On the Implementation of Matching Theory Based Resource Allocation in Networking Testbeds

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***Abstract*—In this paper, we demonstrate the implementation of a matching theory based algorithm that extends the well known Top-Trading-Cycles (TTC) in the resource allocation mechanism of the NITOS networking testbed. We first provide an overview of prominent networking testbeds and the common approach that is used for the allocation of testbed resources to experimenters. We briefly describe our extended TTC algorithm and how it is applied in the enhanced architecture of NITOS resource allocation framework, by illustrating the interactions that take place between the testbed users and the testbed management services.**

I. Introduction

Networking testbeds offer experimentation capabilities in real world conditions, constituting valuable tools for network engineering research, beyond simulations. Over the last decade several testbeds have been built, with Planetlab [1], Emulab [2] and ORBIT [3] being the first and most prominent in their respective research areas. Following the paradigm of US, EU has supported the deployment of networking testbeds like NITOS [4] and VirtualWall [5], through the Future Internet Research and Experimentation (FIRE) framework [6]. These actions culminated in the forming of a testbed federation named Fed4FIRE [7], which incorporates all the significant networking testbeds in Europe. More recent efforts, both in US and Europe, include funding of 5G testbeds within the initiatives of 5G-PPP in Europe [8] and PAWR in the US [9].

Although the aforementioned testbeds feature cutting edge technology equipment for research and experimentation, they lack sophisticated mechanisms for resource allocation to users that run experiments in parallel. Testbeds like Planetlab and ORBIT allocate resources to experimenters by following a simplistic First-Come-First-Served (FCFS) approach, with manual intervention in the case of ORBIT and a Best-Effort approach in the case of Planetlab. In ORBIT, all experimenters request resources in a calendar format and they receive a response 24 hours before the beginning of their reserved time slots. In cases of conflicts, where experimenters have competing interests for the same resources, a resolution is made manually usually prioritising those that have used the testbed for less time in the recent past. In Planetlab, things are simpler, since a resource is allocated depending on its availability at the time of a request. The same principle applies in all Fed4FIRE testbeds, where FCFS and Best Effort approaches are followed. In our paper in [10], we proposed a matching theory based mechanism that can be implemented for resource allocation in networking testbeds, resulting in a more fair and efficient way of allocating resources to experimenters with conflicting reservation requests.

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II. Matching Theory

The problem of resource allocation in networking testbeds presents similarities to the problem of the housing market where owners of houses have preferences over other owners' houses and beneficial mutual exchanges can be performed. In the context of matching theory, the Top-Trading-Cycles (TTC) algorithm has been proposed [11], for trading indivisible items of interest without financial transactions.

We applied the principles of TTC with the objective of allocating indivisible resources, which in NITOS testbed are wireless nodes that experimenters have bare-metal access. This means that reserved resources are exclusive to an experimenter and are not shared. Experimenters provide their preferences over the available resources, which TTC takes into consideration for reaching a Pareto efficient allocation. In more detail, taking into consideration the list of reserved resources of experimenters for the same time slot, our proposed extension of the TTC algorithm allows for multiple mutual exchanges and runs as many times as the maximum cardinality of the largest reservation list of competing experimenters. Our enhanced TTC algorithm and the proposed adaptation to testbed indivisible resource allocation is described in our paper in [10].

III. Architecture & Implementation Details

The aforementioned matching theory algorithm has been incorporated in NITOS resource allocation framework [12]. More specifically, NITOS testbed features a modular architecture based on services and APIs, as presented in Fig. 1. Users may either use NITOS web portal or a GUI/CLI program to reserve resources. In the former, a REST API is used to communicate the requests between the testbed resource manager and the user, whereas in the latter an XML-RPC API named SFA is used, which is a standardized API among all testbed federations. Once an experimenter is authenticated and has the privileges to reserve the requested resources, the scheduler allocates resources based on its scheduling/allocation module.

