An Evaluation of IPFS As A distribution Mechanism for RPKI Repository

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IPFS Primer

What

- A **peer-to-peer distributed** file system that seeks to connect all computing devices with the same system of files. [7]

Why

- Distributed over centralised systems
- Efficient Data Transfer
- Resiliency
- Permanence

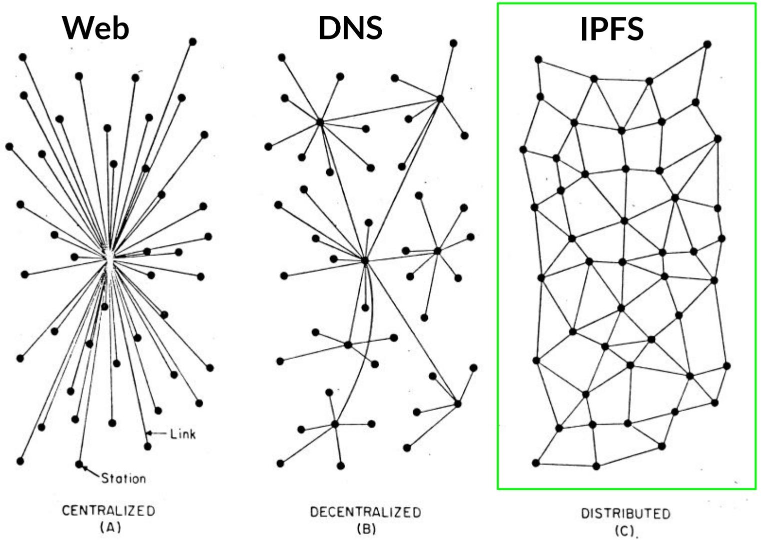


Fig. 1 - Centralized, Decentralized and Distributed Networks [1]

How

- Content Addressing
- InterPlanetary Linked Data (IPLD) formally Merkle DAG
- Distributed Hash Table (Kademlia)
- PKI based Identity

RPKI Primer

What

- Resource Public Key Infrastructure
- A PKI based approach to securing global internet routing
- Makes use of X509 certificates to prove ownership of Internet Number Resources (INR) - ASN, IPv4 and IPv6
- Owners of Internet Number Resources can make verifiable statement on how their resources can be used

Why

- Mechanism to make Internet routing more secure
- Border Gateway Protocol (BGP) has no inbuilt security
- Security is based on trust, which does not scale
- Leads to prevalent prefix hijacks and Misconfiguration mishaps

