ICN4BLOCKCHAIN

EFFICIENT BLOCKCHAIN ACCESS VIA INFORMATION-CENTRIC NETWORKING

TNO innovation for life

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SCALABILITY ISSUES OF BLOCKCHAIN

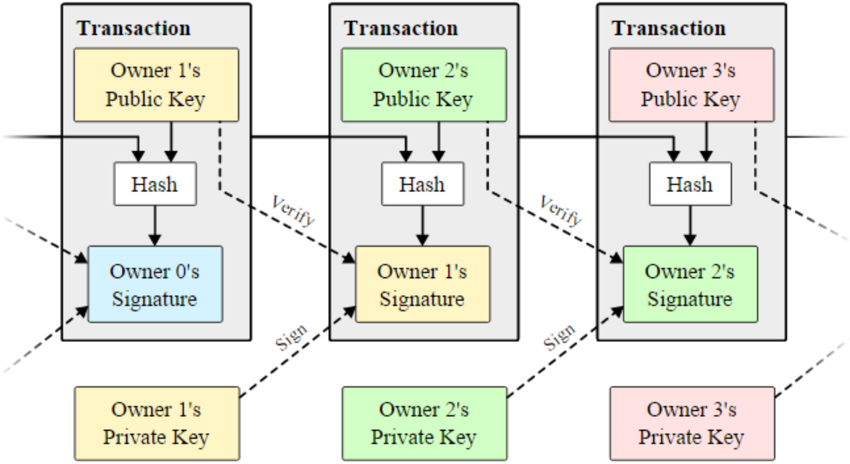
- Recently, Blockchain Technology (BCT) has gained much traction
  - Cryptocurrencies, smart contracts, decentralized registers, international banking, notary agreements
  - https://blockchain.tno.nl/blog/the-blockchain-business-case/

- BCT, however, suffers from a large scalability issue, endangering its global adoption
  - Both transaction verification and update distribution induce a large data overhead
  - The overlay peer-to-peer networks are inefficient and unaware of the underlying network, and hence cannot solve this problem independently

- We show that a specialized Content Distribution Network set up through Information-Centric Networking, in particular Named Data Networking, significantly improves this bottleneck

BLOCKCHAIN TECHNOLOGY (BCT)

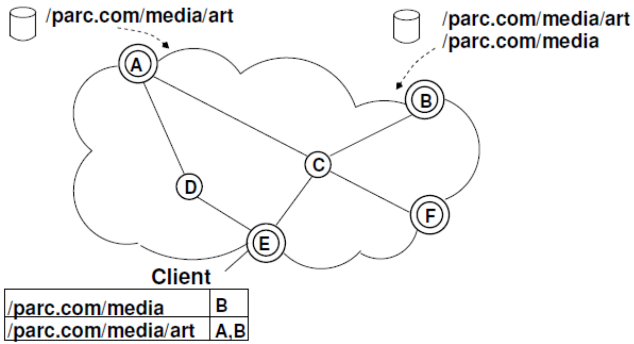
- Peer-to-peer cryptography realizing a fully-distributed architecture reliably storing and processing
  - (Crypto) currencies
  - Transactions (value or property transfer)
  - Registrations
  - Smart contracts
- Everybody can verify all transactions
- Miners validate the set of past transactions since the last block in a new block and add the new block to the public ledger (or Blockchain)

