Cloud Computing: Past, Present and Future

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Topics to be discussed

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1. Public Cloud Computing - Gartner
2. Research Topics
   1. Energy-Efficient Cloud Computing
   2. Renewable Energy-Based Cloud Computing
   3. Vehicular Cloud Computing
3. Conclusion
4. References

Public Cloud Computing - 2 to 5 Years (Grow) and >10 Years (Adaption)

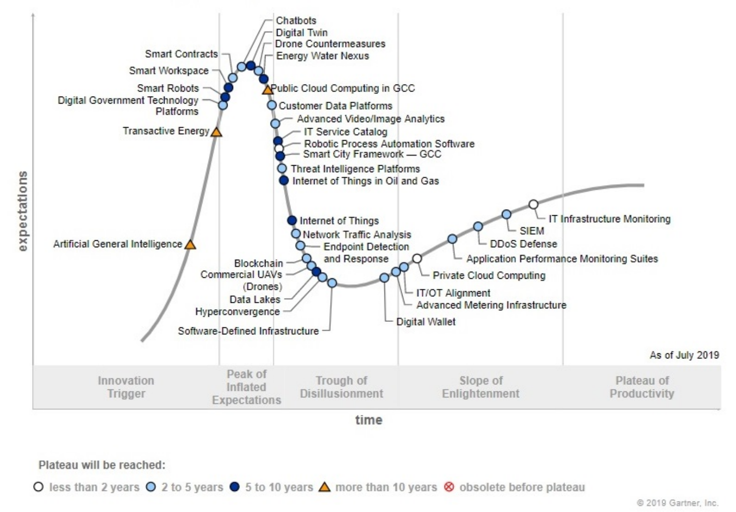


Figure 1: Gartner Hype Cycle for IT in GCC, 2019.

4 Trends Impacting Cloud Adoption in 2020 [2]

Gregor Petri, Vice President Analyst, Gartner

By 2023, the leading **cloud service providers** will have a **distributed ATM**-like presence to serve a subset of their **services**

4 Trends

- **Cost optimization** will drive **cloud adoption**
- **Multicloud** will reduce **vendor lock-in**
- **Insufficient cloud IaaS skills** will **delay migrations**
- **Distributed cloud** will support **expanded service availability**

Energy-Efficient Cloud Computing

- How to **Utilize Resources** and How to Reduce **Power Consumption** [21]?
- Energy Consumption - CPU Utilization [22]
- **Datacenter**: 25,000 Householders [23]
- **ICT Resources**: 8% of Total Energy Consumption (50% in Next Decade) [24]
- **U. S. Electricity**: 66% using Coal and Natural Gas [24]
- **NRDC Report**: 91 billion kilowatt-hours (kWh) of Electricity Consumed by U. S. Datacenters (140 billion kWh by 2020) [25]

CPU Utilization Vs. Power Consumption [26]

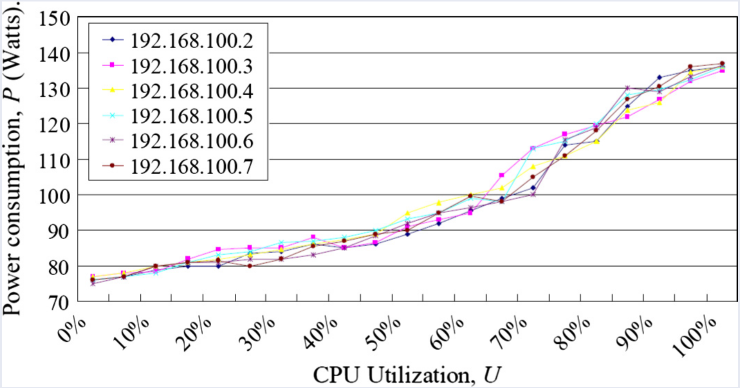


Figure 2: The power consumption of six typical workloads served by a streaming server.

- **CPU utilization Vs. Energy Consumption**: Not Linear

CPU Utilization Vs. Power Consumption [26]

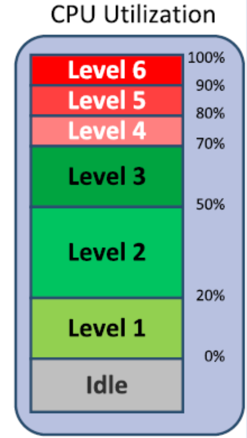
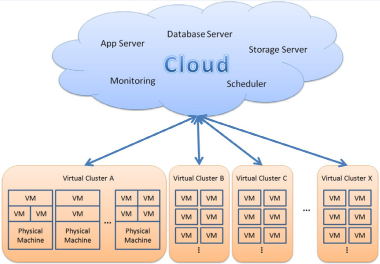


Figure 3: A Suggested Model [21].

