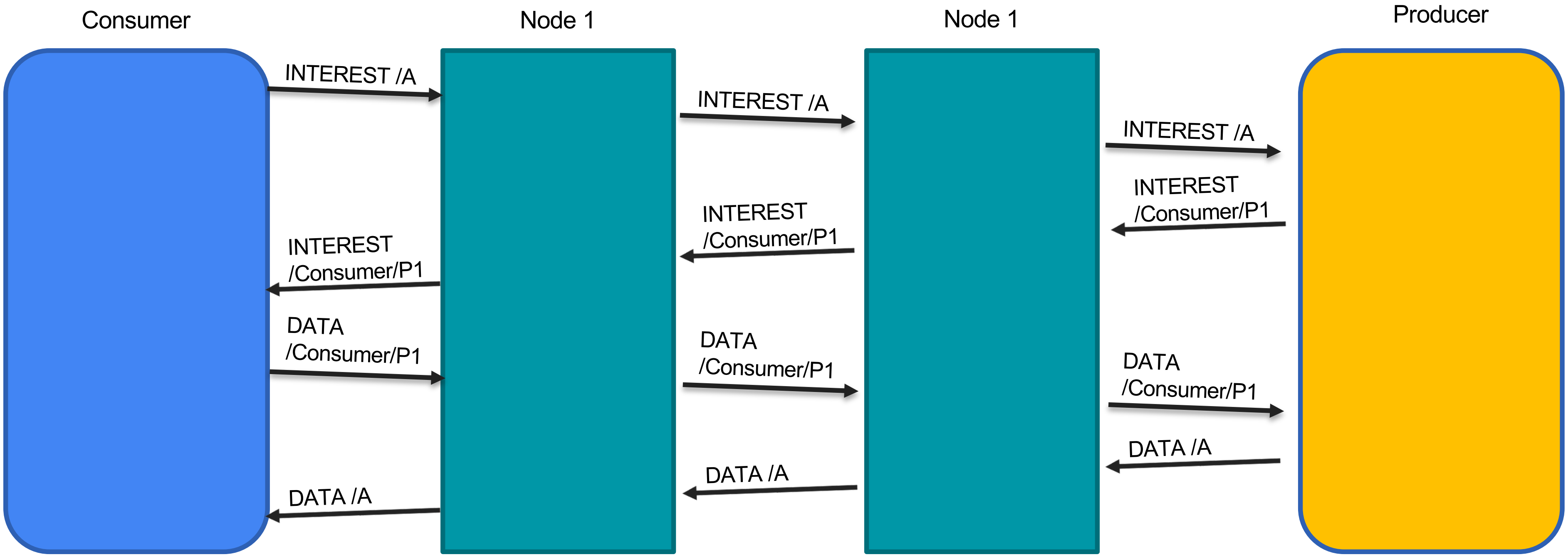
- Peer State Synchronization
  - 3-way (or more) handshakes needed to avoid hazards
  - Complicated state machines for things needing negotiation (e.g. SIP/SDP)

Requests parameters in INTEREST messages?



- Large input data – not advisable
  - Flow balance
  - Computional overload attacks (server has to process arbitrary client data…)
  - Extra state on forwarders
  - Potential INTEREST fragmentation

Reverse INTEREST for Parameters to Consumer?



- Would require consumer identity (disclosure) with routable prefix
  - Not idiomatic in ICN (no source addresses/names)
  - Consumer mobility much harder
  - Potential reflection attacks (consumer can provide arbitrary “paramter prefix”)
- Correlating two independent INTEREST/DATA exchange complicates state machine on both sides
  - Catastrophic if done wrong for key exchange

Outline

- Motivations for multi-way interactions in ICN
- Problems with existing approaches.
- Overview of the Reflexive Forwarding design
- Use Cases for reflexive forwarding
- If time available:
  - Implementation implications
  - Operational considerations
  - Security and Privacy considerations

Problems with Existing approaches: Pushing Data

- Interest messages get big
  - Might need fragmentation (ugh!)
  - Messes up assumption of small(ish)interests for congestion control
- Need to sign interests for pushed data to be believed
  - Bigger interest still
  - Computational cost on producer to check signature
- Wasted bandwidth if computation started by pushed data winds up abandoned

