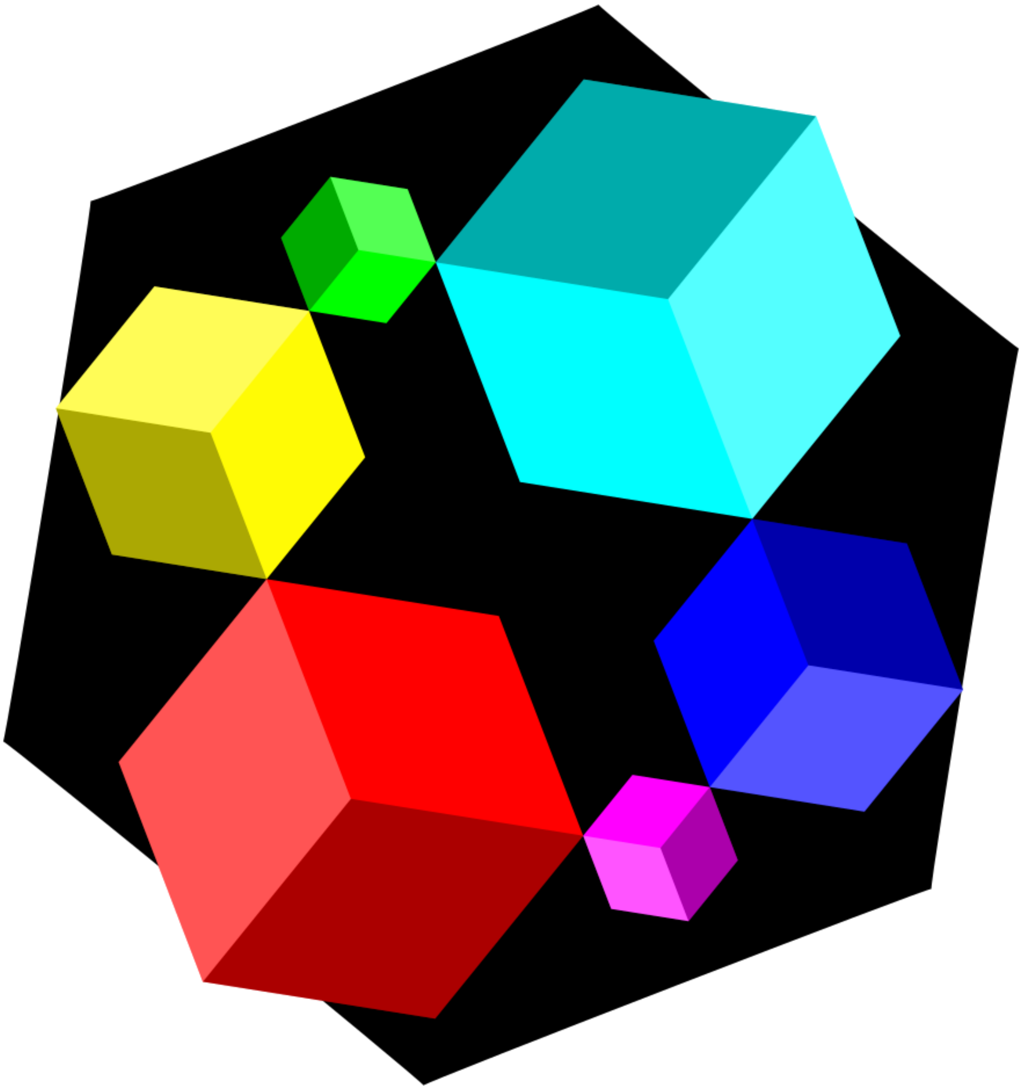
Indranet Protocol White Paper



Onion routed distributed virtual private network protocol with anonymised payments to create scaling incentives.

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Abstract

The state of counter-surveillance technologies has remained largely unchanged in the 20 years since the inception of the Tor network.

The primary use case has always been obscuring the location information of users from clear net sites, and the more it has been used for this purpose, the more hostile clear net sites have become towards this network, due to its frequent use to launch attacks on web services.

With the increasing amounts of value being transported in data packets on the Internet since the appearance of the Bitcoin network, the need for eliminating the risks of geographical correlation between payments and user locations continues to rise.

However, without any way for users to pay routers without creating an audit trail, the anonymising networks have not grown in nearly a decade, and thus well heeled attackers have largely been able to keep pace and pluck off high value targets, such as the Carnegie Mellon University - implicated in part of what led to the arrest of the Silk Road founder, Ross Ulbricht.

It is the central thesis of this paper to demonstrate how obfuscating correlation between payments and session usage can be achieved and create a marketplace in routing services which can economically increase to a size that is beyond the capabilities of a state sized actor to fund an attack, while also improving latency and stability of routed connections.

