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CloudSim (Cloud Simulation) Toolkit for Modeling and Simulation of Clouds

Description: Create cloud simulators for evaluating executions of applications in cloud datacenters with different characteristics and deployment models.

Developers hate servers. The idea of serverless architectures is a panacea for developers. Hence, serverless architectures and microservices are evolving rapidly by implementing FaaS model of hybrid clouds as being a complete replacement for normal application architectures. In my humble opinion, function-based apps are a perfect fit for replacing potential microservice style architectures and background type services.

The idea of remote code execution by deploying distributed objects over a network is not new. Nowadays, various cloud providers have employed these architectures and developed their own FaaS models such as AWS Lambda, IBM's OpenWhisk and Google Cloud Functions.

These functions are coded and deployed on the cloud. The users can then spawn Virtual Machines and call these functions. Their outputs can then be transferred as streams to the next App module or stored for further analysis. Moreover, the next set of events in the pipeline can occur once a function based on the results of a function. Such a function is a stateful function. Many functions can retrieve or store their parameters and return values on some backend database for further actions. Hence, FaaS are event-driven and help extend Application functionalities.

FaaS implementation takes low resources and less memory to execute than an entire application. Hence, the pricing of the execution is less, and it depends on the number of requests (calls) made by the user. This low-cost nature enables users to pay only for what they use. A fixed fee is charged plus the incremental cost is calculated by the time slice of the execution of the function measured in intervals of time as low as 100ms. AWS Lambdas also provide a free tier for low usage.

Servers are fully abstracted, and these services are scalable so that they can be powered down and not incurring charges when not in use.

This simulation simulates one such scalable FaaS service and evaluates execution costs on different architectures, combination of devices (VMs, Hosts and Datacenters). Finally, Cloudlets are abstracted as tasks or basically requests made to execute the function. These function calls will also employ their own set of instructions and hence also incur some additional cost as they transmitted over the network utilizing its bandwidth.

Many Streaming services like Netflix and Hulu provide their services to users on a monthly subscription basis. They also charge the user based on the number of simultaneous sessions open at a given point of time using a single account. This is done so that friends and family cannot share their passwords and enjoy their favorite movies without buying additional subscriptions. Therefore, these companies have setup certain FaaS services which denies service to the user from opening more than 2-3 sessions simultaneously. This is an exciting example of FaaS implementation, and I have tried to model the same in my simulation.

These functions would have to write their states and fetch them from some backend database. Hence, I have tried to abstract the same by deploying multiple cloudlets on a single VM which would act as different tasks namely: the actual logic preventing user logging in, the database read and update operations and tasks which requests server for updating the states of the function itself.

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I have also tried to replicate the original scenario by spawning multiple VMs which would act as having multiple instances of the function doing the same job for an array of users constantly firing requests to the streaming companies cloud infrastructure.

The scheduling of these many cloudlets requires a combination of time-shared as well as space shared VMs and cloudlets which I have simulated using a Hybrid Workload Scheduling Algorithm.

LIMITATIONS
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- A group of Cloudlets pertaining to a single user would require chaining and hence, the requests of a single user would be sequential

- We cannot randomize the cloudlet instruction length or deploy complex heuristics for cloudlet scheduling as they would spoil the order of timed requests

- We cannot use Stochastic Utilization model for the same reason mentioned above

Being a broker purchasing resources and compute time from cloud providers, I have to think about various parameters like costs, device usage, VM creation and Cloudlet Allocation policies. There are different policies that datacenters can use for allocating Virtual Machines (VMs) to hosts, scheduling them for executions on those hosts, determining how network bandwidth is provisioned, and for scheduling cloudlets to execute on different VMs. Randomly assigning these cloudlets to different datacenters may result in situation where the executions of these cloudlets are inefficient and they take long time.

For the simulation, I have calculated the cost of running Lambda functions on two datacenters which employ different VM allocation, Cloudlet Scheduling and VM Scheduling policies. I would then sell the compute time to my customers by adding a profit of 32%. This high profit margin would also cover the services provided by my company for configuration and deployment of my clients' functions and stream outputs through a proprietary technology. In this manner, my revenue will always exceed my expenses and I will always be in profit and would never go bankrupt unless and until the simulation keeps giving me insights to make smart decisions. The cloud provider would also let me purchase compute time at a lesser cost because I will be buying it in bulk.

