VIRTUAL MACHINE DYNAMIC MIGRATION STRATEGY BASED INTELLIGENT FLOW FORECAST TECHNIQUE FOR CLOUD DATA CENTERS

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Abstract : It is a challenging task to propose an efficient Cost-Effective Network Topology to provide consistent performance for large networks that consists of more number of Servers, Routers and Nodes. From its earlier literature survey, we found that a few popular Server-Centric Network Topologies such as BCube, Bidiensional Compound Network (BCN) and FiConn were proposed. These three topologies were studied thoroughly and noticed that all these topologies were are not expandable and also it was noticed that it is needed to spent considerable cost to expand further. This is considered as the major issue and concern to expand or upgrade the Data Centre. It is also observed that, as almost all Industries and Institutes needed powerful Data Centers for their Business demands and growth, the Data Centre Network (DCN) is much researched and improved. This massive usage of DCN, the Energy Consumption is significantly higher side. Thus, to manage the massive power demand, the Software Defined Network (SDN) Model was proposed to control Resources by Turning Off or on in accordance with the traffic demands. The Software Defined Networking (SDN) is the current promising solution for controlling the resources of DCN and still it is noticed that the Power Efficiency is one of the major challenges. To address the above mentioned issues, it is highly needed to propose an efficient model to improve the power efficiency for Data Centre Network (DCN). This Research work focusses on the issues of Energy Saving and maintaining high QoS. To achieve the same, we proposed an efficient Technique called Intelligent Flow Forecast Technique for Distributed Centre Networks (IFF-DCN) that will predict the Resources Utilization and Traffic Demands as well in advance and accordingly resources will be Turn On or Turn Off. To improve its efficiency further, the Virtual Machine (VM) Dynamic Migration Technology (VMDMS) was proposed. The proposed VMDMS is implemented and simulated. The performances of the proposed Model were studied thoroughly. From the simulation results, it was noticed that the proposed model VMDMS achieves higher performances as compared with the existing IFF-DCN in terms of Energy Efficiency, Server Resource Utilization, and Server/Physical Machine Failure Rate.

IndexTerms **-** Virtual Machine, Physical Machine, BCube Connected Crossbars (BCCC), Data Centre Network (DCN), Energy Efficiency, Software Defined Networking (SDN), ARIMA.

I. INTRODUCTION

Large online service providers such as Google, Amazon and Microsoft have built thousands of Servers in the huge Data Centres. The Data Centre Network (DCN)[1,2,3,4,5] can be classified as Switch-Centric Networks and Server-Centric Networks. In a Switch-Centric Network [1,2,5,7], the switches are accountable for routing and addressing and the servers are used only to send and receive packets. In a Server-Centric Network [1,2,3,5], the servers are responsible for the Routing. The Server acts as end hosts and relay nodes. The main advantage of this network is low hardware cost. The most complex task can be shifted to the servers, by using inexpensive commodity switches. The Server-Centric Network can accelerate the network innovation, as the servers are programmable than the switches.

BCube [1,2,3,4,5,8] is a popular Server-Centric Network with benefits such as Low Network Diameter and High Routing Efficiency. But it is limited to poor expandability [9,10,11,12], as it incurs tremendous human effort and hardware replacement. It is impossible to manipulate the existing network structure.

A server-centric network topology called as BCube Connected Crossbars (BCCC) [1,3,6,7,8,9] was proposed which constructed using dual-port commodity servers and commodity switches. This makes it a cost-effective network solution for large-scale data centres. This is easily expandable, without requiring any change to the existing network infrastructure or the number of server ports. However, it is revealed that the BCCC fails to focuses Energy Efficiency.

An Energy-Efficiency-Elastic Multi-Controller (E3MC) based BCube Connected Crossbars (BCCC) was the previous proposed work of this research work [2] to improve Energy Efficiency of the large Data Centers in Cloud Setup. In E3MC based BCCC, there is a dual consideration of power optimization for forwarding plane and control plane.

In the forwarding plane, the multi-path routing with traffic/flow split is used to improve power efficiency. Also, the power saving of multiple controllers is studied in control plane. In this work, the energy consumption model is used to choose the key devices and other idle devices/ports could be shut down to optimize the energy efficiency in DCNs.

