ToMaTo Documentation

Release 3

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Contents

CHAPTER 1

ToMaTo parts

Hostmanager Documentation

Contents:

Hostmanager Installation

The hostmanager offers the virtualization technology found on the host to backends. For simple installation of the hostmanager, it has been packaged for Debian systems.

Installation on Debian systems

All of the following commands must be issued as **root**.

1. Adding the repository

   ToMaTo has its own repository for debian packages that needs to be added in order to install its packages.

   ```
   echo 'deb http://packages.tomato-lab.org/deb stable main' > /etc/apt/sources.
   ↪list.d/tomato.list
   ```

2. Accepting the repository key

   Since all packages are signed with keys, the repository key must be accepted once, otherwise the Debian package manager will complain on every update that the package is unauthorized.

   ```
   wget http://packages.tomato-lab.org/key.gpg -O - | apt-key add -
   ```

3. Updating the package lists

   ```
   apt-get update
   ```

4. Installing the Hostmanager package

```
apt-get install tomato-hostmanager
```

During the configuration phase of this package, dialogs will appear and propmt for information. All of these prompts can be answered by pressing *enter*.

5. Optional: Install the Updater package

```
apt-get install tomato-updater
```

This package will add a cronjob that keeps your ToMaTo installation automatically up-to-date.

Installation on Proxmox systems

The target platform for the hostmanager is Proxmox VE so there exists a meta-package specifically for Proxmox systems, that installs all additional software that is needed to use the full potential of Proxmox systems.

To install the hostmanager on Proxmox systems, the **steps 1 to 4 from above** have to be executed. Additionally the package `tomato-host-proxmox` has to be installed:

```
apt-get install tomato-host-proxmox
```

After the installation

Some steps are needed to finalize the installation:

- Installation of additional packages so that more *Element types* and *Connection types* become available. (For Proxmox hosts, the package `tomato-host-promxmox` installs all needed software.
- *Hostmanager Configuration*
- *Backend management*

Hostmanager Configuration

Hostmanager API

The hostmanager offers the following methods via an XML-RPC interface. The interface uses an encoding as documented in *XML-RPC Interface*. All of the methods can be called by their method names without modules, etc.

Elements

Connections

Accounting

Resources

Host

Backend management

The hostmanager allows different backends to use it.

Component separation

All components (i.e. elements and connections) of different backends are separated by the hostmanager. Each component will have an owner attribute, that references the backend that created it. The component will only be visible and accessible by that backend.

Resource separation

All resources (i.e. networks and templates) of different backends are separated by the hostmanager. Each resource will have an owner attribute, that references the backend that created it. The resource will only be visible and accessible by that backend.

Access control

The authentication of backends uses SSL keys. Each backend has a key of its own and uses it to authenticate and encrypt connections to hostmanagers. On the side of the hostmanager all backend keys must be present as files in *PEM format* in a specific directory (`/etc/tomato/client_certs` in default config).

Indexing the backend keys

After modifying the SSL keys, the certificate index must be rebuilt.

```
update-tomato-client-certs
```

Note that the hostmanager does not have to be restarted after rebuilding the index. Also note that the hostmanager will issue the command to rebuild the certificate index automatically when it is starting.

Backend identification

The identity of a backend is based on the *common name (CN)* in its certificate. Different certificates with the same common name field will be treated as the same backend and share access to components.

Generating a key-pair

A self-signed key-pair can be created with the following command:

```
openssl req -new -x509 -days 1000 -nodes -out key.pem -keyout cert.pem
```

It is important to create a key without a password if the the key should be used for a backend.

Integrated Fileserver

The backend has an integrated fileserver that allows ToMaTo users to upload and download data files like disk images, packet capture files directly from/to the hostmanager without indirection via the backend.

Access

The fileserver uses the HTTP protocol on a port set in the config file. The public address of the host and the fileserver port can obtained using the API call `hostmanager.tomato.api.host.host_info()`.

Element types

OpenVZ (`openvz`, `openvz_interface`)

KVM with QM frontend (`kvmqm`, `kvmqm_interface`)

KVM with VirSH frontend (`kvm`)

Repy (`repy`, `repy_interface`)

Tinc VPN (`tinc`)

UDP Tunnel (`udp_tunnel`)

Connection types

Bridge (`bridge`)

Fixed bridge (`fixed_bridge`)

Other topics:

XML-RPC Interface

The interface is an RPC interface, i.e. it offers a set of methods that can be called (with parameters) and that return a return value. The internal data format is XML but this should be transparent. The interface adheres the XML-RPC standard with the following modifications:

- It uses an extension for null-value encoding that is not part of the standard. This extension is part of many implementations since the absence of the feature is seen as a flaw in the standard.
- It uses a special parameter encoding that allows for keyword arguments. If exactly two parameters are given, where the first one is a list and the second one is key/value-map the keyword mode is used. In the keyword mode, the first parameter (the list) is expanded and used as normal positional arguments nad the second argument (the key/value-map) is expanded and used as the keyword arguments.