BGP without RPKI

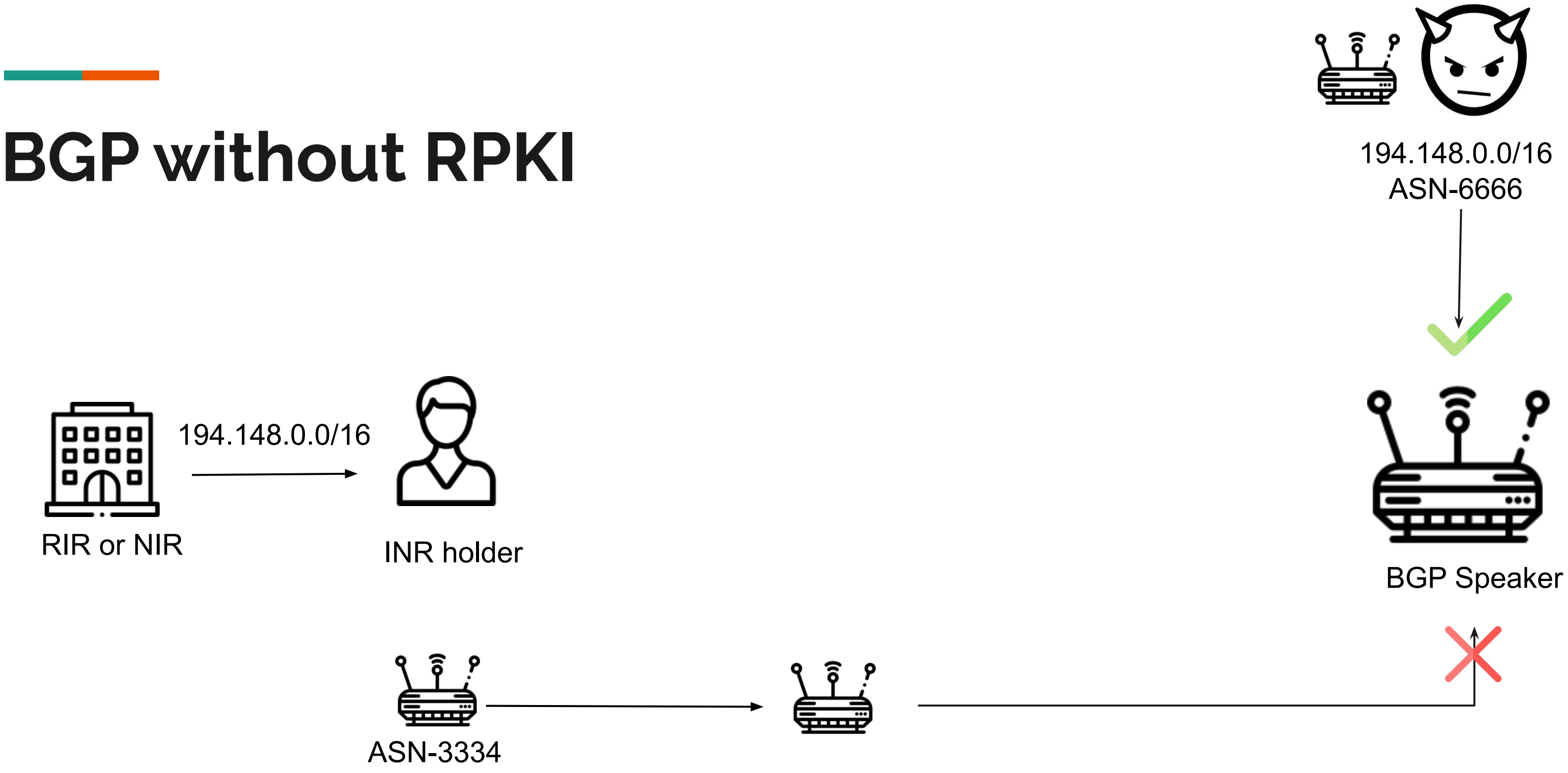


Fig. 2 - Prefix Hijacking in BGP

RPKI Primer

How

- Ties into the hierarchical resource allocation driven by Regional Internet Registry (RIR) and National Internet Registry (NIR)
- Resource is allocated to user, together with a resource certificate
