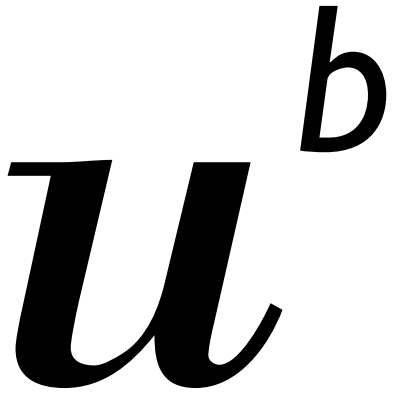

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Seminar Cryptography and Data Security

Exploring the Bitcoin P2P network

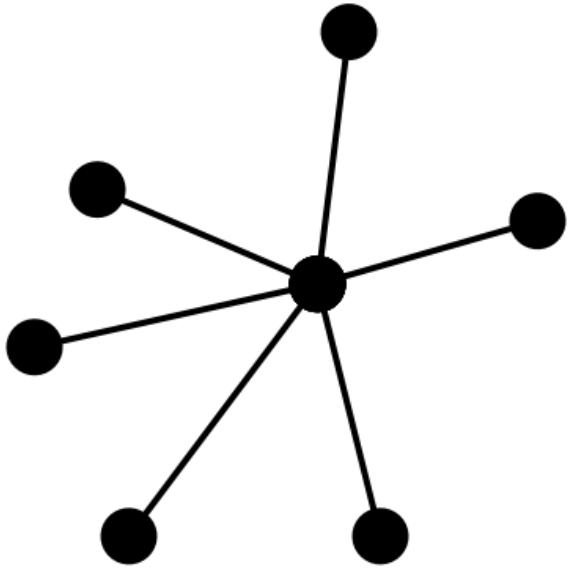
Chris Rüttimann & Thushjandan Ponnudurai

Bern, 6. April 2022

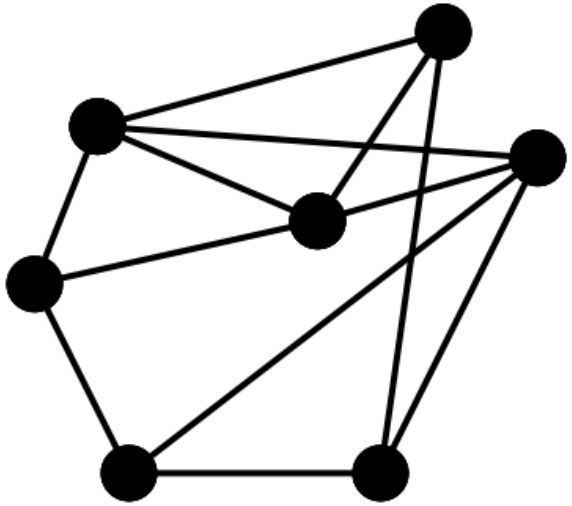
Outline

- Peer to Peer fundamentals
- How Bitcoin P2P networks work
- Bitcoin P2P protocol
- Deanonymization attacks
  - Mitigations
- Our Bitcoin mainnet network analysis

Peer to Peer Network



Server based



P2P

Bitcoin P2P Protocol

Public P2P networks

- Different P2P networks
  - Mainnet
  - Testnet
  - signet
  - Regtest (local)
- Differentiation over TCP ports, magic bytes and use cases

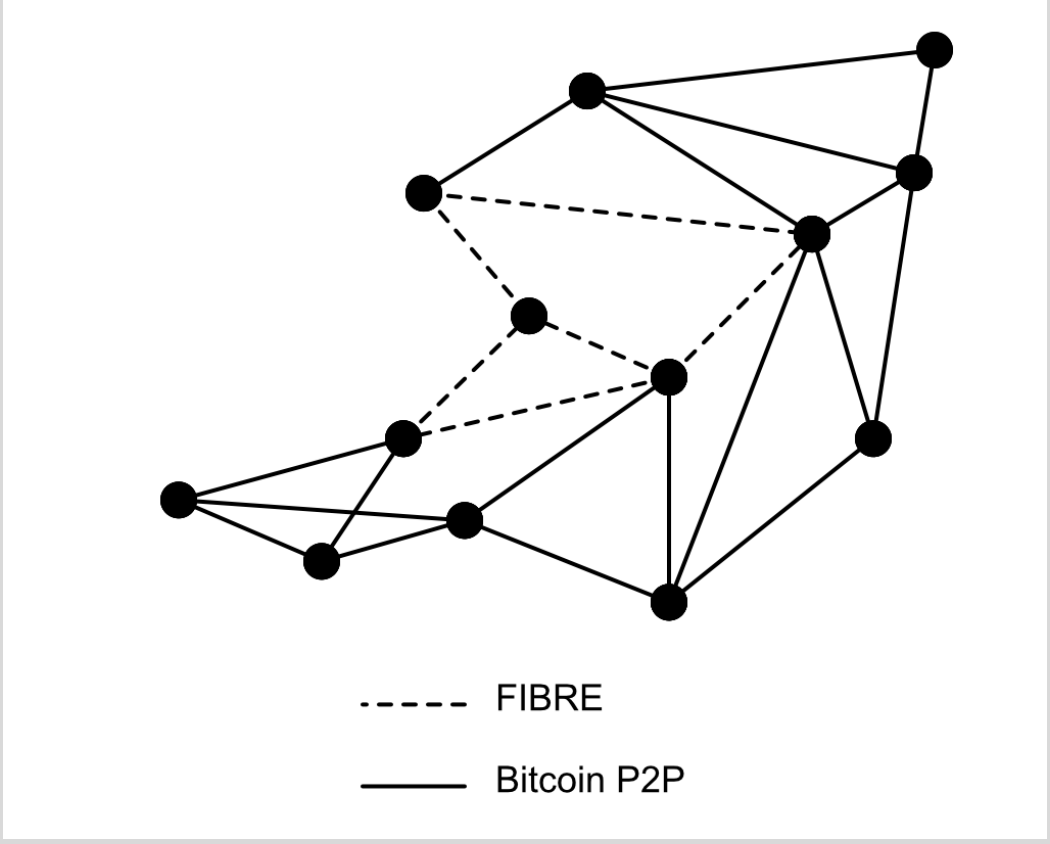
Bitcoin P2P Protocol

Private Relay Network

- FIBRE (Fast Internet Bitcoin Relay Engine)
  - UDP
  - Error Correction
- Bitcoin Relay Network
  - Predecessor of FIBRE

Source: https://bitcoinfibre.org/

Bitcoin P2P Protocol



Bitcoin P2P Protocol

How to find peers?

- DNS Record
  - Bitcoin Main Network: https://github.com/bitcoin/bitcoin/blob/master/src/chainparams.cpp#L121

    vSeeds.emplace_back("seed.bitcoin.sipa.be."); // Pieter Wuille, only supports x1, x5, x9, and xd
    vSeeds.emplace_back("dnsseed.bluematt.me."); // Matt Corallo, only supports x9

- addr messages
  - Sent as response to getaddr message
  - Sent by peers to announce new peers

Bitcoin P2P Protocol

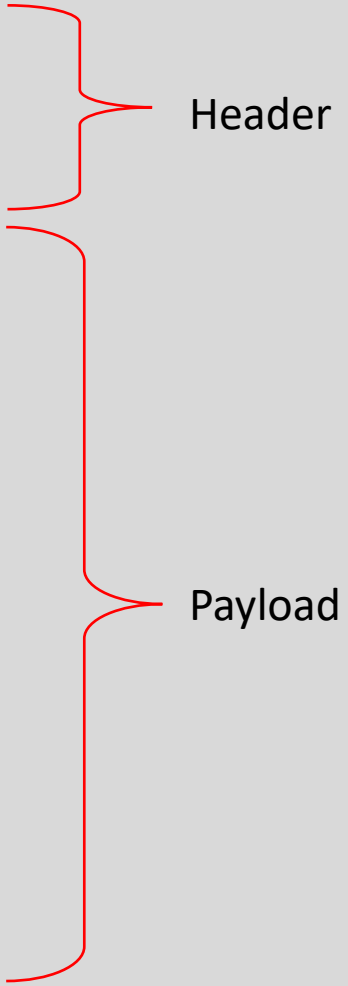
Version message

- Information about transmitting node
- Needs to be exchanged before other messages
- Followed by a verack message

