

The PlaNet-PTN Module: a Single Layer Design Tool for Packet Transport Networks

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Abstract—PlaNet is a multilayer network planning tool developed at the University of Texas at Dallas. This paper illustrates some of the features of *PlaNet-PTN*, one of the modules available in the PlaNet tool. *PlaNet-PTN* can be used to design and plan a single layer packet transport network (PTN). Quality of protection, routing constraints, minimization of the network equipment cost, and user’s desired run time of the tool are just some examples of the features available in PlaNet. As shown in the paper, the *PlaNet-PTN* planning module is able to provide, among others, optimization of Label Switched Path (LSP) routes, link capacity placement, node and link equipment configuration.

I. INTRODUCTION

Both number of traffic demands — or Label Switched Paths (LSPs) — and number of distinct types of service supported by today’s networks are continuously growing. Point to point (P2P) and point to multi-point (P2MP) traffic demands may coexist in the same network. Some LSPs are bidirectional, others are unidirectional. Some require end-to-end path protections, others require link protection (fast reroute). Network standards are also allowing loose definition of routing, for example by requiring that one or more network elements are included in the route of the LSP [1]–[3]. Affinities can also be used to match the LSP’s required level of service with the performance offered by the available equipment in the network [4].

These requirements, along with thousands of LSPs jointly carried by the same network must be accounted for when planning the network and provisioning the right amount of network resources while containing the overall network equipment cost. Computer aided tools that are required to plan and design networks are therefore becoming increasingly more complex, as new features must be continuously added and integrated with the already existing ones. Such tools must also be able to design multilayer networks, dealing with physical fiber/cable layer, optical/wavelength division multiplexing (WDM) layer, optical transport network (OTN) layer, and packet transport network (PTN) layer, e.g., multiprotocol label traffic engineering (MPLS-TE).

Quite a number of planning tools has been developed commercially. Some tools are designed and maintained by network equipment vendors to support design and marketing of their products, e.g., [5]. Some others are commercially available to both industry and academia, e.g., OPNET [6], VPI [7], and WANDL [8].

PlaNet is a multilayer network planning tool recently designed, developed and extensively tested by the University of Texas at Dallas. PlaNet is a collection of software modules that can be combined to achieve design and planning of multilayer networks with the total cost of the network component minimized. Layers that can be optimized and designed with the help of PlaNet include: the physical fiber layer, WDM layer [9], [10], OTN layer [11], and the PTN layer [4]. The tool modules can handle the design of metro, as well as core networks.

This paper presents PlaNet-PTN, one of the modules in the PlaNet suite. PlaNet-PTN can be used to optimize the PTN layer in the network. One example of PTN layer is MPLS-TE [4]. Given the input traffic demands, node locations, physical connectivity between nodes, input constraints, and available hardware, PlaNet-PTN can design the network by:

- allocating node hardware, i.e., MPLS-TE chassis (switching fabric or backplane) and MPLS-TE line cards,
- providing a basic configuration for the node hardware,
- associating interfaces with a physical connection between nodes,
- computing routes for LSPs,
- assigning routes to LSPs based on QoS,
- assigning routes to LSPs based on input routing constraints, and
- adding redundancy in the network in order to provide reliability to the LSPs, should they require it.

The objective of the design is to minimize CAPEX, i.e., the cost associated with the provisioning of all the hardware required to build (or update) the network.

PlaNet-PTN attempts to provide a viable solution to the network design problem by including a number of features

and a modular software architecture, which easily allows for upgrades and improvements to the current feature set.

II. PLANET-PTN GENERAL PHILOSOPHY AND MAIN MODULES

This section provides first a high level description of the principles used to design and implement PlaNet-PTN. Then the main modules of the tool are introduced.

Multi-phase Optimization. The user must be able to define a sequence of optimization steps to be applied sequentially to the network under optimization. The result found at the end of each step may be saved (option selected by the user), and used as the input for the next step. For example, the user may decide to optimize P2P traffic alone first. On top of the result found, the user may decide to optimize P2MP traffic without modifying the solution found for the P2P traffic in the earlier step.

