# TOTEM 2.3 - User Guide


**Project Title** : **TOTEM : TOolbox for Traffic Engineering Methods**
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**Abstract** : The TOTEM 2.3 toolbox provides a framework where researchers can integrate their traffic engineering algorithms. These algorithms can therefore be applied on models of real networks. The TOTEM toolbox also gives network operators the opportunity to experiment the currently developed traffic engineering algorithms on their own network. Today, the TOTEM toolbox already federates a large set of traffic engineering algorithms published in the scientific literature.
**Website** : http://totem.run.montefiore.ulg.ac.be

# Contents

# 1 Introduction

Today the usual way of providing a suitable level of service in an enterprise intranet or an Internet Service Provider is to overprovision the network with respect to the real needs. With the increase in bandwidth demand, this approach is less and less tenable economically. An alternative way is to deploy traffic engineering techniques. However, most of the problems that are encountered in this field are combinatorial and of large size, which implies to find efficient and near optimal heuristics.

We would like to set up an open source toolbox of traffic engineering methods called TOTEM[1] that would federate many independent software pieces. The resulting toolbox is expected to include more functionality than existing commercial ones, and is clearly designed to be open, i.e. incrementally extensible.

This guide presents how to use the TOTEM toolbox and what is needed to know in order to deal with it. The traffic engineering methods can be classified along several axes: intra-domain versus inter-domain, IP versus (G)MPLS, on-line versus off-line, or centralized versus distributed. They are suitable for network optimization, better routing of traffic for providing QoS, load balancing, protection and restoration in case of failure, etc.

The design of the toolbox also considers different possible use cases. For example, it can be deployed as an on-line centralized tool in an operational network, or used off-line as an optimization tool or as a traffic engineering simulator. Section 2 describes how to easily install and compile the toolbox. Sections 3 and 4 describe the XML format that can be used to represent a network topology and a traffic matrix respectively. Section 5 describes how to use Diffserv in the toolbox. Section 6 describes the tools designed to use the toolbox in a real network environment. Section 7 presents the algorithms that are already included in the toolbox. Section 8 presents how to use the toolbox without having to write Java code (the scenario XML interface). Section 9 describes the functionnalities of the GUI and how to use it. Section 10 describes how to use the toolbox to generate Traffic Matrix files from netflow data.

[1] About the TOTEM project : `http://totem.info.ucl.ac.be`

# 2 Getting started...

The toolbox comes in two archives : a binary one with a precompiled toolbox and a source one with all the Java sources. These archives contain the following directories :

- `dist` contains the executable JAR (Java Archive File) `totem-<version>.jar` (only for binary package)
- `documentation` contains this UserGuide
- `example` contains examples of topology, traffic matrix and scenario
- `licence` contains the licence of the third libraries
- `lib` contains the libraries needed to compile and execute the toolbox
- `src` contains the source code (only for source package)

Currently, the toolbox has been tested only on linux platforms.

## 2.1 Installation

To use the toolbox, you need a Java Virtual Machine [2] (J2SE 5.0 or newer). If you haven't a Java Virtual machine you have to download and install it. Don't forget to set the JAVA_HOME environment variable to your JVM installation directory.

Decompress the TOTEM archive with

```
tar -xzvf totem-<version>.tar.gz
```

With the binary archive, the installation is finished. You can go to section 2.3 to briefly see how to use the toolbox. With the source release, you need to compile the toolbox as described in the next section.

## 2.2 Compilation

The source archive contains all the Java source files and you need to compile them before running the toolbox. To compile the toolbox, we need Ant [3] (release 1.6.2 or newer) provided by the Apache project. Ant is a Java-based build tool. It is kind of tool like Make. If you haven't Ant installed, download and install it. Don't forget to set the ANT_HOME environment variable.

The Ant build file (`build.xml`) contains the following interesting targets :

- `build` builds the TOTEM project
- `clean` cleans the project and prepares the directory
- `doc` generates the javadoc in `doc` directory

[2] http://java.sun.com/j2se/1.5/
[3] http://ant.apache.org/bindownload.cgi

By using :

```
ant clean build
```

You compile and build the whole toolbox in the `dist/totem-<version>.jar` file. If you compile for the first time the toolbox, you need to call `ant clean` to create the needed directories. More information can be found in the README file.

## 2.3 The "totem.sh" command

This shell script runs the toolbox setting the maximum heap size to 512Mb. The following options are available to the command line. If no option is set, the GUI will be launched (see section 9).

`-demo`. Launch the GUI with increased font size (so that it can be projected for a live demo).

`-s <scenario.xml>`. Executes the scenario `scenario.xml` (see section 8 for more information about scenarios). In the `example` directory, you can see some scenarios examples highlighting the main functionalities of the toolbox [4].

`-validate <file.xml> <schemaLocation>`. Validates the XML file `file.xml`. `schemaLocation` is optional (if not present, the validator uses the schema specified in the XML file).

`-gs <type> -f <scen.xml> -d <domain.xml> -t <tm.xml> -m <method>`. Generates a scenario XML file `scen.xml` using the XML domain file `domain.xml` and the XML traffic matrix file `tm.xml`. The generated scenario depends on `type` which can be `wca` or `fullmesh`. `wca` generates a scenario which simulates the failure of each link and displays the resulting load. `fullmesh` generates a scenario which establishes a full mesh of LSPs. The method used to route the traffic is given by `method` which can be `CSPF`, `CSPFInvFreeBw`, `CSPFHopCount`, `CSPFInvCap`, `CSPFTEMetric` and `DAMOTE`.

For example, the following command line

```
./totem.sh -s examples/abilene/scenario/CSPF-fullmesh.xml
```

execute the scenario file *CSPF-fullmesh.xml* of the directory *examples/abilene/scenario*. This scenario computes an LSP between each nodes with a reservation corresponding to the demand given by TM0-abilene.xml using CSPF. At the end, it displays the bandwidth reservation on each links. This scenario has been generated using `./totem.sh -gs fullmesh`.

[4] You can find more example files on the toolbox web page (`http://totem.run.montefiore.ulg.ac.be/`).

# 3 A standard XML format for a network topology representation

In this section, we will explain the XML format we defined to represent network topology information. We have chosen the XML language because it is widely used and many tools exist for dealing with this language. We have created an XML Schema[1] [5]. The schema allows us to validate a domain file so that we are sure that an XML instance satisfies the data structure we have defined.

## 3.1 Description of the XML network representation format

The root element of the XML file is the `domain` element. It contains five sub-elements: `info`, `topology`, `mpls`, `igp` and `bgp`. The `topology` and the `info` elements are mandatory. In this document, by default, all the elements and attributes are optional except when the contrary is specified. We decided to separate the information into sections for a clarity and ease of use reason. So, for example, if an algorithm only needs topology and igp information, it may just not care about the mpls and the bgp section... The `domain` element has two attributes : a `name` (string) and an `ASID` (integer). The `ASID` attribute is mandatory.

The `info` element contains all the extra information about the topology, including the units in use. The `topology` element contains all the information about the topology seen at the network layer (IP level). So it is a set of nodes and links. The `mpls` element is composed of a list of `lsp` elements. The `igp` element contains all the information of the intra-domain routing protocol. And finally, the `bgp` element contains all the information of the inter-domain routing protocol.

```
<domain name="domain_test" ASID="1234">
    <info>
        ...
    </info>
    <topology>
        ...
    </topology>
    <mpls>
        ...
    </mpls>
    <igp>
        ...
    </igp>
    <bgp>
        ...
    </bgp>
</domain>
```

Table 1: Example of the XML DOMAIN element usage.

### 3.1.1 The info element

The `info` element contains all the extra information about the topology. It contains the following sub-elements : `title` (string), `date` (date), `author` (string) and `description` (a string).

[5] http://totem.run.montefiore.ulg.ac.be/Schema/Domain-v1_2.xsd

It contains also a `units` element which is used to specify the units of the values found in the document. The `units` element is a list of `unit` sub- elements. One `unit` element only has two mandatory attributes : `type` (which can be either `delay` or `bandwidth`) and `value` (which can be `ns`, $\mu$`s`, `ms`, `s` for the delay values and `bps`, `kbps`, `mbps`, `gbps` or `tbps` for the bandwidth values). The `units` element is mandatory and must contain two `unit` sub-elements, one for bandwidth and the other for delay. The `info` element also contains a `diff-serv` element that contains the Diffserv information, which is the correspondance between the pairs (Classes Types, Preemption level) and the priority levels. Formally, the `diff-serv` element is a list of `priority` elements (minimum 1 and maximum 8 `priority` elements) which are composed of three mandatory attributes : an `id` (the identifier of the priority, i.e. an integer in the interval [0,7]), a `ct` (the identifier of the corresponding class type, i.e. an integer in the interval [0,7]) and a `preemption` (the corresponding preemption level, i.e. an integer in the interval [0,7]). The last sub-element of the `info` element is the `srlgs` element which is a list of `srlg` elements (at least one). A `srlg` element is a string (the information about the physical origin of the Shared Risk Link Group) and has one mandatory `id` attribute which is an integer).

```
<info>
    <title>This is the title of the topology</title>
    <date>2005-02-16</date>
    <author>University of Liï£¡e</author>
    <description>
        The description of this domain
    </description>
    <units>
        <unit type="delay" value="ms"/>
        <unit type="bandwidth" value="kbps"/>
    </units>
    <diff-serv>
        <priority id="0" ct="0" preemption="0"/>
        <priority id="1" ct="0" preemption="1"/>
        <priority id="2" ct="1" preemption="0"/>
        <priority id="3" ct="1" preemption="1"/>
    </diff-serv>
    <srlgs>
        <srlg id="241">information about this SRLG</srlg>
    </srlgs>
</info>
```

Table 2: Example of the XML INFO element usage.

### 3.1.2 The topology element

The `topology` element contains all the information about the topology seen at the network layer (IP level). So it is a set of nodes and links.

The `topology` element is composed of two sub-elements : `nodes` (which is mandatory) and `links`.

One `nodes` element is a list of `node` elements (at least one). Each `node` element contains one mandatory attribute : `id` which is an unique identifier (string). The `node` element contains the following sub-elements : `status` which can be `UP` or `DOWN` (`UP` by default), `rid` (IP

address), `description` (string), `type` which can be `CORE` or `EDGE`, `location` (which contains two mandatory float attributes : `latitude` and `longitude`) and finally an `interfaces` element which is a list of `interface` elements (at least one). An `interface` element has one mandatory `id` attribute (string which is (locally) unique). An `interface` element contains the following sub-elements : `status` which can be `UP` or `DOWN` (`UP` by default), `ip` which is an IP address and has a mandatory `mask` attribute (IP mask of the form X.X.X.X/Y, Y is in [0, 32])

One `links` element is a list of `link` elements (at least one). Each `link` element contains one mandatory attribute : `id` which is a unique identifier (string). A link joins two nodes and more precisely, two interfaces on two nodes. So a link must have `from` and `to` sub-elements which point respectively to the source interface and to the destination interface. A `from` element has two attributes : `node` (string, the identifier of the source node) which is mandatory and `if` (string, the identifier of the interface on the source node). A `to` element has three attributes : `as` (integer, the AS number of the destination node, which is used for inter-domain links), `node` (string, the identifier of the destination node) which is mandatory and `if` (string, the identifier of the interface on the destination node). A `link` element can also contain the following sub-elements : `status` which can be `UP` or `DOWN` (`UP` by default), `description` (string), `type` which can be `INTRA`, `ACCESS`, `PEERING` or `INTER`, `bw` which is the bandwidth of the link (float), `technology` (string), `delay` which is the delay of the link (float) and `srlgs` which is a list of `srlg` elements. An `srlg` element is an integer (the identifier of the SRLG the link belong to).

```
<topology>
    <nodes>
        <node id="router1.foo.net">
            <rid>10.0.0.1</rid>
            <interfaces>
                <interface id="10.0.2.0/30">
                    <ip mask="10.0.2.0/30">10.0.2.1</ip>
                </interface>
            </interfaces>
        </node>
        ...
    </nodes>
    <links>
        <link id="1 -> 2">
            <from if="10.0.2.0/30" node="10.0.0.1"/>
            <to if="10.0.2.0/30" node="10.0.0.2"/>
        </link>
        ...
    </links>
</topology>
```

Table 3: Example of the XML TOPOLOGY element usage.

### 3.1.3 The mpls element

The `mpls` element is composed of a list of `lsp` elements (at least one). An `lsp` element is composed of the following sub-elements : `path` (which is mandatory), `bw` which is the bandwidth demand of the LSP (float), `metric` which is the metric of the LSP (a float), `max_rate` which

is the maximal bandwidth rate of the LSP (a float), `diff-serv` and `backup`. An `lsp` element also has a mandatory attribute `id` which is the identifier of the LSP (a string).

A `path` element is a list of at least one `link` sub-element which is the identifier of a link (string).

A `diff-serv` element contains the following mandatory sub-elements : `ct` (the identifier of the corresponding class type, i.e. an integer in the interval [0,7]) and `preemption` which has two mandatory attributes : `setup` and `holding` which are the setup and holding preemption levels, i.e. an integer in the interval [0,7].

The `backup` element must be present if the LSP is a backup LSP. This element has one mandatory attribute `type`, a string that can be `DETOUR_LOCAL` (for a local detour LSP), `DETOUR_E2E` (for an end-to-end detour LSP) or `BYPASS` (for a local bypass LSP). The `backup` element has the following sub-elements : `protected_lsp` (string) which contains the identifier of the protected lsp (in case of detour LSP) and `protected_links` which is mandatory and is composed of a list of `protected_link` elements (at least one). A `protected_link` element is a string which is the identifier of the link that is protected by the LSP. In case of local protection, the list should contain the protected link and in case of end-to-end protection, the list should contain all the links of the primary path.

```
<mpls>
    <lsp id="LSP1">
        <path>
            <link>1 -> 2</link>
            <link>2 -> 3</link>
        </path>
        <bw>155000</bw>
    </lsp>
    ...
</mpls>
```

Table 4: Example of the XML MPLS element usage.

### 3.1.4 The igp element

The `igp` element contains all the information of the intra-domain routing protocol. The `type` attribute specify the running routing protocol (string that can be ISIS or OSPF). The `igp` element contains a list of `link` elements (at least one). One `link` element contains all the link state information that is transmitted by the intra-domain routing protocol. The `id` attribute (mandatory) of the `link` element is a string that contains the identifier of the link to which the information is related. One `link` element contains two sub-elements : `static` and `dynamic`.

The `static` element contains the following sub-elements : `metric` (the IGP metric of the link, a float), `te-metric` (the Traffic-Engineering metric, also a float), `mrbw` (maximum reservable bandwidth, a float), `mbw` (maximum bandwidth, a float), `admingroup` (integer) and finally `diff-serv`. One `diff-serv` element contains the following sub-elements : `bcm` which is mandatory and contains the bandwidth constraint model, a string that can be either MAM (Maximum Allocation Model) or RDM (Russian Doll Model)[6], and a list of `bc` elements (at least one). One `bc` element contains a float (which is the value of the bandwidth constraint) and a mandatory

[6] this feature is not already supported by the toolbox.

attribute `id` (integer) which identifies to what the bandwidth constraint is related (in MAM, it is related to one Class Type).

The `dynamic` element contains one mandatory sub-element : `rbw` (for Reservable Band-Width). The `rbw` element is a list of between 1 and 8 (inclusive) `priority` elements. One `priority` element has one mandatory attribute `id` (which is an integer in the interval [0,7] and should correspond to a priority defined under the `diff-serv` element of the `info` element) and contains a float which is the reservable bandwidth associated with this priority.

The reservable bandwidth is *dynamic* in the sense that it can vary with the time (when a new LSP is established on the link, for example).

```
<igp type="IS-IS">
    <links>
        <link id="1 -> 2">
            <static>
                <metric>20050.0</metric>
                <te-metric>50.0</te-metric>
                <mrbw>2488320.0</mrbw>
                <mbw>2488320.0</mbw>
            </static>
            <dynamic>
                <rbw>
                    <priority id="0">2488320.0</priority>
                    <priority id="1">2488320.0</priority>
                    <priority id="2">2488320.0</priority>
                    <priority id="3">2488320.0</priority>
                </rbw>
            </dynamic>
        </link>
        ...
    </links>
</igp>
```

Table 5: Example of the XML IGP element usage.

### 3.1.5 The bgp element

The `bgp` element contains the information related to the inter-domain routing protocol, BGP. The `bgp` element is thus the place where nodes existing in the `topology` element will be defined as BGP routers. This is also the place one defines the BGP sessions between the BGP routers as well as the IP prefixes to be advertised outside the domain. An example of the XML BGP element usage is shown in Table 6.

Basically, the `bgp` element is a sequence of BGP router definitions. Each BGP router is encoded in a `router` element which is composed of many attributes. The `router` is identified by a mandatory `id` attribute whose value is a free-form string of characters. There is currently a single uniqueness constraint on the `id` attribute. That is there cannot exist two routers that share the same value of the `id` attribute.

In addition to this, the `router` element also has a mandatory `rid` attribute which represents the *router-ID*. This `rid` attribute is an IP address that identifies the BGP router in the BGP protocol. Usually, the *router-ID* is taken as the highest IP address of the router or as the loopback of the

```
<bgp>
    <routers>
        <router id="router1.foo.net">
            <rid>10.0.0.1</rid>
            <networks>
                <network prefix="10.0.1/24"/>
            </networks>
            <neighbors>
                <neighbor ip="10.0.0.2" as="666"/>
                <neighbor ip="10.0.0.3" as="666"/>
            </neighbors>
        </router>
        ...
    </routers>
</bgp>
```

Table 6: Example of the XML BGP element usage.

router. In the toolbox, we will assume that the value of the `rid` attribute corresponds to the `rid` of the corresponding `node` element in the `topology` section.

Then, comes the definition of the networks that this router will advertise through the BGP protocol. The networks are defined in a `networks` element which is a sequence of `network` elements. Each `network` element contains a single CIDR prefix. This CIDR prefix has the form of a dotted IP address followed by a slash ("/") followed by a mask length. The `networks` element is optional and can be omitted if no network is originated by this router. However, if a `networks` element is present, it cannot be empty. That is, it must contain at least a `network` element.

Finally, the `router` also contains a list of neighbors, i.e. a list of other BGP neighbors with which it has BGP sessions. The list of neighbors is defined with a `neighbors` element which is a sequence of `neighbor` elements. Each `neighbor` represents a single BGP neighbor and has several attributes. Two attributes are used to identify the neighbor: an IP address and an AS number. The IP address is specified using the `ip` element. It represents the *router-ID* of the neighbor router. The AS number is specified using the `as` element. It represents the AS number of the neighbor router. This AS number can be the same as the local router if both routers share an internal (iBGP) session or they are different if both routers share an external (eBGP) session.