Web-Frontend Documentation

Command-Line-Client Documentation

Basic CLI functionality

`cli.tomato.`**`getLocals`**(*api*)

Combines the api with additional functionalities in one dictionary. It adds a list of all commands, a help method and a method to load and initialize python modules from a file.

Parameter *api*: Connection to a host api

Return value: This method returns a dictionary with a connection to a API, an help method and a method to load and initialize python modules from a file.

`cli.tomato.parseArgs()`

Defines required and optional arguments for the cli and parses them out of sys.argv.

Available Arguments are:

Argument –*help*: Prints a help text for the available arguments

Argument –*url*: The whole URL of the server

Argument –*protocol*: Protocol of the server

Argument –*hostname*: Address of the host of the server

Argument –*port*: Port of the host server

Argument –*ssl*: Whether to use ssl or not

Argument –*client_cert*: Path to the ssl certificate of the client

Argument –*username*: The username to use for login

Argument –*password*: The password to user for login

Argument –*file*: Path to a file to execute

Argument *arguments* Python code to execute directly

Return value: Parsed command-line arguments

`cli.tomato.run()`

Parses the command-line arguments, opens an API connection and creates access to the available commands of the host. It decides based on the options whether to directly execute python code or to execute a file or to grant access to the interactive cli.

`cli.tomato.runFile(locals, file, options)`

Opens a connection to a remote socket at address (host, port) and closes it to open the TCP port.

Parameter *locals*: Dict containing a connection to an API, a help function and a file load function.

Parameter *file*: Path to the file which should be executed

Parameter *options*: Command-line arguments which will be used to create an interactive console which executes the file.

`cli.tomato.runInteractive(locals)`

Creates a interactive console based on the local available methods.

Parameter *locals*: Dict containing a connection to an API, a help function and a file load function.

`cli.tomato.runSource(locals, source)`

Executes a python code using an interpreter based on the methods provided by the API found in locals.

Parameter *locals*: Dict containing a connection to an API, a help function and a file load function.

Parameter *source*: Source code to execute

Additional functionality

Upload / Download commands

`cli.lib.createUrl(protocol, hostname, port, username=None, password=None)`

Creates a URL for connecting to a server.

Parameter *protocol*: Protocol of the server

Parameter *hostname*: Address of the host of the server

Parameter *port*: Port of the host server

Parameter *ssl*: Boolean whether ssl should be used or not

Parameter *username*: The username to use for login

Parameter *password*: The password to user for login

Return value: This method returns a full server URL.

`cli.lib.`**`getConnection`**(*url*, *sslCert=None*)

Creates a server proxy to a host using the given URL.

Parameter *url*: URL of the server

Parameter *sslCert*: SSL certificate to use for a ssl connection

Return value: This method returns a server proxy object.

`cli.lib.`**`tcpPortOpen`**(*host*, *port*)

Opens a connection to a remote socket at address (host, port) and closes it to open the TCP port.

Parameter *host*: Host address of the socket

Parameter *port*: TCP port that will be opened

Return value: This method returns a boolean which is true, if the TCP Port is open and false otherwise.

Advanced link commands

`cli.lib.misc.`**`is_superset`**(*obj1*, *obj2*, *path=''*)

Checks whether obj1 is a superset of obj2.

Parameter *obj1*: Superset object

Parameter *obj2*: Subset object

Parameter *path*: Should be "" in initial call

Return value: Returns a tuple with 2 arguments. The first argument is a boolean which is true, if obj1 is superset of obj2, false otherwise. The second argument returns a string if the first argument is false. The string contains the reason why obj1 is not a superset of obj2.

`cli.lib.misc.`**`link_check`**(*id*, *ip*, *tries=5*, *waitBetween=5*)

Checks the availability of a link by trying to reach him a certain number of tries.

Parameter *id*: ID of device which should be reached

Parameter *ip*: IP address of the ping target

Parameter *tries*: Number of tries

Parameter *waitBetween*: Time between each try

Return value: Returns a boolean which is true, if the link was available within the number of tries, false otherwise.

`cli.lib.misc.`**`link_config`**(*top*, *con*, *c*, *attrs*)

Configures an link by modifying the certain attributes

Parameter *top*: Topology in which the link can be found

Parameter *con*: Link which should be modified

Parameter *c*: Target interface

Parameter *attrs*: Key value pair of attributes which should be configured

`cli.lib.misc.`**`link_info`**(*id*, *ip*, *samples=10*, *maxWait=5*, *oneWayAdapt=False*)

Pings a target IP address from a certain device and returns the results. The number of samples and the maximum wait time for responds can be set. Also a one-way adaption of the results is possible.

Parameter *id*: ID of device which should be used.

