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# Comparative study between Cluster, Grid, Utility, Cloud and Autonomic computing

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***Abstract:*** *Autonomic computing was an idea that came to existence because of the great need to its basic concepts, which it's to have available resources, applications that can manage themselves in accordance with high level guidance from humans. The idea of Autonomic computing is not new, but it developed Cloud computing through the years to reach the current situation (Autonomic computing) In this paper there will be an overview for other types of computing beside Autonomic computing to highlight the differences between them, the characteristics and the advantages and disadvantages for each. That comparative will lead to the importance of Autonomic computing and its wide open future*

***Key words*****:** *Cluster computing, Grid computing, Utility computing, Cloud computing, Autonomic computing*

## I. Introduction:

Computer users always dreaming about to getting super storage capabilities to their computers and get rid of the obsession of the software purchase one by one, in addition to access the contents of their devices from everywhere without having to carry it with you wherever you go, and this dream might be considered more important for companies, because there's a large amount of computers in the company and ever computer needs its own software, so, the cost of the hardware and software are larger. Autonomic computing has made this requirement by providing for users large storage capacities and customized software with easy access to files from everywhere.

But before the Autonomic computing exist effectively, cloud computing was used by consumption based billing Then appeared Autonomic computing to provide sharing resources service more broadly by managed themselves.

**Objectives of the paper:**
Explain what is Autonomic computing, its importance and its superiority over other types of computing, and encourage to wider use of it.

**Research Methodology:**
A comparison between, Autonomic computing, cloud computing, grid computing, utility computing, Cluster computing, by clarifying the differences and excellence of Autonomic computing in many areas such as speed, performance, privacy, storage and availability of services and flexibility of the system and other differences.

## II. Cluster Computing:

Cluster computing it's a group of computers connected to each other and work together as a single computer. These computers are often linked through a LAN.[1]

The clusters came to existence for the high need for them, because the computing requirements are increasing in a high rate and there's more data to process' so the cluster has been used widely to improve performance. [2]

The cluster is a tightly coupled systems, and from its characteristics that it's a centralized job management and scheduling system. All the computers in the cluster use the same hardware and operating system, and the computers are the same physical location and connected with a very high speed connection to perform as a single computer. The resources of the cluster are managed by centralized resource manager. the cluster is single owned, to only one organization. Its interconnection network is a high-end with low latency and high bandwidth, the security in the cluster is a login/password-based, and it has a medium level of privacy

depends on users privileges. it has a stable and guaranteed capacity. The self healing in the cluster is Limited, it's often restarts the failed tasks and applications. its service negotiations are limited, and the user management is centralized.[1, 9]

The cluster computing is usually used in educational resources, commercial sectors for industrial promotion & Medical research.[1]

**2.1 Architecture:**

The architecture of cluster computing contains some main components and they are**:**

1. Multiple stand alone computers.
2. Operating system.
3. High performance interconnects.
4. Communication software.
5. Different application platforms [5]

**2.2 Advantages:**

In the cluster software is automatically installed and configured, and the nodes of the cluster can be added and managed easily, so it's very easy to deploy, it's an open system, and very cost effective to acquire and manage, clusters have many sources of support and supply, it's fast and very flexible, the system is optimized for performance as well as simplicity and it can change software configurations at any time, also it saves the time of searching the net for latest drivers, The cluster system is very supportive as it includes software updates.[4]

**2.3 Disadvantages:**

Cluster computing contains some disadvantages such as that it's hard to be managed without experience, also when the size of cluster is large, it'll be difficult to find out something has failed, the programming environment is hard to be improved when software on some node is different from the other. [5]

## III. Grid Computing:

Grid computing is a combination of resources from multiple administrative domains to reach a common target, and this group of computers can distributed on several location and each a group of grids can be connected to each other. [1]

The need of access to additional resources and the collaborating between organizations leads to the need for grid computing. [6]

Grid environments are extremely well suited to run jobs that can be split into smaller chunks and run concurrently on many nodes.

