Gancles 1.0.4 manual

Author: Zoltán Zsóka

1 Introduction

This document is a short summary about the capabilities, function, parameters and statistics of the call level simulator of IP/optical networks with grooming.
The simulator is based on the ATM simulator ANCLES of the Politecnico di Torino and on its extension to all-optical networks ASONcles of the Budapest University of Technology and Economics. Mostly it is compatible with their last version so for all missing information you should consult the official sites:

- user documentation of Ancles:
  `http://www1.tlc.polito.it/ancles`
- user documentation of ASONcles:
  `http://www.hit.bme.hu/~zsoka/asoncles`

In the following we summarise our motivations and summarise the new possibilities, algorithms and parameters introduced during the latest development phase.

2 Motivation

Our aim was to create a tool that is able to simulate the interaction of a high speed optical layer and the guaranteed or best effort type flows arriving in a higher layer. The connecting point of the layers is the traffic aggregation or grooming that allows to the upper layer flows to use the physical resources through the lower one.
Obviously, the two layers' technology can be very different but in our work we focused only on the main differences: Lightpaths can be set up for provisioning guaranteed quality links of large capacity according to the wavelength conversion restrictions. IP flows can be constant or variable guaran-

teed rate connections or may show elasticity and their transmission rate is much smaller. In more realistic scenarios an aggregated flow of individual IP flows can be transmitted in the upper network layer. This flow can have then guaranteed bitrate if aggregating guaranteed rate connections. In other case, aggregating best effort connections, it still shows elasticity, i.e., the number of such flows sharing the resources has negative feedback on the rate and positive feedback on the duration of the transmission.
The separated simulation of both levels was available in the preceding simulators (Ancles and ASONcles), their connection is introduced now by grooming schemes. The previously implemented (and mostly analysed) solutions of different problem-fields of networking can be applied with some restrictions in this version too.

3 Main functionality

The simulator can consider both the IP and the optical level of a network (IP over WDM). The optical connections realise virtual IP links componing a virtual topology that is avilable for the upper layer traffic. IP flows will use these links applying routing on the virtual topology.

3.1 Traffic on the different layers

The IP level traffic can be the traffic generated by the call generator of 1-5 type, i.e., not only clients trasmitting elastic traffic (type5) are allowed here, but the other "normal", guaranteed bitrate clients (*gbc*) too. If the two level simulation is choosen, these generators can see only a virtual network and the phisical links are hidden for them under the underlying optical layer.
The introduced grooming solutions are based on the objective to always provide enough virtual resources to satisfy the living IP flows. We started with the two basic solutions well known in the literature. In the more conservative one the set up of virtual links may be performed only if the demands can not be satisfied on the existing topology. The other algorithm tries to open virtual links in a very greedy way actually at the arrival of each upper level flow request. One can find a more detailed description later.
On the other hand, if the utilization of the virtual links is low, the tear-down process can be performed too.

Using the IPoWDM capability (in the further we will speak about only this case of course) the virtual IP links will have the capacity of one wavelength. An optical connection will be established using the ASONability of the simulator. In the simulation of automatic switched optical networks the optical call generators (type 6-9) see the physical links as sets of identical fibers. Realising the multi-fiber concept, the size of the sets can be different for different links. Note that not every optical generator generates connections that realise virtual IP links! Only the type8 (never closing ason) generator is able to do this, the other ones occupy the physical resources but no virtual IP link can be established by their set-up. These (type6, type7 and type9) generators can be used then only as background traffic sources in the analysis IP over WDM networks.
According to the above facts, when a virtual link establishment is requested, a call request between a chosen type8-type12 generator pair is handled. It is important that this is not a simple call request from the simulator point of view, i.e., it is not driven by a call request event, but works based on the interaction of the two layers. The routing and statistic collection happens the same way as in the case of a *normal call* and a type8 call will be really created. As the release of the virtual link is requested (normally, by a closing event), the type8 call will be torn down.

