Katzenpost administrator's guide

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Quickstart guide

This topic provides collects basic commands for installed Katzenpost server components in a single convenient place. All system commands require superuser privileges.

The commands in this topic do not apply to the Katzenpost Docker image, which has its own controls. For more information, see Using the Katzenpost Docker test network [https://katzenpost.network/docs/admin_guide/docker.html].

Systemd commands

These commands match the suggested systemd setup described in Installing Katzenpost [https://katzenpost.network/docs/admin_guide/install.html].

Table 1. Systemd control commands for Katzenpost

Task	Command
Start a mix node.	systemctl start katzenpost-mixserver
Stop a mix node. systemctl stop katzenpost-mixserver	
Restart a mix node. systemctl restart katzenpost-mixserve	
tart a diectory authority node. systemctl start katzenpost-authority	
Stop a diectory authority node.	systemctl stop katzenpost-authority
Restart a diectory authority node. systemctl restart katzenpost-authority	

Server CLI commands

The primary Katzenpost server binaries are **katzenpost-mixserver**, which instantiates a mix node, gateway node, or service provider depending on its configuration, and **katzenpost-authority**, which instantiates a directory authority.

Table 2. Command options for the Katzenpost server binaries

Task	Command
Control a mix node.	Run katzenpost-mixserver -h for options.
	<pre>\$ katzenpost-mixserver -h Usage of katzenpost-mixserver: -f string Path to the authority config file. (default "kat</pre>
	 -g Generate the keys and exit immediately. -v Get version info. The -f parameter can be used to specify a customized path and filename for the etc/katzenpost-mixserver/katzenpost.toml.
	The -g option is used to generate the public and private signing and link keys. I directory defined by the DataDir parameter in /etc/katzenpost-mixse
Control a directory authority.	Run katzenpost-authority -h for options.
	<pre>\$ katzenpost-authority -h Usage of katzenpost-authority: -f string</pre>

Path to the authority config file. (default "aut

Task	Command
	-g Generate the keys and exit immediatelyv Get version info.
	The -f parameter can be used to specify a customized path and filename for the etc/katzenpost-authority/authority.toml.
	The -g option is used to generate the public and private signing and link keys. Edirectory defined by the DataDir parameter in /etc/katzenpost-author

Management interface

Katzenpost provides a management interface that is accessed through a unix domain socket. The interface supports run-time changes to nodes without requiring a restart. By default, the management interface is disabled. To enable it, change the Management section of the node's configuration file so that Enable = true:

```
[Management]
   Enable = true
   Path = "/node_datadir/management_sock"
```

For more information about management configuration, see the details for your node type in Components and configuration of the Katzenpost mixnet [https://katzenpost.network/docs/admin_guide/components.html].

Use the socat [https://manpages.org/socat] command-line utility to connect to the management socket and issue commands, with the following syntax:

socat unix:/node-datadir/management_sock STDOUT

The following commands are supported.

- QUIT Exit the management socket session.
- SHUTDOWN Shut down the server gracefully.
- ADD_USER Add a user and associate it with a public link key provided in either hexadecimal or Base64 format.

```
ADD_USER user key
```

• UPDATE_USER - Update a user's link key.

```
UPDATE_USER user key
```

• REMOVE_USER - Remove a user.

```
REMOVE USER user
```

• SET_USER_IDENTITY - Set a user's identity key.

```
SET_USER_IDENTITY user key
```

• REMOVE_USER_IDENTITY - Remove a user's identity key. This command must be followed up with a REMOVE_USER command.

```
REMOVE_USER_IDENTITY user
```

• USER_IDENTITY - Retrieve a user's identity key.

```
USER_IDENTITY user
```

• SEND_RATE - Set the packet rate limit to a per-minute integer value.

```
SEND_RATE value
```

• SEND_BURST - Set the packet burst-rate limit to a per-minute integer value.

```
SEND_BURST value
```

Monitoring

Katzenpost logging information can be viewed in real time with the following commands:

```
# journalctl -u katzenpost-mixserver -f -n 2000
or
```

journalctl -u katzenpost-authority -f -n 2000

Logging levels include ERROR, WARNING, NOTICE, INFO, and DEBUG, with INFO as the default. For information about setting the log level, see the documentation for each node type in Components and configuration of the Katzenpost mixnet [https://katzenpost.network/docs/admin_guide/components.html].

Installing Katzenpost

The section provides an overview of how to download Katzenpost, set up a development environment, build the code, install the Katzenpost binaries, and configure the components.

Requirements

An up-to-date Debian [https://www.debian.org] or Ubuntu [https://ubuntu.com] Linux system is assumed as the build and hosting environment for all Katzenpost server-side components. Required packages include the following:

- git
- gcc
- build-essential
- libc-dev-bin

Obtain the Katzenpost code

Complete the following steps to set up a local Katzenpost git repository.

1. Clone Katzenpost.

```
$ git clone git@github.com:katzenpost/katzenpost.git
```

2. Get the latest tagged commit of the Katzenpostwith the following commands.

```
$ git fetch --tags
$ tag=$(git describe --tags `git rev-list --tags --max-count=1`)
$ git checkout $tag
```

Install the latest Go version

Download the latest version of the Go programming language from https://go.dev/dl and unzip it in a suitable location. As root, set the necessary environment variables:

```
# export PATH=$PATH:/<your Go location>/bin
# export GO111MODULE=on
# export CGO_CFLAGS_ALLOW="-DPARAMS=sphincs-shake-256f"
```

The go/bin path must be included in your user \$PATH environment variable.



Do not use the Debian/Ubuntu golang packages. They are probably too old.

Build server components

To build a Katzenpost server component, navigate to the directory containing its source code and run **go build**. The paths shown are relative to the Katzenpost repository root.

Table 1. Server component directories

Component	Source code directory	Binary
Mix, gateway, or service node	server/cmd/server/	server

Component	Source code directory	Binary
Directory authority	authority/cmd/	dirauth
	dirauth/	

Build clients

The Katzenpost client components are useful for testing an operational mixnet. To build them, navigate to the directory containing each component's source code and run **go build**. The paths shown are relative to the Katzenpost repository root.

Note

The Katzen [https://github.com/katzenpost/katzen] chat client is under development and not currently functional. For more information about the clients generally, see Clients [https://katzenpost.network/docs/admin_guide/components.html#intro-client].

Table 2. Client directories

Component	Source code directory	Binary or application
Ping	ping/	ping
Fetch	authority/cmd/fetch/	fetch
Status	Obtain from GitHub repository katzenpost/status [https://github.com/katzenpost/status].	
Worldmap	Obtain from GitHub repository katzenpost/worldmap [https://github.com/katzenpost/worldmap]	

Install the server components

To install the server binaries, run the following commands from the katzenpost repository root.

```
# cp server/cmd/server/server /usr/local/bin/katzenpost-mixserver
# cp authority/cmd/dirauth/dirauth /usr/local/bin/katzenpost-authority
```

Create service accounts

Create a service account account for each of the node types that you deploy.

To create a service user for a directory authority.

```
# adduser \
    --disabled-login \
    --disabled-password \
    --system \
    --group \
    --home /var/lib/katzenpost-authority \
    katzenpost-authority
```

To create a service user for a mix, gateway, or service node.

```
# adduser \
    --disabled-login \
```

```
--disabled-password \
--system \
--group \
--home /var/lib/katzenpost-mixserver \
katzenpost-mixserver
```

Create configuration files

The best way currently to construct a node configuration file is to use one of the samples in Appendix: Configuration files from the Docker test mixnet [https://katzenpost.network/docs/admin_guide/docker-config-appendix.html], and to modify it based on the published component parameters [https://katzenpost.network/docs/admin_guide/components.html], combined with attention to the latest state of the code tree. Bear in mind that the IP *address:port* scheme used in the Docker image is specific to that container environment, and is not transferable to a production network without modification.

Katzenpost currently has no configuration automation tool that is ready for general use.

Configure systemd

If you are running your Katzenpost components under systemd [https://systemd.io/], create and install a systemd service file for each node type that you plan to deploy. The following scripts are examples of how to do this.

To create a systemd service file for a directory authority.

```
#!/bin/bash -x
cat << EOF > /etc/systemd/system/katzenpost-mixserver.service
Description=Katzenpost Mix Server
After=network.target
[Service]
IPAccounting=yes
Type=simple
User=katzenpost-mixserver
WorkingDirectory=/var/lib/katzenpost-mixserver
ExecStart=/usr/local/bin/katzenpost-mixserver -f /etc/katzenpost-mixserver/katz
PrivateTmp=yes
NoNewPrivileges=yes
# RestartSec=5
Restart=on-failure
[Install]
WantedBy=default.target
EOF
```

To create a systemd service file for a mix, gateway, or service node.

```
#!/bin/bash -x

cat << EOF > /etc/systemd/system/katzenpost-authority.service
[Unit]
Description=Katzenpost Authority
After=network.target

[Service]
Type=simple
```

```
IPAccounting=yes
User=katzenpost-authority
WorkingDirectory=/var/lib/katzenpost-authority
ExecStart=/usr/local/bin/katzenpost-authority -f /etc/katzenpost-authority/auth
PrivateTmp=yes
NoNewPrivileges=yes
Restart=on-failure

[Install]
WantedBy=default.target
EOF
```

Generate keys

The first time that you run a server binary directly or using systemd, identity and encryption keys are automatically generated and installed if they are not already present. The key location is specified by the value of <code>DataDir</code> in the <code>[Server]</code> section of the configuration. For configuration parameter details, see Components and configuration of the Katzenpost mixnet <code>[https://katzenpost.network/docs/admin_guide/components.html]</code>. For server binary commandline options, see the Quickstart guide <code>[https://katzenpost.network/docs/admin_guide/quickstart.html]</code>.

Once the keys are in place, restart the server to begin operations.

This section of the Katzenpost technical documentation provides an introduction to the software components that make up Katzenpost and guidance on how to configure each component. The intended reader is a system administrator who wants to implement a working, production Katzenpost network.

For a quickly deployable, non-production test network (primarily for use by developers), Using the Katzenpost Docker test network [https://katzenpost.network/docs/admin_guide/docker.html].

Understanding the Katzenpost components

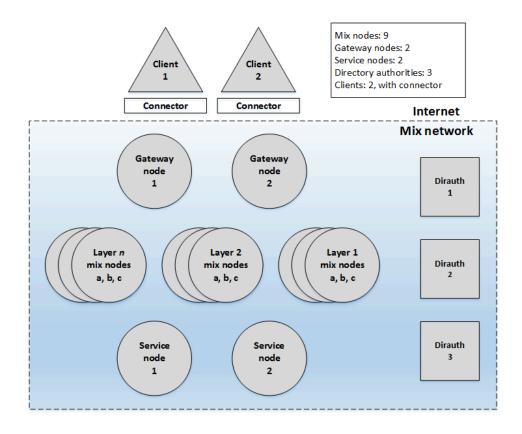
The core of Katzenpost consists of two program executables, dirauth [https://github.com/katzenpost/katzenpost/tree/main/authority] and server [https://github.com/katzenpost/tree/main/server]. Running the **dirauth** commmand runs a *directory authority* node, or *dirauth*, that functions as part of the mixnet's public-key infrastructure (PKI). Running the **server** runs either a *mix* node, a *gateway* node, or a *service* node, depending on the configuration. Configuration settings are provided in an associated katzenpost-authority.toml or katzenpost.toml file respectively.

In addition to the server components, Katzenpost also supports connections to client applications hosted externally to the mix network and communicating with it through gateway nodes.

A model mix network is shown in Figure 1.

Figure 1. The pictured element types correspond to discrete client and server programs that Katzenpost requires to function.

Components of a production mix network



Enlarge diagram [https://katzenpost.network/docs/admin_guide/pix/components-production.png]

The mix network contains an *n*-layer topology of mix-nodes, with three nodes per layer in this example. Sphinx packets traverse the network in one direction only. The gateway nodes allow clients to interact with the mix network. The service nodes provide mix network services that mix network clients can interact with. All messages sent by clients are handed to a *connector* daemon hosted on the client system, passed across the Internet to a gateway, and then relayed to a service node by way of the nine mix nodes. The service node sends its reply back across the mix-node layers to a gateway, which transmits it across the Internet to be received by the targeted client. The mix, gateway, and service nodes send *mix descriptors* to the dirauths and retrieve a *consensus document* from them, described below.

In addition to the server components, Katzenpost supports connections to client applications hosted externally to the mix network and communicating with it through gateway nodes and, in some cases, a client connector.

Directory authorities (dirauths)

Dirauths compose the decentralized public key infrastructure (PKI) that serves as the root of security for the entire mix network. Clients, mix nodes, gateways nodes, and service nodes rely on the PKI/dirauth system to maintain and sign an up-to-date consensus document, providing a view of the network including connection information and public cryptographic key materials and signatures.

Every 20 minutes (the current value for an *epoch*), each mix, gateway, and service node signs a mix descriptor and uploads it to the dirauths. The dirauths then vote on a new consensus document. If consensus is reached, each dirauth signs the document. Clients and nodes download the document as needed and verify the signatures. Consensus fails when 1/2 + 1 nodes fail, which yields greater fault tolerance than, for example, Byzantine Fault Tolerance, which fails when 1/3 + 1 of the nodes fail.

The PKI signature scheme is fully configurable by the dirauths. Our recommendation is to use a hybrid signature scheme consisting of classical Ed25519 and the post-quantum, stateless, hash-based signature scheme known as Sphincs+ (with the parameters: "sphincs-shake-256f"), which is designated in Katzenpost configurations as "Ed25519 Sphincs+". Examples are provided below.

Mix nodes

The mix node is the fundamental building block of the mix network.

Katzenpost mix nodes are arranged in a layered topology to achieve the best levels of anonymity and ease of analysis while being flexible enough to scale with traffic demands.

Gateway nodes

Gateway nodes provide external client access to the mix network. Because gateways are uniquely positioned to identify clients, they are designed to have as little information about client behavior as possible. Gateways are randomly selected and have no persistent relationship with clients and no knowledge of whether a client's packets are decoys or not. When client traffic through a gateway is slow, the node additionally generates decoy traffic.

Service nodes

Service nodes provide functionality requested by clients. They are logically positioned at the deepest point of the mix network, with incoming queries and outgoing replies both needing to traverse all *n* layers of mix nodes. A service node's functionality may involve storing messages, publishing information outside of the mixnet, interfacing with a blockchain node, and so on. Service nodes also process decoy packets.

Clients

Client applications should be designed so that the following conditions are met:

- Separate service requests from a client are unlinkable. Repeating the same request may be lead to linkability.
- Service nodes and clients have no persistent relationship.
- Clients generate a stream of packets addressed to random or pseudorandom services regardless of whether a real service request is being made. Most of these packets will be decoy traffic.
- Traffic from a client to a service node must be correctly coupled with decoy traffic. This can mean that the service node is chosen independently from traffic history, or that the transmitted packet replaces a decoy packet that was meant to go to the desired service.

Katzenpost currently includes several client applications. All applications make extensive use of Sphinx single-use reply blocks (SURBs), which enable service nodes to send replies without knowing the location of the client. Newer clients require a connection through the client *connector*, which provides multiplexing and privilege separation with a consequent reduction in processing overhead.

The following client applications are available.

Table 1. Katzenpost clients

Name	Needs connector	Description	Code
Ping	no	The mix network equivalent of an ICMP ping utility, used for network testing.	1 -
Fetch	no	Fetches the PKI document containing peer information.	GitHub: fetch [https://github.com/katzenpost/katzen-post/tree/main/authority/cmd/fetch]
Katzen	no	A text chat client with file-transfer support.	GitHub: katzen [https://github.com/katzenpost/katzen]
Status	yes	An HTML page containing status information about the mix network.	1 -
Worldmap	yes	An HTML page with a world map showing geographic locations of mix network nodes.	[https://github.com/

Configuring Katzenpost

This section documents the configuration parameters for each type of Katzenpost server node. Each node has its own configuration file in TOML [https://toml.io/en/v1.0.0] format.

Configuring directory authorities

The following configuration is drawn from the reference implementation in katzenpost/docker/dirauth mixnet/auth1/authority.toml. In a real-world mixnet, the component hosts would not be sharing a single IP address. For more information about the test mixnet, see Using the Katzenpost Docker test network [https://katzenpost.network/docs/admin_guide/docker.html].