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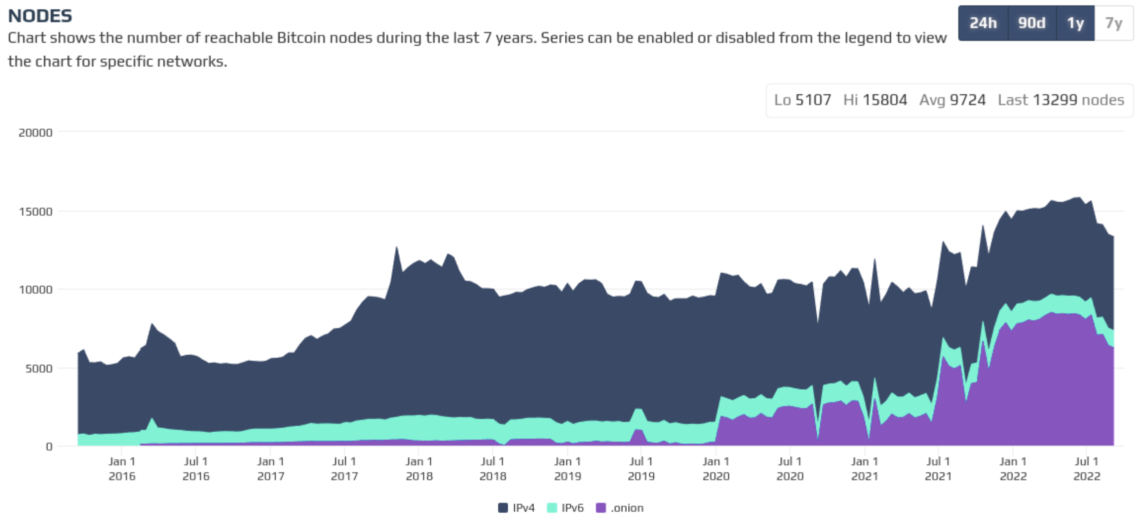
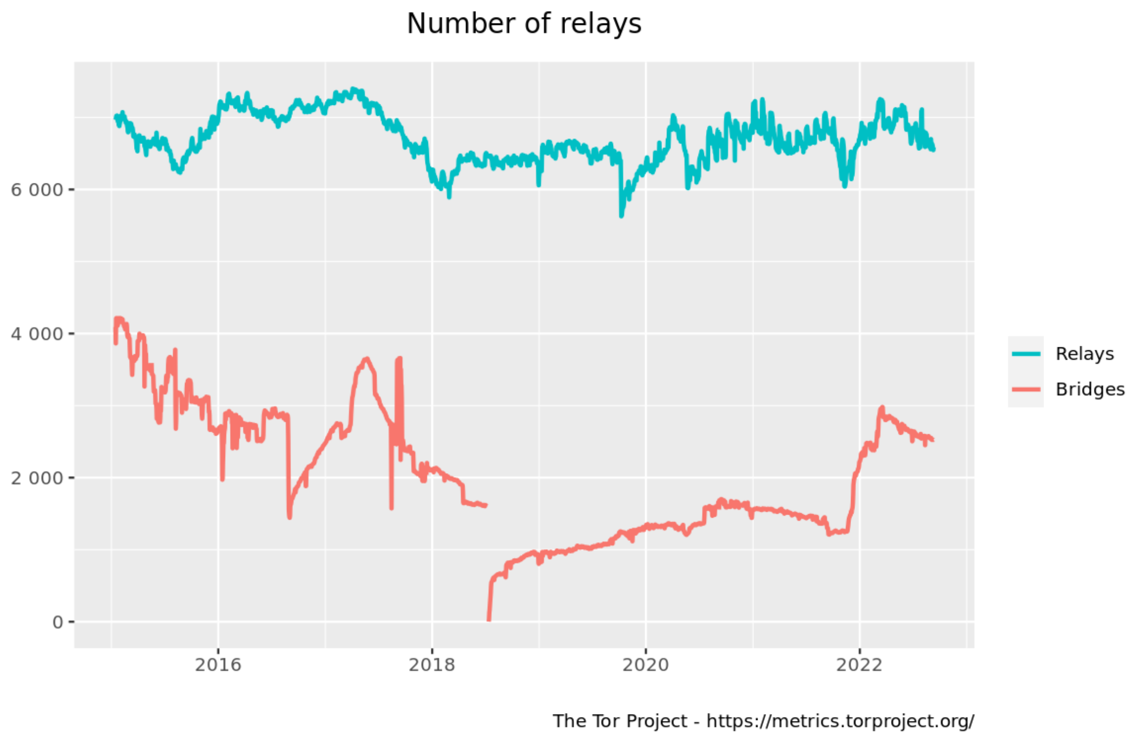
Tor Isn't Scaling, But Bitcoin Needs Onion Routing

For comparison, this is Bitcoin's node count:



Versus Tor in a comparable period:



It is not hard to see:

- Tor is not growing, it has flat-lined.
- Bitcoin is growing.

Not only that, you can also see that onion routing is forming an increasingly large component of Bitcoin connectivity.

How Indranet Improves Upon Existing Mixnet Designs

Indranet, in contrast to other anonymising network designs, is pure source routed. This means that only the clients know the full path along which their traffic moves, and relays have no influence on the path of traffic aside from failing to deliver it. It is similar in many ways to the HORNET mixnet protocol.