A Cloud System Composed of Virtual Clusters (VCs) and Network Bandwidth between VCs



From \ To		Virtual Cluster A	B	C	...
Virtual Cluster	A		250 MB/s	500 MB/s	...
	B	200 MB/s		250 MB/s	...
	C	300 MB/s	300 MB/s		...
	⋮	⋮	⋮	⋮	

Figure 4: A Research Model [21].

Task Consolidation

Table 1: A List of Tasks [27]

Task	Arrival Time	Processing Time	Utilization
0	0	20	40%
1	3	8	50%
2	7	23	20%
3	14	10	40%
4	20	15	70%

Task Consolidation

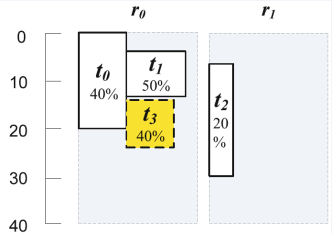


Figure 5: Consolidation Example for Tasks - Choice 1 [27].

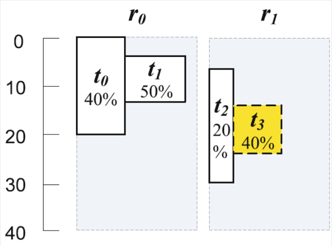


Figure 6: Consolidation Example for Tasks - Choice 2 [27].

Task Consolidation Among VCs - Threshold 70%

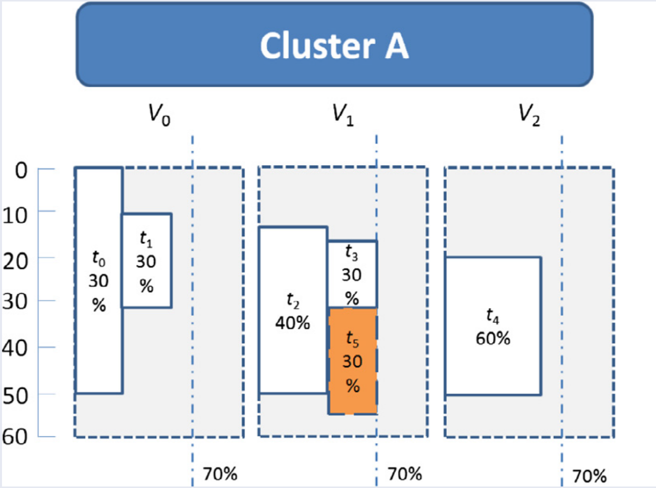


Figure 7: Assigning Tasks in VC_A.

Task Consolidation Among VCs - Threshold 70%

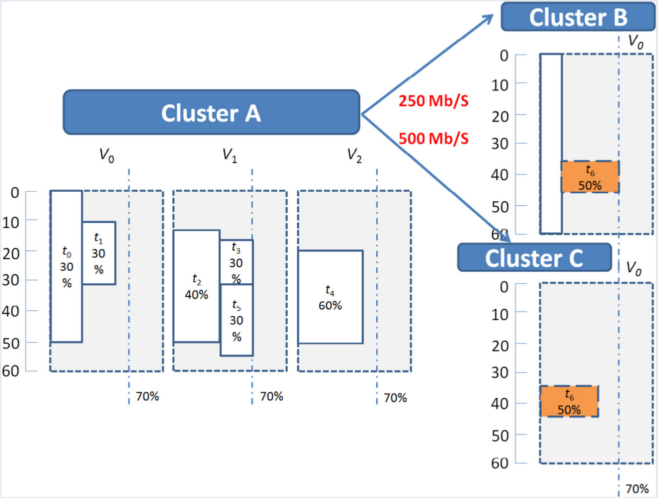


Figure 8: VC_A Asks for Resource Support When Assigning t_6 [21].

Task Consolidation Among VCs - Threshold 70%

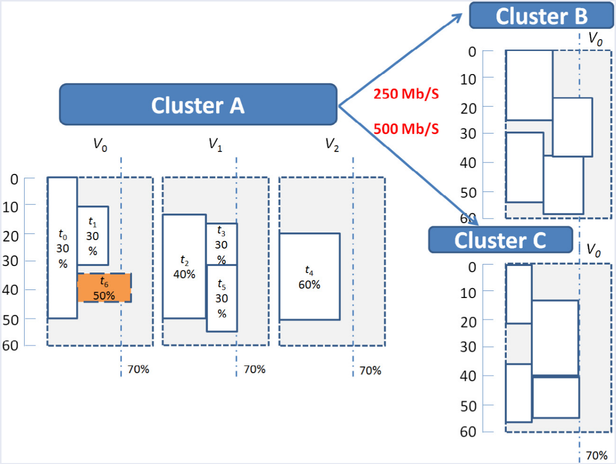


Figure 9: VC_A Assigns t_6 to V_0 Without Conforming to 70% CPU Utility [21].