However, from the analysis of the author [1,2], it was noticed that the existing models unable to provide the required QoS to the requested Cloud Users. This is considered as one of the challenges in Cloud Setups. To address this issue, this research work proposed an efficient Technique called Intelligent Flow Forecast Technique for Distributed Centre Networks (IFF-DCN) that will predict the Resources and Traffic Demands as well in advance. Experimental Results shown that the performance of IFF-DCN can further be improved in term of Energy Consumption by introducing Virtual Machine (VM) Dynamic Migration Technology (VMDMS). Thus, this research work proposed an efficient Virtual Machine Dynamic Migration Strategy based Intelligent Flow Forecast Technique (VMDMS-IFF)

The remaining sections of this work are organized as follows: Section 2 describes the BCCC Network Structure and the structure properties of BCCC. In section 3, our previous work Intelligent Flow Forecast Technique for Distributed Centre Networks (IFF-DCN) was narrated. The proposed Model called Virtual Machine Dynamic Migration Strategy based Intelligent Flow Forecast Technique (VMDMS-IFF) is discussed in Section 4. Section 5 presents the performance analysis of the proposed VMDMS-IFF and findings are concluded in Section.

II. BCUBE CONNECTED CROSSBARS (BCCC)

The BCCC Network Structure and Structure Properties were described in this section.

2.1 Network Structure

The BCube Connected Crossbars BCCC [1,2,3,8,14,15] is a recursively defined structure that is built with the switches and dual-port servers. Within an element, each server is connected to the switch using its first port, and the second port is left for expansion purpose.

The BCCC is denoted with order 'k' as BCCC (n, k), where 'n' is the number of servers connected to each switch in each element. A BCCC (n, 0) is simply constructed by one element and 'n' switches, in which each server in the element is connected to one of then switches using its second port. A BCCC(n, k) is constructed by 'n' BCCC(n, k−1)s connected with nk elements.

To build BCCC (n,k), there is a need for indexing n BCCC(n,k-1)s from 0 to n-1. In each, the servers are denoted as $a_{k+1}a_k a_{k-1} \dots a_0$, where $a_0 \in [0, k-1], a_i \in [0, n-1], 1 \le i \le k+1$. Here a_{k+1} is the most significant digit of the server with the address $a_k a_{k-1} \dots a_0$ in a BCCC(n,k-1). To build BCCC (n, k), there is a need for $(k+1)n^{k+1}$ dual port servers, $(k+1)n^k$ n-port switches and n^{k+1} $(k+1)$ port switches.

Two types of switches called as type A and type switch are required. A type 'A' switch has 'n' ports used to form an element. Type 'B' switch has (k+1) ports used for connecting different elements. Hence, the intra-element communication between the servers within an element is conducted through the first port of each server. The inter-element communication between the servers in different elements is conducted through the second port of the server.

A server is connected to a (k +1) port switch through its second port, when it satisfies the condition that server $a_{k+1}a_k a_{k-1} \dots a_0$ is connected to switch $s_k s_{k-1} \dots s_0$ with $s_i = a_{i+1}, \forall i, 0 \le i \le k$. Thus the addressing scheme is given to build BCCC(n,k), each server in those elements denoted as $a_{k+1}a_k a_{k-1} \dots a_0$, where $a_0 = k$ is connected only to a switch in one of the n BCCC(n,k-1)'s denoted as $s_k s_{k-1} \dots s_0$ through the second port under the rule that $s_i = a_i + 1$, where $0 \le i \le k$. Based on the above construction, a pair of servers acts as neighbors, such that they are connected to the same switch, only if $\exists i, i = a_0 + 1$ or $i = 0$, such that $a_i \ne a_i'$, and $\forall j, 0 \le j \le k+1, i \ne j$, such that $a_j = a_j'$.

If the server $A = a_{k+1}a_k a_{k-1} \dots a_0$ and its neighbour $A' = a_{k+1}' a_k' a_{k-1}' \dots a_0'$, $\exists i \in [0, k+1]$ such that $a_i \ne a_i'$ and $a_j \ne a_j'$, where $\forall j, 0 \le j \le k+1$ and $j \ne i$ are connected by a switch $s_k s_{k-1} \dots s_0$ equal to.

$$\begin{cases} a_{k+1}a_k a_{k-1} \dots a_{i+1}a_{i-1} \dots a_1 \{i-1+n\} & i = a_0 + 1 \\ a_{k+1}a_k a_{k-1} \dots a_1 & i = 0 \end{cases} \quad (1)$$

Where $\{i-1+n\}$ is the least significant digit in the address of the switch. Fig.1 shows the example of BCCC(4,1). BCCC(4,1) has four BCCC(4,0)s and four elements. Servers 000, 010, 020 and 030 belong to the first BCCC(4,0) and they are connected to switch 04 through their first ports. Servers 001, 101, 201 and 301 belong to the same element, and they are connected to switch 05 through their first ports.