One way to achieve this is to take cloudlets from your customers and estimate how long they will execute. Then you charge for executing cloudlets some fixed fee that represent your cost of resources summarily. Some cloudlets may execute longer than you expected, the other execute faster.

My clients can execute their jobs, i.e., cloudlets on the infrastructure of these cloud providers that have different policies and constraints and I can be rest assured that they will never overuse resources and incur larger expenses than the ones given by their similar cloudlets in the simulation environment. Modeling and simulating the executions of cloudlets in your clouds will definitely help me chose a proper model for my business.

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Let us have a look at the results of my simulations: (Cloudlet Resource utilization is Full throughout)

RESULTS

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[1] *Hybrid Cloudlet Scheduling with Time Shared VM Scheduling*

Cloudlet ID	STATUS	Data center ID	VM ID	Time	Start Time	Finish Time	Processing Cost
0	SUCCESS	2	0	0.45	0.1	0.55	1.35
5	SUCCESS	2	0	0.45	0.1	0.55	1.35
10	SUCCESS	2	0	0.45	0.1	0.55	1.35
15	SUCCESS	2	0	0.45	0.1	0.55	1.35
20	SUCCESS	2	0	0.45	0.1	0.55	1.35
25	SUCCESS	2	0	0.45	0.1	0.55	1.35
30	SUCCESS	2	0	0.45	0.1	0.55	1.35
35	SUCCESS	2	0	0.45	0.1	0.55	1.35
40	SUCCESS	2	0	0.45	0.1	0.55	1.35
45	SUCCESS	2	0	0.45	0.1	0.55	1.35
1	SUCCESS	2	1	0.45	0.1	0.55	1.35
6	SUCCESS	2	1	0.45	0.1	0.55	1.35
11	SUCCESS	2	1	0.45	0.1	0.55	1.35
16	SUCCESS	2	1	0.45	0.1	0.55	1.35
21	SUCCESS	2	1	0.45	0.1	0.55	1.35
26	SUCCESS	2	1	0.45	0.1	0.55	1.35
31	SUCCESS	2	1	0.45	0.1	0.55	1.35
36	SUCCESS	2	1	0.45	0.1	0.55	1.35
41	SUCCESS	2	1	0.45	0.1	0.55	1.35
46	SUCCESS	2	1	0.45	0.1	0.55	1.35
2	SUCCESS	2	2	0.45	0.1	0.55	1.35
7	SUCCESS	2	2	0.45	0.1	0.55	1.35
12	SUCCESS	2	2	0.45	0.1	0.55	1.35
17	SUCCESS	2	2	0.45	0.1	0.55	1.35
22	SUCCESS	2	2	0.45	0.1	0.55	1.35
27	SUCCESS	2	2	0.45	0.1	0.55	1.35
32	SUCCESS	2	2	0.45	0.1	0.55	1.35
37	SUCCESS	2	2	0.45	0.1	0.55	1.35
42	SUCCESS	2	2	0.45	0.1	0.55	1.35
47	SUCCESS	2	2	0.45	0.1	0.55	1.35
4	SUCCESS	2	4	0.45	0.1	0.55	1.35
9	SUCCESS	2	4	0.45	0.1	0.55	1.35
14	SUCCESS	2	4	0.45	0.1	0.55	1.35
19	SUCCESS	2	4	0.45	0.1	0.55	1.35
24	SUCCESS	2	4	0.45	0.1	0.55	1.35
29	SUCCESS	2	4	0.45	0.1	0.55	1.35
34	SUCCESS	2	4	0.45	0.1	0.55	1.35

39	SUCCESS	2	4	0.45	0.1	0.55	1.35
44	SUCCESS	2	4	0.45	0.1	0.55	1.35
49	SUCCESS	2	4	0.45	0.1	0.55	1.35
3	SUCCESS	2	3	0.45	0.1	0.55	1.35
8	SUCCESS	2	3	0.45	0.1	0.55	1.35
13	SUCCESS	2	3	0.45	0.1	0.55	1.35
18	SUCCESS	2	3	0.45	0.1	0.55	1.35
23	SUCCESS	2	3	0.45	0.1	0.55	1.35
28	SUCCESS	2	3	0.45	0.1	0.55	1.35
33	SUCCESS	2	3	0.45	0.1	0.55	1.35
38	SUCCESS	2	3	0.45	0.1	0.55	1.35
43	SUCCESS	2	3	0.45	0.1	0.55	1.35
48	SUCCESS	2	3	0.45	0.1	0.55	1.35

