EnergyEfficiencyinCloudComputing

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***Abstract*—Cloud computing is one of the recent emergingtechnologiesthatprovidesservicestoconsumersinapayasyougo model. Cloud computing offers ITC based services over theinternetandtheuseofvirtualizationallowsittoprovidecomputingresources.DataCentersarethecoreofcloudcomputing, which consists of: networked servers, cables, powersources,etc.whichhosttherunningapplicationsandstoreBusiness information. High performance has always been themost critical concern in cloud data centers, which comes at thecost of energy consumption. The vital challenge is balancingbetweensystemperformanceandpowerconsumptionbyreducingenergyconsumptionwithoutprejudicialimpactontheperformance and quality of services delivered. There are manytechniques and algorithms proposed to achieve efficient energyutilization in cloud computing, these techniques include: VMMigration, Consolidation and Resources orchestration in cloudcomputing. This paper provides a survey of approaches andtechniquesfor energy efficiency in cloudcomputing.**

***Index Terms*—Cloud computing, energy efficiency, resourcemanagement, virtualization.**

I. Introduction

The progress of technology and incorporating networks,storage and processing power led to new era of computing,called cloud computing or commonly known as the cloud.Cloud computing is defined as a technological paradigm thatallowson-demandaccessviatheinternettoacommonsharedcomputingresources.Itisconsideredtobeamodelforsupervision,storingandprocessingdataonlineviatheinternet [1]. Some cloud computing characteristics includeon-demand services, network access by using internet as amedium,sharedresourcesbypoolingresourcestogethertobeusedbymultipleclientsandscalabilitybymaintainingelasticityofresources.Cloudcomputingoffersdifferentservicesbased on threedelivery models, namely:

1) Softwareasaservice(SaaS):thisallowsusersofcloudtoaccessthe providers apps(PA) overtheinternet.
2) Platform as a Service (PaaS): this allows users to deploytheir apps on a platform which service provider of cloud(SPC)provides.
3) InfrastructureasaService(IaaS):thisallowsuserstorent,store,process inan infrastructureprovided bySPC.

The rapid growth in mobile devices and the storage needsdue to the adoption of cloud data networking are creatinghuge data traffic due to the emerging issues of data centersandalsodigitalcontent,mediaandtechnology.Energyconsumption by the organizations that provide cloud serviceiscontinuouslyincreasing.Ithasbeenconcludedthatthe amount of energy consumed by the data centers of the cloudservice providers is equal to 1.5% of power supplied to anentire city [2]. The data centers for cloud service providersareusedforhostingthecloudapplicationswhicharenormallyconsumingmassiveamountsofresourcesthatutilizeahuge percentageofelectricalenergy,whichproducesgrowthinoperationalcostandresultsinemissionofCo2[3].Cloud service providers ensure reliability and load balancingfor the services provided to the users around the world bykeeping servers operating all the time. In order to satisfy theServiceLevelAgreement(SLA),cloudserviceprovidershastosupplypowercontinuouslytodatacenters,whichutilizesahuge amount of energy by the data center and subsequentlyincreases the cost of investment. Thus, it has been noticedthat highperformancehas beenthesoleconcernin datacenter deployments. This demand has been achieved withoutpaying attention to the amount of energy consumed. The keychallenge is to balance between system performance and thepower consumption. It was found that a huge amount ofenergyisconsumedduetoidleandoverloadedserversindatacenter. According to [4], idle servers use 69-97% of totalenergyinthepresenceofenabledpowermanagementfunction.Thispaperwillpresentanoverviewofthedifferentmethodologiestohaveenergyefficiencyincloudbyintroducingsomeofthecurrentproposedsolutionsasserversloadbalancing,VMvirtualization,VMmigrationandresource allocation.