Parameter *ip*: IP address of the ping target.

Parameter *samples*: Number of messages to send.

Parameter *maxWait*: Time to wait for a responds in seconds.

Parameter *oneWayAdapt*: Change results to a one-way adaption.

Return value: The return value of this method is a dict containing information about the route between the link and the destination.

`lossratio` The loss ratio of the route between the link and the destination.

`delay` The average round-trip time.

`delay_stddev` The average standard deviation for the delay.

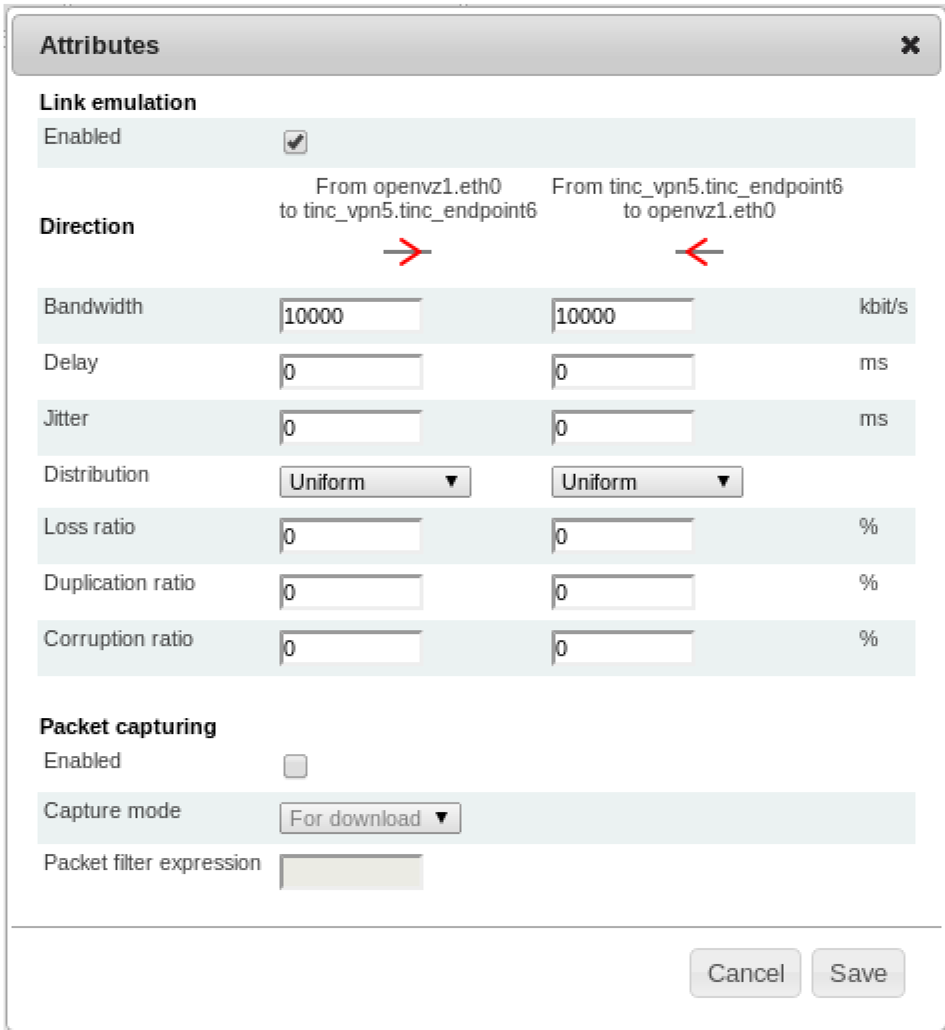
CHAPTER 2

Other topics

Link Emulation

Link emulation is an important feature for some experiments. Link emulation means that conditions of real networks and their effects on traffic are emulated in an environment with different conditions.

ToMaTo supports an extended set of link characteristics based on the tc/netem capabilities. With ToMaTo, users can add *packet loss*, *packet duplication*, *packet corruption*, *delay*, and *bandwith limitation* to existing connections. These conditions are applied to the data that flows over the connection additionally to the conditions that it already possesses. The conditions can be set separately on each direction of a conection. The emulated conditions can be changed any time (even on running connectors) in the graphical editor.



Mode of operation

To emulate the link characteristics ToMaTo uses two combined queues per direction. The queues for the different directions of the connection are completely independent.

The first queue each packet has to go through is a netem queue that emulates all link characteristics except bandwidth limitations. This queue delays packets, drops them depending on the loss and emulates duplication and corruption. Packets that exit this queue (after being delayed) are processed by the second queue.

A token-bucket-filter queue is used as the second queue to enforce bandwidth limitations. Tokens are produced with a fixed rate limited to a certain maximum. If there are tokens left, packets are sent immediately and the tokens are reduced. Otherwise the packets are put on hold and delayed until enough tokens have been produced.

