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Energy Optimization in Cloud Computing: A Review

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***Abstract*—** Nowadays, modern computing environment, having lots of challenges towards flexibility and processing capabilities. So Data Centers are required. Each data center provides physical wires by which enormous compute, network and storage resources are connected. Data centers are responsible for computation, space, network points and their effective and efficient operations. Therefore, enhancing the performance of the system likes total productivity, reliability and availability having the requirement to minimize the energy consumption of Data Centers. So, energy Consumption reductions are not only to enhance the system performance but also optimize the cost. Thus, an energy optimization is becoming a challenging task due to speedy growth in data and computing applications. In this paper we critically studied about the different energy based proposed methods and comprehensive survey along with a taxonomy of network topologies, either used in commercial data centers, or proposed by researchers

***Keywords*—** Cloud Computing, Energy Consumption, Energy Saving, DCN Topology, Energy Architecture

I. INTRODUCTION

Cloud computing administers computation over the internet on demand basis as per the requirement of the clients. It is a model for enabling all over, on- demand access to a shared pool of configurable computing resources. Cloud computing guarantees a few appealing advantages for organizations and end clients. In recent times, cloud provides different types of services through Internet likes online functions, computing power, space, infrastructure etc. In addition to power consumption there are 26GW energy consumption of data centers are worldwide is estimated about which 1.4% of worldwide electrical energy consumption with a growth rate of 12% per year [1,2]. The Barcelona medium-size Supercomputing Center or a data center pays an annual bill of about £1 million only for its energy consumption of 1.2 MV [3]. Which is equivalent to the power of 1, 200 houses [4]. The effective utilization of resources and cost optimization are the essentials to improve the performance balancing the load and optimizing energy. 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 is much researched and improved with respect to energy. The primary objective of the paper to compare the existing energy optimization techniques and various concepts related to energy in cloud environment. There are various parameters under the expressions of cloud which are explained below:

Datacenter: Hardware infrastructure services composed of set of host responsible of managing VM during their life cycle.

Datacenter Broker: Software as a Services and Cloud providers are arbitrary negotiated by Datacenter Broker.
Host: Host modeled physical server.
Virtual machine (VM): Virtual machine is run on Cloud host to deal with the cloudlet.
Cloudlet: It provides Cloud-based application services. In datacenter, it is behaving like a datacenter in box responsible to "carry the cloud closer". It has four main parameters:

1. **Only soft state**
   The input data from the mobile devices are buffered by the cloudlet and vice-versa.
2. **Powerful, well-connected and safe**
   Cloudlets are having their own influential processors and random access memory to work with. It provides the secure and good connectivity due to wired internet with the server.
3. **Close at hand**
   It is responsible for closure of the mobile devices to the cloud server.
4. **Builds on standard cloud technology**
   The generated offload code from mobile devices is wrapped in VMs It encapsulates offload code from mobile devices in virtual machines (VMs), and thus

looks like standard cloud infrastructure such as Amazon EC2 and OpenStack.

VmAllocation: It is kind of provisioning policy responsible to run on datacenter level assist to assign VMs to hosts.
VmScheduler: Virtual scheduler is responsible to run for all host in Datacenter. It provides the provisioning policies for the allocation of process cores to virtual machines.
Cloudlet Scheduler: Cloudlet Scheduler is run on Virtual machine. It is responsible to determines how to share the processing power among Cloudlets on a virtual machine.
Cloud Information Service: It is an entity that registers indexes and discovers the resource.

Section II contain the narrative about the various data center network topologies, Section III of this paper presents the related work and background of available research, Comparison and findings of different energy based proposed methods in tabular form is presented in Section IV **,** Finally the conclusion of findings with future directions is presented in section V.

II. DATA CENTER NETWORK TOPOLOGIES

There are different types of Data center networks topologies which are explained below and have been changed over the time.

1. Fat Tree Topology

It customize amount of internal blocking while exploiting locality of traffic with option for non blocking operations. Fat Tree Topology was made for organizing processors in complete binary tree based on onchip Networks. In fat tree topology packet routing needs 2log(n) space for destination. Parent–child identical fashion is the drawbacks of fat tree topology shown in figure 1[5].