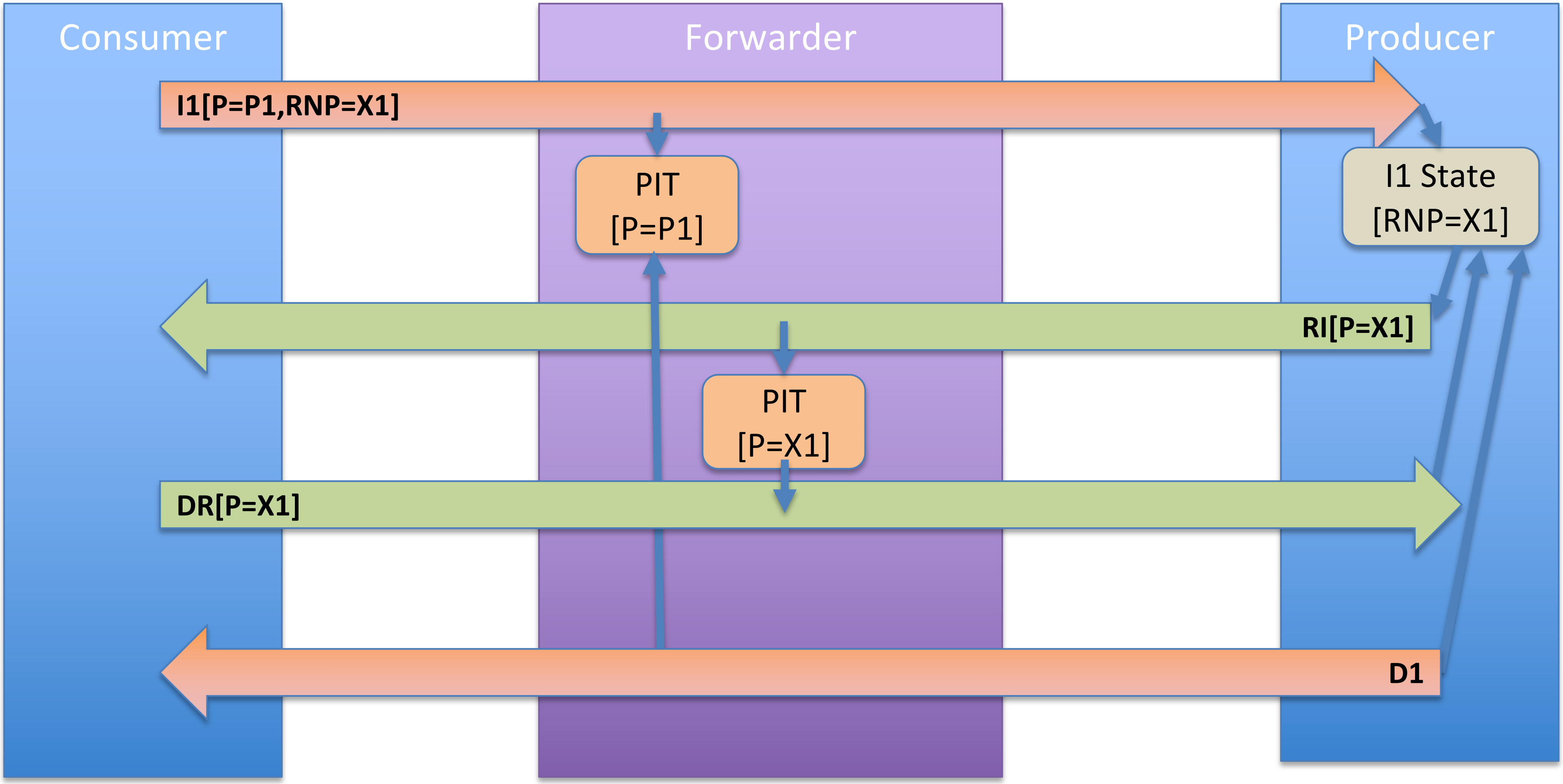
Problems with Existing approaches: Independent Exchanges

- Consumer needs a routable name prefix
  - Exposes consumer to unwanted traffic
  - Puts burden on routing to propagate far enough to reach producer
  - In mobile environments, consumer becomes producer as well, necessitating producer mobility machinery for pure client-initiated client/server exchanges
- Consumer gets to choose the name to use to reach it by
  - Opens up big hole to mount reflection attacks
- Correlating the two independent Interest/Data exchanges can be error-prone
  - Catastrophic if done wrong for key exchange
  - Complicated state machine management (c.f. SIP & SDP)