Many of the vulnerabilities of mixnets relate to the relays having the ability to change the path of traffic. In Indranet, relays either forward traffic as instructed, or not. To some degree, source routing creates protection against byzantine type faults, because failure to deliver and most malicious attack methods result in clients distrusting the malicious nodes, the same way as they distrust unreliable nodes. Because unreliable nodes cost clients money, effectively, malicious nodes will be quickly forgotten and end up being used by nobody.

Active Attacks

It is not possible for adversaries to modify packets without effectively breaking the path, as messages are integrity protected by cryptography that is opaque to other than the client and the at each layer, the relay that will forward or process the message. This can adversely effect the randomly selected next path because it may be inferred that possibly the receiver is faulty rather than the sender. The client will use probes to check the liveness and latency of the path, and by a process of elimination it will determine the sender is faulty and deprecate it from further use, potentially eventually fully blacklisting it and not sharing the node's existence with peers.

Artificial Gap (packet dropping/delay) and Artificial Bursts

These attacks fail because the client will determine via ping probes that nodes are failing to execute the forwarding/returning of packets and this will gradually result in the malicious nodes not being shared by clients altogether, not just way down the scale of reliability. It is part of the contract of operating a relay on Indranet that your node follows the instructions given to it.

Timing Analysis

Discovering the relationships between clients and the services they are connecting to is the essence of all of the attacks on mixnets. Indra takes several approaches to resolving this issue:

- **Packet scheduling is shuffled constantly** - Relays do not simply behave as First In First Out buffers, but rather, mix together the messages they receive. All messages have to be segmented for network transport, and as these segments are fed into the outbound queue, they are shuffled so that the ordering is broken up. This slightly increases latency but it decreases associativity between streams of packets constituting messages.
- **Deliberate delays** - This is a tactic that is more often seen in email mixnets but can be used to a degree in lower latency mixnets like Indranet because not all traffic is time critical. Bitcoin transactions and blocks are relatively time critical, but DNS requests can comfortably take up to 100 ms without disrupting the functioning of ancillary centralised type services using them (IE, DNS for web traffic). Email is also a potential service type on Indranet, and because it is inherently slow and non-interactive, the delays can be even longer, potentially several seconds to deliver, and so the segments of the packets as they pass through will not have strong timing correlation. The delays are defined by the client, and raise the cost of the data from a regular non-delayed message by a percentage in proportion with the length of the delay.

Why We Need Indranet

Three key elements of the Tor protocol make it less than desirable in general.

1. **High Latency** - Establishment of circuits is quite slow, taking a large number of steps to "telescope" into a circuit.

2. **Low Reliability** - Once a circuit is running, when it fails, the failure is opaque to the client side, and there is no way to provide a latency guarantee or connection stability. It is unsuitable for interactive *and* long living connections.
3. **Poor Scaling Incentives** - There is no profit motive to drive expansion of relaying capacity, weakening anonymity by not expanding the anonymity set to cope with a rise in the number of users. As the charts showed in the foregoing, there is around 8,000 nodes, of which 6,000 are relays and the remainder private bridges, but the average daily user count of Tor is around 100,000 users. Both numbers could be a lot higher if running a relay wasn't a money losing exercise, and if the system could handle interactive grade latency and very long living connections.

Tor is a poor solution for a very limited subset of the use cases that benefit from the security of route obfuscation. Indra aims to provide what Tor has definitely now failed to achieve for a large majority of internet users for all purposes: location privacy.

Indranet does not aim to compete with Tor for the use case of tunneling out to clear-net websites and services: the focus is on obscuring the source of traffic within decentralised, peer to peer protocols like Bitcoin, Lightning Network, Bittorrent, IPFS, and other similar, decentralised protocols. Enabling such services are possible for relay operators to do, since they can offer a Socks5 tunnel exit service on well known web service ports, though this feature may be integrated later, but not enabled by default.

General Principles of Indranet Protocol

There is four main types of traffic in Indranet:

1. **Peer to peer protocol chatter** - sharing lists of known network nodes, their advertised exit services, and collaboratively generated statistics on bandwidth and uptime, their long lived public keys for session initiation, and hidden service introducers.
2. **Purchase and topping up of bandwidth sessions** - Combining with the use of Lightning Network to perform payments to proxy nodes, and specially formed layered encryption of messages, enabling clients to acquire sessions that grant users the ability to relay arbitrary traffic through relays.
3. **Liveness diagnostics** - When messages fail to circle back to the client that are expected to, an Indranet client can perform a diagnostic message protocol to discover which nodes are failing automatically to avoid using them and causing failed transmissions.
4. **Relaying messages to network services** - This is the bulk of traffic, relaying messages from clients to their intended destinations inside the network.

Protocol Concepts

Packet and Message Encryption

Indranet uses a message encryption scheme based on [Elliptic Curve Diffie Hellman](#) (ECDH) key exchange.

The message and packet headers contain the following elements:

- **Message checksum** - 4 bytes of the truncated hash of the remainder of the message or packet, for preventing tampering and ensuring integrity of the message.
- **Initialisation Vector** - cryptographically secure random value used for the payload encryption.