A server A=a_(k+1) a_k a_(k-1)…a_0 is in the ith dimension, if a_0=i-1, where 1≤i≤k+1. By this token, the dimension of servers within the same element is same and dimension of servers connected by type B switch is different. The size of a BCCC(n,k), S_BCCC (n,k) is the number of servers within a BCCC(n,k) network. Then

$$\begin{cases} S_{BCCC}(n, 0) = S_{element}(n) = n \\ S_{BCCC}(n, k) = n \cdot S_{BCCC}(n, k-1) + n^k \cdot S_{element}(n) \end{cases} \quad (2)$$

Thus, the size of BCCC(n,k) is $(k+1)n^{k+1}$. Let $L_{BCCC}(n, k)$ denotes the number of linking wires required to build BCCC(n,k) and 'd' is the degree of each server. Each server is connected to switches through two wires. There is no wire between any pair of servers.

$$L_{BCCC}(n, k) = d \cdot S_{BCCC}(n, k) = 2(k+1)n^{k+1}$$

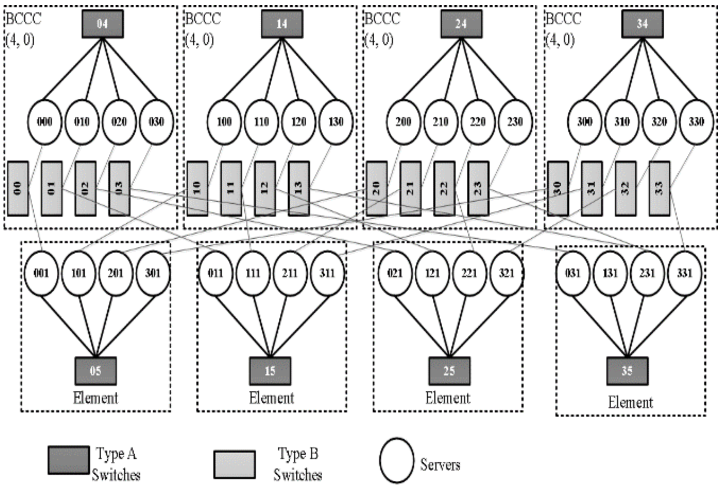

Fig.1 Topology of BCCC(4,1) comprising 4 BCCC(4,0)s along with 4 elements

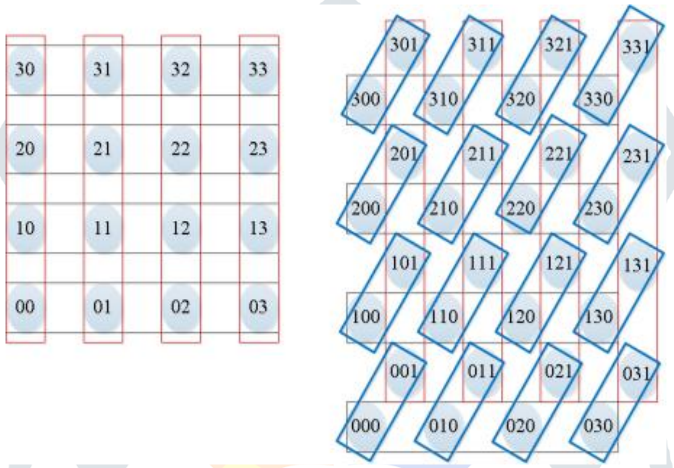

Fig.2 Geometrical view of BCube(4,1) and BCCC(4,1).

2.2 Structure properties of BCCC

Some important properties of BCCC that are critical to the routing performance are analyzed with the following Theorem. Theorem: The diameter of a BCCC(n, k) is 2(k+1). Consider the BCCC (4,1) as an example. Its diameter is 4. If a packet is to be sent from server 001 to server 221, one possible path is 001, 000, 020, 021 and finally to 221. The number of hops through this path is 4. Another candidate path is from 001, to 201, 200, 220, and finally to 221. The number of hops for this path is also 4.

Algorithm 1:

BCCC routing algorithm

Input: source A and destination A' where

A is $a_{k+1} a_k a_{k-1} \dots a_0$ and $A[i] = a_i$; A' is $a'_{k+1} a'_k a'_{k-1} \dots a'_0$ and $A'[i] = a'_i, i \in [0, k+1]$ and

$\prod$ is the permutation of $[k+1, k, k-1, \dots, 1]$

Output: A list of intermediate servers of path from A to A', path (A, A')

BCCC Routing $(A, A', \prod)$ Path (A, A') = {A}; B=A;

for $(i = k+1; i > 0; i--)$//k+1 iterations;

if $A[\pi_i] \neq A'[\pi_i]$ { $B[0] = \pi_i - 1$;}

if $A \neq B$ { append B to path (A, A'); $B' = B$; $B'[\pi_i] = A'[\pi_i]$; $B' = B$;append B' to path (A, A'); }

if $A' = B'$ { append A' to path (A, A');} return path;