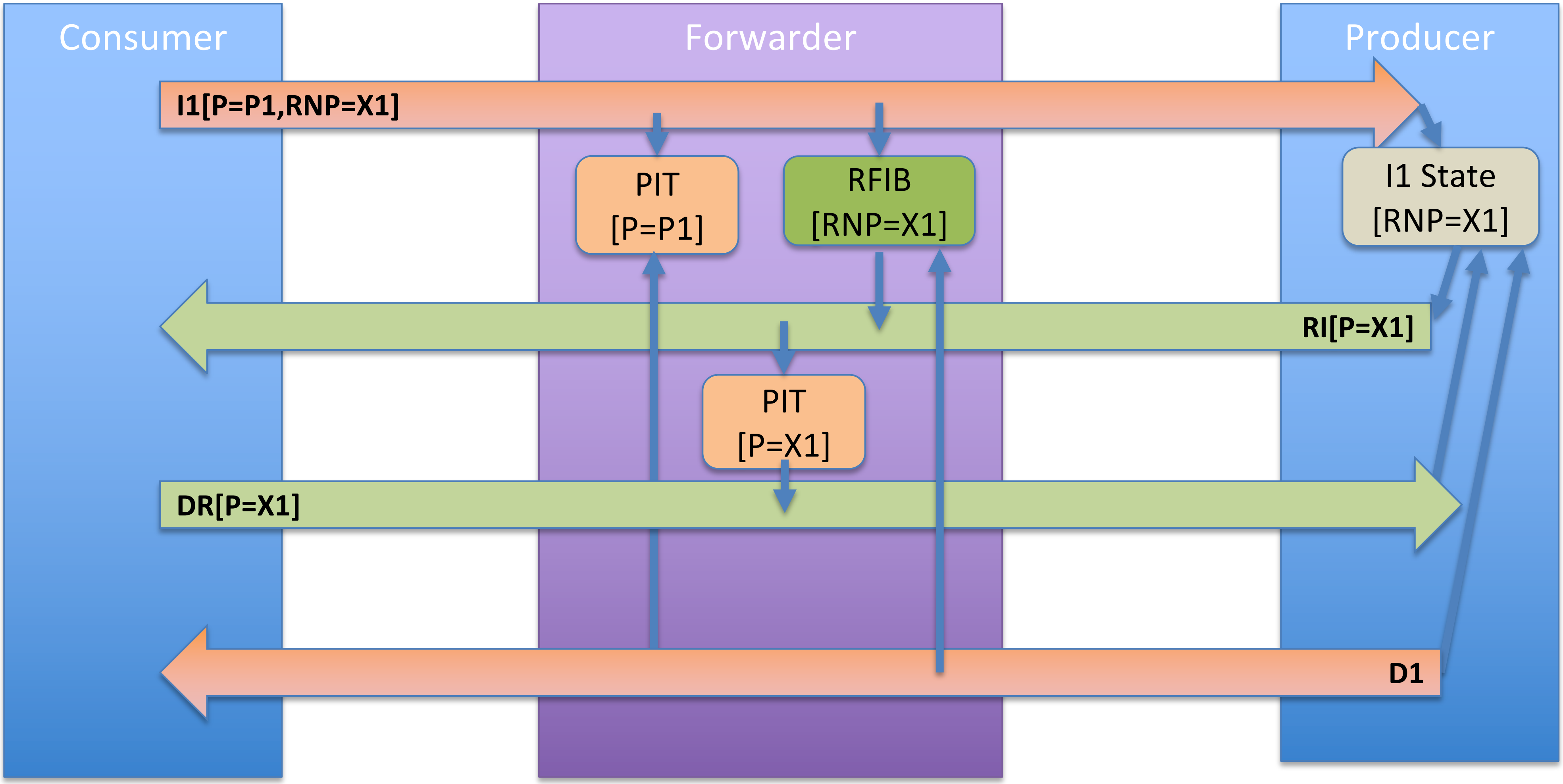
Design Overview

- Utilize forwarder state established by an Interest sent from consumer to producer
  - Allow for not just a returning Data message, but a *Reflexive* Interest to flow from producer to the unique consumer who sent the original Interest
- Define a scheme for *Reflexive Name Prefixes*
  - These can only be seen and understood by the already established consumer/producer pairing
  - They do not reveal consumer identity (temporary names within the RI context)
- Provide a forwarder mechanism to allow routing these back to the consumer from the producer
- Couple the state of the original Interest/Data exchange with the reflexive exchange(s)
  - ensure state gets mapped correctly by both consumer and producer
  - and unwound properly at the forwarders when the Data message responding to the original Interest is sent back

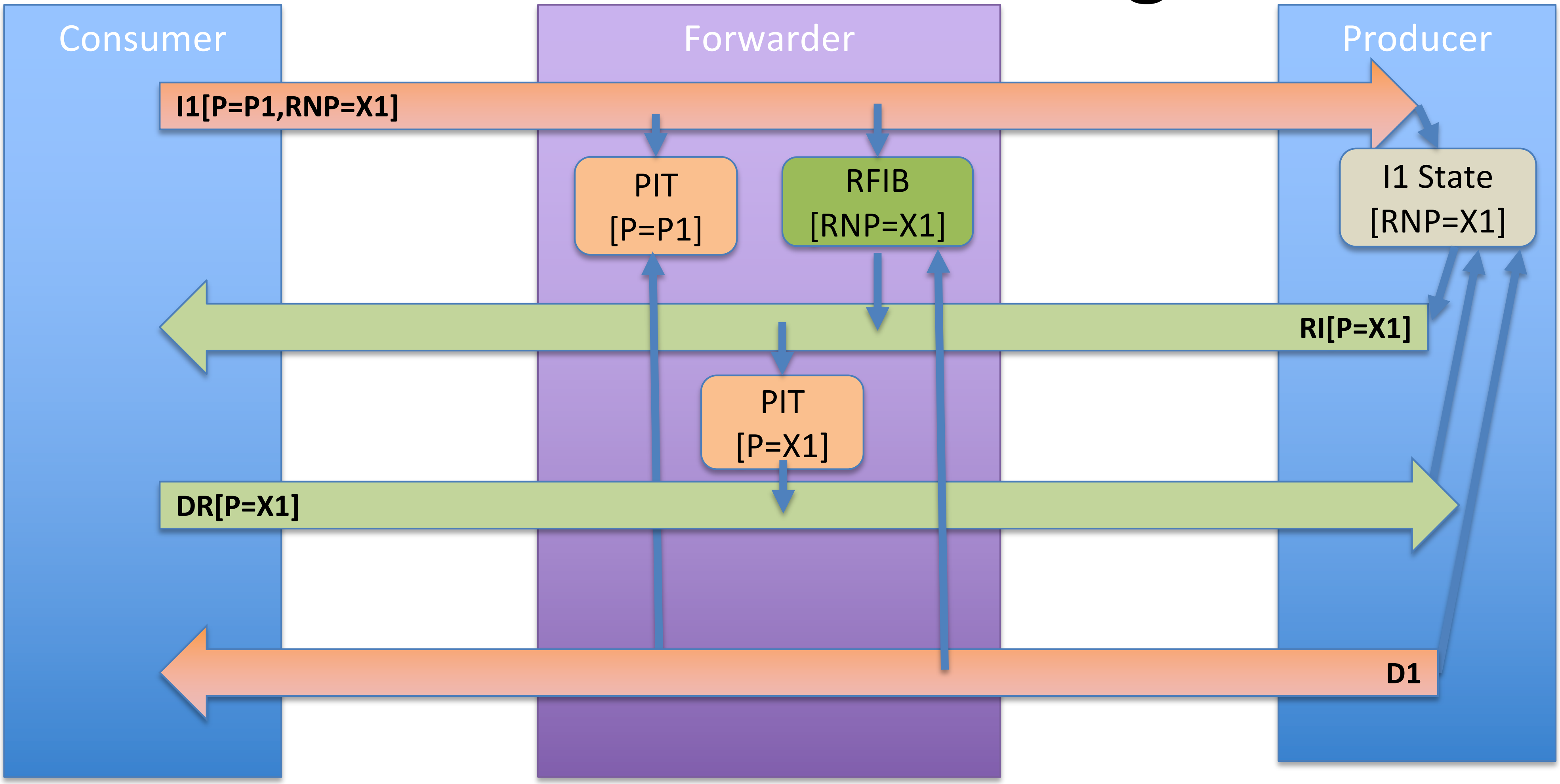
High-Level Protocol Overview



Previous Approach (version 01)