Incremental Traffic Demands. The user must be able to define multiple matrices of traffic demands. Each matrix defines a group of traffic demands that are handled as a whole by the tool. It is possible to run PlaNet-PTN using one group at a time, or multiple groups all together. It is possible to run PlaNet-PTN using a sequence of groups, thus studying the evolution of the network over time with incremental traffic demands. Alternatively, the user can, at any time, split a group into multiple groups for differentiated handling of traffic demands. For example, a graphical user interface (GUI) could allow the user to define attributes for an entire group of demands at once, instead of assigning the attributes to each individual LSP.

Objects to Optimize and Their Constraints. For each optimization step, the user must be able to specify what objects (e.g., equipment at a node, routing of LSPs) can be optimized, and what objects are final, i.e., they cannot be changed. Objects include backplanes chosen for a node, line cards chosen for a backplane, and routing for an LSP. For the objects to optimize the user must provide the constraints, e.g., range of possible options. For example, the node size can be 3 backplanes, each backplane can be in the range of (16, 32 etc.) slots, and each slot port can be in the (OC12, OC48) rate range.

Network Descriptor. The user must describe various key aspects of the network under optimization. The topology must be defined (e.g., using a graphical interface), specifying which spans (node pairs) are available, and for each span how many links are possible, and what set of transmission rates are available for that span. For each node, it may be necessary to indicate the product models (backplanes and cards) that are allowed to be used. Cost values must be provided for each network component.

LSP Descriptor. The user can address an individual LSP, or a group of LSPs. For the LSP (individual or in a group), the user must specify whether it is P2P or P2MP, the desired maximum hop count, nominal bandwidth, class type, protection requirement, affinity, etc.

Optimization Algorithm and Parameters. The user must specify the desired run time, or desired goodness of the

optimized result.

Optimization Mode. The user must specify if the optimization must start from a network with no existing equipment, or must build upon the previously obtained results (resume of an existing planning session).

Optimizer Output. At the end of an optimization step, the solution is made available to the user for analysis and saved to files. The solution includes the specific description of the node hardware, the paths of the demands, their reserved bandwidth, etc. The values of the objective functions are also made available, and where applicable, they can be shown for individual demands, group of demands, including averages, min/max, variance, distributions, etc. A history or trace of the optimization steps must be saved (as part of the solution) and made available to the user, who may want to be able to repeat the procedure under which a certain result was obtained.

Graphical User Interface. A (graphical) user interface allows the user to interact with the optimizer and specify all of the above functions. The interface allows the user to save optimization configurations, make them the user default configuration, etc. The planning tool provides a default configuration for every parameter, thus making it simple for the inexperienced user to run the optimizer the first time with some meaningful setup.

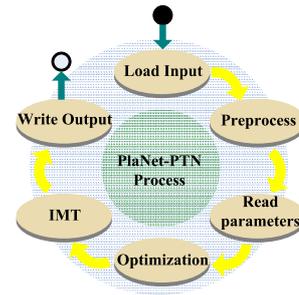


Fig. 1. PlaNet-PTN Modules.

Fig. 1 shows the main modules of the PlaNet-PTN tool. They operate according to the following flow.

- 1) Load input: this module reads all information from input files, e.g., topology description, constraints and traffic demands.
- 2) Preprocess: this module checks for possible inconsistency in the input files and preprocess the LSP requirements, e.g., routing constraints, protection requirements, etc..
- 3) Read parameters: this module reads the parameters used by the Optimize module, e.g., running time.
- 4) Optimize: this module performs the required optimization tasks according to the objective function, e.g., minimize cost, increase equipment utilization, etc..
- 5) Interconnect Intermission Trunks (IMT): this module optimizes the intermission trunks. IMT allows LSPs to be routed from one backplane to another within the same node.

- 6) Write output: this module saves the optimization results into the output files.

III. PLANET-PTN FEATURE SET

This section presents a list of features that PlaNet-PTN supports. PlaNet-PTN tool can handle the following:

- traffic types: PlaNet-PTN supports LSPs that can be bidirectional P2P, unidirectional P2P, and unidirectional P2MP,
- Differentiated Services (DiffServ): this model is used for the purposes of bandwidth allocation based on types and priorities of traffics. PlaNet-PTN supports up to eight classes [12],
- bandwidth allocation models: PlaNet-PTN implements the maximum allocation model [13] and russian doll model [14],
- protection types: PlaNet-PTN supports unprotected, 1+1 and 1:1 dedicated path protection, FRR Detour [15] and FRR Bypass¹ [16],
- technology types: the following technologies are supported: gigabit Ethernet (GE) and packet over SONET (PoS),
- affinity values: affinity is a 32 bit parameter, used to define a subset of equipments and spans that a given LSP can use,
- constraints:
 - hardware: this constraint is used to specify which equipments that can be used at each node and on each span,
 - routing: this constraint is used to specify the routing metric (e.g., hops vs. distance), or when a LSP is forced to use a specific primary and/or secondary path (tree), the affinity value, the maximum hop count for a path, possible nodes/spans that need to be included/excluded during route computation, etc.,
 - running time: this parameter defines the time limit (measured in seconds) for the PlaNet-PTN tool to perform the optimization tasks,
- operation mode: four optimization modes are available. One is called *greenfield* and the other three are called *incremental*. In the *greenfield mode*, new LSPs are added to a network with equipment at all. In an *incremental mode*, new LSPs are added to a network with already existing equipments and/or with some LSPs already routed. In *incremental mode 1*, the following rules apply: while optimizing the routing for the new traffic demands, no new equipment can be added to the network, the existing equipments can not be changed/upgraded, and the routing of the LSPs already present in the network can not be re-optimized. In *incremental mode 2*, the following rules apply: while optimizing the routing for the new traffic demands, new equipment can be added to the network, but the existing equipments can not be changed/upgraded, and the routing

of the LSPs already present in the network can not be re-optimized. In *incremental mode 3*, the following rules apply: while optimizing the routing for the new traffic demands, new equipment can be added, and/or existing equipments can be changed/upgraded and the routing of the LSPs already present in the network can be re-optimized.

IV. USING PLANET-PTN

This section gives a brief overview of the capability of the PlaNet-PTN module.

A. Graphical User Interface (GUI)

Fig. 2 shows a screenshot of GUI with an example of input topology. Since the screenshot refers to a greenfield design, the topology shows only the node location and the possible physical interconnection between node pairs, i.e., the spans, while it does not show any equipment or LSP.

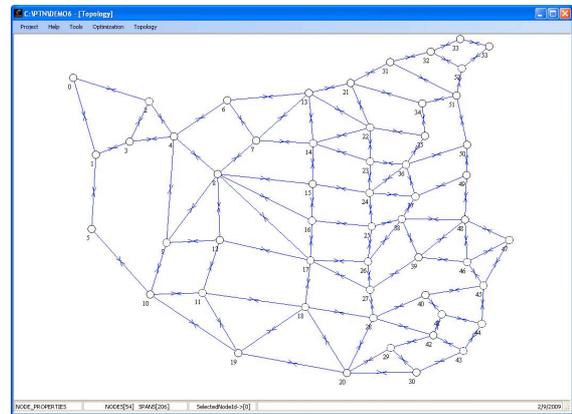


Fig. 2. GUI screenshot: one example of input topology.

Fig. 3 shows a screenshot of the LSP property page within the GUI. Although the input files are text based and an experienced user could input all the requirements from the input files directly, the GUI can read and edit those files for a more intuitive user experience. As the screenshot reveals, a large number of parameters (some of them described in Section III) can be set for each individual LSP.

Fig. 4 shows a screenshot of GUI with an example of output topology, after one optimization run. This screenshot reveals more information when compared to the one in Fig. 2, e.g., each link is color coded in order to visually identify the percent load on each link. The thresholds for the different colors can be changed on the fly from the GUI to investigate what are the critical load levels in the network. Information on a per-class base is also available upon selection.

Fig. 5 shows the form used to select LSP(s) and later visualize their routing. Different sorting method are available. The *Select LSP* part is letting the user select the LSP(s) to be visualized according the LSP class and traffic type (P2P or P2MP or ALL). After sorting, one or more LSP can be selected to have their routing displayed, as shown in Fig. 6.

¹P2MP traffic cannot use FRR detour.