A. *Clouds*

Inordertomeettherapid-changingbusinessandorganization needs, organizations need to devote budget andtime to accelerate up their IT infrastructure such as software,hardware and network services. Regardless of the utilizationofon-siteITframework,scalingthesystemcouldbedifficult.And also the organizations are often incapable of achievingan ideal use of IT foundation. Thus, the cloud computing istheproposedsolution.AccordingtoNationalInstituteofStandards and Technology (NIST), cloud computing is thedeliveryofITresourceson-demandutilizationbyprovidingapayasyougomodelfortheconsumers,whileyoucanself-servefortheservicesthatyouneedtoyourownapplication or any IT infrastructure that you need. A cloudcomputingserviceconsistsofhighlyutilizedresourcesincluding software applications or virtual storages that can beused upon user request, consumers can simply connect to thecloudandusetheavailableresources.Thiscausesorganizationstostayawayfromcapitalconsumptionforon-premises framework assets and scaling up or downsizingaccording to business requirements [3]. Cloud computingservicescanbedeployedusingthreedifferentmodelsa private cloud, public cloud or a hybrid cloud. Private cloudfunction solely for one organization on a private network andis itshighly secure.Public cloudis owned bythecloudserviceproviderandoffersthehighestlevelofefficiencyand sharedresourcesandhybridcloudisconsideredtobeacombination of private and public deployment models. In ahybrid cloud, specific resources are run or used in a publiccloud and others are run or used on-premises in a privatecloud this provides increased efficiency. Fig. 1 illustrates thearchitectureof cloud computing [3].

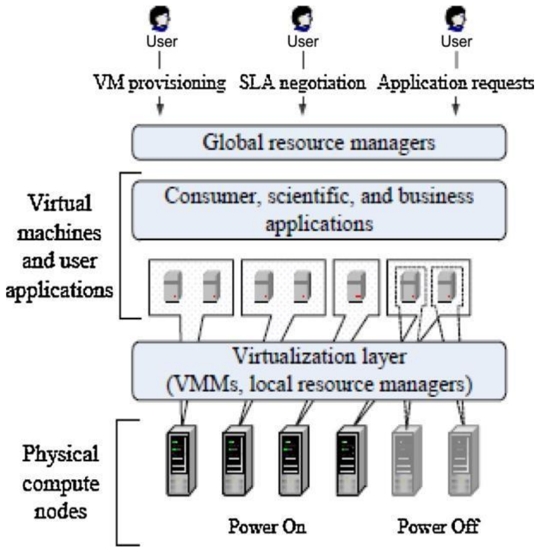

Fig.1.Ahigh levelsystemarchitectureof cloudcomputing[3].

B. DataCenters

Datacentersprovide anITbackboneforcloudcomputing.A data center is a technical facility that houses organizationsIT operations and equipment where it stores, manages anddisseminates its data. A data center houses and networksmost critical systems and are vital to business continuity andoperations. A Data center is considered to be the heart ofcloudcomputingwhichcontainsallthecloudresourcesincluding servers, network, cables, etc. on which businessinformation is stored and applications run. Until recently,high performance has been the sole concern in data centerdistributionsandthisdemandhasbeensatisfiedwithoutpaying much attention to energy consumption. However, anaveragedatacenterconsumesasmuchastheconsumptionof25,000 houses [3]. As the energy availability decreases andenergycostproportionallyincreases,theneedforshiftingthefocusforutilizingdatacenterresourcemanagementtooptimizeenergyperformancewhilemaintainingserviceperformance is becoming a necessity. Thus cloud serviceproviders need to adjust their energy measures to ensure thattheir profit margin is not dramatically reduced due to highenergy costs.

II. ENERGYEFFICIENTCOMPUTING

Energy saving techniques in computing equipment havebeenclassifiedasstaticpowermanagement(SPM)andDynamic power management (DPM). SPM and DPM arecompletely different in categorization, SPM are more energyefficientatsinglesystemandsupposedtobeunderthecategoryofhardwareleveltechniques,andsinceSPMtechniquesarerelatedtohardwarelevelefficiency,lowpower consumption circuit designing is an example of thistechnique. On the other side, DPM are more energy efficientinlargesystemsandsupposedtobeunderthecategoryoflevel resource management methods. Also, DPM techniquesare mostly implemented in software or on network layer, forexample protocol design and algorithms. Fig. 2 shows anoverviewofvariousenergymanagementschemesincomputing equipment.Energyawarescheduling,energyefficientrouting,loadbalancing,virtualization,resourceconsolidation and migration. Since high availability as wellasqualityofserviceandperformanceguaranteearestillignoredwhichismostrequiredinsuchdistributedenvironmentsasthecustomerspayfortheirprovisionedresources. The customers would not pay or may switch toother similar service providers if either quality of service orexpected performance level is not achievable. Energy issuesare supposed to be critical and also needs to be managedproperlyinsomeenvironmentwheremobilecloudcomputing is involved. Reducing the amount of energy usedbyapplicationsthroughgreencompilersandrobustprogramming can be achieved through application/softwarelevel methods [5]. In next sections, Application level andhigh level resource management techniques are discussed toachieveenergyefficiencyinsinglesystem,clusters,gridsandclouddatacenters.