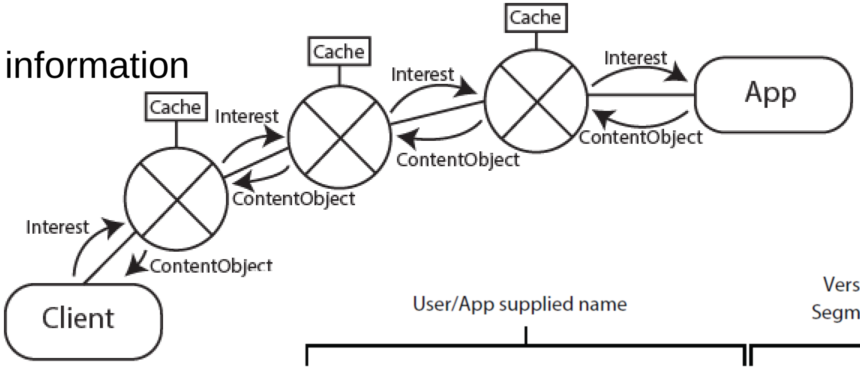


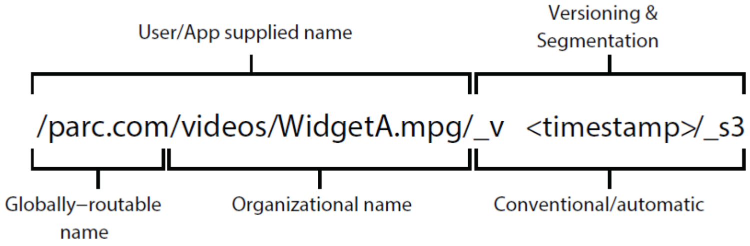
An example of transferring a crypto-coin from owner 0 to 1, 1 to 2, and 2 to 3
[Nakamoto, Satoshi. "Bitcoin: A peer-to-peer electronic cash system." (2008).]

INFORMATION CENTRIC NETWORKING (ICN)

- ICN offers technology optimizing the Internet for content distribution.
- Route-and-cache by name principle through Layer 3 request for information (Interests)
- Rely on next hop to either
  - Deliver Data (from cache)
  - Send out Interest to a node closer to the information







[V. Jacobson, D. K. Smetters, J. Thornton, M. F. Plass, N. Briggs, and R. Braynard, “Networking Named Content,” *CoNEXT 2009*, 2009.]

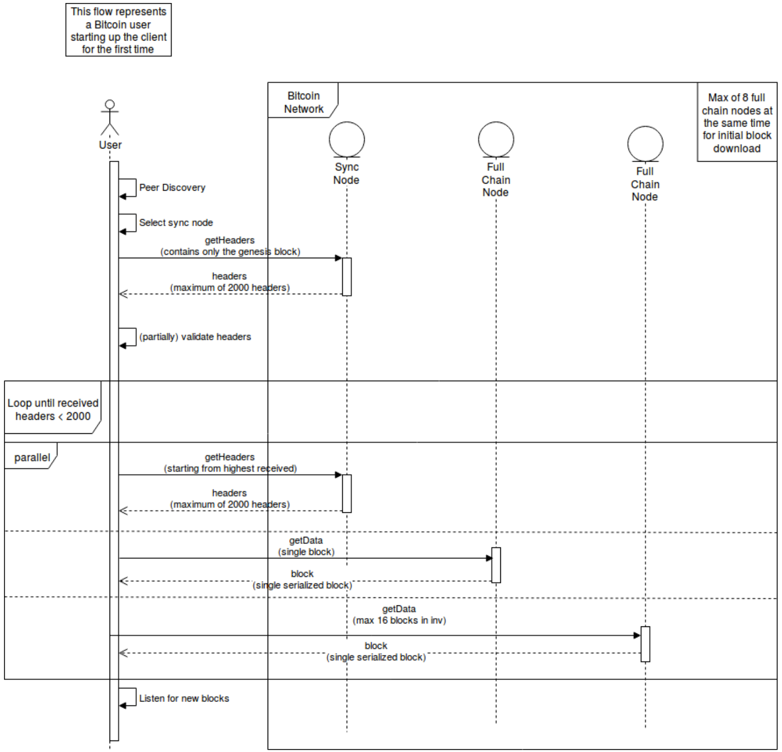
THE ICN4BLOCKCHAIN SOLUTION

- Blockchain’s data overhead is essential to its reliability/authenticity determination
  Hence, it is difficult to improve without effecting Blockchain’s reliability
- The derived communication overhead, however, is a typical content distribution problem
- Since ICN technology is designed to improve content distribution, we foresee this to be a natural solution to relieve this bottleneck

- With ICN4Blockchain, we have successfully
  - Designed an architecture describing the essential ICN and Blockchain interoperability functions
  - Implemented Proof-of-Concept software verifying its functionality
  - Evaluated through quantitative experimentation

