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## Technologies related to cloud computing

Cloud computing typically has characteristics of all these technologies:

- Grid computing
- Virtualization
- Utility Computing
- Autonomic Computing

A quick overview of these technologies is given here.

### Grid Computing

Grid Computing involves a network of computers that are utilized together to gain large supercomputing type computing resources. Using this network of computers large and complex computing operations can be performed. In grid computing these network of computers may be present in different locations.

A famous Grid Computing project is [Folding@Home](#). The project involves utilizing unused computing powers of thousands of computers to perform a complex scientific problem. The goal of the project is "to understand protein folding, misfolding, and related diseases".

### Virtualization

Virtualization introduces a layer between Hardware and operating system. During the sixties mainframe started supporting many users using virtual machines. These virtual machines simulated behavior of an operating system for each user. VMWare launched a product called VMware Workstation in 1999 that allows multiple operating systems to run on personal computers.

The virtualization forms the foundation of cloud technology. Using virtualization, users can access servers or storage without knowing specific server or storage details. The virtualization layer will execute user request for computing resources by accessing appropriate resources.

Typically server utilization in data centers can be as low as 10%. Virtualization can help in significantly improving server utilization.

### Utility Computing

Utility Computing defines a "pay-per-use" model for using computing services. In utility computing, billing model of computing resources is similar to how utilities like electricity are traditionally billed. When we procure electricity from a vendor, the initial cost required is minimal. Based upon the usage of electricity, electricity companies bills the customer (typically monthly). In utility computing billing is done using a similar protocol.

Various billing models are being explored. A few common ones are:

1. Billing per user count. As an example if an organization of 100 people uses Google's gmail or Microsoft Live as their internal email system with email residing on servers in the cloud, Google/Microsoft may bill the organization on per user basis.
2. Billing per Gigabyte. If an organization is using Amazon to host their data on the cloud, Amazon may bill the organization on the disk space usage.
3. Billing per hour/day. As an example a user may pay for usage of virtual servers by time utilized in hours.

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In reality pricing on cloud computing can be very complex. As an example [pricing of Amazon S3](#) as on November 2009 is explained below. Amazon charges for using US S3 are divided into three parts - storage charges, data transfer charges and charges for number of requests. These charges are summed together to compute the total billing.

<b>S3 storage charges</b>		<b>US server</b>	<b>Europe server</b>
	First 50 TB / month	\$0.150 per GB	\$0.180 per GB
	next 50 TB / month	\$0.140 per GB	\$0.170 per GB
	next 400 TB /month	\$0.130 per GB	\$0.160 per GB
	over 500 TB / month	\$0.120 per GB	\$0.150 per GB

Data transfer charges are further divided into data transfer input and data transfer output. Data transfer rate for incoming data \$0.100 per GB. Data transfer rate for outputting data is explained in the table below.

<b>S3 data transfer out charges</b>		<b>US server</b>	<b>Europe server</b>
	First 10 TB / month	\$0.170 per GB	\$0.170 per GB
	next 40 TB / month	\$0.130 per GB	\$0.130 per GB
	next 100 TB /month	\$0.110 per GB	\$0.110 per GB
	over 150 TB / month	\$0.100 per GB	\$0.100 per GB

<b>S3 charges for requests made</b>		<b>US server</b>	<b>Europe server</b>
	Per 1,000 PUT, COPY, POST, or LIST requests	\$0.01	\$0.012
	Per 10,000 other requests	\$0.01	\$0.012

Utility computing helps in reducing initial investment. As the computing requirements for an individual or an organization changes, the billing changes accordingly, without incurring any additional cost. If the usage has reduced, then billing will also reduce accordingly.

**Autonomic computing**

Autonomic computing is an initiative started by IBM in 2001. Autonomic means “self-managing” computers. In Autonomic computing, computers can automatically correct themselves without human intervention. As an example consider is a network of computers running a set of programs. When there is a hardware failure on one of the computers on the network, the programs running on that computer are “transferred” to other computers in the network. This is an example of “self-correction” or autonomic computing. The analogy typically used is that of human biological systems. Our biological systems take action in self-correcting mode without our explicit knowledge. In the same way the goal of autonomic computing is for computing infrastructure to self-correct itself in unforeseen situations.

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