Total cost of execution of 50 Cloudlets = $67.5
Our Selling Price would be $91.66 (adding the profit)

[2] *Space Shared Cloudlet Scheduling with Time Shared VM Scheduling*

Cloudlet ID	STATUS	Data center ID	VM ID	Time	Start Time	Finish Time	Processing Cost
0	SUCCESS	2	0	0.65	0.1	0.75	1.95
1	SUCCESS	2	1	0.65	0.1	0.75	1.95
2	SUCCESS	2	2	0.65	0.1	0.75	1.95
4	SUCCESS	2	4	0.65	0.1	0.75	1.95
3	SUCCESS	2	3	0.65	0.1	0.75	1.95
5	SUCCESS	2	0	0.65	0.75	1.4	1.95
6	SUCCESS	2	1	0.65	0.75	1.4	1.95
7	SUCCESS	2	2	0.65	0.75	1.4	1.95
9	SUCCESS	2	4	0.65	0.75	1.4	1.95
8	SUCCESS	2	3	0.65	0.75	1.4	1.95
10	SUCCESS	2	0	0.65	1.4	2.05	1.95
11	SUCCESS	2	1	0.65	1.4	2.05	1.95
12	SUCCESS	2	2	0.65	1.4	2.05	1.95
14	SUCCESS	2	4	0.65	1.4	2.05	1.95
13	SUCCESS	2	3	0.65	1.4	2.05	1.95
15	SUCCESS	2	0	0.65	2.05	2.7	1.95
16	SUCCESS	2	1	0.65	2.05	2.7	1.95
17	SUCCESS	2	2	0.65	2.05	2.7	1.95
19	SUCCESS	2	4	0.65	2.05	2.7	1.95
18	SUCCESS	2	3	0.65	2.05	2.7	1.95
20	SUCCESS	2	0	0.65	2.7	3.35	1.95
21	SUCCESS	2	1	0.65	2.7	3.35	1.95
22	SUCCESS	2	2	0.65	2.7	3.35	1.95
24	SUCCESS	2	4	0.65	2.7	3.35	1.95

23	SUCCESS	2	3	0.65	2.7	3.35	1.95
25	SUCCESS	2	0	0.65	3.35	4	1.95
26	SUCCESS	2	1	0.65	3.35	4	1.95
27	SUCCESS	2	2	0.65	3.35	4	1.95
29	SUCCESS	2	4	0.65	3.35	4	1.95
28	SUCCESS	2	3	0.65	3.35	4	1.95
30	SUCCESS	2	0	0.65	4	4.65	1.95
31	SUCCESS	2	1	0.65	4	4.65	1.95
32	SUCCESS	2	2	0.65	4	4.65	1.95
34	SUCCESS	2	4	0.65	4	4.65	1.95
33	SUCCESS	2	3	0.65	4	4.65	1.95
35	SUCCESS	2	0	0.65	4.65	5.3	1.95
36	SUCCESS	2	1	0.65	4.65	5.3	1.95
37	SUCCESS	2	2	0.65	4.65	5.3	1.95
39	SUCCESS	2	4	0.65	4.65	5.3	1.95
38	SUCCESS	2	3	0.65	4.65	5.3	1.95
40	SUCCESS	2	0	0.65	5.3	5.95	1.95
41	SUCCESS	2	1	0.65	5.3	5.95	1.95
42	SUCCESS	2	2	0.65	5.3	5.95	1.95
44	SUCCESS	2	4	0.65	5.3	5.95	1.95
43	SUCCESS	2	3	0.65	5.3	5.95	1.95
45	SUCCESS	2	0	0.65	5.95	6.6	1.95
46	SUCCESS	2	1	0.65	5.95	6.6	1.95
47	SUCCESS	2	2	0.65	5.95	6.6	1.95
49	SUCCESS	2	4	0.65	5.95	6.6	1.95
48	SUCCESS	2	3	0.65	5.95	6.6	1.95

Total cost of execution of 50 Cloudlets = $97.5
Our Selling Price would be $134.45 (adding the profit)