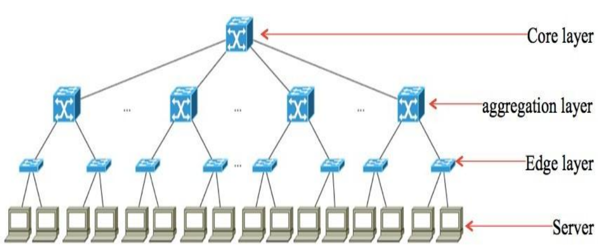

Figure 1. Fat tree topology

2. Google Fat Tree

Fat tree topology has been trivial changed by Google for the production of scalable huge data centers with the help of interconnection of commodity Ethernet switches [5]. The fundamental building square of the server farm is known as a pod.. At the bottom level of the tree called leaves computes nodes as terminals for k-port routers shown in figure 2 [5].

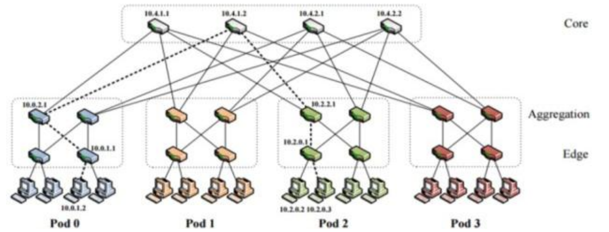

Figure 2. Google fat tree

3. Hierarchical Irregular Compound Network (HCN)

It is dualport-server based, symmetric, regular and extensible architectures. In this network function calling itself so it is also called recursively defined structure. It has trouble free implementation and low costing because of expansibility and equal degree topological advantage. Hierarchical Irregular Compound Network is shown in figure 3 [5].

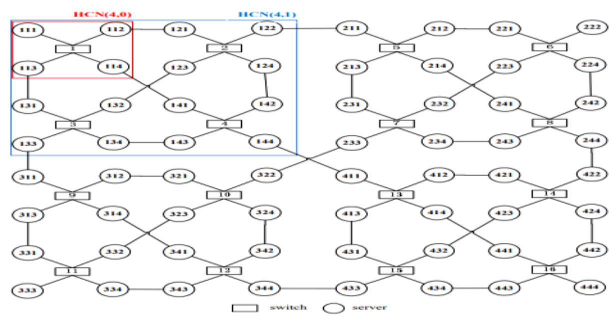

Figure 3. HCN(n,h), where n=4 and h=2

4. Facebook Fat Tree

Fat Tree topology version has been released by Facebook to improve the performance of scalability, rapid development of network and high section of bandwidth to progress at the same rate with the agile nature of applications running in the data centers. There are pods and a standard unit of network as show in figure 3 [6].

1 top of racks $_{\text{uplink bandwidth}}$ = 4 * downlink bandwidth for each server connected to it (1)

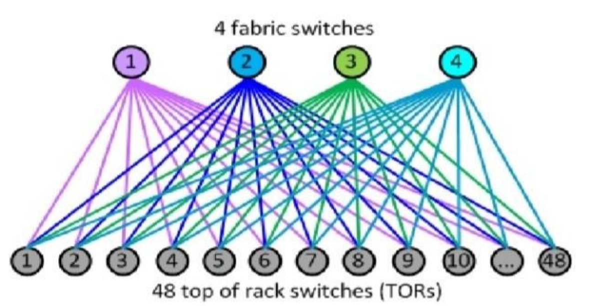

Figure 4. Facebook fat tree topology

5. F10 (Fault Tolerant Engineered Network)

Fault Tolerant Engineered Network is a trouble- free up gradation of face book tree to attain enhanced fault tolerance properties [7]. To overcome the difficulties in face book tree Fault Tolerant Engineered Network have proposed in figure 4[7].

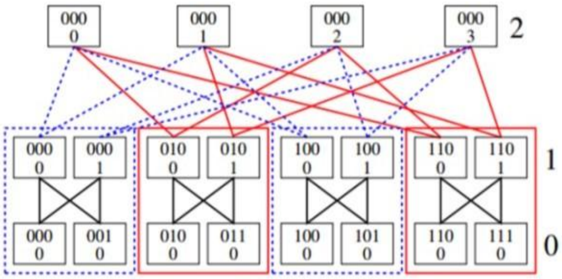

Figure 5. F10 Topology, blue links are part of a sub-tree, red links are part of b sub-tree

6. **Jellyfish**

It is a kind of network topology having high flexibility and high bandwidth. It has higher throughput because of low average path lengths in comparison to symmetric topologies such as fat tree.