- **Cloaked public key** - generated via the use of a strongly random 3 byte value that is concatenated with the receiver's public key, and the first 5 bytes of the combined hash is concatenated to the 3 byte nonce value to prevent inferring association of a stream of message packets with each other. This key also acts as a session identifier, and must be cloaked in order to not provide information to malicious nodes who would then be able to correlate messages.
- **Public key** - In order to enable the receiver, who knows the cloaked public key's private key, to be able to generate the message encryption cipher, the public key is included in the header of each message and packet.

Signing/Encryption Key Generation and Message Segmentation

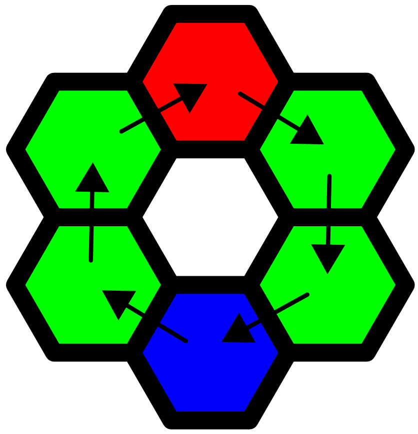
The signatures on messages must be different for each subsequent message, and when a message exceeds 1382 bytes (based on a 1410 byte MTU, typical for mobile networks) the message will be segmented into pieces of this size, the last packet padded out with random based hash chain generated noise.

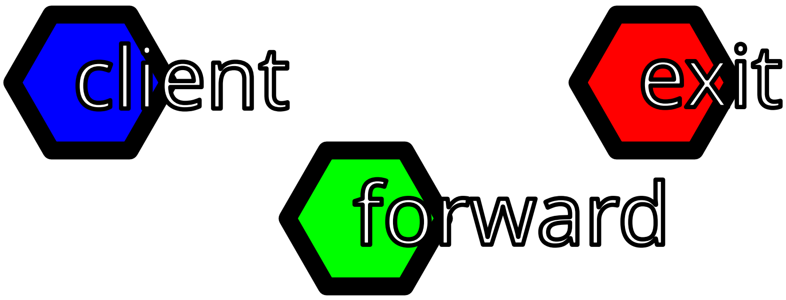
These keys are generated by creating two secure, secp256k1 private keys, the base and the secondary, and the base is scalar summed with the secondary to produce a new key, and this new key is then used again the same way for subsequent keys.

This scalar sum operation guarantees that the new private key is also a valid secp256k1 curve point (values not in the curve weaken the encryption), and can be performed very quickly without the resultant key being outside of the curve.

This scheme is more aggressive than the Signal Protocol's Double Ratchet algorithm, which was designed for low bandwidth short message systems, and it consumes a fair bit of processing power. Benchmarks of initial implementations show that a single thread of a Ryzen 7 2021 mobile processor can process more than 100 mbit per CPU thread, which is more than fast enough for a gigabit dedicated relay with at least 10 CPU threads (and usually, 6 to spare for the rest of the work).

Onion Path Topology





Indra uses a single topology that provides two hops between the client and the exit/endpoint being connected to. Only two are required to provide optimal anonymity - the first hop can infer it received a message from a client, but the second hop cannot, as it did not, and while most clients are not also providing relay service, a lot will also run one it, especially such as hidden p2p services or multi-server setups that forward inbound requests one or more separate servers providing the services offered at the exit.

Because it is mostly not possible to fully hide the fact that a node is a client, there is separate sessions for each of the 5 hops in the circuit. First and last hop sessions can make session balance queries directly, whereas for the other 3 hops it uses the standard path, except in reverse for the second last, and randomly, exit point to perform these queries, and the last two hops and the return hop carry back the response.

Because Indra is source routed, every single request can pass through different paths, eliminating observable correlations between clients and relays for attempts to unmask users, and eliminating any discretion a relay can have about where traffic is forwarded - it either goes, or it does not. Attempts to attack users anonymity by delaying or dropping messages by evil relays will violate expected relaying performance parameters and the offending nodes will be downgraded in their selection frequency as punishment. Tor and I2P have limitations on how many paths they can open at any given time, whereas Indra can, and by default, does choose different paths for every single message cycle.

Return Path Routing

As distinct from most mixnet implementations, interactive connections are not built out of chains of bidirectional connections between the hops in the circuit. The outbound message path is entirely unrelated to the inbound message path, except that the client initiates the messages outbound first, and must always.

This means that for "push" type interactive services, the client must send out a message containing the reverse path to deliver "pushed" messages. But fundamentally this is how websockets work anyway, using a subscribe message to start listening, the difference being that the client must send new return message headers in order to get responses.

To support the connection type model of HTTP, the protocol always pushes a few extra reply message packets in addition to the ones associated with a given outbound message, so that if more replies come back it can keep prompting for more to come. This is a limitation of source routing with anonymity, as the reply path is entirely under the control of the client.

Ping Messages and Path Failure Diagnosis

Because there is several intermediaries in paths in Indranet, and a failure for the response or confirmation to arrive in a timely fashion can mean a failure in any of the nodes in a circuit. The first and last hops can be openly probed for operation using a Get Balance query (which is a single hop out and back), but the others must be diagnosed differently. The reason being that using relays for the outer 3 hops at the same time as using them as first hops would potentially unmask the location of the client associated with the session.

