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Grade of Service (GoS) based adaptive flow management for Software Defined Heterogeneous Networks (SDHetN)

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ABSTRACT

In today's wireless Heterogeneous Networks (HetNets) deployments, the physical resources which are supposed to handle the huge mobile data requests, are clustered statically by the operators, leading an ineffective resource management. In this paper, we solve this ineffective static resource assignment, by proposing a novel queueing-theoretic Software Defined HetNet (SDHetN) model which orchestrates the HetNets topology using adaptive and scalable flow management heuristics. The proposed SDHetN takes its flexible and scalable characteristics thanks to two algorithms; the Topology Control Algorithm (TCA) and the Flow Admission Control Algorithm (FACA). Specifically, the proposed TCA clusters several OpenFlow (OF) switches using the flows' Grade of Service (GoS) in order to optimize physical resource assignment. The proposed FACA fairly distributes each Flow Authority Virtual Switch (FAVS) that are created in TCA by grouping several switches virtually. We also propose a thread-based parallelization in TCA and FACA increasing the response time and service rate of the SDN Controller. The performance of SDHetN is evaluated by 48 different scenarios and it is shown that SDHetN provides a scalable and fair flow management according to different performance metrics.

1. Introduction

Recently, there has been tremendous increase on the mobile data requests in HetNets. According to Cisco Visual Networking Index (VNI) report, the amount of global mobile data traffic is expected to reach 15.9 exabytes per month in 2018 [1]. Here, due to the limited physical resources in current wireless deployments, the mobile traffic flows should be managed adaptively in order to meet the increased demands. Each flows should be forwarded and distributed according to the physical resources' availability to enhance overall network performance. However, conventional operators does not have any adaptive flow management frameworks that balances flow load in a fairer way according to physical resources. Moreover, the GoSs, i.e. flow blocking probabilities also increase to unacceptable levels.

The solutions based on switching among different Radio Access Technologies (RATs) such as offloading techniques, cognitive radio and dynamic spectrum access technologies could not handle the increasing flow intensities after a certain scalability level, due to limitation in the statically assigned physical resources. Thus, the resource constraints occur and this degrades the overall resource efficiency of the system. In the following subsection, the resource constraint will be defined and illustrated with a specific example.

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1.1. The main challenge: the physical resource constraints in HetNets deployments

In generic wireless architectures, the number of flows that a base station can handle is constant. They are statically clustered. This static clustering limits the serving flows by conceding GoSs of each flow. In Fig. 1, the clustering effect on the number of flows is shown with respect to the blocking probabilities. a.k.a. GoS. Here, GoS is modeled by $M/M/C/K$ markov model [2] where C is the number of physical resources and $[K - C]$ is the queue length. The x-axis in Fig. 1 indicates different topologies with same number of physical resources. In each topology, there are different number of physical clusters, i.e. Access Points (APs) of HetNets. However, as seen in the figure, this clustering of physical resources decreases the number of flows that can be handled. For instance, while GoS parameter is 0.01 and there are 20 physical resources in total, approximately 180 flows can be served with 4 clusters (4 APs), each having 5 physical resources. By using 2 clusters (2 APs) instead of 4, 452 flows can be handled with same GoS value.[1] Consequently, the resource efficiency decreases because of static clustering of physical resources. In other words, the resource efficiency is limited by physical resource constraints.

1.2. Related work about physical resource constraint in HetNets

There exists many studies that try to overcome aforementioned challenge of HetNets by different approaches. The offloading between different RATs offers suitable solution that increases resource efficiency and QoS of offloaded flow. ElSawy et al. [3] presents various offloading strategies to offload users from stressed macrocell to small cells. Kokku et al. [4] emphasizes that inefficiently resource utilization can be removed with their proposed model named as Network Virtualization Substrate (NVS) for effective virtualization of wireless resources in HetNets. In [5], the importance of Network Function Virtualization (NFV) is also clarified as offering rapid service, greater flexibility, improved operational efficiencies etc. Another technique to increase resource efficiency is cognitive radio technologies. In [6], the authors study on spectrum sharing and power allocation in heterogeneous cognitive radio networks with energy efficiency perspective. The energy-efficient resource allocation is examined and formulated in heterogeneous cognitive radio networks with femtocells as a Stackelberg game. Tachwali et al. [7] also studies resource allocation optimization for one cell that subscribes multiuser for the case of the primary user existence in cognitive radio network. The authors in [8] propose location based solution to inefficient utilization of spectrum problem. The novel architecture is designed, which is called the Cognitive Capacity Harvesting network (CCH) that is an aggregation of relay stations which enhance the allocation for secondary users with cognitive capability. On the other hand, [9] tries to have scalable network by indicating an alternative resource allocation mechanism which guarantees a fully efficient allocation when users are price taking. Hong et al. [10] explains the significance of cooperative communication in resource constrained wireless networks. They give wide survey about optimal power allocation for various network topologies and propose cooperation scheme. In [11], a random access protocol that provides fair access to spectrum for different radio systems is proposed by modeling system with Queueing Theory. This is also extended to spectral agile radio in order to provide general model about dynamic spectrum access. Apart from these, there are studies that solve emphasized challenge by using flow based approaches. Liu et al. [12] solves trade-off between resource efficiency and QoS by proposing opportunistic link overbooking technique that is quality guaranteed in flow-level. In [13], the authors manages trade-off between resource efficiency and user fairness. They propose adaptive resource allocation method that consists of subcarrier assignment and power allocation algorithms. Besides flow-based solutions, self-organized networks also offers solution to resource efficiency problem of HetNets. Due to having self-management methods such as self-optimization and self-configuration, E3 project of [14] enhances wireless network efficiency by using cognitive, self-organized resource reconfiguration.

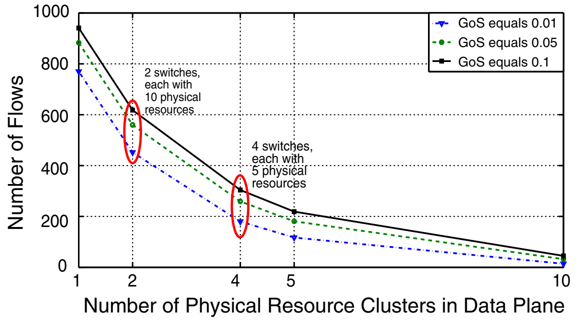

Fig. 1. Clustering effect into the number of flows under certain GoS values on typical HetNet Scenario.

The aforementioned technologies are not enough to meet increasing intensity of flows after a certain scalability level. To overcome this challenge, we strongly believe that resource constraint should be isolated to handle more flows with higher GoS. Moreover, if the flows can be managed fairly via global view on physical topology, scalability and GoSs can be enhanced more than these approaches. In the light of these motivations, we propose a novel adaptive flow management in Software Defined HetNet (SDHetN).

SDHetN redefines network management by separating Data Plane and centralized Controller in Control Plane [15]. Incoming flows are forwarded by OF switches[2] which have only forwarding capability. If a flow could not match any flow table entries in switch, it is defined as newcomer

[1] This decrease on the number of flows is also proved by applying Queueing Theory as seen in Appendix.

[2] The terms "OF switch" and "switch" will be used interchangeably throughout the paper.