The grid is a loosely coupled systems and from its characteristics that it's a distributed Job Management and scheduling, the computers in the grid are not required to be in the same physical location and can be operated independently, so each computer on the grid is concerned a distinct computer, the computers in the grid are not tied to only on operating system and can run different OSs and different hardware, when it comes to a large project, the grid divides it to multiple computers to easily use their resources. The grid is multiple owned, it could be owned by several companies. Interconnection network is mostly internet with high latency and low bandwidth. The security in the grid is public and private based on authentication and mapping user to an account. And it has limited support privacy, its capacity is not stable, it varies, but it's high. The self healing in the cluster is Limited, it's often restarts the failed tasks and applications. its service negotiations are based on service level agreements, and the user management is decentralized.[1 ,9]

The grid computing is usually used in predictive modeling and simulations, engineering design and automation, energy resources exploration, medical, military, basic Research and visualization. [1]

**3.1 Architecture:**

Fabric layer to provide the resources which shared access is mediated by grid computing.

Connectivity layer and it means the core communication and authentication protocols required for grid specific network functions.

Resource layer and it defines the protocols, APIs and SDK for secure negotiations, imitations, monitoring control, accounting and payment of sharing operations on individual resources.

Collective layer which it contains protocols and services that capture interactions among a collection of resources

Finally the Application layer, and it's user applications that operate within VO environment. [2]

**3.2 Advantages:**

One of the advantages of grid computing that you don't need to buy large servers for applications that can be split up and farmed out to smaller commodity type servers, secondly it's more efficient in use of resources. Also the grid environments are much more modular and don't have much points of failure. About policies in the grid it can be managed by the grid software, beside that upgrading can be done without scheduling downtime, and jobs can be executed in parallel speeding performance.[7]

**3.3 Disadvantages:**

It needs fast interconnect between computers resources, and some applications may need to be pushed to take full advantage of the new model, and licensing across many servers may make it forbidden for some applications, and the grid environments include many smaller servers across various administrative domains. also political challenges associated with sharing resources especially across different admin domains. [7]

## IV. Utility Computing:

Utility Computing refers to a type of computing technologies and business models which provide services and computing resources to the customers, such as storage, applications and computing power.[9] This model has the advantage of a low cost with no initial price to reach the computer resources. This repackaging of computing services is the foundation of the shift to on demand computing, software as a service and cloud computing models which late developed the idea of computing, applications and network as a service. [8]

Utility computing is kind of virtualization, that means the whole web storage space and computing power which it's available to users is much larger than the single time-sharing computer. Multiple backend web servers used to make this kind of web service possible. [9]

Utility computing is similar to cloud computing and it often requires a cloud-like infrastructure. [10]

**4.1 Architecture of utility computing:**

It depends on the devices of the users and the providing company for the utility service. And similar to the architecture of the cloud.

**4.2 Advantages of utility computing:**

Here are some benefits of utility computing such as that the client doesn't have to buy all the hardware, software and licenses needed to do business. Instead, the client relies on another party to provide these services. It also gives companies the option to subscribe to a single service and use the same suite of software throughout the entire client organization. And it offers compatibility of all the computers in large companies. [9]

**4.3 Disadvantages of utility computing:**

There's some issues are considered as disadvantages such as reliability which means the service could be stopped from the utility computing company for any reason such as a financial trouble or equipment problems. Also utility computing systems can also be attractive targets for hackers, and much of the responsibility of keeping the system safe falls to the provider [9]

