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Enhanced Virtual Network Function for Cloud Radio Access Networks

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Abstract

The rapid increase of the demand for online services heavily influenced the data traffic over the networks. The main reason behind the data traffic over various networks is the increase of mobile computing technologies and the billions of tiny devices that generate frequent data for various IoT based applications [7]. In order to accommodate the data growth, the network operators are pulled down to the situation to deploy more resources to share the computational load over the cloud environment [15]. In this paper, we propose an Enhanced Virtual Network Function (EVNF) Placement strategy for Cloud Radio Access Networks (CRAN) with maximized number of base stations for load balancing on distributed cloud environment. The proposed strategy allows the flexible migration of NF from hardware instance to software instance with the optimized utilization of network resources. This approach not only satisfies the resource and latency constrains, but also achieves the optimal operational cost for the network operators. The simulation results confirm that the new approach performs better compared with the ILP based algorithms and heuristic algorithms in terms of load balancing, network utilization and operational cost for network operators.

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1. Introduction

1.1 Virtual Network Function

Virtual Network Functions or VNFs are the software implementations of the different network system functions that can be implemented on a Network system functions that are expected to empower the system to work. Along these lines, a VNF handles a particular system work that keep running on at least one virtual machine over the hardware organizing framework [16].

The individual VNFs, can be viewed as a block of structures and they can be associated or consolidated together, giving every one of the abilities required to give an overall systems administration services. Instances of different VNFs can be found inside all regions of a telecommunications system and they can include: Switching, Tunneling gateway elements, Traffic analysis, Signaling, Application-level optimization, Mobile network nodes, Network-wide functions and Security functions.

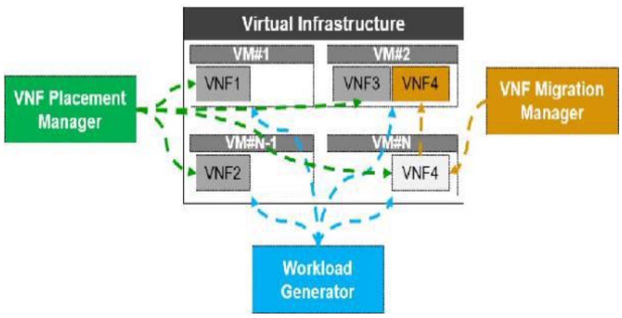

Figure 1: Virtual Network Framework

1.2 Virtual Network Embedding

The advancement in the networking technologies enables the cloud user to operate with flexible, scalable and resource shared environment effectively. This opens the way for designing new paradigm for network architecture, protocol, and services without changing the existing infrastructures. Virtual Network Embedding is a

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major function in deploying virtual machine concepts in the base station to function with the cloud environment [14]. But the major issue faced in this implantation of VNF embedding is effective resource allocation [3, 19]. As VNE is limited to resource constraints, access control limitations and random arrival of virtual service requests, the VNE problem is difficult to solve with the large amount of instances.

1.3 VNF Placement

The network operators are expected to provide multiple instances of the VNR services in order to satisfy the client requests [11]. This could be achieved by balancing the work load among the available cloud resources as well as with the optimal placement of VNF over multiple instances [12]. The effectiveness of the placement algorithms demands the acceptable delays to the end users without violating the Quality of Service requirements and cost effectiveness.

1.4 Cloud RAN

An optimal Mobile Network Architecture focuses on minimizing the operational cost for the network operators and accommodates the heterogeneous demands of the user with the expected QoS satisfaction [19, 21].

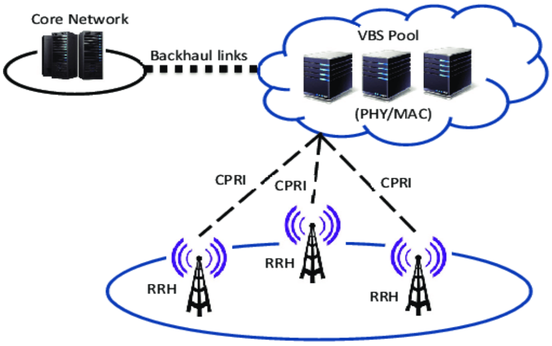

Figure 2: Cloud based Radio Access Network for Mobile Networks

CRAN is such kind of architecture having the potential to meet the challenges like compatibility of existing equipment with the new paradigm, flexible network resource planning and managing [18, 22]. This enables the network operators to share their available resources with the low-cost platforms to balance the increasing workload.