The `neighbor` element also makes possible the definition of BGP filters. This part is however still in development and the form that will be given to these filters is not yet precisely defined.

## 3.2 Example

In table 7, we present an example of the very simple network of figure 1.

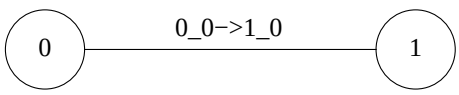



Figure 1: An example simple topology

```
<?xml version="1.0" encoding="UTF-8"?>
<domain ASID="1234">
    <info>
        <title>Test Topology</title>
        <date>2005-01-31</date>
        <author>RUN - University of Liege</author>
        <description>
            TOTEM Project (http://totem.info.ucl.ac.be/)
        </description>
        <units>
            <unit type="bandwidth" value="kbps"/>
            <unit type="delay" value="ms"/>
        </units>
    </info>
    <topology>
        <nodes>
            <node id="0">
                <location latitude="5" longitude="7"/>
                <interfaces>
                    <interface id="0">
                    </interface>
                </interfaces>
            </node>
            <node id="1">
                <location latitude="44" longitude="1"/>
                <interfaces>
                    <interface id="0">
                    </interface>
                </interfaces>
            </node>
        </nodes>
        <links>
            <link id="0_0->1_0">
                <from node="0" if="0"/>
                <to node="1" if="0"/>
                <bw>200000</bw>
                <delay>1.4</delay>
            </link>
        </links>
    </topology>
</domain>
```

Table 7: Example of an XML domain file.

# 4 A standard XML format for a traffic matrix representation

We have defined an XML format for intra and inter-domain traffic matrices.

- An intra-domain traffic matrix is associated with a domain, and represents the traffic in this domain. For example, the traffic matrix expresses the fact that there is traffic of $X$ Mbps between node $A$ and node $B$ (both nodes $A$ and $B$ belonging to the particular domain, the traffic enters the domain at node $A$ and exits the domain at node $B$).
- An inter-domain traffic matrix is also associated with a domain, but traffic is not defined as going from a node $A$ to a node $B$ inside the domain. Traffic is defined as arriving on a specific domain node and coming from a source prefix to a certain destination prefix. These informations are precious for inter-domain traffic engineering. If one wants to map such an inter-domain traffic matrix to the corresponding intra-domain traffic matrix, one already knows the node where the traffic enters, but one has to find the egress node for each destination prefix. It is possible for example to use the C-BGP simulator included in the toolbox.

We have created an XML Schema defining our XML traffic matrix representation format [7].

The root element is `TrafficMatrixFile` which is composed of two elements : `info` (optional) and either `intraTM` either `interTM` (choice, mandatory).

The `info` element is composed of the following sub-elements : `title` (`string`), `date` (`dateTime`), `duration` (`double`) expressed in minutes, `author` (`string`), `description` (`string`) and `units`. The `units` element is composed of one (and only one) sub-element `unit`. The `unit` element has two mandatory attributes : `type` (which is contrained to be `bandwidth`) and `value` which can be `bps`, `kbps`, `mbps`, `gbps` or `tbps`.

The `intraTM` element is composed of a list of `src` elements and has one mandatory `ASID` attribute (`int`). One `src` element has one mandatory `id` attribute (`string` which specifies to which source node the value is related to) and is composed of a list of `dst` elements. A `dst` element contains a non-negative `float` value (the traffic from the source node `src` to the destination node `dst`) and has one mandatory `id` attribute (`string` which identifies the destination node).

The `interTM` element is composed of a list of `node` elements and has one mandatory `ASID` attribute (`int`). One `node` element has one mandatory `id` attribute (`string` which identifies the node in the domain) and is composed of a list of `src` elements. A `src` element has one mandatory attribute `prefix` (which identifies the source prefix from where data is coming) and is composed of a list of `dst` elements. A `dst` element contains a non-negative `float` value (the bandwidth from the source prefix `src` to the destination prefix `dst`) and has one mandatory attribute `prefix` (which identifies the destination prefix where data is going to).

Here is an example of the XML `TrafficMatricFile` element usage (intra-domain traffic matrix) :

```
<TrafficMatrixFile>
    <info>
        <date>2004-10-14T01:03:00</date>
        <units>
            <unit type="bandwidth" value="kbps"/>
        </units>
    </info>
    <IntraTM ASID="1234">
        <src id="0">
```

[7] http://totem.run.montefiore.ulg.ac.be/Schema/TrafficMatrix-v1_2.xsd

```
            <dst id="1">37</dst>
            <dst id="2">23</dst>
            ...
        </src>
        <src id="1">
            <dst id="0">17</dst>
            <dst id="2">69</dst>
            ...
        </src>
        ...
    </IntraTM>
</TrafficMatrixFile>
```

Here is an example of the XML `TrafficMatricFile` element usage (inter-domain traffic matrix) :

```
<TrafficMatrixFile>
    <info>
        <date>2004-10-14T01:03:00</date>
        <units>
            <unit type="bandwidth" value="kbps"/>
        </units>
    </info>
    <InterTM ASID="1234">
        <node id="node1">
            <src prefix="131.130.0.0/16">
                <dst prefix="150.214.0.0/16">37</dst>
                <dst prefix="202.13.4.0/23">23</dst>
                ...
            </src>
        </node>
        ...
    </InterTM>
</TrafficMatrixFile>
```

# 5 Diffserv support

Diffserv [2] support is implemented into the toolbox. If you don't want to use Diffserv, you just have to avoid putting Diffserv fields in the different XML files, and to never use the Java methods which specify a priority level.

## 5.1 Current state of Diffserv support

We implemented basic Diffserv-aware TE support into the toolbox and in particular the MAM (*Maximum Allocation Model*) bandwidth constraints model [3]. Other bandwidth constraints models will perhaps be implemented in the future. We now give some brief explanations about MAM. If you would like to have more information, see [3]. Suppose we have a certain number of categories of services (called Class-Types or CTs) and the same number of associated bandwidth constraints (BCs). MAM states that

$$Reserved\_Bandwith(CT_c) \leq BC_c \quad (1)$$

What we call a priority level in this document is in fact a Traffic Engineering Class (TEC), i.e. a combination of a CT and a preemption priority allowed for that CT. During admission control on a link for a reservation at priority (TEC) $i$, all we have to check is that the unreserved bandwidth at priority $i$ (stored in the toolbox database) is larger than the bandwidth requested by this reservation. This unreserved bandwidth per priority level is the data that should be advertised in IGP link state packets.

We also implemented a basic preemption support inside CTs.

### 5.1.1 Conventions

It is always considered that a higher numerical value corresponds to less priority traffic, i.e. traffic from CT 0 should correspond to more important traffic than traffic from CT 1. And traffic with preemption level 0 has more priority than traffic with preemption level 1.

## 5.2 Default behaviour

We will explain here the behaviour you can expect from the Diffserv manager integrated into the toolbox when specifying some Diffserv fields in domain XML files.

### 5.2.1 No Diffserv fields in domain XML files

If you don't need Diffserv support, do not put any `diff-serv` fields into the `<info>` field of the domain XML file (see section 3.1.1). However note that the following information will be added automatically

```
<diff-serv>
       <priority id="0" ct="0" preemption="0"/>
</diff-serv>
```

under the `<info>` element.

Then, concerning links, the following information will be added in the `<static>` section (see section 3.1.4)

```
<diff-serv>
       <bcm>MAM</bcm>
       <bc id="0">bandwidth</bc>
</diff-serv>
```

where `bandwidth` is the total bandwidth of the link.

Some fields will also be automatically added in the `<dynamic>` section (see section 3.1.4)

```
<rbw>
       <priority id="0">bc_id_0</priority>
</rbw>
```

where `bc_id_0` is the value of the bandwidth constraint (bc) with id 0.

Thus the reservable bandwidth at the unique priority 0 is set the link bandwidth. This is the behaviour you expect when you don't want to use Diffserv.

### 5.2.2 Info field specified but static or dynamic information missing

Suppose now that you want to specify some priority levels but don't want to specify specific information for static and dynamic fields of all links. In this case, here is the default behaviour.

Suppose we specify the following information in the `<info>` field.

```
<diff-serv>
       <priority id="0" ct="0" preemption="0"/>
       <priority id="1" ct="0" preemption="1"/>
       <priority id="4" ct="1" preemption="0"/>
       <priority id="5" ct="1" preemption="1"/>
       <priority id="6" ct="1" preemption="2"/>
       <priority id="7" ct="1" preemption="3"/>
</diff-serv>
```

Thus we have 2 CTs: 2 accepted preemption levels for the first and 4 for the second.

If you do not specify Diffserv information in the static link fields, following information will be added in the `<static>` section of the link.

```
<diff-serv>
       <bcm>MAM</bcm>
       <bc id="0">bandwidth/2</bc>
       <bc id="1">bandwidth/2</bc>
</diff-serv>
```

One constraint is thus defined for each CT, and their value is equal to the maximum reservable bandwidth divided by the number of CTs.

Dynamic information is set accordingly.

```
<rbw>
       <priority id="0">bc_id_0</priority>
       <priority id="1">bc_id_0</priority>
       <priority id="4">bc_id_1</priority>
       <priority id="5">bc_id_1</priority>
       <priority id="6">bc_id_1</priority>
       <priority id="7">bc_id_1</priority>

</rbw>
```

Note that if you choose to specify some BC values for some links, dynamic information will also be set according to the values you specified.

### 5.2.3 Adding a reservation

Suppose you want to establish an LSP of priority $i$ (i.e. a couple of CT and preemption level) with reservation $b$. You have to check for each link in the path the unreserved bandwidth for this priority level is bigger than $b$. If it is, you can add this reservation. Now, you may want to not specify a priority (this parameter being often optional). In this case the considered priority level is the least priority existing one (i.e. least priority CT, and in this class type, lowest preemption level).

## 5.3 Preemptions

A basic preemption mechanism had been developed to allow preemption inside CTs. With this basic mechanism, preemption will never occur between CTs. In fact, preemption between CTs can be useful only if the following condition holds true, which is not of common use.

$$\sum_c BC_c > Max\_Reservable\_Bandwidth \quad (2)$$

Here is how the preemption mechanism works :

- Lowest preemption levels are looked first for LSPs to preempt.
- If only one LSP can be preempted at least preemption level to free enough bandwidth, it is preempted.
- If not, arbitrary LSPs of least preemption levels are preempted.

## 5.4 Bandwidth Sharing

When loading a domain, you can choose to use bandwidth sharing or not. If you choose so, bandwidth will be shared among LSPs that are not activated at the same time (primary-backup sharing and backup-backup sharing, see [4]). However, Diffserv is not compatible with bandwidth sharing. If you decide to use bandwidth sharing, only one class type must be defined in the domain or an exception will be thrown. Even if multiple preemption levels are defined in the class type, those levels will be ignored and preemption will never occur.

# 6 On-line tools

## 6.1 Socket Interface

### 6.1.1 Description

The TOTEM toolbox can execute events sent from a remote place through a socket interface. In this mode, the toolbox acts as a server and processes events coming from another machine on the network. Once a client is connected, it can send XML scenario events to the toolbox which executes them before returning a result.

For example the socket interface can be used online in a network for path computation : `LSPCreation` events are sent to the server which will respond by sending the computed path.

### 6.1.2 Message format

The messages that the clients should send consist of XML scenario events described in section 8. However it is important to note that for implementations reasons a single event sent through the socket interface must b written in only one text line.

Once the event has been executed by the toolbox, a response message is sent back to the client. The response message is also always transmitted in only one text line. It has the following format (shown here in multiple lines for readability):

```
<result>
    <command>
        ...
    </command>
    <output>
        <object>
            ...
        </object>
        <message>
            ...
        </message>
    </output>
    <status>
        ...
    </status>
    <exceptions>
        ...
    </exceptions>
</result>
```

The `command` element is a copy of the XML event sent by the client. The `output` element contains two subelements: `object` and `message`. These are respectively a representation of an object and a text message both related to the execution of the event. The text message is the same message that is written on standard output when the event is executed locally. For example, if a `LSPCreation` event is correctly executed, the object will be the XML representation of the new LSP and the message will be a string representation of the new LSP path followed by a list of preemped LSP ids. Note that both subelements are optional.

The `status` element can be either OK or FAILED depending on the success of the event execution. If the status is FAILED, the event was not correctly executed because of an exception.

The exception is then described in the `exceptions` element. In this case, it contains one (or more) subelement(s) of the following form:

```
<exception class="...">
    ...
</exception>
```

The class attribute correspond to the class of the exception and the content of the `exception` element is the message of the exception.

### 6.1.3 How to use it

The toolbox socket interface can be started either by means of a scenario event, either in the GUI. The corresponding scenario event is `ListenToLSPsDemands`. An example of a scenario that starts the server is `LSPComputationServer.xml` located in the `examples` directory of the root TOTEM folder.

To start the server from the GUI, click on the `Start server` item under the `Scenario` menu. The result of every event executed from the remote place will be visible in the GUI.

The toolbox is also shipped with a simple client. This client sends a complete scenario to a toolbox running the socket interface. It takes three mandatory command line arguments (host, port and filename) and one optional (delay). The client establishes a connection with the given host on the given port, reads the scenario given by its filename and sends it to the server one event at a time. If delay is also given, the client will wait a certain time between each event.

To build the client, use the specific ant task:

```
ant build-socketclient
```

The jar file containing the client is then located in `dist/socketclient.jar` under the TOTEM root folder. You can start the client by using the script `socketclient.sh`.

## 6.2 Loading a domain from network

### 6.2.1 Description

TOTEM can be feeded with a domain that comes from network. This feature was originally developed to allow network discovery tools to feed the toolbox with a real domain.

In this operational mode, TOTEM acts as a client and it connects to a topology server. Once the server is ready, it sends a topology to the toolbox. The topology is loaded as it is being received. Note that the domain must be in the TOTEM XML format (see section 3).

### 6.2.2 How to use it

A domain can be loaded from a remote place either by using the corresponding scenario event (`loadDistantDomain` event), either by using the GUI (use `"Load Topology from network"` under the `"File"` menu). In both cases, the server host and port should be provided. If no server is present at the given host and port, this will result in an execution error. If the server is present, the connection will be established and TOTEM will start waiting for the topology to be received.

A simple topology server is provided as an example. It is located in the class `TopologyServer` in the `be.ac.ulg.montefiore.run.totem.core` package. This server sends a given topology file to a TOTEM toolbox instance that connects to it. It has two mandatory arguments: the port on which to listen for new connections and the filename from which to read the topology.

To build the server, use the specific ant task:

```
ant build-toposerver
```

The jar file containing the server is then located in `dist/toposerver.jar` under the TOTEM root folder. You can start the server by using the script `toposerver.sh`.

# 7 Algorithms already present in the toolbox

## 7.1 Shortest Path First algorithm

The toolbox contains a flexible implementation of the SPF algorithm and its constrained extension CSPF. The implementation is very efficient and uses a priority queue to store the list of temporary visited nodes. For computing the path of a LSP with a given reservation, the CSPF skips links that do not meet the bandwidth requirement. The scenario section explains in more detail how to use the CSPF to compute a LSP with the toolbox. Differents metrics can be used by the CSPF:

- IGP metric given in the topology (called CSPF)
- IGP TE metric given in the topology (called CSPFTEMetric)
- the inverse of the link capacity (called CSPFInvCap)
- the inverse of the reservable bandwidth (called CSPFInvFreeBw)
- 1 for each link (called CSPFHopCount)

Each different CSPF method has a name (between parentheses) used by the scenario to identify which metric to use.

Note that the implementation allows the efficient computation of all the paths from a particular source to all the destinations or from all the sources to a particular destination.

The CSPF implementation is also able to compute backup paths. These calculated backup paths can be either local or global, link disjoint or node disjoint.

## 7.2 DAMOTE

We will first begin by introducing DAMOTE itself, and then see which additional parameters can be passed to corresponding scenario events to deal with the power of DAMOTE.

DAMOTE (*Decentralized Agent for MPLS Online Traffic Engineering*) provides two main basic functionalities:

- QoS-based routing of Diffserv LSPs (Label Switched Paths) under constraints.
- Local and global detour (backup) LSP routing for fast restoration

Let us review both of them.

The first main function of DAMOTE is to compute primary paths at ingress nodes, in a way similar to the classical CSPF (Constraint Shortest Path First). This means that all edge nodes will compute and set up the "best" path for any given LSP for which they are the ingress. This computation requires that ingress nodes have enough information about all link states in the network. This is usually achieved by using extensions of link-state routing protocols like OSPF-TE or ISIS-TE, which flood the network regularly with updated link-states.

Although similar in principle to CSPF, our scheme generalizes it in several ways. While CSPF is a simple SPF on a pruned topology, obtained by removing links that have not enough capacity to accept the new LSP, DAMOTE can perform much clever optimizations based on a network-wide score function. Examples of such functions are: load balancing, hybrid load balancing (where long detours are penalized), pre-emption-aware routing (where LSP reroutings are penalized).

DAMOTE is generic in the sense that this score function is a parameter of the algorithm. Like in CSPF, constraints can be taken into account, but here again the constraints can be parameterised quite freely. Typical constraints refer to the available bandwidth on links per class type (CT), or to pre-emption levels. For example, it is possible to specify that an LSP of a given CT can only be accepted on a link if there is enough unreserved bandwidth for this CT by counting only the resources reserved by LSPs at higher pre-emption levels. This allows us to pre-empt other LSPs if needed. In that case, DAMOTE can also calculate the "best" subset of LSPs to pre-empt.

DAMOTE can also compute local detour LSPs for fast rerouting. In our approach, each primary can be protected by a series of detour LSPs, each of them originating at the node immediately upstream of any given link on the primary path. Those detour LSPs thus protect the downstream node (if possible) or the downstream link and merges with the primary LSP anywhere between the protected resource (exclusive) and the egress node (inclusive). Those many LSPs have to be pre-established for fast rerouting in case of failure, and provisioned with bandwidth resource. In terms of bandwidth consumption, this scheme is only viable if detour LSPs are allowed to share bandwidth among themselves or with primary LSPs, which is what we have achieved. The main idea is that we assume that at most one link or node will fail at the same time in the network. Under this assumption, we can share bandwidth between LSP that will never be activated together.

We will now explain which additional parameters can be passed to corresponding scenario events to deal with the power of DAMOTE.

### 7.2.1 Starting DAMOTE

DAMOTE can be started using the `startAlgo` scenario event (see 8.8.3). If backup LSPs need to be calculated and bandwidth sharing is a desirable feature, the domain must be loaded with bandwidth sharing enabled (see `loadDomain` scenario event 8.2.5).