Algorithm 2:

Building Multipath between pair of source and destination

Input: source A and destination A' where

A is $a_{k+1} a_k a_{k-1} \dots a_0$ and $A[i] = a_i$

A' is $a'_{k+1} a'_k a'_{k-1} \dots a'_0$ and

$A'[i] = a'_i, i \in [0, k+1]$

Output: A set of all parallel paths, PathSet

BuildingMultiPaths(A, A')

PathSet = {};

for $i = 1; i \leq k; i++$

ifA[i] $\neq$ A′[i] { P_j = DirectRouting(A, A′, i); }else { P_j = IndirRouting(A, A′, i); }add P_j to PathSet;
return PathSet
DirectRouting(A, A′,i)
d=1;
for $j = 1; j \geq i - j; j--$
{ $\pi_d = j \bmod (k+1) + 1;$
// $\prod = \pi_{k+1}\pi_k \ldots \pi_D$} d++;
return BCCCRouting(A, A′, ∏);
IndirRouting(A, A′,i)
path ={A}; B = A;
if $A[0] + 1 \neq I$ { $B[0] = i - 1;$
path += B; set B[i] to a value different to A[i];
path += B; d = 1;
for $j = i - 1; j \geq i - 1 - k; j$—
{ $\pi_d = j \bmod (k+1) + 1;$ } d++;
path += BCCCRouting (B, A′, ∏);
return path;

III. INTELLIGENT FLOW FORECAST TECHNIQUE FOR DISTRIBUTED CENTRE NETWORKS (IFF-DCN)

This model IFF-DCN was designed to address the following

i. Improving Resource Utilization by controlling Resources through control plane
ii. Minimizing Energy Usage and Energy Consumption
iii. Maximizing Power Efficiency
iv. Predicting and satisfying Resources' Utilization and future Traffic Demands
v. Prediction of Future Traffic Load
vi. Satisfying QoS Demands

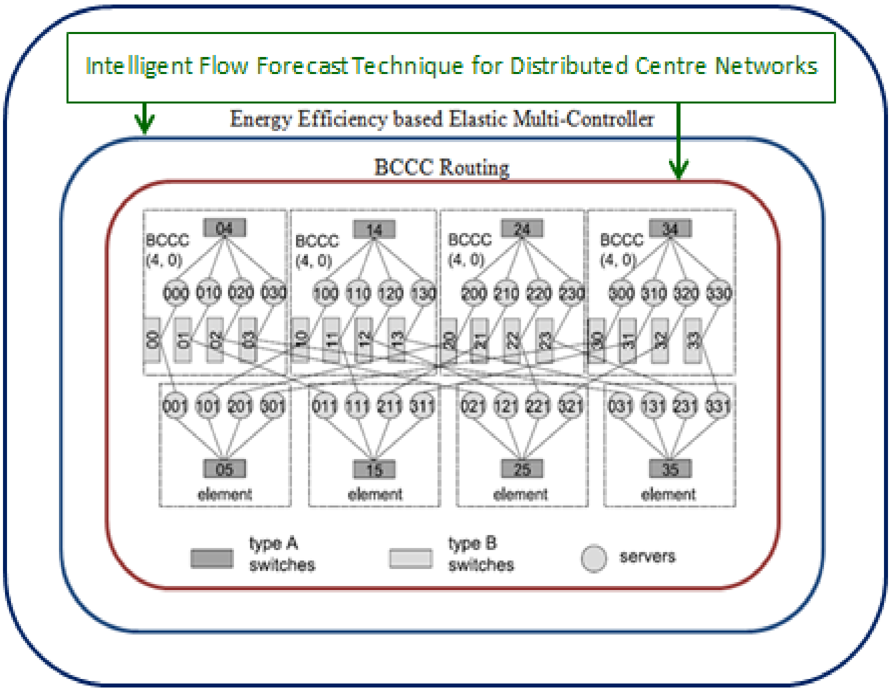

Fig.3 Simulation view of IFF-DCN

The Elastic Multi-Controller (E3MC) based BCube Connected Crossbars (BCCC) Model is improved with integrating the proposed Intelligent Flow Forecast Technique which is shown in the Fig. 4. The prime objective of the proposed model is used to forecast the Traffic Load that will demand in future. Based on the predicted information, the control plane will be instructed resources to activate functions to address users' demands and QoS efficiently and effectively. That is, the Intelligent Flow Forecast Technique is used to scale-up or scale-down the scheduler to optimize functions to execute tasks.

The proposed model consists of two phases namely i. Prediction of Energy Consumption and ii. Prediction of Traffic Load and QoS Demand.