- User creates Resource Origin Authorization (ROA)
- ROAs are published to publicly available repositories
- Relying Party (RP) downloads and creates Validated ROA Payload (VRP)
- BGP speakers uses VRP to make routing decision

BGP with RPKI

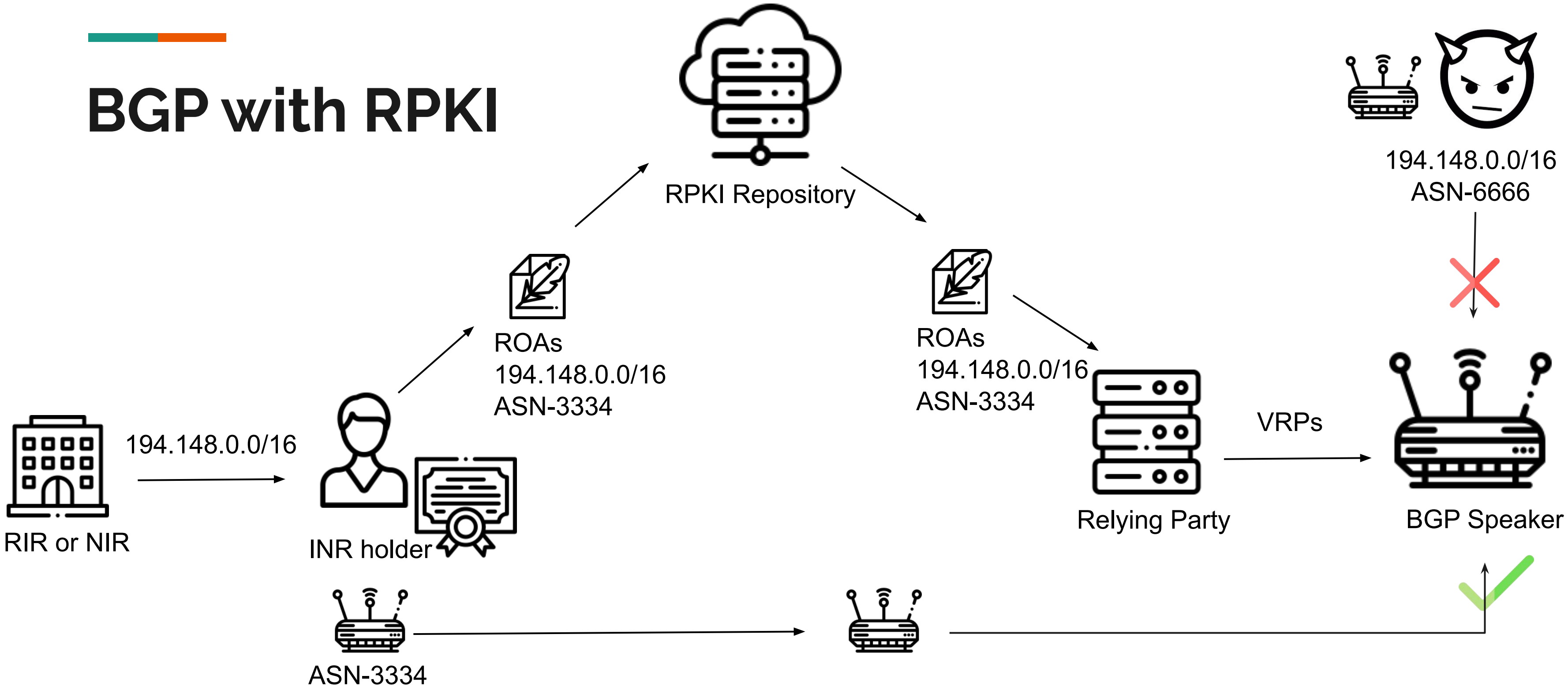
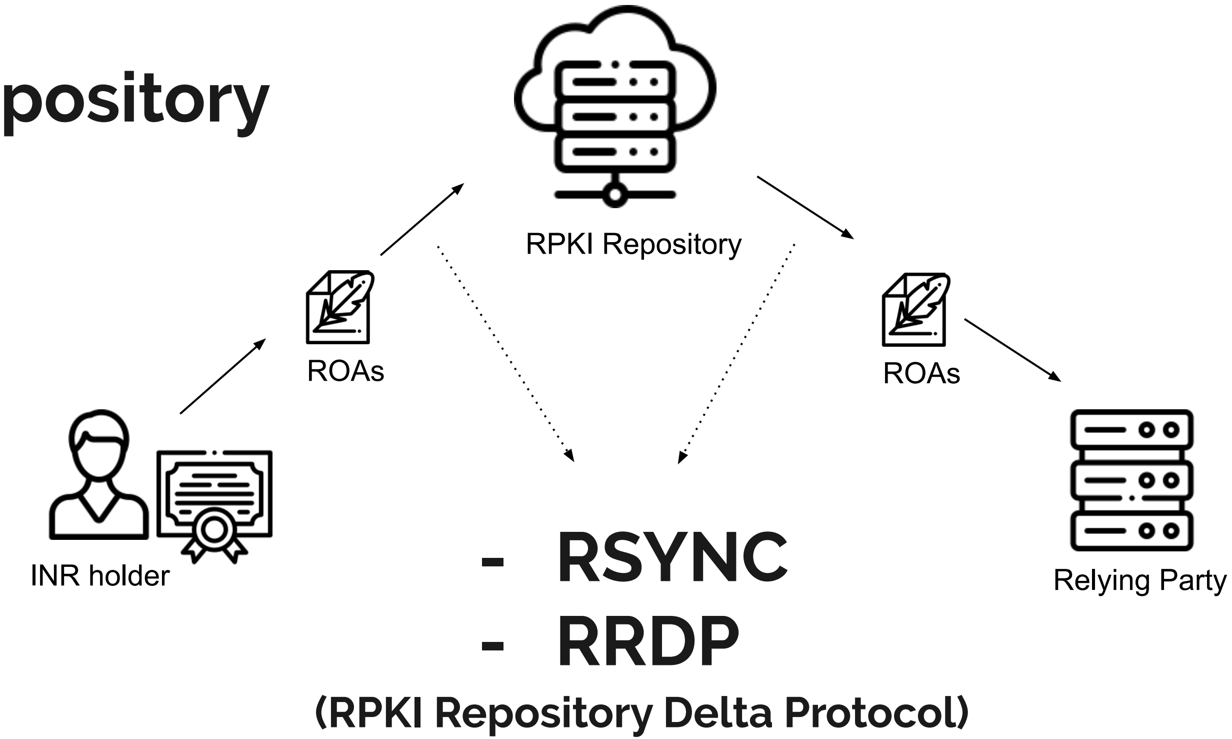


