TOTEM: A TOolbox for Traffic Engineering Methods

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***Abstract*— In this document, we propose a demonstration of TOTEM, a TOolbox for Traffic Engineering Methods. This toolbox integrates a series of tools for intra-domain and inter-domain traffic engineering of IP and MPLS networks. It provides an open source software that allows an operator to test methods coming from the academic research. A researcher can also use the toolbox to compare and promote new TE algorithms. The toolbox is designed to be deployed either as an on-line tool in an operational network, or as an off-line traffic engineering simulator.**

I. Introduction

Today, a simple and classical way to provide Quality of Service (QoS) in a network is to overprovision it. To deal with increasing bandwidth requests and to meet some specific QoS or Service Level Agreement (SLA), this approach is less and less tenable economically. One alternative way is to deploy traffic engineering techniques. This is not so simple. Indeed, most of the problems encountered in this field are huge in size and combinatorial, which implies to find efficient heuristics.

Research in the traffic engineering field has already been carried out for some years. Solutions exist, but few of these are actually used by operators to manage their network. One reason is that these methods are specifically implemented for research and simulation purpose. It is considered difficult to integrate these methods in an operational environment. The main objective of our TOTEM toolbox ([1]) is to reconcile the academic and the operational worlds by providing interoperable and user-friendly interfaces with existing tools. This open source toolbox can also be used by a researcher whose objective is to test, compare and promote his/her own research.

The design of the toolbox also allows different utilisation modes. It can be deployed either as an on-line tool in an operational network or as an off-line traffic engineering simulator. Moreover, a large variety of traffic engineering methods can be integrated. These methods can be classified with respect to different axes like intra-domain or inter-domain, on-line or off-line, IP or MPLS (Multi Protocol Label Switching) [2], centralised or distributed.

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This document is structured as follows. In section II, we briefly present TOTEM, its software architecture and the included algorithms. Then, in section III, we outline the content of the proposed demonstration.

II. Presentation of TOTEM

We will first describe the main TE algorithms shipped with TOTEM and then its software architecture.

A. Main TE algorithms shipped with TOTEM

First, there are some basic algorithms which can be used as a starting point for comparison purposes or as building blocks of more complex methods. These basic algorithms are Dijkstra's shortest path algorithm, Constraint Shortest Path First algorithm (CSPF), K shortest disjoint paths ([3]) and "all distinct paths" (this algorithm computes all the distinct acyclic paths between a pair of nodes, with a possible upper limit on the number of hops of the returned paths).

IGP-WO (*Interior Gateway Protocol-Weight Optimisation*) is a tool whose goal is to find a link weights setting in the domain for near optimal load balancing. It provides a routing scheme adapted to one or several traffic matrices (a traffic matrix gives for each `(origin, destination)` pair the amount of traffic flowing from the `origin` to the `destination`). For more information about IGP-WO, see [4], [5].

We also have a tool called DAMOTE (Decentralised Agent for MPLS Online Traffic Engineering) [6], [7]. It is a routing algorithm whose purpose is to compute LSPs under constraint. DAMOTE is more sophisticated than a mere CSPF algorithm. The difference is that DAMOTE finds the path of an LSP that minimizes a given objective function under bandwidth constraints. Examples of such objective functions are: resource utilisation (DAMOTE operates as a CSPF with a hop-count metric in this case), load balancing, hybrid load balancing (where long detours are penalised), preemption-aware routing (where induced reroutings are penalised). The score function and the constraints are parameters: DAMOTE is quite generic in many aspects. DAMOTE computes in an efficient way a near optimal solution. Finally, DAMOTE can also compute backup LSPs while minimizing the bandwidth consumption required for this protection [8], [9].

TOTEM also includes an hybrid IP/MPLS optimisation 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 optimisation (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 allow a researcher to validate/invalidate new TE approaches, we have a tool called Topgen to generate random topologies and traffic matrices on these topologies. Indeed, many operators refuse to communicate information about their network and so researchers have to generate test cases to assess their algorithms. Topgen is suitable for this purpose. It uses the well-known topology generator BRITE [10] and several probability distributions to generate traffic matrices.

C-BGP brings to TOTEM a Border Gateway Protocol (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 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 details concerning C-BGP can be found in [11].

Note that all these algorithms can interact together thanks to TOTEM, as we see in section II-C (an example of this interaction can be found in [12]).

B. Software architecture of TOTEM

While keeping good performance, the software architecture has to satisfy the following objectives: minimise the integration work of a new algorithm in the toolbox, provide interoperable interfaces making possible the collaboration with other existing tools, provide different execution modes (on-line/off-line and centralised/decentralised) and allow the collaboration of algorithms written in different languages.

The toolbox is developed in Java to benefit from the flexibility and object oriented abstraction level of this langage, but also for the many libraries dealing with XML, graphs, etc. Moreover, the JNI technology (Java Native Interface) allows us to integrate some algorithms that were previously written in `C` or `C++`.

The software architecture (see Figure 1) contains differents modules:

- **Topology module:** contains the set of classes related to the network topology which allows for example to add or remove some links, to add or remove some LSPs, to check some properties on the network (e.g., the connectivity), or to obtain some statistics (e.g. the network utilisation).
- **Traffic matrix module:** contains some functionalities related to traffic matrices like reading files, checking the consistency of the traffic matrix with respect to the link capacities and generation of traffic matrices.
- **Scenarios module:** contains the classes related to simulation scenarios providing the ability to read, execute or generate scenarios. The simulation scenarios are described below.
- **Algorithm repository:** contains all the traffic engineering algorithms given above.
- **Chart module:** contains some functionalities related to charts generation. This module allows the user to automatically generate charts using various data sources.
- **Graphical User Interface (GUI):** provides an user-friendly but powerful interface to the toolbox.