Table 2. Directory authority (dirauth) configuration sections

Dirauth: Server section
Dirauth: Authorities section
Dirauth: Logging section
Dirauth: Parameters section
Dirauth: Debug section
Dirauth: Mixes sections
Dirauth: GatewayNodes section
Dirauth: ServiceNodes sections
Dirauth: Topology section
Dirauth: SphinxGeometry section

Dirauth: Server section

The Server section configures mandatory basic parameters for each directory authority.

```
[Server]
   Identifier = "auth1"
   WireKEMScheme = "xwing"
   PKISignatureScheme = "Ed25519 Sphincs+"
   Addresses = ["tcp://127.0.0.1:30001"]
   DataDir = "/dirauth_mixnet/auth1"
```

• Identifier

Specifies the human-readable identifier for a node, and must be unique per mixnet. The identifier can be an FQDN but does not have to be.

Type: string
Required: Yes

WireKEMScheme

Specifies the key encapsulation mechanism (KEM) scheme for the PQ Noise [https://eprint.i-acr.org/2022/539]-based wire protocol (link layer) that nodes use to communicate with each other. PQ Noise is a post-quantum variation of the Noise protocol framework [https://noiseprotocol.org/], which algebraically transforms ECDH handshake patterns into KEM encapsulate/decapsulate operations.

This configuration option supports the optional use of hybrid post-quantum cryptography to strengthen security. The following KEM schemes are supported:

• Classical: "x25519", "x448"

Note

X25519 and X448 are actually non-interactive key-exchanges (NIKEs), not KEMs. Katzenpost uses a hashed ElGamal cryptographic construction to convert them from NIKEs to KEMs.

• **Post-quantum:** "mlkem768", "sntrup4591761", "frodo640shake", "mceliece348864", "mceliece460896", "mceliece460896f", "mceliece6688128",

 $\label{lem:condition} $$\operatorname{mceliece} 6688128f'', \quad \operatorname{mceliece} 6960119'', \quad \operatorname{mceliece} 6960119f'', \quad \operatorname{mceliece} 8192128f'', \quad \operatorname{mceliece} 8192128$

Hybrid post-quantum: "xwing", "Kyber768-X25519", "MLKEM768-X25519", "MLKEM768-X448", "FrodoKEM-640-SHAKE-X448", "sntrup4591761-X448", "mceliece348864-X25519", "mceliece348864f-X25519", "mceliece460896-X25519", "mceliece6688128-X25519", "mceliece6688128-X25519", "mceliece6688128f-X25519", "mceliece6960119-X25519", "mceliece6960119f-X25519", "mceliece8192128-X25519", "mceliece8192128f-X25519", "CTIDH512-X25519", "CTIDH512-X25519"

Type: string
Required: Yes

• PKISignatureScheme

Specifies the cryptographic signature scheme which will be used by all components of the mix network when interacting with the PKI system. Mix nodes sign their descriptors using this signature scheme, and dirauth nodes similarly sign PKI documents using the same scheme.

The following signature schemes are supported: "ed25519", "ed448", "Ed25519 Sphincs+", "Ed448-Sphincs+", "Ed25519-Dilithium2", "Ed448-Dilithium3"

Type: string
Required: Yes

Addresses

Specifies a list of one or more address URLs in a format that contains the transport protocol, IP address, and port number that the node will bind to for incoming connections. Katzenpost supports URLs with that start with either "tcp://" or "quic://" such as: ["tcp://192.168.1.1:30001"] and ["quic://192.168.1.1:40001"].

Type: []string
Required: Yes

DataDir

Specifies the absolute path to a node's state directory. This is where persistence.db is written to disk and where a node stores its cryptographic key materials when started with the "-g" command-line option.

Type: string
Required: Yes

Dirauth: Authorities section

An Authorities section is configured for each peer authority. We recommend using TOML's style [https://quickref.me/toml.html] for multi-line quotations for key materials.

```
[[Authorities]]
    Identifier = "auth1"
    IdentityPublicKey = """
----BEGIN ED25519 PUBLIC KEY----
dYpXpbozjFfqhR45ZC2q97SOOsXMANdHaEdXrP42CJk=
----END ED25519 PUBLIC KEY----
```

```
PKISignatureScheme = "Ed25519"
LinkPublicKey = """
----BEGIN XWING PUBLIC KEY----
ooQBPYNdmfwnxXmvnljPA2mG5gWgurfHhbY87DMRY2tbMeZpinJ5BlSiIecprnmm
QqxcS9o36IS62SVMlOUkw+XEZGVvc9wJqHpgEgVJRAs1PCR8cUAdM6QIYLWt/lkf
SPKDCtZ3GiSIOzMuaglo2tarIPEv1AY7r9B0xXOgSKMkGyBkCfw1VBZf46MM26NL
...
gHtNyQJnXski52003JpZRIhR40pF0hAAcMMAZDpMTVoxlcdR6WA4SlBiSceeJBgY
Yp9PlGhCimx9am99TrdLoLCdTHB6oowt8tss3POpIOxaSlguyeym/sBhkUrnXOgN
ldMtDsvvc9KUfE4I0+c+XQ==
----END XWING PUBLIC KEY-----
"""
WireKEMScheme = "xwing"
Addresses = ["tcp://127.0.0.1:30001"]
```

• Identifier

Specifies the human-readable identifier for the node which must be unique per mixnet. The identifier can be an FQDN but does not have to be.

Type: string
Required: Yes

· IdentityPublicKey

String containing the node's public identity key in PEM format. IdentityPublicKey is the node's permanent identifier and is used to verify cryptographic signatures produced by its private identity key.

Type: string
Required: Yes

• PKISignatureScheme

Specifies the cryptographic signature scheme used by all directory authority nodes. PKISignatureScheme must match the scheme specified in the Server section of the configuration.

Type: string
Required: Yes

· LinkPublicKey

String containing the peer's public link-layer key in PEM format. LinkPublicKey must match the specified WireKEMScheme.

Type: string
Required: Yes

• WireKEMScheme

Specifies the key encapsulation mechanism (KEM) scheme for the PQ Noise [https://eprint.i-acr.org/2022/539]-based wire protocol (link layer) that nodes use to communicate with each other. PQ Noise is a post-quantum variation of the Noise protocol framework [https://noiseprotocol.org/], which algebraically transforms ECDH handshake patterns into KEM encapsulate/decapsulate operations.

This configuration option supports the optional use of hybrid post-quantum cryptography to strengthen security. The following KEM schemes are supported:

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Note

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- Post-quantum: "mlkem768", "sntrup4591761", "frodo640shake", "mceliece348864", "mceliece348864f", "mceliece460896f", "mceliece460896f", "mceliece6688128f", "mceliece6960119f", "mceliece6960119f", "mceliece8192128f", "CTIDH511", "CTIDH512", "CTIDH1024", "CTIDH2048",
- Hybrid post-quantum: "xwing", "Kyber768-X25519", "MLKEM768-X25519", "MLKEM768-X448", "FrodoKEM-640-SHAKE-X448", "sntrup4591761-X448", "mceliece348864-X25519", "mceliece348864f-X25519", "mceliece460896-X25519", "mceliece6688128-X25519", "mceliece6688128-X25519", "mceliece6688128f-X25519", "mceliece6960119-X25519", "mceliece6960119f-X25519", "mceliece8192128-X25519", "mceliece8192128f-X25519", "CTIDH512-X25519", "CTIDH512-X25519"

Type: string
Required: Yes

Addresses

Specifies a list of one or more address URLs in a format that contains the transport protocol, IP address, and port number that the node will bind to for incoming connections. Katzenpost supports URLs with that start with either "tcp://" or "quic://" such as: ["tcp://192.168.1.1:30001"] and ["quic://192.168.1.1:40001"].

Type: []string Required: Yes

Dirauth: Logging section

The Logging configuration section controls logging behavior across Katzenpost.

[Logging]

```
Disable = false
File = "katzenpost.log"
Level = "INFO"
```

• Disable

If true, logging is disabled.

Type: bool Required: No

• File

Specifies the log file. If omitted, stdout is used.

An absolute or relative file path can be specified. A relative path is relative to the DataDir specified in the Server section of the configuration.

Type: string

Required: No

Level

Supported logging level values are ERROR | WARNING | NOTICE | INFO | DEBUG.

Type: string
Required: No

Warning

The DEBUG log level is unsafe for production use.

Dirauth: Parameters section

The Parameters section contains the network parameters.

```
[Parameters]

SendRatePerMinute = 0

Mu = 0.005

MuMaxDelay = 1000

LambdaP = 0.001

LambdaPMaxDelay = 1000

LambdaL = 0.0005

LambdaLMaxDelay = 1000

LambdaD = 0.0005

LambdaDMaxDelay = 3000

LambdaM = 0.0005

LambdaG = 0.0

LambdaGMaxDelay = 100

LambdaGMaxDelay = 100

LambdaGMaxDelay = 100
```

• SendRatePerMinute

Specifies the maximum allowed rate of packets per client per gateway node. Rate limiting is done on the gateway nodes.

Type: uint64
Required: Yes

• Mu

Specifies the inverse of the mean of the exponential distribution from which the Sphinx packet perhop mixing delay will be sampled.

Type: float64
Required: Yes

MuMaxDelay

Specifies the maximum Sphinx packet per-hop mixing delay in milliseconds.

Type: uint64
Required: Yes

LambdaP

Specifies the inverse of the mean of the exponential distribution that clients sample to determine the time interval between sending messages, whether actual messages from the FIFO egress queue or decoy messages if the queue is empty.

Type: float64 Required: Yes

· LambdaPMaxDelay

Specifies the maximum send delay interval for LambdaP in milliseconds.

Type: uint64
Required: Yes

• LambdaL

Specifies the inverse of the mean of the exponential distribution that clients sample to determine the delay interval between loop decoys.

Type: float64 Required: Yes

LambdaLMaxDelay

Specifies the maximum send delay interval for LambdaL in milliseconds.

Type: uint64 Required: Yes

• LambdaD

LambdaD is the inverse of the mean of the exponential distribution that clients sample to determine the delay interval between decoy drop messages.

Type: float64 Required: Yes

LambdaDMaxDelay

Specifies the maximum send interval in for LambdaD in milliseconds.

Type: uint64 Required: Yes

• LambdaM

LambdaM is the inverse of the mean of the exponential distribution that mix nodes sample to determine the delay between mix loop decoys.

Type: float64 Required: Yes

· LambdaG

LambdaG is the inverse of the mean of the exponential distribution that gateway nodes to select the delay between gateway node decoys.

Warning

Do not set this value manually in the TOML configuration file. The field is used internally by the dirauth server state machine.

Type: float64 Required: Yes

• LambdaMMaxDelay

Specifies the maximum delay for LambdaM in milliseconds.

Type: uint64 Required: Yes

• LambdaGMaxDelay

Specifies the maximum delay for LambdaG in milliseconds.

Type: uint64
Required: Yes

Dirauth: Debug section

```
[Debug]
  Layers = 3
  MinNodesPerLayer = 1
  GenerateOnly = false
```

• Layers

Specifies the number of non-service-provider layers in the network topology.

Type: int

Required: Yes

• MinNodesrPerLayer

Specifies the minimum number of nodes per layer required to form a valid consensus document.

Type: int

Required: Yes

· GenerateOnly

If **true**, the server halts and cleans up the data directory immediately after long-term key generation.

Type: bool Required: No

Dirauth: Mixes sections

The Mixes configuration sections list mix nodes that are known to the authority.

[[Mixes]]

```
Identifier = "mix1"
   IdentityPublicKeyPem = "../mix1/identity.public.pem"

[[Mixes]]
   Identifier = "mix2"
    IdentityPublicKeyPem = "../mix2/identity.public.pem"

[[Mixes]]
   Identifier = "mix3"
   IdentityPublicKeyPem = "../mix3/identity.public.pem"
```

Identifier

Specifies the human-readable identifier for a mix node, and must be unique per mixnet. The identifier can be an FQDN but does not have to be.

Type: string
Required: Yes

· IdentityPublicKeyPem

Path and file name of a mix node's public identity signing key, also known as the identity key, in PEM format.

Type: string
Required: Yes

Dirauth: GatewayNodes section

The GatewayNodes sections list gateway nodes that are known to the authority.

```
[[GatewayNodes]]
    Identifier = "gateway1"
    IdentityPublicKeyPem = "../gateway1/identity.public.pem"
```

• Identifier

Specifies the human-readable identifier for a gateway node, and must be unique per mixnet. Identifier can be an FQDN but does not have to be.

Type: string
Required: Yes

• IdentityPublicKeyPem

Path and file name of a gateway node's public identity signing key, also known as the identity key, in PEM format.

Type: string
Required: Yes

Dirauth: ServiceNodes sections

The ServiceNodes sections list service nodes that are known to the authority.

```
[[ServiceNodes]]
```

```
Identifier = "servicenode1"
IdentityPublicKeyPem = "../servicenode1/identity.public.pem"
```

Identifier

Specifies the human-readable identifier for a service node, and must be unique per mixnet. Identifier can be an FQDN but does not have to be.

Type: string
Required: Yes

• IdentityPublicKeyPem

Path and file name of a service node's public identity signing key, also known as the identity key, in PEM format.

Type: string
Required: Yes

Dirauth: Topology section

The Topology section defines the layers of the mix network and the mix nodes in each layer.

[Topology]

Identifier

Specifies the human-readable identifier for a node, and must be unique per mixnet. The identifier can be an FQDN but does not have to be.

Type: string

• IdentityPublicKeyPem

Path and file name of a mix node's public identity signing key, also known as the identity key, in PEM format.

Type: string

Required: Yes

Dirauth: SphinxGeometry section

Sphinx is an encrypted nested-packet format designed primarily for mixnets. The original Sphinx paper [https://www.freehaven.net/anonbib/cache/DBLP:conf/sp/DanezisG09.pdf] described a non-interactive key exchange (NIKE) employing classical encryption. The Katzenpost implementation strongly emphasizes configurability, supporting key encapsulation mechanisms (KEMs) as well as NIKEs, and enabling the use of either classical or hybrid post-quantum cryptography. Hybrid constructions offset the newness of post-quantum algorithms by offering heavily tested classical algorithms as a fallback.

Note

Sphinx, the nested-packet format, should not be confused with Sphincs or Sphincs+ [http://sphincs.org/index.html], which are post-quantum signature schemes.

Katzenpost Sphinx also relies on the following classical cryptographic primitives:

- CTR-AES256, a stream cipher
- HMAC-SHA256, a message authentication code (MAC) function
- HKDF-SHA256, a key derivation function (KDF)
- AEZv5, a strong pseudorandom permutation (SPRP)

All dirauths must be configured to use the same SphinxGeometry parameters. Any geometry not advertised by the PKI document will fail. Each dirauth publishes the hash of its SphinxGeometry parameters in the PKI document for validation by its peer dirauths.

The SphinxGeometry section defines parameters for the Sphinx encrypted nested-packet format used internally by Katzenpost.

The settings in this section are generated by the gensphinx [https://github.com/katzenpost/katzenpost/tree/main/gensphinx] utility, which computes the Sphinx geometry based on the following user-supplied directives:

- The number of mix node layers (not counting gateway and service nodes)
- The length of the application-usable packet payload
- The selected NIKE or KEM scheme

Warning

The values in the SphinxGeometry configuration section must be programmatically generated by **gensphinx**. Many of the parameters are interdependent and cannot be individually modified. Do not modify the these values by hand.

The **gensphinx** output in TOML should then be pasted unchanged into the node's configuration file, as shown below.

```
[SphinxGeometry]
```

```
PacketLength = 3082
NrHops = 5
HeaderLength = 476
RoutingInfoLength = 410
PerHopRoutingInfoLength = 82
SURBLength = 572
SphinxPlaintextHeaderLength = 2
```

PayloadTagLength = 32 ForwardPayloadLength = 2574 UserForwardPayloadLength = 2000 NextNodeHopLength = 65 SPRPKeyMaterialLength = 64 NIKEName = "x25519" KEMName = ""

PacketLength

The length of a Sphinx packet in bytes.

Type: int

Required: Yes

• NrHops

The number of hops a Sphinx packet takes through the mixnet. Because packet headers hold destination information for each hop, the size of the header increases linearly with the number of hops.

Type: int

Required: Yes

· HeaderLength

The total length of the Sphinx packet header in bytes.

Type: int

Required: Yes

· RoutingInfoLength

The total length of the routing information portion of the Sphinx packet header.

Type: int

Required: Yes

• PerHopRoutingInfoLength

The length of the per-hop routing information in the Sphinx packet header.