3.1 Prediction of Energy Consumption

The Energy Consumption is the summation of Energy Consumption by Active Functions (nt) and Energy Consumption of the Function Transition (mt – mt-1), where m is slots. The procedure to calculate energy Consumption is shown below.

$$E(n_t, \lambda) = \tau \sum_{t=1}^{m} n_t \times P(a_t / n_t) + \emptyset \times \sum_{t=1}^{m} |m_t - m_{t-1}| \quad (3)$$

Here nt is the Function and Sequence, a_t is the Load in the sequence ($\lambda_1, \lambda_2, \lambda_3, \ldots.. \lambda_m$), m is the time slot.

3.2 Prediction of Traffic Load and QoS Demand

From the Literature Survey, it was noticed that the Linear Time-Series Forecasting model called Auto-Regressive Integrated Moving Average (ARIMA) is popularly used for predicting the Traffic Load. This model is separated as three Unique Parts such as

- Auto-Regressive : Regressed ie Prior Value(s), this is representing as p
- Moving Average: Regression Error which is the Linear Error occurred in the Past. This is representing as q and the difference between orders.
- Integrated : Used to fit the Model for a Process

This research work employed an improved Auto-Regressive Integrated Moving Average Model called Seasonal ARIMA (SARIMA) for predicting Traffic Load and pattern with higher accuracy [16].

The general model of the Seasonal ARIMA is designed as follows.

$$ARIMA\ Model\ \{ \emptyset_p(B^s)\, \theta(B)\, \nabla_s^D\, \nabla^d\, x_t \} \quad (4)$$

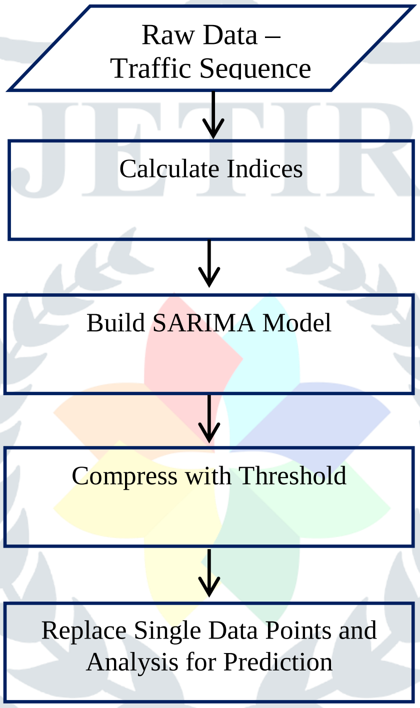

Fig.4 SARIMA Model for Traffic Pattern Prediction

$\emptyset_p\,(B^s)$ is representing as the Components of Moving Average where the parameters p and s are orders and the B is Backshift Operator.

$\nabla_s^D\, \nabla^d$ is representing as the components of ordinary and difference as well.

IV. VIRTUAL MACHINE (VM) DYNAMIC MIGRATION TECHNOLOGY (VMDMS)

This Research work noticed that the performance of IFF-DCN can further be improved in term of Energy Consumption by introducing Virtual Machine (VM) Dynamic Migration Technology (VMDMS). It will facilitate to reduce energy consumption in Data Centers that designed for Cloud Setup. The proposed Virtual Machine (VM) Dynamic Migration Technology (VMDMS) Technology monitors CPU usage and it will help to place Virtual Machine to manage CPU Usage to maintain at our required Threshold Level. That is if the CPU utilization reached predicted level, the Virtual Machines will be placed on the Cluster to maintain Utilization and avoid CPU overloading. The VM Dynamic Migration Model is shown in Fig. 5 and the procedure is described in the following section.