Fig. 3 - Preventing prefix hijacking with RPKI

RPKI Repository



RPKI Repository

ROAs

ROAs

INR holder

Relying Party

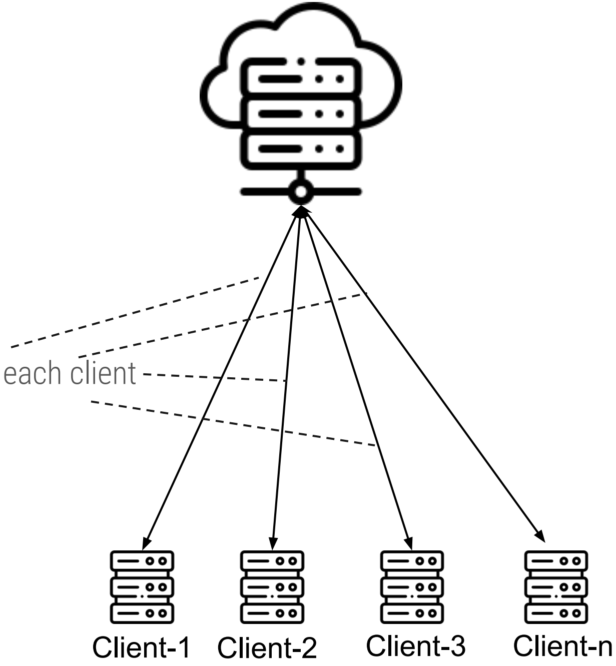
- RSYNC
- RRDP

(RPKI Repository Delta Protocol)

Fig. 4 - Publication components of RPKI

RSYNC Drawbacks

- Compute intensive.
- Lack of implementation library
- Atomic updates not guaranteed



Diff needs to be calculated for each client

Fig. 5 -RSYNC server and clients

RRDP Improvements

- Reduces computation resources by generating Delta files once and not at every request
- Guarantees atomic updates
- Takes advantage of CDN and Caching Infrastructure.
- Uses HTTPS which has both client and server library implementations