By default, DAMOTE is configured with a hybrid score function (load balancing with traffic minimization contribution). But DAMOTE can also use pure load balancing score function, delay-oriented score function, min-hop routing,... Let us review the available options.

#### Pure load balancing score function

DAMOTE can first be used with a pure load balancing score function, which is the following:

$$\sum_{(i,j)\in\mathcal{U}} \left( \frac{L_{(i,j)}}{\omega^{cap}(i,j)} - \overline{\frac{L}{\omega^{cap}}} \right)^2$$

$$with \quad \overline{\frac{L}{\omega^{cap}}} = \frac{1}{|\,\mathcal{U}\,|} \sum_{(i,j)\in\mathcal{U}} \frac{L_{(i,j)}}{\omega^{cap}(i,j)}$$

the mean of the relative link load throughout the network. This function is then the variance on the relative link load and, as such, represents the deviation from the optimal load balancing situation. In a perfectly balanced network, this deviation would be zero for all links so that all would be occupied in exactly the same proportions.

To use DAMOTE with a pure load balancing score function, you must set parameter “loadBal” to 1 and parameter “tMin” to 0 within the StartAlgo event.

#### Hybrid load balancing score function

The main problem with the load-balancing function presented above is that the only thing it tries to do is to flatten the relative load throughout the network. It will not matter if some of the paths go a long way around in order to achieve a better load-balancing. We must then try to limit the length of the paths chosen for the LSPs by adding a kind of "shortest path length" term to the objective function.

Our "traffic minimization" term is the sum of the square relative link loads,

$$\sum_{(i,j)\in\mathcal{U}} \left(\frac{L_{(i,j)}}{\omega^{cap}(i,j)}\right)^2$$

As a consequence, the compromise between load balancing and traffic minimization can be expressed as follows

$$loadBal * \sum_{(i,j)\in\mathcal{U}} \left(\frac{L_{(i,j)}}{\omega^{cap}(i,j)} - \overline{\frac{L}{\omega^{cap}}}\right)^2 + tMin * \sum_{(i,j)\in\mathcal{U}} \left(\frac{L_{(i,j)}}{\omega^{cap}(i,j)}\right)^2$$

The (weighted) combination of both terms will give more importance to the load-balancing term if the deviation is high enough to justify the detour, else it will let the "shortest path" term minimize the resources used.

By default, DAMOTE is configured with “loadBal” equals to 2 and “tMin” equals to 1. You can change freely these two parameters.

**Delay-oriented score function**

Another available objective function is an average delay objective function

$$\sum_{(i,j)\in\mathcal{U}} \frac{1}{\omega^{cap}(i,j) - L_{(i,j)}}$$

Since, for a packet size $P$, $\frac{P}{\omega^{cap}(i,j)-L_{(i,j)}}$ approximates the queuing and transmission delay on link $(i,j)$, optimizing this function will strive to minimize the average delay throughout the network. This will naturally lead to load-balance the network. Moreover, this objective has a built-in traffic minimization feature in the sense that long paths would degrade the average delay and are therefore discouraged.

To use this objective function, you must set “loadBal” to 0, “tMin” to 0 and “delay” to 1.

**Shortest-path score function**

Finally, if you want to use min-hop routing, you can set “loadBal” to 0, “tMin” to 0 and “load” to 1.

### 7.2.2 Computing a primary path with DAMOTE

An LSP can be computed with DAMOTE using the `LSPCreation` scenario event (see 8.3.6. When computing an LSP, you can pass an additional parameter to DAMOTE called `preempt` (boolean). This parameters tells DAMOTE whether it can preempt LSPs to establish the new one. In this case, DAMOTE returns a list of LSPs to preempt, and immediately deletes them from its own database. These LSPs are also removed from the toolbox database itself. Diffserv parameters can also be passed, but note that DAMOTE does not correctly support preemption when multiple categories of services (CTs) are used (to be fixed in the future). If you plan to use preemption,

please only specify one category of service and several preemption levels for this category of service.

**Additionnal note on preemption levels and categories of service**

The default library (lib/libdamote.so) included in the release supports up to eight preemption levels and eight class types. If speed is a main concern for you and if you are using DAMOTE in a single class type and single preemption level environnement, you should link libdamote.so to libdamote11.so (instead of libdamote88.so) in order to increase speed perforcalculatemance.

### 7.2.3 Computing backups paths with DAMOTE

Detour LSPs can be created with the scenario event `LSPBackupCreation`. DAMOTE supports end-to-end and local detour. Corresponding parameters can then be passed to the scenario event.

### 7.2.4 Restrictions

Inside TOTEM, as bandwidth sharing is not compatible with Diffserv (see section 5.4), DAMOTE cannot be used to calculate backup paths when multiple priority levels are used.

Moreover, DAMOTE should be used to calculate backups only when bandwidth sharing is enabled. Otherwise, DAMOTE may return a backup path for which bandwidth is shared with other lsps; so it is possible that there is not enough free bandwidth to establish this lsp in TOTEM (as bandwidth sharing does not occur). In fact, an exception will be thrown if you try to compute a backup path without bandwidth sharing enabled.

## 7.3 MIRA

This section describes how to use the MIRA implementation included in the toolbox. This algorithm can be used to compute LSPs between two nodes of the network. In that sense, the use of this algorithm is quite similar to the use of CSPF algorithm.

Two MIRA algorithms are integrated in the TOTEM Toolbox : NEWMIRA (described in [5]) and Simple MIRA (SMIRA, described in [6]). These algorithms are both based on the principle of Minimum Interference Routing. When you start the algorithm, it is needed to specify which algorithm you want to use. In order to specify which algorithm you want to use, you have to add a param XML element whose name is “version” and the value is either “NEWMIRA” or “SMIRA”. By default, SMIRA is used.

The MIRA algorithms make distinction between “EDGE” nodes and “CORE” nodes. “EDGE” nodes can be LSPs extremity while “CORE” nodes can only be intermediate nodes. If the node type is not set, the node is considered as “EDGE”. Report to section 3.1.2 to see how to define the node type in the topology file.

A example of scenario using MIRA can be found in
`examples/simpleDomain/Scenario/create_lsp_mira.xml`.

## 7.4 SAMCRA

This section describes how to use the SAMCRA implementation included in the toolbox. This algorithm can be used to compute LSPs between two nodes of the network. Once again, the use of this algorithm is quite similar to the use of CSPF algorithm.

SAMCRA is an exact multi-constrained shortest path algorithm that was originally proposed in [7] and later extended in [8]. The implementation of SAMCRA included in the toolbox is the one described in [8].

To use SAMCRA, you have first to start the algorithm (called `XAMCRA`) precising the QoS constraints you desire and the version of the algorithm (till now only SAMCRA is included, but we plan to integrate other algorithm of the X-AMCRA familly). Once started, you can compute a path using this algorithm precising the QoS constraint for the desired path. If one QoS constraint that was desired is not provided, we assume $\infty$ for this constraint (i.e. no constraint) and if one constraint is provided for a parameter that was not desired, it is discarded.

When starting the algorithm, you can use the following boolean parameters : `useDelay`, `useMetric` and `useTEMetric`. The bandwidth constraint is allways used. When routing a LSP using `LSPCreation` element, you can use the following routing parameters : `DelayConstraint`, `MetricConstraint` and `TEMetricConstraint` to specify corresponding constraints. The bandwidth constraint is included in the `addLSP` element.

You can find an example of scenario file using SAMCRA in
`examples/abilene/Scenario/XAMCRA-fullmesh.xml`.

### 7.5 optDivideTM

This algorithm consists of dividing the traffic matrix into $N$ sub-matrices, called strata, and route each of these independently. We can use two different implementations of this method in routers. The method can also be used to compute a very precise approximation of the optimal value of a given objective function for comparison to heuristic Traffic Engineering algorithms. For this application, the algorithm is very efficient on large topologies compared to an LP formulation.

More information about this algorithm can be found in paper [9].

You can find an example of scenario file using optDivideTM in
`examples/abilene/Scenario/optDivideTM.xml`.

### 7.6 CBGP

C-BGP is a BGP routing solver. It aims at computing the interdomain routes selected by BGP routers in a domain. The route computation relies on an accurate model of the BGP decision process [10] as well as several sources of input data. The model of the decision process takes into account every decision rule present in the genuine BGP decision process as well as the iBGP hierarchy (route-reflectors). More information on how C-BGP works can be obtained from the C-BGP web site [11].

The input data required by C-BGP includes intradomain and interdomain information. First, the knowledge of the interdomain routes learned through BGP from the neighbor domains is required. This information can be obtained from MRT [12] dumps collected on the genuine BGP routers or it can be introduced manually. The route computation also relies on the knowledge of the intradomain structure. Indeed, the BGP decision process relies at some point on the IGP weight of the interdomain paths from ingress to egress routers to perform its route selection. This is often related to as the hot-potato routing rule. For this purpose, C-BGP also contains a model of the intradomain routing relying on shortest-path computation. The intradomain structure knowledge is obtained from the TOTEM XML topology. Finally, C-BGP needs to be told what must be computed through a simulation scenario. See Section 8 for more information on the scenario events that are currently available in the TOTEM toolbox.

The C-BGP algorithm is available in the toolbox through the `CBGP` class in the package `be.ac.ucl.ingi.totem`. C-BGP currently provides the following functionnalities within the TOTEM toolbox. First, when the C-BGP algorithm is started (see Section 8.8.3), it builds an

internal representation of the domain being considered from the TOTEM XML topology which was previously loaded. This includes building a model of the domain's network based on the `topology` element. The intradomain model built by C-BGP currently only takes into account the nodes, links and IGP weights found in the `nodes` and `igp`. It does not model the multiple interfaces of one node. Nor does it model multiple links between a pair of nodes.

The internal representation of the domain also contains a model of BGP routing. This includes nodes that are modelled as BGP routers and the BGP sessions that are established between the BGP routers. This information is also obtained from the TOTEM XML topology, within the `bgp` element (see Section 3.1.5).

Then, C-BGP makes possible running the path computation and later extracting information on the path computation results. Running the path computation requires calling the **int simRun()** method. In order to extract the paths selected by C-BGP, the following methods are provided:

- **Vector netNodeGetRT(String** *sNodeAddr***, String** *sPrefix***)**
  This method returns the content of the routing table of the node identified by *sNodeAddr*. The *sNodeAddr* is a string that contains the IP address of the node. The *sPrefix* arguments permits retrieving only the routes that match the given prefix. The *sPrefix* contains a CIDR prefix in the form "address / mask length".

- **Vector bgpRouterGetRib(String sRouterAddr, String** *sPrefix***)**
  This method returns the content of the BGP routing information base (RIB) of the BGP router identified by *sRouterAddr*. The *sRouterAddr* is a string that contains the IP address of the router. The *sPrefix* arguments permits retrieving only the routes that match the given prefix. The *sPrefix* contains a CIDR prefix in the form "address / mask length".

- **Vector bgpRouterGetAdjRib(String sRouterAddr, String** *sNeighborAddr***, String** *sPrefix***, boolean** *bIn***)**
  This method returns the content of the BGP routing adjacent information bases (Adj-RIBs) of the BGP router identified by *sRouterAddr*. The *sRouterAddr* is a string that contains the IP address of the router. The *sNeighborAddr* argument specifies the IP address of the peer corresponding to the requested Adj-RIB. The *sPrefix* arguments permits retrieving only the routes that match the given prefix. The *sPrefix* contains a CIDR prefix in the form "address / mask length". The *bIn* argument controls which Adj-RIB is requested. If *bIn* is true, the input Adj-RIB is returned. Otherwise, the output Adj-RIB is returned.

In order to load interdomain routes in C-BGP, the Java class provides the following method: **int bgpRouterLoadRib(String** *sRouterAddr***, String** *sFileName***)**. This method loads the content of the specified MRT dump file into the BGP router identified with the *sRouterAddr* argument. The MRT file must be provided uncompressed in ASCII format. Use the **route_btoa** conversion tool provided with the MRTd routing toolkit [12] for this purpose.

A convenient way to call C-BGP commands from the TOTEM toolbox is to rely on the **int runCmd(String sCommand)** method. The command takes a single argument, *sCommand*, which is a string containing a C-BGP command. If it is a valid C-BGP command, it is executed.

Many additional methods are provided, but not yet documented. Please refer to C-BGP's documentation [11] and C-BGP's Java classes for more details.

## 7.7 IGP-WO

IGP-WO (*Interior Gateway Protocol-Weight Optimization*) module aims at finding a link weight setting in the domain for an optimal load balancing. It provides a routing scheme adapted to the traffic demand matrix for congestion avoidance. The main inputs to the IGP-WO module are:

- Network topology: routers (nodes), links (arcs), link capacities
- Traffic demand matrix: source, destination, demand (bandwidth)
- Number of iterations: total number of iterations used in the heuristic search
- Maximum weight value ($W_{max}$): maximum weight value that can be assigned to links

The program yields an output as the weights for the links in the network. Here are some remarks regarding the current version of the tool.

- Multiple path routing: The traffic is assumed to be split equally among all of the shortest paths.
- A special objective function is used. Each link is assigned a function, which is convex and piecewise linearly increasing with the total load on the link. The main objective is to minimize the sum of these functions over all the links. For the definition of the function, see [13] or [14].

Since the problem of finding the optimal weight setting is NP-hard (no efficient algorithm available), a heuristic algorithm is applied to find a *good but not necessarily optimal* solution [14]. The algorithm is based on a well-known heuristic technique, called tabu search [15], whose attributes are summarized as follows:

- Solution representation: The solution is represented as a vector of weights. The weights are restricted to be integers in the range of $[1, W_{max}]$.
- Neighborhood structure: Two types of neighborhood search are carried out.
  - Single weight change: The weight of a randomly selected link is changed.
  - Evenly balancing flows: Given a destination node ($t$), another node ($u$) is selected randomly among the ones that are on any shortest path toward $t$. The weights of the arcs outgoing from $u$ is adjusted in such a way that the traffic from $u$ to $t$ is shared among multiple arcs. The weight change is restricted to the arcs which have less load than a threshold. The changes leading infeasible weight values are also avoided.
- Tabu lists: Tabu lists are used in tabu search to avoid cycling during the whole run. In order to save memory and time, special hash functions are utilized in IGP-WO.
- Diversification: Diversification is carried out when the working solution is not improved for $300$ iterations. During the diversification, each link weight is changed with a probability rate $10\%$ by adding a randomly chosen integer between $[-2, +2]$. If the resulting weight is infeasible (less than $1$ or larger than $W_{max}$), it is forced to the corresponding bound value.
- Neighborhood Sampling: At each iteration, a proportion of the neighborhood is evaluated due to the large size of the problems. The initial rate by which the neighborhood is sampled is determined by the users. During the algorithm run, the value of the sampling rate is updated. If the current solution is improved, the sampling rate is divided by three, if not it is multiplied by two. The upper and lower bounds of the sampling rate are determined by the users, too.

The main IGP-WO algorithm is written in C and integrated through JNI. The `IGPWO` class is located in the `package be.ac.ucl.poms.repository.IGPWO`. The following method is provided by IGP-WO:

```
TotemActionList calculateWeightsParameters(int ASID, int[] TMID,
int num_iters, int w_max, int random_initial, int seed,
double min_samp_rate, double max_samp_rate, double init_samp_rate,
double[] initialWeights) throws Exception
```

where `ASID` and `TMID` represent the domain and traffic matrix idenditification numbers. IGP-WO supports multiple traffic matrices. In case of multiple traffic matrices, the algorithm minimizes the sum of objective functions over the given traffic matrices.

`num_iters` ans `w_max` is the number of iterations and maximum possible weight value, respectively. `random_initial` determines whether the initial solution of the algorithm is created randomly, or is assigned to the currently used weights in the network. `seed` (default 0) is used for the random number generator. `min_samp_rate`, `max_samp_rate`, `init_samp_rate` control the sampling rate during the algorithm run. The sampling rate is not allowed not to go behind `min_samp_rate` and `max_samp_rate`.

The default value for the number of iterations is set to 150. The default value is kept low for the small example problems in the toolbox. If you have a large problem, it is suggested to assign a higher value to `num_iters`. The run time of the program increases with the number of iterations.

The default value for `w_max` is set to 50. The maximum value that can be given to `w_max` is 65535. The authors of the program suggest not to give a very large value for `w_max`. As the value increases, the output weights become less user-friendly and the running time increases due to the computations necessary for hash table values.

The default values for `min_samp_rate`, `max_samp_rate`, `init_samp_rate` are 0.01, 0.4 and 0.2, respectively. The running time of the algorithm increases with the sampling rate control parameters.

### 7.8 SAMTE

TOTEM also includes an hybrid IP/MPLS optimization method called SAMTE (Scalable Approach for MPLS Traffic Engineering). The idea of SAMTE is to combine both the simplicity and robustness of IGP routing and the flexibility of MPLS. This approach lies between the pure IP metric-based optimization (as IGP-WO) and the full mesh of LSPs. SAMTE uses the simulated annealing meta-heuristic to find a small number of LSPs (given as parameter) to establish in the network. The combination of the set of LSPs computed by SAMTE and the IGP routing for remaining flows optimise a given operational objective.

To use SAMTE, you first have to generate a Candidate Path List using the `samte:generateCPL` scenario element. This element accept the following parameters `nbPath` (the number of path to generater per source destination pair of nodes), `maxDepth` (the maximal number of nodes per path), `verbose` (print some information while generating the candidate path list) and `fileName` which specifies the file where to store the candidate path list. Once you have a candidate path list (be carefull, this list can take a huge amount of place on your hard disk !), you can use SAMTE with the scenario event `samte:SAMTE`. You have to provide the Candidate Path List file with the parameter `cplName`. You can also specify the number of runs of the algorithm (`nbRun`), the number of LSP to establish (`nbLSP`) and the Traffic Matrix to use (`TMID`). The subelement `samte:simulatedAnnealing` configures the parameters of the simulated annealing heuristic via the parameters `T0` the initial temperature, `alpha` the cooling factor, `L` the size of the plateau and `E`, $\epsilon$, parameter for the stopping conditions. The subelement of `samte:simulatedAnnealing` is `samte:objectiveFunction` which specify the used objective function.

To show the link loads with the established LSPs, you have to use the `ShowLinkInfo` element with the `type` set to `LOAD_BIS`. This means Basic IGP Shortcut. This specifies the traffic

that is routed on each LSP.

An example of use of SAMTE can be found in `examples/abilene/Scenario/samte.xml`.