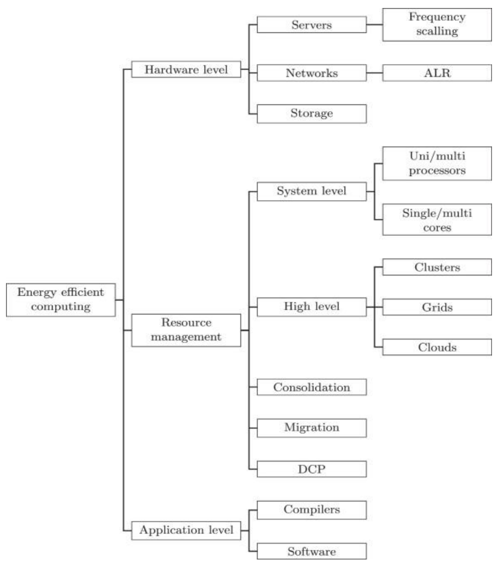

Fig.2.Overviewofvariousenergymanagementschemesincomputingequipment[6].

III. RESOURCE SCHEDULING MODEL FOR ENERGY SAVINGINCLOUD COMPUTING

Basically the resource model of the cloud data center andthe dynamic power model of the physical machine are bothbuilt,andafterwardathree-dimensionalvirtualresourcescheduling method (TVRSM) is proposed along with relatedalgorithms [7]. The process of virtual resource scheduling inTVRSM is divided into three stages, these stages are virtualresource allocation stage, virtual resource scheduling stageand virtual resource optimization stage. Regarding TVRSM,threealgorithmsaredesignedcorrespondingtothementioned stages of the virtual resource scheduling. ThesealgorithmsareMVBPPbasedheuristicvirtualresourceallocationalgorithm(HVRAA),multi-dimensionalpowerawarebasedvirtualresourceschedulingalgorithm

(MP-VRSA)andvirtualresourceoptimizationalgorithm(VROA).

Initially,thefirststageinTVRSMwhichisvirtualresource allocation stage is basically in charge of allocatingtherequestedVMsbythecustomertothesuitablehosts. Thisstageistreatedasmulti-dimensionalvectorbinpackingproblem (MVBPP) and the MVBPP based heuristics virtualresourceallocationalgorithm(HVRAA)isproposedtosolveit. In addition, the second stage which is virtual resourcescheduling stage is responsible for migrating the VMs fromtheoverloadhoststootherhostswithlowerresourceutilization by using the VM migration technology in order toachieve load balancing of the cloud data centers and also tominimizetheamountofviolationsofServiceLevelAgreement. Themultidimensionalpower-awarebasedvirtualresource scheduling algorithm (MP-VRSA) is proposed inthisstage.Furthermore,thethirdstagewhichisvirtualresource optimizationstageisinchargeofmigratingtheVMsfrom the hosts with the least resource utilization to otherhostsandswitchtheoriginalhoststosleepmode,thisprocess can further reduce the energy consumption of the cloud datacentersbydesigningthevirtualresourceoptimizationalgorithm(VROA).Finally,theauthorsverifiedtheeffectivenessoftheproposedmethodthroughexperimentation.TheresultsprovethattheTVRSMisabletoefficiently allocate and manage the virtual resources in thecloud data center. And a comparison is made between theproposedmethodswithothertraditionalalgorithms.Theresults showed that the TVRSM can effectively reduce theenergy consumption of the cloud data center and minimizetheamountofviolationsofService LevelAgreement.