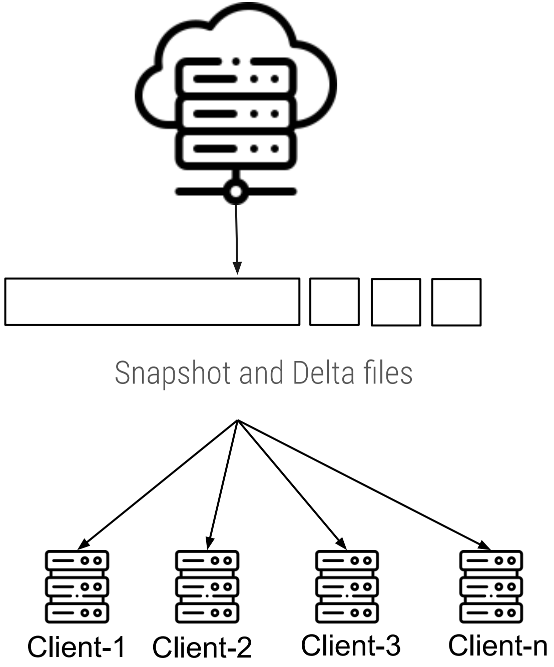


Fig.7 - HTTP server and clients using RRDP

Further Improvements Possible?

Research Question

To what extent can IPFS be used as a distribution mechanism within RPKI?

- How is publishing and retrieving contents currently implemented with RRDP in RPKI?
- What are the features of IPFS that can replace or augment the current RRDP implementation of the RPKI repository?
- What are the network characteristics of IPFS and how would these characteristics influence the operations of an RPKI repository?

Related Work

- No RRDP specific research to the best of our knowledge (Introduced in 2017).

- J. Shen et al. “**Understanding I/O Performance of IPFS Storage: A Client's Perspective**". In: 2019 IEEE/ACM 27th International Symposium on Quality of Service (IWQoS). 2019, pp. 1-10.
- Netflix: **New improvements to IPFS Bitswap for faster container image distribution.**
- V. Kotlyar et al. “**Torrent Base of Software Distribution by ALICE at RDIG**”. In: (2012), pp. 171-175.
- B. Confais, A. Lebre, and B. Parrein. **An Object Store Service for a Fog/Edge Computing Infrastructure Based on IPFS and a Scale-Out NAS**". In: 2017 IEEE 1st International Conference on Fog and Edge Computing (ICFEC). 2017, pp. 41{50.
- IPFS for Off Chain Storage:
  - Sihua Wu and Jiang Du. **Electronic medical record security sharing model based on blockchain**".
  - R. Norvill et al. **IPFS for Reduction of Chain Size in Ethereum**".
  - Q. Zheng et al. **An Innovative IPFS-Based Storage Model for Blockchain**". In: 2018

Methodology - assessing network performance

- **Qualitative Analysis** - Literature study of RPKI, RRDP and IPFS[1,2]
- **Quantitative Analysis** - Direct HTTPs and IPFS comparison (exclude RSYNC to limit scope)
  - Compare data transfer
  - Test environment based on Containernet (Mininet) [2]
- **Quantitative Analysis** - HTTPs and IPFS comparison within RPKI (exclude RSYNC to limit scope)
  - Compare fetching of VRP
  - Modify Krill - RPKI Certificate Authority/Repository - to use IPFS] [3]
  - Modify Routinator - RPKI Relying Party software - to use IPFS [4]
  - Test environment based on Docker containers using Docker Compose [5]

[1] **References:** RFC 8630, RFC 8182, RFC 6486, RFC 6482, RFC 6480, IPFS-Specification, IPFS Documentation, [2] More available in the report

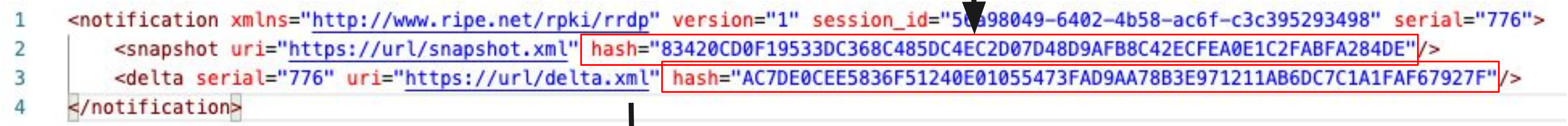
Results

- **Qualitative Analysis**
  - Removing the need for hashes in notification.xml
- **Quantitative Analysis** - Direct HTTPs and IPFS comparison (exclude RSYNC to limit scope)
  - Bandwidth test
- **Quantitative Analysis** - HTTPs and IPFS comparison within RPKI (exclude RSYNC to limit scope)
  - Number of nodes test

Remove checksum in RRDP notification file

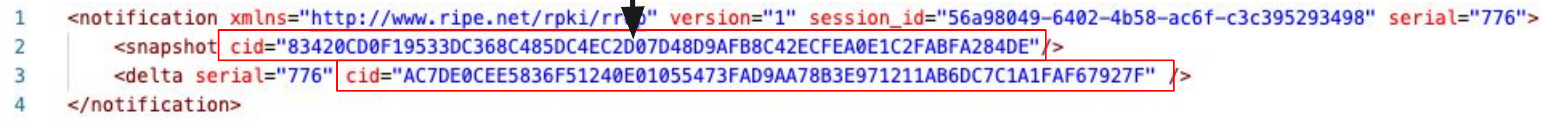
IPFS uses content addressing, hence cryptographic hash of contents can be used for both retrieval and assurance of integrity