3.2 Duplex/Simplex connections

In Ancles each link is simplex, from the generator point of view, i.e., if link l goes from node a to node b, no flow can use it in the direction b to a. Indeed, a link l' going from node b to node a is necessary to transmit the other direction traffic. This way a general, one layer IP network topology shall consist of link pairs.
In ASONcles beside this simplex pair otion there is the option to apply duplex links that are available from both endpoints. This option can be set for each link individually and it is very useful if we consider the circuit switch-like properties of automatically switched optical networks: an optical connection occupies an optical channel in both direction. In the duplex case the network consist of single links that represent a pair. (This option should have been inserted for bwb calls as well, but it is still not done.)
Gancles inherited the duplex option for optical links but also an other duplexity option is introduced here: if the lower level duplexity is set, each type8 optical connection will perform the creation of a virtual link pair (instead of

a single virtual link). These two links are very similar the only difference is their direction.
To get a clear network concept we suggest to use the two type of duplex options parallelly, i.e., either using simplex links in both level, or apply duplex optical links and setting the lower level duplexity option. The networks of the other two cases are not easy to imagine from functionality point of view and seems meaningless even if they can work.

4 Management of virtual IP links

4.1 Static virtual IP links

The type8 calls in ASONcles were never closing, static connections established at the beginning of the simulation and never torn down. The same way static virtual links can be created actually at the start of simulation with Gancles. How to establish this kind of calls, consult the ASONcles documentation and our examples.
By the recently introduced parameter `ena_close_predef_virtlinks` we can enable the tear-down of these connections too. Using this option a starting virtual topology can be created at the simulation start but later the links of this toplogy can be torn down. Ignoring this option these links will remain static and are present in the virtual topology till the end of simulation. Note that depending on IP routing algorithm these virtual links can be empty.

4.2 Dynamic virtual IP links

Two main functionalty had to be realised to manage the virtual links: establish and cancel them according to the applied grooming scheme. Note, that some sophisticated schemes can perform both opening and closing virtual links at the same time.
During the routing of a recently arrived IP level flow request or during a closing process of an IP level flow, a decision may taken about possible changes of virtual topology. The aim of these changes is to fit better the virtual topology to the actual IP level flows.
We have to determine two factors of the decision in the case of set-up a new virtual links: how many set-ups we need and the endpoint-pairs of the new links. The grooming algorithm shall define both the factors according to the

current traffic situation. Not each algorithm consider the both network layers. If there is no cg8-cg12 generator present at the chosen nodepair or there are not enough resources in the optical layer to set up the typ8 connection, it will be refused and no virtual link will be created. This situation is called *optical lack* and is handled differently by the grooming algorithms. One can read more about them in the next section.
In the case of virtual link tear-down, one or more virtual links are chosen to close. The simulator gives the possibility of delayed closure using a timeout parameter: `vl_close_hold_time`. After the decision about the tear-down, the link is still open for the timeout period and gets closed only if its state does not change.
Now only one tear-down policy (`vl_close_algorithm`) is available independently from the applied grooming algorithms:

EMPTY_CLOSE : if a virtual link(pair) becomes empty, the closing event of the realising type8 connection will be replaced to a finite timepoint according to the value of the time-out. If new IP calls will be routed on this virtual link before the time is out, the closing event will be replaced to infinite again ($maximal\_simulation\_time + 1$), since we have no advice when the virtual link has to be closed. The emptiness condition is needed to be satisfied on both virtual links if duplex lightpaths are considered.

In our further work other closing solutions may developed for the virtual links. As advice to the development, we have to consider that if the closing link is not empty, each carried call needs to be rerouted to other virtual resources.