Type: int

Required: Yes

• SURBLength

The length of a single-use reply block (SURB).

Type: int

Required: Yes

• SphinxPlaintextHeaderLength

The length of the plaintext Sphinx packet header.

Type: int

Required: Yes

· PayloadTagLength

The length of the payload tag.

Type: int

Required: Yes

· ForwardPayloadLength

The total size of the payload.

Type: int

Required: Yes

• UserForwardPayloadLength

The size of the usable payload.

Type: int

Required: Yes

• NextNodeHopLength

The NextNodeHopLength is derived from the largest routing-information block that we expect to encounter. Other packets have NextNodeHop + NodeDelay sections, or a Recipient section, both of which are shorter.

Type: int

Required: Yes

• SPRPKeyMaterialLength

The length of the strong pseudo-random permutation (SPRP) key.

Type: int

Required: Yes

NIKEName

The name of the non-interactive key exchange (NIKE) scheme used by Sphinx packets.

NIKEName and KEMName are mutually exclusive.

Type: string

Required: Yes

KEMName

The name of the key encapsulation mechanism (KEM) used by Sphinx packets.

NIKEName and KEMName are mutually exclusive.

Required: Yes

Configuring mix nodes

The following configuration is drawn from the reference implementation in katzenpost/dock-er/dirauth_mixnet/mix1/katzenpost.toml. In a real-world mixnet, the component hosts would not be sharing a single IP address. For more information about the test mixnet, see Using the Katzenpost Docker test network [https://katzenpost.network/docs/admin_guide/docker.html].

Table 3. Mix node configuration sections

```
Mix node: Server section

Mix node: Logging section

Mix node: PKI section

Mix node: Management section

Mix node: SphinxGeometry section

Mix node: Debug section
```

Mix node: Server section

The Server section configures mandatory basic parameters for each server node.

```
[Server]
  Identifier = "mix1"
  WireKEM = "xwing"
  PKISignatureScheme = "Ed25519"
  Addresses = ["127.0.0.1:30008"]
  OnlyAdvertiseAltAddresses = false
  MetricsAddress = "127.0.0.1:30009"
  DataDir = "/dirauth_mixnet/mix1"
  IsGatewayNode = false
  IsServiceNode = false
  [Server.AltAddresses]
```

Identifier

Specifies the human-readable identifier for a node, and must be unique per mixnet. The identifier can be an FQDN but does not have to be.

```
Type: string
Required: Yes
```

WireKEM

WireKEM specifies the key encapsulation mechanism (KEM) scheme for the PQ Noise [https://eprint.iacr.org/2022/539]-based wire protocol (link layer) that nodes use to communicate with each other. PQ Noise is a post-quantum variation of the Noise protocol framework [https://noiseprotocol.org/], which algebraically transforms ECDH handshake patterns into KEM encapsulate/decapsulate operations.

This configuration option supports the optional use of hybrid post-quantum cryptography to strengthen security. The following KEM schemes are supported:

```
• Classical: "x25519", "x448"
```

Note

X25519 and X448 are actually non-interactive key-exchanges (NIKEs), not KEMs. Katzenpost uses a hashed ElGamal cryptographic construction to convert them from NIKEs to KEMs.

- Post-quantum: "mlkem768", "sntrup4591761", "frodo640shake", "mceliece348864", "mceliece348864f", "mceliece460896f", "mceliece460896f", "mceliece6688128f", "mceliece6960119f", "mceliece6960119f", "mceliece8192128f", "CTIDH511", "CTIDH512", "CTIDH1024", "CTIDH2048",
- Hybrid post-quantum: "xwing", "Kyber768-X25519", "MLKEM768-X25519", "MLKEM768-"sntrup4591761-X448", "FrodoKEM-640-SHAKE-X448", "mceliece348864-X448", X25519", "mceliece348864f-X25519", "mceliece460896-X25519", "mceliece460896f-"mceliece6688128f-X25519", X25519", "mceliece6688128-X25519", "mceliece6960119-X25519", "mceliece6960119f-X25519", "mceliece8192128-X25519", "mceliece8192128f-X25519", "CTIDH512-X25519", "CTIDH512-X25519"

Type: string

Required: Yes

• PKISignatureScheme

Specifies the cryptographic signature scheme that will be used by all components of the mix network when interacting with the PKI system. Mix nodes sign their descriptors using this signature scheme, and dirauth nodes similarly sign PKI documents using the same scheme.

The following signature schemes are supported:

- Classical: "ed25519", "ed448"
- Hybrid post-quantum: "Ed25519 Sphincs+", "Ed448-Sphincs+", "Ed25519-Dilithium2", "Ed448-Dilithium3"

Type: string

Required: Yes

Addresses

Specifies a list of one or more address URLs in a format that contains the transport protocol, IP address, and port number that the server will bind to for incoming connections. Katzenpost supports URLs with that start with either "tcp://" or "quic://" such as: ["tcp://192.168.1.1:30001"] and ["quic://192.168.1.1:40001"].

Addresses is overridden if **BindAddresses** is **true**. In that scenario, one or more advertised, external addresses is provided as the value of **Addresses**, and is advertised in the PKI document.

Note that **BindAddresses**, below, holds the address values for non-adverstised, internal-only listeners. The addition of **BindAddresses** to the node configuration is required for hosts connecting to the Internet through network address translation (NAT).

Type: []string

Required: Yes

BindAddresses

If **true**, allows setting of listener addresses that the server will bind to and accept connections on. These addresses are not advertised in the PKI document. For more information, see **Addresses**, above.

Type: bool, []string

Required: No

MetricsAddress

Specifies the address/port to bind the Prometheus metrics endpoint to.

Type: string

Required: No

DataDir

Specifies the absolute path to a node's state directory. This is where persistence.db is written to disk and where a node stores its cryptographic key materials when started with the "-g" commmand-line option.

Type: string

Required: Yes

• IsGatewayNode

If **true**, the server is a gateway node.

Type: bool

Required: No

• IsServiceNode

If **true**, the server is a service node.

Type: bool

Required: No

Mix node: Logging section

The Logging configuration section controls logging behavior across Katzenpost.

```
[Logging]
```

```
Disable = false
File = "katzenpost.log"
Level = "INFO"
```

• Disable

If true, logging is disabled.

Type: bool

Required: No

• File

Specifies the log file. If omitted, stdout is used.

An absolute or relative file path can be specified. A relative path is relative to the DataDir specified in the Server section of the configuration.

Type: string
Required: No

• Level

Supported logging level values are ERROR | WARNING | NOTICE |INFO | DEBUG.

Type: string
Required: No

Warning

The DEBUG log level is unsafe for production use.

Mix node: PKI section

The PKI section contains the directory authority configuration for a mix, gateway, or service node.

```
[PKI]
[PKI.dirauth]
            [[PKI.dirauth.Authorities]]
                       Identifier = "auth1"
                       IdentityPublicKey = """----BEGIN ED25519 PUBLIC KEY----
tqN6tpOVotHWXKCszVn2kS7vAZjQpvJjQF3Qz/Qwhyg=
----END ED25519 PUBLIC KEY----
                       PKISignatureScheme = "Ed25519"
                      LinkPublicKey = """----BEGIN XWING PUBLIC KEY----
JnJ8ztQEIjAkKJcpuZvJAdkWjBim/5G5d8yoosEQHeGJeeBqNPdm2AitUbpiQPcd
tNCo9DxuC9Ieqmsfw0YpV6AtOOsaInA6QnHDYcuBfZcQL5MU4+t2TzpBZQY1rSED
hPCKrAG+8GEU16akseG371WQzEtPpEWWCJCJOiS/VDFZT7eKrldlumN6gfiB84sR
arFh/WKwYJUj + aGBsFYSqGdzC6MdY4x/YyFe2ze0MJEjThQE91y1d/LCQ3Sb7Ri + arFh/WKwYJUj + arFh/WKwyJWwyJwy + arFh/WKwyJWwyJwwyJwy + arFh/WWWyJwwy + arFh/WWWyJwwy + arFh/WWyJwwy + arFh/WWwyJwwy + arFh/WWwyJw
u6PBi3JU2qzlPEejDKwK0t5tMNEAkq8iNrpRTdD/hS0gR+ZIN8Z9QKh7Xf94FWG2
H+r8OaqImOhqHabrWRDyLq==
 ----END XWING PUBLIC KEY----
                       WireKEMScheme = "xwing"
                      Addresses = ["127.0.0.1:30001"]
            [[PKI.dirauth.Authorities]]
                       Identifier = "auth2"
                       IdentityPublicKey = """----BEGIN ED25519 PUBLIC KEY----
O51Ty2WLu4C1ETMa29s03bMXV72gnjJfTfwLV++LVBI=
----END ED25519 PUBLIC KEY----
                      PKISignatureScheme = "Ed25519"
                      LinkPublicKey = """----BEGIN XWING PUBLIC KEY----
TtQkg2XKUnY602FFBaPJ+zpN0Twy20cwyyFxh7FNUjaXA9MAJXs0vUwFbJc6BjYv
```

```
f+olKnl1KFSmDvcF74U6w1F0ObugwTNKNxeYKPKhX4FiencUbRwkHoYHdtZdSctz
TKy08qKQyCAccqCRpdo6ZtYXPAU+2rthjYTOL7Zn+7SHUKCuJClcPnvEYjVcJxtZ
ubJIe5U4nMJbBkOqr7Kq6niaEkiLODa0tkpB8tKMYTMBdcYyHSXCzpo7U9sb6LAR
HktiTBDtRXviu2vbw7VRXhkMW2kjYZDtReQ5sAse04DvmD49zgTp1YxYW+wWFaL3
37X7/SNuLdHX4PHZXIWHBQ==
----END XWING PUBLIC KEY----
       WireKEMScheme = "xwing"
        Addresses = ["127.0.0.1:30002"]
    [[PKI.dirauth.Authorities]]
        Identifier = "auth3"
        IdentityPublicKey = """----BEGIN ED25519 PUBLIC KEY----
zQvydRYJq3npeLcg1NqIf+SswEKE5wFmiwNsI9Z1whQ=
----END ED25519 PUBLIC KEY----
       PKISignatureScheme = "Ed25519"
       LinkPublicKey = """
----BEGIN XWING PUBLIC KEY----
OYK9FiC53xwZ1VST3jD004tR+cUMSVRSekmigZMChSjDCPZbKut8TblxtlUfc/yi
Ugorz4NIvYPMWUt3QPwS2UWq8/HMWXNGPUiAevg12+oV+jOJXaJeCfY24UekJnSw
TNcdGaFZFSR0FocFcPBBnrK1M2B8w8eEUKQIsXRDM3x/8aRIuDif+ve8rSwpgKeh
OdVD3yw700S8uPZLORGQFyJbHtVmFPVvwja4G/o2gntAoHUZ2LiJJakpVhhlSyrI
yuzvwwFtZVfWtNb5gAKZCyg0aduR3qgd7MPerRF+YopZk3OCRpC02YxfUZrHv398
FZWJFK0R8iU52CEUxVpXTA==
 ----END XWING PUBLIC KEY----
       WireKEMScheme = "xwing"
        Addresses = ["127.0.0.1:30003"]
```

Identifier

Specifies the human-readable identifier for a node, which must be unique per mixnet. The identifier can be an FQDN but does not have to be.

Type: string
Required: Yes

· IdentityPublicKey

String containing the node's public identity key in PEM format. IdentityPublicKey is the node's permanent identifier and is used to verify cryptographic signatures produced by its private identity key.

Type: string
Required: Yes

• PKISignatureScheme

Specifies the cryptographic signature scheme that will be used by all components of the mix network when interacting with the PKI system. Mix nodes sign their descriptors using this signature scheme, and dirauth nodes similarly sign PKI documents using the same scheme.

Type: string
Required: Yes

· LinkPublicKey

String containing the peer's public link-layer key in PEM format. LinkPublicKey must match the specified WireKEMScheme.

Type: string
Required: Yes

WireKEMScheme

The name of the wire protocol key-encapsulation mechanism (KEM) to use.

Type: string
Required: Yes

Addresses

Specifies a list of one or more address URLs in a format that contains the transport protocol, IP address, and port number that the server will bind to for incoming connections. Katzenpost supports URLs that start with either "tcp://" or "quic://" such as: ["tcp://192.168.1.1:30001"] and ["quic://192.168.1.1:40001"]. The value of **Addresses** is advertised in the PKI document.

Type: []string
Required: Yes

Mix node: Management section

The Management section specifies connectivity information for the Katzenpost control protocol which can be used to make run-time configuration changes. A configuration resembles the following, substituting the node's configured DataDir value as part of the Path value:

```
[Management]
   Enable = false
   Path = "/node_datadir/management_sock"
```

• Enable

If true, the management interface is enabled.

Type: bool Required: No

Path

Specifies the path to the management interface socket. If left empty, then management_sock is located in the configuration's defined DataDir.

Type: string
Required: No

Mix node: SphinxGeometry section

The SphinxGeometry section defines parameters for the Sphinx encrypted nested-packet format used internally by Katzenpost.

The settings in this section are generated by the gensphinx [https://github.com/katzenpost/katzenpost/tree/main/gensphinx] utility, which computes the Sphinx geometry based on the following user-supplied directives:

- The number of mix node layers (not counting gateway and service nodes)
- · The length of the application-usable packet payload
- The selected NIKE or KEM scheme

Warning

The values in the SphinxGeometry configuration section must be programmatically generated by **gensphinx**. Many of the parameters are interdependent and cannot be individually modified. Do not modify the these values by hand.

The **gensphinx** output in TOML should then be pasted unchanged into the node's configuration file, as shown below.

[SphinxGeometry]

```
PacketLength = 3082
NrHops = 5
HeaderLength = 476
RoutingInfoLength = 410
PerHopRoutingInfoLength = 82
SURBLength = 572
SphinxPlaintextHeaderLength = 2
PayloadTagLength = 32
ForwardPayloadLength = 2574
UserForwardPayloadLength = 2574
UserForwardPayloadLength = 65
SPRPKeyMaterialLength = 64
NIKEName = "x25519"
KEMName = ""
```

· PacketLength

The length of a Sphinx packet in bytes.

Type: int

Required: Yes

• NrHops

The number of hops a Sphinx packet takes through the mixnet. Because packet headers hold destination information for each hop, the size of the header increases linearly with the number of hops.

Type: int

Required: Yes

· HeaderLength

The total length of the Sphinx packet header in bytes.

Type: int

Required: Yes

• RoutingInfoLength

The total length of the routing information portion of the Sphinx packet header.

Type: int

Required: Yes

• PerHopRoutingInfoLength

The length of the per-hop routing information in the Sphinx packet header.

Type: int

Required: Yes

SURBLength

The length of a single-use reply block (SURB).

Type: int

Required: Yes

• SphinxPlaintextHeaderLength

The length of the plaintext Sphinx packet header.

Type: int

Required: Yes

· PayloadTagLength

The length of the payload tag.

Type: int

Required: Yes

· ForwardPayloadLength

The total size of the payload.

Type: int

Required: Yes

• UserForwardPayloadLength

The size of the usable payload.

Type: int

Required: Yes

• NextNodeHopLength

The NextNodeHopLength is derived from the largest routing-information block that we expect to encounter. Other packets have NextNodeHop + NodeDelay sections, or a Recipient section, both of which are shorter.

Type: int

Required: Yes

• SPRPKeyMaterialLength

The length of the strong pseudo-random permutation (SPRP) key.

Type: int

Required: Yes

NIKEName

The name of the non-interactive key exchange (NIKE) scheme used by Sphinx packets.

NIKEName and KEMName are mutually exclusive.

Type: string

Required: Yes

KEMName

The name of the key encapsulation mechanism (KEM) used by Sphinx packets.

NIKEName and KEMName are mutually exclusive.

Type: string

Required: Yes

Mix node: Debug section

The Debug section is the Katzenpost server debug configuration for advanced tuning.

[Debug]

```
NumSphinxWorkers = 16
NumServiceWorkers = 3
NumGatewayWorkers = 3
NumKaetzchenWorkers = 3
SchedulerExternalMemoryQueue = false
SchedulerQueueSize = 0
SchedulerMaxBurst = 16
UnwrapDelay = 250
GatewayDelay = 500
ServiceDelay = 500
KaetzchenDelay = 750
SchedulerSlack = 150
SendSlack = 50
DecoySlack = 15000
ConnectTimeout = 60000
HandshakeTimeout = 30000
ReauthInterval = 30000
SendDecoyTraffic = false
DisableRateLimit = false
GenerateOnly = false
```

• NumSphinxWorkers

Specifies the number of worker instances to use for inbound Sphinx packet processing.