7. Scafida

For short distance, high error tolerance and incremental build have been achieved by Scafida. It is asymmetric Scale-free networks topology. It has small diameter and high resistance to random failures as a benefit. It provides reasonable modifications to original scale-free network paradigm. Scafida consists of heterogeneous set of switches and hosts in terms number of ports/links/interfaces shown in figure 6 [7]. The topology is constructed gradually by including a hub and after that, haphazardly interfacing all the accessible ports to existing void ports. The quantity of ports is constrained by the accessible ports on a hub not at all like unique without scale systems. Such a system gives high adaptation to internal failure. No directing calculation is proposed yet for such systems however, the possibility of irregular development of a server farm looks encouraging. In any case, wiring, taking care of disappointment of hubs with vast degree, directing calculation as yet serious issues that should be tended to.

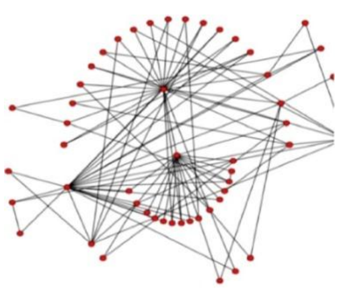
Figure 6. Scale free network

8. DCell

It is directly communicate to lot of the other servers by one server. It is having server-centric hybrid data center architecture. A server in a DCell is prepared with multiple NICs and follows a recursively build hierarchy of cells shown in figure 7 [8]. DCell is exceedingly versatile and blame tolerant topology in any case, it gives low separation data transmission.

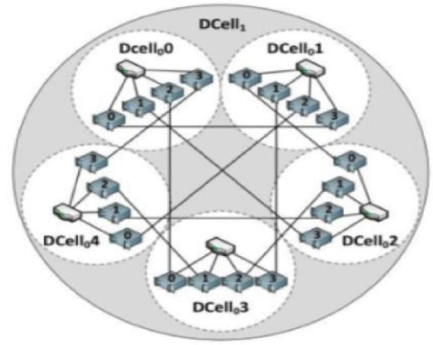

Figure 7. DCell network for n=4

9. **BCube**

It works on server-centric approach uses commodity switches to produce a modular data center. It proved the provisioning of intelligence on modular data center servers. Bcube are having two types of devices servers with multiple ports and switches that connect to a constant number of servers shown if figure 8 [9]. In Bcube, function calling itself. So it is having recursively defined function.

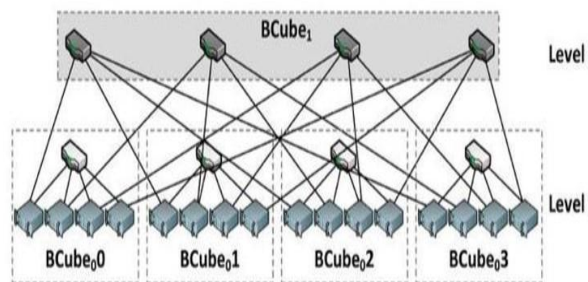

Figure 8. BCube network

10. MDCube

High network capacity is achieved by MD cube. In 1- D or 2-D fashion large inter communication are allowed by MD cube. Either in row or column it joins two containers to form complete graph by direct link shown in figure 9 [10].

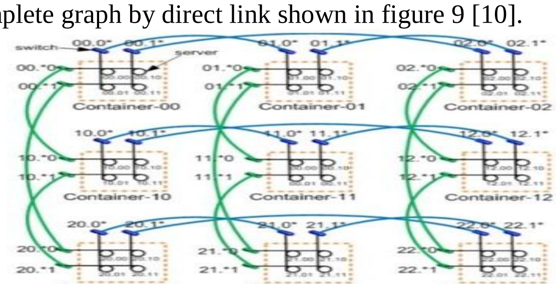

Figure 9. MDCube network

11. Bidimensional Compound Network (BCN)

It is also dualport-server based, symmetric, irregular compound graph and extensible architectures. In this network function calling itself so it is also called recursively defined structure same as HCN. There are two dimensions. It is defined as irregular compound graph and regular compound graph in first and second dimension respectively. All the dimension having one low level unit cluster and joins most of the cluster by complete graph as shown in Fig. 10 [11].