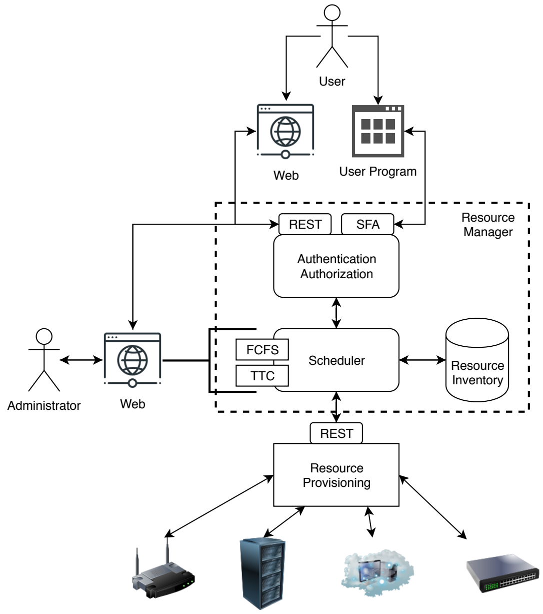

Fig. 1. NITOS Resource Allocation Framework Architecture

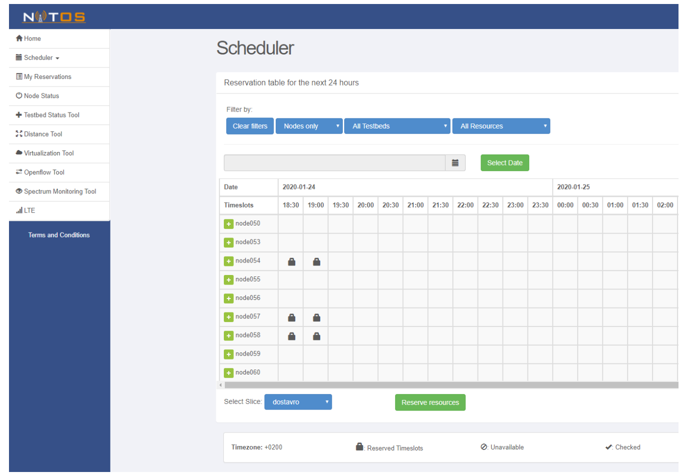

Fig. 2. NITOS Resource Reservation Portal

Administrators of the testbed can configure through the NITOS portal which policy should be followed for resource allocation. In our implementation, we provide a simple FCFS policy, as well as the aforementioned enhanced TTC algorithm policy.

In the case of FCFS, users receive instantaneously the confirmation of their resource reservation requests. In the case of TTC, the scheduler receives all resource requests up to 24 hours before the beginning of the experimentation time slot, and it reaches a Paretto efficient allocation by running our enhanced TTC algorithm. The result of the algorithm is sent back to the interested users as the final allocation of the testbed resources. In both cases, the users send their resource requests through a web portal presented in Fig. 2. In this portal, the offered testbed resources are listed in a calendar format so that users can indicate the timeslots and the resources they prefer.

Once all the requests have been received by the scheduler, the TTC algorithm runs an initial allocation assigning a random node to each experimenter in the same time slot. Based on the initial random allocation and the experimenters' preferences, the TTC algorithm detects cycles and mutual exchange opportunities before reaching a core allocation of 1 node per experimenter. Our enhanced TTC algorithm repeats the previous steps until all resource requests have been served, leading to a final Paretto optimal resource allocation for the specific testbed experimentation time slot.

IV. Conclusion

In this paper, we focused on the implementation of our proposed mechanism of matching theory based efficient resource allocation for networking testbeds. We provided the background of networking testbeds and their current allocation mechanisms and briefly presented the TTC matching theory algorithm and our enhancement for its application in testbed resource allocation. Finally, we demonstrated how the enhanced TTC was implemented in NITOS testbed architecture and described the interactions that take place between the users of the testbed and its resource allocation framework.

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