A. ResourcesModel ofCloud Data Center

In [8], the authors proposed a resource model of the clouddata center, which is shown in Fig. 3, it consisted of Mclusters,andeachclustercontainsNphysicalmachines.Severalvirtualmachinesaredeployedoneachphysicalmachine. According to the resources owned by the virtualmachine, each virtual machine can run multiple applications.Sotheloadofeachvirtualmachineresultsfromtheapplicationsrunningonthevirtualmachine.Thenode controllerrunsoneachphysicalmachineisresponsiblefor monitoring the resource utilization of each physical machineand control the physical machines status such as setting thephysicalmachinetosleepmodeoractivatingthesleeping virtualmachines quickly.

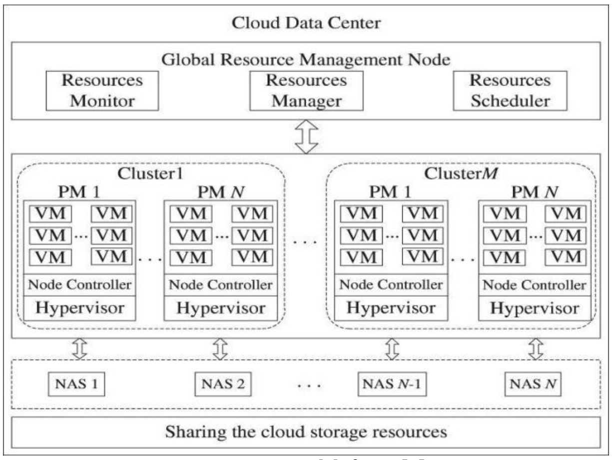

Fig.3.Resource modelofCDC[7].

B. Dynamic Power Model

In[7],theauthorshaveshownthatthepowerconsumptionbyPMscanbedescribedbyalinearrelationshipbetweenthepower consumption and CPU utilization. Hence, the powerconsumptionPi(t)ofPMirunningontimetcanbeexpressedbytherelationshipbetweentheCPUutilizationui(t)ofPMion time t and the maximum power consumption PiMax ofPMi, as shown inthebelow formula:

$$p_i(t)=k.P_{iMax}+(1-k).P_{iMax}.(t) \quad (1)$$

As shown in formula 1, PiMax is considered to be themaximum power consumption of host, Pi(t) is considered tobe the power consumption of PM i running on time t, kconsideredtobethefractionofpowerconsumptionwhenthehostisinidlestateandui(t)istheCPUresourceutilizationofthePMontimet.Inthebelowformula,theCPUutilizationofthe PM i is defined as the ratio of the total CPU resourcesrequested by the all VMs running on PMi on time t to the allCPUresourcesowned by thePM I asshown in formula 2.

$$u_i(t)= \sum_{j=1}^{VMS_i} \frac{cpu_{rj}(t)}{CPU_{iTotal}} \quad (2)$$

physicalmachine.Also,thenodecontrollersendsthemanagement commands to the Hypervisor in order to adjusttheresourcesownedbythelocalvirtualmachines.Theglobalresources management node is responsible for schedulingand allocating all the resources owned by the cloud datacenter.Itcanmanageandmonitoralltheresourcesandimplement the load balance of the cloud data center. Asshown in Fig. 3, each physical machine is characterized bytheCPUperformance,amountofRAMandnetworkbandwidth,andeachphysicalmachinecanrunmultiplevirtual machines, and the physical resource owned by eachvirtualmachineconsistsofCPU,memorycapacityandnetworkbandwidth.ThephysicalmachinesuseNetworkAttachedStorage(NAS)insteadofhavinglocaldisks.ItusesNAS in order to save data, which can ease the data sharingbetweenallphysicalmachinesandenablelivemigrationofRESOURCESCHEDULINGMODELFORENERGYSAVING INCLOUDCOMPUTING