### 7.9 Reopt

This algorithm written by Sandford Bessler from FTW[8] allows to dimension an LSP. It is written in AMPL and uses the CPLEX solver. It is based on a MCF problem and uses multiple explicit paths calculated in advance. The idea of this algorithm is to adapt existing LSPs to new traffic conditions while minimizing the number of LSP size changes.

You can find more information about this algorithm in [16].

### 7.10 LSPDimensioning

This algorithm written by Hung Tuan Tran from FTW is an adaptive provisioning algorithm based on:

1. Traffic load measurements
2. Packet-level target QoS constraint

$$P(delay > D) < \epsilon \tag{3}$$

where $D$ is the given delay bound and $\epsilon$ the given delay violation probability.

The traffic load is measured in a slot-by-slot manner. A certain number of such measurement slots constitutes a resizing window. The bandwidth is recalculated and updated (using one of the four prediction schemes) at the end of each resizing window and the newly assigned bandwidth is valid for the next resizing window. The algorithm is written in C and was integrated thanks to JNI.

More details about this algorithm can be found in [17].

[8] http://www.ftw.at

# 8 A standard XML format for a scenario representation

The XML scenario format is very simple: it's a list of events. There are four super abstract types that can only be extended: `eventType`, `ASEventType`, `TMEventType`, `ASTMEventType`. The first one has only one optional attribute `time` which specifies when the event has to occur. `ASEventType` and `TMEventType` define each an other optional attribute (`ASID` and `TMID` respectively). `ASEventType` is intended to be extended by intra-domain events, and `TMEventType` by traffic-related events. Finally, `ASTMEventType` combine the two last types. Note that if `ASID` is not specified, the events use the default domain and if `TMID` is not specified, the events use the default traffic matrix for the specified domain (or for the default domain).

Some events have to point out to files located on the local hard drive (`loadDomain`, `loadTrafficMatrix`, ...). By default, the paths are defined relatively to the TOTEM root folder. This default behaviour can be changed by setting the `pathRelativeTo` attribute of the `scenario` element. The value of this attribute corresponds to the directory from which the relative paths defined in the events must be interpreted. It is even possible to specify a relative path for this attribute. In this case, the path is interpreted relatively to the current scenario file path.

For example, if you want to create a scenario that will load a domain that is in the same folder as the scenario file, you write something like the following.

```
<scenario pathRelativeTo="./">
     <loadDomain file="topology.xml"/>
</scenario>
```

If you did not specify the `pathRelativeTo` attribute, TOTEM will look for a file named `topology.xml` in its root folder.

Here is an example of a short scenario:

```
<?xml version="1.0" encoding="ISO-8859-1" standalone="yes"?>
<!--
    This scenario uses CBGP to simulate the failure of a peering session
    between Abilene and Geant.
    Author: Bruno Quoitin (bqu@info.ucl.ac.be)
    Author: Jean Lepropre (lepropre@run.montefiore.ulg.ac.be)
-->
<scenario
    xsi:schemaLocation="http://jaxb.model.scenario.totem.run.montefiore.ulg.ac.be
    http://totem.run.montefiore.ulg.ac.be/Schema/Scenario-v1_1.xsd
    http://jaxb.model.scenario.totem.ingi.ucl.ac.be
    http://totem.run.montefiore.ulg.ac.be/Schema/CBGP-Scenario-v1_0.xsd"
    xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
    xmlns:cbgp="http://jaxb.model.scenario.totem.ingi.ucl.ac.be"
    xmlns="http://jaxb.model.scenario.totem.run.montefiore.ulg.ac.be">

    <loadDomain file="examples/abilene/abilene.xml" defaultDomain="false"
        removeMultipleLinks="true"/>
    <startAlgo name="CBGP"/>
    <cbgp:CBGPPeerRecv router="198.32.8.202" peer="62.40.103.253"
        msg="BGP4|0|A|198.32.8.202|11537|130.104/16|20965 2611|IGP|62.40.103.253|0|0|"/>
    <cbgp:CBGPPeerRecv router="198.32.8.199" peer="198.32.11.62"
        msg="BGP4|0|A|198.32.8.199|11537|130.104/16|20965 2611|IGP|198.32.11.62|0|0|"/>
    <cbgp:CBGPPeerRecv router="198.32.8.193" peer="62.40.103.165"
        msg="BGP4|0|A|198.32.8.193|11537|130.104/16|20965 2611|IGP|62.40.103.165|0|0|"/>
    <cbgp:CBGPRun/>
    <cbgp:CBGPInfo info="AdjRIB">
        <param name="router">198.32.8.193</param>
    </cbgp:CBGPInfo>
    <cbgp:CBGPInfo info="AdjRIB">
        <param name="router">198.32.8.199</param>
```

```
    </cbgp:CBGPInfo>
    <cbgp:CBGPInfo info="AdjRIB">
        <param name="router">198.32.8.202</param>
    </cbgp:CBGPInfo>
    <cbgp:CBGPInfo info="RecordRoute">
        <param name="src">198.32.8.200</param>
        <param name="dst">130.104.230.54</param>
    </cbgp:CBGPInfo>
    <cbgp:CBGPInfo info="RecordRoute">
        <param name="src">198.32.8.201</param>
        <param name="dst">130.104.230.54</param>
    </cbgp:CBGPInfo>
    <cbgp:CBGPInfo info="RecordRoute">
        <param name="src">198.32.8.202</param>
        <param name="dst">130.104.230.54</param>
    </cbgp:CBGPInfo>
    <cbgp:CBGPPeerDown node="198.32.8.193" peer="62.40.103.165"/>
    <cbgp:CBGPRun/>
    <cbgp:CBGPInfo info="RecordRoute">
        <param name="src">198.32.8.200</param>
        <param name="dst">130.104.230.54</param>
    </cbgp:CBGPInfo>
    <cbgp:CBGPInfo info="RecordRoute">
        <param name="src">198.32.8.201</param>
        <param name="dst">130.104.230.54</param>
    </cbgp:CBGPInfo>
    <cbgp:CBGPInfo info="RecordRoute">
        <param name="src">198.32.8.202</param>
        <param name="dst">130.104.230.54</param>
    </cbgp:CBGPInfo>
</scenario>
```

Since TOTEM 1.1, it's possible to plug new scenario events into the toolbox at the runtime. This slightly complicates the writing of a scenario file but allows the user to really extend the scripting language defined by the scenarios. In the developer guide, we explain how to write new scenario events. In this user guide, we will only give some XML notions necessary to write scenario files at hand[9].

The above scenario file illustrates how to write scenario files which use several schemas. In this particular scenario, there are two types of events:

- Core events defined in the main scenario schema: `loadDomain`, `startAlgo`, etc.
- CBGP-related events defined in a separate schema: `CBGPInfo`, `CBGPPeerDown`, etc.

The idea is that the toolbox must know in which schema the events are defined. This is done thanks to the attributes of the `scenario` element. There are four attributes:

`xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"`. This attribute defines a namespace called `xsi`. In the W3C recommandation about XML namespaces, we can read: "...An XML namespace is a collection of names, identified by a URI reference [RFC2396], which are used in XML documents as element types and attribute names...". The URI of a namespace has no special meaning, this is just a way to give a unique name to the namespace. However, as in our case, the URI can be used for a special purpose. Companies often use it as a pointer to a real Web page where you can find information about the namespace. In the toolbox, we use it to identify the package in which the class of an event is defined (as a package name is supposed to be unique, scenario namespaces will also be unique). So this attribute defines the `xsi` namespace. This definition allows us to use the `schemaLocation` attribute defined in the `xsi` namespace.

[9] If you use JAXB to write your scenario files, you can just skip all these explanations as JAXB will do the job for you...

`xsi:schemaLocation="http://jaxb.model.scenario.totem.run.montefiore.ulg.ac.be http://totem.run.montefiore.ulg.ac.be/Schema/Scenario-v1_1.xsd http://jaxb.model.scenario.totem.ingi.ucl.ac.be http://totem.run.montefiore.ulg.ac.be/Schema/CBGP-Scenario-v1_0.xsd"`. In the XML Schema Part 0: Primer document, we can read: "...In an instance document, the attribute xsi:schemaLocation provides hints from the author to a processor regarding the location of schema documents. The author warrants that these schema documents are relevant to checking the validity of the document content, on a namespace by namespace basis..." and "...The schemaLocation attribute value consists of one or more pairs of URI references, separated by white space. The first member of each pair is a namespace name, and the second member of the pair is a hint describing where to find an appropriate schema document for that namespace. The presence of these hints does not require the processor to obtain or use the cited schema documents, and the processor is free to use other schemas obtained by any suitable means, or to use no schema at all...". So in this example, we use two namespaces: `http://jaxb.model.scenario.totem.run.montefiore.ulg.ac.be` and `http://jaxb.model.scenario.totem.ingi.ucl.ac.be`. The first namespace contains the core elements and the associated schema is located at `http://totem.run.montefiore.ulg.ac.be/Schema/Scenario-v1_1.xsd`. The second namespace contains the CBGP-related elements and the associated schema can be found at `http://totem.run.montefiore.ulg.ac.be/Schema/CBGP-Scenariov1_0.xsd`.

`xmlns:cbgp="http://jaxb.model.scenario.totem.ingi.ucl.ac.be"`. This attribute indicates that all the elements coming from the `http://jaxb.model.scenario.totem.ingi.ucl.ac.be` namespace are prefixed with `cbgp:`. So, as `CBGPPeerRecv`, `CBGPRun`, etc. are defined in `http://jaxb.model.scenario.totem.ingi.ucl.ac.be`, they are prefixed with `cbgp:`.

`xmlns="http://jaxb.model.scenario.totem.run.montefiore.ulg.ac.be"`. This attribute indicates which namespace is the default namespace. In this case, this is the namespace associated with the core elements. It means that in the sequel of the document all core elements have no prefix. For example, `param` and `loadDomain` are core events defined in `http://jaxb.model.scenario.totem.run.montefiore.ulg.ac.be` and have no prefix.

Currently, there are three scenario XML schemas shipped with the toolbox:

1. `Scenario-v1_1.xsd`, which contains the core events;
2. `CBGP-Scenario-v1_0.xsd`, which contains the CBGP events;
3. `SAMTE-Scenario-v1_0.xsd`, which contains the events used by SAMTE;

We now describe two elements used by many events and all the core events classified by functions. Then we give more details about the CBGP-related events and the SAMTE-related events.

## 8.1 Common elements

### 8.1.1 routingAlgo

This element is used by events manipulating routing algorithms' instances. It has one required attribute `name` which is a `string`. This attribute is the routing algorithm's name (see 7 for the allowed values and their meaning). You can also specify parameters for the routing algorithm. The maximum number of `param` elements is unbounded and their type is described in section 8.1.2.

### 8.1.2 param

This element is a general purpose element which is used whenever a general "param-value" scheme is required. It has one required attribute `name` which is a `string` and which represents the parameter's name. The content of the element is a `string` and represents the parameter's value.

## 8.2 Domain Events

### 8.2.1 linkDown

This event extends `ASEventType`. It has two attributes: `linkId` which is a `string` and is required and `cause` which is a `string` and is optional.

This event sets the status of the link `linkId` that belongs to the given domain to `DOWN`. The cause is just printed using the logger.

### 8.2.2 linkMetricChange

This event extends `ASEventType`. It has two required attributes: `linkId` which is a `string` and `metric` which is a `float`.

This event sets the metric of the link `linkId` that belongs to the given domain to `metric`.

### 8.2.3 linkTeMetricChange

This event is the same as `linkMetricChange` described in section 8.2.2 except that it changes the traffic engineering metric instead of the metric.

### 8.2.4 linkUp

This event extends `ASEventType`. It has one required attribute `linkId` which is a `string`.

This event sets the status of the link `linkId` that belongs to the given domain to `UP`.

### 8.2.5 loadDomain

This event extends `eventType`. It has one required attribute `file` and three optional attributes (`defaultDomain`, `useBWSharing` and `removeMultipleLinks`). `file` is a `string` and the three other attributes are `boolean`s. Note that the three `boolean`s attributes are `false` by default.

This event loads the domain contained in the file `file`. `removeMultipleLinks` must be `true` if you want to force the graph to **not** be a multigraph and `false` otherwise. `defaultDomain` must be `true` if you want to set the loaded domain as the default domain and `false` otherwise. `useBWSharing` must be `true` if you want to use bandwidth sharing and `false` otherwise. If backup LSPs need to be calculated, `useBWSharing` should be set to true.

#### 8.2.6 nodeDown

This event extends ASEventType. It has two attributes which are strings. The first one is nodeId which is required and the second one is cause which is optional.

This event sets the status of the node nodeId that belongs to the given domain to DOWN. The cause is just printed using the logger.

#### 8.2.7 nodeUp

This event extends ASEventType. It has only one required attribute nodeId which is a string.

This event sets the status of the node nodeId that belongs to the given domain to UP.

#### 8.2.8 saveDomain

This event extends ASEventType. It has only one required attribute file which is a string.

This event saves the given domain in the file file.

#### 8.2.9 topologyGeneration

This event extends eventType. It only accepts an unbounded number of param elements. The param element is described in section 8.1.2.

This event allows you to use the topology generation capabilities of the toolbox. In order to make the use of this event simple, all the parameters are optional and good default values have been defined[10]. So, you can simply type

```
<topologyGeneration/>
```

to generate a topology. We now list in the tables 8 and 9 all the possible parameters and their possible values (you can find more information about the BRITE-specific parameters in the BRITE user manual).

### 8.3 Lsp & Routing Events

#### 8.3.1 computeMCF

This event extends ASTMEventType. It has also three optional attributes: runGLPSOL, dataFile and resultFile. The two latter attributes are strings and the former is a boolean.

This event runs the MCF algorithm on the given domain and traffic matrix and prints the result (mean, max, standard deviation and percentile 10) using the logger at the info level. runGLPSOL must be true if you want to run glpsol and false if you want only to generate the data file. resultFile is the name of the file that glpsol must produce and dataFile is the name of the file that glpsol takes as input.

#### 8.3.2 deleteAllLSP

This event extends ASEventType. It deletes all the LSPs established on the specified domain or on the default domain if no domain is specified.

[10] These default values are taken in part from [18].

### 8.3.3 IGPWOCalculateWeights

This event extends ASEventType. It has three optional attributes which are ints: maxPossibleWeight, nbIter and seed. It also has an optional attribute called initialWeightArray which can be CURRENT or RANDOM. The default value for nbIter is 150, 50 for maxPossibleWeight, 0 for seed and RANDOM for initialWeightArray. It also accepts zero or one samplingRate element and an unbounded number of trafficMatrix elements. These trafficMatrix elements have only one required attribute TMID that represents the ID of a traffic matrix. The samplingRate element has three optional attributes which are floats: initial (default value: 0.2), min (default value: 0.01) and max (default value: 0.4).

This event runs the IGPWO algorithm on the given domain and traffic matrices. nbIter is the number of iterations that IGPWO must do and maxPossibleWeight is the maximum weight that IGPWO can produce. seed is used for the random number generator in the algorithm.

The samplingRate element controls the sampling of neighborhoods during local search. At each iteration, a proportion of the neighborhood is evaluated due to the large size of the problems. The initial rate by which the neighborhood is sampled is determined by initial. During the algorithm run, the value of the sampling rate is updated. If the current solution is improved, the sampling rate is divided by three, if not it is multiplied by two. The upper and lower bounds of the sampling rate are determined by max and min.

### 8.3.4 LSPBWChange

This event extends ASEventType. It has two required attributes lspId which is a string and bw which is a float.

This event sets the reservation of the LSP lspId of the given domain to bw.

### 8.3.5 LSPBackupCreation

This event extends ASEventType. It has two optional attributes: lspId which is a string and bw which is a float. It also accepts the following subelements in sequence:

- Detour or Bypass. Exactly one of these two elements must occur exactly one time. The Detour element has one required attribute protectedLSP which is a string and two optional attributes (methodType and protectionType). methodType can be LOCAL or GLOBAL (default value). protectionType can be NODE_DISJOINT (default value) or LINK_DISJOINT. The Bypass element accepts one or several protectedLink elements which have only one required attribute linkId which is a string.
- The routingAlgo element that must occur exactly one time. This element is described in section 8.1.1 page 34.

This event creates a backup LSP on the specified domain using the specified routing algorithm. The ID of the newly created LSP will be lspId and its bandwidth will be bw. If these parameters are not specified, default values will be used (an ID will be automatically generated and the bandwidth will be, for example, the bandwidth of the protected LSP). If the Detour element is present, a detour LSP will be created. Otherwise, we create a bypass LSP. In the case of a detour LSP, protectedLSP must be the ID of the LSP to protect, methodType indicates whether the backup LSP to create must be local (LOCAL) or global (GLOBAL), and protectionType indicates whether the backup LSP must be node disjoint (NODE_DISJOINT) or link disjoint (LINK_DISJOINT) from the protected LSP. In the case of a bypass LSP, the linkId attributes of the protectedLink elements are the IDs of the links to protect.

**Important note**: do not forget to start the routing algorithm before using it in a `LSPBackupCreation` event. See the section 8.8.3 for more information.

#### 8.3.6 `LSPCreation`

This event extends `ASEventType`. It has two required attributes (`src` and `dst`) which are `string`s and three optional attributes (`lspId`, `bw` and `establishLSP`). `lspId` is a `string`, `bw` is a `float` and `establishLSP` is a `boolean`. It also accepts the following subelements in sequence:

- A `metric` element that contains a `float` and that can occur 0 or 1 time.
- A `maxRate` element that contains a `float` and that can occur 0 or 1 time.
- A `diff-serv` element that can occur 0 or 1 time. The content of this element is the same as the `diff-serv` element described in section 5.
- A `path` element that can occur 0 or 1 time. The content of this element specifies the route of the LSP. It can be described as a sequence of node ids (`<node>node_id</node>`) or a sequence of links ids (`<link>link_id</link>`).
- The `routingAlgo` element that is optional. This element is described in section 8.1.1 page 34.

This event creates a primary LSP on the specified domain using the specified routing algorithm. The source of the LSP is `src` and the destination of the LSP is `dst`. Its reserved bandwidth is `bw`. If `bw` is not specified, the reserved bandwidth will be 0. `lspId` is the ID given to the created LSP (if it is not specified, an ID is automatically generated). `metric` is the metric of the created LSP and `maxRate` is the maximum rate at which it will be possible to send data over the LSP. For more information about the `diff-serv` element, see the section 5.

The `path` element is used to establish explicit route LSPs. If it is present, the element `routingAlgo` will be ignored and the LSP will be established following the given route.

The `establishLSP` attribute, which is `true` by default, can be set to `false` in order to only calculate the LSP route without establishing it. The calculated route will be printed on standard output.