Bitcoin P2P Protocol

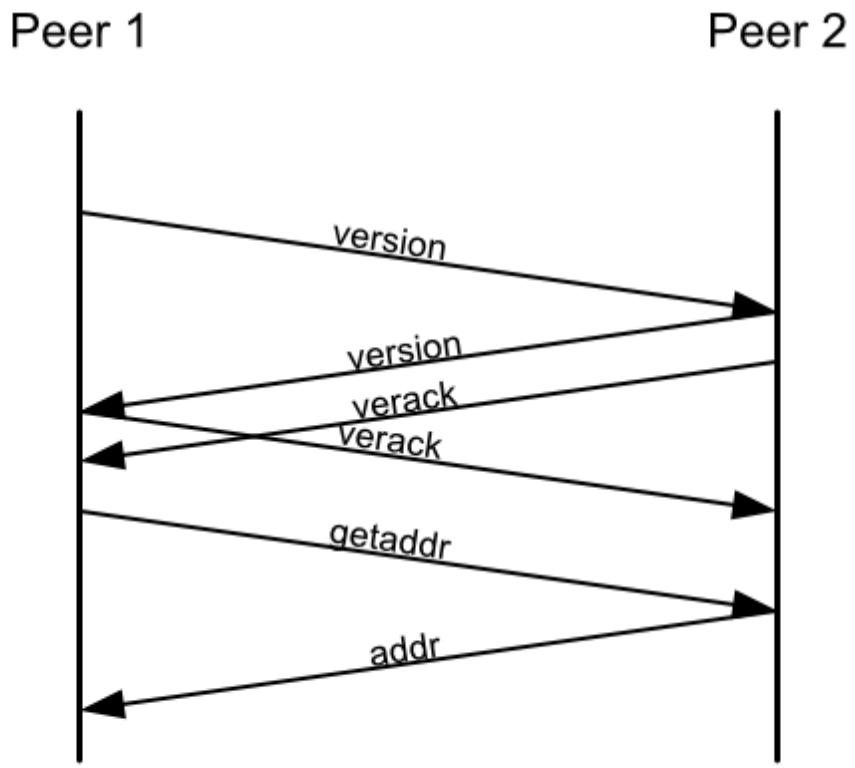
Version message

```
0b110907                        # Magic
76657273696f6e0000000000        # Command
56000000                        # Length
a71a4acd                        # Checksum
7f110100                        # Version
0000000000000000                # Services
9298396200000000                # Timestamp
0000000000000000                # addr_recv services
00000000000000000000ffff        # addr_recv IPv6 part
c0a80014                        # addr_recv IPv4
075b                            # port_recv
0000000000000000                # from services
00000000000000000000000000      # sender IPv6 part
00000000                        # sender IPv4 part
0000                            # sender port
ab1e7b09b53138b4                # Nonce
00                              # Agent Bytes
52190900                        # Starting Height
00                              # relay
```



Bitcoin P2P Protocol

Connecting to peers



Bitcoin P2P Protocol

Demo

Bitcoin P2P Protocol

Addrman

- A node maintains 256 buckets, which can save up to 64 address
  - Total 16’384 addresses
- GetAddr returns only a subset
  - 23% from addrman
  - Max 1000 addresses
- Endpoints pseudo randomly from addrman selected
  - Nodes from different ASN or address range (/16 for IPv4) are chosen
- A node can maintain up to 125 connections (default)
  - 10 outbound connections

Bitcoin P2P Protocol

Misbehavior

- IPs can be banned for 24h for rogue behaviour
  - Penalty score
- Not following the protocol
  - Invalid data
    - Trying to build invalid chain
    - Valid header with invalid tx
  - Flooding
    - Ex. Sending more than 1000 addresses in addr msg

Discovering Bitcoin's Network Topology

Motivation / Attacks

- Who is operating a bitcoin node?
- Where is the weakest point in the chain to attack?
  - Split the network
- Link user pseudonyms to IP addresses where the transactions are generated

Discovering Bitcoin's Network Topology

Motivation / Research

- Is the Bitcoin network really decentralized?
  - Super nodes
  - Point of failures
  - Private peering agreement between miners (private relay)
- Metrics should be exposed by the Bitcoin software itself

Discovering Bitcoin's Network Topology

Coinscope

- Addrman maintains a timestamp to every known address
- Timestamp of active connections are updated within 20mins
- Timestamp of a new address doesn't change once added to addrman

Discovering Bitcoin's Network Topology

Coinscope - Mitigations

Coinscope

Mitigation

3 src/addrman.cpp

```
@@ -252,28 +252,29 @@
252 252     // we just overwrote an entry in vTried; no need to update nTried
253 253     info.fInTried = true;
254 254     return;
255 255 }
256 256
257 257 void CAddrMan::Good_(const CService& addr, int64_t nTime)
258 258 {
259 259     int nId;
260 260     CAddrInfo* pinfo = Find(addr, &nId);
261 261
262 262     // if not found, bail out
263 263     if (!pinfo)
264 264         return;
265 265
266 266     CAddrInfo& info = *pinfo;
267 267
268 268     // check whether we are talking about the exact same CService (including same port)
269 269     if (info != addr)
270 270         return;
271 271
272 272     // update info
273 273     info.nLastSuccess = nTime;
274 274     info.nLastTry = nTime;
275     -   info.nTime = nTime;
276 275     info.nAttempts = 0;
    276 +   // nTime is not updated here, to avoid leaking information about
    277 +   // currently-connected peers.
277 278
```

Coinscope

Mitigation

```
272  272        // update info
273  273        info.nLastSuccess = nTime;
274  274        info.nLastTry = nTime;
275       -      info.nTime = nTime;
276  275        info.nAttempts = 0;
     276   +    // nTime is not updated here, to avoid leaking information about
     277   +    // currently-connected peers.
277  278
```