Type: int

Required: No

• NumProviderWorkers

Specifies the number of worker instances to use for provider specific packet processing.

Type: int

Required: No

• NumKaetzchenWorkers

Specifies the number of worker instances to use for Kaetzchen-specific packet processing.

Type: int

Required: No

• SchedulerExternalMemoryQueue

If **true**, the experimental disk-backed external memory queue is enabled.

Type: bool

Required: No

• SchedulerQueueSize

Specifies the maximum scheduler queue size before random entries will start getting dropped. A value less than or equal to zero is treated as unlimited.

Type: int

Required: No

SchedulerMaxBurst

Specifies the maximum number of packets that will be dispatched per scheduler wakeup event.

Type:

Required: No

UnwrapDelay

Specifies the maximum unwrap delay due to queueing in milliseconds.

Type: int

Required: No

· GatewayDelay

Specifies the maximum gateway node worker delay due to queueing in milliseconds.

Type: int

Required: No

· ServiceDelay

Specifies the maximum provider delay due to queueing in milliseconds.

Components and configura-

tion of the Katzenpost mixnet Type: int Required: No · KaetzchenDelay Specifies the maximum kaetzchen delay due to queueing in milliseconds. Type: int Required: No SchedulerSlack Specifies the maximum scheduler slack due to queueing and/or processing in milliseconds. Type: int Required: No SendSlack Specifies the maximum send-queue slack due to queueing and/or congestion in milliseconds. Type: int Required: No · DecoySlack Specifies the maximum decoy sweep slack due to external delays such as latency before a loop decoy packet will be considered lost. Type: int Required: No ConnectTimeout Specifies the maximum time a connection can take to establish a TCP/IP connection in milliseconds. Type: int Required: No • HandshakeTimeout Specifies the maximum time a connection can take for a link-protocol handshake in milliseconds. Type: int Required: No · ReauthInterval Specifies the interval at which a connection will be reauthenticated in milliseconds. Type: int

• SendDecoyTraffic

Required: No

If **true**, decoy traffic is enabled. This parameter is experimental and untuned, and is disabled by default.

Note

This option will be removed once decoy traffic is fully implemented.

Type: bool

Required: No

· DisableRateLimit

If **true**, the per-client rate limiter is disabled.

Note

This option should only be used for testing.

Type: bool

Required: No

GenerateOnly

If **true**, the server immediately halts and cleans up after long-term key generation.

Type: bool

Required: No

Configuring gateway nodes

The following configuration is drawn from the reference implementation in katzenpost/dock-er/dirauth_mixnet/gateway1/katzenpost.toml. In a real-world mixnet, the component hosts would not be sharing a single IP address. For more information about the test mixnet, see Using the Katzenpost Docker test network [https://katzenpost.network/docs/admin_guide/docker.html].

Table 4. Gateway node configuration sections

```
Gateway node: Server section
Gateway node: Logging section
Gateway node: Gateway section
Gateway node: PKI section
Gateway node: Management section
Gateway node: SphinxGeometry section
Gateway node: Debug section
```

Gateway node: Server section

The Server section configures mandatory basic parameters for each server node.

```
[Server]
   Identifier = "gateway1"
   WireKEM = "xwing"
   PKISignatureScheme = "Ed25519"
```

```
Addresses = ["127.0.0.1:30004"]
OnlyAdvertiseAltAddresses = false
MetricsAddress = "127.0.0.1:30005"
DataDir = "/dirauth_mixnet/gateway1"
IsGatewayNode = true
IsServiceNode = false
[Server.AltAddresses]
    TCP = ["localhost:30004"]
```

Identifier

Specifies the human-readable identifier for a node, and must be unique per mixnet. The identifier can be an FQDN but does not have to be.

Type: string
Required: Yes

WireKEM

WireKEM specifies the key encapsulation mechanism (KEM) scheme for the PQ Noise [https://eprint.iacr.org/2022/539]-based wire protocol (link layer) that nodes use to communicate with each other. PQ Noise is a post-quantum variation of the Noise protocol framework [https://noiseprotocol.org/], which algebraically transforms ECDH handshake patterns into KEM encapsulate/decapsulate operations.

This configuration option supports the optional use of hybrid post-quantum cryptography to strengthen security. The following KEM schemes are supported:

• Classical: "x25519", "x448"

■ Note

X25519 and X448 are actually non-interactive key-exchanges (NIKEs), not KEMs. Katzenpost uses a hashed ElGamal cryptographic construction to convert them from NIKEs to KEMs.

- Post-quantum: "mlkem768", "sntrup4591761", "frodo640shake", "mceliece348864", "mceliece348864f", "mceliece460896f", "mceliece460896f", "mceliece6688128f", "mceliece6960119f", "mceliece6960119f", "mceliece8192128f", "CTIDH511", "CTIDH512", "CTIDH1024", "CTIDH2048",
- Hybrid post-quantum: "xwing", "Kyber768-X25519", "MLKEM768-X25519", "MLKEM768-"FrodoKEM-640-SHAKE-X448", "mceliece348864-X448", "sntrup4591761-X448", X25519", "mceliece348864f-X25519", "mceliece460896-X25519", "mceliece460896f-"mceliece6688128f-X25519", X25519", "mceliece6688128-X25519", "mceliece6960119-X25519", "mceliece6960119f-X25519", "mceliece8192128-X25519", "mceliece8192128f-X25519", "CTIDH512-X25519", "CTIDH512-X25519"

Type: string
Required: Yes

• PKISignatureScheme

Specifies the cryptographic signature scheme that will be used by all components of the mix network when interacting with the PKI system. Mix nodes sign their descriptors using this signature scheme, and dirauth nodes similarly sign PKI documents using the same scheme.

The following signature schemes are supported:

• Classical: "ed25519", "ed448"

• **Hybrid post-quantum:** "Ed25519 Sphincs+", "Ed448-Sphincs+", "Ed25519-Dilithium2", "Ed448-Dilithium3"

Type: string
Required: Yes

Addresses

Specifies a list of one or more address URLs in a format that contains the transport protocol, IP address, and port number that the server will bind to for incoming connections. Katzenpost supports URLs with that start with either "tcp://" or "quic://" such as: ["tcp://192.168.1.1:30001"] and ["quic://192.168.1.1:40001"].

Addresses is overridden if **BindAddresses** is **true**. In that scenario, one or more advertised, external addresses is provided as the value of **Addresses**, and is advertised in the PKI document.

Note that **BindAddresses**, below, holds the address values for non-adverstised, internal-only listeners. The addition of **BindAddresses** to the node configuration is required for hosts connecting to the Internet through network address translation (NAT).

Type: []string Required: Yes

BindAddresses

If **true**, allows setting of listener addresses that the server will bind to and accept connections on. These addresses are not advertised in the PKI document. For more information, see **Addresses**, above.

Type: bool, []string

Required: No

MetricsAddress

Specifies the address/port to bind the Prometheus metrics endpoint to.

Type: string Required: No

• DataDir

Specifies the absolute path to a node's state directory. This is where persistence.db is written to disk and where a node stores its cryptographic key materials when started with the "-g" commmand-line option.

Type: string

Required: Yes

IsGatewayNode

If **true**, the server is a gateway node.

Type: bool

Required: No

IsServiceNode

If **true**, the server is a service node.

Type: bool Required: No

Gateway node: Logging section

The Logging configuration section controls logging behavior across Katzenpost.

```
[Logging]

Disable = false

File = "katzenpost.log"

Level = "INFO"
```

• Disable

If true, logging is disabled.

Type: bool Required: No

• File

Specifies the log file. If omitted, stdout is used.

An absolute or relative file path can be specified. A relative path is relative to the DataDir specified in the Server section of the configuration.

Type: string Required: No

Level

Supported logging level values are ERROR | WARNING | NOTICE | INFO | DEBUG.

Type: string
Required: No

Warning

The DEBUG log level is unsafe for production use.

Gateway node: Gateway section

The Gateway section of the configuration is required for configuring a Gateway node. The section must contain UserDB and SpoolDB definitions. Bolt [https://github.com/boltdb/bolt] is an embedded database library for the Go programming language that Katzenpost has used in the past for its user and spool databases. Because Katzenpost currently persists data on Service nodes instead of Gateways, these databases will probably be deprecated in favour of in-memory concurrency structures. In the meantime, it remains necessary to configure a Gateway node as shown below, only changing the file paths as needed:

```
[Gateway]
[Gateway.UserDB]
```

```
Backend = "bolt"
        [Gateway.UserDB.Bolt]
            UserDB = "/dirauth_mixnet/gateway1/users.db"

[Gateway.SpoolDB]
    Backend = "bolt"
        [Gateway.SpoolDB.Bolt]
        SpoolDB = "/dirauth mixnet/gateway1/spool.db"
```

Gateway node: PKI section

The PKI section contains the directory authority configuration for a mix, gateway, or service node.

```
[PKI]
[PKI.dirauth]
    [[PKI.dirauth.Authorities]]
        Identifier = "auth1"
        IdentityPublicKey = """----BEGIN ED25519 PUBLIC KEY----
tqN6tpOVotHWXKCszVn2kS7vAZjQpvJjQF3Qz/Qwhyg=
----END ED25519 PUBLIC KEY----
        PKISignatureScheme = "Ed25519"
       LinkPublicKey = """----BEGIN XWING PUBLIC KEY----
JnJ8ztQEIjAkKJcpuZvJAdkWjBim/5G5d8yoosEQHeGJeeBqNPdm2AitUbpiQPcd
tNCo9DxuC9Ieqmsfw0YpV6AtOOsaInA6QnHDYcuBfZcQL5MU4+t2TzpBZQYlrSED
hPCKrAG+8GEU16akseG371WQzEtPpEWWCJCJOiS/VDFZT7eKrldlumN6gfiB84sR
arFh/WKwYJUj+aGBsFYSqGdzC6MdY4x/YyFe2ze0MJEjThQE91y1d/LCQ3Sb7Ri+
u6PBi3JU2qzlPEejDKwK0t5tMNEAkq8iNrpRTdD/hS0qR+ZIN8Z9QKh7Xf94FWG2
H+r8OaqImQhgHabrWRDyLg==
----END XWING PUBLIC KEY----
        WireKEMScheme = "xwing"
       Addresses = ["127.0.0.1:30001"]
    [[PKI.dirauth.Authorities]]
        Identifier = "auth2"
        IdentityPublicKey = """----BEGIN ED25519 PUBLIC KEY----
O51Ty2WLu4C1ETMa29s03bMXV72gnjJfTfwLV++LVBI=
----END ED25519 PUBLIC KEY----
        PKISignatureScheme = "Ed25519"
       LinkPublicKey = """----BEGIN XWING PUBLIC KEY----
TtQkg2XKUnY602FFBaPJ+zpN0Twy20cwyyFxh7FNUjaXA9MAJXs0vUwFbJc6BjYv
f+olKnl1KFSmDvcF74U6w1F0ObuqwTNKNxeYKPKhX4FiencUbRwkHoYHdtZdSctz
TKy08qKQyCAccqCRpdo6ZtYXPAU+2rthjYTOL7Zn+7SHUKCuJClcPnvEYjVcJxtZ
ubJIe5U4nMJbBkOqr7Kq6niaEkiLODa0tkpB8tKMYTMBdcYyHSXCzpo7U9sb6LAR
HktiTBDtrXviu2vbw7VrXhkMW2kjYZDtreQ5sAse04DvmD49zgTp1YxYW+wWFaL3
37X7/SNuLdHX4PHZXIWHBQ==
----END XWING PUBLIC KEY----
        WireKEMScheme = "xwing"
        Addresses = ["127.0.0.1:30002"]
    [[PKI.dirauth.Authorities]]
        Identifier = "auth3"
```

```
IdentityPublicKey = """----BEGIN ED25519 PUBLIC KEY----
zQvydRYJq3npeLcg1NqIf+SswEKE5wFmiwNsI9Z1whQ=
----END ED25519 PUBLIC KEY----
"""

PKISignatureScheme = "Ed25519"
LinkPublicKey = """
----BEGIN XWING PUBLIC KEY-----
OYK9FiC53xwZ1VST3jDOO4tR+cUMSVRSekmigZMChSjDCPZbKut8TblxtlUfc/yi
Ugorz4NIvYPMWUt3QPwS2UWq8/HMWXNGPUiAevg12+oV+jOJXaJeCfY24UekJnSw
TNcdGaFZFSR0FocFcPBBnrK1M2B8w8eEUKQIsXRDM3x/8aRIuDif+ve8rSwpgKeh
...
OdVD3yw7OOS8uPZLORGQFyJbHtVmFPVvwja4G/o2gntAoHUZ2LiJJakpVhhlSyrI
yuzvwwFtZVfWtNb5gAKZCyg0aduR3qgd7MPerRF+YopZk3OCRpC02YxfUZrHv398
FZWJFK0R8iU52CEUxVpXTA==
----END XWING PUBLIC KEY-----
"""

WireKEMScheme = "xwing"
Addresses = ["127.0.0.1:30003"]
```

• Identifier

Specifies the human-readable identifier for a node, which must be unique per mixnet. The identifier can be an FQDN but does not have to be.

Type: string
Required: Yes

IdentityPublicKey

String containing the node's public identity key in PEM format. IdentityPublicKey is the node's permanent identifier and is used to verify cryptographic signatures produced by its private identity key.

Type: string
Required: Yes

• PKISignatureScheme

Specifies the cryptographic signature scheme that will be used by all components of the mix network when interacting with the PKI system. Mix nodes sign their descriptors using this signature scheme, and dirauth nodes similarly sign PKI documents using the same scheme.

Type: string
Required: Yes

· LinkPublicKey

String containing the peer's public link-layer key in PEM format. LinkPublicKey must match the specified WireKEMScheme.

Type: string
Required: Yes

• WireKEMScheme

The name of the wire protocol key-encapsulation mechanism (KEM) to use.

Type: string

Required: Yes

Addresses

Specifies a list of one or more address URLs in a format that contains the transport protocol, IP address, and port number that the server will bind to for incoming connections. Katzenpost supports URLs that start with either "tcp://" or "quic://" such as: ["tcp://192.168.1.1:30001"] and ["quic://192.168.1.1:40001"]. The value of **Addresses** is advertised in the PKI document.

Type: []string Required: Yes

Gateway node: Management section

The Management section specifies connectivity information for the Katzenpost control protocol which can be used to make run-time configuration changes. A configuration resembles the following, substituting the node's configured DataDir value as part of the Path value:

```
[Management]
   Enable = false
   Path = "/node_datadir/management_sock"
```

Enable

If true, the management interface is enabled.

Type: bool Required: No

• Path

Specifies the path to the management interface socket. If left empty, then management_sock is located in the configuration's defined DataDir.

Type: string Required: No

Gateway node: SphinxGeometry section

The SphinxGeometry section defines parameters for the Sphinx encrypted nested-packet format used internally by Katzenpost.

The settings in this section are generated by the gensphinx [https://github.com/katzenpost/katzenpost/tree/main/gensphinx] utility, which computes the Sphinx geometry based on the following user-supplied directives:

- The number of mix node layers (not counting gateway and service nodes)
- · The length of the application-usable packet payload
- The selected NIKE or KEM scheme

Warning

The values in the SphinxGeometry configuration section must be programmatically generated by **gensphinx**. Many of the parameters are interdependent and cannot be individually modified. Do not modify the these values by hand.

The **gensphinx** output in TOML should then be pasted unchanged into the node's configuration file, as shown below.

```
[SphinxGeometry]
```

```
PacketLength = 3082

NrHops = 5

HeaderLength = 476

RoutingInfoLength = 410

PerHopRoutingInfoLength = 82

SURBLength = 572

SphinxPlaintextHeaderLength = 2

PayloadTagLength = 32

ForwardPayloadLength = 2574

UserForwardPayloadLength = 2000

NextNodeHopLength = 65

SPRPKeyMaterialLength = 64

NIKEName = "x25519"

KEMName = ""
```

PacketLength

The length of a Sphinx packet in bytes.

Type: int

Required: Yes

• NrHops

The number of hops a Sphinx packet takes through the mixnet. Because packet headers hold destination information for each hop, the size of the header increases linearly with the number of hops.

Type: int

Required: Yes

HeaderLength

The total length of the Sphinx packet header in bytes.