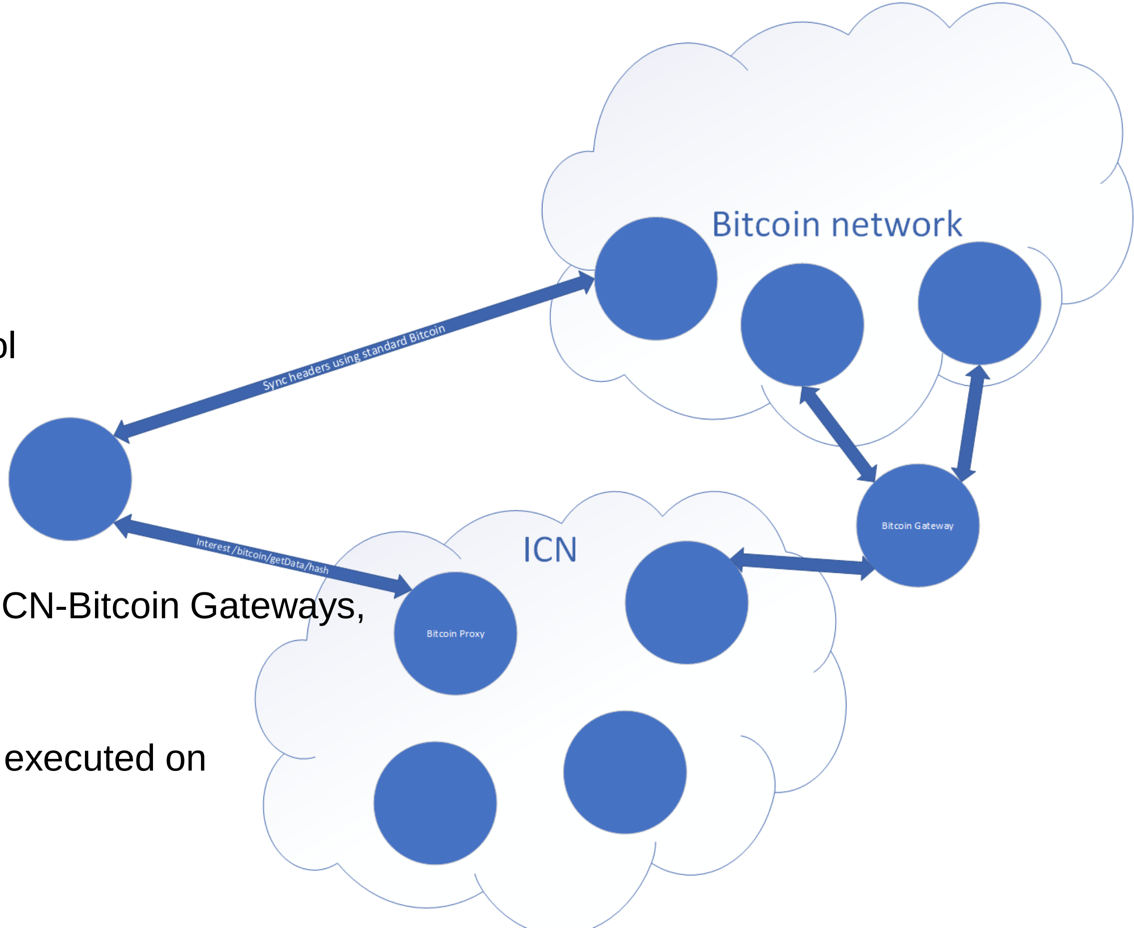
BCT SYNCHRONIZATION

- Due to its widespread use, use private Bitcoin as PoC
- Initial block download ~185 GB
- Online transaction updates core part of Bitcoin code
  - Initialization more easily modifiable
- Online transactions should also be ICNified
  - PoC can already prove our point on just the sync