- **Current notification.xml**



```
<notification xmlns="http://www.ripe.net/rpki/rrdp" version="1" session_id="56a98049-6402-4b58-ac6f-c3c395293498" serial="776">
    <snapshot uri="https://url/snapshot.xml" hash="83420CD0F19533DC368C485DC4EC2D07D48D9AFB8C42ECFEA0E1C2FABFA284DE"/>
    <delta serial="776" uri="https://url/delta.xml" hash="AC7DE0CEE5836F51240E01055473FAD9AA78B3E971211AB6DC7C1A1FAF67927F"/>
</notification>
```

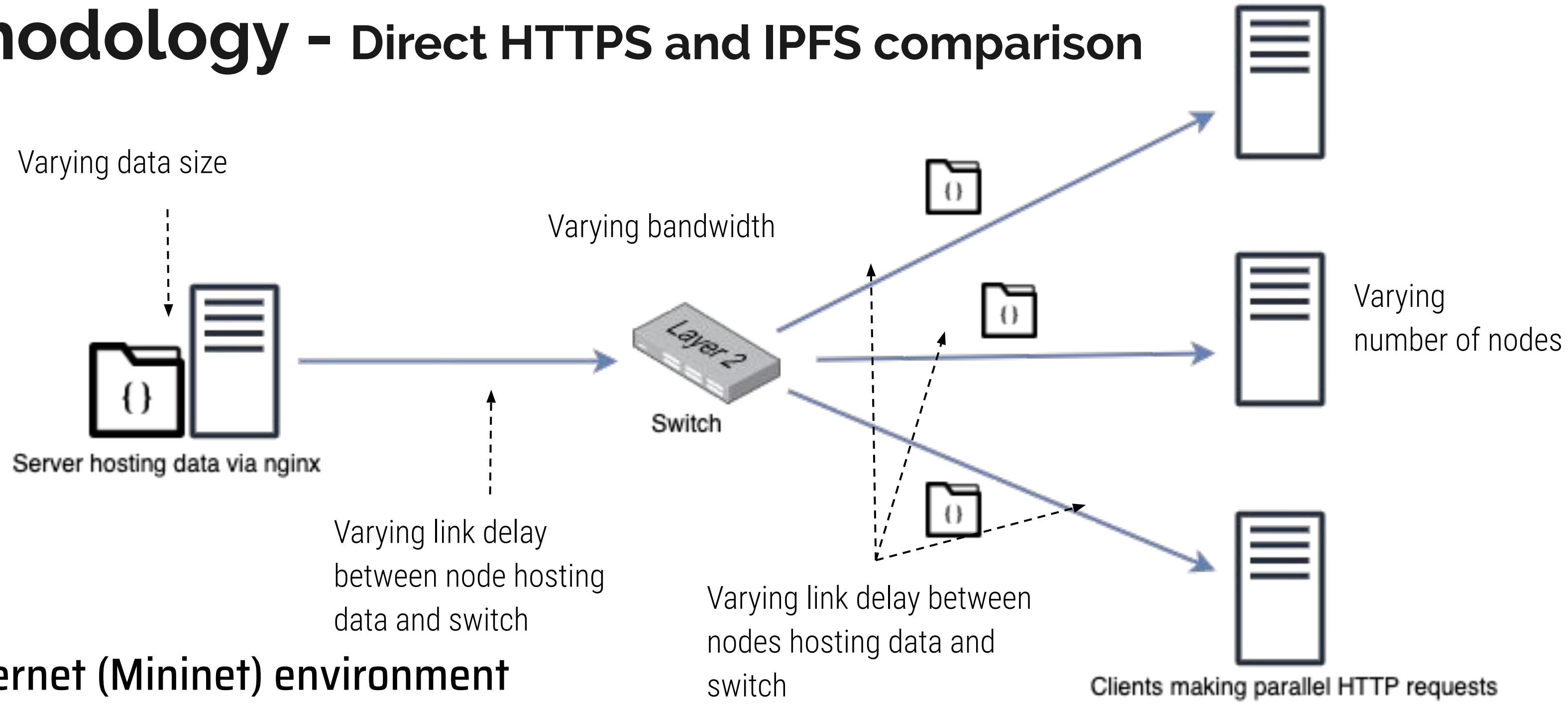
- **Possible modification using IPFS**



```
<notification xmlns="http://www.ripe.net/rpki/rrdp" version="1" session_id="56a98049-6402-4b58-ac6f-c3c395293498" serial="776">
    <snapshot cid="83420CD0F19533DC368C485DC4EC2D07D48D9AFB8C42ECFEA0E1C2FABFA284DE"/>
    <delta serial="776" cid="AC7DE0CEE5836F51240E01055473FAD9AA78B3E971211AB6DC7C1A1FAF67927F" />
</notification>
```