## V. Cloud computing:

Cloud computing is a term used when we are not talking about local devices which it does all the hard work when you run an application, but the term used when we're talking about all the devices that run remotely on a network owned by another company which it would provide all the possible services from e-mail to complex data analysis programs. This method will decrease the users' demands for software and super hardware. The only thing the user will need is running the cloud computing system software on any device that can access to the Internet [1]. Cloud computing is useful for the small business companies to make their resources from external sources as well as for medium companies, the large companies have obtained the largest storage without the need to build internal storage centers, thus, the cloud computing has given for both small and large companies the ability to reduce the cost clearly. In return for these services, the providing companies for cloud computing requires a financial gain determined by use. [1] The cloud is a dynamic computing infrastructure, IT service-centric approach; also it's a self-service based usage model and self-managed platform and its consumption based on billing, the computers in cloud computing are not required to be in the same physical place, wherever you are you will be served. The operating system of the basic physical cloud units manages the memory, the storage device and network communication. In the cloud you can use multiple operating systems at the same time. Every node in the cloud is an independent entity. It allows multiple smaller applications to run at the same time. The cloud is owned by only one company and it provides its services to the users, it interconnection network is a high-end with low latency and high bandwidth. The security in the cloud is high and the privacy is guaranteed, each user/application is provided with a virtual machine. Its capacity is provided on demand. The self healing in the cloud has a strong support for failover and content replication, and

virtual machines can be easily migrated from one node to other. its service negotiations are based on service level agreements, and the user management is centralized or can be delegated to third party. [1, 11]

The cloud computing is usually used in banking, insurance, weather forecasting, space exploration, software as a service, platform as a service, infrastructure as a service. [1]

**5.1 Cloud Computing & Utility Computing:**

Cloud computing and utility computing are a lot alike and they can be mistaken for one to each other, Cloud computing is a broader concept than utility computing, though cloud and utility computing often conjoined together as a same concept but the difference between them is that utility computing relates to the business model in which application infrastructure resources are delivered, whether these resources are hardware, software or both. While cloud computing relates to the way of design, build, and run applications that work in a virtualization environment, sharing resources and boasting the ability grow dynamically, shrink and the ability of self healing. [12]

**5.2 Architecture:**

Cloud computing architecture consists of two components the first one is the front end which it's comprises the client's device or a computer network and some applications are needed for accessing the cloud computing system. The second one is the back end it refers to the cloud itself which may contain various computer machines, data storage systems and servers. Group of these clouds make a whole cloud computing system.

Cloud computing has five properties and clarified by the National Institute of Standards and Technology (NIST):

1. On-demand self-service, the services are available on demand, the user can get the services at any time, all it takes is an Internet connection.
2. Broad network access, the cloud is accessed remotely over the network, while the access to the cloud is through the internet; it means that it is accessible to its computing capabilities, software, and hardware from anywhere.
3. Resources pooling in an independent location and resources serve a large number of users with all their different devices and their required resources.
4. Rapid elasticity, dealing with the cloud is very easy, the user can simply reduce or increase the capacity, and also it's faster than the regular computing types.
5. Measured Service, the cloud systems control and reuse the resources by using measurement capabilities and according to the type of service, these services also have financial return, depending on usage. [13]

**5.3 Advantages:**

There's a lot of reasons that makes cloud computing very popular and that's because it offers an unlimited storage capacity also it provides lower computer costs, so, instead of buying a high features computer you can only get a regular computer can access to the net, also you can get most of the applications

You need for free instead of buying it and it's very expensive, also computers in a cloud computing performs faster because there's fewer programs and processes in the memory. Also there's no need to worry about upgrading software because the cloud updates them automatically. You don't have to worry about the compatibility of the documents you create on your machine with other users' applications or operating systems. Beside if your hard-disk crashes and all your valuable data destroyed this will not affect the storage of your data because it's stored in the cloud. You can access to your data whenever you have a computer and an Internet connection wherever you are and that's because it's reachable through the internet, also you are no longer connected to a single computer to reach your data, also sharing documents leads to a better collaboration between companies and people. [13]

**5.4 Disadvantages:**

Although the great advantages of cloud computing it faces some obstacles such as it requires a constant internet connection because it's impossible to reach it without an internet connection, also it doesn't work well with low-speed connections, such as dial-up services, though that the cloud sometimes can be slow, even with using fast connection, because web based applications can be slower than accessing a similar software program on your desktop. Besides that, its applications may have limited featured compared to their desktop based applications. Also there's

## VI. Autonomic:

The Autonomic Computing Paradigm has been inspired by the human autonomic nervous system. Its overarching goal is to realize computer and software systems and applications that can manage themselves in accordance with high-level guidance from humans. Meeting the grand challenges of autonomic computing requires scientific and technological advances in a wide variety of fields, as well as new programming paradigm and software and system architectures that support the effective integration of the constituent technologies.