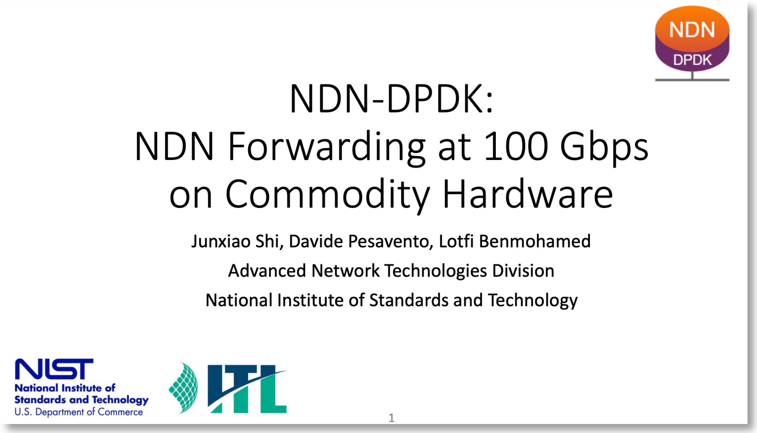


Protocol Walk-through



New Approach (version 02)

- PIT Tokens for reverse forwarding
  - Much more efficient PIT lookups
  - No special RFIB forwarder requirements
- Forward Direction PIT tokens (FPTs)
  - Attached to
    - Forwarded Interests in upstream direction
    - Forwarded Reflexive Interests in downstream direction
- Reverse Direction PIT tokens (RPTs)
  - Attached to
    - Reflexive Interests in downstream direction
    - Data responses to Interests in both directions



NDN-DPDK:
NDN Forwarding at 100 Gbps
on Commodity Hardware

Junxiao Shi, Davide Pesavento, Lotfi Benmohamed
Advanced Network Technologies Division
National Institute of Standards and Technology

NIST National Institute of Standards and Technology U.S. Department of Commerce

ITL

NDN DPDK

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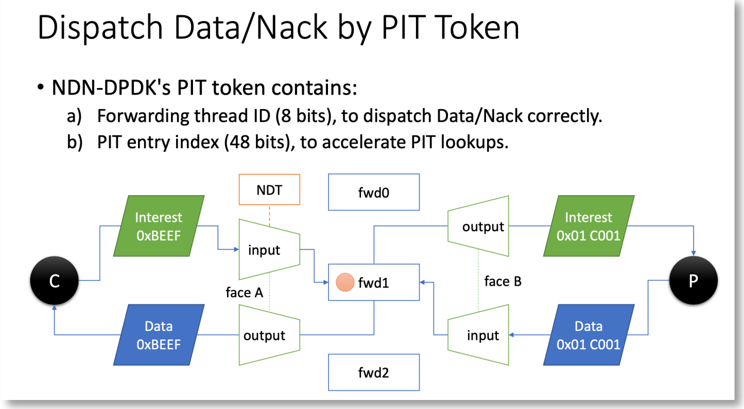
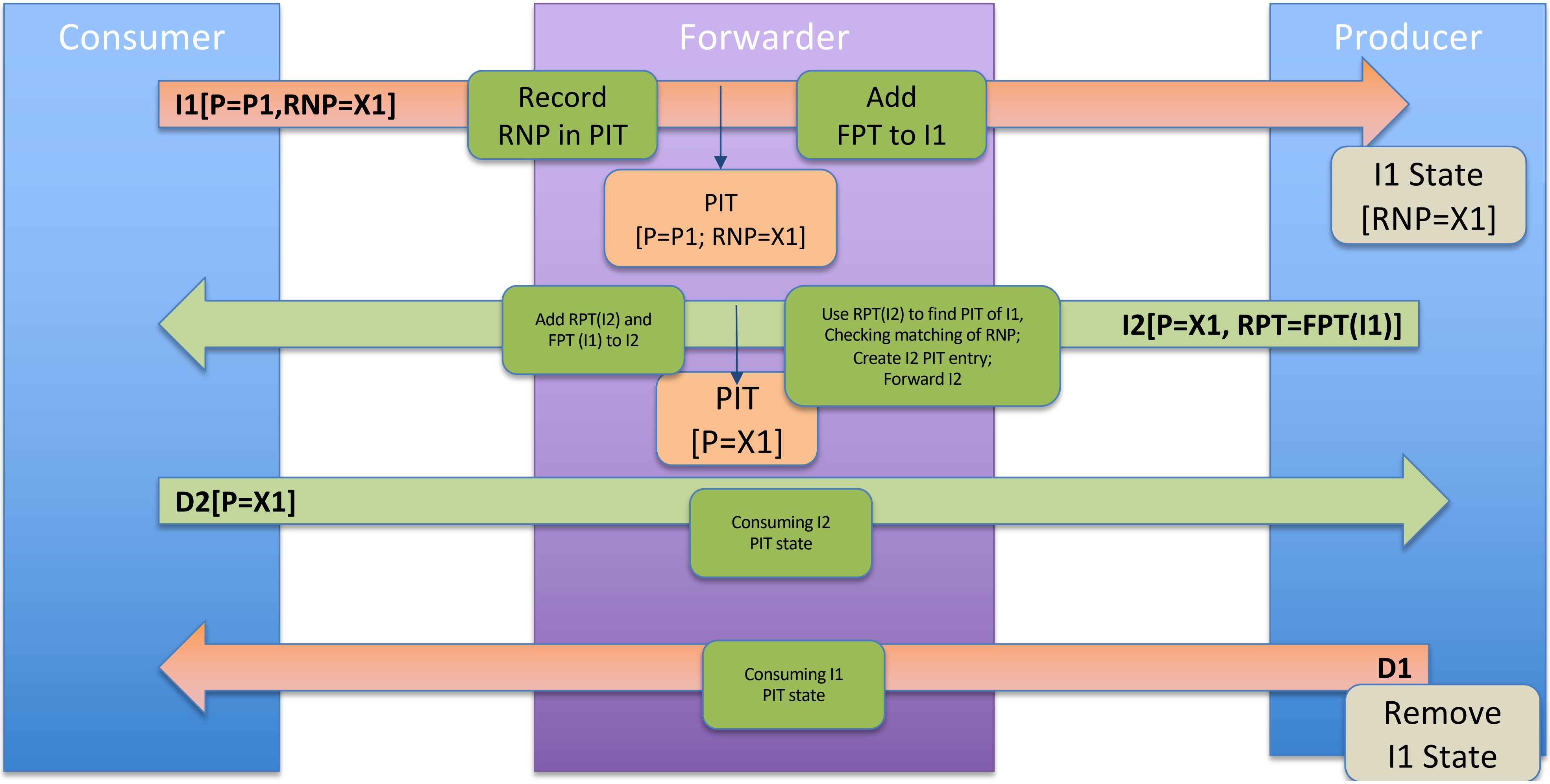