**Important note**: do not forget to start the routing algorithm before using it in a `LSPCreation` event. See the section 8.8.3 for more information.

#### 8.3.7 `LSPDeletion`

This event extends `ASEventType`. It has one required attribute `lspId` which is a `string`.

This event deletes the LSP `lspId` of the given domain.

### 8.4 Traffic matrix Events

#### 8.4.1 `generateIntraTM`

This event extends `eventType`. This element requires the following attributes: `NETFLOWbasedirectory`, `NETFLOWdirFileName`, `BGPbasedirectory`, `BGPdirFileName`, `clusterFileName`, `trafficMatrixFileName`, `minutes` and `samplingRate`. All these attributes are `string`s, except the last two which are `int`s.

This event is used to generate an intra-domain traffic matrix from BGP dump information and NetFlow traces. See section 10 for more information about required formats. You will find details

about the parameters in section 10. The `minutes` and `samplingRate` parameters are used to convert flow sizes (in bytes) found in NetFlow traces in kbps. You must fill `minutes` with the length (in minutes) of the NetFlow traces period. `samplingRate` must contain the sampling rate used in the NetFlow traces.

#### 8.4.2 `loadTrafficMatrix`

This event extends `TMEventType`. It has one required attribute `file` which is a `string`.

This event loads the traffic matrix contained in the file `file`. The traffic matrix ID of the loaded traffic matrix will be the given traffic matrix ID. If you don't specify an ID, it will be generated automatically and the matrix will be set as the default traffic matrix.

#### 8.4.3 `removeTrafficMatrix`

This event extends `ASTMEventType`. It has no other parameters.

This event removes the traffic matrix from the manager. If the attribute `tmId` is not provided, the default traffic matrix is removed.

#### 8.4.4 `trafficMatrixGeneration`

This event extends `ASTMEventType`. It only accepts an unbounded number of `param` elements. The `param` element is described in section 8.1.2.

This event allows you to use the traffic generation capabilities of the toolbox. A traffic matrix with the specified `TMID` will be created for the specified domain. In order to make the use of this event simple, all the parameters are optional and default values have been defined. So, you can simply type

```
<trafficMatrixGeneration/>
```

to generate a traffic matrix. We now list in the table 10 all the possible parameters and their possible values.

### 8.5 Display Events

#### 8.5.1 `echo`

This event extends `eventType`. It has one required attribute `msg` which is a `string`.

This event prints the string `msg` on the standard output stream.

#### 8.5.2 `ECMPAnalysis`

This event extends `ASEventType`. It accepts no attribute nor element.

This event prints information about existing equal cost paths on the standard output stream. Note that this event uses the standard metrics (not the TE metrics) of the given domain.

#### 8.5.3 `listShortestPaths`

This event extends `ASEventType`. It has five attributes: `src`, `dst` and `SPFType` which are `string`s and `ECMP` and `nodeList` which are `boolean`s. All these attributes are optional.

This event prints information about shortest paths of the given domain on the standard output stream. If `src` and `dst` are specified, it prints only shortest paths between these two nodes. If only `src` (resp. `dst`) is specified, the shortest paths from `src` (resp. to `dst`) to (resp. from) all the other nodes are listed. If neither is specified, it prints all the shortest paths of the given domain.

If you want to take ECMP into account, `ECMP` must be set to `true` and `false` otherwise (note that it is `false` by default). `SPFType` is exactly the same attribute as the one described in section 8.5.4. Finally, `nodeList` specifies whether the paths must be printed under the form of a list of nodes or a list of links. If it is `true`, a list of nodes is printed. Otherwise, the event prints a list of links. Note that the attribute is `true` by default.

### 8.5.4 `ShowLinkInfo`

This event extends `ASTMEventType`. It has four optional attributes `type`, `verbose`, `ECMP` and `SPFtype`. `type` can be `LOAD`, `LOAD_BIS`, `LOAD_IS`, `RESERVATION` and `PRIMARY_BACKUP`. `verbose` and `ECMP` are `boolean`s and `SPFtype` is a `string`.

This event prints information about the load or about the reservation of links (if the value of `type` is `LOAD` or `RESERVATION`) on the standard output stream. If `type` is not specified, it prints information about the load of links by default. `verbose` must be `true` if you want to have information about each link of the given domain and `false` if you just want to print the following values: maximum, mean, standard deviation and percentile 10 (`verbose` is `false` by default). `SPFtype` allows you to choose the SPF algorithm used to compute the load or the reservation of links (see the section 7.1 for the possible values). By default, a classical SPF algorithm based on the links' metrics is used. If you want to enable ECMP (Equal Cost MultiPath), `ECMP` must be `true` and `false` otherwise. By default, `ECMP` is `false`.

If the value of `type` is `PRIMARY_BACKUP`, the event prints some information about primary and backup link reservation (total primary bandwidth reserved, oversubscription for backup (with or without taking sharing between primary and backup paths into account), mean and max link utilization). In order to use this feature correctly, you have to set the `useBWSharing` attribute of the `loadDomain` element to `true`.

The values `LOAD_BIS`, `LOAD_IS`, `LOAD_OVERLAY` are used when part of the traffic is routed with IGP routing (shortest path based on link weigths) while other part of the traffic is routed with MPLS label switched paths. In particular, the values `LOAD_BIS` and `LOAD_IS` can be used for SAMTE (see section 7.8), but can also be used in other algorithms. The value `LOAD_BIS` corresponds to the Basic IGP Shortcut model. In this model, the traffic that is forwarded on the path of an LSP is the whole traffic that crosses the ingress node of the LSP and whose exit point is the egress of the LSP. The value `LOAD_IS` is used for IGP Shortcut. In this model, the traffic that is forwarded on the path of an LSP is the whole traffic that crosses both the ingress and egress nodes of the LSP. In this last model, more traffic is forwarded on the LSP (there is no restriction about the exit point of the traffic). Finally, the `LOAD_OVERLAY` value corresponds to the overlay model. In this model, the traffic is forwared on a LSP if the source and destination of the traffic match the ingress and egress of the LSP.

### 8.5.5 `ShowLinkReservableBandwidth`

This event extends `ASEventType`. It has two attributes: a `string linkId` which is required and an `int priority` which is optional.

This event prints the reservable bandwidth of the link `linkId` for the given `priority` level on the standard output stream. If `priority` is not specified, it uses the minimum priority level of the specified domain.

## 8.6 Charts Events

It is now possible (since version 2.0) to generate some charts from the data in the toolbox. The chart creation uses the JFreeChart[11] library. An interface has been created to output charts in graphics files from the scenario XML.

Examples of scenario that use charts can be found in

- `example/abilene/Scenario/charts1.xml`
- `example/abilene/Scenario/charts2.xml`
- `example/abilene/Scenario/SPF-load-chart.xml`

The chart creation process is divided into three parts : selecting the data to collect, collecting the data and outputting the chart.

Each of these steps refers to a specific scenario event detailed hereunder.

### 8.6.1 `chartCreation`

This is the first event to use when willing to create a chart. This event takes one mandatory attribute `id` which is the referring name of the chart and has only one mandatory sub-event (`collector`). The latter specifies the type of data to collect before the chart can be built. The attribute `name` refers to the name of the java class that is used to collect the data. Specifics parameters can be passed to the collector via an unbounded number of `param` sub-elements. For now, there are only two types of chart data collectors : `LinksLoadDataCollector` and `LinksReservedBWDataCollector`. The first one collects the load of each link computed via a shortest path algorithm and the second one collects the reserved bandwidth of each link. The parameters that can be passed are the domain on which to collect the data (via the parameter `asId`) and whether the load should be taken as relative or not (via the `absoluteLoad` parameter which can be `true` or `false`). If they are not set, the default domain is taken and relative load is used, i.e. $absoluteload/capacity$. Note that both collectors uses the same parameters set.

### 8.6.2 `chartAddSeries`

At the moment when this event is executed, data are added to the currently under construction chart. The chart to which to add the data is specified by the `chartId` attribute. The `seriesName` attribute is used to identify the data series. It must have an unique value in a single chart. It might be used by the plotter as the legend name of the data series. Again, parameters can be passed to the collector through the `collector` sub-element. The `LinksReservedBWDataCollector` takes no parameters when adding data series and the `LinksLoadDataCollector` can take up to four parameters (`tmId`, `strategy`, `routingAlgo` and `ECMP`). These corresponds to IGP routing parameters used to compute the load (see section 9.5). If you do not provide some of the parameters, the default value will be used. The default values for these parameters are SPF routing as strategy with CSPF as routing algo and ECMP disabled. The default traffic matrix will be used when the parameter `tmId` is not set.

### 8.6.3 `chartSave`

When the chart is created and contains some data, it can be output to a file. Note that we did not specify the type of chart that we want to build, only the chart data is defined at this point.

[11] http://www.jfree.org/jfreechart/

The `chartSave` event takes the mandatory attributes `chartId`, `file` and `format` with obvious mean. The format can be JPG, PNG or EPS. Some other obvious parameters of the chart must be provided through sub-elements. It is `title`, `xAxisTitle`, `yAxisTitle`, `width`, `height`. The last element that should be provided is the `plotter` whose name corresponds to a java class and defines the type of graph to build. Again, specifics parameters can be passed to the plotter.

For now, three kinds of chart plotters are included in the toolbox: `LoadIntervalChartPlotter`, `DecreasingLineChartPlotter` and `LoadChartPlotter`.

The `LoadIntervalChartPlotter` take two optional parameter: `maxValue` and `nbInterval`, default values are respectively 1 and 10. The interval 0-maxValue is divided in a number of disjoint sets. For each of these sets, a bar is represented. The height of the bar corresponds to the frequency of the data for the considerated set.

The `DecreasingLineChartPlotter` takes no parameters. It is used to plot a line graph where all values in a series are sorted. The plotted point with the highest Y coordinate has the smallest X coordinate, so that the chart represent a decreasing line.

The `LoadChartPlotter` takes two parameters: `asId` and `allLinks`. The `asId` parameter has no default value. `allLinks` is `false` by default. This plotter creates bar charts using links loads. The x-axis represents the links and the y-axis represents the (absolute or relative) load. The plotter has been designed to allow the creation of two different bar charts:

- Charts where the load of all links is displayed
- Charts where only a statistic about the load of links is displayed

The distinction of the two types of charts is made thanks to the `allLinks` parameter. If it is `true`, the first type of charts is created. Otherwise, the second type of charts is created. There is also a distinction in the meaning of the series names. In the first case, they give the name of the algorithm used to compute loads. In the second case, they give the links IDs. Finally, for the first type of plots, a legend will be displayed. This is not the case for the second type of plots. Note that the `asId` parameter gives the domain on which the data were collected. If it is not provided, the default domain is used.

### 8.6.4 `chartDeletion`

This event refers to a chart created with `chartCreation` through the `chartId` attribute. Use it to free the resources associated with a chart.

## 8.7 optDivideTM Events

In this section, we describe the events related to optDivideTM (described in scetion 7.5).

### 8.7.1 `optDivideTM`

This element launch the algorithm. It has four optional attributes: `N` (an `int` whose default value is 3), `objectiveFunction` which can be equal to `MeanDelay`, `WMeanDelay` or `NLFortz`, `establishMultipleFullMesh` which is a boolean and specify if a full-mesh of LSP has to be established or not and finally `verbose` (a `boolean`).

## 8.8 Other core events

### 8.8.1 `addNetworkController`

This event extends `ASTMEventType`. It has two required attributes `name` and `className` which are `string`s. It also accepts an unbounded number of `param` elements.

This event records a new network controller for the specified domain and traffic matrix. The `param` elements are used to specify parameters specific to the network controller to record. `name` is a unique name identifying the network controller and `className` is the class name of the network controller to record.

### 8.8.2 `removeNetworkController`

This event extends `eventType`. It has only one required attribute `name` that is a `string`.

This event removes the network controller `name` if it exists.

### 8.8.3 `startAlgo`

This event extends `ASTMEventType`. It has one required attribute `name` which is a `string`. It also accepts an unbounded number of `param` elements as subelements.

This event starts the algorithm `name` on the specified domain and traffic matrix (if the algorithm is independent of one or both of these elements, you are allowed to not specify them). By means of the `param` elements, you can specify algorithm-specific parameters to start it. The available algorithms (and the possible values for `name`) are given in section 7.

**Important note**: you always have to start an algorithm before using it. Note that the started algorithms are automatically stopped when the execution of the scenario is finished.

### 8.8.4 `stopAlgo`

This event extends `ASTMEventType`. It has one required attribute `name` which is a `string`.

This event stops the algorithm `name` on the specified domain and traffic matrix (if the algorithm is independent of one or both of these elements, you are allowed to not specify them). The available algorithms (and the possible values for `name`) are given in section 7.

**Important note**: this event allows the user to reinitialise an algorithm which doesn't use the observer design pattern. Other uses of this event must be avoided!

## 8.9 CBGP Events

In this section, we describe the events related to the C-BGP simulator. These are defined in the schema available at

`http://totem.run.montefiore.ulg.ac.be/Schema/CBGP-Scenario-v1_0.xsd`.

### 8.9.1 `CBGPExecute`

The `CBGPExecute` element is used to run a single C-BGP command. It requires a single attribute, `command`, of type `string`. The parameter contains a C-BGP command which will be executed by C-BGP if it is valid. Please refer to the C-BGP documentation [11] for more information on the available commands.

### 8.9.2 `CBGPInfo`

The `CBGPInfo` element is used to extract information from C-BGP. It requires an attribute, `info`, of type `string`. This parameter indicates which information type is requested. For each information type, additional parameters are requested. These parameters must be specified using the `params` attribute. The `CBGPInfo` currently supports the following information types:

- **Links** : Dumps all the links of the node identified by the parameter *router*. The *router* parameter must contain the IP address of the node.
- **Peers** : Dumps all the BGP peers of the router identified by the parameter *router*. The *router* parameter must contain the IP address of the router.
- **AdjRIB** : Dumps the BGP adjacent routing information base (Adj-RIB) of the router identified by the parameter *router*. The *router* parameter must contain the IP address of the router. The following optional parameters are also understood. First, the *peer* parameter can be used to only dump the routes related to this peer. Second, the *prefix* parameter can be used to only dump the routes that match this prefix. Finally, the *in* parameter can be used to select if the input or output Adj-RIB must be dumped. The default value of *in* is *true*, which means that the Adj-RIB-in are dumped.
- **RecordRoute** : Traces the route from a source node specified using the *src* parameter towards a destination node specified using the *dst* parameter.
- **RT** : Dumps the routing table of the node identified by the parameter *router*. The *router* parameter must contain the IP address of the node.
- **RIB** : Dumps the BGP routing information base (RIB) of the router identified by the parameter *router*. The *router* parameter must contain the IP address of the router. Note, the optional *prefix* parameter described in the **AdjRIB** information type can also be used for the **RIB** information type.

Figure 2 shows an example of use of the `CBGPInfo` element. The example requests the **RIB** of router `10.0.0.1`.

```
<CBGPInfo info="RIB">
    <param name="router">10.0.0.1</param>
</CBGPInfo>
```

Figure 2: Example of the XML CBGPInfo element usage.

### 8.9.3 `CBGPLoadRib`

The `CBGPLoadRib` element is used to load BGP routes collected on a genuine BGP router in C-BGP. The BGP routes are provided in a file whose format is ASCII MRT (see [11] and [12] for more information). The `CBGPLoadRib` element requires two attributes: `node` and `file`, both of type `string`. The `node` attribute specifies the IP address of the router in which the routes must be loaded. The `file` specifies the name of the file that contains the BGP routes.

#### 8.9.4 CBGPPeerDown

The CBGPPeerDown element is used to tear down a BGP session between a router and one of its peers. The CBGPPeerDown element requires two attributes: node and peer, both of type string. The node attribute specifies the IP address of the router and the peer attribute specifies the IP address of the router's peer.

#### 8.9.5 CBGPPeerRecv

The CBGPPeerRecv element is used to feed a router with one BGP route. The route will appear to the router as if it was learned from one of its peers. There are a few preconditions in order for this scenario element to be working. First, the peer from which the router will learn the route must have been declared with one neighbor element in the BGP section of the TOTEM XML topology. Second, this peer must be virtual, that is, the peer router must not really exist in the topology, it will be created when the C-BGP algorithm is loaded in the TOTEM toolbox (see Section 8.8.3).

The CBGPPeerRecv element requires three attributes, all of type string. First, the router attribute specifies the IP address of the BGP router that will receive the BGP route. Second, the peer attribute specifies the IP address of the peer of the router. Finally, the msg attribute describes the BGP route, using the MRT format [12]. An example is shown in Fig 3.

```
<CBGPPeerRecv
  router="10.0.0.1"
  peer="20.0.0.1"
  msg="BGP4|0|A|10.0.0.1|1|30.0.1/24|20 30|IGP|20.0.0.1|0|0|"
/>
```

Figure 3: Example of the XML CBGPPeerRecv element usage.

#### 8.9.6 CBGPPeerUp

The CBGPPeerUp element is used to establish a previously configured BGP session between a router and one of its peers. The CBGPPeerDown element requires two attributes: node and peer, both of type string. The node attribute specifies the IP address of the router and the peer attribute specifies the IP address of the router's peer.

#### 8.9.7 CBGPRun

The CBGPRun element is used to start the computation of routes. This element does not require any argument. This element must be used after changes such as BGP sessions state changes or after the first topology representation has been built.

### 8.10 SAMTE Events

In this section, we describe the events related to SAMTE (described in section 7.8). These are defined in the schema available at

http://totem.run.montefiore.ulg.ac.be/Schema/SAMTE-Scenario-v1_0.xsd.

### 8.10.1 generateCPL

This event extends ASEventType. It has five optional attributes: nbPath and maxDepth (which are ints), verbose (which is a boolean), fileName (which is a string) and type (which must be SINGLE_PATH). Note that the default value of nbPath and maxDepth is 5, the default value of verbose is false and the default value of fileName is cpl.txt.

This event can be used to generate a candidate path list. nbPath specifies the number of path to generate for each pair of nodes. maxDepth is the maximal size of the paths in term of number of hops. verbose set to true will print more details about the simulation. fileName specifies the file to store the candidate path list. type has now to be set to SINGLE_PATH but could be used differently in future releases.

### 8.10.2 SAMTE

This event extends ASTMEventType. It accepts one optional sub-element simulatedAnnealing (defined in section 8.10.3) and four optional attributes: nbRun and nbLSP (which are ints), cplName (which is a string) and verbose (which is a boolean). Note that the default value of nbRun and nbLSP is 5, the default value of verbose is false and the default value of cplName is cpl.txt.