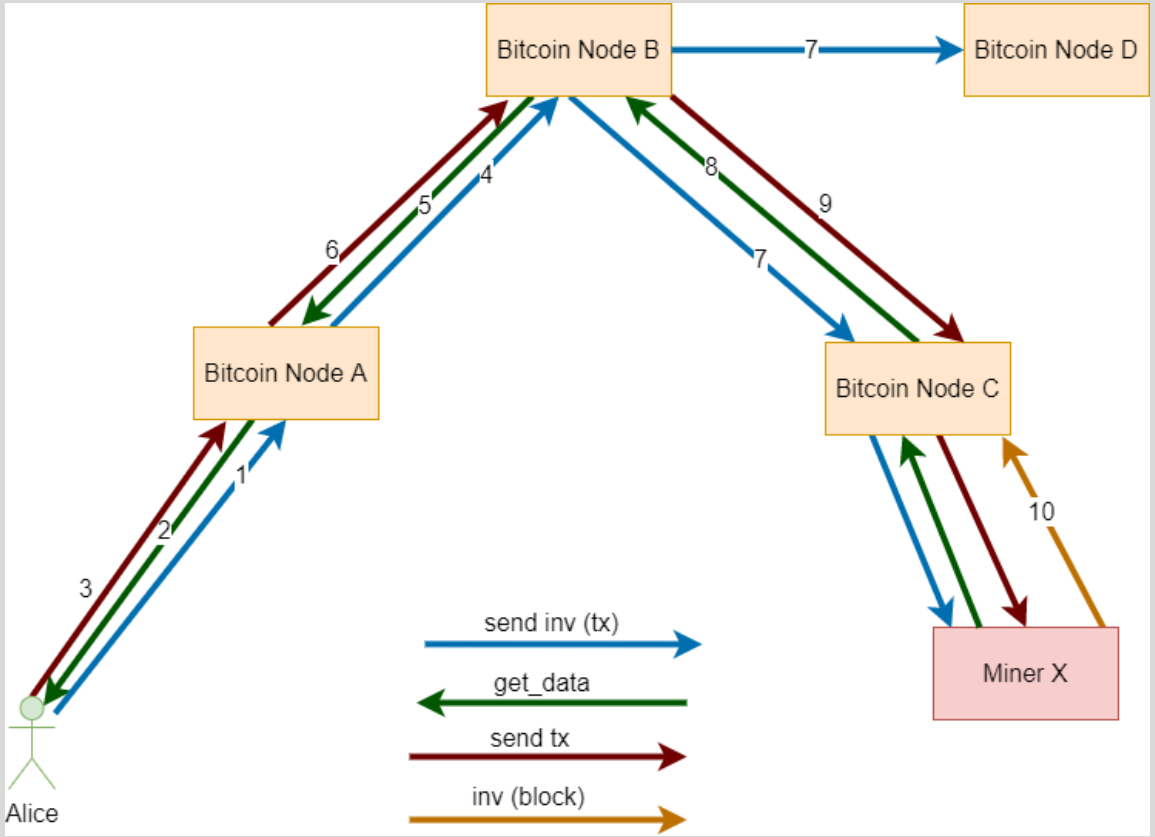
Discovering Bitcoin's Network Topology

TxProbe

- **inv** message
  - Used to announce new blocks or transactions
  - Contains only hashes of blocks or transactions
- **get_data** message
  - Used to request certain block or transaction
  - Uses hashes to request certain item

Discovering Bitcoin's Network Topology

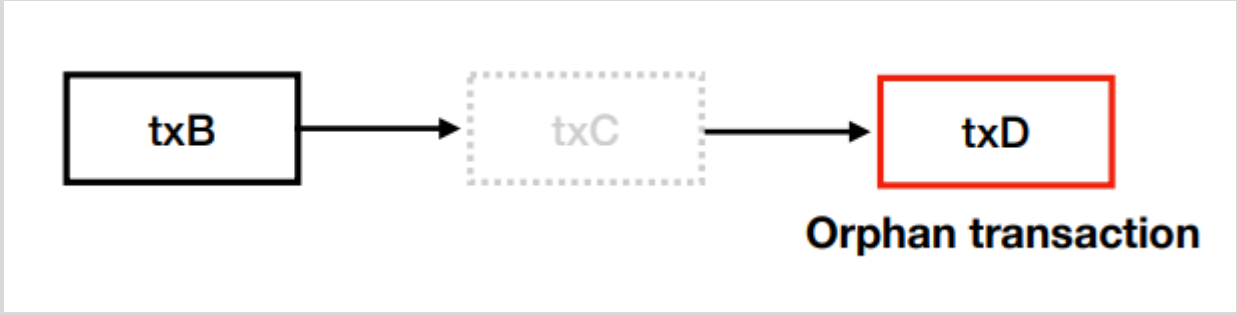
Relay mechanism



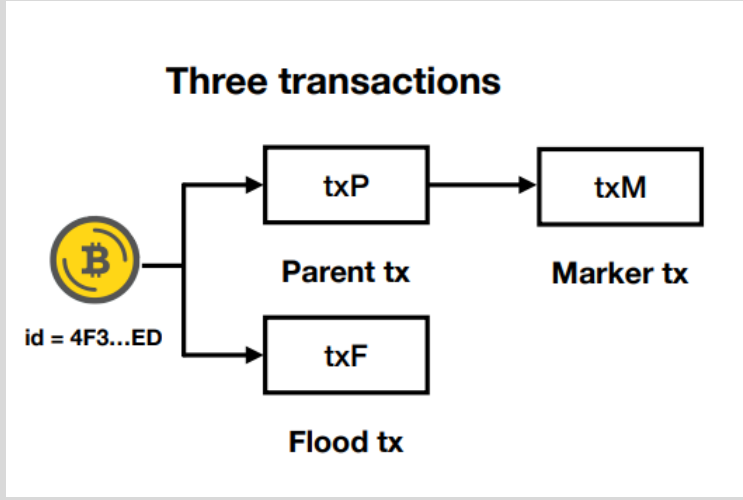
Discovering Bitcoin's Network Topology

TxProbe

– Orphans transactions are used to probe connections between nodes



Source: Delgado-Segura, Sergi, et al. “TxProbe: Discovering Bitcoin’s Network Topology Using Orphan Transactions.” Crossref, https://srgi.me/resources/slides/CESC19-TxProbe.pdf.



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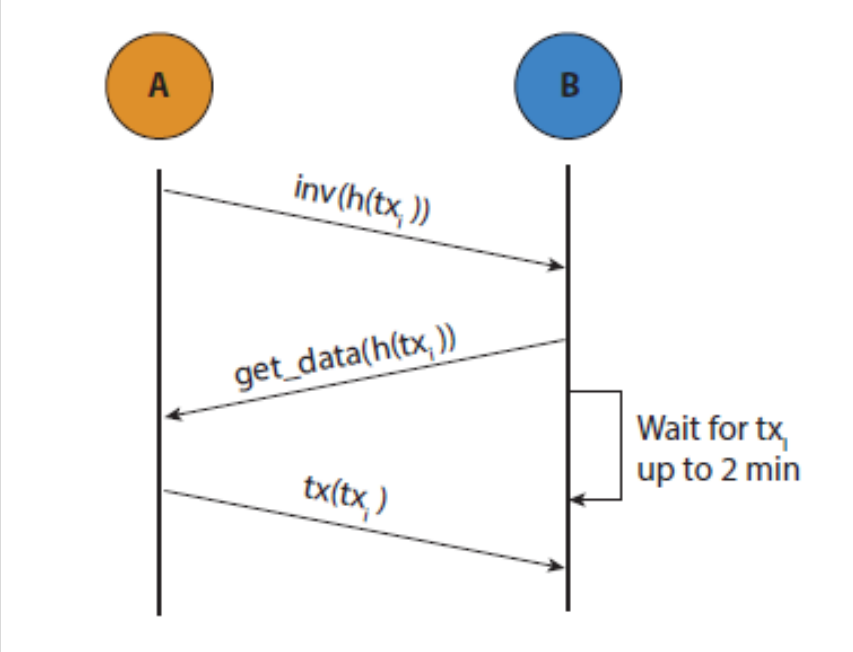
Discovering Bitcoin's Network Topology