Dispatch Data/Nack by PIT Token

- NDN-DPDK's PIT token contains:
  a) Forwarding thread ID (8 bits), to dispatch Data/Nack correctly.
  b) PIT entry index (48 bits), to accelerate PIT lookups.

New Approach (version 02)



Consumer

Forwarder

Producer

I1[P=P1,RNP=X1]

Record
RNP in PIT

Add
FPT to I1

PIT
[P=P1; RNP=X1]

I1 State
[RNP=X1]

Add RPT(I2) and
FPT (I1) to I2

Use RPT(I2) to find PIT of I1,
Checking matching of RNP;
Create I2 PIT entry;
Forward I2

I2[P=X1, RPT=FPT(I1)]

PIT
[P=X1]

D2[P=X1]

Consuming I2
PIT state

Consuming I1
PIT state

D1

Remove
I1 State

Naming of Reflexive Interests

- New Name Component type for CCNx and NDN
  - High-order component of any reflexive name, used to form prefix
- Value is a 128-bit random number
  - Entropy to uniquely identify the consumer for duration of the exchange
  - Different value for each outer exchange limits linkability
  - UUID (RFC4122)
- Possible reflexive names that can be constructed:
  - A single full name of object to fetch
  - Prefix out of which producer/consumer name multiple objects
  - Full name of a FLIC Manifest

Forwarder Operation

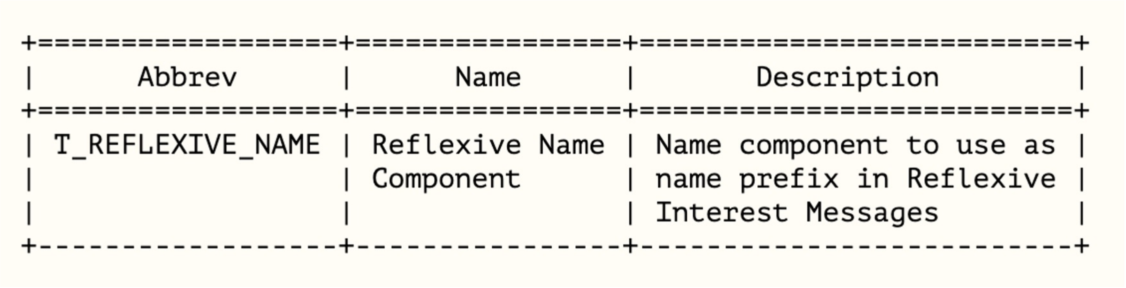
- Create and manage short-lifetime FIB entries for any reflexive name prefix from an incoming Interest.
- Query these FIB entries (and no others) if an Interest arrives whose first name component is of type Reflexive Name Prefix
- FIB entry consumed along with original PIT entry when the data message is returned by the producer
  - Could be removed lazily due to randomness properties of the values

New Node Behavior

- Consumer, Producers, Forwarders
- Forwarder modifications include PIT Token generation when receiving INTERESTs with Reflexive name prefix
- All modifications should be doable for high-performance and standard software-based forwarders
- Details in the draft

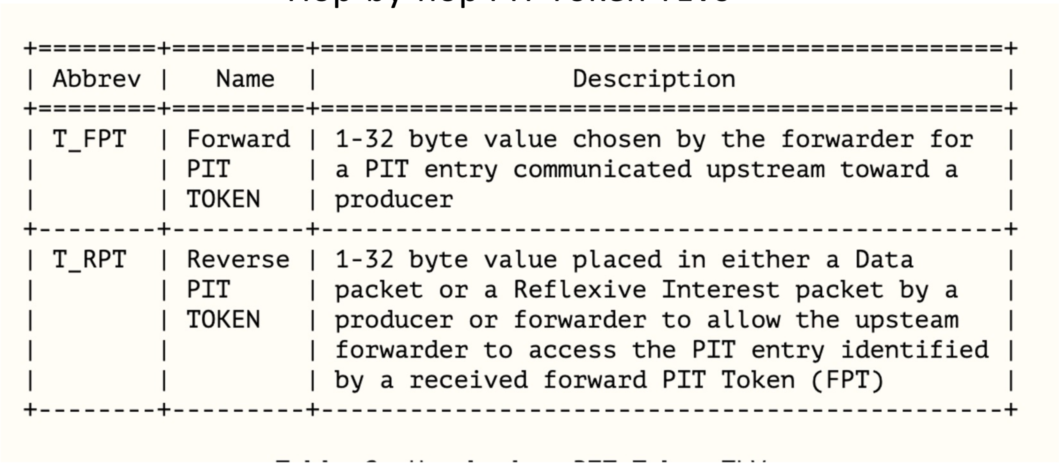
CCNx Encoding

Reflexive Name TLV



Abbrev	Name	Description
T_REFLEXIVE_NAME	Reflexive Name Component	Name component to use as name prefix in Reflexive Interest Messages