InHVRAA,themainobjectiveofthealgorithm istoassign all the VMs requested by customers to the minimumnumber of PMs. The core idea of HVRAA is as follows:select the VM which has the largest Weight Dot Product(WDP), Select all the VMs that can fit the host and finally, ifthere is no any fit the current host, then start a new host untilall the VMs are assigned intothehosts.In MP-VRSA, the main objective of this algorithm is tofurther reduce the energy consumption by identifying anddetectingtheoverloadinghosts.TheMP-VRSAiscomposedof four steps: detecting the overloading hosts, choose theVMs that need to be migrated from the overloadinghosts,selectingnewhostsfortheVMstobemigratedandimplementingthemigrationoperationforall theoverloading

hosts.ThefirststepinMP-VRSAisdetectingtheoverloading hosts where the overloading detection strategy isused in order to find the overloading hosts in the CDC todetermine whether the VMs running on the host need to bemigrated. The below steps are essential for detecting theoverloading hosts; setting the utilization threshold and if theCPU utilization of a host exceeds the threshold, then theoverloading host can be detected and some VMs running onthehostneedtobemigrated.ThesecondstepinMP-VRSAisVMselectionstrategy,oncethehosthasbeendetectedoverload. Maximum Correlation (MC) VM selection strategyisusedforselectingVMstomigratefromtheoverloadedhost.TheideaofMaximumCorrelation(MC)VMselectionstrategyisthatthehigherthecorrelationbetweentheloadsofVMs running on a host, the higher the probability of the hostoverloading. The CPU utilization of VM is considered as theload of VM. So according to this idea, VMs to be migratedthat have the highest correlation of the CPU utilization withother VMs are selected. The third step in MP-VRSA is VMplacement strategy where the main task of this strategy is toselectthesuitablehostfortheVMsthataremigratedfromtheoverloadinghosts.However,whentheVMsarereallocatedto other hosts it is bound to make the CPU utilization of thehosts increased. So, the Minimum Power Increasing Strategy(MPIS) is designed in order to place the VMs into hostsquickly and reduce the energy consumption in the CDC. InVirtualResourceOptimizationAlgorithm(VROA),thisalgorithm migrates the VMs from the hosts with the leastresourceutilizationtootherPMs,andswitchtheoriginalhosttosleepmode.Therefore,itcanreducetheenergyconsumption of data centers. VROA consists of three mainsteps; after the virtual resource scheduling step is finished,the VROA will select the host PM lowest with the lowestCPU utilization and attempts to migrate the VMs to otherhosts.Then,thesystemwillsethostPMlowesttosleepmodewhen the VMs migrate to other hosts successfully. Finally, Ifany of the VMs on host PM lowest cannot be migrated, thenthe host is kept active and all the migration of VMs arecanceled.

IV. ENERGY-AWAREVIRTUALMACHINEMIGRATIONFOR CLOUDCOMPUTING

Theproposedtechniqueproposesanothermethodologyformaintainingenergyefficiencyincloudcomputing,bymigrating the maximally loaded virtual machines to the leastloadedactivemachine,whilemaintainingsystemperformance by performing a live migration of the virtualmachines to ensure that all the running applications will notget disconnected during migration. The proposed techniqueintroducesanewmethodologyforimprovingresourceutilizationlevelsbaseduponthebio-inspiredFireflyoptimization technique to achieve energy efficiency in clouddatacenters.Theachievabilityoftheproposedtechniquehas been shown by executing the results by using the CloudSimsimulator.

A.FireflyOptimization (FFO)Algorithm

TheFireflyOptimization(FFO)algorithmhasbeenintroduced by Xin-She Yang in the late 2007 and 2008 atCambridgeUniversity[9]–[11].Itwasimplementeduponthe firefliesflashingcharacteristicsandbehavior,thecharacteristic shavebeen introduced asfollows:

1) One firefly is attracted to the other fireflies regardless oftheirsexasallfireflies areunisex
2) Theattractivenessisproportionatetothebrightness,thusth eybothdecreaseastheirdistanceincreasesandforanytwofl ashingfireflies,thelessbrightonewillbeattractednear the brighterone
3) Thebrightnessofafireflyiscalculatedusingtheobjectivefu nction to beoptimized

The(FFO-EVMM)Techniqueintroducestheideaofmigrating the most loaded VM from an active node whichsatisfiesminimumcriteriaforenergyconsumption,toan otheractivenodethatconsumestheleastenergy.Thetechniquei simplementedinfourmainpartsasshowninFig.4:

1) Selectionof sourcenode
2) Selectionof VMs
3) Selectionof destination node
4) Distanceupdated values.