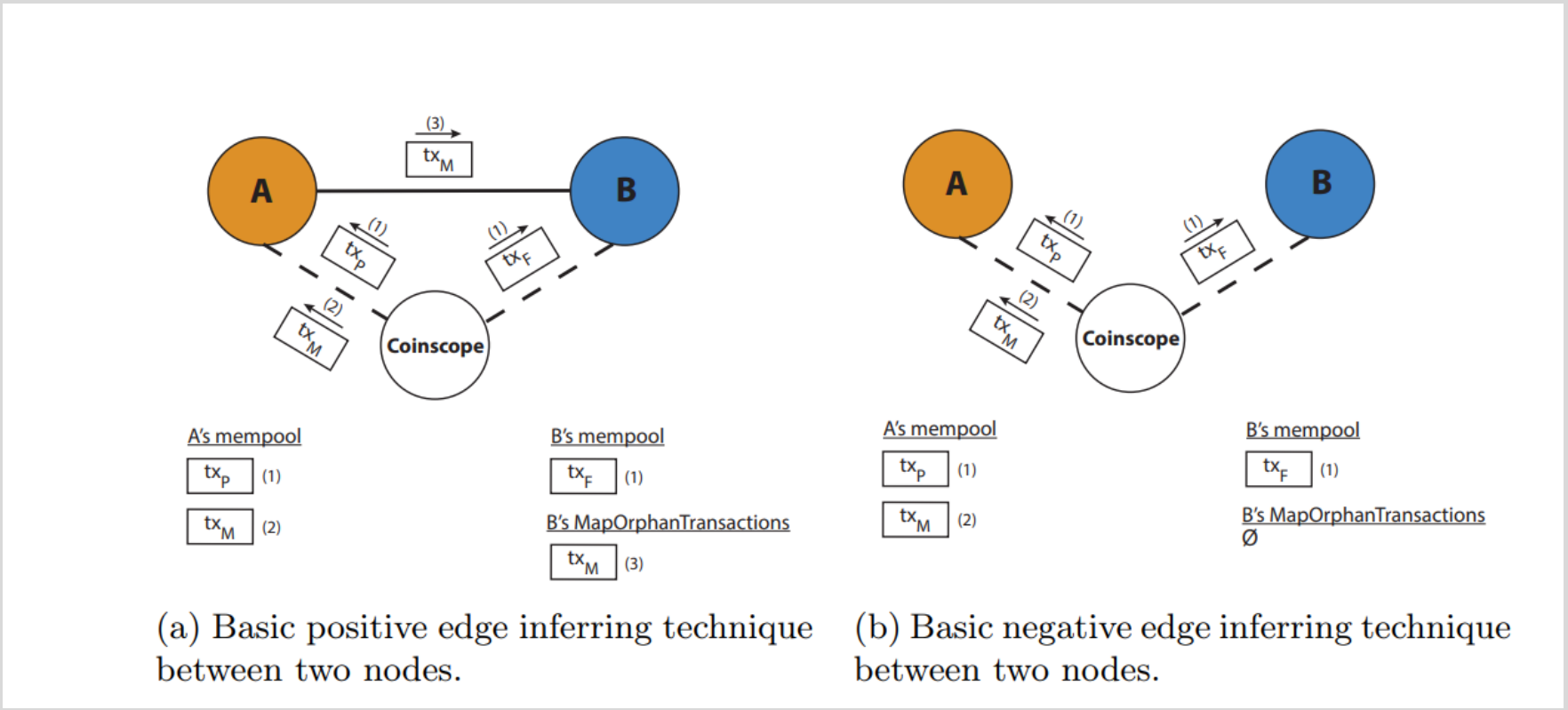
TxProbe



Source: Delgado-Segura, Sergi, et al.
"TxProbe: Discovering Bitcoin's Network Topology Using Orphan Transactions."
Crossref, https://doi.org/10.1007/978-3-030-32101-7_32.

Discovering Bitcoin's Network Topology

TxProbe



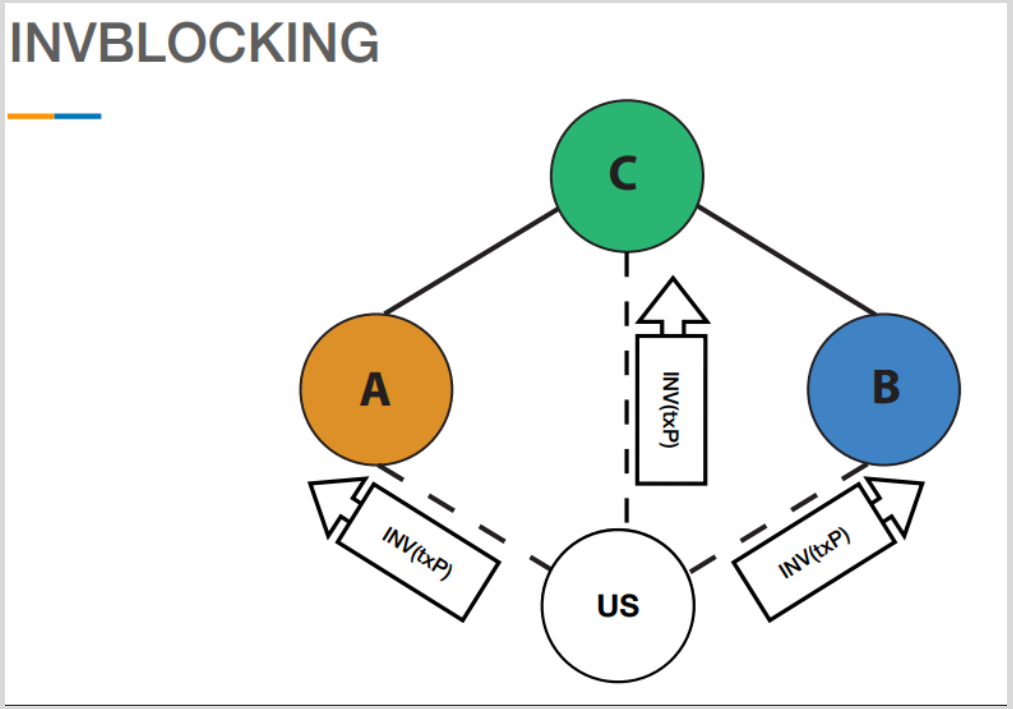
(a) Basic positive edge inferring technique between two nodes.

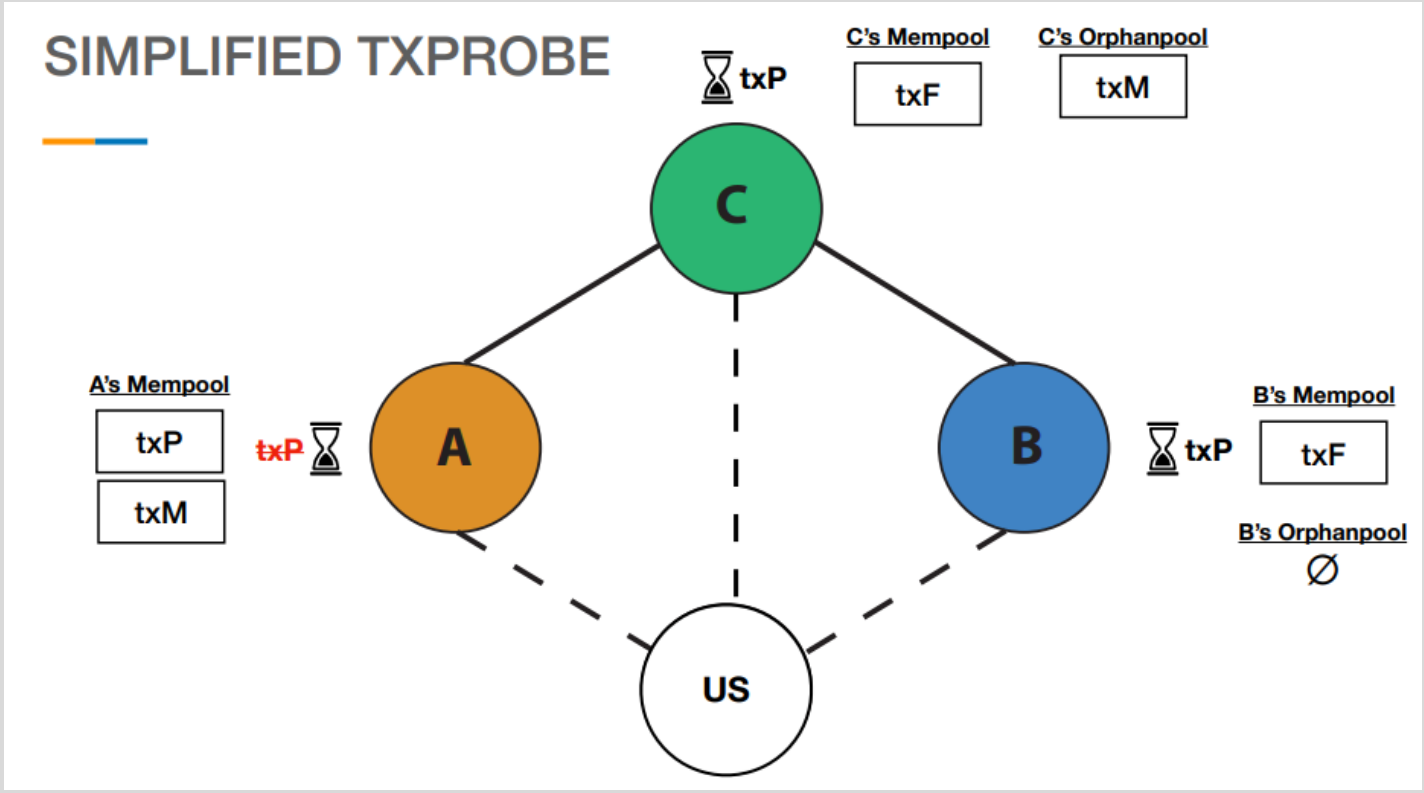
(b) Basic negative edge inferring technique between two nodes.