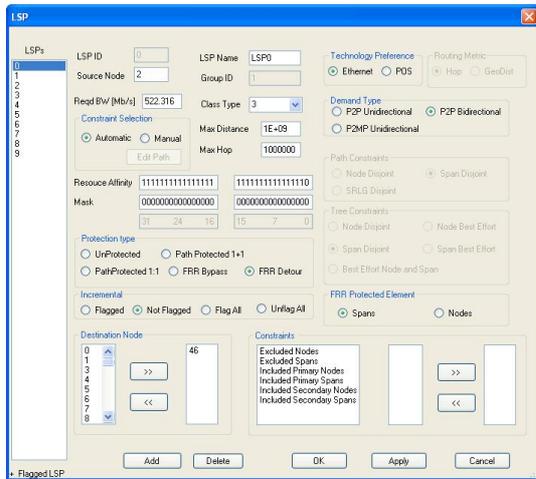


Fig. 3. GUI screenshot: page used to review or modify LSP properties.

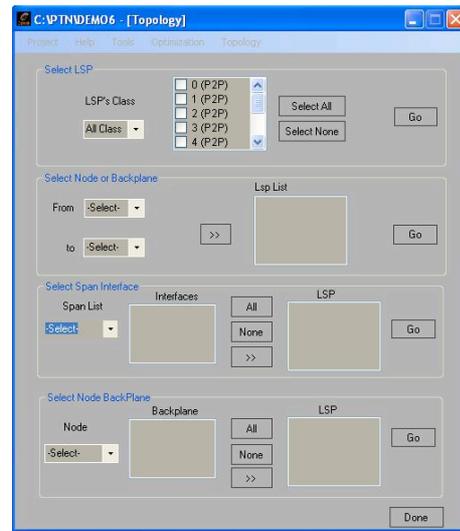


Fig. 5. GUI screenshot: page used to select the LSP(s) whose routing should be visualized.

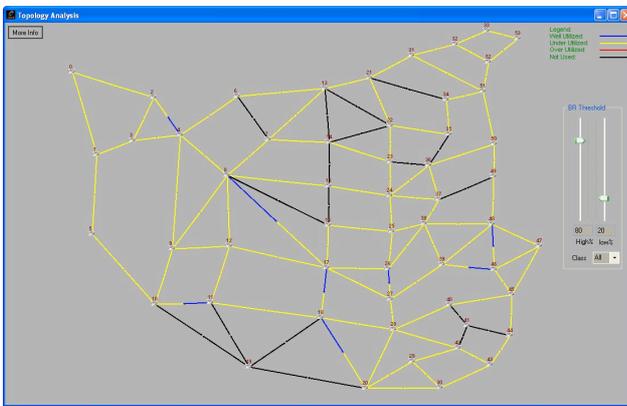


Fig. 4. GUI screenshot: page used to display the topology information and span load using color codes according to user selected threshold.

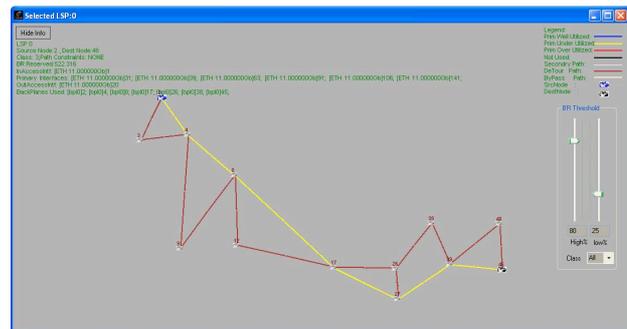


Fig. 6. GUI screenshot: page used to display LSP routing after optimization. Working and protection (FRR Detour) paths are visualized.

The *Select Node or Backplane* part is letting the user decide among the LSP(s) traversing a node or a backplane pair. The *Select Span Interface* part is used to select which LSP(s), among the ones originating at, or traversing a given interfaces, should be displayed. The *Select Node Backplane* part is letting the user decide among the LSP(s) originating at, or traversing a given node or backplane.

Fig. 6 shows an example of how the GUI can be used to visualize the routing of one (or more) LSP(s). In this particular screenshot one LSP is protected by FRR detour. For each protected facility, e.g., link, the dark line indicates the FRR tunnel.