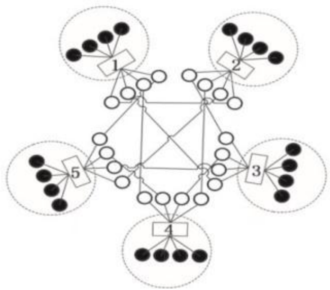

Figure 10. Bidimensional Compound Network

III. RELATED WORK AND BACKGROUND

In this paper critically reviewed have been done based on the different proposed energy based cloud computing methods. In this paper advantages and limitations or future work of different proposed energy based cloud computing methods are discussed. In [12] adjustment of load in time by migration for higher degree of load balancing is found out as problem identification. To remove this forecast resource load using gray theory to reduce the delay of load throttling has been proposed which optimizes overall energy as benefit but there are certain limitations as prediction for accuracy improvement. In [13] globe method has been proposed as to improve system performance of network Joint Geographical Load Balancing and Admission Control to make system performance optimal with energy causality constraints as limitations. There are two problems GPS is costly for mobile edge computing and high intermittency and unpredictability of energy harvesting had been identified.

In [14] Snapshot Based Solution has been proposed but it was suffering from server Consolidation. Reduce energy consumption have found with optimum computing time.

In [15] DNA-Based Fuzzy Genetic Algorithm with real time task as well as reduced energy consumption suffering from high operational cost and large carbon emission has been used. In [16] increased energy consumption controlled by Resource Management System which identified Virtualization problem.

In [17] Scheduling and Load Balancing Algorithm is used with the costs and operating Expenses issues. In this research work energy scalability has improved with the limitation of cost expenses.

In [18] Eevs method is used which consumes less energy and processes more virtual machines successfully suffering from heterogeneity.

In [19] Virtualization Energy-Aware Routing In data center network has used with the identified problem of fat tree. In this energy efficiency is maximized with low cost. In [20] DVFS method has been proposed to increase the resource utilization and reduced the energy consumption. In this large amount of carbon dioxide problem is identified which was affected environment at large scale.

In [21] model EARH method is proposed for the real time task issue. It provides the good tradeoff between task schedulability and energy conservation. In [22] Linear Integer Programming has used. By this method, minimizing both the number of migrations needed for consolidation and energy consumption in a single algorithm and also reduced the Excessive Energy.

In [23] CPU Re-Allocation Algorithm has used. Problem is identified as performance and energy management. There are different kinds of techniques have been proposed like Longest Completion Time (LCT), Highest Utilization (HU) and Lowest Utilization (LU). In this paper energy consumption is reduced and maintains the execution time. In [24] Coolemall, Eco2Clouds method is used. Energy is optimized and overlapping problem has been resolved in it.

In [25] Formal Mathematical Model has used. There are issues with Communication resources because it becomes bottleneck in service provisioning. In this energy efficiency and bandwidth consumption of the system method has proposed. In this paper certain kind of issue have been resolved like it minimizing network delays and bandwidth usage and reduced communication delays. In [26] Analytical Performance Model of Server is used. Sate Explosion Problem has identified in it. Saving of energy consumption in operational range has found as advantages with the limitation load constraints.

In [27] Green Cloud Computing method is used with the advantages of minimizing operational cost and reduces environment impact. Most of the problem has been identified in this paper there are huge amount of electrical energy, high operational cost and high carbon emission. In [28] Optimal Cloud Resource Provisioning Algorithm is used as method. The problem has been identified as an uncertainty of consumer's demand and providers' resource prices advance reservation. Stochastic Programming Model has proposed to reduce the cost of resource provisioning. It also provides an optimally adjust tradeoff between reservation of resources and allocation of on-demand resources.

BACKGROUND

A. ENERGY SAVING ARCHITECTURE

The whole state Optimization, Reconfiguration and Monitoring of Cloud environment is automatic monitored. take the most appropriate energy minimization decisions .It has the ability to forecast the energy consumption of Cloud environment after a possible reconfiguration option.