This event launch the execution of SAMTE. In simulatedAnnealing element, you can specify the parameters of simulated annealing meta-heuristic. nbRun specifies the number of times you want to execute SAMTE (I suggest to start with 1). nbLSP is the number of LSP you want to install in the network. cplName specifies the Candidate path list file to use. verbose can be set to true to print more information about the simulation.

### 8.10.3 simulatedAnnealing

This element accepts three optional sub-elements: objectiveFunction (defined in section 8.10.4), neighbourhood (which must contain ONE_CHANGE) and initialSolution (which must contain RANDOM).

It also has five optional attributes: T0 (which is a float), alpha (which is a float $\in [0, 1]$), L, E and K (which are ints).

The default value of L and K is 5, the default value of E and T0 is 10 and the default value of alpha is 0.8.

objectiveFunction specifies the objective function used in the algorithm. neighbourhood specifies the neighborhood to search into (only one choice for the moment) and initialSolution specifies how to compute the initial solution (also only one choice for the moment).

T0 is the initial temperature, alpha is the cooling factor, L is the size of the plateaus, and finally, E and K are the parameters of the stopping conditions. The algorithm stops if there are less than E % of accepted moves during the last K plateaus.

### 8.10.4 objectiveFunction

This element accepts an unbounded number of param sub-elements defined in section 8.1.2. It also has one required attribute name which can be MAX_LOAD or LOAD_BAL.

MAX_LOAD can be used for the objective function $\max_{a \in A} u_a$, if $A$ is the set of links of the network and $u_a$ is the utilisation (in %) of link $a$. LOAD_BAL is the objective function $\sum_{a \in A}(u_a - u_{mean})^2 + \alpha \sum_{a \in A}(u_a)^2$ if $u_{mean}$ is the mean link utilisation ($u_{mean} = \frac{1}{\|A\|} \sum_{a \in A} u_a$).

| Parameter | Meaning | Values |
|---|---|---|
| BRITE-specific parameters | | |
| topologyType | Type of topology | "1 Level: AS Only"<br>"1 Level: Router (IP) Only"<br>"2 Level: Top-Down"<br>"2 Level: Bottom-Up"* |
| topLevelModel | Model for the top level | "Waxman"<br>"Barabasi-Albert 1"<br>"Barabasi-Albert 2"<br>"GLP"* |
| bottomLevelModel | Model for the bottom level | "Waxman"<br>"Barabasi-Albert 1"<br>"Barabasi-Albert 2"<br>"GLP" |
| edgeConnectionModel | See BRITE manual | "Random"<br>"Smallest-Degree"<br>"Smallest-Degree NonLeaf"<br>"Smallest k-Degree" |
| k | See BRITE manual | integer |
| groupingModel | See BRITE manual | "Random Walk"<br>"Random Pick"* |
| asAssignment<br>interBWDist<br>intraBWDist | See BRITE manual | "Constant"<br>"Uniform"*<br>"Exponential"<br>"Heavy Tailed" |
| numAS | See BRITE manual | integer (def.: 9) |
| interBWMax | See BRITE manual | float (def.: 20000) |
| interBWMin | See BRITE manual | float (def.: 10000) |
| intraBWMax | See BRITE manual | float (def.: 1000) |
| intraBWMin | See BRITE manual | float (def.: 500) |
| topHS | See BRITE manual | integer (def.: 10) |
| topLS | See BRITE manual | integer (def.: 1) |
| topN | See BRITE manual | integer (def.: 15) |
| topNodePlacement | See BRITE manual | "Random"*<br>"Heavy Tailed" |
| topGrowthType | See BRITE manual | "All"*<br>"Incremental" |
| topPreferentialConnectivity | See BRITE manual | "None"*<br>"On" |
| topAlpha | See BRITE manual | float (def.: 0.42) |
| topBeta | See BRITE manual | float (def.: 0.65) |
| topM | See BRITE manual | integer (def.: 2) |
| bottomHS | See BRITE manual | integer |
| bottomLS | See BRITE manual | integer |
| bottomN | See BRITE manual | integer |

Table 8: Topology generation parameters (default values have an asterisk) (part 1).

| Parameter | Meaning | Values |
|---|---|---|
| BRITE-specific parameters | | |
| bottomNodePlacement | See BRITE manual | "Random"<br>"Heavy Tailed" |
| bottomGrowthType | See BRITE manual | "All"<br>"Incremental" |
| bottomPreferentialConnectivity | See BRITE manual | "None"<br>"On" |
| bottomAlpha | See BRITE manual | float |
| bottomBeta | See BRITE manual | float |
| bottomM | See BRITE manual | integer |
| General parameters | | |
| mustBeConnected | Topology connected or not | boolean (def.: "true") |
| mustBeDualConnected | At - two links per node | boolean (def.: "true") |
| metric | The metric to use | "Hop count"<br>"Inverse of BW"* |
| numTopologies | The number of topologies | integer (def.: 1) |
| topologyPrefix | The prefix of the files | string (def.: "topo") |
| tmpDirectory | Temp. dir. to use | string (def.: home directory) |
| fileName | Name of the zip file | string (def.: "~/topology.zip") |

Table 9: Topology generation parameters (default values have an asterisk) (part 2).

| Parameter | Meaning | Values |
|---|---|---|
| numTrafficMatrices | Nb of traffic matrices | integer (def.: 1) |
| trafficMatrixPrefix | The prefix of the files | string (def.: "TM") |
| trafficFraction | Frac. of nodes generating traffic | float (def.: 1) |
| trafficModel | Traffic model to use | "Synthetic traffic"<br>"Gravity model"* |
| syntheticTraffic-Distribution | The distribution of the synth. traffic model | "Bimodal"<br>"Constant"<br>"Normal"<br>"Poisson"<br>"Uniform (float)"<br>"Uniform (integer)" |
| gravityScalingConstant | The scaling constant of the gravity traffic model | double (def.: 0.000001) |
| gravityFrictionFactor | The friction factor of the gravity traffic model | "Distance"<br>"Probability Distribution"* |
| gravityFrictionFactor-Distribution | The distribution of the friction factor | "Bimodal"<br>Constant"<br>"Normal"<br>"Poisson"<br>"Uniform (float)"<br>"Uniform (integer)"* |
| bimodalMean1 | First mean of the bimodal distribution | double |
| bimodalMean2 | Snd. mean of the bimodal distribution | double |
| bimodalStddev1 | First std. dev. of the bimodal dis. | double |
| bimodalStddev2 | Snd. std. dev. of the bimodal dis. | double |
| bimodalCoinFlip | Coin flip of the bimodal dis. | double |
| constant | Constant of the constant dis. | double |
| normalMean | Mean of the normal dis. | double |
| normalStddev | Std. dev. of the normal dis. | double |
| poissonMean | Mean of the Poisson dis. | double |
| uniformFloatLower | Lower bound of the unif. float dis. | double |
| uniformFloatUpper | Upper bound of the unif. float dis. | double |
| uniformIntLower | Lower bound of the unif. integer dis. | long (def.: 15) |
| uniformIntUpper | Upper bound of the unif. integer dis. | long (def.: 25) |
| path | Target directory | string (def.: home dir.) |
| generateOnlyEdgeTraffic | if true, generate only traffic for edge nodes | boolean (def.: false) |

Table 10: Traffic matrix generation parameters (default values have an asterisk).

# 9 GUI

The toolbox is also shipped with a *Graphical User Interface*. This section illustrates the use and the functionnalities of the GUI.

## 9.1 Domain loading and unloading

Probably the first thing you want to do is to load a domain. This can be done by selecting the "Load Topology" item in the "File" menu (or by pressing Alt+L). The topology must be a "good" topology, i.e. a instance of the topology XML schema (see section 3) and no domain with the same ASID shall already be loaded.

Once the domain is loaded, it becomes automatically the default domain, i.e. the domain that is displayed in the right part of the TOTEM main window. The tabbed tables (located on the bottom part of the window) shows the links, nodes and LSPs attributes of the current default domain. It is also possible, via the "View" menu, to display those tables (representing links, nodes and lsps properties) in new windows. Note that those windows won't follow a change of the default domain, on the contrary of the tabbed tables which are always displaying default domain information. Right clicking on the columns headers displays a menu that allows columns to be shown or hidden (see figure 4). Note that some columns are not displayed by default. You can change the column display order by dragging the column header.

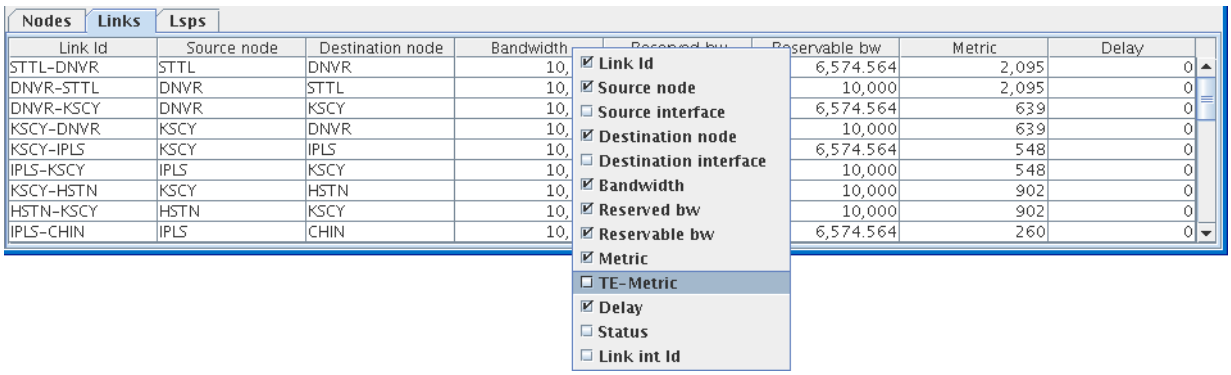



Figure 4: You can select which columns are displayed

The menu items "Network stats" and "Load Tables" under the "View" menu give more information about the loaded domain and its resource usages. The information concerns the MPLS reservation as well as the calculated loads. "Network stats" gives domain-wise statistics and "Load Tables" per link information.

You can see the loaded domains by looking at the "Domains" menu (see figure 5). Every loaded domain is an item in that menu and you can change the default domain by simply clicking on the correpsponding item. The "Domain Manager" (see figure 6), which is accessible from the same menu, displays the domain description and can be used to unload domains or change default one.

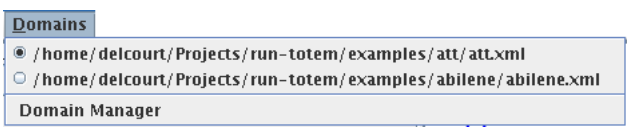



Figure 5: Domains Menu

Finally, you can save the domain by selecting "Save topology as..." from the "File" menu. Note that you won't be prompted to save a modified domain that you are closing. If you want to save your changes in a file, you must do it explicitly.

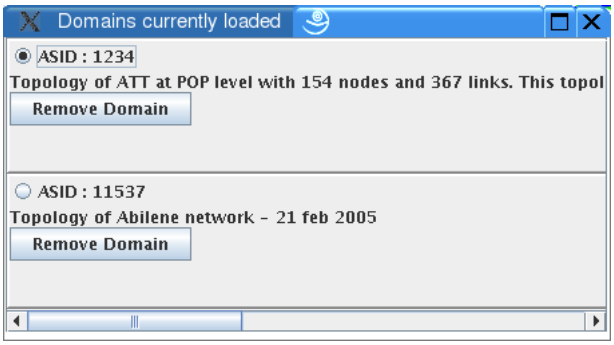



Figure 6: Domain Manager

## 9.2 Manipulating graph

The right part of the main window displays the current default domain. The nodes can be moved by dragging them. Once the nodes has been moved, their latitude and longitude can be updated by clicking on the small button located in the bottom right corner of the visualization panel (between the two scrollbars). Note that when the domain is saved, the node positions are automatically updated.

Clicking outside a node and dragging will select multiple nodes. The graph can be zoomed with mouse wheel. There are two kinds of zoom modes : one won't change the size of nodes, labels and links, so a more detailed view will be displayed when zooming. The other is proportional zoom. It has to be used when graph items (labels, nodes, links) should be drawn in bigger size. Proportional zoom is obtained by holding down the control key and using mouse wheel. The control key is also used to move the graph inside the window to display a specific part (panning). Leaving the mouse on a node or link during a short period of time will result in a tooltip display, showing useful information about the element under the mouse pointer (see figure 7).

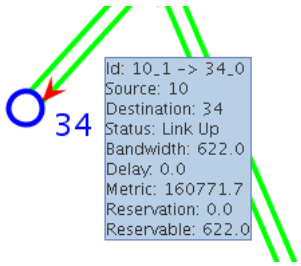



Figure 7: Link information

You can also change the appearance of the represented graph by selecting one of the pre-defined layouts from the "Layout" submenu from the "View" menu.

Right clicking on the graph window displays a contextual menu whose content is different if the click is made on a link, a node or somewhere else. Table 11 summarizes the actions that can be performed from contextual menus.

The links colors and their meaning can be freely chosen You can choose in which color should the links be displayed and what is the meaning of the colors. The legend located on the left side

| Click location | Menu elements | Action description |
|---|---|---|
| Node | set Node UP/DOWN<br>View BGP Info<br>View Routing Table | Enable/Disable the node<br>see section 9.12<br>see section 9.12 |
| Link | set Link UP/DOWN<br>Change Link Bandwidth | Enable/Disable the link<br>change the link capacity |
| Anywhere else | add LSP<br>Save as Image... | Pop up the Add LSP dialog (see section 9.4)<br>Save the window content as an bitmap image (png, bmp or jpg) |

Table 11: Contextual menus from graph window

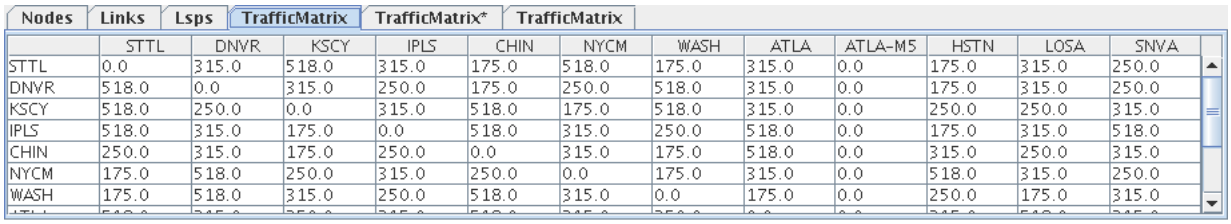
of the main window shows the colors that are currently displayed on the graph. From the panel straight above, you can choose the color meaning: you can display the link status (link up or down) by selecting "Link status" or the MPLS reservation by selecting "Reservation". It is also possible to display the relative load of the links resulting from traffic matrix routing (see section 9.5).

You can change the colors of the displayed legend by selecting "Choose Link colors" from the "View" menu. Changing the colors for the reservation or the load will lead to a change for both reservation and loads. Note that the colors for the link status can be independently changed.

## 9.3 Using traffic matrices

You can load a traffic matrix from the "Load Traffic Matrix" item of the "Traffic Matrix" menu (shortcut: Alt+M). The matrix must be an instance of the Traffic Matrix XML schema (see section 4) and must correspond to one of the loaded domain.

The loaded traffic matrices can be seen in the tabbed tables on the bottom of the main window, where a new tab is added for each loaded traffic matrix relative to the default domain. The domain can have a default traffic matrix, which is identified on the tab label by a * following the word TrafficMatrix (see figure 8). You can also manage traffic matrices of the current domain by using the TrafficMatrix Manager window. It lists the loaded matrices of the domain and permits to change the default one as well as unload a matrix, or view it in a new window.




| | STTL | DNVR | KSCY | IPLS | CHIN | NYCM | WASH | ATLA | ATLA-M5 | HSTN | LOSA | SNVA |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| STTL | 0.0 | 315.0 | 518.0 | 315.0 | 175.0 | 518.0 | 175.0 | 315.0 | 0.0 | 175.0 | 315.0 | 250.0 |
| DNVR | 518.0 | 0.0 | 315.0 | 250.0 | 175.0 | 250.0 | 518.0 | 315.0 | 0.0 | 175.0 | 315.0 | 250.0 |
| KSCY | 518.0 | 250.0 | 0.0 | 315.0 | 518.0 | 175.0 | 518.0 | 315.0 | 0.0 | 250.0 | 250.0 | 315.0 |
| IPLS | 518.0 | 315.0 | 175.0 | 0.0 | 518.0 | 315.0 | 250.0 | 518.0 | 0.0 | 175.0 | 315.0 | 518.0 |
| CHIN | 250.0 | 315.0 | 175.0 | 250.0 | 0.0 | 315.0 | 175.0 | 518.0 | 0.0 | 315.0 | 250.0 | 315.0 |
| NYCM | 175.0 | 518.0 | 250.0 | 315.0 | 250.0 | 0.0 | 175.0 | 315.0 | 0.0 | 518.0 | 315.0 | 250.0 |
| WASH | 175.0 | 518.0 | 315.0 | 250.0 | 518.0 | 315.0 | 0.0 | 175.0 | 0.0 | 250.0 | 175.0 | 315.0 |

Figure 8: Bottom part of the main window: there are three matrices loaded for the current domain, the second one is the default one (represented by a star *).

## 9.4 MPLS routing

### 9.4.1 Adding a primary LSP

Once a domain is loaded, you can compute LSPs and add them to the domain. Click on the "Routing" menu, then "Add Primary Lsp". The "Add LSP" dialog is displayed (see figure 9) and invites you to give lsp parameters such as ingress and egress nodes, lsp bandwidth, the algorithm to

compute the path and some additional algorithm-specific parameters. It is also possible to specify the id of the new lsp. If it is not specified, it'll be automatically generated. Finally, you can change the default Diffserv parameters by expanding the corresponding panel. There, either the priority identifier either the class type and preeemption levels can be specified. Note that if the panel if retracted, the default Diffserv parameters will be used (least preemption level, lowest class type value).