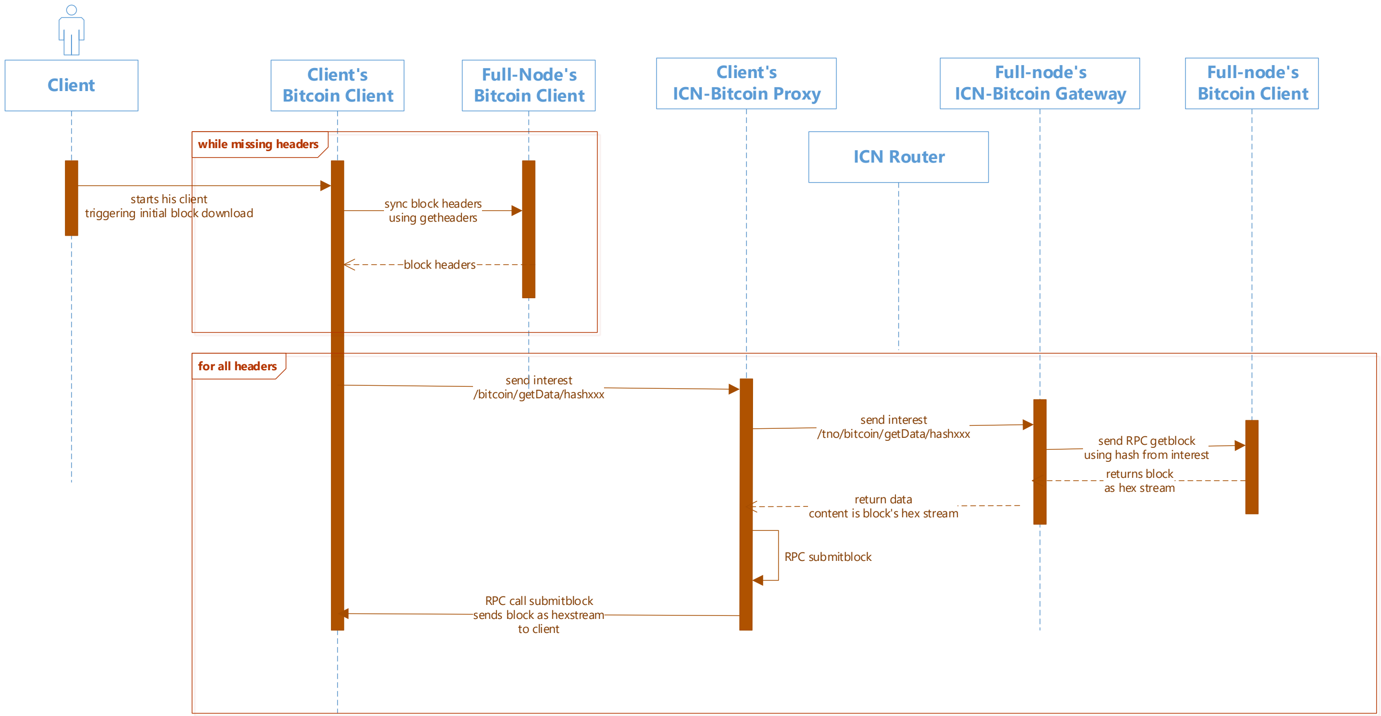
IMPLEMENTED POC

- Adapted Bitcoin+ICN client
- Download headers using Bitcoin protocol
- Download Blocks through ICN interface, connected to ICN-Bitcoin Proxy
- ICN Bitcoin Proxy forwards Interests to ICN-Bitcoin Gateways, which connect to Bitcoin Full Nodes
- Implementation efforts and experiments executed on TNO's Private Hi5 Research Cloud



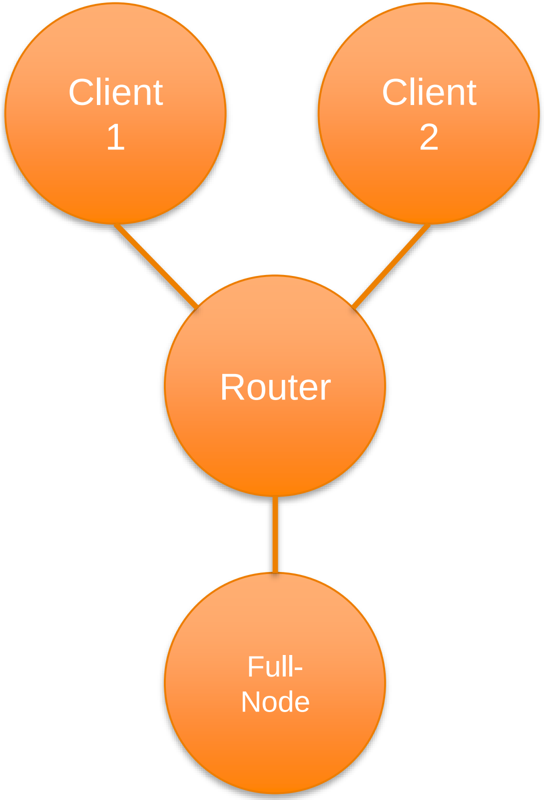
ICN SEQUENCE

- Changed the sequence of Bitcoin to download actual Blocks through Named-Data Networking