[3] *Time Shared Cloudlet Scheduling with Time Shared VM Scheduling*

Cloudlet ID	STATUS	Data center ID	VM ID	Time	Start Time	Finish Time	Processing Cost
0	SUCCESS	2	0	0.49	0.2	0.69	1.47
1	SUCCESS	2	1	0.49	0.2	0.69	1.47
2	SUCCESS	2	2	0.49	0.2	0.69	1.47
4	SUCCESS	2	4	0.49	0.2	0.69	1.47
3	SUCCESS	2	3	0.49	0.2	0.69	1.47
5	SUCCESS	2	5	0.49	0.2	0.69	1.47
6	SUCCESS	3	6	0.49	0.2	0.69	1.47
7	SUCCESS	3	7	0.49	0.2	0.69	1.47
8	SUCCESS	3	8	0.49	0.2	0.69	1.47
10	SUCCESS	3	10	0.49	0.2	0.69	1.47
9	SUCCESS	3	9	0.49	0.2	0.69	1.47

11	SUCCESS	3	11	0.49	0.2	0.69	1.47
12	SUCCESS	2	0	0.49	0.69	1.18	1.47
13	SUCCESS	2	1	0.49	0.69	1.18	1.47
14	SUCCESS	2	2	0.49	0.69	1.18	1.47
16	SUCCESS	2	4	0.49	0.69	1.18	1.47
15	SUCCESS	2	3	0.49	0.69	1.18	1.47
17	SUCCESS	2	5	0.49	0.69	1.18	1.47
18	SUCCESS	3	6	0.49	0.69	1.18	1.47
19	SUCCESS	3	7	0.49	0.69	1.18	1.47
20	SUCCESS	3	8	0.49	0.69	1.18	1.47
22	SUCCESS	3	10	0.49	0.69	1.18	1.47
21	SUCCESS	3	9	0.49	0.69	1.18	1.47
23	SUCCESS	3	11	0.49	0.69	1.18	1.47
24	SUCCESS	2	0	0.49	1.18	1.67	1.47
25	SUCCESS	2	1	0.49	1.18	1.67	1.47
26	SUCCESS	2	2	0.49	1.18	1.67	1.47
28	SUCCESS	2	4	0.49	1.18	1.67	1.47
27	SUCCESS	2	3	0.49	1.18	1.67	1.47
29	SUCCESS	2	5	0.49	1.18	1.67	1.47
30	SUCCESS	3	6	0.49	1.18	1.67	1.47
31	SUCCESS	3	7	0.49	1.18	1.67	1.47
32	SUCCESS	3	8	0.49	1.18	1.67	1.47
34	SUCCESS	3	10	0.49	1.18	1.67	1.47
33	SUCCESS	3	9	0.49	1.18	1.67	1.47
35	SUCCESS	3	11	0.49	1.18	1.67	1.47
36	SUCCESS	2	0	0.49	1.67	2.16	1.47
37	SUCCESS	2	1	0.49	1.67	2.16	1.47
38	SUCCESS	2	2	0.49	1.67	2.16	1.47
40	SUCCESS	2	4	0.49	1.67	2.16	1.47
39	SUCCESS	2	3	0.49	1.67	2.16	1.47
41	SUCCESS	2	5	0.49	1.67	2.16	1.47
42	SUCCESS	3	6	0.49	1.67	2.16	1.47
43	SUCCESS	3	7	0.49	1.67	2.16	1.47
44	SUCCESS	3	8	0.49	1.67	2.16	1.47
46	SUCCESS	3	10	0.49	1.67	2.16	1.47
45	SUCCESS	3	9	0.49	1.67	2.16	1.47
47	SUCCESS	3	11	0.49	1.67	2.16	1.47
48	SUCCESS	2	0	0.49	2.16	2.65	1.47
49	SUCCESS	2	1	0.49	2.16	2.65	1.47
50	SUCCESS	2	2	0.49	2.16	2.65	1.47
52	SUCCESS	2	4	0.49	2.16	2.65	1.47
51	SUCCESS	2	3	0.49	2.16	2.65	1.47
53	SUCCESS	2	5	0.49	2.16	2.65	1.47
54	SUCCESS	3	6	0.49	2.16	2.65	1.47

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Total cost of execution of 55 Cloudlets = $80.85
Our Selling Price would be $104.56 (adding the profit)

INFERENCE

Even though our selling price is higher in the case of Time-Shared and Space-Shared scheduling, it comes so because of usage of more resources and more higher execution time. Hence, the Hybrid Workload Scheduling gives the best results and maximum profits whilst optimizing the execution of remote procedures.