Source: Delgado-Segura, Sergi, et al. "TxProbe: Discovering Bitcoin's Network Topology Using Orphan Transactions." Crossref, https://doi.org/10.1007/978-3-030-32101-7_32.

Discovering Bitcoin's Network Topology

TxProbe





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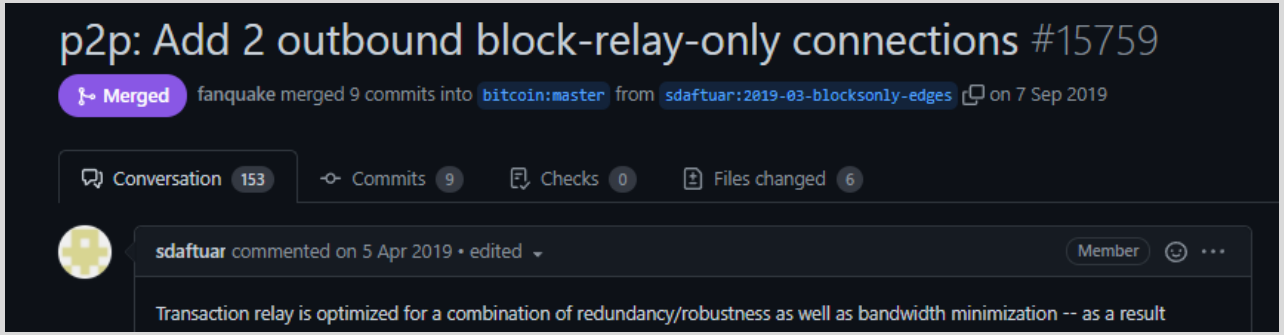
TxProbe

Mitigations



TxProbe

Mitigation – Orphan pool

- Bug: Transaction with lowest hash was evicted
  - Not truly random
- Fix: Select a random position in a list of orphaned transactions

TxProbe

Mitigation - InvBlock

- Bug: Not accepting any tx from other nodes after sending get_data to a node
- Fix: Randomized fetch order
  - Outbound connections are preferred over inbound connections

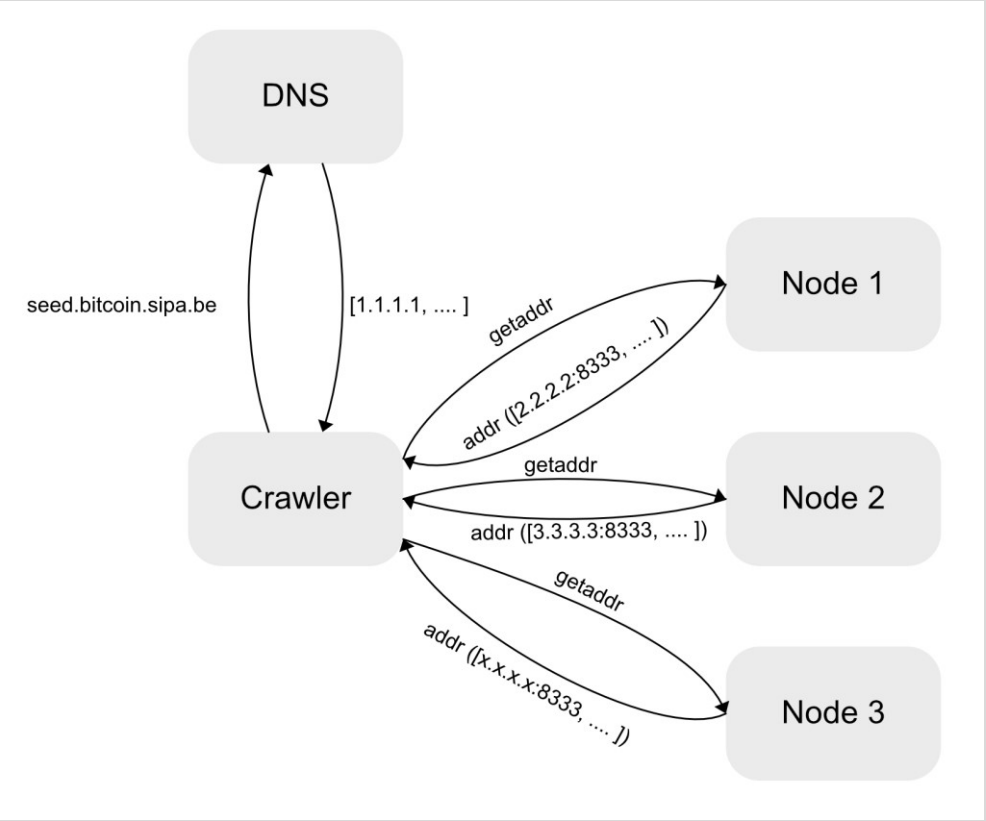
TxProbe

Mitigation – Outbound block-only relay

- Bug: Possible to infer the topology graph
- Fix: Additional 2 block-only relay outbound connections
  - Hide 2 additional connections from outside
  - Only block messages are relayed
  - Addr & tx message are not relayed

Seminar Project

Crawler



Seminar Project

Tools

- Python3
- MaxMind GeoLite2 location database
  - Accuracy 50km
- MaxMind GeoLite2 ASN database
- DNS resolution
- Bitcoin-seeder
  - https://github.com/sipa/bitcoin-seeder