Fig.8 - RRDP notification.xml file without and with IPFS based modification

Methodology - Direct HTTPS and IPFS comparison



Varying data size

Server hosting data via nginx

Varying link delay between node hosting data and switch

Varying bandwidth

Switch

Varying link delay between nodes hosting data and switch

Varying number of nodes

Clients making parallel HTTP requests

Containernet (Mininet) environment

Fig.9 - Network topology for direct HTTPs and IPFS comparison

Results - IPFS latency test

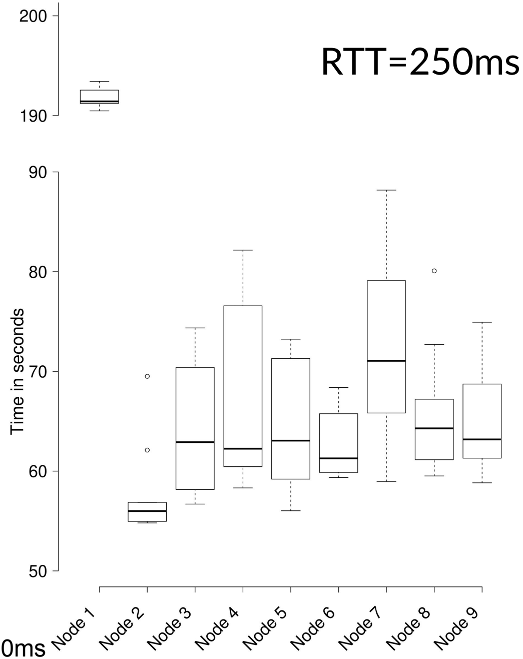


Fig.10 - IPFS w/ RTT of 250ms

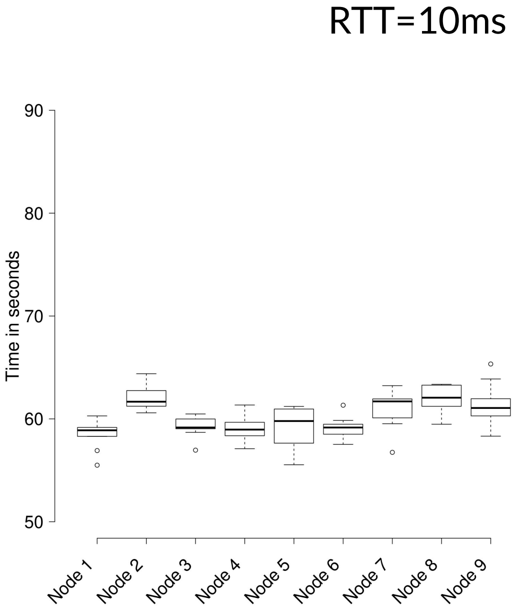


Fig.11 - IPFS w/ RTT of 10ms

Results - HTTPs latency test

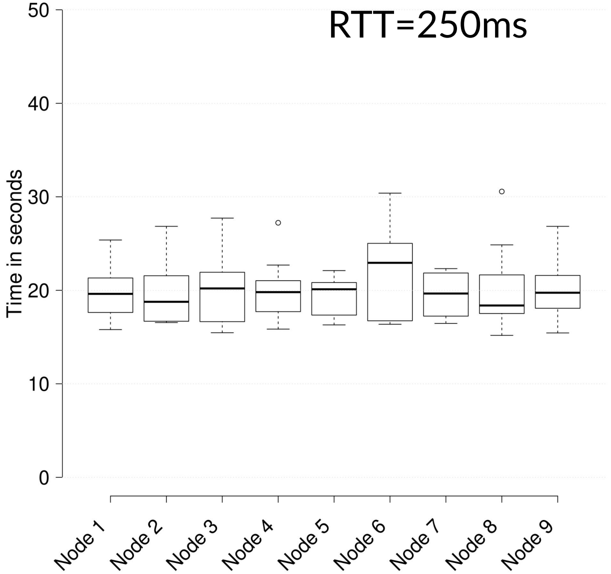


Fig.12 - HTTPS w/ RTT of 250ms

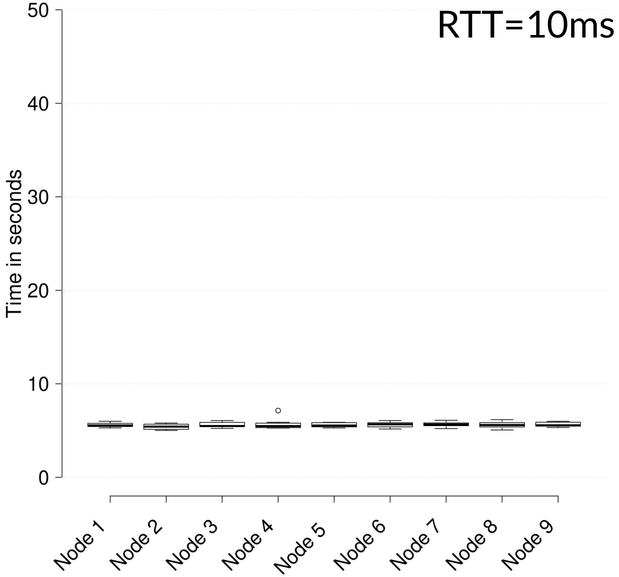
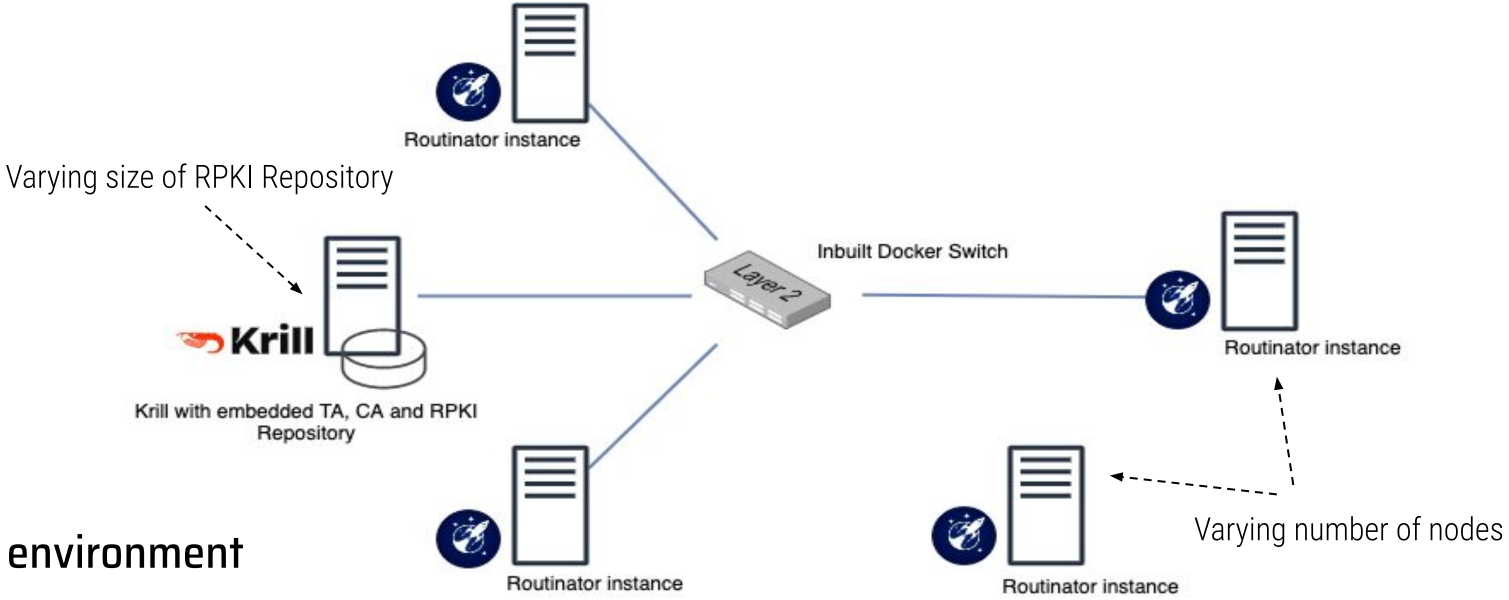