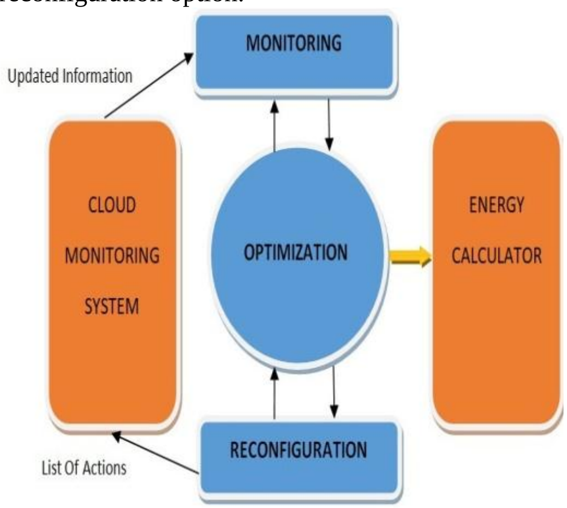

Figure 11. Energy Saving Architecture

Optimization module for enabling energy minimization need to find out proxy software application and service allocated (energy-saving) configurations. Once an appropriate energy-saving configuration is detected, the loop is closed by issuing a set of action on Cloud environment to reconfigure the allocation of energy-saving setup.

Monitoring and Reconfiguration modules It is responsible **to** commune with the cloud monitoring system to perform tasks. The aim of optimization module maintains the ranks of the target configurations without violating existing service level agreements establishing by using energy-saving policies envisaged by the energy calculator module to take the most appropriate energy minimization decisions .It has the ability to forecast the energy consumption of Cloud environment after a possible reconfiguration option.

B. TAXANOMY ON ENERG CONSUMPTION

The way to optimizing the operational cost of service providers by diminishes energy utilization at data centers.

The total energy consumption (when server activated) = energy consumed (fixed) + energy consumed (dynamic) (2)

There are two classification of energy consumption.

a. Fixed energy consumption
b. Dynamic energy consumption

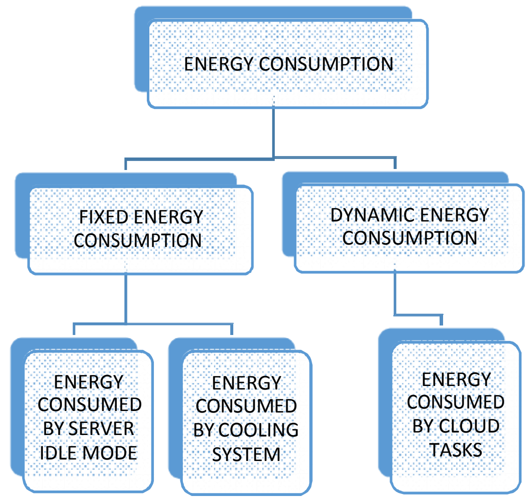

Figure 12. Energy Consumption Hierarchy

a. Fixed Energy Consumption

Case1. server is idle

In the recent scenario performance are degraded drastically of idle energy for core or processor due to decreasing DVFS of a core or processor. To compute the idle energy consumption of given processor is computed as be low.

Idle mode$_{\text{energy consumption}}$ = sum of n processor for reduced energy consumption of core i (3)

So for computing the energy consumption in idle mode sum of N processor for reduced energy consumption of core i is to be performed.

Case 2. cooling system

Energy consumed by the cooling system is computed by the Coefficient of Performance which is finding out by dividing amount of heat to amount of energy consumed as follows.

COP = Q (amount of heat)/E (amount of energy consumed) (4)

Where, COP means Coefficient of Performance, Q is amount of heat and E is amount of energy consumed.

b. Dynamic Energy Consumption

(Energy consumed by cloud task)

There are various assignment likes computation, storage and communication which are consuming huge energy based on the size of data to be transmitted, system configuration, the number of processes. For each task, the share of the energy consumed at the dynamic state may be calculated from the amount of processes concerned in cloud like size of information to be processed throughout allocation and to be transmitted throughout programming besides host configuration.

