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VM placement over WDM-TDM AWGR PON Based Data Centre Architecture

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ABSTRACT

Passive optical networks (PON) can play a vital role in data centres and access fog solutions by providing scalable, cost and energy efficient architectures. This paper proposes a Mixed Integer Linear Programming (MILP) model to optimize the placement of virtual machines (VMs) over an energy efficient WDM-TDM AWGR PON based data centre architecture. In this optimization, the use of VMs and their requirements affect the optimum number of servers utilized in the data centre when minimizing the power consumption and enabling more efficient utilization of servers is considered. Two power consumption minimization objectives were examined for up to 20 VMs with different computing and networking requirements. The results indicate that considering the minimization of the processing and networking power consumption in the allocation of VMs in the WDM-TDM AWGR PON can reduce the networking power consumption by up to 70% compared to the minimization of the processing power consumption.

Keywords: Passive optical Network (PON), Wavelength Division Multiplexing (WDM), Time Division Multiplexing (TDM), Virtual Machines (VM), Arrayed Waveguide Grating Router (AWGR).

1. INTRODUCTION

Several studies have focused on the optimization of power efficiency and architectures in data centres and core networks in order to satisfy the high increase in demand for data rates and energy efficiency [1]-[10]. Conventional data centre architecture designs have faced many challenges over the past few decades which resulted in the need to develop new designs that are capable of providing more scalable, reliable and efficient data centre architectures [11]-[18], [22]-[41].

With the growth of data centres and the increasing number of power-hungry devices within them, a need for designs with passive components has risen to provide more energy efficient architectures with better resource utilization and lower cost [19]. Passive optical networks were introduced as a solution to several challenges in data centre and core networks, which led to enhanced performance in access networks while lowering the cost and latency, increasing the capacity, scalability and providing overall energy efficiency. The passive devices used in these architecture designs are Arrayed Waveguide Grating Routers (AWGR), Fibre Bragg gratings (FBG), and star couplers/splitters [20].

One of the main challenges in data centre architecture design is the underutilization of resources due to the use of ineffective resource allocation algorithms such as round robin. To tackle this issue, virtualization can be used alongside resource provisioning algorithms to mitigate the non-energy efficient utilization of resources within the network.

This paper proposes a Mixed Integer Linear Programming (MILP) model to optimize the placement of virtual machines (VMs) over an energy efficient WDM-TDM AWGR PON based data centre architecture. This model efficiently maps VMs to servers to ensure the most effective utilization of servers, which lowers the number of active servers hence reducing the power consumption.

The remainder of this paper is organized as follows, Section 2 discusses the WDM-TDM PON based data centre architecture, Section 3 discusses the optimization model, Section 4 discusses the results while Section 5 concludes the paper with an overall summary.

2. WDM-TDM PON-BASED DATA CENTRE ARCHITECTURE

Figure.1 shows the WDM-TDM AWGR PON-based data centre architecture, which is a PON cell consisting of 4 racks holding 7 servers each. Communication among racks is provisioned through two intermediate AWGRs through 4 different wavelengths. Another set of 1:N AWGRs provision the communication with the OLT. Each server is equipped with photodetectors and tuneable lasers to enable optimum wavelength selection. Inter-rack communication is achieved either through the AWGR or the OLT, where the AWGR relay traffic to the designated server according to the selected wavelength. All routes available are kept in a routing interconnection map, which facilitates the ability to find alternative routes if required hence providing multi-path routing and load balancing [11].

WDM-TDM-PON was deployed in this architecture to optimize the connections within the architecture whether among the OLT and PON groups or within the PON groups. Introducing TDM to the WDM architecture enabled better utilization of resources where several wavelengths can be sent using different time slots to different destination, providing full connectivity among the OLT, ONU and PON groups [21].