Thus, the ping message, which consists of 5 hops using the forward-only relaying instruction message, can be sent out several times to pass through these inner hops of the failed path. The failing node will not forward these messages and thus the confirmation of the ping will not arrive back at the client. Of course it can be that the randomly selected other relays in the ping path also are failing, which can then require further probing, using sessions that already proved to work until the one or more hops in the failed path are identified. While the process of diagnosis is occurring, Indra will not choose the relays in the failed path until the diagnostic is completed.

When a delivery failure occurs, Indra will inform the client application by returning a connection reset by peer message so the client retries, and Indra then uses a different path that does not include any of the relays from the failed path until they are diagnosed.

Client

Unlike Tor and other anonymising protocols, every client has the capacity to act as an **exit** for traffic while it is online, for at minimum, Bitcoin and Lightning Network messages. They advertise themselves as "unreliable" exit nodes, this descriptor indicating that they are intermittently offline, and do not attempt to stay online. This will also mean they don't get a lot of traffic but users on the network will be able to use them when they see a status update on the peer to peer network.

Users primarily using Indranet as clients can also gain an increase in their anonymity by also running a relay. This is generally not advisable on mobile devices since their intermittency and the latency of the p2p network DHT updates make them impractical for frequent use, but when they are online, they can be used, and the payments on their sessions can be used later to balance their channels, and amortise some of their relay session costs.

Because of the unreliability of especially mobile clients providing relay service, they are not subject to the same consensus about reliability, but will mainly be selected as exit points when they are online as a way to further boost the anonymity of the services being provided. And of course this will include hidden services, which can be leveraged for peer to peer protocols on the mobile devices.

Payment for Traffic

Using [Atomic Multi-path Payment](#) (AMP), relays advertise their LN node public keys alongside their Indra identity keys, they send a message constructed as follows:

- Preimage hash of the forward and return private keys that will be delivered after payment to prove payment and provide the keys for handling return messages.
- Amount of bytes the payment is for.

The payment will be for an amount of satoshis in accordance with the rate advertised by the seller, and the amount of advance payment the client is willing to put forward. There is no direct return confirmation in this process. As with the rest of Indranet's design, the client is in control of everything, tightening the security.

In the initial bootstrap, the client will send out 5 such payments to establish enough hops to form a secure path. With 5 payments made, relating to 5 sets of header/payload keys by the hash of these keys being the preimage used.

Then after sending out the payments with the preimages to the relevant relays, the client then sends out a "SendKeys" message which provides the relay with the two private keys that both identify the session being used in a hop in an onion message, as well as provide the relay with the necessary keys to unwrap their layer to be processed.

Proof of HODL Consensus

Following from the model of loyalty building between customers and businesses in the open market, a number of consensus rules and protocols help reward honest nodes and reduce the impact of bad behaviour in both clients and relays that harm the security and value of the network.

Decentralised, and especially anonymous networks have a primary common vulnerability to Sybil attacks, since identities can be created in large numbers and used to overwhelm a network with false information.

In order to prevent this attack there is a number of rules that honest peers follow, and mechanisms by which peers on the network evaluate each other on the relay and client side both.

1. To rate limit the creation of new nodes on the network, nodes must make an on chain Bitcoin payment with a time delay back to themselves, and after a period of time they can then repeat the transaction, the latest head of the chain of transactions tied to the original TXID must be active in order for nodes to use the relay.

   The size of the value of the time locked UTXO is a factor in node selection to weight probability, lower than the factor of age in first time usage by clients.

   The UTXO hash is signed by the UTXO's private key in the node identity, proving ownership. It leverages the strong security of Bitcoin to anchor a relay identity to a definite time as well as raising the new relay identity creation cost in the short term.

   The fees a relay pays to renew can be zero, but this will reduce their ranking during the interim periods after one expiry and the next activation.

   Bigger UTXOs expire later than smaller, so the more a relay defers spending the more reliable they intend to be, and cutting down their transaction fee overheads. Sybil attacks rely on cheap identities, this creates a dilemma for attackers, who must lock up more for longer if they want to be more likely to win new loyal client customers, and putting a cap on how many Sybil clones they can create for any hypothetical get paid but not deliver attacks.

The expiry times must conform to the rules of the network, as a ratio of satoshis and blocks, some deviation is allowed, but the point is that smaller time locked spends must expire sooner and thus cost more in transaction fee overhead, it is just better to sink more than less, as well as it raising the probability of first time selection by clients.

2. The age and cumulative time active for a TL UTXO is also used as a factor in the evaluation of the reliability of a peer. No matter how big the UTXO the clients will not pick it with higher probability until the relay has remained operational in a time/value weighting formula.
3. For relays a client has used, the ones with the highest rates of fulfillment are weighted above all else. The previous two criteria are more used for distributing risk of first time use of a relay, so as to minimise the unfulfilled sessions versus delivered. At the same time, a client also needs to slowly shift its session usage around, and thus also try new relays out, and intermittently cease using some of its known and trusted relays for traffic for some period, which is necessary also for the feedback system described in the next section.