Note: A note on buffering

Both queues need buffers for their normal execution. The netem queue needs the buffer to store packets that have to be delayed and the TBF queue needs the buffer to store packets until enough tokens are ready to send them. ToMaTo tries to automatically calculate good values for these buffers.

The TBF buffer is sized so that 25ms of data (at the maximal rate) can be buffered. This should be enough to actually reach the maximal rate. The minimal buffer size is one MTU of 1540 bytes.

The netem buffer is sized so that enough packets of an average size of 250 bytes can be delayed by the configured delay to reach the configured maximal bandwidth without causing loss.

Note: A note on transitions

Due to technical restrictions changes to the link emulation settings can only be applied in two steps: First the token bucket filter is changed to apply the new bandwidth settings, which results in the Netem queue being temporarily removed. After this the Netem queue that does all the other link emulation is reestablished.

Because of this two-step process there is a short gap between these steps where only the bandwidth is enforced but the delay, loss, etc. are not applied and the link has perfect properties. In most cases this gap is too short to be noticeable but sometimes, depending on load, scheduling can result in the gap length rising to about 10ms (The length of a scheduler time slice).

Bandwidth limitations

Bandwidth limitations can be set on connections to limit the maximal data rate. The bandwidth limitation must be configured in kilobits per second. The default bandwidth limitation for all connections (if no limit is configured) is 10 MBits.

Note that due to the token bucket filter short bursts can have a higher effective bandwidth than the configured limit but the sustained bandwidth is limited by the configured maximum.

Also note that traffic that exceeds the limit first fills the buffers and then is dropped if the buffers are full. See above for an explanation of the buffer sizes.

Delay

If delay is configured for a connection, packets on that connection are stored in a queue and sent when they are due. The timing granularity depends on the capabilities of the realtime clock of the hosts but in general is very precise. Delays must be configured in milliseconds.

Note that delays are only added to the connection and that other delays like processing delays and real transmission delays add to the configured delay.

Jitter

Jitter can be applied as a random modification of the delay per packet. The jitter value must be configured in milliseconds and configures the delay by which the configured delay can be increased or reduced per packet. The way jitter is calculated depends on the chosen distribution.

Note that jitter can cause packets to be reordered if the jitter value has the same order of magnitude as the time between two packets.

Note that if the jitter is higher than the delay all resulting negative per packet delays are treated as zero delay.

Delay distribution

The delay jitter can be allied with a _uniform_ distribution meaning that all values in the jitter range are equally likely (this is the default).

The _normal_ distribution has a higher probability for values near the configured delay but is still symmectric for values higher and lower than the configured delay.

The _pareto_ distribution follows a power law where most of the delays are a little lower than the configured delay and some delays are much higher.

The _paretonormal_ distribution is a mixture of both distributions with 75% pareto and 25% normal distribution.

Note that only the uniform distribution guarantees that the per packet delay will be in [delay-jitter .. delay+jitter] and that the median of the pareto distribution is lower than the configured delay