Task Consolidation Algorithms

- Random [27]
- ECTC [27]
- MaxUtil [27]
- ETC [21]
- ETSA [28]

Renewable Energy-Based Cloud Computing

- Motivation [29]
  - **Datacenters:** 8.6 million Datacenters (3 million in the U. S.)
  - 50,000 to 80,000 Servers - 25 to 30 megawatts
  - **Global Datacenters**: 416 terawatts of Electricity per Year
- Cloud Service Providers [30]
  - **Non-renewable Energy Sources:** Fossil Fuels
    - Coal, Gas, Orimulsion and Petroleum
  - **Carbon Dioxide, Particle and Heat** - Harmful for Environment
  - **Solution:** Renewable Energy Sources (RES)
    - Biomass, Hydropower, Solar and Wind
  - **Google and Microsoft Datacenters**: Fully Powered by RES

Renewable Energy-Based Cloud Computing [30]

- **Renewable Energy Sources**: Not Available Round the Clock
- Both **Non-Renewable** and **Renewable Energy Sources**

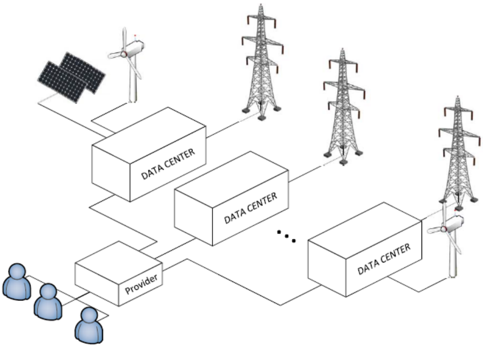
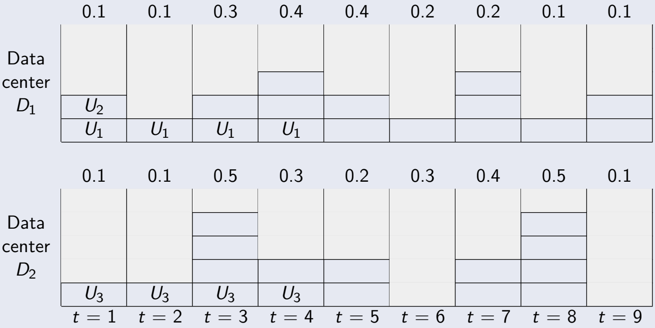


Figure 10: A System Model [30].

Research Topic #2

Nine tasks, U_1 to U_9 (i.e., 3 assigned tasks and 6 unassigned tasks) and two datacenters, D_1 and D_2 (each with 5 nodes) [30]

User Request	U_1	U_2	U_3	U_4	U_5	U_6	U_7	U_8	U_9
Start Time	1	1	1	3	4	5	5	7	8
Nodes	1	1	1	2	1	1	1	2	3
Duration	4	1	4	5	3	2	3	2	2



Future-Aware Best Fit (FABEF) [30]

- Route each request to a datacenter leading to the **lowest cost**

Example - U_4: ST - 3, N - 2 and D - 5

Data center D_1

	0.1	0.1	0.3	0.4	0.4	0.2	0.2	0.1	0.1
			U_4	U_4					
	U_2		U_4	U_4	U_4	U_4	U_4		
	U_1	U_1	U_1	U_1	U_4	U_4	U_4		

Data center D_2

	0.1	0.1	0.5	0.3	0.2	0.3	0.4	0.5	0.1
			U_4	U_4					
			U_4	U_4	U_4	U_4	U_4		
	U_3	U_3	U_3	U_3	U_4	U_4	U_4		
	$t=1$	$t=2$	$t=3$	$t=4$	$t=5$	$t=6$	$t=7$	$t=8$	$t=9$

- Cost of datacenter D_1 for request $U_4 = 0.3 + 0.2 = \mathbf{0.5} \leftarrow$ Lowest cost
- Cost of datacenter D_2 for request $U_4 = 0.3 + 0.3 + 0.3 = 0.9$

Renewable Energy-Based Algorithms

- Future-Aware Best Fit [30]
- Static Cost-Aware Ordering [31]
- Round Robin [30]
- Highest Available Renewable First [30]
- MinBrown [32]
- Fuzzy Logic-Based Load Balancing [30]
- Worst Fit [31]
- MinUtil [33]