Anonymous Probabilistic Feedback Propagation

In order to create a feedback loop between relays and clients, both relays and clients share random selections of known peers with each other that have been given a weighted probability of selection in the message of this small subset.

The p2p layer ensures that any node can discover with fairly high convergence of the current full list of peers on the network if desired. This is a separate process that works a little bit like "shout-outs" in social media.

In order to prevent the correlation of esteemed peers to a client's currently active traffic, the most recent activity and volumes of traffic over their circuits is weighed to not leak current connection data in close time proximity to this chatter.

The messages are only sent out once a day, and in proportion with the time known and the amount of first/last hop connection traffic sending these "shout-outs" are then combined with the frequencies of clients' recommendations lists allows long serving customers running honest clients to evaluate their peers in a way that doesn't either unmask them or enable spammy advertisement from constantly new clients attempting to poison these scores.

> With the combination of a form of lightweight bonding, timestamp anchoring to Bitcoin with proof of ownership, subjective histories of fidelity and a probabilistic feedback mechanism, it will be difficult to find a way to make income from Indranet without actually delivering service.

Rate Limiting

Because inherently anonymous, and especially source routed traffic volumes cannot be controlled by the use of client identifiers, Indranet needs a mechanism to enforce bandwidth limits and prevent congestion caused by the coincidence of many clients selecting a relay at the same time randomly.

When a relay is exceeding its momentary traffic volume limit, as set by the relay operator, it will delay processing of message, and if the volume continues to flood, it will start to drop packets. This is obviously a potential vector for attacking a specific relay, but because although clients are not identifiable, sessions are, the sessions with the highest volumes will be dropped before lesser volume messages.

Such sessions are clearly being used by attackers, and rightly can be denied, even if the session has allocation remaining. Thus, the messages are not only dropped, but the sessions balances are decremented as though they were relayed, as further punishment.

In order to help smooth out the naturally fluctuating traffic levels, every exit session the relay processes, in the reply header of the response there is a single byte value that informs the client of the current utilisation rate as a percentage represented as a value between 0 and 255. Clients will then record this information in the session database and nodes with high utilisation will be reduced in their odds of selection for a path. Updating this data will be client-driven, and be based on the existing probabilities of selection as used to pick hops for paths.

Non-exit nodes do not have the ability to pass such messages through on the path to and from the exit, so in addition, a longer period EMA of utilisation rate (traffic vs configured bandwidth capacity) is published to the p2p DHT and propagates to clients at lower time precision. Since this specific update is quite important to the network consensus, the client will try to also shuffle paths around so that circuits using a relay for an intermediate hop also is used as an exit point where possible.

Requesting this information to peers would leak client's current running circuits to peers, so relays will interpret an exit message with no request data to be a utilisation state request and return this byte in a reply with no body. Clients will send out these empty requests randomly in the same way as the relays are chosen for paths to gather advance intelligence about potential congestion, and avoid a given relay for a while until a later request reveals the relay's traffic has returned to nominal levels.

With the combination of periodic updating of longer time windows of recent activity from the p2p network, and the direct queries via empty exit onions, clients will avoid overloading relays. Users will even be able to define a threshold for "too busy" for a peer at a lower level in order to get a better latency guarantee, indeed, some service ports relate to applications with high interactivity and these can be automatically evaluated using this different threshold and achieve low latency as well as preventing network congestion.

Relay to Relay Traffic

Messages are segmented into 1382 byte segments and reassembled by relays when they receive them. The relays return an acknowledgement being a signature on the hash of the packet data (which includes the checksum prefix), and these are dispatched in a stream after shuffling already queued messages by the sending relay, as well as interleaving messages passing to the common next hop when this happens.

If a message fails to be received on the other end, the relay will retry the send a few times before giving up. Unfortunately it is not possible, while minimising packet overhead, to allow intermediate hops to return replies (it is around 250 bytes), and so from the client's perspective, the message has failed to be delivered as it does not receive the expected return trip confirmation or response, and it is impractical to then return a failure response back to the client.

By not allowing such back-propagation in the protocol, attempting to attack the network by disrupting protocol packets with delays, corruption and dropping does not prompt a reverse path chain of messages that lead from the intermediate hop to the client.

Because it is not possible, due to protecting anonymity, to connect an intermediate hop with an exit point's sessions, clients are simply in the dark when a message fails to travel forwards, and by the use of a time to live on the return path (which clients open after sending out a message to enable the last hop to send back the reply) for a given service type, the client caches the forward message payload and exit point after sending them, and then flushes them from the cache once they receive the confirmation/response.

If it does not arrive before the TTL for the service type, the client will then construct a new path to deliver the message to the same exit a few more times before giving up. This value will also have the requested packet delay total added to it when there is delay messages in the onions. Failed messages may turn out to be failing on the return path, so on the other side, when a request is received, it is cached for a little while in case the request is sent again with a different return path, though it only needs to store the request message hash to achieve this.