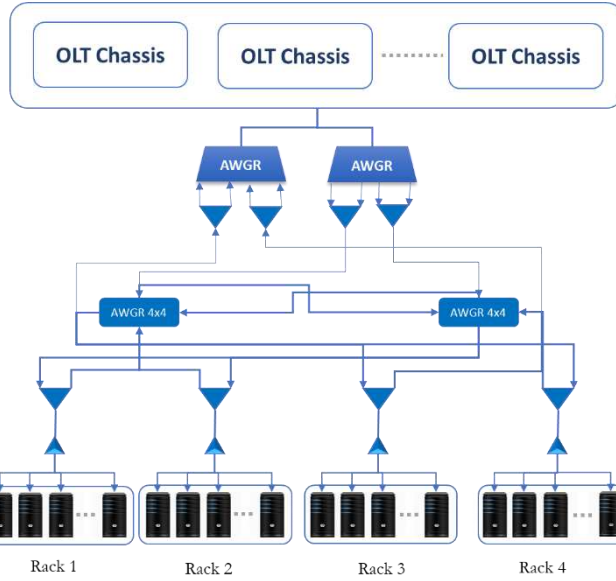


Figure 1. AWGR-Based Passive Optical Network Data Centre Architecture

3. The OPTIMIZATION MODEL

A linear mathematical programming approach was used in this model to mitigate the effects of the underutilized resources by optimally provisioning resources through a resource allocation algorithm. Several conventional algorithms such as the Best Fit Decreasing Bin-Packing have tackled this issue. Our approach is to minimize the power consumption by the use of a MILP model to optimize the virtualization, where VMs are mapped into servers and only utilized when requested.

The objective of this MILP optimization model is to minimize the power consumption of the WDM-TDM AWGR PON-based data centre architecture. Several parameters are considered in this model such as the number of VMs, inter VM traffic, and the processing requirements of the VMs. In addition, consideration is given to the processing capacity of each server and the capacity of each server's ONU. The traffic and demands between the VMs is randomly generated using a uniform distribution between 0.1Gbps and 4 Gbps. The processing capacities of the total 28 servers are also randomly generated between 1.8 GHz and 2.75 GHz with uniform distribution.

Moreover, a constraint is applied to limit the number of servers mapped to VMs at a certain time. Another set of constraints are applied to facilitate the communication among the PON groups and within them, to ensure that the traffic among different groups is within the capacity of the utilized wavelength. The CPLEX solver was used to provide the solution and the model file is written using AMPL. Table 1 below summarizes the key MILP model parameters.

Table 1. Key parameters for the MILP model.

| Parameter | Value |
|---|--------------------|
| Maximum power consumption of a server [14] | 301 Watt |
| Idle power consumption of a server [14] | 201 Watt |
| Processing capacity of a server | 1.8 GHz - 2.75 GHz |
| Number of servers per rack | 7 |
| Number of racks | 4 |
| Power consumption of an ONU [14] | 2.5 Watt |
| Maximum upload and download capacities of the ONU | 10 Gbps |
| Number of VMs | 5 VMs - 20 VMs |
| Processing requirements of a VM | 0.1 GHz - 0.5 GHz |
| Inter VMs traffic | 0.1Gbps - 4 Gbps |

4. RESULTS

In this paper, the WDM-TDM AWGR PON-based data centre architecture was modelled to provision the resources and optimize the VMs allocation with the objective of minimizing the power consumption. The model was run using different numbers of VM requests, and different VMs processing requirements. The number of VM requests used were 5, 10,15, and 20 requests.

The results showed that the model favours allocating several VMs to the same server as long as it meets the capacity constraints, which reduces the levels of traffic flow between servers in the network and the amount of power consumed. This results in a number of servers being switched off or idle, hence lowering the levels of power consumption.

The model was run with two objectives. The first considers minimizing the processing power consumption (Pc) only while the second considers minimizing the processing and networking power consumption (Pc + Pn). Figure 2 (a) and (b) show the total power consumption and the networking power consumption, respectively, when considering the two objectives for 5, 10, 15, and 20 VMs. In this comparison, the average processing requirement for each VM is 0.3 GHz. For such number of VMs and relatively low processing requirements, most of the allocations were fit in a server or two which leads to low networking power consumption and hence both objectives achieve similar total power consumption. Figure 3 (a) and (b) show the total power consumption and the total networking power consumption results for the case of 10 VMs while increasing processing requirement per VM. As this requirement increases, more servers are needed to serve each VM which leads to utilizing more servers and having increased inter VMs traffic between the servers. The total power consumption results under the two objectives show that the allocation is different for each, hence, up to 70% difference in the networking power consumption.