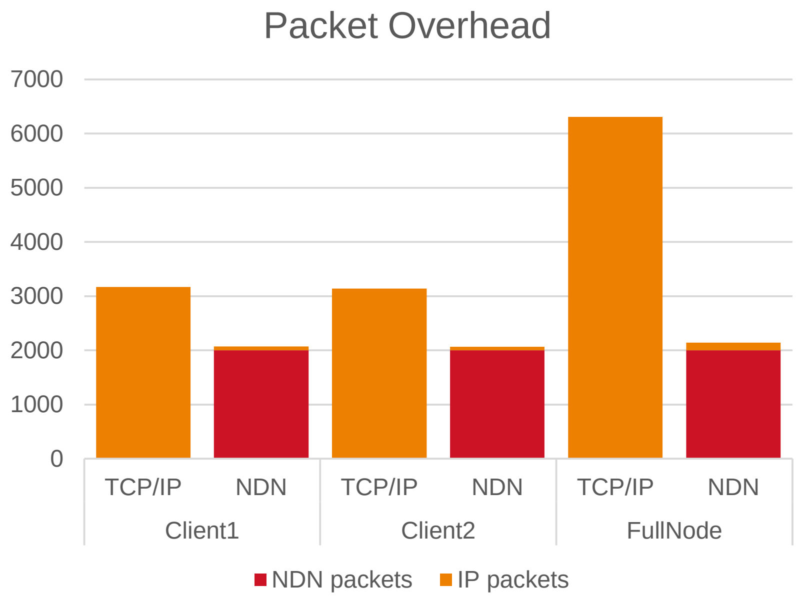
EVALUATION POC

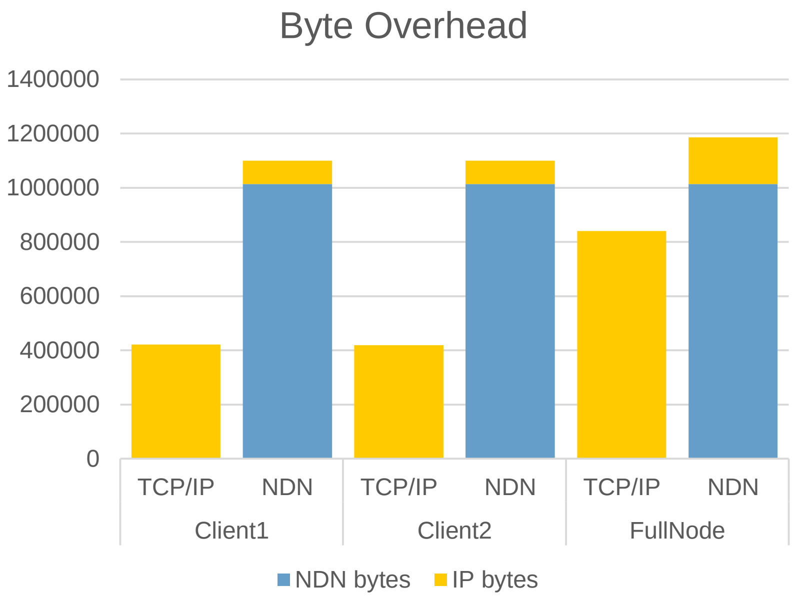
- Classic Bitcoin with TCP/IP scenario
  - Clients 1 and 2 run regular Bitcoin clients
  - Router performs IP routing
  - Full-node is regular Bitcoin full node
- Bitcoin with ICN scenario
  - Clients 1 and 2 run ICN-Bitcoin clients and local ICN-Bitcoin Proxies
  - Router performs ICN caching and forwarding
  - Full-node runs ICN-Bitcoin Gateway and regular Bitcoin full node
  - ICN implies using Named Data Networking (NDN) over Ethernet
- 100 iterations of Initial Block Download
  - Measure OSI Layer 3 (both IP and NDN) communication overhead



INITIAL MEASUREMENTS

- Measured IP and NDN packets transmitted and received on different hosts
- Some IP overhead in Bitcoin with NDN exists due to Bitcoin header exchange