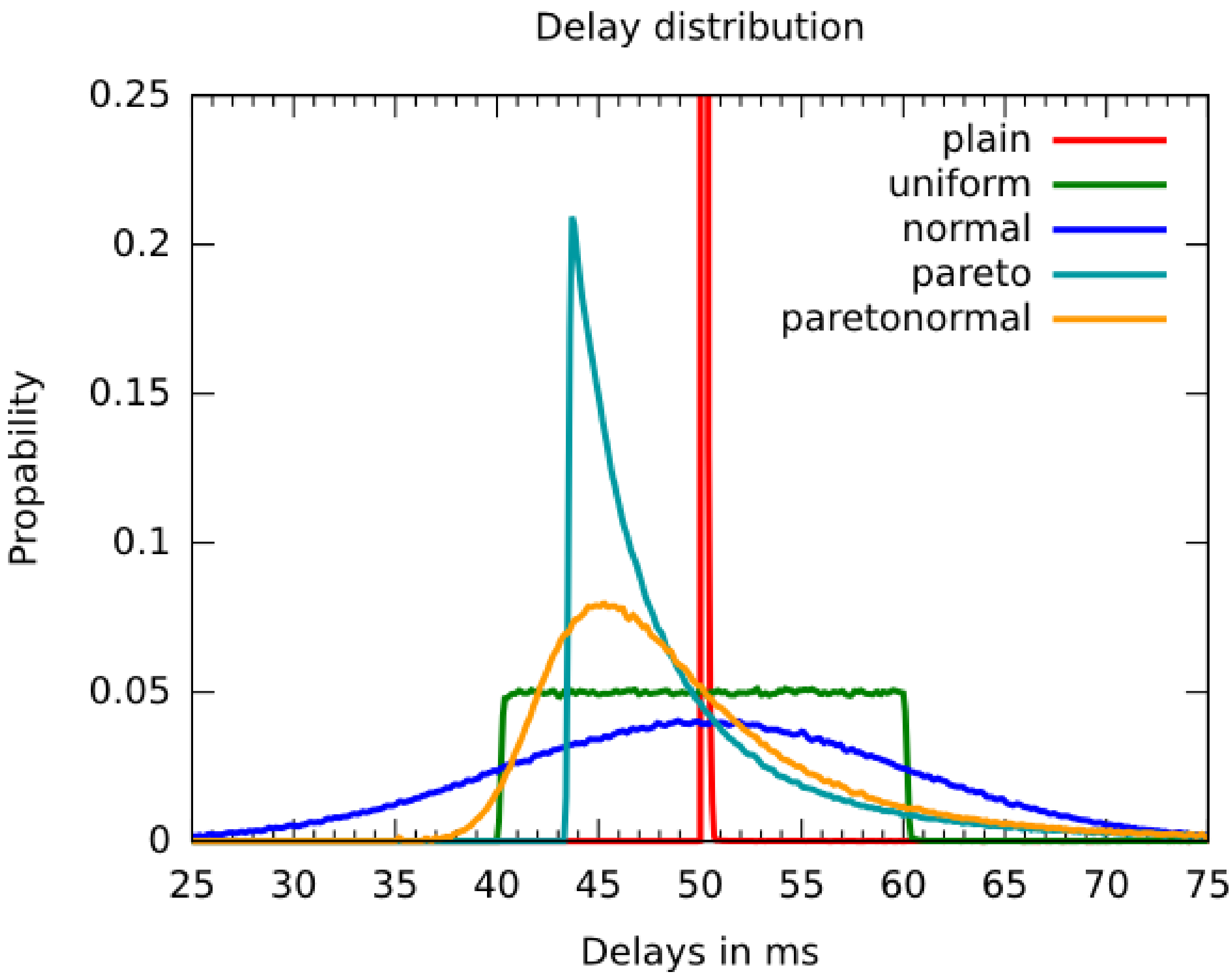


Fig. 2.1: Different delay distributions with delay=50ms and jitter=10ms

Packet loss

Packet loss in ToMaTo in applied as a per-packet probability. This means that for a 20% loss ratio there is no guarantee that one of 5 packets gets lost or that at most one of two packets gets lost. It might take a lot of packets until the number of lost packages is somewhere near to 20%. Packet loss is configured in percent, thus 20% is represented as 20 (not 0.2).

Loss correlation

Packet loss can optionally be correlated. That means that the loss probability of a packet depends on the loss probability of the packet before. The loss correlation is configured in percent like the loss probability.

Packet duplication

If a packet duplication probability is configured, packets are duplicated with that probability. That means that an exact copy of the packet is constructed and send directly after it. Duplication will create one copy at maximum.

Note that since the packets first pass the duplication and then the rate limiting duplicated packets count twice on the bandwidth usage.

Packet corruption

If a packet corruption probability is configured, packets are corrupted with that probability. That means that a bit at a random position in the packet is flipped. Corruption will flip at most one bit in a packet.

Note that in most cases checksums of the underlying layers prevent corrupted packets to be seen on higher layers.

Physical link statistics

As said before, the link emulation applies additionally to the existing conditions on the underlying links. To set up an experiment it is important to estimate these conditions. ToMaTo supports this by running periodic checks to measure delay and packet loss between all sites. The averages of these measurements can be viewed in the web-frontend in the admin section (accessible by all users).

Other link emulation possibilities

If you need more that the built-in link emulation of ToMaTo you can use a KVM machine as the center of the network and add a link emulation software with your emulation rules.

Another way to do link emulation in ToMaTo is to use an entity outside ToMaTo (on a physical host) to do the link emulation and to get access to it via external network connectors.

Packet Capturing

Packet capturing can help to trace packages through the network and analyze communication streams.

ToMaTo capabilities

ToMaTo supports capturing of packets on connections on Tinc-based connectors. The capturing can be enabled in the graphical editor in the properties panels of the connections. The captured packets are saved to a rotating set of files holding at most 50 MB of data. The capture files can be downloaded by clicking the “download capture” button in the control panel of the connection.

The timestamp in the capture files do not exactly correspond with the time of sending the packet in the virtual machine since the scheduling might introduce a delay. However the timestamp is guaranteed to be between the time of sending and the time of the forwarding to the connection.

Also note that timestamps from different hosts might have a certain offset, depending on how good the clocks of the hosts are synchronized. In the German-Lab testbed currently no actions are taken to synchronize the clocks among the hosts.

Analysis programs

ToMaTo generates capture files in the pcap format. When downloaded from the hosts multiple capture files are packed into a tar.gz archive.