Type: int

Required: Yes

• RoutingInfoLength

The total length of the routing information portion of the Sphinx packet header.

Type: int

Required: Yes

· PerHopRoutingInfoLength

The length of the per-hop routing information in the Sphinx packet header.

Type: int

Required: Yes

SURBLength

The length of a single-use reply block (SURB).

Type: int

Required: Yes

• SphinxPlaintextHeaderLength

The length of the plaintext Sphinx packet header.

Type: int

Required: Yes

· PayloadTagLength

The length of the payload tag.

Type: int

Required: Yes

· ForwardPayloadLength

The total size of the payload.

Type: int

Required: Yes

· UserForwardPayloadLength

The size of the usable payload.

Type: int

Required: Yes

• NextNodeHopLength

The NextNodeHopLength is derived from the largest routing-information block that we expect to encounter. Other packets have NextNodeHop + NodeDelay sections, or a Recipient section, both of which are shorter.

Type: int

Required: Yes

· SPRPKeyMaterialLength

The length of the strong pseudo-random permutation (SPRP) key.

Type: int

Required: Yes

• NIKEName

The name of the non-interactive key exchange (NIKE) scheme used by Sphinx packets.

NIKEName and KEMName are mutually exclusive.

Type: string

Required: Yes

KEMName

The name of the key encapsulation mechanism (KEM) used by Sphinx packets.

NIKEName and KEMName are mutually exclusive.

Type: string
Required: Yes

Gateway node: Debug section

The Debug section is the Katzenpost server debug configuration for advanced tuning.

[Debug]

```
NumSphinxWorkers = 16
NumServiceWorkers = 3
NumGatewayWorkers = 3
NumKaetzchenWorkers = 3
SchedulerExternalMemoryQueue = false
SchedulerQueueSize = 0
SchedulerMaxBurst = 16
UnwrapDelay = 250
GatewayDelay = 500
ServiceDelay = 500
KaetzchenDelay = 750
SchedulerSlack = 150
SendSlack = 50
DecoySlack = 15000
ConnectTimeout = 60000
HandshakeTimeout = 30000
ReauthInterval = 30000
SendDecoyTraffic = false
DisableRateLimit = false
GenerateOnly = false
```

• NumSphinxWorkers

Specifies the number of worker instances to use for inbound Sphinx packet processing.

Type: int

Required: No

• NumProviderWorkers

Specifies the number of worker instances to use for provider specific packet processing.

Type: int

Required: No

• NumKaetzchenWorkers

Specifies the number of worker instances to use for Kaetzchen-specific packet processing.

Type: int

Required: No

• SchedulerExternalMemoryQueue

If true, the experimental disk-backed external memory queue is enabled.

Type: bool

Required: No

• SchedulerQueueSize

Specifies the maximum scheduler queue size before random entries will start getting dropped. A value less than or equal to zero is treated as unlimited.

Type: int

Required: No

SchedulerMaxBurst

Specifies the maximum number of packets that will be dispatched per scheduler wakeup event.

Type:

Required: No

UnwrapDelay

Specifies the maximum unwrap delay due to queueing in milliseconds.

Type: int

Required: No

· GatewayDelay

Specifies the maximum gateway node worker delay due to queueing in milliseconds.

Type: int

Required: No

ServiceDelay

Specifies the maximum provider delay due to queueing in milliseconds.

Type: int

Required: No

· KaetzchenDelay

Specifies the maximum kaetzchen delay due to queueing in milliseconds.

Type: int

Required: No

SchedulerSlack

Specifies the maximum scheduler slack due to queueing and/or processing in milliseconds.

Type: int

Required: No

SendSlack

Specifies the maximum send-queue slack due to queueing and/or congestion in milliseconds.

Type: int

Required: No

· DecoySlack

Specifies the maximum decoy sweep slack due to external delays such as latency before a loop decoy packet will be considered lost.

Type: int

Required: No

ConnectTimeout

Specifies the maximum time a connection can take to establish a TCP/IP connection in milliseconds.

Type: int

Required: No

· HandshakeTimeout

Specifies the maximum time a connection can take for a link-protocol handshake in milliseconds.

Type: int

Required: No

ReauthInterval

Specifies the interval at which a connection will be reauthenticated in milliseconds.

Type: int

Required: No

• SendDecoyTraffic

If **true**, decoy traffic is enabled. This parameter is experimental and untuned, and is disabled by default.

Note

This option will be removed once decoy traffic is fully implemented.

Type: bool

Required: No

• DisableRateLimit

If true, the per-client rate limiter is disabled.

Note

This option should only be used for testing.

Type: bool Required: No

GenerateOnly

If true, the server immediately halts and cleans up after long-term key generation.

Type: bool Required: No

Configuring service nodes

The following configuration is drawn from the reference implementation in katzenpost/dock-er/dirauth_mixnet/servicenode1/authority.toml. In a real-world mixnet, the component hosts would not be sharing a single IP address. For more information about the test mixnet, see Using the Katzenpost Docker test network [https://katzenpost.network/docs/admin_guide/dock-er.html].

Table 5. Mix node configuration sections

```
Service node: Server section

Service node: Logging section

Service node: ServiceNode section

Service node: PKI section

Service node: Management section

Service node: SphinxGeometry section

Service node: Debug section
```

Service node: Server section

The Server section configures mandatory basic parameters for each server node.

```
[Server]
    Identifier = "servicenode1"
    WireKEM = "xwing"
    PKISignatureScheme = "Ed25519"
    Addresses = ["127.0.0.1:30006"]
    OnlyAdvertiseAltAddresses = false
    MetricsAddress = "127.0.0.1:30007"
    DataDir = "/dirauth_mixnet/servicenode1"
    IsGatewayNode = false
    IsServiceNode = true
    [Server.AltAddresses]
```

Identifier

Specifies the human-readable identifier for a node, and must be unique per mixnet. The identifier can be an FQDN but does not have to be.

Type: string

Required: Yes

WireKEM

WireKEM specifies the key encapsulation mechanism (KEM) scheme for the PQ Noise [https://eprint.iacr.org/2022/539]-based wire protocol (link layer) that nodes use to communicate with each other. PQ Noise is a post-quantum variation of the Noise protocol framework [https://noiseprotocol.org/], which algebraically transforms ECDH handshake patterns into KEM encapsulate/decapsulate operations.

This configuration option supports the optional use of hybrid post-quantum cryptography to strengthen security. The following KEM schemes are supported:

• Classical: "x25519", "x448"

Note

X25519 and X448 are actually non-interactive key-exchanges (NIKEs), not KEMs. Katzenpost uses a hashed ElGamal cryptographic construction to convert them from NIKEs to KEMs.

- Post-quantum: "mlkem768", "sntrup4591761", "frodo640shake", "mceliece348864", "mceliece348864f", "mceliece460896f", "mceliece460896f", "mceliece6688128f", "mceliece6960119f", "mceliece6960119f", "mceliece8192128f", "CTIDH511", "CTIDH512", "CTIDH1024", "CTIDH2048",
- Hybrid post-quantum: "xwing", "Kyber768-X25519", "MLKEM768-X25519", "M "FrodoKEM-640-SHAKE-X448", X448", "sntrup4591761-X448", "mceliece348864-X25519", "mceliece348864f-X25519", "mceliece460896-X25519", "mceliece460896f-X25519", "mceliece6688128-X25519", "mceliece6688128f-X25519", "mceliece6960119-"mceliece6960119f-X25519", "mceliece8192128-X25519", "mceliece8192128f-X25519", "CTIDH512-X25519", "CTIDH512-X25519"

Type: string

Required: Yes

PKISignatureScheme

Specifies the cryptographic signature scheme that will be used by all components of the mix network when interacting with the PKI system. Mix nodes sign their descriptors using this signature scheme, and dirauth nodes similarly sign PKI documents using the same scheme.

The following signature schemes are supported:

- Classical: "ed25519", "ed448"
- **Hybrid post-quantum:** "Ed25519 Sphincs+", "Ed448-Sphincs+", "Ed25519-Dilithium2", "Ed448-Dilithium3"

Type: string

Required: Yes

Addresses

Specifies a list of one or more address URLs in a format that contains the transport protocol, IP address, and port number that the server will bind to for incoming connections. Katzenpost supports URLs with that start with either "tcp://" or "quic://" such as: ["tcp://192.168.1.1:30001"] and ["quic://192.168.1.1:40001"].

Addresses is overridden if **BindAddresses** is **true**. In that scenario, one or more advertised, external addresses is provided as the value of **Addresses**, and is advertised in the PKI document.

Note that **BindAddresses**, below, holds the address values for non-adverstised, internal-only listeners. The addition of **BindAddresses** to the node configuration is required for hosts connecting to the Internet through network address translation (NAT).

Type: []string Required: Yes

BindAddresses

If **true**, allows setting of listener addresses that the server will bind to and accept connections on. These addresses are not advertised in the PKI document. For more information, see **Addresses**, above.

Type: bool, []string

Required: No

MetricsAddress

Specifies the address/port to bind the Prometheus metrics endpoint to.

Type: string

Required: No

• DataDir

Specifies the absolute path to a node's state directory. This is where persistence.db is written to disk and where a node stores its cryptographic key materials when started with the "-g" commmand-line option.

Type: string

Required: Yes

· IsGatewayNode

If **true**, the server is a gateway node.

Type: bool

Required: No

IsServiceNode

If true, the server is a service node.

Type: bool

Required: No

Service node: Logging section

The Logging configuration section controls logging behavior across Katzenpost.

[Logging]

Disable = false

```
File = "katzenpost.log"
Level = "INFO"
```

• Disable

If **true**, logging is disabled.

Type: bool

Required: No

• File

Specifies the log file. If omitted, stdout is used.

An absolute or relative file path can be specified. A relative path is relative to the DataDir specified in the Server section of the configuration.

Type: string Required: No

Level

Supported logging level values are ERROR | WARNING | NOTICE | INFO | DEBUG.

Type: string
Required: No

Warning

The DEBUG log level is unsafe for production use.

Service node: ServiceNode section

The ServiceNode section contains configurations for each network service that Katzenpost supports.

Services, termed Kaetzchen [https://github.com/katzenpost/blob/main/docs/Specificatons/pdf/kaetzchen.pdf], can be divided into built-in and external services. External services are provided through the CBORPlugin [https://pkg.go.dev/github.com/katzenpost/katzenpost@v0.0.35/server/cborplugin#ResponseFactory], a Go programming language implementation of the Concise Binary Object Representation (CBOR) [https://datatracker.ietf.org/doc/html/rfc8949], a binary data serialization format. While native services need simply to be activated, external services are invoked by a separate command and connected to the mixnet over a Unix socket. The plugin allows mixnet services to be added in any programming language.

[ServiceNode]

```
[[ServiceNode.Kaetzchen]]
   Capability = "echo"
   Endpoint = "+echo"
   Disable = false

[[ServiceNode.CBORPluginKaetzchen]]
   Capability = "spool"
   Endpoint = "+spool"
   Command = "/dirauth_mixnet/memspool.alpine"
   MaxConcurrency = 1
   Disable = false
```

```
[ServiceNode.CBORPluginKaetzchen.Config]
       data_store = "/dirauth_mixnet/servicenode1/memspool.storage"
        log_dir = "/dirauth_mixnet/servicenode1"
[[ServiceNode.CBORPluginKaetzchen]]
   Capability = "pigeonhole"
   Endpoint = "+pigeonhole"
   Command = "/dirauth_mixnet/pigeonhole.alpine"
   MaxConcurrency = 1
   Disable = false
   [ServiceNode.CBORPluginKaetzchen.Config]
       db = "/dirauth_mixnet/servicenode1/map.storage"
        log_dir = "/dirauth_mixnet/servicenode1"
[[ServiceNode.CBORPluginKaetzchen]]
   Capability = "panda"
   Endpoint = "+panda"
   Command = "/dirauth_mixnet/panda_server.alpine"
   MaxConcurrency = 1
   Disable = false
   [ServiceNode.CBORPluginKaetzchen.Config]
        fileStore = "/dirauth_mixnet/servicenodel/panda.storage"
        log_dir = "/dirauth_mixnet/servicenode1"
       log_level = "INFO"
[[ServiceNode.CBORPluginKaetzchen]]
   Capability = "http"
   Endpoint = "+http"
   Command = "/dirauth_mixnet/proxy_server.alpine"
   MaxConcurrency = 1
   Disable = false
   [ServiceNode.CBORPluginKaetzchen.Config]
       host = "localhost:4242"
        log_dir = "/dirauth_mixnet/servicenode1"
       log_level = "DEBUG"
```

Common parameters:

Capability

Specifies the protocol capability exposed by the agent.

Type: string
Required: Yes

Endpoint

Specifies the provider-side Endpoint where the agent will accept requests. While not required by the specification, this server only supports Endpoints that are lower-case local parts of an email address.

Type: string
Required: Yes

Command

Specifies the full path to the external plugin program that implements this Kaetzchen service.

Type: string

Required: Yes

MaxConcurrency

Specifies the number of worker goroutines to start for this service.

Type: int

Required: Yes

Config

Specifies extra per-agent arguments to be passed to the agent's initialization routine.

Type: map[string]interface{}

Required: Yes

• Disable

If true, disables a configured agent.

Type: bool

Required: No

Per-service parameters:

echo

The internal echo service must be enabled on every service node of a production mixnet for decoy traffic to work properly.

spool

The spool service supports the catshadow storage protocol, which is required by the Katzen chat client. The example configuration above shows spool enabled with the setting:

Disable = false

Note

Spool, properly memspool, should not be confused with the spool database on gateway nodes.

• data_store

Specifies the full path to the service database file.

Type: string

Required: Yes

• log_dir

Specifies the path to the node's log directory.

Type: string

Required: Yes

· pigeonhole

The pigeonhole courier service supports the Blinding-and-Capability scheme (BACAP)-based unlinkable messaging protocols detailed in **Place-holder for research paper link**. Most of our future protocols will use the pigeonhole courier service.

• db

Specifies the full path to the service database file.

Type: string

Required: Yes

· log_dir

Specifies the path to the node's log directory.

Type: string

Required: Yes

• panda

The panda storage and authentication service currently does not work properly.

• fileStore

Specifies the full path to the service database file.

Type: string

Required: Yes

· log_dir

Specifies the path to the node's log directory.

Type: string

Required: Yes

log_level

Supported values are ERROR | WARNING | NOTICE | INFO | DEBUG.

Warning

The DEBUG log level is unsafe for production use.

Type: string

Required: Yes

Required: Yes

• http

The http service is completely optional, but allows the mixnet to be used as an HTTP proxy. This may be useful for integrating with existing software systems.

host

The host name and TCP port of the service.

```
Type: string
Required: Yes
```

• log_dir

Specifies the path to the node's log directory.

Type: string
Required: Yes

• log_level

Supported values are ERROR | WARNING | NOTICE | INFO | DEBUG.

Type: string
Required: Yes
Required: Yes

Warning

The DEBUG log level is unsafe for production use.