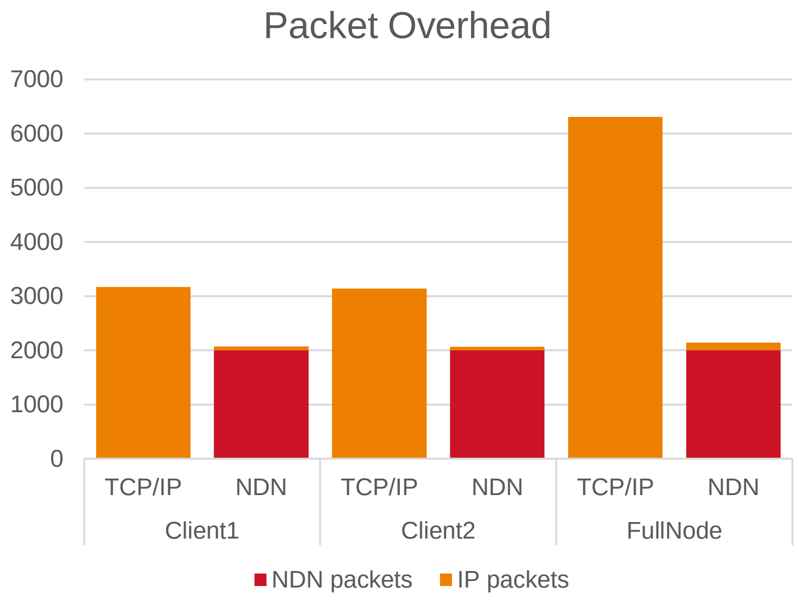
INITIAL MEASUREMENTS

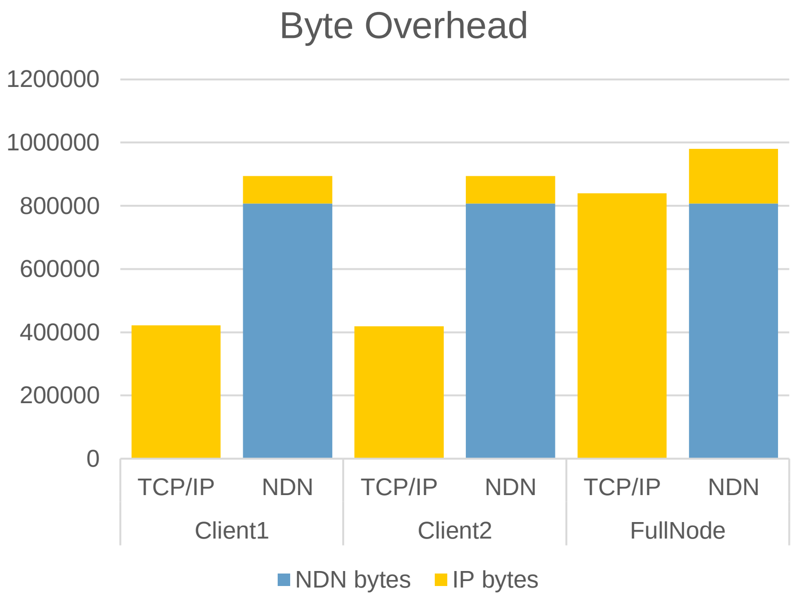
- Great improvement in number of transmitted packets
  - Switch performance bottleneck principally upper bound and measured by Millions of Packets Per Second (MPPS)

- However, total transmitted bytes increased
  - Additional analysis shows plenty room for further improvements