Relay to Relay Encryption

In order to further secure traffic, relays in their chatter with each other provide private relay-to-relay keys to use for message encryption. These are rolled over in accordance with the traffic volume between the peers.

Dynamic error correction adjustment for Re-transmit Avoidance

Based on the conditions of the paths between two relays, by the ratio of packet loss the nodes adjust the error correction to use in order to maintain a margin above the current loss rate, built using a moving average of successful deliveries versus failed between the two relays.

Client Path Generation Configuration

A flexible configuration system for selecting paths and exit points is required to cover several different types of use case of obfuscated traffic paths.

- Geo-location based exit and route hop selection:
    - Users may need to avoid using exits within their own or some specified outside jurisdiction.
    - Users may specifically want their exits to emerge in a specified geographical region.
    - Users may want to specify, or avoid selecting intermediate paths in a list of specified geographical regions.
- Selection of specific routers for exits for a given protocol:
    - Using a user's own servers, this can be generalised to allow remote access to a server controlled by the user.
    - A company may provide specific services that users can access at a given set of addresses, whether IP based or domain based.

Simply providing the IP or domain name of the endpoint to the built in Socks5 proxy will also pick the exit if it is an Indra peer, which makes servers like Bitcoin and LN nodes transparently reachable over Indranet without any user intervention, and makes Indranet the default path for all of the Indra relays when they connect to Indra peers.

Since the net effect will be that relays will spend the same amount on tunnelling to other Indranet LN and Bitcoin nodes as others do to their own, the relays will be able to use this to prompt usage of nodes with imbalanced channels to correct their inbound liquidity. And of course this increases the amount of traffic and thus the anonymity set to include not just client initiated traffic but relay initiated as well.

Hidden Services

Because Indranet is source routed, unlike the connection oriented onion paths that Tor uses, it can avoid the potential problem of all of its rendezvous points becoming congested and impacting user experience via increased latency and dropped packets. It requires more than 6 hops but these are changed at every message cycle.

1. The hidden service selects a set of 6 randomly selected relays to act as introducers. It sends out a few messages to the relay so that it can handle several requests and a reply header to request more.
2. The client contacts the introducer and requests one of there routing headers, and the introducer delivers one and also sends back a reply to the hidden service in its pending reply packet provided precisely for requesting new routing headers, and the hidden service duly dispatches a new one on a new path.
3. The client then creates a 2 hop, but 3 layer "reverse" header, then puts the routing header provided by the introducer inside it, so the second hop unwraps it and continues to forward the rest of the onion. And then at the end of the message just before the request payload, it provides a 3 hop reply path, two intermediaries and its own randomly selected session keyset.
4. The packet arrives at the hidden service after the path defined by its 3 hop header, it dispatches the payload out to the connected service for the message, and then creates another two hop, but 3 layer "reverse" header, which it then wraps the client's routing header, and attaches the response payload to it, with the hash of the request payload to identify what request the response relates to, and lastly, the next 3 hop routing header like the one the introducer provides, enabling the next message cycle.
5. Embedded in the payload part of the routing headers on both sides is a 64 bit nonce which acts as the connection cookie to identify quickly what connection a message relates to, which is translated into a fake hexadecimal pretend domain name, enabling a web service to block this connection if the app determines the client is up to mischief.
6. To minimise DoS attack potential in repeatedly requesting routing headers and then not using them, the introducer node charges a substantially larger fee for delivering the routing headers, raising the barrier against such attempts to congest the introducer's message stream back to the hidden service. After a message session has gone quiet for a timeout period, maybe around 1 hour, the last delivered routing header is expired and cannot be used to continue the hidden service connection.

With this scheme, the anonymity of both sides of the connection is maintained, at the cost of the extra 4 hops versus the potentially small channel created by a set of 6 rendezvous nodes in Tor. Because all the processing is done at the endpoints, the trip time is a little longer, but because it is dynamically generated, peers can minimise bottlenecks along the path through their constant updating of reported utilisation levels for relays both on the p2p network as well as via the replies to exit onion messages.

And of course, in stark contrast to Tor, the paths change every time meaning that timing patterns require a far larger number of evil nodes to capture meaningful patterns, a difficulty level that rises asymptotically with the number of relays and clients on the network, as well as the advantage of source routing eliminating the ability for evil nodes to reroute traffic.

Fully Anonymous VPS Hosting

With the use of Indranet's hidden services protocol, in theory a user can establish an account with a remote VPS rental provider that uses Indranet, with an package that includes a pre-installed instance of Indranet (not providing relay service, but appearing in the peer DHT), running a certificate authenticated SSH endpoint, and then install whatever applications they want, hook them up to the server's service configuration, and thus remain completely anonymous and untraceable to the public IP of the VPS. In this plain configuration the user knows the IP address of the server's Indra node.

Or it can even go one step further, where even the server IP address is hidden, connected by a point to point connection to the provider's network infrastructure, which further increases security against an application breach leaking the IP address of the hidden services running on it. Neither the provider, or the client know anything about each other, and thus cannot be connected together, and likewise, none of the clients of the hidden service will reveal any location data by default to the applications on the server.