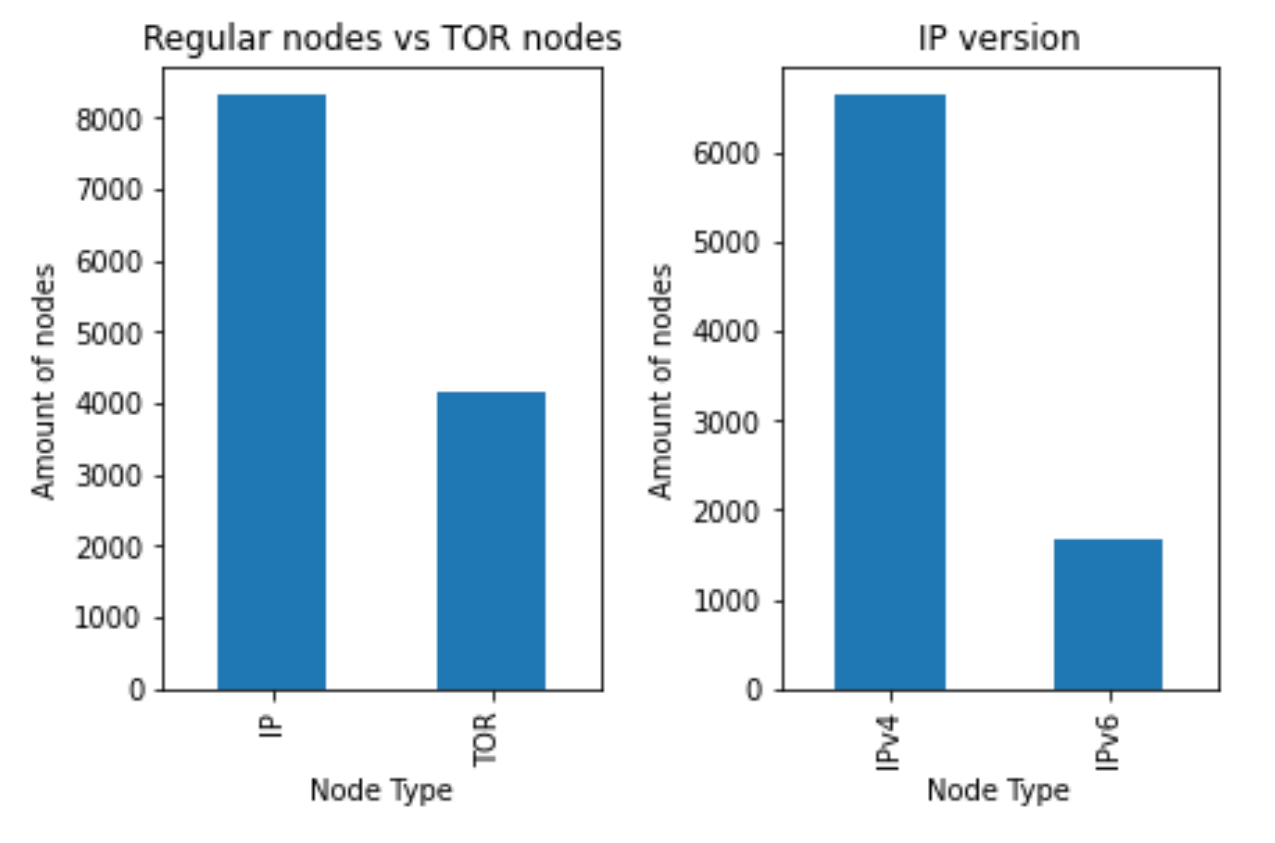
Seminar Project

Tools

```
sysop@btc01:~$ ps aux | grep dnsseed
dnsseed    71836  0.5  1.8 1031908 37320 ?       SLsl Apr03   6:57 /usr/bin/dnsseed
sysop     104961  0.0  0.0   6432   720 pts/0    S+   12:16   0:00 grep --color=auto dnsseed
sysop@btc01:~$ sudo head -n 10 /var/lib/dnsseed/dnsseed.dump
# address                                       good  lastSuccess    %(2h)   %(8h)   %(1d)   %(7d)  %(30d)  blocks      svcs  version
176.209.115.111:8333                               0   1649073958   99.99%  91.46%  55.97%  11.06%   2.70%  730389  00000408  70016 "/Satoshi:22.0.0/"
193.32.127.162:60969                               0   1649073934   99.99%  91.46%  55.96%  11.05%   2.70%  730389  00000409  70016 "/Satoshi:22.0.0/"
95.168.168.108:8333                                1   1649073909   99.99%  91.45%  55.95%  11.05%   2.70%  730389  00000409  70016 "/Satoshi:22.0.0/"
[2a05:d016:98f:5203:6f3a:54ce:5bd9:2770]:8333      1   1649073947   99.99%  91.45%  55.95%  11.05%   2.70%  730389  0000040d  70015 "/Satoshi:0.20.1/"
162.196.143.112:8333                               1   1649073867   99.99%  91.45%  55.94%  11.05%   2.70%  730389  00000409  70016 "/Satoshi:22.0.0/"
5.9.51.253:8333                                    1   1649073955   99.99%  91.45%  55.94%  11.05%   2.70%  730389  00000409  70015 "/Satoshi:0.20.1/"
34.83.108.62:8333                                  1   1649073898   99.99%  91.45%  55.94%  11.05%   2.70%  730389  0000040d  70015 "/Satoshi:0.20.1/"
[2a02:c207:0:4971::1]:8333                         1   1649073854   99.99%  91.44%  55.93%  11.05%   2.69%  730389  0000040d  70015 "/Satoshi:0.18.0/"
79.46.37.101:8333                                  1   1649073857   99.99%  91.43%  55.92%  11.04%   2.69%  730389  00000409  70016 "/Satoshi:22.0.0/"
sysop@btc01:~$
```