Type: string
Required: Yes

Service node: PKI section

The PKI section contains the directory authority configuration for a mix, gateway, or service node.

```
[PKI]
[PKI.dirauth]
    [[PKI.dirauth.Authorities]]
        Identifier = "auth1"
        IdentityPublicKey = """----BEGIN ED25519 PUBLIC KEY----
tqN6tpOVotHWXKCszVn2kS7vAZjQpvJjQF3Qz/Qwhyg=
----END ED25519 PUBLIC KEY----
        PKISignatureScheme = "Ed25519"
       LinkPublicKey = """----BEGIN XWING PUBLIC KEY----
JnJ8ztQEIjAkKJcpuZvJAdkWjBim/5G5d8yoosEQHeGJeeBqNPdm2AitUbpiQPcd
tNCo9DxuC9Ieqmsfw0YpV6AtOOsaInA6QnHDYcuBfZcQL5MU4+t2TzpBZQYlrSED
hPCKrAG+8GEU16akseG371WQzEtPpEWWCJCJOiS/VDFZT7eKrldlumN6qfiB84sR
arFh/WKwYJUj+aGBsFYSqGdzC6MdY4x/YyFe2ze0MJEjThQE91y1d/LCQ3Sb7Ri+
u6PBi3JU2qzlPEejDKwK0t5tMNEAkq8iNrpRTdD/hS0gR+ZIN8Z9QKh7Xf94FWG2
H+r8OaqImQhgHabrWRDyLg==
----END XWING PUBLIC KEY----
        WireKEMScheme = "xwing"
       Addresses = ["127.0.0.1:30001"]
    [[PKI.dirauth.Authorities]]
```

```
Identifier = "auth2"
        IdentityPublicKey = """----BEGIN ED25519 PUBLIC KEY----
O51Ty2WLu4C1ETMa29s03bMXV72gnjJfTfwLV++LVBI=
----END ED25519 PUBLIC KEY----
        PKISignatureScheme = "Ed25519"
       LinkPublicKey = """----BEGIN XWING PUBLIC KEY----
TtQkg2XKUnY602FFBaPJ+zpN0Twy20cwyyFxh7FNUjaXA9MAJXs0vUwFbJc6BjYv
f+olKnliKFSmDvcF74U6w1F0ObuqwTNKNxeYKPKhX4FiencUbRwkHoYHdtZdSctz
TKy08qKQyCAccqCRpdo6ZtYXPAU+2rthjYTOL7Zn+7SHUKCuJClcPnvEYjVcJxtZ
ubJIe5U4nMJbBkOqr7Kq6niaEkiLODa0tkpB8tKMYTMBdcYyHSXCzpo7U9sb6LAR
HktiTBDtrXviu2vbw7VRXhkMW2kjYZDtReQ5sAse04DvmD49zgTp1YxYW+wWFaL3
37X7/SNuLdHX4PHZXIWHBQ==
----END XWING PUBLIC KEY----
       WireKEMScheme = "xwing"
        Addresses = ["127.0.0.1:30002"]
    [[PKI.dirauth.Authorities]]
        Identifier = "auth3"
        IdentityPublicKey = """----BEGIN ED25519 PUBLIC KEY----
zQvydRYJq3npeLcg1NqIf+SswEKE5wFmiwNsI9Z1whQ=
----END ED25519 PUBLIC KEY----
        PKISignatureScheme = "Ed25519"
       LinkPublicKey = """
----BEGIN XWING PUBLIC KEY----
OYK9FiC53xwZ1VST3jDOO4tR+cUMSVRSekmigZMChSjDCPZbKut8TblxtlUfc/yi
Ugorz4NIvYPMWUt3QPwS2UWq8/HMWXNGPUiAevg12+oV+jOJXaJeCfY24UekJnSw
TNcdGaFZFSR0FocFcPBBnrK1M2B8w8eEUKQIsXRDM3x/8aRIuDif+ve8rSwpgKeh
OdVD3yw70OS8uPZLORGQFyJbHtVmFPVvwja4G/o2gntAoHUZ2LiJJakpVhhlSyrI
yuzvwwFtZVfWtNb5gAKZCyg0aduR3qgd7MPerRF+YopZk3OCRpC02YxfUZrHv398
FZWJFK0R8iU52CEUxVpXTA==
----END XWING PUBLIC KEY----
       WireKEMScheme = "xwing"
        Addresses = ["127.0.0.1:30003"]
```

Identifier

Specifies the human-readable identifier for a node, which must be unique per mixnet. The identifier can be an FODN but does not have to be.

Type: string
Required: Yes

IdentityPublicKey

String containing the node's public identity key in PEM format. IdentityPublicKey is the node's permanent identifier and is used to verify cryptographic signatures produced by its private identity key.

Type: string
Required: Yes

• PKISignatureScheme

Specifies the cryptographic signature scheme that will be used by all components of the mix network when interacting with the PKI system. Mix nodes sign their descriptors using this signature scheme, and dirauth nodes similarly sign PKI documents using the same scheme.

Type: string
Required: Yes

LinkPublicKey

String containing the peer's public link-layer key in PEM format. LinkPublicKey must match the specified WireKEMScheme.

Type: string
Required: Yes

WireKEMScheme

The name of the wire protocol key-encapsulation mechanism (KEM) to use.

Type: string
Required: Yes

Addresses

Specifies a list of one or more address URLs in a format that contains the transport protocol, IP address, and port number that the server will bind to for incoming connections. Katzenpost supports URLs that start with either "tcp://" or "quic://" such as: ["tcp://192.168.1.1:30001"] and ["quic://192.168.1.1:40001"]. The value of **Addresses** is advertised in the PKI document.

Type: []string Required: Yes

Service node: Management section

The Management section specifies connectivity information for the Katzenpost control protocol which can be used to make run-time configuration changes. A configuration resembles the following, substituting the node's configured DataDir value as part of the Path value:

```
[Management]
  Enable = false
  Path = "/node_datadir/management_sock"
```

Enable

If **true**, the management interface is enabled.

Type: bool Required: No

Path

Specifies the path to the management interface socket. If left empty, then management_sock is located in the configuration's defined DataDir.

Type: string

Required: No

Service node: SphinxGeometry section

The SphinxGeometry section defines parameters for the Sphinx encrypted nested-packet format used internally by Katzenpost.

The settings in this section are generated by the gensphinx [https://github.com/katzenpost/katzenpost/tree/main/gensphinx] utility, which computes the Sphinx geometry based on the following user-supplied directives:

- The number of mix node layers (not counting gateway and service nodes)
- · The length of the application-usable packet payload
- The selected NIKE or KEM scheme

Warning

The values in the SphinxGeometry configuration section must be programmatically generated by **gensphinx**. Many of the parameters are interdependent and cannot be individually modified. Do not modify the these values by hand.

The **gensphinx** output in TOML should then be pasted unchanged into the node's configuration file, as shown below.

[SphinxGeometry]

```
PacketLength = 3082
NrHops = 5
HeaderLength = 476
RoutingInfoLength = 410
PerHopRoutingInfoLength = 82
SURBLength = 572
SphinxPlaintextHeaderLength = 2
PayloadTagLength = 32
ForwardPayloadLength = 2574
UserForwardPayloadLength = 2574
UserForwardPayloadLength = 65
SPRPKeyMaterialLength = 64
NIKEName = "x25519"
KEMName = ""
```

· PacketLength

The length of a Sphinx packet in bytes.

Type: int

Required: Yes

NrHops

The number of hops a Sphinx packet takes through the mixnet. Because packet headers hold destination information for each hop, the size of the header increases linearly with the number of hops.

Type: int

Required: Yes

HeaderLength

The total length of the Sphinx packet header in bytes.

Type: int

Required: Yes

RoutingInfoLength

The total length of the routing information portion of the Sphinx packet header.

Type: int

Required: Yes

• PerHopRoutingInfoLength

The length of the per-hop routing information in the Sphinx packet header.

Type: int

Required: Yes

• SURBLength

The length of a single-use reply block (SURB).

Type: int

Required: Yes

• SphinxPlaintextHeaderLength

The length of the plaintext Sphinx packet header.

Type: int

Required: Yes

· PayloadTagLength

The length of the payload tag.

Type: int

Required: Yes

• ForwardPayloadLength

The total size of the payload.

Type: int

Required: Yes

• UserForwardPayloadLength

The size of the usable payload.

Type: int

Required: Yes

NextNodeHopLength

The NextNodeHopLength is derived from the largest routing-information block that we expect to encounter. Other packets have NextNodeHop + NodeDelay sections, or a Recipient section, both of which are shorter.

Type: int

Required: Yes

· SPRPKeyMaterialLength

The length of the strong pseudo-random permutation (SPRP) key.

Type: int

Required: Yes

NIKEName

The name of the non-interactive key exchange (NIKE) scheme used by Sphinx packets.

NIKEName and KEMName are mutually exclusive.

Type: string

Required: Yes

KEMName

The name of the key encapsulation mechanism (KEM) used by Sphinx packets.

NIKEName and KEMName are mutually exclusive.

Type: string

Required: Yes

Service node: Debug section

The Debug section is the Katzenpost server debug configuration for advanced tuning.

[Debug]

```
NumSphinxWorkers = 16
NumServiceWorkers = 3
NumGatewayWorkers = 3
NumKaetzchenWorkers = 3
SchedulerExternalMemoryQueue = false
SchedulerQueueSize = 0
SchedulerMaxBurst = 16
UnwrapDelay = 250
GatewayDelay = 500
ServiceDelay = 500
KaetzchenDelay = 750
SchedulerSlack = 150
SendSlack = 50
DecoySlack = 15000
ConnectTimeout = 60000
HandshakeTimeout = 30000
ReauthInterval = 30000
SendDecoyTraffic = false
```

DisableRateLimit = false
GenerateOnly = false

• NumSphinxWorkers

Specifies the number of worker instances to use for inbound Sphinx packet processing.

Type: int

Required: No

• NumProviderWorkers

Specifies the number of worker instances to use for provider specific packet processing.

Type: int

Required: No

· NumKaetzchenWorkers

Specifies the number of worker instances to use for Kaetzchen-specific packet processing.

Type: int

Required: No

• SchedulerExternalMemoryQueue

If **true**, the experimental disk-backed external memory queue is enabled.

Type: bool

Required: No

• SchedulerQueueSize

Specifies the maximum scheduler queue size before random entries will start getting dropped. A value less than or equal to zero is treated as unlimited.

Type: int

Required: No

• SchedulerMaxBurst

Specifies the maximum number of packets that will be dispatched per scheduler wakeup event.

Type:

Required: No

UnwrapDelay

Specifies the maximum unwrap delay due to queueing in milliseconds.

Type: int

Required: No

· GatewayDelay

Specifies the maximum gateway node worker delay due to queueing in milliseconds.

Type: int Required: No ServiceDelay Specifies the maximum provider delay due to queueing in milliseconds. Type: int Required: No KaetzchenDelay Specifies the maximum kaetzchen delay due to queueing in milliseconds. Type: int Required: No SchedulerSlack Specifies the maximum scheduler slack due to queueing and/or processing in milliseconds. Type: int Required: No SendSlack Specifies the maximum send-queue slack due to queueing and/or congestion in milliseconds. Type: int Required: No · DecoySlack Specifies the maximum decoy sweep slack due to external delays such as latency before a loop decoy packet will be considered lost. Type: int Required: No ConnectTimeout Specifies the maximum time a connection can take to establish a TCP/IP connection in milliseconds. Type: int Required: No • HandshakeTimeout Specifies the maximum time a connection can take for a link-protocol handshake in milliseconds. Type: int

Required: No

ReauthInterval

Specifies the interval at which a connection will be reauthenticated in milliseconds.

Type: int

Required: No

· SendDecoyTraffic

If **true**, decoy traffic is enabled. This parameter is experimental and untuned, and is disabled by default.

Note

This option will be removed once decoy traffic is fully implemented.

Type: bool

Required: No

• DisableRateLimit

If **true**, the per-client rate limiter is disabled.

Note

This option should only be used for testing.

Type: bool

Required: No

GenerateOnly

If true, the server immediately halts and cleans up after long-term key generation.

Type: bool

Required: No

Using the Katzenpost Docker test network

Katzenpost provides a ready-to-deploy Docker image for developers who need a non-production test environment for developing and testing client applications and server side plugins. By running this image on a single computer, you avoid the need to build and manage a complex multi-node mix net. The image can also be run using Podman [https://podman.io/]

The test mix network includes the following components:

- Three directory authority (PKI [https://katzenpost.network/docs/specs/pki.html]) nodes
- Six mix [https://katzenpost.network/docs/specs/mixnet/] nodes, including one node serving also as both gateway and service provider
- A ping utility, run-ping

Requirements

Before running the Katzenpost docker image, make sure that the following software is installed.

- A Debian GNU Linux [https://debian.org] or Ubuntu [https://ubuntu.com] system
- Git [https://git-scm.com/]
- Go [https://go.dev/]
- GNU Make [https://www.gnu.org/software/make/]
- Prometheus [https://prometheus.io/docs/introduction/overview/]
- Docker [https://www.docker.com], Docker Compose [https://docs.docker.com/compose/], and (optionally) Podman [https://podman.io]

Note

If both Docker and Podman are present on your system, Katzenpost uses Podman. Podman is a drop-in daemonless equivalent to Docker that does not require superuser privileges to run.

On Debian, these software requirements can be installed with the following commands (running as superuser). **Apt** will pull in the needed dependencies.

```
# apt update
# apt install git golang make docker docker-compose podman
```

Preparing to run the container image

Complete the following procedure to obtain, build, and deploy the Katzenpost test network.

- 1. Install the Katzenpost code repository, hosted at https://github.com/katzenpost. The main Katzenpost repository contains code for the server components as well as the docker image. Clone the repository with the following command (your directory location may vary):
 - ~\$ git clone https://github.com/katzenpost/katzenpost.git
- 2. Navigate to the new katzenpost subdirectory and ensure that the code is up to date.

- ~\$ cd katzenpost
- ~/katzenpost\$ git checkout main
- ~/katzenpost\$ git pull
- 3. (Optional) Create a development branch and check it out.
 - ~/katzenpost\$ git checkout -b devel
- 4. (Optional) If you are using Podman, complete the following steps:
 - 1. Point the DOCKER_HOST environment variable at the Podman process.
 - \$ export DOCKER_HOST=unix:///var/run/user/\$(id -u)/podman/podman.sock
 - 2. Set up and start the Podman server (as superuser).

```
$ podman system service -t 0 $DOCKER_HOST &
$ systemctl --user enable --now podman.socket
```

Operating the test mixnet

Navigate to katzenpost/docker. The Makefile contains target operations to create, manage, and test the self-contained Katzenpost container network. To invoke a target, run a command with the using the following pattern:

```
~/katzenpost/docker$ make target
```

Running make with no target specified returns a list of available targets.

Table 1. Table 1: Makefile targets

[none]	Display this list of targets.
start	Run the test network in the background.
stop	Stop the test network.
wait	Wait for the test network to have consensus.
watch	Display live log entries until Ctrl-C.
status	Show test network consensus status.
show-latest-vote	Show latest consensus vote.
run-ping	Send a ping over the test network.
clean-bin	Stop all components and delete binaries.
clean-local	Stop all components, delete binaries, and delete data.
clean-local-dryrun	Show what clean-local would delete.
clean	Same as clean-local , but also deletes go_deps image.

Starting and monitoring the mixnet

The first time that you run **make start**, the Docker image is downloaded, built, installed, and started. This takes several minutes. When the build is complete, the command exits while the network remains running in the background.

~/katzenpost/docker\$ make start

Subsequent runs of **make start** either start or restart the network without building the components from scratch. The exception to this is when you delete any of the Katzenpost binaries (dirauth.alpine, server.alpine, etc.). In that case, **make start** rebuilds just the parts of the network dependent on the deleted binary. For more information about the files created during the Docker build, see the section called "Network topology and components".