IMPROVEMENT 1: BLOCK LINE ENCODING

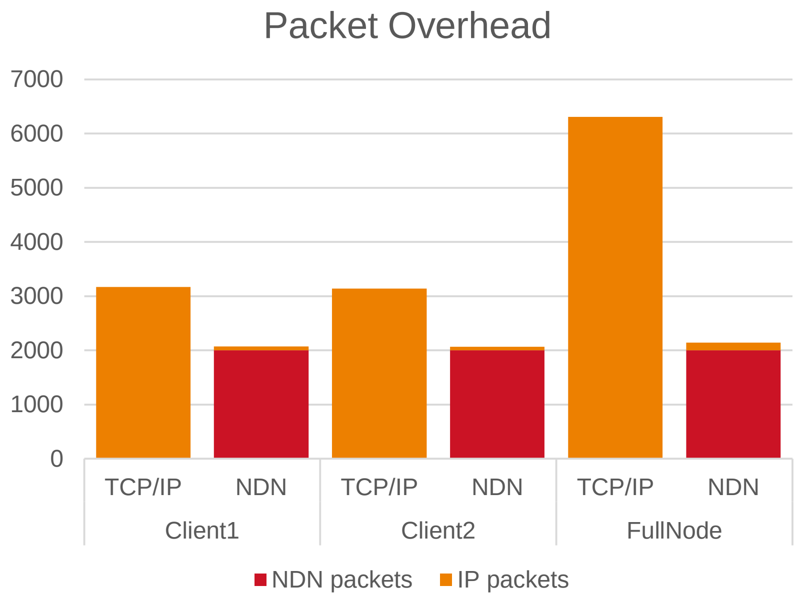
- Initially, we used the encoding of blocks into Bitcoin's RAM, instead of the line encoding of blocks which is more compact

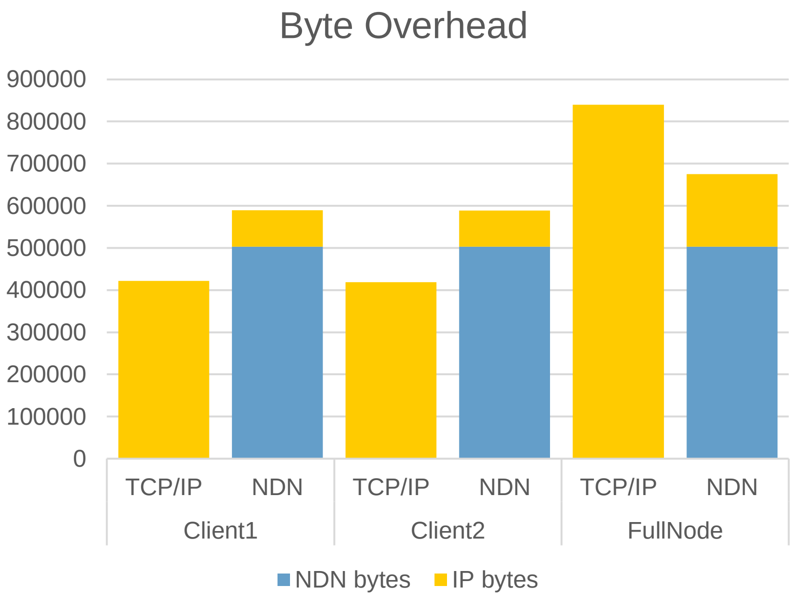




IMPROVEMENT 2: REMOVE REDUNDANT SIGNATURES

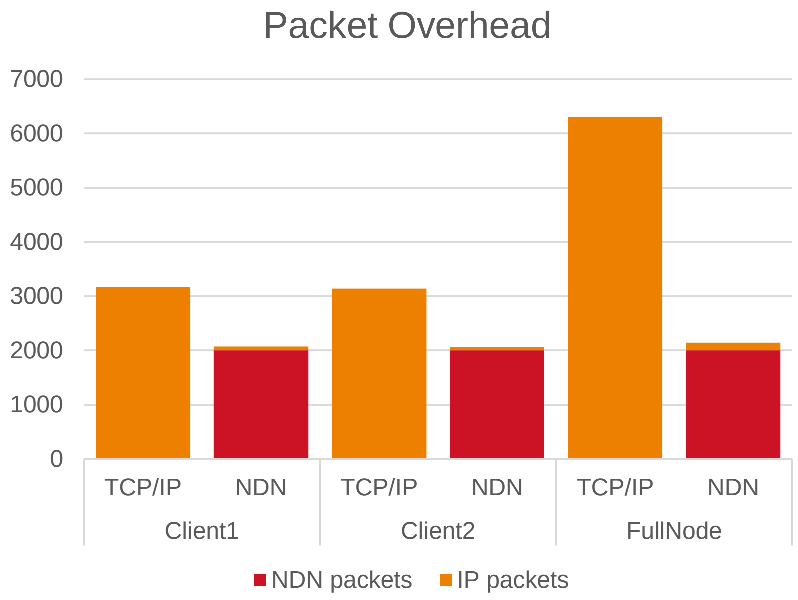
- Block identifier is self-authenticating hash, hence, we don't need the NDN signature
  - Transmitted bytes already improved for Full-Node at only 2 clients