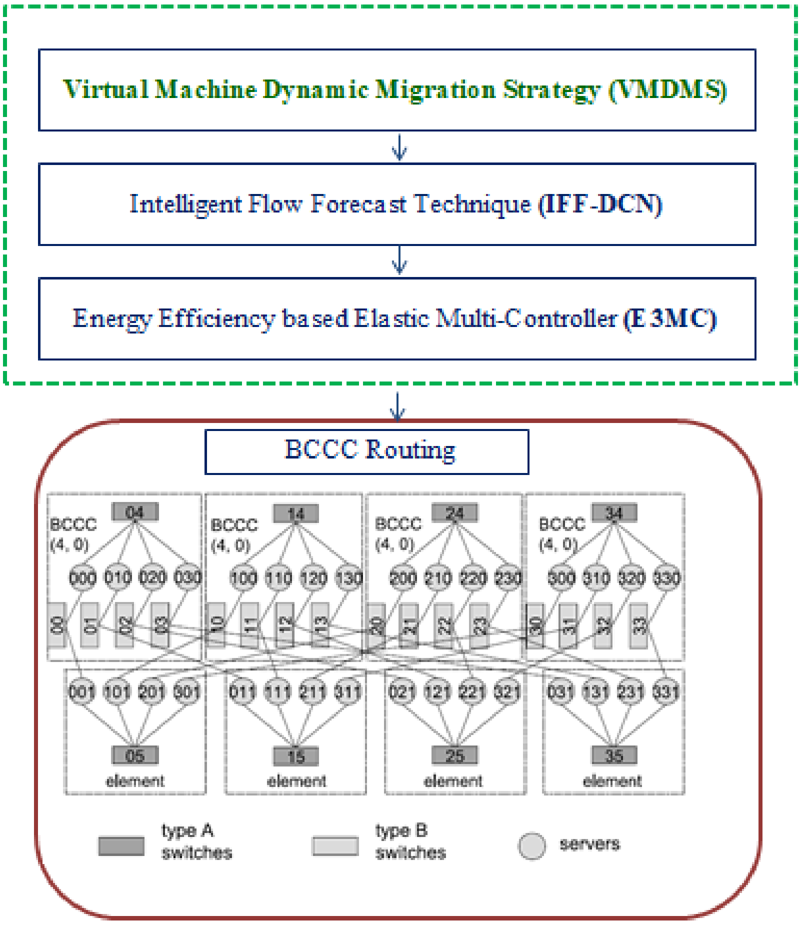

Fig. 5 VM dynamic Migration Model

4.1 VM Dynamic Migration Model

VM Dynamic Migration Model helps VMs to move between Clusters of Physical Hosts without being suspended any Physical Memories. The purpose of having dynamic migration is to reduce the power consumption for large percentage because of VM dynamic migration and aggregation of VMs to small set of PMs and bring to down state of unused ones.

The migration process also brings extra energy consumption which may decreases the advantage of VM migration. Physical machines movement from pm_j to pm_k of Virtual Machine energy consumption is as follows:

$$E_{migr}(vm_i, pm_j, pm_k, t) = t_{migr}(vm_i, pm_j, pm_k, t)\ X\ (P_{cpuinc}(pm_k, vm_i, t) + P_{network}(pm_j, t) + P_{network}(pm_k, t) \quad (5)$$

CPU Power Consumption of pm_k where denoted as $(P_{cpuinc}(pm_k, vm_i, t)$ pm_k of after the migration of vm_i and $t_{migr}(vm_i, pm_j, pm_k, t)$ denotes the time of the total migration process which can be formulated as:

$$t_{migr}(vm_i, pm_j, pm_k, t) = \frac{RAM(vm_i)}{min(BW_{re}(pm_j, t), BW_{re}(pm_k, t))} \quad (6)$$

where $RAM(vm_i)$ denotes the RAM size of *vmi* and *BWre(pmj)* denotes the available and width of *pmj* at time t. With the energy consumption model of VM dynamic migration mentioned before, the reduction of system energy consumption caused by a VM dynamic migration is formulated as follows:

$$E_{save}(vm_i, pm_j, pm_k, t) = E_{dif}(vm_i, pm_j, pm_k, t) - E_{migr}(vm_i, pm_j, pm_k, t) \quad (7)$$

Where $E_{dif}(vm_i, pm_j, pm_k, t)$ it denotes difference between energy consumption of vm_i
Incurred to pm_j and to pm_k and it can be expressed as

$$E_{dif}(vm_i, pm_j, pm_k, t) = t_{re}(vm_i) - t_{migr}(vm_i, pm_j, pm_k, t)X - P_{cpudec}(pm_i, vm_j, vm_i, t) - E_{migr}(vm_i, pm_j, pm_k, t) - P_{cpudec}(pm_k, vm_j, t) \quad (8)$$

where $tre(vm_i)$ denotes the residual service time of vm_i, it depends on the task length and allocated CPU resource while $P_{cpudec}(pm_k, vm_j, t)$ is the CPU power after reduction of pm_j after vm_i being migrated out.

4.2 Techniques of VM Dynamic Migration Mode

This Technique was proposed for migrating Virtual Machine (VMs) between Clusters of Physical Memory. It consist of Fours Processes to predict CPU usage and utilization in Clusters. They are CPU Load Status Prediction, Virtual Machine Selection, and Virtual Machine Placement.

4.2.1 CPU Load Status Prediction

The prime objective of this Process is to achieve energy Consumption and achieve demanded QoS. It ensure that CPU Utilization and Usage will be monitored as the give QoS.

4.2.2 Virtual Machine Selection

When CPU Utilization exceeds its assigned Utilization, as the procedure, Virtual Machine will be identified and selected for placing at the required Cluster to maintain CPU Utilization.