This paper presents an introduction to autonomic computing, its challenges, and opportunities. In this paper, we first give an overview of the architecture of the nervous system and use it to motivate the autonomic computing paradigm.

We then outline the key challenges of autonomic computing and present an overview of existing autonomic computing systems and applications. [14]

**6.1 Architecture:**

Autonomic systems and applications are constructed from autonomic elements as dynamic, opportunistic and/or ephemeral compositions. These compositions may be defined by policies and context, and may be negotiated. The key parts of an autonomic element are described below.

**– Managed Element:** This is the smallest functional unit of the application and contains
The executable code (program, data structures) (e.g., numerical model of a Physical process). It also exports its functional interfaces, its functional and behavioral attributes and constraints, and its control mechanisms. At runtime, the managed Element can be affected in different ways, for example, it can encounter a Failure, run out of resources, be externally attacked, or may hit a bottleneck impacting Performance.
**– Environment:** The environment represents all the factors that can impact the managed Element. The environment and the managed element can be viewed as two Subsystems forming a stable system. Any change in the environment causes the Whole system to go from a stable state to an unstable state. This change is then offset by reactive changes in the managed element causing the system to move back from the unstable state to a different stable state.
**– Control:** Each autonomic element has its own manager that (1) accepts user specified
Requirements (performance, fault tolerance, security, etc.), (2) interrogates The element and characterizes its state, (3) senses the state of the overall System/application, (4) determines state of the environment, and (5) uses this information To control the operation of the managed element in order to effectively Achieve the specified behaviors. This control process repeats continuously throughout The lifetime of the autonomic element. [14]

**6.2 Advantages:**

The main Advantages of autonomic computing is reduced TCO (Total Cost of Ownership). Breakdowns will be less frequent, thereby drastically reducing maintenance costs. Fewer personnel will be required to manage the systems.

The most immediate Advantages of autonomic computing will be reduced deployment and maintenance cost and increased stability The challenge for a customer today is that his IT infrastructure is most likely heterogeneous, meaning it's comprised of hardware from multiple vendors. This makes it increasingly difficult to add systems and manage them automatically Customers spend three-fourths of their application deployment time and costs on the integration equation. We need autonomic capabilities so that IT infrastructures can be self-configuring, self-healing, self-optimizing and self-protecting

Another Advantages of this technology is that it provides server consolidation to maximize system availability, and minimizes cost and human effort to manage large server farms [15]

**6.3 Disadvantages:**

The complexity construction and requires a constant internet connection because it's impossible to reach it without an internet connection, also it doesn't work well with low-speed connections, such as dial-up services, though that the autonomic sometimes can be slow.

**Differentiations between cluster, grid, utility, cloud, autonomic computing [1, 15]**

| computing type | Characteristics | Advantages | Disadvantage | Comments | S/W and H/W |
|---|---|---|---|---|---|
| Cluster | 1. Tightly coupled systems<br>2. Single system image<br>3. Centralized Job management & scheduling system | 1. Easy to deploy<br>2.Complete<br>3.Open<br>4.Easy to manage<br>5.Flexible | 1. no need to experience<br>2. difficult to find failure<br>3.Programming is hard to be improved when software is | In cluster computing, a bunch of similar (or identical) computers are hooked up locally (in the same physical | The cluster computers all have the same hardware and OS. |