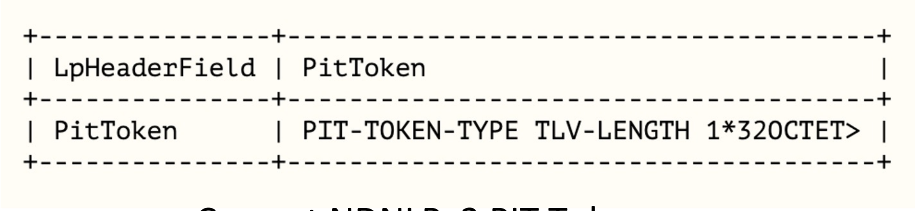
Hop-by-hop PIT Token TLVs



Abbrev	Name	Description
T_FPT	Forward PIT TOKEN	1-32 byte value chosen by the forwarder for a PIT entry communicated upstream toward a producer
T_RPT	Reverse PIT TOKEN	1-32 byte value placed in either a Data packet or a Reflexive Interest packet by a producer or forwarder to allow the upsteam forwarder to access the PIT entry identified by a received forward PIT Token (FPT)

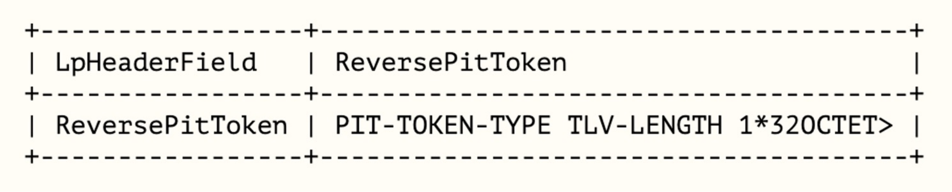
NDN Encoding

- Reflexive Name Component Type
  - Need a new component type (type RNP)
- Reflexive Name Prefix TLV
  - `RNP ::= | RNP-TYPE | TLV-LENGTH(=16) BYTE8)`
- PIT Tokens for NDNLPv2
  - Need additional type for reverse PIT token



```
+---------------+--------------------------------------+
| LpHeaderField | PitToken                             |
+---------------+--------------------------------------+
| PitToken      | PIT-TOKEN-TYPE TLV-LENGTH 1*32OCTET> |
+---------------+--------------------------------------+
```

Current NDNLPv2 PIT Token



```
+-----------------+--------------------------------------+
| LpHeaderField   | ReversePitToken                      |
+-----------------+--------------------------------------+
| ReversePitToken | PIT-TOKEN-TYPE TLV-LENGTH 1*32OCTET> |
+-----------------+--------------------------------------+
```

Proposed Reverse PIT Token

Typical Use Cases

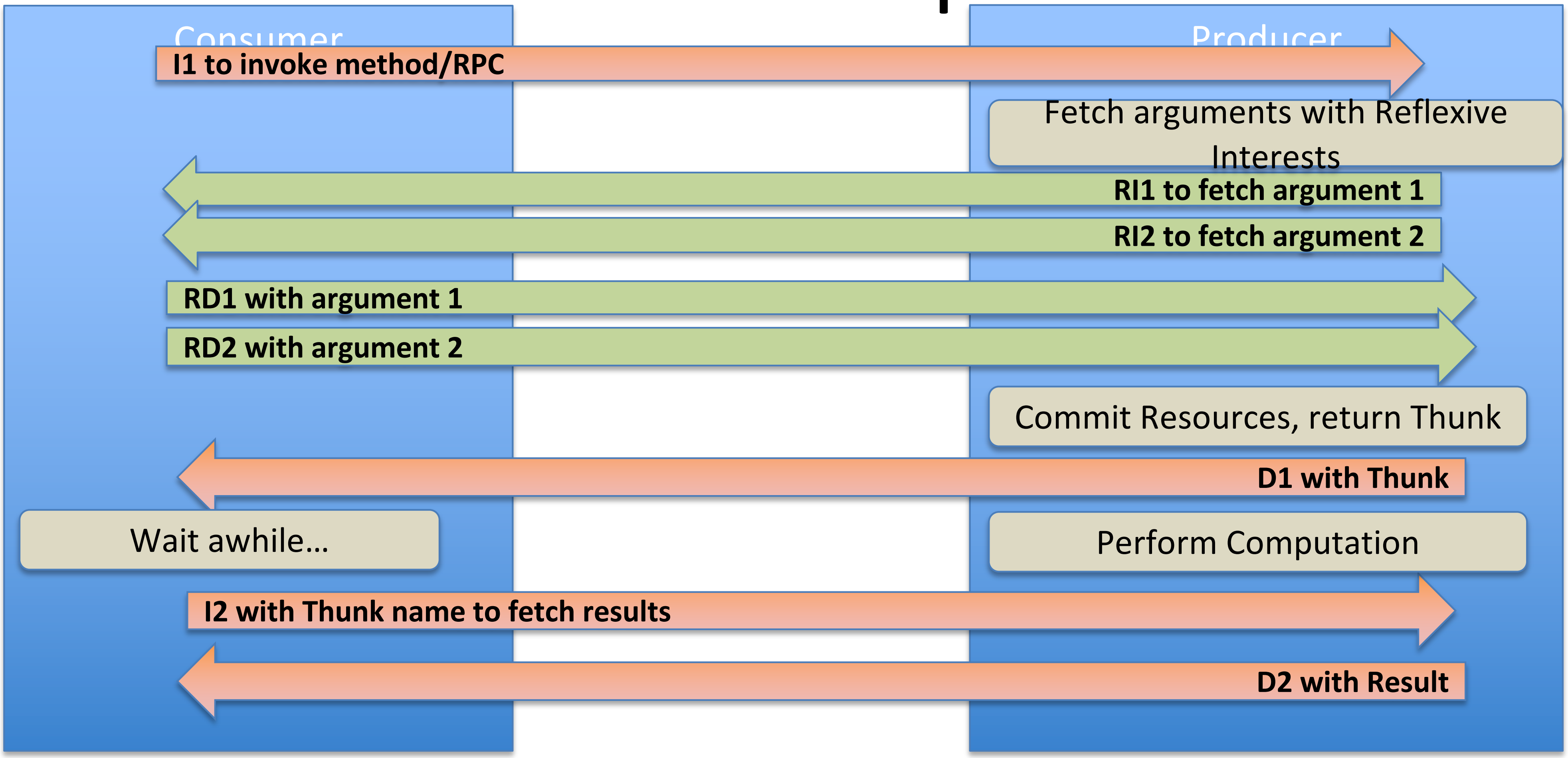
- Remote Method Invocation
- RESTful Web Interactions
- Data Pull from sensors