4.2.3 Virtual Machine Placement

The Selected Virtual Machine will be moved to concerned Cluster of CPU that Overloaded and Utilization will be optimized and maintained as per the QoS assigned. This is the prime purpose of this CPU Load Status Prediction Process.

V. PERFORMANCE ANALYSIS

This Research Work has created experimental setup and conducted Simulations for evaluating the performance of the proposed Virtual Machine Dynamic Migration Strategy based Intelligent Flow Forecast Technique (VMDMS-IFF) and the existing Routing Protocol IFF-DCN. The experiments were repeated to thoroughly study the efficiency of the proposed model. As shown in the Fig. 6, the Simulation Model was constructed with max of 33 nodes in the each Switch/Router Network and Nodes ‘6’, ‘20’ and ‘12’ are defined as the properties of the multi-controller SDN.
This setup can be edited to evaluate the efficiency of the proposed model. This research work created 80 Functions related to Cloud-Content Delivery Network.

All these functions can be controlled in accordance with the Users Demands and Traffic Availability as well. The experimental set up was made as to control (Switch On or Switch Off) Resources such as Servers, Routers, and even Firewalls depends upon Users’ QoS demands and available load. This is facilitating to reduce cost and Energy as well for computations and communications. This can be achieved with the help of the proposed Model.

The Simulation is setup to create different Traffic Rates during simulation Periods and the Maximum Traffic is assigned as 120000 MBs. These Bandwidth was shared by all Functions and for each function, around 1200 MBs is reserved or functions during executions, it may avail maximum of 1200 MBs for its various operations and communications.

The simulation has created a Testbed that consists of 10 Hosts with 8 GB RAM and 64 Bit OS.

The experimental results were shown in the Figures Fig. 7 to Fig. 10.

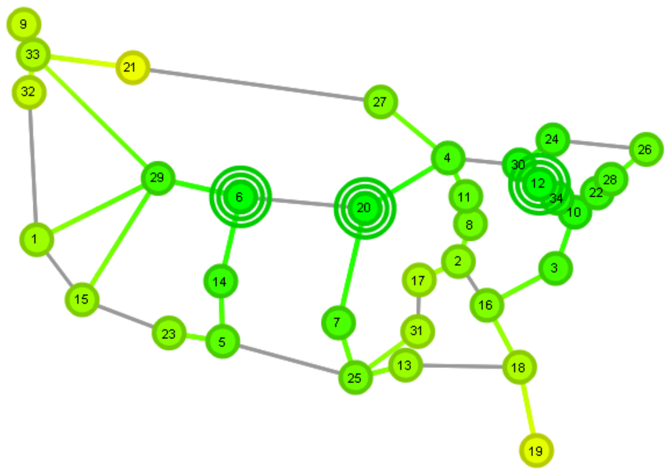

Fig.6 Simulation view of IFF-DCN

As shown in the Fig.6, the proposed Model Virtual Machine Dynamic Migration Strategy based Intelligent Flow Forecast Technique (VMDMS-IFF) needs relatively less number of Servers/Physical Machine needed to accommodate and configure more number of Nodes with the help of Virtual Machine Placement approach. This helps to reduce Server maintenance cost and power consumption as well.

The Traffic Load measured during the simulation is shown in the Fig.7.

Fig. 7 shows the Average Traffic recorded for Seven Hours. Based on this pattern, we scheduled various Functions which created for execution and analysis purpose. From the Fig. 8 to Fig. 10, we evaluated the performances of the proposed model with the recorded Traffic and demanded QoS.