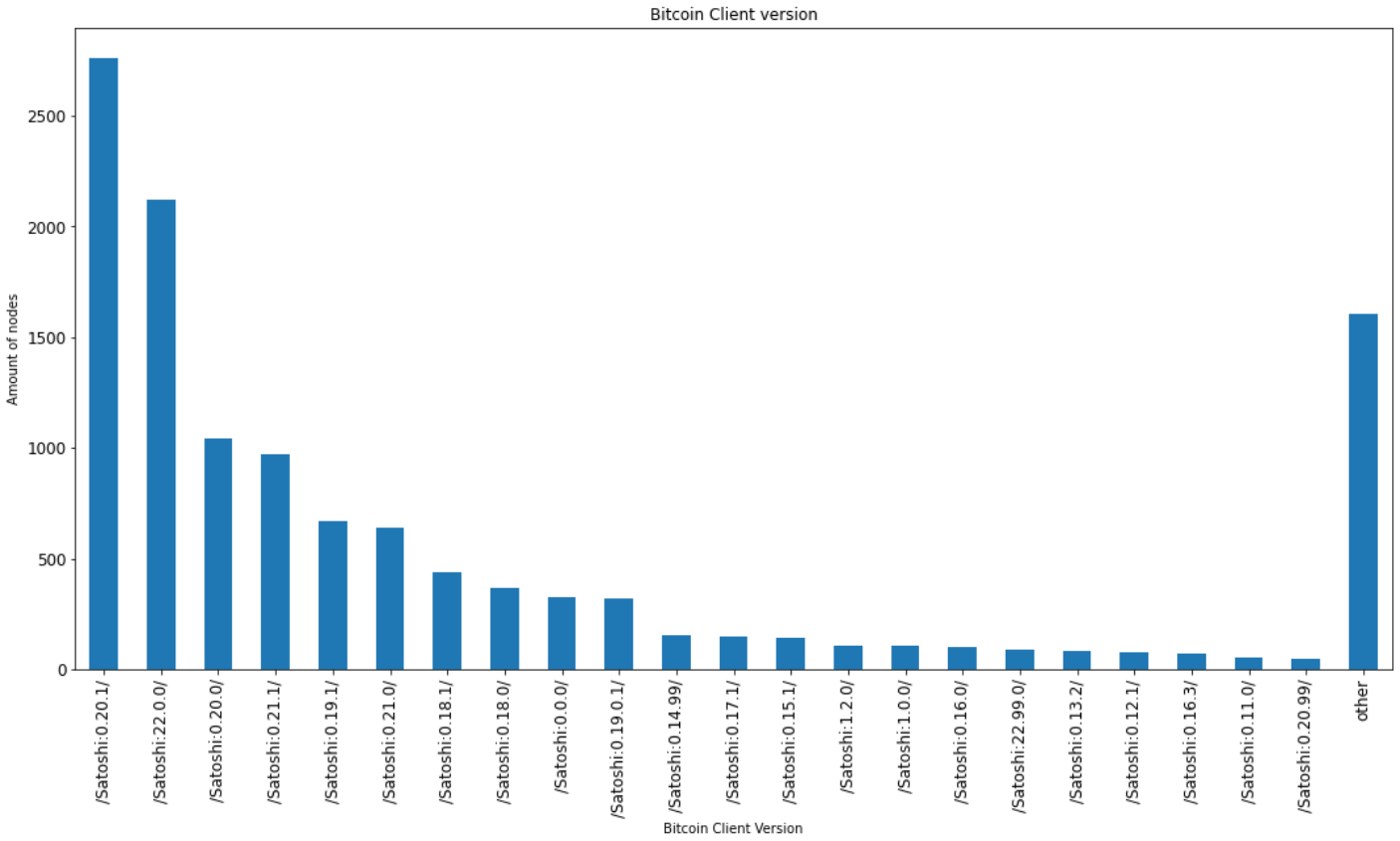
Seminar Project

Reachability of Bitcoin nodes



Seminar Project

Bitcoin nodes grouped by Version



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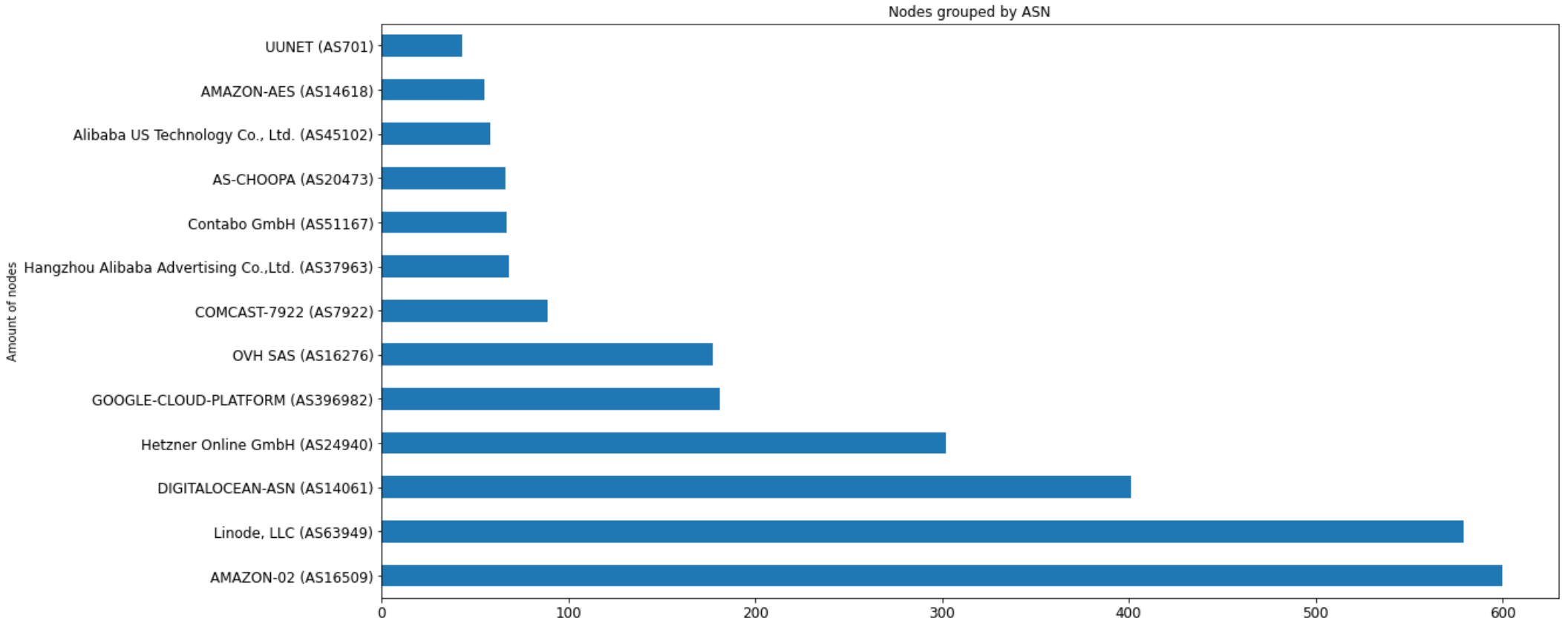
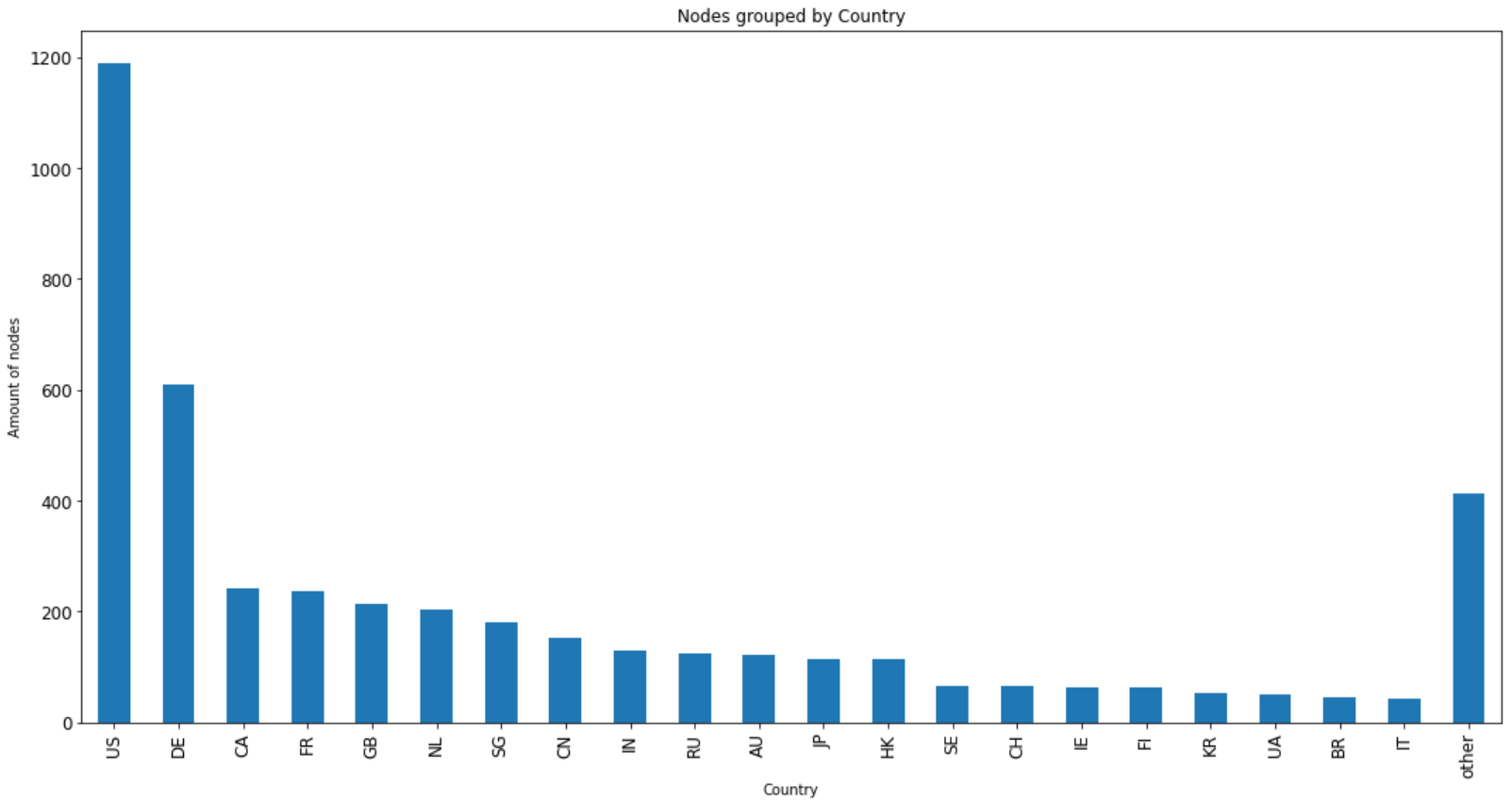
Bitcoin nodes grouped by ASN