Remote Method Invocation

(Pioneered by RICE)

- RICE uses (an earlier version of) Reflexive Interests for the following:
  - Retrieve authentication/authorization information from consumer
  - Fetch arguments to method calls
- Completion can be either:
  - Immediate through the returning Data message, or
  - Deferred to a separate exchange to retrieve results buy utilizing *Thunks.*
- Illustrated on following slide

RMI Example



Consumer

Producer

I1 to invoke method/RPC

Fetch arguments with Reflexive Interests

RI1 to fetch argument 1

RI2 to fetch argument 2

RD1 with argument 1

RD2 with argument 2

Commit Resources, return Thunk

D1 with Thunk

Wait awhile…

Perform Computation

I2 with Thunk name to fetch results

D2 with Result

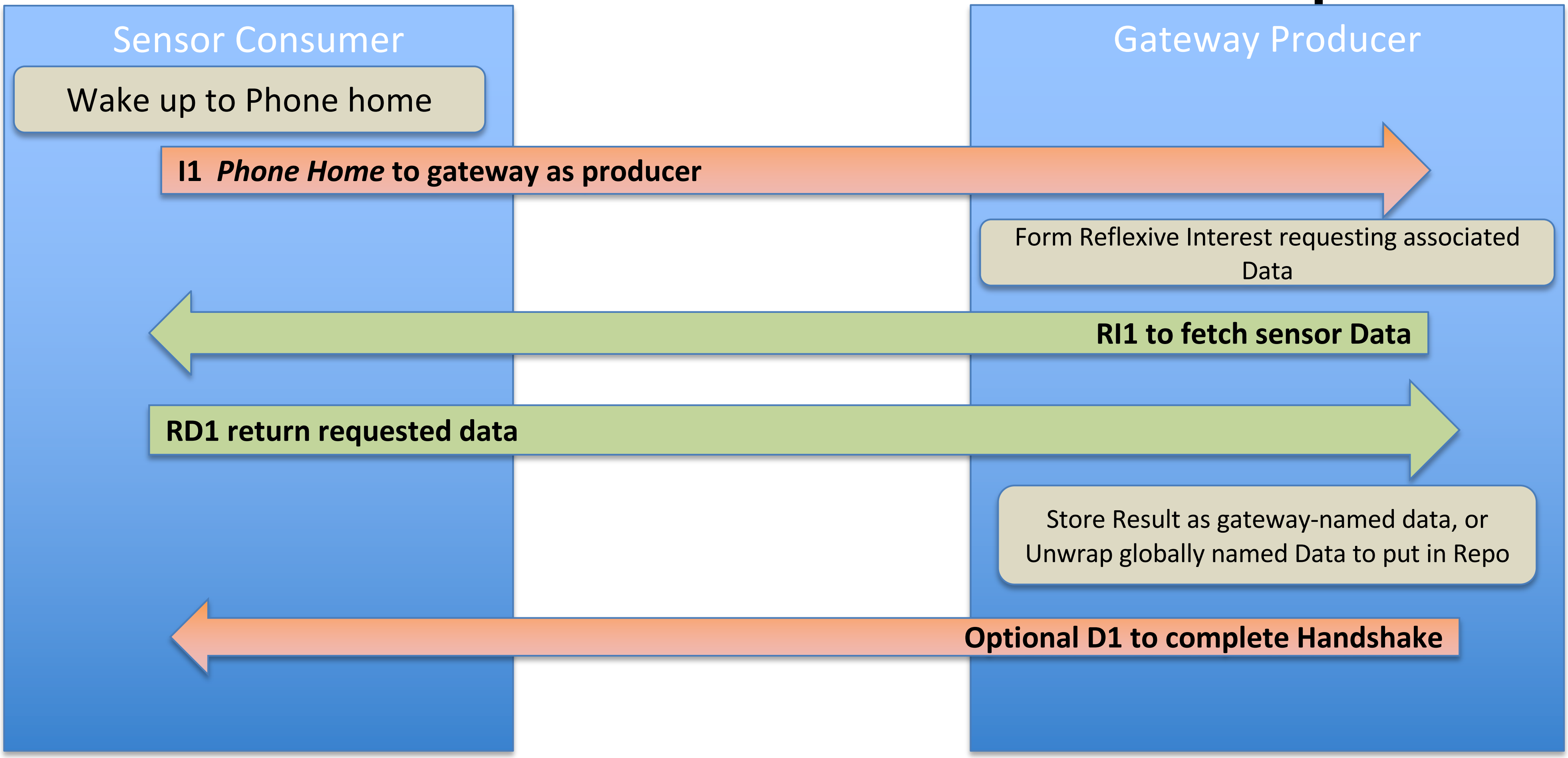
RESTful Web Interactions

- Only place RESTful request via the URI in the initial Interest
- Get all the parameters, including AuthZ with Reflexive Interests
  - Cookies, Accept-foo headers, other HTTP goop
- Return results via regular Data messages

Data Pull from sensors

- Sensor only needs to act as consumer
- Wake up (on timer or event)
- ”Phone Home” to an application gateway or REPO
- This provokes a Reflexive Interest/Data exchange initiated from the gateway
- Data can either be:
  - Packaged/stored by gateway as the authoritative source
  - Named, encapsulated and signed by sensor itself

Phone Home Data Pull Example



Sensor Consumer

Gateway Producer

Wake up to Phone home

I1 *Phone Home* to gateway as producer

Form Reflexive Interest requesting associated Data

RI1 to fetch sensor Data

RD1 return requested data

Store Result as gateway-named data, or Unwrap globally named Data to put in Repo

Optional D1 to complete Handshake

Operational Considerations

- This is **NOT** backward-compatible
  - Need an unbroken chain of forwarders that support reflexive forwarding or things don’t work right

- Possible ways to overcome this
  - Ignore the problem; let producers get a *no route* error if they try to send a reflexive interest. This is ugly:
    - how does producer figure out why no route
    - How does he tell consumer that original exchange has failed for this reason – may need a new interest return error
  - Bump the CCNx/NDN protocol version on Interests carrying Reflexive Name Prefix TLVs
    - key off this to send back an error from a back-version forwarder
    - Pretty big hammer!
  - Create a capabilities-exchange protocol so forwarders know capabilities of next hops
    - Lots of work, but we probably need such a thing anyway!

Security Considerations

- This scheme is partly motivated by trying to improve both Security and Privacy:
  - Avoids payloads in Interests that then have to be signed, with associated vulnerability to computational attacks on producers
  - Avoids routable names for consumers so they aren’t exposed to various crafted and flooding attacks
  - Avoids sending names crafted by consumers to producers, which can open up reflection attacks

Some things on Security to Consider

- Collisions of Reflexive Name prefixes
  - Avoid by using a crypto-quality PRNG
- Resource pressure on PIT