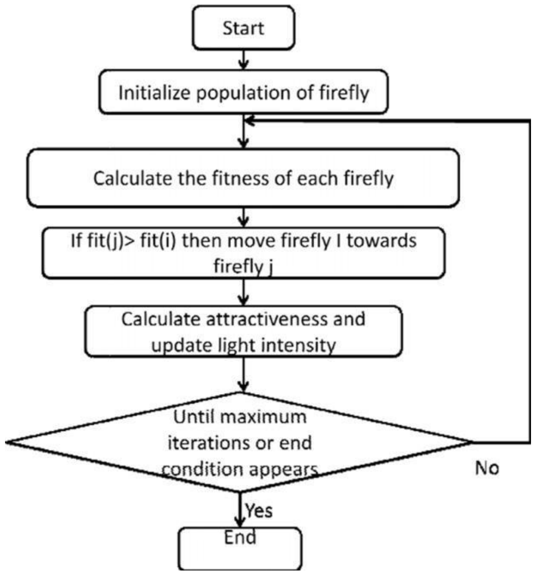

Fig.4.Flow chartforFFOalgorithm[12].

V. RESULTSAND ANALYSIS

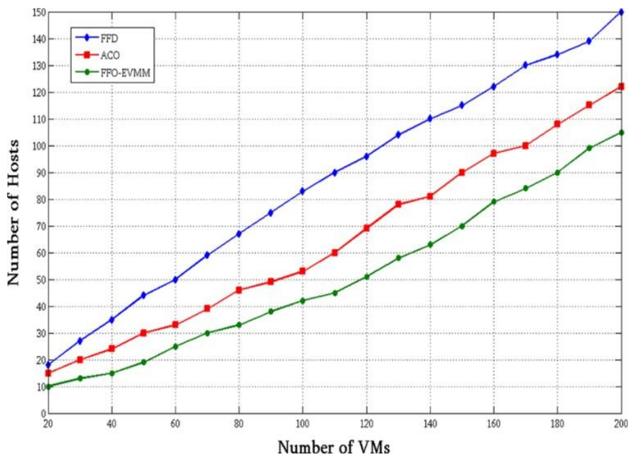

Fig.5.VMsvshosts[12].

ThestatisticalresultsfortheproposedFFO-EVMMalgorithmwerecomparedwiththeACO-basedand FFD-based algorithms, using the CloudSim toolkit simulatorwhichhascapturedthatthatFFO-EVMMtechniquerunslessnumber of active hosts and performs less number of virtualmachines migration in comparison to ACO and FFD-basedalgorithms.

As it's shown with the less number of running hosts andlive migrations, FFO-EVMM requires lesser energy demandcomparingtoFFDandACOalgorithmsasithasbeennoti cedfromFig. 5 and 6.

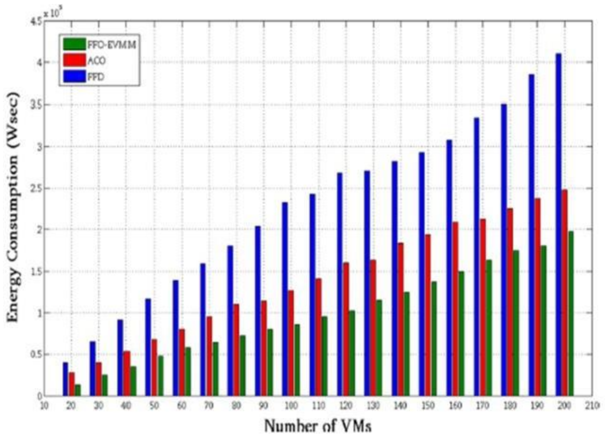

Fig.6.VMsvsenergyconsumption[12].

VI. CONCLUSION

Cloud computing is considered one of the most crucialtechnologies that provide services to consumers in a pay asyou go model. It offers ITC based services over the internetandtheutilizationofvirtualizationallowsittoprovidecom putingresources.Datacentersarethecoreofcloudcomputingthatst orebusinessinformationandhosttherunning applications. High performance has always been thesole concern of all in data centers. This concern has beenmanagedwithoutconsideringenergyconsumptionandperfo rmance. The challenge is to balance between powerconsumption and system performance. Many techniques andalgorithms have been proposed to achieve adequate energyutilizationinclouddatacenters.Thispaperprovidedasurve yof recent approaches and techniques for energy efficiency incloudcomputing.

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