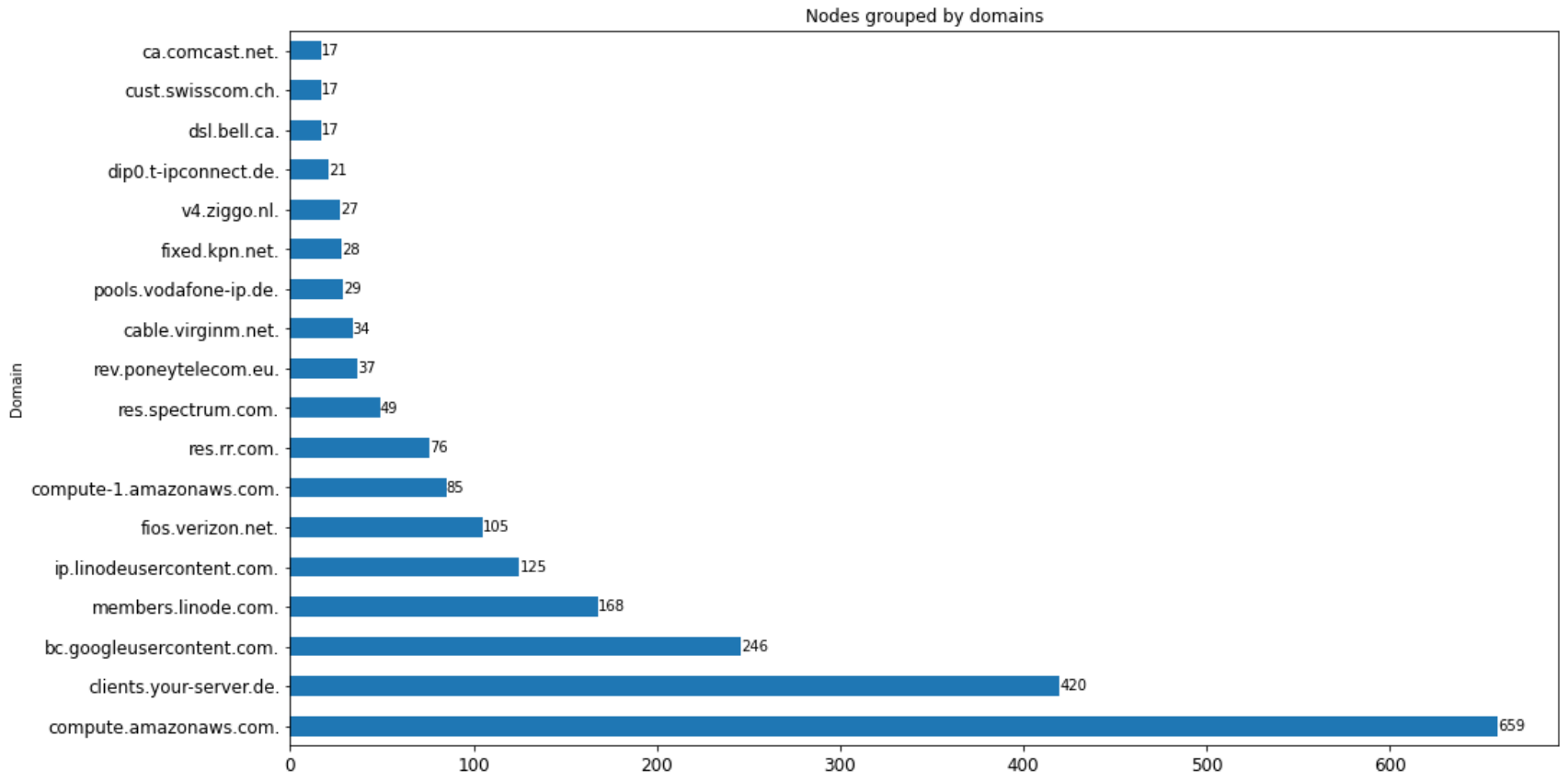
Seminar Project

Bitcoin nodes grouped by country



Seminar Project

Bitcoin nodes grouped by domain



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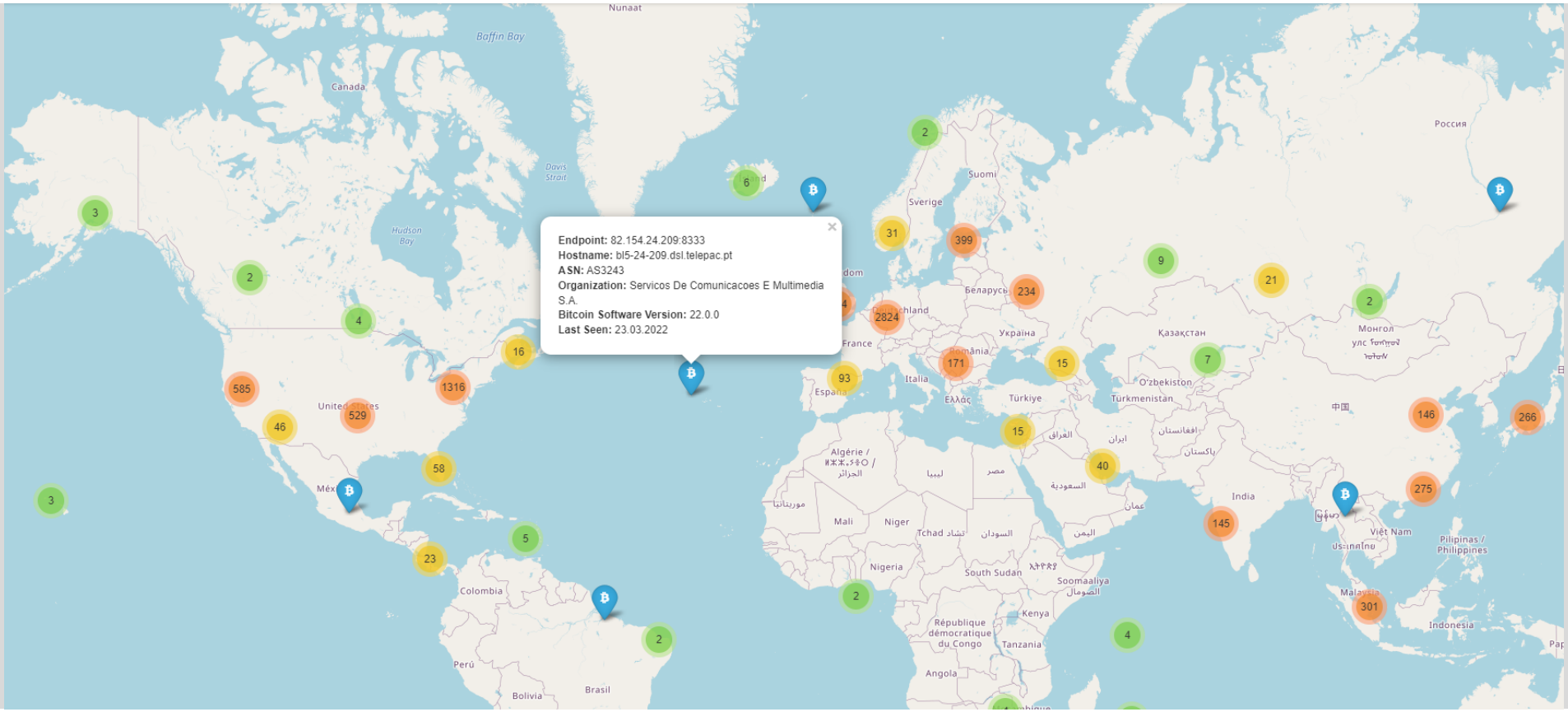
Seminar Project

IPv4 & IPv6 Bitcoin nodes in mainnet



Thank you

For your attention

Chris Rüttimann & Thushjandan

Bern, 6. April 2022