The capture files created by ToMaTo can be used by a lot different programs:

- Wireshark - a graphical pcap explorer an analysis tool
- Cloudshark - a web-based pcp explorer with a similar UI to Wireshark
- tcpreplay - a Linux tool to replay pcap files

Device Templates

Template distribution

The device templates are distributed using the bittorrent protocol. This way the templates can be distributed among the hosts without a noteworthy central component.

For the bittorrent disctribution the backend and all hosts run a bittorrent client that automatically downloads and uploads the contents of torrent files in a certain directory. The backend also runs a so called bittorrent tracker, i.e. a central registry for the bittrorrent protocol that keeps track of all available peers for a torrent file.

The backend periodically checks that all templates are known to all hosts and are up-to-date. Otherwise the backend will create resource entries for the missing templates containing the torrent information. Since the torrent information has a size of several KiB (depending on the content size) the host will include an MD5 hash in its information and the backend will only update the torrent information when it does not match the hash.

The host will periodically check the file size of the templates and compare them to the information given in the torrent file to determine if the download has finished.

Template setup

To make them easier for users, templates should follow some common priciples.

1. Templates should be **secure by default**. This means that by default templates should only run services that are essential to the function of the template. For Linux templates that means that the SSH server will be deactivated by default and has to be activated manually by the user.
2. Templates should **only contain needed modifications**. This means that a template should match the default version of the operating system except where adaptations are needed. This should help users that are already familiar with the operating system to use a template of that OS.
3. Templates should **be as small as possible**. This means that templates will be compressed to save space and only include useful software. For some operating systems this might mean to remove some drivers and software that will never be used, to save space.
4. Templates should be **international but work in Germany**. The language for all templates should be set to american english but the keyboard layout should be set to german.

5. Templates should be **self-explaining and helpful**. That means that templates should contain some documentation on their special features and how to use them.
6. Templates should **not assume internet access**. Without internet access the templates should still work unless they explicitly require an external service in the internet.
7. Templates should **use DHCP**. All existing interfaces should be configured using DHCP. Hostname, DNS and time servers should also be used if included in the DHCP offer.
8. Templates should **require no login for local users and use a default password**. This means that local users (via VNC) should be loggen in directly without entering a username or password. If a password is needed for some actions, the password should be the same for all templates. Note that templates still must be secured against the network and require passwords for non-local login.
9. Templates should **include useful tools**. Not all devices will have internet access so templates should already include the most useful tools that users want installed. There is a clear trade-off between keeping a template small and including useful tools.
10. Templates should be **updated regularely**. This is important in two cases:
    (a) If the device has internet access, it is important that the template is up-to-date so that is initially secure. After device preparation, the user will have the responsibility to keep the system updated but it should be secure to start with.
    (b) If the device does not have internet access, it is important that the template is not outdated because the user can not easily update it.

Template generation

Scripts that can help to create and clean up templates can be found in the repository in the directory `contrib`. The scripts `create_kvm_template.sh` and `create_openvz_template.sh` can be used to create templates for debian-based systems in a semi-automatic way. The script `prepare_vm.sh` can be used to adapt a running system to be a proper template.

Torrent creation

Torrent files for templates can be created using the command

```
btmakemetafile TRACKERURL FILENAME
```

where TRACKERURL is the URL of the tracker and FILENAME is the name of the template file. The result will be a torrent file, that is named like the template file with `.torrent` appended.

Note: The ToMaTo backend includes a tracker that can be used for template torrents. Its URL can be determined by the backend API call `backend.tomato.api.host.server_info()`.

Accounting data types

Usage record

A *usage record* represents a data set with usage statistics of a certain time range. Each usage record has the following fields:

type: The *type* of a usage record describes the time frame which the record covers. Possible values are `single` for a single measurement, `5minutes`, `hour`, `day`, `month` and `year` for aggregated values.

begin and end: The fields *begin* and *end* describe the covered time of the measurement. For a *single* measurement these fields specify the begin and the end of the measurement execution for this single data point. For all other record types these fields specify the time frame of aggregated measurements. Both fields are timestamps in the form if seconds since the epoch (1970-01-01 00:00:00).

measurements: The field *measurements* contains the number of single data points that are combined in the record. This field is `1` for all *single* records and contains the number of aggregated single records for all other types.

usage: This field describes the resource usage during the given time period. For *single* records this time period is the period between the measurement and the last single measurement. For all other types, the time period is the combined time period of the aggregated *single* records. The field *usage* is a dict containing the following fields:

cputime: This field contains the used CPU time in seconds as a float value. CPU time is automatically measured by the operating system, so the measurement results do not depend in measurement timing. Even bigger gaps in measurement do not cause inaccurate values. Note that CPU time is calculated per core, so it is possible to consume several seconds of CPU time during one second.

memory: This field contains the used memory (RAM) in bytes. Memory consumption is measured on certain measurement points and the different data points are averaged into aggregated values.

diskspace: This field contains the used disk space in bytes. The measurement is similar to that of the *memory* field.

traffic: This field contains the traffic volume in bytes. Like *cputime*, traffic is automatically measured by the operating system and the values are very accurate because of this.