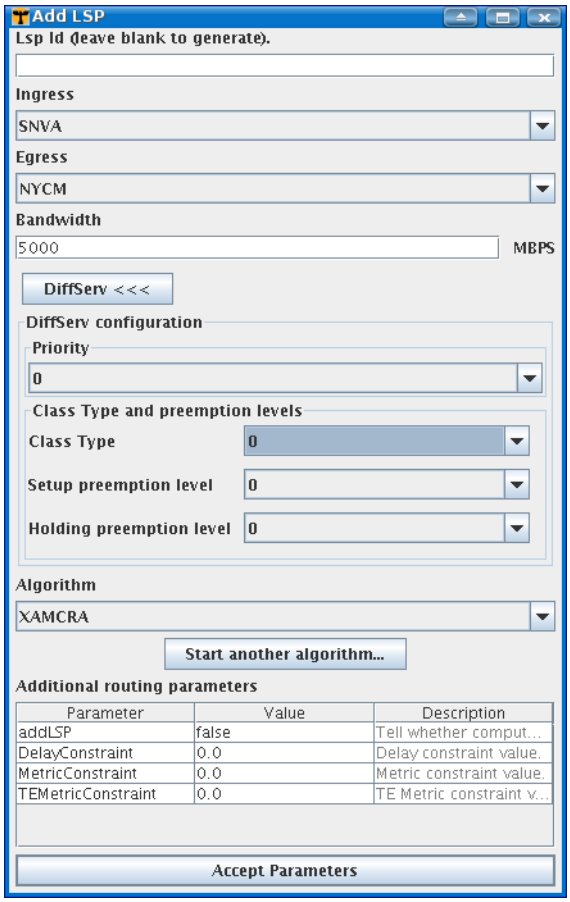



Figure 9: add LSP dialog window

The algorithm combobox shows all the started algorithms compatible with the current default domain. Some algorithm uses an internal topology database (such as XAMCRA, MIRA, DAMOTE,...) while others don't. These ones can be used only on the domain on which they were started. So the combobox displays all the started generic algorithms and the algorithms with a local database that were started on the domain.

**Important note:** If you modify the topology (removing/adding nodes or links, changing link bandwidth), it is preferable to stop and restart the algorithms in order to rebuild the internal database. Indeed, these cases had not been tested thoroughly with all the algorithms, so it might lead to unexpected results.

If you have not started an algorithm on the domain yet – or you want to use another one –, click on the "start another algorithm..." button. There, you are proposed with a list of all the available algorithms (see figure 10). You can choose from that list and tune the parameters relevant for the chosen algorithm. Note that some algorithms have no parameters at all. It is notably the case for all the CSPF algorithms.

Once you click the "Start Algorithm" button, the algorithm is started. You can see all the

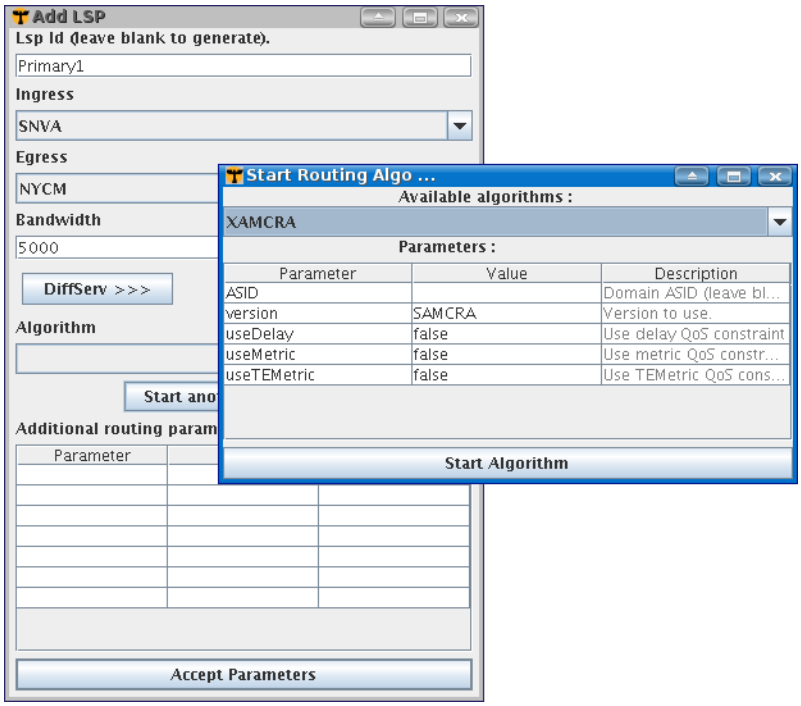



Figure 10: Start an algorithm

started algorithm and their parameters in the algorithm manager (see figure 11), accessible from the "Algorithms" menu.

Note that when you close a domain (by choosing "close Topology" from the file menu or via the domain Manager), the algorithms that are specific to the domain are also stopped.

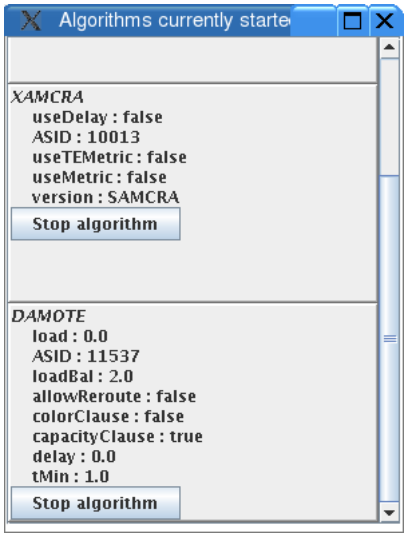



Figure 11: Algorithm Manager

### 9.4.2 Adding a detour Lsp

Since TOTEM version 2.2, the GUI includes the possibility to compute detour lsps (backup paths). This can be achieved by selecting "Compute Detour Lsp" from the "Routing" menu (see figure 12).

The dialog allows you to specify an id for the new lsp, to choose the lsp to protect, the detour type (local or global), the protection type, the algorithm and its parameters. Among the algorithms shipped with the toolbox, DAMOTE and CSPF algorithms are able to compute backup paths.

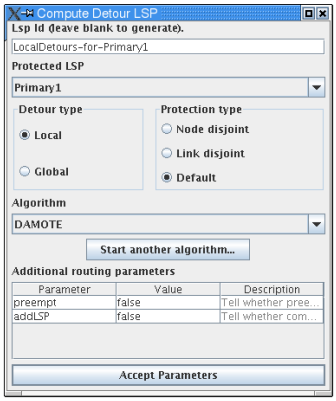



Figure 12: Add Detour Lsp dialog

If local backup is selected, you can choose if the calculated paths should protect the primary lsp from nodes or from links failures. The last option of the protection type category ("Default") lets the algorithm choose the parameter value for you. Note that DAMOTE doesn't take this parameter into account at all: it always tries to protect the downstream link AND the downstream node. If the downstream node cannot be protected, only the link will be.

### 9.4.3 Computing a fullmesh

The GUI also offers the possibility to compute a fullmesh of LSPs on a domain. The *modus operandi* is quite the same as for adding a single LSP. The only differences are that you mustn't provide the source and destination nodes as it is a fullmesh and that you must specify a traffic matrix instead of the bandwidth of the LSP.

You can access the fullmesh dialog (see figure 13) via the "Apply Full Mesh" item from the "Routing" menu. The dialog won't open if no traffic matrix is loaded for the default domain. The dialog allows you to choose the algorithm to use to route the LSPs, the traffic matrix from which the lsps bandwidth will be derived, the diff-serv parameters and the algorithm-specific parameters. You can also choose the LSP establishment order (Decreasing bandwidth, increasing bandwidth or shuffle). After accepting the parameters by clicking the "compute" button, you will be prompted to choose between adding the fullmesh while keeping existent LSPs or adding the fullmesh after removing all the LSPs already existing in the domain.

## 9.5 IP routing

You can route a traffic matrix on the network, simulating IP routing. From the routing menu, select "IGP Routing". From there you can select the metric to use, the IP strategy, the traffic matrix and options (see figure 14).

You can choose from different metric that can be used by the shortest path algorithm (see also 7.1). These are :

- Metric which is the IGP weight of the link
- TE-Metric which is the TE weight of the link
- Inv. Capacity which is the inverse of the link capacity

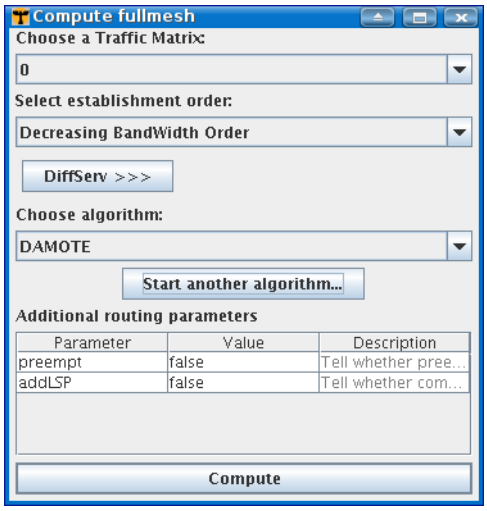



Figure 13: The computation of a fullmesh requires that you load a traffic matrix which provides the bandwidth of the LSPs to compute.

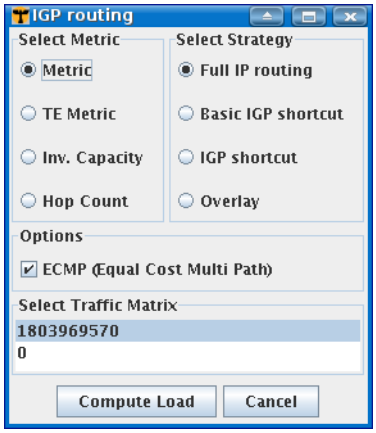



Figure 14: IGP routing dialog.

- HopCount which is 1 for each link

You can choose from the following IP strategies:

- Full IP routing which simulates normal IP routing.
- Basic IGP shortcut which is an hybrid IP/MPLS model
- IGP shortcut which is also an hybrid model.
- Overlay strategy which is also an hybrid model.

You can find more information about these strategies in the paragraph describing `ShowLinkInfo` event (8.5.4).

You can also choose to use ECMP (Equal Cost Multi Path) or not. If you tick the ECMP checkbox, the calculated traffic will be split over all paths of equal metric. If not checked, the traffic will take an arbitrary chosen path among all the equal cost paths of minimum cost.

Once the load is calculated, an entry will be added to the panel where you can choose what the link colors represents (on the left side of the screen). On this panel, you can choose to display the

link reservation, the link status (up and down links) and one of the calculated load (see figure 15). Note that the calculated load will try to be up-to-date with the current state of the network. That is, if you set a link down, the load will be computed again next time you display it on the graph (or immediately if it is currently displayed). Note that if you close a traffic matrix, all the links load calculated thanks to this matrix will disappear from the panel.

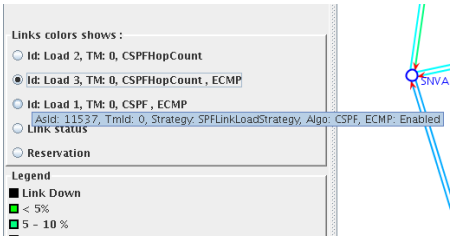



Figure 15: You can display the calculated load by selecting it in the panel. The tooltip gives all the information about the calculated load it represents.

## 9.6 Optimizing link Weight with IGP-WO

It is also possible to optimize link weights from the GUI thanks to IGP-WO algorithm (see section 7.7). To start IGP-WO weight optimization, you must load a domain and a traffic matrix for that domain. Starting IGP-WO is done via the "IGP-WO" menu by selecting "Optimize Link Weight...". A dialog where you can tune the algorithm parameters is displayed and filled with default values (see figure 16). You may also want to select different traffic matrices to use in the computation. The loaded traffic matrix ids are displayed in a listbox and you can select multiple ones by pressing and holding the control key while clicking on the matrix ids. Pay attention to the fact that the calculation may require a long amount of time to perform. For now, it is not possible to cancel the operation. After the calculation is completed, the new optimized metric values are put in the TEMetric property of the links, and displayed on the graph next to the corresponding links. Also, a report is generated by IGP-WO during computation and displayed in a window after the calculations are done. You can save the report as a text file for futur use. It is also possible to consult the lastly generated report via the "View last report" item of the "IGPWO" menu. The last report is in fact located in the text file named "IGP-WO-output.txt" in the Totem root folder.

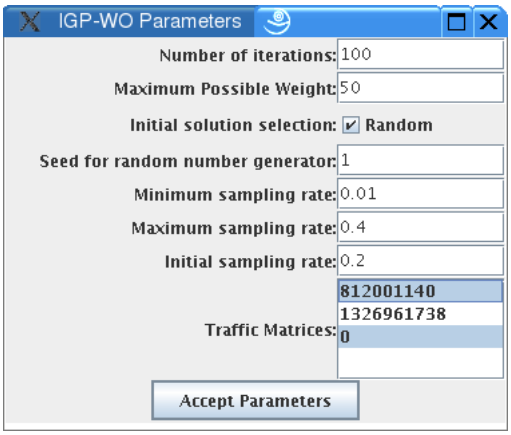



Figure 16: IGPWO dialog: you can select multiple traffic matrices for computation.

## 9.7 Executing a scenario

The Totem graphical interface allows you to load a scenario and take control on its execution process and see the step by step results graphically.

A scenario file (see section 8) can be loaded from the "Execute scenario" item of the "Scenario" menu. The loaded scenario is then shown in a new window with a hierarchical structure reflecting the XML document content (see figure 17).

The window is divided into two parts: the top part represents the scenario hierarchical structure and the bottom one is a text area that displays the results and the error messages coming from event execution.

The window is also decorated with three buttons : Step, Advance to selection and Finish Execution. The action of the first button is to execute the next event in the scenario. The second one executes all the events until and including the selected one. The last one execute all the remaining events until the end of the scenario. As you can see on picture 17, the events that are correctly executed appears in green and those that led to an execution error are displayed in red. Note that it is impossible to undo execution of an event or to rollback the scenario.

At the very bottom of the window, there is a checkbox named "Stop on error". If it is checked, the execution will stop on the first error and an error dialog message will be displayed. Otherwise, the error will be ignored and the scenario will continue to execute.

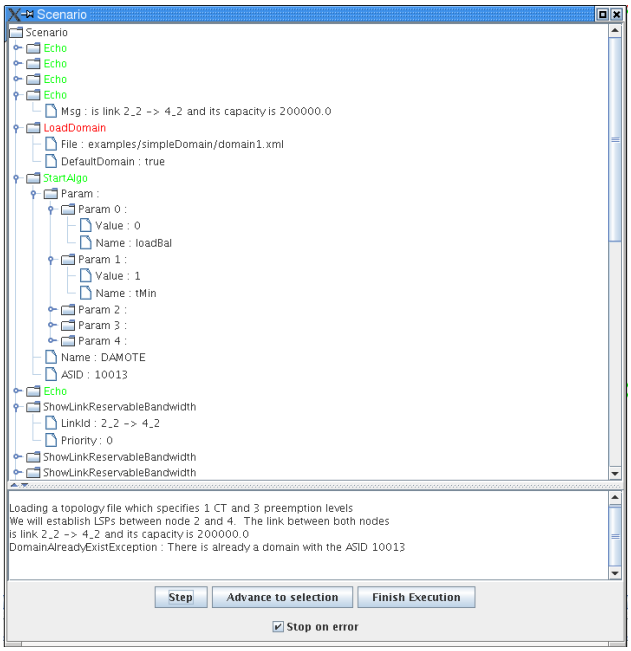



Figure 17: Load a scenario and execute it step by step.

**Important note:** If you close the window before finishing scenario execution, you can't get the rest of the scenario executed.

## 9.8 Console

If you want to have more detailed information about what is going on in the toolbox, you can display the console (by selecting "Console" from the "View" menu). The console displays what should normally go on the standard and error output in addition to more detailed logging information. You can choose the level of logging information to display in the console by selecting one

of the item (DEBUG, INFO, WARN, ERROR, FATAL) from the combobox located on top of the console window (see figure 18).

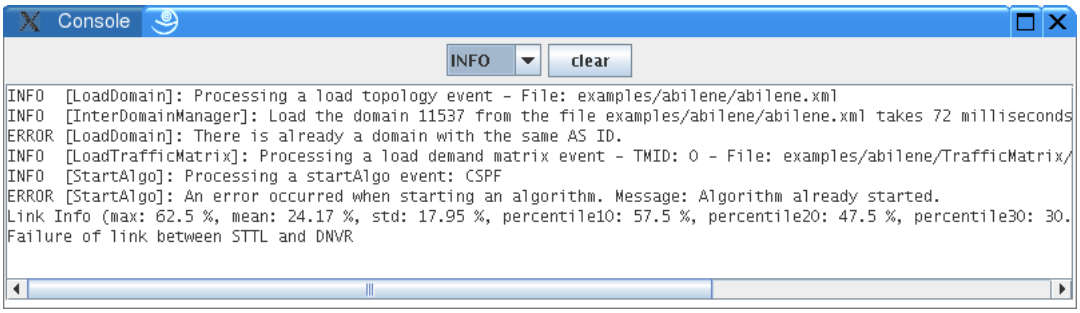



Figure 18: Console displaying part of a scenario execution output.

Note that when you close the Console window, the standard output and error output are displayed where they were before you open the window console.

## 9.9 SAMTE

SAMTE is a hybrid IP/MPLS optimization algorithm. The description of the algorithm and its parameters can be found in the section 7.8.

You can start SAMTE after loading a traffic matrix, by clicking "SAMTE..." from SAMTE menu of the main window. You first have to specify candidate path list parameters such as the the maximum number of hops of the solution (MAX_HOP) and number of sortest path that are taken into account (NB_SHORTEST_PATH). On the same dialog, you can also choose the traffic matrix to use and the number of LSPs to establish (Max Lsp). After accepting those parameters you will have a dialog that permit searching for SAMTE solutions (see 19). Tune the parameters according to your wishes (on the left part of the dialog) then click on "Execute SA" to start SAMTE heuristic. You will see on the right part of the dialog a graph representing the evolution of the solution. If the solution found satisfies your needs, you may want to display it by clicking the "Display solutions" button. You will have a list of the LSPs found by SAMTE and you can establish them in the network if you wish to.

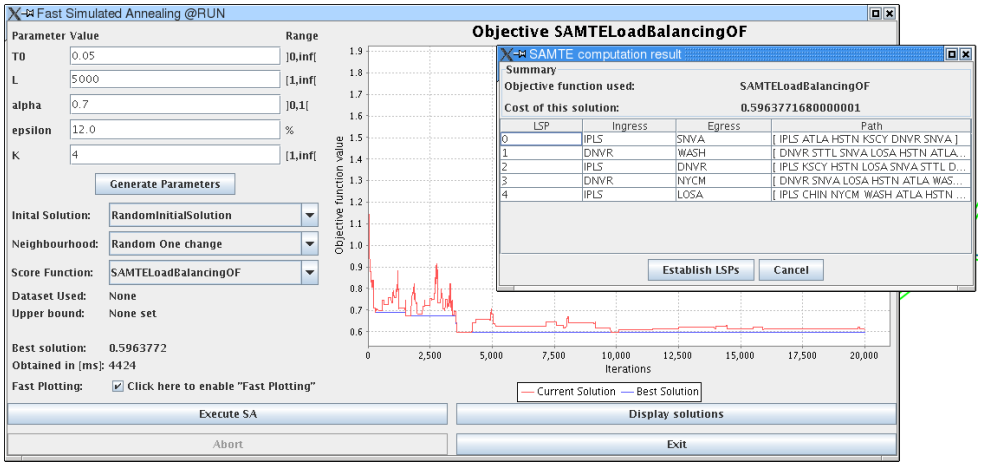



Figure 19: SAMTE main window and solution dialog.