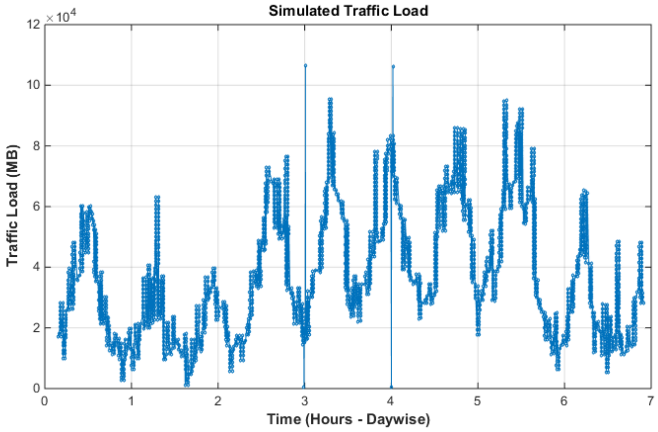

Fig.7 Traffic Load Recorded by the proposed Model VMDMS-IFF

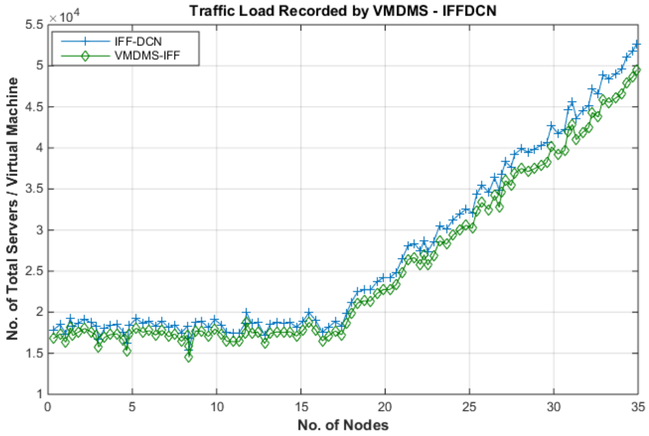

Fig.8 No. of virtual Machines involved Traffic Load Recorded by the proposed Model VMDMS-IFF

It is revealed that till n < 19, the proposed Model manages all Users demand with QoS with almost fixed number of Servers/Physical Machine, which are relatively lesser than that of our previous model and achieves better Resource Utilization. As the Nodes increased, ie n > 19, the utilization is relatively declined but however, the proposed model VMDMS-IFF performs better than that of our previous model as shown in the Fig. 8.

It is also observed that the proposed model VMDMS-IFF Satisfies the Users Demands in term of QoS with minimum number of Servers/Physical Machine that maximizes Servers Utilization which reduces Cost and Power consumption to Users. This is shown in the Fig. 9.

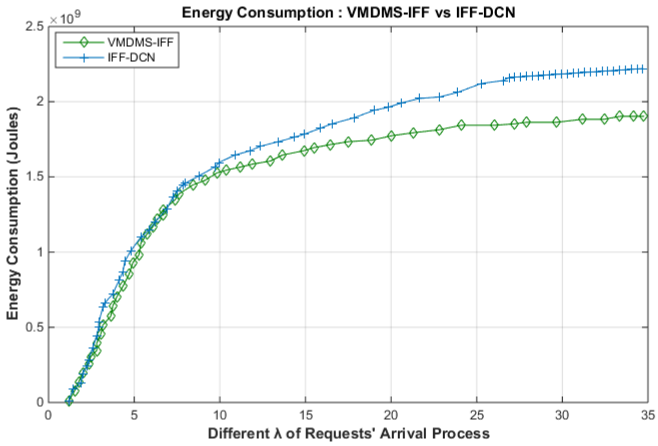

Fig.9 Energy Consumption by the proposed Model VMDMS-IFF

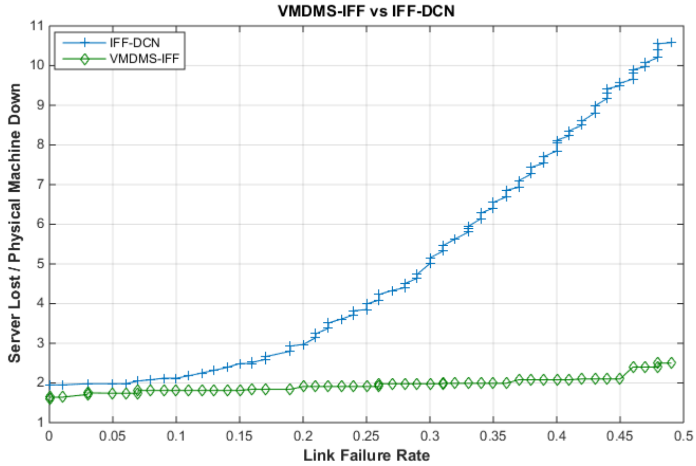

Fig.10 Server Failure Status of the proposed Model VMDMS-IFF

As shown in the Fig. 10, Server/Physical Machine failure rate by the proposed model is relatively less. This is facilitating less Link Failure that improve better Throughput.

VI. CONCLUSION

This Research Work proposed an efficient Virtual Machine (VM) Dynamic Migration Technology (VMDMS) to maximize the performances of its previous Model IFF-DCN in terms of Energy Efficiency, Server Resource Utilization, Server Failure Rate. This will capable of predicting the required number of Resources and Traffic Demands as well in advance and accordingly resources will be Turn On or Turn Off. The proposed VMDMS is implemented and simulated. The performances of the proposed Model were studied thoroughly. From the simulation results, it was noticed that the proposed model achieves high performance as compared with the existing IFF-DCN in terms of Energy Efficiency, Server Resource Utilization, and Server Failure Rate.

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