B. Tool Run Time vs. Optimization Level

The tool was tested under different scenarios. Fig. 7 refers to a topology with 76 nodes, 400 spans and a demand matrix of 600 unprotected P2P LSPs. It can be noticed that with increasing running times, the tool returns lower network costs. Fig. 8 shows results obtained using the same network as Fig. 7, but this time with a demand matrix of 600 P2P LSPs,

20% with FRR Detour protection and 80% unprotected. The plot reveals a consistent behavior, i.e., longer run times yield lower cost network solutions. Fig. 9 shows how the tool scales with respect to the topology and demand matrix size, the heterogeneity of the traffic and the number of routing constraints. The total network cost is plotted as a function of the tool running time for a topology with 200 nodes, 1000 spans and a demand matrix of 12000 LSPs: 6000 P2MP and 6000 P2P, using in both cases (P2P and P2MP) 1+1 and 1:1 dedicated path protection.

V. SUMMARY

This paper describes the features available in PlaNet-PTN, one of the modules available in the PlaNet tool. The module may be used to design a single layer packet transport network, either starting from a clean slate (no existing equipment in the field), or adding equipment incrementally to an already existing network. The main objective of the PlaNet-PTN module is to minimize the cost of the equipment that is required in the network to support a given set of traffic demands, while taking

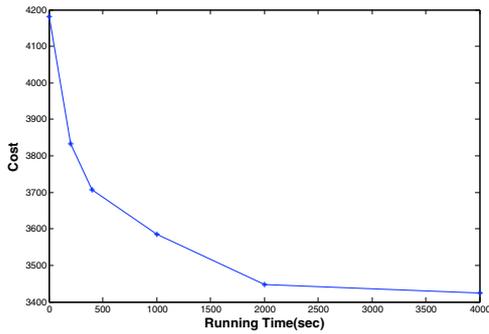


Fig. 7. Total network cost as a function of the tool running time. Topology with 76 nodes, 400 spans. Demand matrix with 600 unprotected P2P LSPs.

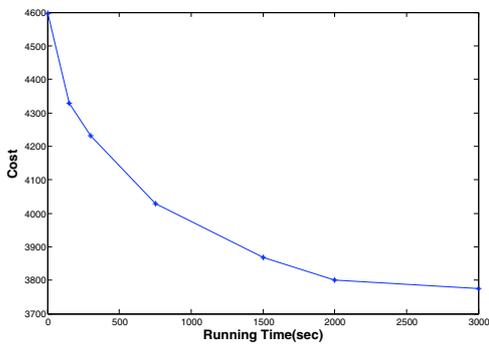


Fig. 8. Total network cost as a function of the tool running time. Topology with 76 nodes, 400 spans. Demand matrix 600 P2P LSPs: 20% protected (FRR Detour), 80% unprotected.

into account a number of factors: (a) a realistic set of traffic demand types, including P2P and P2MP traffic, directional and bidirectional flows, end-to-end path protection and fast reroute link protection, multiple classes of priority, (b) the network equipment type, capacity, and cost, which the network designer provides as part of the tool input, (c) a number of routing constraints, e.g., requesting the include or exclude of multiple

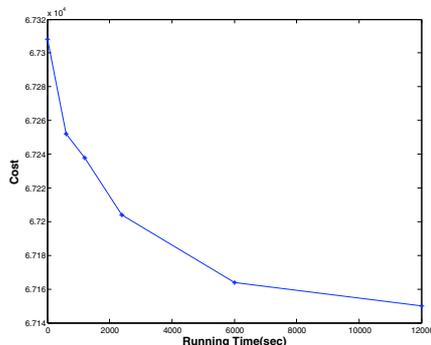


Fig. 9. Total network cost as a function of the tool running time. Topology with 200 nodes, 1000 spans. Demand matrix 1200 LSPs: 6000 P2MP and 6000 P2P with 1+1 and 1:1 dedicated path protection.

network elements along the route of special traffic demands, affinity between traffic demands and equipments, disjoint (in terms of link, node, and SRLG) routing for diversity purpose, (d) a pragmatic approach to designing network, whereby the network designer may wish to trade the optimization run time of the module for the optimality level of the solution returned by the module.

The PlaNet tool was designed, developed and extensively tested by a team that includes both graduate and undergraduate students at the University of Texas at Dallas. At current time, the tool consists of about 170,000 lines of C++ code, which can be compiled on both Windows and Linux operating system. The challenge of designing, implementing, and integrating all the features available in the PlaNet tool offered this team of students a unique opportunity to experience and understand the R&D type of environment, where loose specifications are given at the beginning of the project and must be turned into concrete requirements that can be met in the limited time frame given for development.

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