You can display the load on the links when using the established LSPs by starting IGP routing with strategy set to one of the hybrid strategy, i.e. Basic IGP shortcut or IGP shortcut.

## 9.10 What-if scenario

The What-if menu helps you to see the changes made on a domain in reaction to a (set of) specific event(s). For now, only two sorts of events can be simulated by this mean: Link failure/Repare Link events and change Traffic Matrix events. Once you have chosen the events you want to simulate, you can see the result on the network as tables of values and as charts.

The "What-If" menu contains an item for each event that you can simulate ("Link Failure" and "Change TrafficMatrix") and an item that allows you to combine multiple of these events ("Compose Events").

In order to simulate a link failure, you must first load a domain and a traffic matrix as the default one for that domain. Then, click on the "link failure" menu item, choose the link you want to see down and choose the characteristics that you want to observe on the domain (only the load can be observed for now). The link (and the reversed one) will be disabled, so the load on the other links will be increased to keep in accordance with the loaded traffic matrix. You can see the effect of the link failure on the report that is generated.

You can also compare the difference of load on the links of the domain between two different traffic matrices. To simulate a change of traffic matrix, you must have at least two traffic matrices loaded for the domain. The default one is the initial one and you can choose the final one from the dialog.

The last thing you can do is to create a scenario composed with multiple events of the two kinds described above. This is done by selecting and adding the events you want to a list that represent the generated scenario.

Each of the What-if scenario executions will result in the display of a report (see figure 20) that shows the initial and final load for all links of the domain as well as some aggregation of these values (such as max, mean, standard deviation and percentile10). The report also contains a "show charts" button that displays two charts, each of them comparing the load before and after the simulated scenario. You can then right click on the charts to access some functionnalities and properties of the graph (saving, printing, zooming, changing titles, changing appearance, ...).

## 9.11 Creating Charts

The interface of the GUI for chart creation functions quite the same way as in the scenario XML files (see section 8.6).

As already said, the chart creation process is divided into 3 steps : Create the chart by selecting a data collector and its parameters, add series of data to the chart and plot the chart.

To create a chart from the GUI, go in the chart menu then select "New chart...". You are then proposed to give an identifier, to choose a data collector among those available and to tune the collector-specific parameters. After accepting, a new Chart object is created internally. However, no data represents the chart : you just specified which sort of data your chart will be able to receive. Now that your chart is created and that you have specified a collector, it’s time to add some data series. Go on the "Charts" menu again, you should be able to see the chart identifier you give as a sub-menu (see figure 21). By selecting "Add series..." from the sub-menu, a new series of data will be added to the chart. You are prompted to enter a series name and eventually to tune some parameters, specifying how the data will be collected by the collector. Series name identifies the data series and will be used on the chart legend. Note that the series name should be unique.

Draw the chart by selecting "Plot..." from your chart menu. You can then enter the general title of the chart, the axises title and you can select a plotter and its parameters. The plotter is in charge of creating a specific chart representation given the data. After acceptance of the parameters, the chart representation is generated and displayed in a new window. From there, you can right click

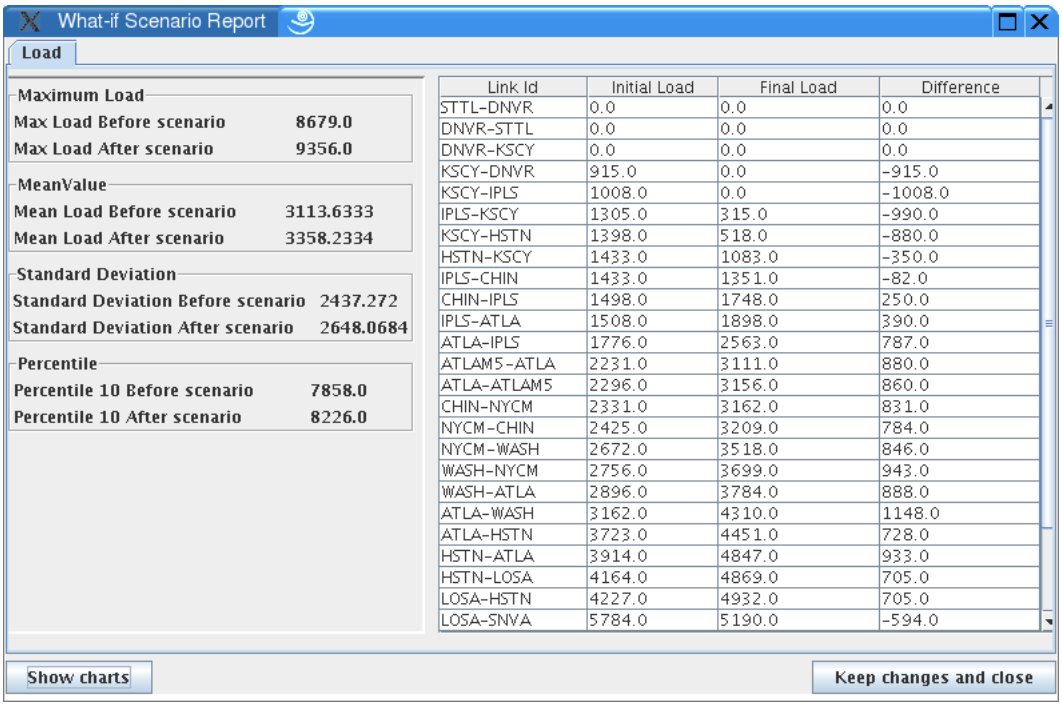



Figure 20: What if scenario report.


Figure 21: Chart menu with two charts created.

to get a contextual menu (see figure 22) where you can do various operation on the chart such as saving, printing, changing appearence, zooming, ...

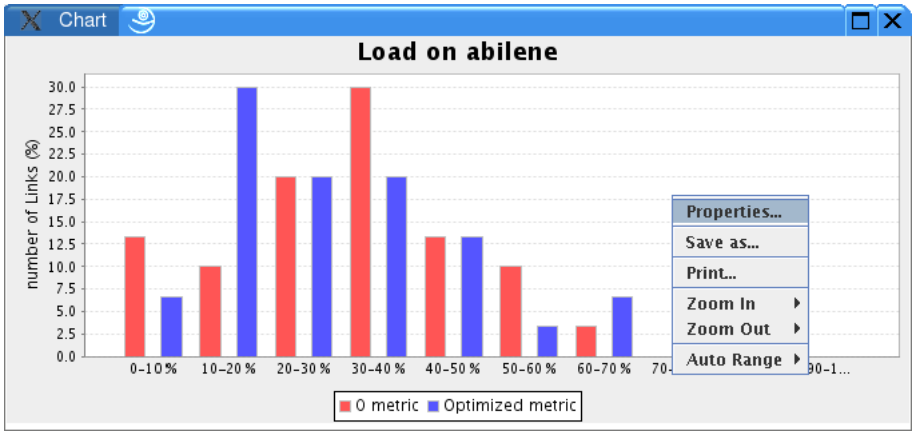



Figure 22: Chart sample with contextual menu.

You can always view the last chart that you plot by selecting "View last plot" from the cor-

responding chart sub-menu. Until you remove the chart (by selecting "Remove chart"), you can always add new data series and replot the chart possibly using different plotter and parameters.

## 9.12 Using CBGP

CBGP description can be found in section 7.6. CBGP GUI integration was not yet tested thoroughly and might contains some bugs.

Prior to using CBGP, you need to start a CBGP instance by selecting "Start..." from the "Algorithms" menu and choosing CBGP. You can have access to CBGP functionnalities using "CBGP" menu from the main window or by right clicking on a node of the domain.

Examples of XML files that you can use with CBGP are located in `examples/abilene/cbgp` (see README for more info).

More information about CBGP utilisation coming soon.

# 10 Traffic matrix generation using NetFlow traces

This section explains how to use the toolbox to generate traffic matrices from Netflow data. The toolbox includes data from Abilene network to generate an accurate traffic matrix using topology, BGP and NetFlow information. We will first explain the required data formats and needed file/directory structures. We will then explain how to generate an inter-domain traffic matrix from NetFlow traces, and eventually how to produce the corresponding intra-domain traffic matrix.

## 10.1 Required data formats and file/directory structures

One example of BGP information and Netflow traces is available is the archive:
example/abilene/abilene_20050101_bgp_netflow.tar.gz

### 10.1.1 BGP information

You will need a snapshot of the entire BGP RIB of each router. Typically, such information is obtained using an additional monitoring machine running Zebra bgpd which participates in the iBGP full-mesh. Resulting format is Zebra binary MRT dump, which can be converted to ASCII machine readable format using `route_btoa` from the MRTd package (`http://www.mrtd.net`). We have included the tool on the CVS in directory `src/perl/bgp/`.

Typically, the toolbox module expects the following directory structure. Each BGP RIB (converted in ASCII machine readable format using `route_btoa rib_file -m > output`) should be in a directory called `BGPbaseDirectory/router_id/optionaldumpsubdir` or `BGPbaseDirectory/router_rid/optionaldumpsubdir` where router identification information is found exclusively in the XML topology format. Please note that if a router has several ip addresses, these should be added in the XML topology format. For each node, the `rid` field should be filled with router main IP address. If the router has other addresses, you must add an interface for each of them (field `interface` and in particular its subfield `ip`). For a concrete example, see Abilene topology in `examples/abilene/abilene.xml`.

C-BGP has some scalability problems when too much prefixes are passed to it. That's why we use *clustering* which allows to group prefixes announced with same BGP parameters, and to advertise only one of them for each group (cluster). The clustering is done by an ad-hoc perl script, we provide a perl script for Abilene called `bgpsum2.pl`[12] in `src/perl/bgp/`. Here is the command to execute the script `./bgp-sum2.pl -ribs-dir=directory_holding_ribs > clusterFileName`.

### 10.1.2 NetFlow traces

NetFlow traces for each router are also required. The toolbox expects an aggregated text format extracted from the NetFlow traces which is the following

```
src_prefix dst_prefix flow_size
```

Where the flow size is expressed in bytes.

A perl script to generate these aggregated files `netflow2prefixes.pl` [13]is supplied in `src/perl/netflow/`. All required libraries can be found in `src/perl/netflow/perl`. First parameter to give to this script is the directory with the BGP ribs, second parameter is the directory with non aggregated traffic, third one is the directory where aggregated traffic should be

[12] contributed by Steve Uhlig, Bruno Quoitin and Sebastien Tandel, UCL, Belgium
[13] contributed by Steve Uhlig, UCL, Belgium

written, and finally last parameter is the day on which you want to work (example: 2005-01-01). We have also included the necessary flow tools in `src/perl/netflow/flowtools/`

All the aggregated files should be placed in directories following the same structure as BGP dumps.

## 10.2 Traffix matrix generation steps

You can find a typical example of source code doing this in `examples/abilene/AbileneExampleTM.java`. To use it as is, you can move the file to `src/java/be/ac/ulg/montefiore/run/totem/trafficMatrix/`. Otherwise, you have also a scenario event for the traffic matrix creation in itself, see last section.

### 10.2.1 Generating domain BGP information from BGP dump

Information about iBGP and eBGP sessions must be added to the XML topology format. eBGP sessions can typically be extracted from BGP dumps (structured as presented above). The class `BgpFieldsCreation` has two useful methods `addiBGPFullMesh(String topologyName, String iBGPTopologyName)` which will add an iBGP full mesh to a topology file specified by its name, and produce a topology file with added iBGP full-mesh. The second method `addeBGPSessions(String topologyName, String eBGPTopologyName, String BGPbaseDirectory, String optionaldumpsubdir/filename)` will create the eBGP sessions.

### 10.2.2 Creating inter-domain traffic matrix from NetFlow

Starting from the aggregated NetFlow traces, we first generate an inter-domain traffic matrix. The class `InterDomainTrafficMatrixGeneration` has the method `generateXMLTrafficMatrixfromNetFlow(Domain domain, String NETFLOWbaseDirectory, String optionalsubdir/filename, String[] suffixes, String interdomainTrafficMatrixFileName)`. The array `suffixes` can be used to specify potential suffixes for NetFlow file names.

### 10.2.3 Generating intra-domain traffic matrix from inter-domain traffic matrix

From this inter-domain traffic matrix, we can generate an intra-domain traffic matrix. The class `POPPOPTrafficMatrixGeneration` contains the method `HashMap readCluster(Domain domain, String clusterFileName, CBGP cbgpinstance, String BGPbaseDirectory, String optionaldumpsubdir/filename)` that will load BGP messages corresponding to "cluster prefixes" in the CBGP instance and return a hashmap which allows to find to which cluster a prefix belongs, and thus find the route for this prefix. From then on, the method `TrafficMatrix generateTrafficMatrix(TrafficMatrix temporaryTM, HashMap clusters, Domain domain, String interdomainTrafficMatrixFileName)` will generate the intra-domain traffic matrix. The first argument `temporaryTM` allows to add a traffic matrix to an existing one, for example to produce a traffic matrix for 20 minutes when NetFlow files are available for 5 minutes.

## 10.3 Scenario events

We have created one scenario event documentated in the scenario part of this manual `generateIntraTM`. An example of traffic matrix creation on Abilene using scenarios can be found in `examples/abilene/generateIntraTM-20050101.xml`. To test it, just uncompress

the archive `abilene_20050101_bgp_netflow.tar.gz` found in the same directory, and run the scenario using `totem.sh -s` command line.

# A Summary of xml element and attribute types

| Element | Cardinality | Sub-elements | Attributes |
|---|---|---|---|
| domain | [1,1] | info, topology, mpls, igp, bgp | name, ASID |
| info | [0,1] | title, date, author, description | - |
| title | [0,1] | string | - |
| date | [0,1] | date | - |
| author | [0,1] | string | - |
| description | [0,1] | string | - |
| units | [0,1] | unit | - |
| unit | [1,∞[ | - | type, value |
| diff-serv | [0,1] | priority | - |
| priority | [1,8] | - | id, ct, preemption |
| srlgs | [0,1] | srlg | - |
| srlg | [1,∞[ | string | id |
| topology | [1,1] | nodes, links | - |
| nodes | [1,1] | node | - |
| node | [1,∞] | status, rid, name, description, type, location, interfaces | id |
| status | [0,1] | string : UP or DOWN | - |
| rid | [0,1] | string : IP address | - |
| name | [0,1] | string | - |
| description | [0,1] | string | - |
| type | [0,1] | string : CORE or EDGE | - |
| location | [0,1] | - | longitude, latitude |
| interfaces | [0,1] | interface | - |
| interface | [1,∞[ | status, ip | id, mask |
| status | [0,1] | string : UP or DOWN | - |
| ip | [0,1] | string : IP address | - |
| links | [0,1] | link | - |
| link | [1,∞] | from, to, status, description, type, technology, delay, srlgs | id |
| from | [1,1] | - | node, if |
| to | [1,1] | - | as, node, if |
| status | [0,1] | string : UP or DOWN | - |
| description | [0,1] | string | - |
| type | [0,1] | string : INTRA or INTER | - |
| bw | [0,1] | float | - |
| technology | [0,1] | string | - |
| delay | [0,1] | float | - |
| srlgs | [0,1] | srlg | - |
| srlg | [1,∞] | integer | - |

Table 12: Summary of the elements of an XML network file (part 1)

| Element | Cardinality | Sub-elements | Attributes |
|---|---|---|---|
| mpls | [0,1] | lsp | - |
| lsp | [1,$\infty$] | path, bw, metric, max_rate, diff-serv, backup | id |
| path | [1,1] | link | - |
| bw | [0,1] | float | - |
| metric | [0,1] | float | - |
| max_rate | [0,1] | float | - |
| diff-serv | [0,1] | ct, preemption | - |
| backup | [0,1] | protected_lsp, protected_links | |
| link | [1,$\infty$] | string | - |
| ct | [1,1] | integer $\in$ [0,7] | - |
| preemption | [1,1] | - | setup, holding |
| protected_lsp | [0,1] | string | - |
| protected_links | [1,1] | protected_link | - |
| protected_link | [1,$\infty$] | string | - |
| igp | [0,1] | link | type |
| link | [1,$\infty$] | static, dynamic | id |
| static | [0,1] | metric, te-metric, mrbw, mbw, admingroup, diff-serv | - |
| dynamic | [0,1] | rbw | - |
| metric | [0,1] | float | - |
| te-metric | [0,1] | float | - |
| mrbw | [0,1] | float | - |
| mbw | [0,1] | float | - |
| admingroup | [0,1] | integer | - |
| diff-serv | [0,1] | bcm, bc | - |
| bcm | [1,1] | string : MAM or RDM | - |
| bc | [1,$\infty$] | float | id |
| rbw | [1,1] | priority | - |
| priority | [1,8] | float | id |

Table 13: Summary of the elements of an XML network file (part 2)

| Attribute | Element | mandatory | type |
|---|---|---|---|
| name | domain | No | string |
| ASID | domain | Yes | integer |
| type | unit | Yes | {delay, bandwidth} |
| value | unit | Yes | {ns, $\mu$s, ms, s, bps, kbps, mbps, gbps} |
| id | priority | Yes | Integer $\in [7, 0]$ |
| ct | priority | Yes | Integer $\in [7, 0]$ |
| preemption | priority | Yes | Integer $\in [7, 0]$ |
| id | srlg | Yes | Integer |
| id | node | Yes | string |
| longitude | location | Yes | float |
| latitude | location | Yes | float |
| id | interface | Yes | string |
| mask | interface | Yes | IP mask (X.X.X.X/Y) |
| node | from | Yes | string |
| if | from | No | string |
| as | to | No | integer |
| node | to | Yes | string |
| if | to | No | string |
| id | lsp | Yes | string |
| setup | preemption | Yes | integer $\in$ [0,7] |
| holding | preemption | Yes | integer $\in$ [0,7] |
| type | igp | No | string : ISIS or OSPF |
| id | link | Yes | string |
| id | bc | Yes | integer |
| id | priority | Yes | integer $\in$ [0,7] |

Table 14: Summary of the attributes of an XML network file

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