4.3 Virtual topology issues

The routing of IP traffic is performed on the virtual topology that consist of static and dynamic virtual links and can change according to the grooming scheme. The available routing algorithms in this layer are those introduced in the previous simulator version: Ancles.
Static and dynamic IP routing algorithms can choose a suitable path on the virtual topology using static (e.g. number of hops) or dynamic (e.g. available bandwidth) meters in their decision. Often happens that two paths are of equal cost from the given meter point of view. In normal ATM and IP

simulation a predefined order was applied for these paths realised with the help of load balancing methods.
However, in the case of virtual topology the load balancing concept can not be adapted in an obvious way, since it should follow the dinamically changing topology and traffic situation. Instead, a much less complex concept is assumed for the order of equivalent cost paths: the one consisting of younger virtual links have the priority. Link i is younger than link j if it was created later. Do not forget that many parallel links can exist in the virtual topology.
Another issue of path management in networks is the possibly large number of available paths between a source-destination pair. The previous simulators introduced some parameters to constraint the number, length or hop-number of the available paths. Some of them, using the constraint at the path creation (hard constraint) instead of the cost evaluation phase (soft constraint) work more effectively from the simulation point of view, but can be be defined only generalised for the whole network. Hard constraints are: `xxx_max_no_of_hops, xxx_max_no_of_hops` parameters. For more specialised scenarios the aligned use of more constraints is recommended.
Beside the previously defined constraint two new parameters are introduced and can be applied only in the virtual topology ambient.
`max_no_of_virt_nn_routes` limits the number of considered (created) paths among each node-node pair assuming hop-by-hop ordering, while
`max_no_of_virt_routes` still limits the number of available (created) paths but for source-destination pairs (the ordering here can be different). Both of them are hard constraints considered at each change of the virtual topology but their values are only purposes and not guaranteed. This strange function comes from the fact that on one hand we a younger path may have priority to an elder one but that can not be cancelled if carries IP traffic. A simple example is when the number of considered node-node paths is purposed to be 1: a new virtual link will be surely the first in the order but it is not the one in use if elder paths still exist.
The constraints affecting the number of available paths can reduce dramatically the cumputation complexity and the running time of simulation while their effect on the results are normally not very notable. We suggest to use them but with foresight.

5 Grooming

The central point of our investigations with Gancles is the analysis of dynamic grooming algorithms. Both elastic flows and *gbc*s are considered to be groomed on virtual links.
Two solutions are implemented in the current version of simulator, both of them tries to open one new virtual link, if any. The open process can be performed only at the arrival of an IP flow request. The source and destination nodes of the requested virtual link are equal to the source and destination nodes of the IP request. In case of duplex optical channels a pair of virtual links is created, if any. The two algorithms are the less complex ones, well known in the literature, representing the edges of the conservative vs. gready contrast in the usage of optical resources:

DIRECT_VLINK : is a grooming algorithm that aims to open new optical lightpaths only if the existing virtual topology is not enough to carry the current IP traffic. First the request is routed on the virtual topology and the bandwidth on the assigned route is analysed. If there is no route at all between the entry and exit nodes, the virtual link opening is attempted obviously.

It is easy to decide if a *gbc* would be satisfied on this route since this type of traffic needs guarantees on bandwidth. In the case of elastic traffic, in theory, unlimited number of flows is allowed on the links. However, this algotithm perform the set-up of a new virtual link if the ratio of the estimated assigned bandwidth of the elastic flow and its peak bandwidth would be less than a given threshold. This value can be set by parameter: `vl_open_thrs`.

Independently from the success of the opening attempt, the IP request is routed again and its traffic will be transmitted on the assigned route. Note that in the case of optical lack (i.e., the endnodes are not connected on the virtual topology but there are not enough optical domain resources to open a new direct link between them) the IP request is refused even if it is of an elastic flow.

OCH_FIRST : works in a very greedy way from the optical resources point of view. At the arrival of an IP request a new direct virtual link is attempted to be created. After, independently of the attempt success the IP request is routed on the virtual topology.

Note that in the case of optical lack the IP request is refused even if it is of an elastic flow.

The algorithms presented here define only the policy of opening new virtual links, the closing policy is set separately.