Vehicular Cloud Computing [34]

- Motivation
  - Cloud Computing and Vehicular Ad-Hoc Network
  - **Smart Vehicle**: On-Board Unit (GPS, Sensors, Radar Device, Cameras, Digital Map, Processing Unit, Storage Unit, etc.)
  - Smart Vehicle - Host VMs
  - **Underutilized Resources**: Parking Lot, Roadways and Streets
  - Vehicular Clouds

Vehicular Cloud Computing [34]

Table 2: Comparative Study of CC and VCC

Characteristics	**CC**	**VCC**
Mobility of Clouds	No	Yes
Autonomous Cloud Formation	No	Yes
Automatic Cloud Federation	No	Yes
Moving Network Pool	No	Yes
Large Traffic Event Management	Possible	Yes
Planned and Unplanned Disaster Management	Possible	Yes
Corporation as a Service	Possible	Yes

Vehicular Cloud Computing [35]

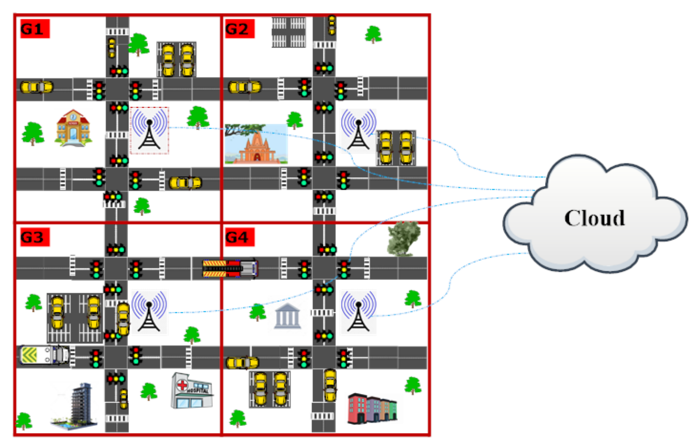


Figure 11: A Large Urban Area With Four Grids.

Vehicular Cloud Computing [35]

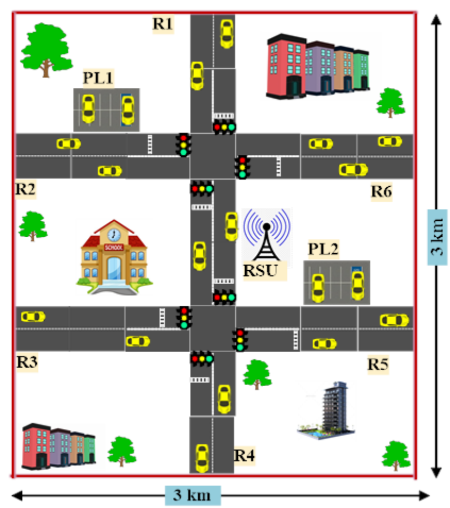


Figure 12: A Sample Grid.

Vehicular Cloud Computing [36]

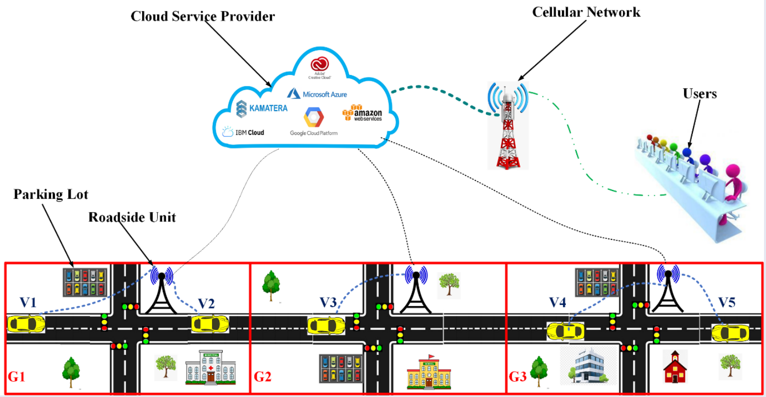


Figure 13: An Overview of VC Model With Three Grids.

Renewable Energy-Based Algorithms

- Vehicular VM Migration-Uniform [37]
- Vehicular VM Migration-Least Workload [37]
- Vehicular VM Migration-Mobility Aware [37]
- Round Robin [38]
- Deficit Weighted RR [39]
- Mobility and Destination Workload Aware Migration [37]
- Dynamic Service Migration [35]
- Smart Cloud Service Management [36]

Conclusion

Public Cloud Computing

- Gartner

Research Topics

1. Energy-Efficient Cloud Computing
2. Renewable Energy-Based Cloud Computing
3. Vehicular Cloud Computing

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Thank You!