C. Simulation scenarios

To make easy the use of the toolbox in simulation mode, we have set up a kind of scripting language by means of scenario XML files. The content of a scenario XML file is a sequence of events that will be executed by the toolbox. We have defined a set of basic events (`linkDown`, `linkUp`, `LSPCreation`, `loadDomain`, etc.) which already allow to build very complex scenarios. An example of a scenario file could be: load a topology and a traffic matrix, display the resulting link loads using a SPF algorithm, optimise the IGP weights using IGP-WO and, finally, display the link loads with updated weights.

The language defined by the scenario XML files can be easily extended, i.e. it is easy to write new events. These new events can be based on already integrated algorithms or on new algorithms that are plugged into the toolbox during runtime.

III. Outline of proposed demonstration

The demonstration will show how the toolbox can be used to traffic engineer a network. The following simulations will be performed:

- Analysis of the impact of IP metric optimisation on link loads,
- Comparison of different routing strategies (CSPF, DAMOTE, SAMTE),
- Analysis of the worst case link failure,
- Simulation of the BGP decision process resulting from a network condition change (like a peering link failure).

A case study on two real ISP networks, Abilene and another operational network, will be presented. Two user-friendly interfaces will be demonstrated: the simulation scenarios in XML format and the graphical user interface. According to the interest of the audience, we can also

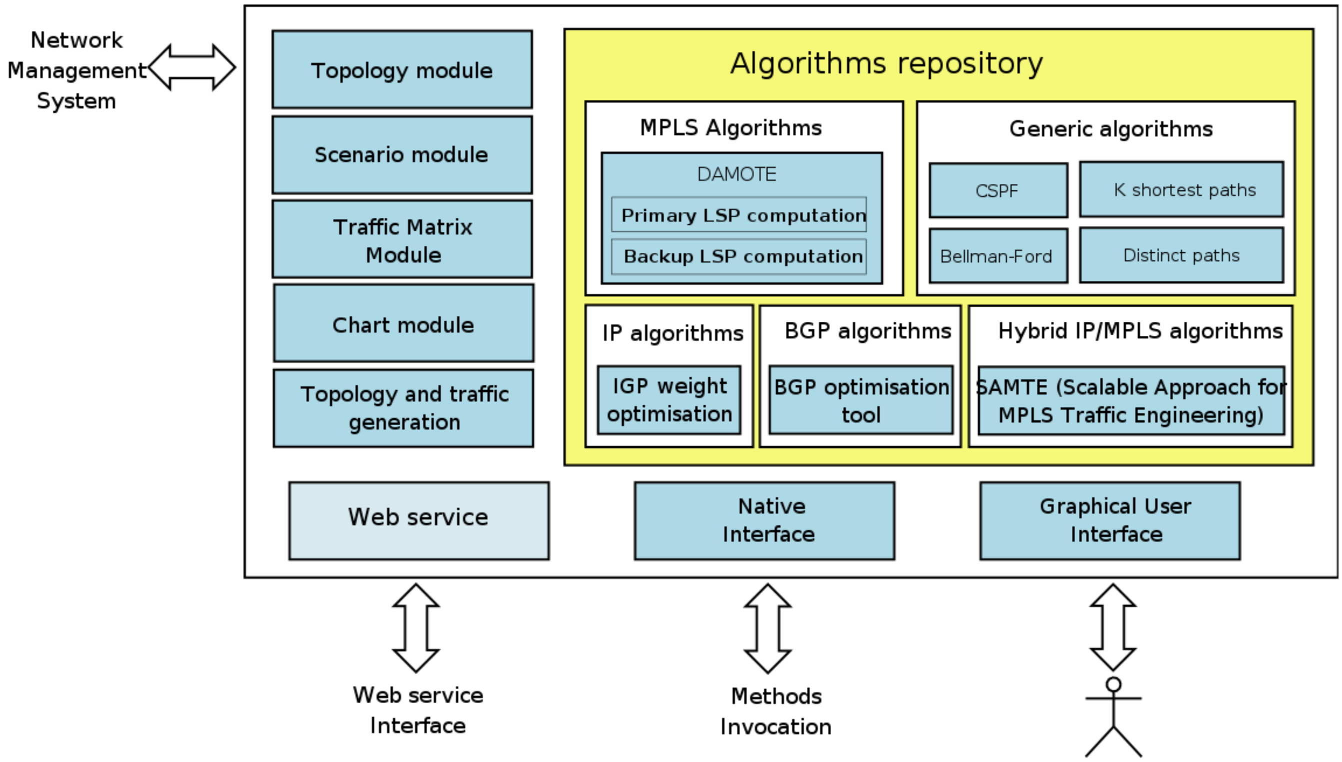

Fig. 1. Software architecture of TOTEM.

create new simulation scenarios and allow interested users to test the toolbox on their own.

If the audience is interested in, we can also briefly show how to integrate a new algorithm in the toolbox and define new events to use this algorithm.

IV. Further information

For more information about TOTEM, see [1].

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