  - Interests carrying Reflexive Name prefixes are more slightly expensive in both compute and storage
- Privacy
  - Same concerns about leaking information via names as all other cases for CCNx or NDN
  - Use cases may have message exchange and timing patterns that allow easier linkability than independent exchanges

Outlook

- CCNx Key Exchange
- RESTful communication
- Information-Centric Web

- Multi-protocol cookie concept
  - Many protocols utilize “cookie” concept: key exchange, web etc.
  - Idea: minimize number of RTTs (think QUIC 0-RTT)
  - Provide way to integrate a “cookie map” in I1 Interest

Forwarder Operation (1)

1. Upon **receiving an Interest** containing a RNP TLV:
   - MUST record RNP as element of PIT entry for that Interest
2. When **forwarding an Interest** with RNP TLV:
   - MAY generate FPT and append it to the forwarded Interest to be processed by the next hop
3. If an Interest contains an RPT:
   - MAY use value to access corresponding PIT entry
   - or do a direct lookup based on the Reflexive Interest Name Prefix

Forwarder Operation (2)

1. MUST check that the high-order Name component of Interest is of type RNP
    - IF NOT, simply process the Interest as a normal non-reflexive Interest
    - ELSE treat as Reflexive Interest
        - Create a new PIT entry for the Reflexive Interest
        - Record the FPT (if any, as for other Interests)
        - Look up ingress face from originating Interest's PIT entry and forward the Reflexive Interest on this single face
            - Append RPT from the ingress face information of original Interest's PIT entry, if any
            - Append FPT TLV to Interest if forwarder requires downstream forwarder to supply an RPT in any returning Data packet for this Reflexive interest

Implementation: Forwarders

- Interest Input – sharded PITs can be tricky
  - Avoid cross-chard updates whebn handling reflexive interests, or
  - Force reflexive interests into same shard as original interest
- Interest Lifetime – extended by possibly multiple RTTs
  - Could be hard for consumer to guess a good value
    - Likely result is consumers grossly overestimating with bad effects when Interests can experience undetected loss
  - May need to have forwarder account for this by adjusting interest lifetime of original interest when reflexive interests arrive
- Interest Aggregation – actually this all works out without any changes
  - Like other Interest fields, **MUST** create separate PIT entry if Interests carry different reflexive name prefix values.

Implementation: Consumers

- Decide how to name data returned for an arriving reflexive Interest
  - Use a plain Data message if lifetime is just the enclosing enchange
  - Encapsulate a whole Data message with its own fullname if global visibility/lifetime is desired
- Set other fields appropriately for data useful within the enclosing exchange
  - Recommended cache time zero or small
  - Data expiry no longer than Interest lifetime of original interest
- Terminate unwanted reflexive Interest arrivals
  - Send a *Prohibited* Interest Return error
  - Forwarders with then wipe out the corresponding RFIB entry