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Experimentation on end-to-end performance aware algorithms in the federated environment of the heterogeneous PlanetLab and NITOS testbeds ☆

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ABSTRACT

The constantly increasing diversity of the infrastructure used to deliver Internet services to the end user has created a demand for experimental network facilities featuring heterogeneous resources. Therefore, federation of existing network testbeds has been identified as a key goal in the testbed community, leading to a recent activity burst in this research field. In this paper, we present a federation scheme that was built during the Onelab 2 EU project. This scheme federates the NITOS wireless testbed with the wired PlanetLab Europe testbed, allowing researchers to access and use heterogeneous experimental facilities under an integrated environment. The usefulness of the resulting federated facility is demonstrated through the testing of an implemented end-to-end delay aware association scheme proposed for wireless mesh networks. We present extensive experiments under both wired congestion and wireless channel contention conditions that demonstrate the effectiveness of the proposed approach in realistic settings. The experiments are also reproduced in a well-established network simulator and a comparative study between the results obtained in the realistic and simulated environments is presented. Both the architectural building blocks that enable the federation of the testbeds and the execution of the experiment on combined resources, as well as the important insights obtained from the experimental results are described and analyzed, pointing out the importance of integrated experimental facilities for the design and development of the Future Internet.

1. Introduction

Wireless Mesh Networks (WMNs) are currently considered as the default solution for delivering high-speed Internet access to users within the last few network miles in non-urban areas. As a result, the interest of the research community in proposing WMN-related approaches has dramatically increased during the last few years. The inherent inability of simulation models to accurately estimate performance of wireless networks [2], in accordance with the unique characteristics introduced by the complex nature of WMNs [3] have directed research efforts towards implementation approaches and evaluation through experimentation in real world network scale and settings.

However, development of large scale WMN testbeds is a rather challenging task that requires careful design and

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induces high deployment and maintenance costs. Moreover, as WMNs are usually considered as a promising technology for Internet access provision, experimentation across global scale networks that feature real Internet characteristics is required, in order to acquire experiment results under realistic congestion conditions. Such requirements have led the research community to the decision to develop a global large scale infrastructure that results from the federation of heterogeneous types of networks, such as wired (local, wide-area or optical) and wireless (local, mesh or sensor) networks.

Federation between inherently heterogeneous testbeds introduces several issues that arise due to the difference in the nature of experimental resources, but more importantly due to use of different software frameworks for resource management and control. In this work, we describe the establishment of the federation between two well-known heterogeneous network testbeds, namely the NITOS wireless testbed and the wired PlanetLab Europe (PLE) testbed. The utilization of a common experiment control framework, OMF [4] (cOntrol and Management Framework), and the adoption of the slice abstraction, as the building block for the federation, have been the main keys which made this federation possible.

In order to demonstrate the usefulness of the resulting integrated architecture, we develop and implement an association scheme for WMNs that is aware of end-to-end delay, part of which is generated in the wired section (PLE) and part in the wireless section (NITOS). The implemented mechanism is based on novel association metrics [5] that consider wireless channel contention, which are further enhanced, by taking into account delays incurred in the wired section of the end-to-end path. The evaluation of the proposed mechanism is performed through extensive experiments conducted on the combined network architecture, which results from the federation of the two heterogeneous experimental facilities. In an effort to explore the key differences and potential performance dissimilarities between realistic testbed and simulated environments in performing Mesh Network experimentation, we reproduced several of the testbed experiments in a well-established network simulator.

This paper is organized as follows. In Section 2 we discuss research work related with both association in WMNs and federation of heterogeneous experimental facilities. In Section 3 we describe the architecture of the two heterogeneous testbeds and moreover provide details about the approach followed and the tools used for the establishment of the testbed integration. In Section 4 we analyze and discuss the proposed association approach. The measurement methodology followed in our experiments, as well as a brief experiment description that is OMF compatible are presented in Section 5. In Section 6 we present and comment on the results obtained from the experimental evaluation of the implemented mechanism. Results obtained through the simulation of the real experiments, along with achieved user experience are discussed in Section 7. Finally, in Section 8 we summarize our work, by pointing out conclusions and directions for future work.

2. Related work

2.1. Association in wireless mesh networks

WMNs are composed of Mesh Routers (MRs), which form the wireless backhaul access network and Mesh Clients (MCs). MRs forward packets acting as intermediate relay nodes and may also provide wireless access services to MCs, in which case they are referred to as Mesh Access Points (MAPs). WMNs also consist of Internet Gateway nodes (IGWs) that provide Internet access to the network, through direct connection to wired infrastructure. MCs associate with a certain MAP in order to access the network and do not participate in packet forwarding.

The affordable cost and ease of deployment of IEEE 802.11 compliant equipment has led the majority of WMNs to be based on conventional IEEE 802.11 devices, although this does not limit the potential application of other standards. According to the IEEE 802.11 standard, which was originally proposed for infrastructure Wireless Local Area Networks (WLANs), MCs perform scanning to detect nearby MAPs and simply select to associate with the MAP that provides the highest Received Signal Strength Indication (RSSI) value. The performance of the standard association policy has been extensively studied [6] in the context of IEEE 802.11 WLANs and it is well known that it leads to inefficient use of the network resources. In WMNs, the entire path between the MC and the IGW is composed of two discrete wireless parts: the single-hop access link between the MC and the MAP it is associated with and the multi-hop backhaul part that connects the MAP with the IGW. As the standard policy considers only factors affecting performance on the wireless access link, its direct application on WMNs becomes inappropriate. As a result, more sophisticated association schemes are required to capture performance achieved in both the access and the backhaul network parts.

Trying to address the issues generated by the unique two-tier architecture introduced by WMNs, several approaches on MAP selection have been proposed in the recent literature. An innovative cross-layer association mechanism that considers not only the access link but also routing in the multi-hop backhaul part is proposed in [7]. The authors in [8] consider also the interaction of physical (PHY) layer transmission rate with the packet size and hop count and propose a signaling mechanism through which information about congestion on both parts is passed from the MAPs to the MCs. In [9], a new metric is proposed that takes into account the impact of 802.11 MAC layer contention on bandwidth sharing and results in accurate link throughput estimations. Another approach, proposed in [10], considers also estimation of real-time traffic load conditions trying to cope with the variability of network conditions, which is an inherent characteristic of WMNs. The common characteristic of the works referenced above is that they rely only on simulation-based evaluation of the proposed mechanisms.

Recent research studies in the field of WMNs jointly consider problems that traditionally were considered in isolation, such as association and routing. However, as