2. Related Works

Optimization is the challenging problem in most of the research problems. With the context of cloud based Radio access network, the major focus of research is on the optimal load distribution over multiple clouds and maximizing the number of base stations for satisfying more user demands. This includes the optimization of resource cost and computational cost. And also the delay is another constraint in the radio access networks. Number of works has been done on the service placement strategies in the Virtualization paradigm. But majority of them focusing on the parameters like cost, latency and QoS requirements. But the requirements for the deployment of Cloud RAN are completely different with their counterparts of traditional mobile telecommunication networks. Peng et al. [14] presents an overall framework to realize the cloud base radio access networks. Jun et al. [6] proposed a novel mechanism with the logical structure of Cloud RAN architecture and explained the advantages of the functionalities of various planes. The coordinated user scheduling and optimum coding scheme is described by the authors.

Checko et al. [4] provided a new technology for reviewing the CRAN platform and acknowledges the benefits of deploying the same. Qian et al. [1] proposed a base station oriented centralized approach for the future generation networks. The authors of [8] investigated the initial limitations with the development of cloud radio access networks in terms of resource analysis, latency calculation and capacity estimation. Peng et al. [20] analyzed the advancements of cloud based technologies related with radio networks.

Yuan et al. [9] addressed the basic approach to the latency requirements of the cloud RAN. Scalability of the existing RAN infrastructure is developed on the base of the centralized BBUs approach on the multiplexed clouds [2].

3. Problem Formulation

Our objective is to create a network model with enhanced allocation of VNFs to the physical nodes distributed across the Radio networks in order to optimize the total operational cost of the network operators. Every physical node we considered for the design will have a minimal bandwidth requirements and computational resources such as CPU, memory, storage area and radio link capacity. The model has enough amounts of available resources which is to be considered with the amount of total estimated resources for the allocation of two different level of mapping: One with the mapping between physical nodes and another one among each VNF. The VNF is mapped with the due consideration of resource cost, transmission cost and migration cost.

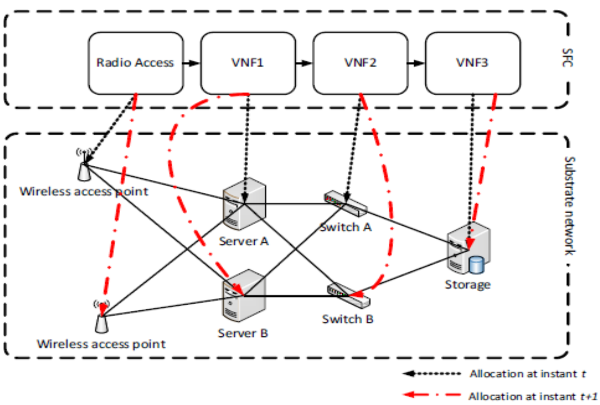

Figure 3: Service Function Chaining in VNF allocation

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3.1 Optimal Distribution of Cloud Services

In this section, the problem of optimizing the overall response time in a multi cloud environment requires the support of strict latency and jitter in the transport networks. Our model deploys the framework using the Enhanced VNF and assigns the requests of clients to meet the service demands [10]. The link delays among the various base stations and the cloud are considered as a significant importance. The variables used in Integer Linear Programming (ILP) are given as a part of the Graph G = {V, E} where the nodes V represent the base stations and the edges E represent the cloud nodes [5], [17]. The capacities of the cloud sites are computed in terms of vector matrix K. The service requirements for the network installation are directly mapped with the available virtual machines. The computing systems are assumed in the representation of basic M/M/1 queuing model, while the queuing model M/D/1 with larger buffer space is used for the links.