Note that because of different nature of the resources *cputime* and *traffic* are summed up during aggregation while *memory* and *diskspace* are averaged.

Usage statistics

The usage statistics data structure contains a set of *usage records*. Usage statistics objects are dict structures that contain the *types* of the usage records as keys and a list of usage records with that type as value.

Example


```
{
  "5minutes": [],
  "hour": [],
  "month": [],
  "single": [
    {
      "usage": {
        "traffic": 0.0,
        "cputime": 0.0,
        "diskspace": 19285.0,
        "memory": 0.0
      },
      "type": "single",
      "begin": 1351241166.88561,
      "measurements": 1,
      "end": 1351241166.89418
    },
    {
```

```
      "usage": {
        "traffic": 0.0,
        "cputime": 0.0,
        "diskspace": 19285.0,
        "memory": 0.0
      },
      "type": "single",
      "begin": 1351241106.80326,
      "measurements": 1,
      "end": 1351241106.81239
    },
    {
      "usage": {
        "traffic": 0.0,
        "cputime": 0.0,
        "diskspace": 19285.0,
        "memory": 0.0
      },
      "type": "single",
      "begin": 1351241226.93197,
      "measurements": 1,
      "end": 1351241226.94053
    },
    {
      "usage": {
        "traffic": 0.0,
        "cputime": 0.0,
        "diskspace": 19285.0,
        "memory": 0.0
      },
      "type": "single",
      "begin": 1351241286.97878,
      "measurements": 1,
      "end": 1351241286.98769
    }
  ],
  "year": [],
  "day": []
}
```


Repy

Repy is a turing-complete subset of Python that allows to run in a sandboxed environment.

Python and Repy

The Python programming language is documented at docs.python.org/reference. Repy is a reduced version of the Python programming language that allows to run scripts in a sandboxed environment. Repy is part of the Seattle Testbed and has an extensive documentation in the Seattle Wiki.

Difference between Repy and Python

- No imports, no external libraries. The `import` statement is forbidden in Repy. Some functionality from Python libraries is made available via special identifiers. (see below)
- No `global` variables. Instead Repy has a dictionary `mycontext` that can be used to store global variables.
- No user input via `input` or `raw_input`.
- **Some Python builtins are not available. The most important are**
  - `print`
  - `eval` and `execfile`
  - `lambda`
  - `reload`
  - `reversed` and `sorted`
  - `staticmethod`
  - `super`
  - `unicode`
  - `yield`
  - `hasattr`, `getattr` and `setattr`
- Parameters are passed as `callargs` instead of `sys.argv` and start with index 0 instead of 1 (`sys.argv[0]` is the script itself).

Methods available to Repy scripts

Output methods

echo(*message*)
will print the message (followed by a newline) to the console.

print_exc(*exception*)
will print an exception and a stack trace to the console.

Threading/Locking methods

createlock()

getthreadname()

createthread()

Misc. methods

exitall()

sleep(*time*)

randombytes()

getruntime()

getlasterror()

Networking methods

tuntap_read(*dev*, *timeout=None*)
will read one packet from the given network device *dev* and return this packet as a byte string. The method will block until a packet arrives at the device but at most *timeout* seconds (forever if *timeout=None*). If no packet has been received before the timeout, *None* will be returned. It is an error if the device does not exist.

tuntap_read_any(*timeout=None*)
will read one packet from any network device and return it. The return value will be a tuple *(dev, packet)* of the incoming device and the packet as a byte string. The first packet that arrives at a network device will be returned. The method will block until a packet arrives at a device but at most *timeout* seconds (forever if *timeout=None*). If no packet has been received before the timeout, *(None, None)* will be returned. It is an error to call this method if no network devices exist.

tuntap_send(*dev*, *data*)
will send the packet *data* via the network device *dev*. The packet must be a byte string. It is an error if the device does not exist.

tuntap_list()
will return a list of all available network devices.

tuntap_info(*dev*)
will return a dictionary containing detailed information about the networking device *dev*.

Struct

The struct library is available via *struct* (no import needed). This library can be used to encode and decode binary data structures.

ToMaTo library

The tomato library contains implementations of protocols and nodes. This library is extensible, so please feel free to contribute.

Databases

The ToMaTo backend needs a database to store information about hosts, topologies and users. The choice of this database is important for the performance of the ToMaTo backend.

ToMaTo uses Django as a database backend so the Django database documentation applies to ToMaTo as well.

SQLite

Note that SQLite lacks some features of real databases and thus is not suitable for running or developing ToMaTo.

PostgreSQL

PostgreSQL is the database that is used in the German-Lab installation. It is a full-featured database with good performance.