Fig.13 - HTTPS w/ RTT of 10ms

Methodology - RRDP and IPFS comparison within RPKI



Docker environment

Fig.14 - Network topology for HTTPs and IPFS comparison within RPKI

Results - RPKI IPFS nodes test

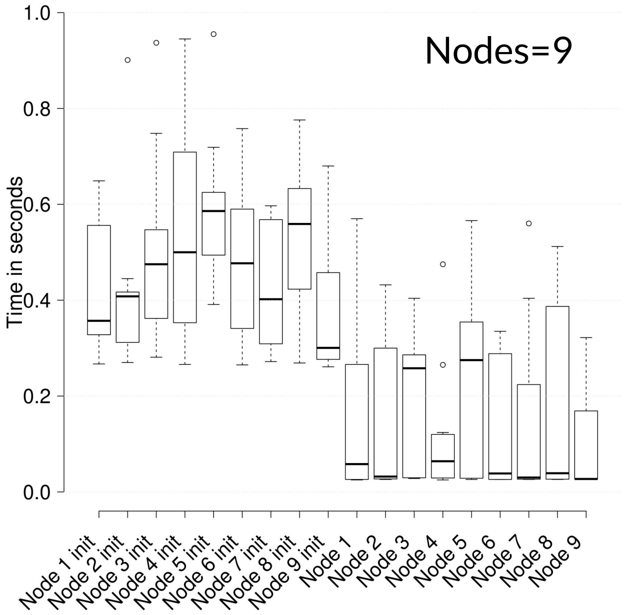


Fig.15 - RPKI IPFS w/ 9 nodes

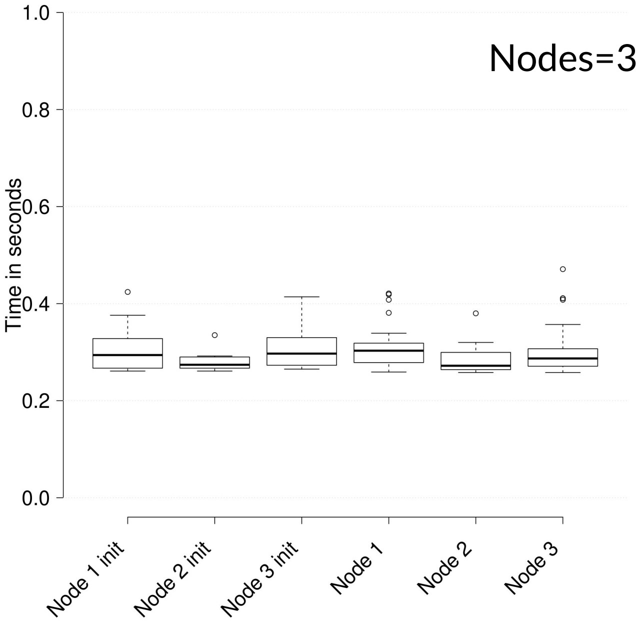


Fig.16 - RPKI IPFS w/ 3 nodes

RPKI RRDP nodes test

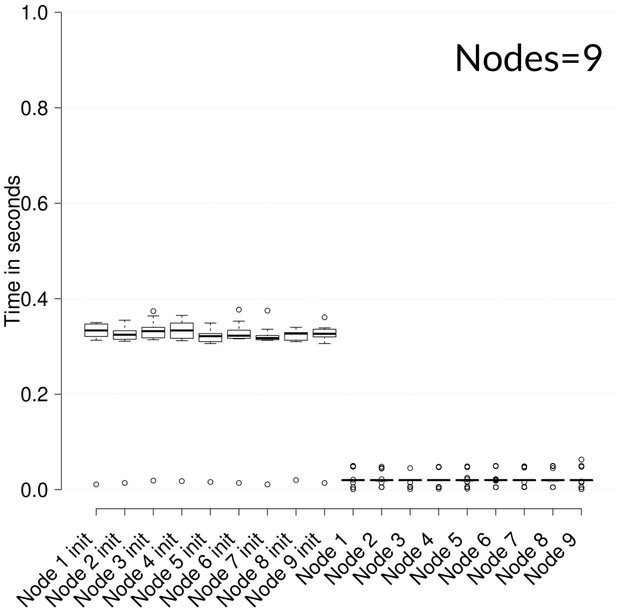


Fig.17 - RPKI RRDP w/ 9 nodes

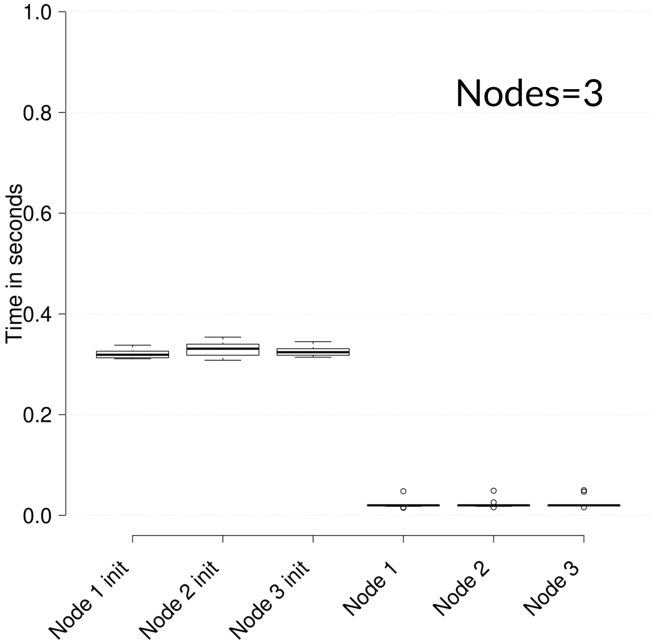


Fig.18 - RPKI RRDP w/ 3 nodes

Conclusion

- IPFS can currently be integrated to distribute RPKI material
  - Removing the need for manual data integrity checks in RRDP
- IPFS performed poorly in direct comparison with HTTPS:
  - Retrieval times were several factors higher than HTTPs under the same circumstances
  - In the low bandwidth, low latency environment it only performed 1.5x as poorly

	Low latency(RTT=10ms)	High latency(RTT=250ms)
Low bandwidth(100Mbit/s)	HTTPs	N/a
High bandwidth(1000Mbit/s)	HTTPs	HTTPs

Future Work

- Research variable delays between retrieving IPFS nodes, not only the server hosting the data
- Research effect of concurrent requests in IPFS (without RPKI)
- Research power consumption of IPFS in comparison to other transfer protocols
- Research integration of IPFS into Krill and Routinator using the IPFS Rust library[6] (once matured)

Thank you for your attention

In short:

- The network is often not the bottleneck in IPFS performance, it is more susceptible to I/O
- IPFS can be integrated into RPKI and replace redundant functionality

References

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2. sne-os3-rp2/ipfshttpbenchmark : Containernet script for performing data transfer benchmark of HTTPs and IPFS:. url: https : / / github . com / sne - os3 - rp2 / ipfs _ http _ benchmark (visited on 06/27/2020).
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4. sne-os3-rp2/routinator: An RPKI Validator written in Rust. url: https://github.com/sne-os3-rp2/routinator (visited on 06/28/2020).
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7. Benet, Juan. (2014). IPFS - Content Addressed, Versioned, P2P File System.