Cloud Capacity is bounded by the demands of the virtual machines for the particular cloud. Hence the overall demand of the particular cloud is kept below the available capacity of the respective cloud.

As Virtual Machine capacity is bounded to the demands of the summations of the corresponding base stations, the cumulative demand should be kept below the total capacity of all instances of that particular VM.

Link delays are pre calculated in order to simplify the complexity of the model and the total load across any path in the graph is defined as the total traffic passing through the path between the base station and the cloud.

3.2 Adaptive Allocation and Migration

The combinatorial optimization problem includes the Branch and Bound approach and simulated annealing approach in the proposed literature. We have implemented an enhanced version of the VNF for placement strategies in Cloud Radio Networks. We are aimed to develop a faster solution to minimize the total response time. First we have taken the relaxed problem to solve with respect to the cost simplification and load balancing. The SFCs are sorted in ascending order based on their total cost estimation. For each SFC, we added some constraints and checked for the feasible solution from the simulation results. While the results are found as Success in terms of minimal values then the optimal cost is estimated for the corresponding SFC and the next SFC is selected for the same computation procedure. Otherwise the constraints for the SFC are taken for subtraction in the reverse order.

For the smooth migration from hardware instances to their software counterpart [18], the input values are considered as fractional values with the assumption that the temporary solution found at this stage is Null. The cost estimation for the each fractional value is carried out and the results are stored in a sorted list so as to fine the least fractional entry from the sorted list easily. With this least value, we add constraints in order to derive the feasible solution among the possibilities. If the experiment produces the result as success in Boolean notation, then the overall cost estimation is carried out for finding the optimal solution. Otherwise subtract the constraints and return to the base solution.

4. Experimental Setup

For the tentative setup, we have considered a closed-loop system for our experiments. It is assumed that the requests from each base station are a set of 1000 data packets. For this set of packets or one request, only one reply is returned back from the cloud to the base station as an acknowledgment in order to complete the request cycle. Further request is initiated only after the completion of the previous one has been received. Each base station sends a predefined amount of data for each service request that are selected randomly from a predefined set. Depending on the chosen rate of transmission, the base station sends data at a specific rate. Also, we consider the link delays and overall computational delays in our model. The link queues are modeled as M/D/1 (single server/Poisson arrival/deterministic service times) and server queues are modeled as M/M/1 (single server/Poisson arrival/exponential service times) based on the statistical analysis given in the literature [19]. We change the number of clouds available in the experiment and observe the variations in the estimated total delays.

We developed the simulation model of CRAN topology as shown in the figure and vary the number of base stations and the number of available clouds as per the parameters specified. For instance, 50 base stations are connected with 5 clouds in an aggregation with core routers. Generally the functionalities of the base station is categories into four levels for each layer in the networking reference model such as physical layer, MAC upper layer, MAC lower layer and network layer.

Number of iterations performed for the initial test starts from square root of total requests in the experiment divided by 6 and up to the maximum of the square root of the total number of requests. The conventional approach [13] significantly takes larger time to complete the execution while our approach takes shorter time for the same number of service requests.

5. Result Analysis

VNE acceptance ratio is defined as the number of VNRs successfully embedded to the total number of VNRs during the particular period of time.

$$VNE\ Acceptance\ Ratio = \frac{\sum_{t=0}^{T} Successful\ VNR}{\sum_{t=0}^{T} Total\ VNR\ arrivals}$$

The revenue generated by accepting the VNR requests is defined as the amount of resources the request demands and the cost of accepting the VNR requests is the total physical resources allocated to the particular request during the allotted time.

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Table 1: Performance comparison on Execution Time

No of Service Requests	Execution Time(msec)			
	SLFL	ILP	Heuristic	EVNF
500	232	213	186	170
1000	418	383	335	306
1500	735	675	589	539
2000	1213	1113	972	889
3000	1819	1670	1458	1333
5000	2638	2422	2115	1933

The profit generated to the network provider can be estimated with the ratio between the embedding revenue to the cost of embedding in a certain period of time.