| | | | | | |
|---|---|---|---|---|---|
| | | 6.Optimized<br><br>7.Expandable<br><br>8.Supported | different between the nodes.[4] | location, directly connected with very high speed connections) to operate as a single computer | |
| Grid | 1. Loosely coupled<br><br>2. Diversity and Dynamism<br><br>3. Distributed Job Management & scheduling | 1. No need to buy large servers for applications<br>2. More efficient use of idle resources.<br>3. Its environments are more modular and don't have much points of failure.<br>4.Policies can be managed by the grid software.<br>5.Upgrading can be done without scheduling downtime. 6.Jobs can be executed in parallel speeding | 1. Needs a fast interconnect.<br><br>2. Some applications don't take full advantage of the new models.<br><br>3. No licensing across many servers for some applications.<br><br>4. Includes many smaller servers across various administrative domains. | In grid computing, the computers do not have to be in the same physical location and can be operated independently. As far as other computers are concerned each computer on the grid is a distinct computer. | The computers that are part of a grid can run different operating systems and have different hardware |
| Utility | 1. Scalability.<br>2. Demand pricing.<br>3. Standardized Utility Computing Services.<br>4. Share the web and other resources in the shared pool of machines.<br>5. Automation.[ | 1. Lower computer costs.<br>2. Subscription of a single service with the same suite of software.<br>3. Compatibility.<br>4. Unlimited storage capacity. | 1. Needs a fast interconnect.<br><br>2. Some applications don't take full advantage of the new models.<br><br>3. No licensing across many servers for some applications.<br><br>4. Includes many smaller servers across various administrative domains.<br><br>5. Political challenges. | In utility computing, the computers need not to be in the same physical location. | The memory, storage devices and net work communications are managed by the OS of the basic physical cloud units |
| Cloud | 1.On-demand self-service.<br><br>2. Broad network access.<br><br>3.Resources pooling<br><br>4. Rapid elasticity<br><br>5.Measured Service.[8] | 1. Lower computer costs.<br>2. Improved performance.<br>3. Reduced software costs.<br>4. Instant software updates<br>5.Improved document format compatibility<br>6.Unlimited storage capacity,<br>7. Increased data reliability,<br>8.Universal document access,<br>9.Latest version availability of your documents,<br>10.Easier group collaboration,<br>11. You are no longer connected to a single computer. | 1. Requires a constant internet connection.<br><br>2. Does not work well with low-speed connections.<br>3. Can be slow, Even with a fast connection<br><br>5. Stored data might not be secure<br><br>6. if the cloud destroyed you can't backup your data.[7] | In cloud computing, the computers need not to be in the same physical location. | The memory, storage device and network communication are managed by the operating system of the basic physical cloud units. |
| Autonomic | 1\ Self-Configuration<br>2\ Self-Healing<br>3\ Self-Optimization | 1\reduced(tco)total cost owner ship , deployment and maintenance cost | 1\autonomic computing has complex architecture | in autonomic computing, the computers | All Computers controlled by individual OS |

| | | | | | |
|---|---|---|---|---|---|
| | 4\ Self-Protection | 2\breakdown will be less frequent<br>3\\fewer personal will to manage the system<br>\increase stability<br>4\ infrastructures can be self-configuring, self-healing, self-optimizing and self-protecting | 2\\autonomic computing depends on internet that mean the quality of service related to the internet speed | need not to be in the same physical location. | Composed Error Correction And Detection |

## VII. Discussion:

In above table we find many differences between cluster, grid, utility, cloud**,** autonomic computing in many views characteristics, advantages, disadvantages, location, and operating system.

## VIII. Conclusion:

Autonomic computing is the future of computing, companies prefers to use it because it has a lot of benefits like decreasing the expensive amount of money than applications. The service provider can offer cheaper, more reliable applications / resources than organizations can buy themselves automatically.

Though the too many advantages, the Autonomic face some obstacles and challenges but in a comparative with its advantages and the hard effort that the Autonomic providers do will lead them to successfully go through these obstacles.

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