Note

When running make start, be aware of the following considerations:

- If you intend to use Docker, you need to run make as superuser. If you are using sudo to elevate
 your privileges, you need to edit katzenpost/docker/Makefile to prepend sudo to
 each command contained in it.
- If you have Podman installed on your system and you nonetheless want to run Docker, you can override the default behavior by adding the argument **docker=docker** to the command as in the following:

```
~/katzenpost/docker$ make run docker=docker
```

After the **make start** command exits, the mixnet runs in the background, and you can run **make watch** to display a live log of the network activity.

```
~/katzenpost/docker$ make watch
...
<output>
...
```

When installation is complete, the mix servers vote and reach a consensus. You can use the **wait** target to wait for the mixnet to get consensus and be ready to use. This can also take several minutes:

```
~/katzenpost/docker$ make wait
...
<output>
```

You can confirm that installation and configuration are complete by issuing the **status** command from the same or another terminal. When the network is ready for use, **status** begins returning consensus information similar to the following:

```
~/katzenpost/docker$ make status
...
00:15:15.003 NOTI state: Consensus made for epoch 1851128 with 3/3 signatur
...
```

Testing the mixnet

At this point, you should have a locally running mix network. You can test whether it is working correctly by using **run-ping**, which launches a packet into the network and watches for a successful reply. Run the following command:

```
~/katzenpost/docker$ make run-ping
```

If the network is functioning properly, the resulting output contains lines similar to the following:

```
19:29:53.541 INFO gateway1_client: sending loop decoy !19:29:54.108 INFO gateway1_client: sending loop decoy 19:29:54.632 INFO gateway1_client: sending loop decoy 19:29:55.160 INFO gateway1_client: sending loop decoy
```

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```
!19:29:56.071 INFO gateway1_client: sending loop decoy !19:29:59.173 INFO gateway1_client: sending loop decoy !Success rate is 100.000000 percent 10/10)
```

If **run-ping** fails to receive a reply, it eventually times out with an error message. If this happens, try the command again.

Note

If you attempt use **run-ping** too quickly after starting the mixnet, and consensus has not been reached, the utility may crash with an error message or hang indefinitely. If this happens, issue (if necessary) a **Ctrl-C** key sequence to abort, check the consensus status with the **status** command, and then retry **run-ping**.

Shutting down the mixnet

The mix network continues to run in the terminal where you started it until you issue a **Ctrl-C** key sequence, or until you issue the following command in another terminal:

```
~/katzenpost/docker$ make stop
```

When you stop the network, the binaries and data are left in place. This allows for a quick restart.

Uninstalling and cleaning up

Several command targets can be used to uninstall the Docker image and restore your system to a clean state. The following examples demonstrate the commands and their output.

· clean-bin

To stop the network and delete the compiled binaries, run the following command:

~/katzenpost/docker\$ make clean-bin

```
[ -e voting_mixnet ] && cd voting_mixnet && DOCKER_HOST=unix:///run/user/1
Stopping voting_mixnet_auth3_1 ... done
Stopping voting_mixnet_servicenode1_1 ... done
Stopping voting_mixnet_metrics_1 ... done
                                     ... done
Stopping voting_mixnet_mix3_1
                                     ... done
Stopping voting_mixnet_auth2_1
Stopping voting_mixnet_mix2_1
                                     ... done
Stopping voting_mixnet_gateway1_1
                                     ... done
                                     ... done
Stopping voting_mixnet_auth1_1
Stopping voting_mixnet_mix1_1
                                     ... done
Removing voting_mixnet_auth3_1
                                     ... done
Removing voting_mixnet_servicenodel_1 ... done
                                     ... done
Removing voting_mixnet_metrics_1
Removing voting_mixnet_mix3_1
                                     ... done
                                     ... done
Removing voting_mixnet_auth2_1
                                     ... done
Removing voting_mixnet_mix2_1
Removing voting_mixnet_gateway1_1
                                     ... done
Removing voting_mixnet_auth1_1
                                     ... done
Removing voting_mixnet_mix1_1
                                     ... done
removed 'running.stamp'
rm -vf ./voting_mixnet/*.alpine
removed './voting_mixnet/echo_server.alpine'
removed './voting_mixnet/fetch.alpine'
removed './voting_mixnet/memspool.alpine'
```

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```
removed './voting_mixnet/panda_server.alpine'
removed './voting_mixnet/pigeonhole.alpine'
removed './voting_mixnet/ping.alpine'
removed './voting_mixnet/reunion_katzenpost_server.alpine'
removed './voting_mixnet/server.alpine'
removed './voting_mixnet/voting.alpine'
```

This command leaves in place the cryptographic keys, the state data, and the logs.

clean-local-dryrun

To diplay a preview of what **clean-local** would remove, without actually deleting anything, run the following command:

~/katzenpost/docker\$ make clean-local-dryrun

· clean-local

To delete both compiled binaries and data, run the following command:

~/katzenpost/docker\$ make clean-local

```
[ -e voting_mixnet ] && cd voting_mixnet && DOCKER_HOST=unix:///run/user/1
Removing voting_mixnet_mix2_1
                                      ... done
Removing voting_mixnet_auth1_1
                                      ... done
                                      ... done
Removing voting_mixnet_auth2_1
Removing voting_mixnet_gateway1_1
                                      ... done
Removing voting_mixnet_mix1_1
                                      ... done
Removing voting_mixnet_auth3_1
                                      ... done
Removing voting_mixnet_mix3_1
                                      ... done
Removing voting_mixnet_servicenodel_1 ... done
Removing voting_mixnet_metrics_1
                                      ... done
removed 'running.stamp'
rm -vf ./voting_mixnet/*.alpine
removed './voting_mixnet/echo_server.alpine'
removed './voting_mixnet/fetch.alpine'
removed './voting_mixnet/memspool.alpine'
removed './voting_mixnet/panda_server.alpine'
removed './voting_mixnet/pigeonhole.alpine'
removed './voting_mixnet/reunion_katzenpost_server.alpine'
removed './voting_mixnet/server.alpine'
removed './voting_mixnet/voting.alpine'
git clean -f -x voting_mixnet
Removing voting_mixnet/
git status .
On branch main
Your branch is up to date with 'origin/main'.
```

• clean

To stop the the network and delete the binaries, the data, and the go_deps image, run the following command as superuser:

~/katzenpost/docker\$ sudo make clean

Network topology and components

The Docker image deploys a working mixnet with all components and component groups needed to perform essential mixnet functions:

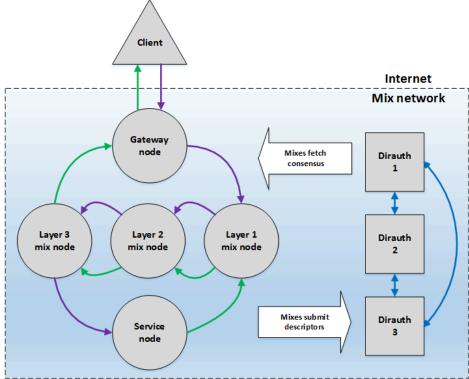
- message mixing (including packet reordering, timing randomization, injection of decoy traffic, obfuscation of senders and receivers, and so on)
- · service provisioning
- · internal authentication and integrity monitoring
- interfacing with external clients

Warning

While suited for client development and testing, the test mixnet omits performance and security redundancies. *Do not use it in production*.

The following diagram illustrates the components and their network interactions. The gray blocks represent nodes, and the arrows represent information transfer.

Figure 1. Test network topology



Enlarge diagram [https://katzenpost.network/docs/admin_guide/pix/katzenpost-docker.png]

On the left, the **Client** transmits a message (shown by purple arrows) through the **Gateway node**, across three **mix node** layers, to the **Service node**. The **Service node** processes the request and responds with a reply (shown by the green arrows) that traverses the **mix node** layers before exiting the mixnet via the **Gateway node** and arriving at the **Client**.

On the right, directory authorities **Dirauth 1**, **Dirauth 2**, and **Dirauth 3** provide PKI services. The directory authorities receive **mix descriptors** from the other nodes, collate these into a **consensus document** containing validated network status and authentication materials, and make that available to the other nodes.

The elements in the topology diagram map to the mixnet's component nodes as shown in the following table. Note that all nodes share the same IP address (127.0.0.1, i.e., localhost), but are accessed through different ports. Each node type links to additional information in Components and configuration of the Katzenpost mixnet [https://katzenpost.network/docs/admin_guide/components.html].

Table 2. Table 2: Test mixnet hosts

Node type	Docker ID	Diagram label	IP address	TCP port
Directory authority [https://katzen-post.network/docs/admin_guide/com-ponents.html#in-tro-dirauth]	auth1	Dirauth1	127.0.0.1 (local-host)	30001
	auth2	Dirauth 2		30002
	auth3	Dirauth 3		30003
Gateway node [https:// katzenpost.net- work/docs/ admin_guide/com- ponents.html#in- tro-gateway]	gateway1	Gateway node		30004
Service node [https:// katzenpost.net- work/docs/ admin_guide/com- ponents.html#in- tro-service]	servicenode1	Service node		30006
Mix node [https://katzenpost.net-work/docs/admin_guide/components.html#in-tro-mix]	mix1	Layer 1 mix node		30008
	mix2	Layer 2 mix node		30010
	mix3	Layer 3 mix node		30012

The Docker file tree

--auth3

The following tree [https://manpages.debian.org/bookworm/tree/tree.1.en.html] output shows the location, relative to the katzenpost repository root, of the files created by the Docker build. During testing and use, you would normally touch only the TOML configuration file associated with each node, as highlighted in the listing. For help in understanding these files and a complete list of configuration options, follow the links in Table 2: Test mixnet hosts.

---auth1 |---authority.toml ---identity.private.pem ---identity.public.pem ---katzenpost.log ---link.private.pem ---link.public.pem |---persistence.db -auth2 ---authority.toml ---identity.private.pem ---identity.public.pem ---katzenpost.log ---link.private.pem ---link.public.pem |---persistence.db

katzenpost/docker/voting_mixnet/

```
|---authority.toml
    ---identity.private.pem
    ---identity.public.pem
    ---katzenpost.log
   ---link.private.pem
   ---link.public.pem
   |---persistence.db
---client
   |---client.toml
---client2
   |---client.toml
---dirauth.alpine
---docker-compose.yml
---echo_server.alpine
---fetch.alpine
---gateway1
    ---identity.private.pem
    ---identity.public.pem
    ---katzenpost.log
   ---katzenpost.toml
   ---link.private.pem
   ---link.public.pem
   ---management_sock
   ---spool.db
   |---users.db
---memspool.alpine
---mix1
   |---identity.private.pem
   |---identity.public.pem
   |---katzenpost.log
    ---katzenpost.toml
    ---link.private.pem
   ---link.public.pem
---mix2
   |---identity.private.pem
   |---identity.public.pem
   |---katzenpost.log
   |---katzenpost.toml
   |---link.private.pem
   |---link.public.pem
---mix3
   |---identity.private.pem
   |---identity.public.pem
   |---katzenpost.log
   ---katzenpost.toml
   ---link.private.pem
   |---link.public.pem
---panda_server.alpine
---pigeonhole.alpine
---ping.alpine
---prometheus.yml
---proxy_client.alpine
---proxy_server.alpine
---running.stamp
---server.alpine
---servicenode1
   |---identity.private.pem
   |---identity.public.pem
```

Using the Katzenpost Docker test network

```
| ---katzenpost.log
| ---katzenpost.toml
| ---link.private.pem
| ---link.public.pem
| ---management_sock
| ---map.storage
| ---memspool.13.log
| ---memspool.storage
| ---panda.25.log
| ---panda.storage
| ---pigeonHole.19.log
| ---proxy.31.log
```

Examples of complete TOML configuration files are provided in Appendix: Configuration files from the Docker test mixnet [https://katzenpost.network/docs/admin_guide/docker-config-appendix.html].

NAT considerations for Katzenpost servers

Any Katzenpost server node can be configured to run behind a properly configured router that supports network address translation [https://www.rfc-editor.org/rfc/rfc1918] (NAT) and similar network topologies that traverse public and private network boundaries. This applies to directory authorities, gateways that allow clients to connect to the network, mix nodes, and service nodes that provide protocols over the mix network such as ping and spool services for storing messages or rendezvous information.

Typically, the router connecting a LAN with the Internet blocks incoming connections by default, and must be configured to forward traffic from the Internet to a destination host based on port number. These target addresses are most often drawn from RFC 6598 [https://www.rfc-editor.org/rfc/rfc6598] private address space, although more exotic topologies involving public IP address may also be targeted. (Router configuration for NAT topologies in general is beyond the scope of this topic.) For such cases, where the host listens on a LAN-side *address:port* but is accessed publicly using a different *address:port*, Katzenpost provides mechanisms to specify both addresses.

Note

Katzenpost does not support NAT penetration protocols such as NATPMP [https://www.rfc-editor.org/rfc/rfc6886], STUN [https://www.rfc-editor.org/rfc/rfc5389], TURN [https://www.rfc-editor.org/rfc/rfc5766], and UPnP [https://en.wikipedia.org/wiki/Universal_Plug_and_Play].

Addresses and BindAddresses

In a direct network connection, the values defined in the server <code>Addresses</code> parameter define the addresses on which the node listens for incoming connections, and which are advertised to other mixnet components in the PKI document. By supplying the optional <code>BindAddresses</code> parameter, you can define a second address group: LAN-side addresses that are not advertised in the PKI document. This is useful for NAT scenarios, which involve both public and private address spaces.

Note

The Addresses and BindAddresses parameters are closely analogous to Tor's Address and ORPort parameters. For more information, see the torrc man page [https://manpages.debian.org/testing/tor/torrc.5.en.html].

The following table shows the details for these two parameters. For more information about node configuration, see Components and configuration of the Katzenpost mixnet [https://katzenpost.network/docs/admin guide/components.html].

Table 1. Addresses and BindAddresses parameters

Parameter	Required	Description
Addresses	Yes	Specifies a list of one or more address URIs in a format that contains the transport protocol (typically TCP), an IP address, and a port number that the node will bind to for incoming connections. This value is advertised in the PKI document.
BindAd- dresses	No	If true (that is, if this parameter is present), this parameter sets listener <i>address:port</i> values that the server will bind to and accept connections on, but that are not advertised in the PKI document. In this case, <i>Addresses</i>

Parameter	Required	Description	
		defines public addresses on the Internet side of a NAT router, while <i>BindAddresses</i> defines a different set of addresses behind the NAT router.	

Note

Directory authorities do not support the BindAddresses parameter, but can still be used behind NAT. For more information, see Hosting a directory authority behind NAT

Hosting mix, gateway, and service nodes behind NAT

This section provides an example of a Katzenpost topology that make use of the <code>BindAddresses</code> parameter. In this scenario, a mix node behind NAT listens on local addresses for connections, while advertising a public address and port to its peer, a directory authority, that is assumed to have a publicly routable address.

Figure 1. Accessing a mix node behind NAT

Enlarge diagram [https://katzenpost.network/docs/admin_guide/pix/mix-behind-nat.png]

Key observations

- The configuration file on the NATed mix node is katzenpost.toml.
- The relevant section of the configuration file is [Server].

Directory authority

Directory authority's address: 198.51.100.20

Mix node's advertised address: 203.0.113.10:1234

- The Addresses parameter specifies the publicly routable address:port, 203.0.113.10:1234, over which the mix node can be reached from the Internet. This value is periodically advertised in the PKI document to other components of the mix network.
- The *BindAddresses* parameter specifies the LAN *address:port*, 192.168.0.2:1234, on which the node listens for incoming Sphinx packets from peers.
- The NAT router has two configured addresses, public address 203.0.113.10 and private LAN address 192.168.0.1.

• The NAT router forwards traffic for 203.0.113.10:1234 to the mix node's LAN *address:port*, 192.168.0.2:1234, where the configured listener is bound.

The configuration in this example applies equally well to a NATed gateway node or service provider. A NATed gateway node would also be reachable by a client with knowledge of the gateway's public address.

Hosting a directory authority behind NAT

Directory authorities have no support for the <code>BindAddresses</code> parameter. They also do not adverstise an address in the PKI document, because peers must already know the address in order to fetch the document, which means that addresses for dirauths must be provided out-of-band.

Consequently, the Addresses parameter for dirauths performs the same function as BindAddresses on the other node types, that is, to define the node's listening *address:port* values, but not an advertised address. In a NAT scenario, these addresses can refer to any target that is situated on the LAN side of the NAT router.

Directory authority

LAN address: 192.168.0.2:1234

Advertised address: None

NAT router

Local network

Address: 192.168.0.1

Address: 198.51.100.50

Mix node

Mix node's address: 198.51.100.10

Dirauth's out-of-band public address: 198.51.100.50:1234

Figure 2. Accessing a directory authority behind NAT

Enlarge diagram [https://katzenpost.network/docs/admin_guide/pix/dirauth-behind-nat.png]

Key observations

- The configuration file on the NATed dirauth is authority.toml.
- The relevant section of the configuration file is [Server].
- The Addresses parameter specifies a private RFC 6598 [https://www.rfc-editor.org/rfc/rfc6598] address:port, 192.168.0.2:1234. By definition, this address cannot be reached directly from the Internet.
- There is no BindAddresses parameter.
- The NAT device has two configured addresses, public address 198.51.100.50, and LAN address 192.168.0.1.
- The NAT device routes traffic targeting 198.51.100.50:1234 to the address:port specified in Addresses, 192.168.0.2:1234.

NAT considerations for Katzenpost servers



Appendix: Configuration files from the Docker test mixnet

As an aid to adminstrators implementing a Katzenpost mixnet, this appendix provides lightly edited examples of configuration files for each Katzenpost node type. These files are drawn from a built instance of the Docker test mixnet [https://katzenpost.network/docs/admin_guide/docker.html]. These code listings are meant to be used as a reference alongside the detailed configuration documentation in Components and configuration of the Katzenpost mixnet [https://katzenpost.network/docs/admin_guide/components.html]. You cannot use these listings as a drop-in solution in your own mixnets for reasons explained in the Network topology and components [https://katzenpost.network/docs/admin_guide/docker.html#topology] section of the Docker test mixnet documentation.