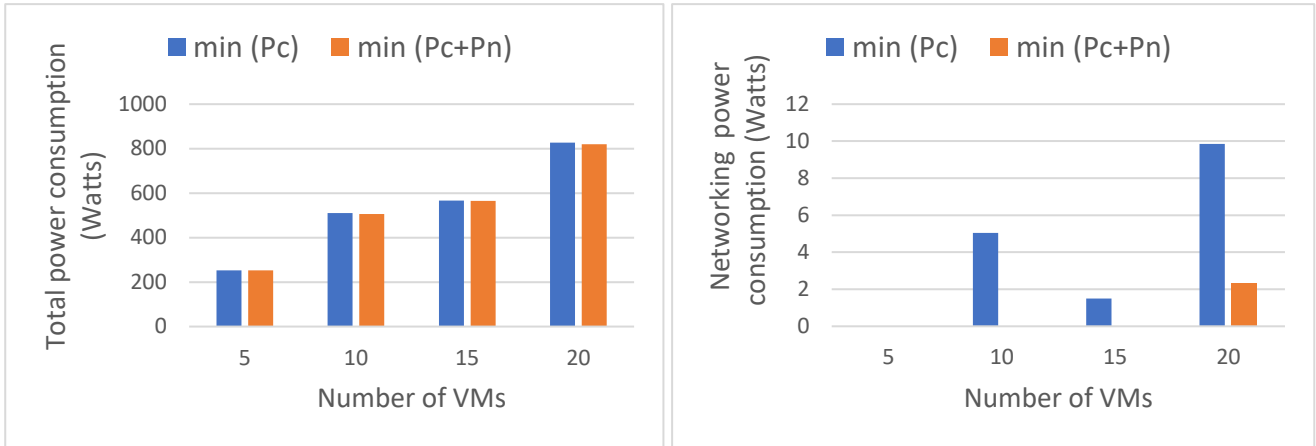


Figure 2. (a) Total power Consumption and (b) Networking power consumption, for different VM numbers

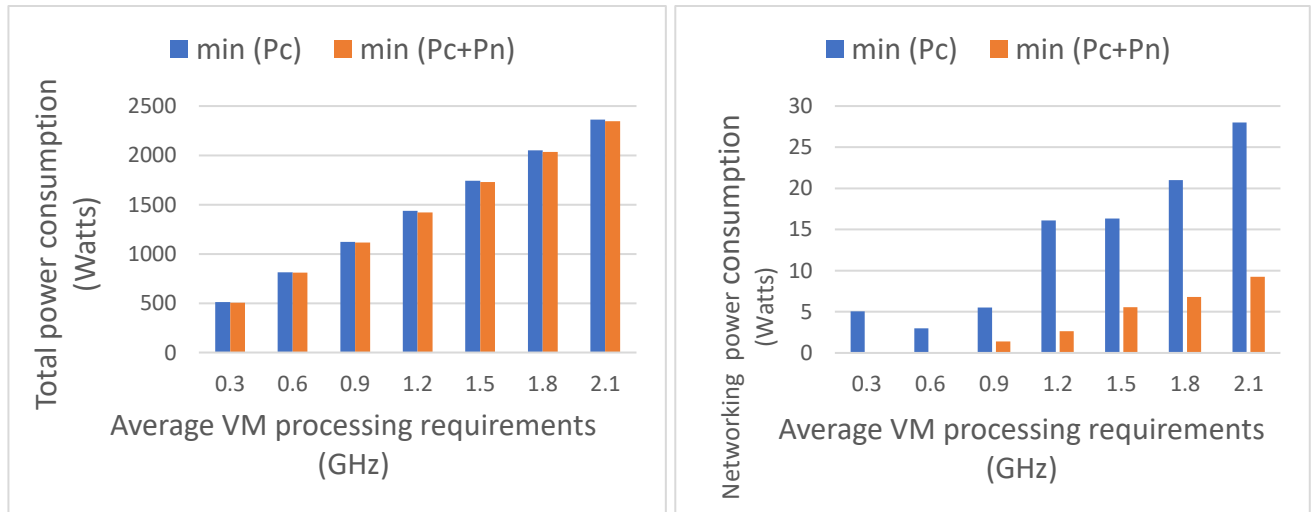


Figure 3. (a) Total, and (b) Networking power consumption of 10 VMs with different average processing requirements.

5. CONCLUSIONS

This paper introduced a mathematical optimization model to optimize the mapping of virtual machines to servers in a WDM-TDM AWGR PON-based data centre architecture. Several VMs were mapped to a single server to ensure that not all the servers in the network are utilized at the same time, which resulted in lower power consumption. The effects of having different numbers of virtual machines and an increasing processing requirement on power consumption has also been tested. Two energy efficiency objectives were also examined and compared. The results show that minimizing the processing and networking power consumption can reduce the networking power consumption by up to 70%. Future work includes considering the memory requirements of the VMs and its impact on the placements and to consider higher number of VMs.

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