IV. COMPARATIVE STUDY FOR ENERGY OPTIMIZATION METHODS

There are various methods for energy optimizations have been proposed in cloud computing environment. In this paper critical assessment has been done which are based on the methodology, problem identification, advantages and future work or limitations. A comparative chart in table 1 is given below:

Table1. Comparative Study for Different Energy Based Proposed Methods in Cloud Computing

Ref.	Method	Identification of problem	Proposed methodology/Forecasting	Advantages	Limitations/Future work
[12]	Game Based Consolidation Method	Adjustment of load in time by Migration for Higher Degree of Load Balance	Forecast Resource Load Using Gray Theory to Reduce the Delay of Load Throttling	Optimizing overall consumption	Prediction for Accuracy improvement
[13]	GLOBE	High Intermittency and Unpredictability of Energy Harvesting	Joint Geographical Load Balancing and Admission Control	Optimal System Performance	Energy causality constraints
[14]	Snapshot based solution	It suffers from Server Consolidation	Solution quality in absolute term	Reduce energy consumption.	Optimization of computing time.
[15]	DNA-based Fuzzy Genetic Algorithm	i.High Operational Cost ii. Large Carbon Emission	Based on real time task	Reduce energy consumption	Cost issue
[16]	Resource Management System	virtualization	Impact of different energy efficiency techniques	Reduce energy wastage	Increasing energy consumption.
[17]	Scheduling and load balancing algorithm	Costs and operating expenses.	Role of communications and network	Improving Energy Scalability	Operating Costs Expenses
[18]	Eevs	i.Vms in Cloud Cannot Work Well if The Physical machines are Heterogeneous ii.Total Power Is Considered	Reduce the energy consumption.	Consumes Less Energy and Processes More Vms Successfully	Cluster and real workload
[19]	Virtualization Energy-Aware Routing In Dcns	Fat-Tree, VL2 and Portland	Maximize Efficiency While Maintaining a Low Cost	Renewable Energy	Conventional tree-based DCN architecture
[20]	dynamic voltage frequency scaling technique	Effected Environment Due to Large Amount Of CO2 Emissions	Green Energy-Efficient Scheduling Algorithm	i.Increase Resource Utilization and Reduce Energy Consumption	Losing light performance of the system
[21]	Model EARH	Real Time Task issue	Rolling Horizon Optimization Scheme	Task Scheduling and Energy Conservation have Good Trade-Off	Energy Conservation
[22]	Linear integer programming	energy aware allocation and migration algorithms	Minimizing both the number of migrations needed for consolidation and energy consumption in a single algorithm.	Reduction of excessive energy	Tested only on few machines
[23]	CPU Re-Allocation Algorithm	Performance and energy management	Longest Completion Time (LCT), Highest Utilization (HU) and Lowest Utilization (LU).	reduction of energy consumption and execution time	increasing number of VMs close to maximum
[24]	CoolEmAll	Energy-costs of application	Eco2Clouds	Optimize energy-efficiency	Overlap
[25]	Formal Mathematical Model	Communication Resources becomes Bottleneck in Service Provisioning	Energy Efficiency and Bandwidth Consumption of the System	i.Minimizing Network Delays & Bandwidth Usage. ii.Reduced Communication Delays	Data Replication in Cloud Computing Data Centers
[26]	Analytical Performance Model of Server	Sate explosion problem	Blocking probabilities, heat emission	Saving of energy consumption in operational range	Load constraints

[27]	Green cloud computing	Huge amount of electrical energy, high operational cost, high carbon emission	Energy aware heuristic provision.	Mimimize operational cost, reduce environment impact	Generic resource manager and plug in software.
[28]	Optimal cloud resource provisioning algorithm	Uncertainty Of Consumer's Demand and Providers' Resource Prices advance reservation is difficult	Stochastic programming model	Minimize total cost of resource provisioning	Optimally adjust the tradeoff between reservation of resources and allocation of on-demand resources

V. CONCLUSION AND FUTURE WORK

Cloud computing is playing a vital role in the field of Information Technology due its high level services to its end users. In this paper, I have critically reviewed different energy consumption based methodology of Cloud with their problem identification, proposed methods, advantages and their limitations or future works. There are big challenges in cloud computing for the energy optimization due to ecological and economical reasons.

As far as this concern we prepared a comparative chart for better understanding of different proposed energy consumption methods. Furthermore, there are also discussed the methodology given by various researchers in different years. As future work, we will find out such kind of techniques which provide the optimal energy consumption.

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