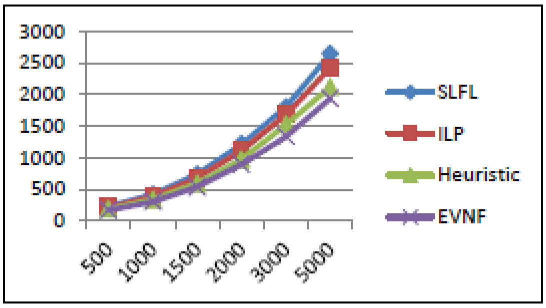

Figure 4: Performance comparison (Execution time)

We have plotted the graph of response time varying with the number of service requests in increasing order against the base line approaches. While keeping only the response time as quicker compared to the baseline methods, it's observed that the overall delay in complete response cycle is also minimized. The results demonstrate the optimal no of cloud requirements at the different traffic loads.

Table 2: Performance Comparison on Response Time over VM Migration Instances

No of Service Requests	Response Time(msec)			
	SLFL	ILP	Heuristic	EVNF
500	220	207	179	186
1000	390	367	331	317
1500	687	656	551	548
2000	1169	977	949	944
3000	1774	1536	1483	1396
5000	2436	2130	1958	1957

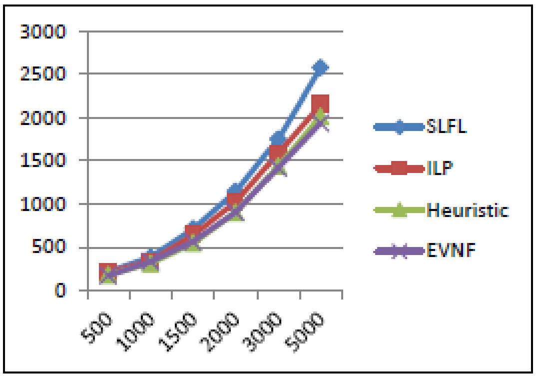

Figure 5: Performance comparison (VM Migration Instances)

The graph shows the service migration instances in accordance with the varying number of service requests. This shows the minimization of response delays during the adjustments of number of service requests.

Table 3: Cost Estimation (Approximate)

No of Service Requests	Total Cost			
	SLFL	ILP	Heuristic	EVNF
500	135	101	159	93
1000	314	341	275	249
1500	452	462	412	334
2000	1149	543	840	517
3000	1727	1031	687	838
5000	1974	1273	1851	1048

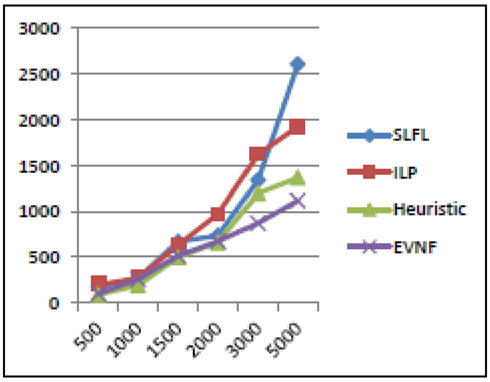

Figure 6: Performance comparison (Total cost)

As the resource utilization is optimized in the proposed model the cost of deployment and operational cost also minimized compared with the regular ILP and SLFL approaches. The graph depicts the total cost estimated for the various sample sizes as an instance of average cost.

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6. Conclusions

At the outset, we have enhanced the performance of the VNF placement strategies for the Cloud Radio Access Networks in terms of response time, load balancing (effective resource utilization), and further the cost for the network operator. This approach meets the optimal requirements for the cost and capacity constraints while satisfying the latency requirements between the base stations and the clouds. We have also worked out the simulation for demonstrating the purpose of effective resource utilization with the existing infrastructures of the network operators so as to make them to compatible for the better scalability for the future expansion.

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