6 Parameters

To set right the parameters one has strictly follow the instructions of this and the previous documents. Several new parameters are introduced. See below a list with their short description:

`enable_IPoWDM` : enables two level (IP over WDM) simulation

`vl_open_algorithm` : algorithm of the opening part of grooming policy

`vl_close_algorithm` : virtual link closure algorithm

`min_vl_open_thrs` : threshold (relative to the peak transmission rate of the elastic flow) used for identification if new virtual link is needed in grooming algorithm `DIRECT_VLINK`. If the recently arrived elastic flow would get less relative bandwidth on the route assigned to it on the current virtual topology than this threshold, a virtual link opening is attempted.

`vl_close_hold_time` : delay of real close of the virtual links (if no IP request is routed on it in the meantime)

`ena_close_predef_virtlinks` : enables the dynamic closure of the predefined virtual links.

`virtlink_bw_update_period` : models the period of link bandwidth information update for virtual topology IP networks. The link information used in the routing is not always fhresh and a periodical update function is introduced to catch this issue. If the parameter is set to 0 the current bandwidth is available for each link. (The same function for normal, fix IP network was introduced in Ancles.)

`duplex_lowerlevel_conn` : indicates duplexity of lightpaths. These optical channels realise than virtual link pairs of inverse direction.

max_no_of_virt_routes : gives the limit objective of the available route number fo each generator pair

max_no_of_virt_nn_routes : gives the limit objective of the available route number fo each node pair

Note, that there are some restrictions in the usage of parameters: i, no optical routing can be applied in the case of IP traffic generators; ii, if IP over WDM is enabled:

- no theoritical analysis can be performed,
- CAC2 and CAC3 call admission control algorithms can not be used,
- load balancing has no effect even if it is set,
- periodical algorithm choice (routing_ra9) can not be applied.

7 Statistics

As one can follow in the description, the two layer network applies earlier (in Ancles and ASONcles) defined network components and call types. Paralelly the largest part of results can be collected the same way as in the previous simulators. Only the possibly modified interpretation has to be considered, e.g. a type8 calls are connected to the virtual links in Gancles.
The most important statistics in the simulation of groomed IP traffic are:

- blocking and/or starvation[1] information of IP flows (file `.cbr` and `.ubr`)
- mean values of flow throughput for users generating elastic IP requests (file `.ubr`)
- lightpath (type8 connection) refusion ratio (file `.cbr`)
- mean route hop number on the optical or the virtual topology for optical and IP layer connections respectively (file `.cbr`)

[1]The capability of interrupt elastic flows if their current bandwidth is too low was introduced in Ancles. This option models the timeout function of the transmit protocol or the impatience of the user.

- utilisation of optical links (file `.awl` and `.awh`)

Correlated to ASONcles only one new statistic report is introduced by this simulator. File `.cg8` contains an aggregated statistic about the dynamic of virtual links:

- The number of closed virtual links is reported here (about the opened and refused requests you can find the statistics in file `.cbr`).
- First and (relative) second order mean values are reported for both the time passed between two accept of virtual link requests (*interarrival time*) and their lifetime (*holding time*).

No new statistical variable was introduced in this version of simulator. From the earlier defined ones `classu_user_assigned_bw` and `total_blocking_probability` may be set to significant in such grooming studies.

8 Example

The following command line starts the simulation:
Gancles 2l_G1dup.nd -trf=3x3u_G.trf -time=50000 -load=0.05 -out=out_1
The attached files, 2l_G1dup.nd and 3x3u_G.trf contain the description of the network and a traffic pattern.
The network has two physical links with capacity of 40. One link consist of one fiber with two available wavelengths (wavelength capacity is 20). At each node there are generators of type 1, 5, 8, and sinks of type 10, 11, 12. The type8 call duplexity is set.
According to the documentation of ASONcles one can set the usage of predefined optical connection by setting cg8_req_waves to a positive value.
The traffic pattern is set now to use only CBR traffic, but any other pattern can be set according to the Ancles/ASONcles rules.