Directory authority

Mu = 0.005

```
Source: ../katzenpost/docker/voting_mixnet/auth1/authority.toml
[Server]
  Identifier = "auth1"
  WireKEMScheme = "xwing"
 PKISignatureScheme = "Ed448-Dilithium3"
  Addresses = ["tcp://127.0.0.1:30001"]
  DataDir = "/voting mixnet/auth1"
[[Authorities]]
  Identifier = "auth1"
  IdentityPublicKey = "----BEGIN ED448-DILITHIUM3 PUBLIC KEY----\nfvcvAfUpeu7
  PKISignatureScheme = "Ed448-Dilithium3"
  LinkPublicKey = "----BEGIN XWING PUBLIC KEY----\nsxxS04mftoEmwjxE/w [...] e
  WireKEMScheme = "xwing"
  Addresses = ["tcp://127.0.0.1:30001"]
[[Authorities]]
  Identifier = "auth2"
  IdentityPublicKey = "----BEGIN ED448-DILITHIUM3 PUBLIC KEY----\n5nsy6uFQ178
  PKISignatureScheme = "Ed448-Dilithium3"
  LinkPublicKey = "----BEGIN XWING PUBLIC KEY----\nkQzCJvaS6jg06szLea [...] P
  WireKEMScheme = "xwing"
  Addresses = ["tcp://127.0.0.1:30002"]
[[Authorities]]
  Identifier = "auth3"
  IdentityPublicKey = "----BEGIN ED448-DILITHIUM3 PUBLIC KEY----\nJzkFpS035de
  PKISignatureScheme = "Ed448-Dilithium3"
  LinkPublicKey = "----BEGIN XWING PUBLIC KEY----\n+pIUsgEGwHa8k4GZcb [...] 1
  WireKEMScheme = "xwing"
  Addresses = ["tcp://127.0.0.1:30003"]
[Logging]
  Disable = false
 File = "katzenpost.log"
  Level = "INFO"
[Parameters]
  SendRatePerMinute = 0
```

```
MuMaxDelay = 1000
 LambdaP = 0.001
 LambdaPMaxDelay = 1000
 LambdaL = 0.0005
 LambdaLMaxDelay = 1000
 LambdaD = 0.0005
 LambdaDMaxDelay = 3000
 LambdaM = 0.0005
 LambdaG = 0.0
 LambdaMMaxDelay = 100
 LambdaGMaxDelay = 100
[Debug]
 Layers = 3
 MinNodesPerLayer = 1
 GenerateOnly = false
[[Mixes]]
 Identifier = "mix1"
 IdentityPublicKeyPem = "../mix1/identity.public.pem"
[[Mixes]]
 Identifier = "mix2"
 IdentityPublicKeyPem = "../mix2/identity.public.pem"
[[Mixes]]
 Identifier = "mix3"
 IdentityPublicKeyPem = "../mix3/identity.public.pem"
[[GatewayNodes]]
  Identifier = "gateway1"
 IdentityPublicKeyPem = "../gateway1/identity.public.pem"
[[ServiceNodes]]
 Identifier = "servicenode1"
 IdentityPublicKeyPem = "../servicenodel/identity.public.pem"
[Topology]
  [[Topology.Layers]]
    [[Topology.Layers.Nodes]]
      Identifier = "mix1"
      IdentityPublicKeyPem = "../mix1/identity.public.pem"
  [[Topology.Layers]]
    [[Topology.Layers.Nodes]]
      Identifier = "mix2"
      IdentityPublicKeyPem = "../mix2/identity.public.pem"
  [[Topology.Layers]]
    [[Topology.Layers.Nodes]]
      Identifier = "mix3"
      IdentityPublicKeyPem = "../mix3/identity.public.pem"
[SphinxGeometry]
```

```
PacketLength = 3082

NrHops = 5

HeaderLength = 476

RoutingInfoLength = 410

PerHopRoutingInfoLength = 82

SURBLength = 572

SphinxPlaintextHeaderLength = 2

PayloadTagLength = 32

ForwardPayloadLength = 2574

UserForwardPayloadLength = 2000

NextNodeHopLength = 65

SPRPKeyMaterialLength = 64

NIKEName = "x25519"

KEMName = ""
```

Mix node

```
Source: ../katzenpost/docker/voting_mixnet/mix1/katzenpost.toml
[Server]
  Identifier = "mix1"
  WireKEM = "xwing"
 PKISignatureScheme = "Ed448-Dilithium3"
  Addresses = ["tcp://127.0.0.1:30010", "quic://[::1]:30011"]
  MetricsAddress = "127.0.0.1:30012"
  DataDir = "/voting_mixnet/mix1"
  IsGatewayNode = false
  IsServiceNode = false
[Logging]
 Disable = false
  File = "katzenpost.log"
  Level = "INFO"
[PKI]
  [PKI.Voting]
    [[PKI.Voting.Authorities]]
      Identifier = "auth1"
      IdentityPublicKey = "----BEGIN ED448-DILITHIUM3 PUBLIC KEY----\nfvcvAfU
      PKISignatureScheme = "Ed448-Dilithium3"
     LinkPublicKey = "----BEGIN XWING PUBLIC KEY----\nsxxS04mftoEmwjxE/w [..
      WireKEMScheme = "xwing"
      Addresses = ["tcp://127.0.0.1:30001"]
    [[PKI.Voting.Authorities]]
      Identifier = "auth2"
      IdentityPublicKey = "----BEGIN ED448-DILITHIUM3 PUBLIC KEY----\n5nsy6uF
      PKISignatureScheme = "Ed448-Dilithium3"
     LinkPublicKey = "----BEGIN XWING PUBLIC KEY----\nkQzCJvaS6jg06szLea [..
     WireKEMScheme = "xwing"
     Addresses = ["tcp://127.0.0.1:30002"]
    [[PKI.Voting.Authorities]]
      Identifier = "auth3"
      IdentityPublicKey = "----BEGIN ED448-DILITHIUM3 PUBLIC KEY----\nJzkFpS0
```

LinkPublicKey = "----BEGIN XWING PUBLIC KEY----\n+pIUsgEGwHa8k4GZcb [..

PKISignatureScheme = "Ed448-Dilithium3"

```
WireKEMScheme = "xwing"
     Addresses = ["tcp://127.0.0.1:30003"]
[Management]
 Enable = false
 Path = "/voting_mixnet/mix1/management_sock"
[SphinxGeometry]
 PacketLength = 3082
 NrHops = 5
 HeaderLength = 476
 RoutingInfoLength = 410
 PerHopRoutingInfoLength = 82
 SURBLength = 572
 SphinxPlaintextHeaderLength = 2
 PayloadTagLength = 32
 ForwardPayloadLength = 2574
 UserForwardPayloadLength = 2000
 NextNodeHopLength = 65
 SPRPKeyMaterialLength = 64
 NIKEName = "x25519"
 KEMName = ""
[Debug]
 NumSphinxWorkers = 16
 NumServiceWorkers = 3
 NumGatewayWorkers = 3
 NumKaetzchenWorkers = 3
 SchedulerExternalMemoryQueue = false
 SchedulerQueueSize = 0
 SchedulerMaxBurst = 16
 UnwrapDelay = 250
 GatewayDelay = 500
 ServiceDelay = 500
 KaetzchenDelay = 750
 SchedulerSlack = 150
 SendSlack = 50
 DecoySlack = 15000
 ConnectTimeout = 60000
 HandshakeTimeout = 30000
 ReauthInterval = 30000
 SendDecoyTraffic = false
 DisableRateLimit = false
 GenerateOnly = false
```

Gateway node

```
Source: ../katzenpost/docker/voting_mixnet/gateway1/katzenpost.toml

[Server]
   Identifier = "gateway1"
   WireKEM = "xwing"
   PKISignatureScheme = "Ed448-Dilithium3"
   Addresses = ["tcp://127.0.0.1:30004", "quic://[::1]:30005", "onion://thisisju
   BindAddresses = ["tcp://127.0.0.1:30004", "quic://[::1]:30005"]
   MetricsAddress = "127.0.0.1:30006"
   DataDir = "/voting_mixnet/gateway1"
   IsGatewayNode = true
```

```
IsServiceNode = false
[Logging]
 Disable = false
 File = "katzenpost.log"
 Level = "INFO"
[Gateway]
  [Gateway.UserDB]
   Backend = "bolt"
    [Gateway.UserDB.Bolt]
     UserDB = "/voting_mixnet/gateway1/users.db"
  [Gateway.SpoolDB]
   Backend = "bolt"
    [Gateway.SpoolDB.Bolt]
      SpoolDB = "/voting_mixnet/gateway1/spool.db"
[PKI]
  [PKI.Voting]
    [[PKI.Voting.Authorities]]
      Identifier = "auth1"
      IdentityPublicKey = "----BEGIN ED448-DILITHIUM3 PUBLIC KEY----\nfvcvAfU
     PKISignatureScheme = "Ed448-Dilithium3"
     LinkPublicKey = "----BEGIN XWING PUBLIC KEY----\nsxxS04mftoEmwjxE/w [..
     WireKEMScheme = "xwing"
     Addresses = ["tcp://127.0.0.1:30001"]
    [[PKI.Voting.Authorities]]
      Identifier = "auth2"
      IdentityPublicKey = "----BEGIN ED448-DILITHIUM3 PUBLIC KEY----\n5nsy6uF
     PKISignatureScheme = "Ed448-Dilithium3"
     LinkPublicKey = "----BEGIN XWING PUBLIC KEY----\nkQzCJvaS6jg06szLea [..
     WireKEMScheme = "xwing"
     Addresses = ["tcp://127.0.0.1:30002"]
    [[PKI.Voting.Authorities]]
      Identifier = "auth3"
      IdentityPublicKey = "----BEGIN ED448-DILITHIUM3 PUBLIC KEY----\nJzkFpS0
     PKISignatureScheme = "Ed448-Dilithium3"
     LinkPublicKey = "----BEGIN XWING PUBLIC KEY----\n+pIUsgEGwHa8k4GZcb [..
     WireKEMScheme = "xwing"
     Addresses = ["tcp://127.0.0.1:30003"]
[Management]
 Enable = true
 Path = "/voting_mixnet/gateway1/management_sock"
[SphinxGeometry]
 PacketLength = 3082
 NrHops = 5
 HeaderLength = 476
 RoutingInfoLength = 410
 PerHopRoutingInfoLength = 82
 SURBLength = 572
 SphinxPlaintextHeaderLength = 2
 PayloadTagLength = 32
 ForwardPayloadLength = 2574
```

```
UserForwardPayloadLength = 2000
 NextNodeHopLength = 65
 SPRPKeyMaterialLength = 64
 NIKEName = "x25519"
 KEMName = ""
[Debug]
 NumSphinxWorkers = 16
 NumServiceWorkers = 3
 NumGatewayWorkers = 3
 NumKaetzchenWorkers = 3
 SchedulerExternalMemoryQueue = false
 SchedulerQueueSize = 0
 SchedulerMaxBurst = 16
 UnwrapDelay = 250
 GatewayDelay = 500
 ServiceDelay = 500
 KaetzchenDelay = 750
 SchedulerSlack = 150
 SendSlack = 50
 DecoySlack = 15000
 ConnectTimeout = 60000
 HandshakeTimeout = 30000
 ReauthInterval = 30000
 SendDecoyTraffic = false
 DisableRateLimit = false
 GenerateOnly = false
```

Service node

```
Source:
            ../katzenpost/docker/voting_mixnet/servicenode1/katzen-
post.toml
[Server]
  Identifier = "servicenodel"
  WireKEM = "xwing"
  PKISignatureScheme = "Ed448-Dilithium3"
  Addresses = ["tcp://127.0.0.1:30007", "quic://[::1]:30008"]
  MetricsAddress = "127.0.0.1:30009"
 DataDir = "/voting_mixnet/servicenodel"
  IsGatewayNode = false
  IsServiceNode = true
[Logging]
 Disable = false
  File = "katzenpost.log"
  Level = "INFO"
[ServiceNode]
  [[ServiceNode.Kaetzchen]]
    Capability = "echo"
    Endpoint = "+echo"
    Disable = false
  [[ServiceNode.Kaetzchen]]
    Capability = "testdest"
    Endpoint = "+testdest"
```

```
Disable = false
  [[ServiceNode.CBORPluginKaetzchen]]
   Capability = "spool"
   Endpoint = "+spool"
   Command = "/voting_mixnet/memspool.alpine"
   MaxConcurrency = 1
   Disable = false
   [ServiceNode.CBORPluginKaetzchen.Config]
     data_store = "/voting_mixnet/servicenode1/memspool.storage"
     log_dir = "/voting_mixnet/servicenodel"
 [[ServiceNode.CBORPluginKaetzchen]]
   Capability = "pigeonhole"
   Endpoint = "+pigeonhole"
   Command = "/voting_mixnet/pigeonhole.alpine"
   MaxConcurrency = 1
   Disable = false
   [ServiceNode.CBORPluginKaetzchen.Config]
     db = "/voting_mixnet/servicenode1/map.storage"
     log_dir = "/voting_mixnet/servicenode1"
 [[ServiceNode.CBORPluginKaetzchen]]
   Capability = "panda"
   Endpoint = "+panda"
   Command = "/voting_mixnet/panda_server.alpine"
   MaxConcurrency = 1
   Disable = false
   [ServiceNode.CBORPluginKaetzchen.Config]
     fileStore = "/voting_mixnet/servicenode1/panda.storage"
     log_dir = "/voting_mixnet/servicenode1"
     log_level = "INFO"
  [[ServiceNode.CBORPluginKaetzchen]]
   Capability = "http"
   Endpoint = "+http"
   Command = "/voting_mixnet/proxy_server.alpine"
   MaxConcurrency = 1
   Disable = false
   [ServiceNode.CBORPluginKaetzchen.Config]
     host = "localhost:4242"
     log_dir = "/voting_mixnet/servicenode1"
     log_level = "DEBUG"
[PKI]
 [PKI.Voting]
   [[PKI.Voting.Authorities]]
     Identifier = "auth1"
     IdentityPublicKey = "----BEGIN ED448-DILITHIUM3 PUBLIC KEY----\nfvcvAfU
     PKISignatureScheme = "Ed448-Dilithium3"
     LinkPublicKey = "----BEGIN XWING PUBLIC KEY----\nsxxS04mftoEmwjxE/w [..
     WireKEMScheme = "xwing"
     Addresses = ["tcp://127.0.0.1:30001"]
   [[PKI.Voting.Authorities]]
     Identifier = "auth2"
     IdentityPublicKey = "----BEGIN ED448-DILITHIUM3 PUBLIC KEY----\n5nsy6uF
```

Appendix: Configuration files from the Docker test mixnet

```
PKISignatureScheme = "Ed448-Dilithium3"
     LinkPublicKey = "----BEGIN XWING PUBLIC KEY----\nkQzCJvaS6jg06szLea [..
     WireKEMScheme = "xwing"
     Addresses = ["tcp://127.0.0.1:30002"]
   [[PKI.Voting.Authorities]]
     Identifier = "auth3"
     IdentityPublicKey = "----BEGIN ED448-DILITHIUM3 PUBLIC KEY----\nJzkFpS0
     PKISignatureScheme = "Ed448-Dilithium3"
     LinkPublicKey = "----BEGIN XWING PUBLIC KEY----\n+pIUsgEGwHa8k4GZcb [..
     WireKEMScheme = "xwing"
     Addresses = ["tcp://127.0.0.1:30003"]
[Management]
 Enable = true
 Path = "/voting_mixnet/servicenode1/management_sock"
[SphinxGeometry]
 PacketLength = 3082
 NrHops = 5
 HeaderLength = 476
 RoutingInfoLength = 410
 PerHopRoutingInfoLength = 82
 SURBLength = 572
 SphinxPlaintextHeaderLength = 2
 PayloadTagLength = 32
 ForwardPayloadLength = 2574
 UserForwardPayloadLength = 2000
 NextNodeHopLength = 65
 SPRPKeyMaterialLength = 64
 NIKEName = "x25519"
 KEMName = ""
[Debug]
 NumSphinxWorkers = 16
 NumServiceWorkers = 3
 NumGatewayWorkers = 3
 NumKaetzchenWorkers = 4
 SchedulerExternalMemoryQueue = false
 SchedulerQueueSize = 0
 SchedulerMaxBurst = 16
 UnwrapDelay = 250
 GatewayDelay = 500
 ServiceDelay = 500
 KaetzchenDelay = 750
 SchedulerSlack = 150
 SendSlack = 50
 DecoySlack = 15000
 ConnectTimeout = 60000
 HandshakeTimeout = 30000
 ReauthInterval = 30000
 SendDecoyTraffic = false
 DisableRateLimit = false
 GenerateOnly = false
```