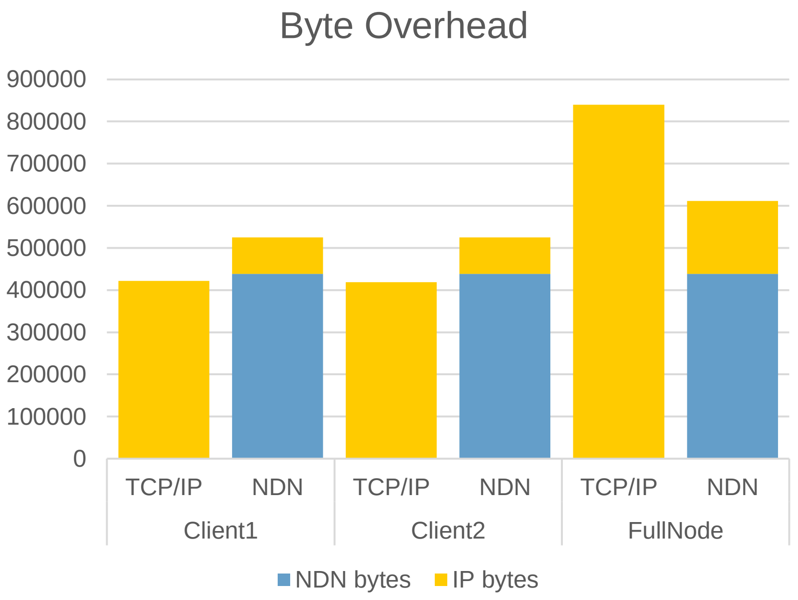




IMPROVEMENT 3: ENCODING OF BLOCK ID

- Using the 32-byte hexadecimal encoding of a Block Id instead of its character string representation in NDN names, further improves byte overhead with 32 bytes per NDN packet





ADDITIONAL IMPROVEMENTS

- We used very small block sizes of the minimum of 250 bytes because we lack actual transactions
  - However, the maximum and current 90-day average block size in public Bitcoin equal respectively 1 MB and 750 KB
  - Larger block sizes imply a much lower relative NDN packet overhead, hence we expect higher performance using Blockchains which contain actual transactions

- Where we retrieve 1 block with each request, Classic Bitcoin over TCP/IP retrieves up to 2000
  - Retrieving multiple blocks with each Interest will further improve Bitcoin over NDN

CONCLUSIONS

- Already in a simple 2-Client and 1-FullNode evaluation the number of packets significantly decreases for the Initial Block Download on all nodes.
  - This dimension is the bottle neck for switching and router logic
- Although Bitcoin Clients experience a small penalty on transmitted bytes, load on Full Nodes significantly reduces
- NDN is suitable to relieve the communication overhead of Blockchain Technology

FUTURE WORK

- Include online transaction updates and verification
- Extend testbed to a larger network of clients and full nodes
- Include other Blockchain Technologies
- Use (part of) public Blockchain(s) to improve data representability
- Find optimal transmission of multiple blocks for a single getData request to improve header overhead
- Disseminate results further in standardization (IETF, ICNRG), market (Techruption, Dutch Blockchain Coalition) and investigate possibilities for IPR

GLOSSARY

- BCT: Blockchain Technology
- Bitcoin: A specific BCT implementation (OSI Layer 5 to 7)
- Ethereum: Another specific BCT implementation (OSI Layer 5 to 7)
- Ethernet: Networking technology used in Local Area Networks (OSI Layer 2)
- ICN: Information-Centric Networking
- IP: Internet Protocol, the networking layer of the Internet (OSI Layer 3)
- NDN: Named Data Networking, a specific ICN architecture (OSI Layer 3)
- OSI: Open Systems Interconnection model, defining the conceptual layers of communication functions in telecommunication networks
- P2P: Peer-to-peer network, a computing or networking distributed application architecture
- PoC: Proof of Concept
- TCP: Transmission Control Protocol, a transport protocol offering reliable pseudo-connections over IP (OSI Layer 4)