Raising the connection limit

The default database connection limit of PostgreSQL is set to 100 which can be reached by ToMaTo if several users are running a lot tasks in parallel. In the config file `postgresql.conf` the value `max_connections` can be raised to allow more concurrent connections. If the postgres server then hits the shared memory limit, the sysctl value `kernel.shmmax` needs to be increased. (See the PostgreSQl documentation for more details.)

Exporting and importing the ToMaTo data

The `manage.py` script that comes with the ToMaTo backend can be used to dump and load the database contents in a generic database-agnostic format. These commands might only work when run as user `tomato`, so `sudo -u tomato ./manage.py ...`. Also note that the commands only work when the database is up-to-date with the current layout in the code. (See migration for details)

Dumping the database

The following command dumps the database to a file named `dump.json` in the current directory:

```
$ ./manage.py dumpdata tomato south > dump.json
```

Loading the data into the database

The following command load a dump from a file named `dump.json` into the database. (Note that the file extension must be skipped in this command)

```
$ ./manage.py loaddata dump
```

Database migrations

As the database layout of ToMaTo changes, the database must be migrated to the new layout. ToMaTo automatically migrates old database schemas to the newest one. (Backups should still be made before the migration.)

Glossary

API API is short for "Application programming interface". Both the *backend* and the *hostmanager* provide APIs with which they can be used.

Backend The backend is one of the parts of ToMaTo. It is the central part that manages all *resources*, *hosts*, *topologies* and users. In a ToMaTo-setup the backend is the only part that can only exist once. The backend uses the capabilities of one or more *hosts* to offer *topologies* to its users through one or more *frontends*.

CLI The command-line interface is a simple way to control both the *backend* and the *hostmanager*. It is one of the *frontends*.

Component A component is either an *element* or a *connection*.

Connection A connection is a relation between exactly two *elements*. The connnection can have attributes of its own.

Connector This is a term from an older version of ToMaTo. Connectors are *elements* that are network elements.

Device This is a term from an older version of ToMaTo. A device is an *element* that is a virtual machine.

Dict Dicts are key-value mappings in the python programming language. In a dict, each key has a value assigned to it. When used in an *API*, the keys are limited to strings and the keys are limited to serializable objects (numbers, strings, booleans, None, lists, dicts).

Element An element refers to virtual objects that the user can control. This includes end systems like virtual machine and scripts as well as networking components like switches, hubs or routers. Each element can have several attributes and child elements (VMs have network interfaces as child elements) and one *connection*.

Entity An entity is a very general term for something that is controlled by either the *hostmanager* or the *backend*. This includes *elements*, *connections*, *topologies*, *users*, *resources* and much more.

Frontend ToMaTo frontends are a part of ToMaTo. Frontends connect to the *backend* and give users access to its capabilties by using the *backend API* and the users credentials. Several frontends exist (e.g. web-frontend and CLI) and can access a *backend* in parallel.

Host A host is a physical machine (computer or server) that hosts parts of *topologies*. Each host is managed by one *host manager*.

Host manager (or Hostmanager) The host manager is one of the parts of ToMaTo. It has exclusive control over one *host* and offers its capabilities to one or more *backends*.

KVM KVM devices are heavy-weight virtual machines that emulate a whole computer with generic hardware. Most things that are possible on physical computers is also possible on KVM. Most operating systems run on KVM.

OpenVZ OpenVZ devices are light-weight virtual machines that translate kernel calls to kernel calls of the host kernel. OpenVZ offers complete usermode access to the virtual machines and a limited kernel-mode access.

Profile Profiles define the resource boundaries for virtual machine *elements*. Depending on the VM technology, profiles define different attributes like RAM limit, disk space and number of CPUs.

Repy Programmable devices are essentially scripts that can work with networking packages. These scripts can be written in a Python dialect called Repy and can read and write raw Ethernet packets to/from their network interfaces. Programmable devices are very light-weight as they are just small Python scripts.

Resource Resources are a generic *entity* type for things that are present at *hosts* and can be used by *elements*. This includes *templates*, external networks but also available port numbers.

Template Templates are pre-installed disk images for virtual machine *elements*. Depending on the VM technology different templates with different operating systems and software exist. For *Repy* the template is the actual script that should be executed.

Topology A topology is a virtual network containing topology *components* (i.e. *elements* and *connections*). For the user, a topology is a virtual world where he can run his experiment.

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```

Frontend

Server code

The frontend code except the graphical topology builder applet is owned by University of Kaiserslautern on behalf of the German-Lab project and licensed under the GNU Affero GPL version 3.

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Icons

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Obtaining the code

All the code can be obtained via git from:

```
git://github.com/dswd/ToMaTo.git
```

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```
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- Accounts & Providers
- Logging

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- Installation
- Configuration
- Permissions

Hostmanager

- **API**
  - Connections

Frontends

CLI

- Usage
- Parameters
- Examples

Webfrontend

- Installation
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