Proxy Service

The client will run a Socks5 proxy, which users then set up as their web browser/other proxy for connections. This proxy will make DNS requests via Indranet for the names in the requests, whether Indra hidden service addresses or clearnet addresses, forwarding the name resolution request out to random Indranet relays, who send back the IP address replies.

Requests for forwarding to a specific Indra relay can be specified by an address matching the relay's IP address, or the zero address, meaning randomly select the exit, or a regular domain name for the case of relays that provide tunnel exit services. As mentioned previously, relays automatically route Bitcoin and LN traffic over Indranet to Indranet Bitcoin and LN nodes.

Relays that wish to provide tunnel exit service simply place a Socks5 proxy listening on their localhost service ports, inbound connections for these services are then forwarded through the proxy which then resolves names via Indra to dissociate this request from the exit, and forwards the messages and routes the replies back to the clients using the exit header reply segment.

In this way, a user can run a bitcoin or lightning wallet or other client application, and set its proxy to the Indra client's proxy and they will then be able to tunnel out to the endpoint, in the case of Indra nodes offering this service, or via tunnel exit services for addresses not part of the Indranet swarm, no modification required except to add the proxy configuration to the server, or even to the operating system settings to enable proxying automatically for any application that knows how to use the OS proxy setting. Or indeed, just providing this outbound routing service to only a specific set of ports.

For software that does not have the ability to use a proxy, the Indra client also opens listeners on localhost addresses for configured port numbers, and then using server configurations' "connect only" type setting, establish a path to a single, randomly chosen Indra peer that provides this service, and of course many of them can be set up as needed. The caveat to this is that during a session, if it were desired to change the endpoint the path leads to, this has to be tolerated by the protocol, that it be ok for an endpoint change to occur periodically, or on every request.

Peer to peer applications may or may not tolerate the apparent change. For services that have no concept of association, like a Bitcoin or other distributed application service RPC API, it is fine for each new request to take a different path and go to a different endpoint. Configuration will allow fixed endpoints (that don't change during a run), a rotating change of endpoint, and a period in which the endpoint is rotated if it is set to rotate, or a new endpoint each time.

However, since most p2p applications understand the use of Socks proxies, this won't be a frequent requirement, and is of lower priority for implementation than the straight Socks5 proxy.

Private Relay Services

To enable users to use Indranet as a transport for accessing private servers, deployments using the `Neutrino` SPV bitcoin node and `lnd` can configure a public key certificate that they can use with a private key, in a similar way to SSH certificate encryption, to enable routing from any client to their specified node identified with its IP address, where there is a relay running at that IP address with the public key registered as enabling access to forward connections to a defined loopback address where the hidden service is running.

This will enable SSH, FTP, and similar services for users to be accessed via Indra, while preventing third parties from identifying the origin of access to the server. This will also enable things like remote desktop access, but it does not include rendezvous routing. It can also, as previously mentioned, to hide the destination point as well using hidden services.

The Indra Tax

Here at Indra Labs we like to call a spade a spade, and we will be establishing in our distribution of the Indranet clients and relays the default establishment of Lightning channels through our peer to peer network seed nodes, which will charge market-typical routing fees to connect clients to the Indranet swarm's Lightning nodes and enable payments. Because we make this the default, and by default relays only connect to other relays and the seed nodes, effectively we can levy a kind of toll for the delivery of payments.

We intend to also offer the option for investors to, preferably independently, run seed nodes, under the conditions they request, which can include our promotion of them on our website and communications. It is better that there be several independent entities involved in this, and of course the fees their seed nodes collect will be part of their reward for this service.

Session payments are always routed through long paths, as permitted by the Lightning Network protocol, selecting a seed node first and then to several intermediary nodes in the swarm before reaching the destination. Users will be able to verify by enabling payment logging, and see a recent history of payments and the hops that the Lighting node in the client used to construct the payment message.

The channels between clients and seed nodes are bidirectional, and users can then add to their client balance by sending payments to an invoice their client creates for adding funds to it. The amount of satoshis in their channels will be at their discretion, though the client will alert them that their channel is empty in order to prompt the user to fill it back up. Seed nodes will collect routing fees on both directions, of course.

The size of Indra client Lightning wallet balances is dictated by the user, but in general it does not need to be very large, as it will likely process maybe several US dollars worth of traffic a day for most users, it is just a matter of convenience to make them larger. Rather than close them and establish new ones, when users want to increase their wallet balance they can simply establish more channels to the seeds, and avoid closure fees. Since a user is not going to pay into their wallet unless the client is running, these channels are ok to be offline the rest of the time.

Users can also configure their client's Lightning node to open other channels to the Lightning Network as they wish, by pointing their wallet application to the IP address of their client, or if they are technically inclined, via `lncli`, as we are using `lnd` as our primary LN node due to it being written in the same language as Indranet itself. Payments into their Indra LN wallets can thus also pass through other channels than the seed nodes' channels, evading the inbound transaction fee to our seeds, although in general that just means paying someone else.

Indra's channel management system will automate most of the task of balancing channels, shifting balance from depleted paths into ones that are not yet depleted, to ensure there is as many routes as possible in case seed nodes happen to be offline at the time of a payment.

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