TRENDS OF COMPUTING

From the time of the invention of the first computer till date, the model of computing has changed drastically. And to be able to process large amount of data, different computing models have been deployed over time as shown in Figure 1.

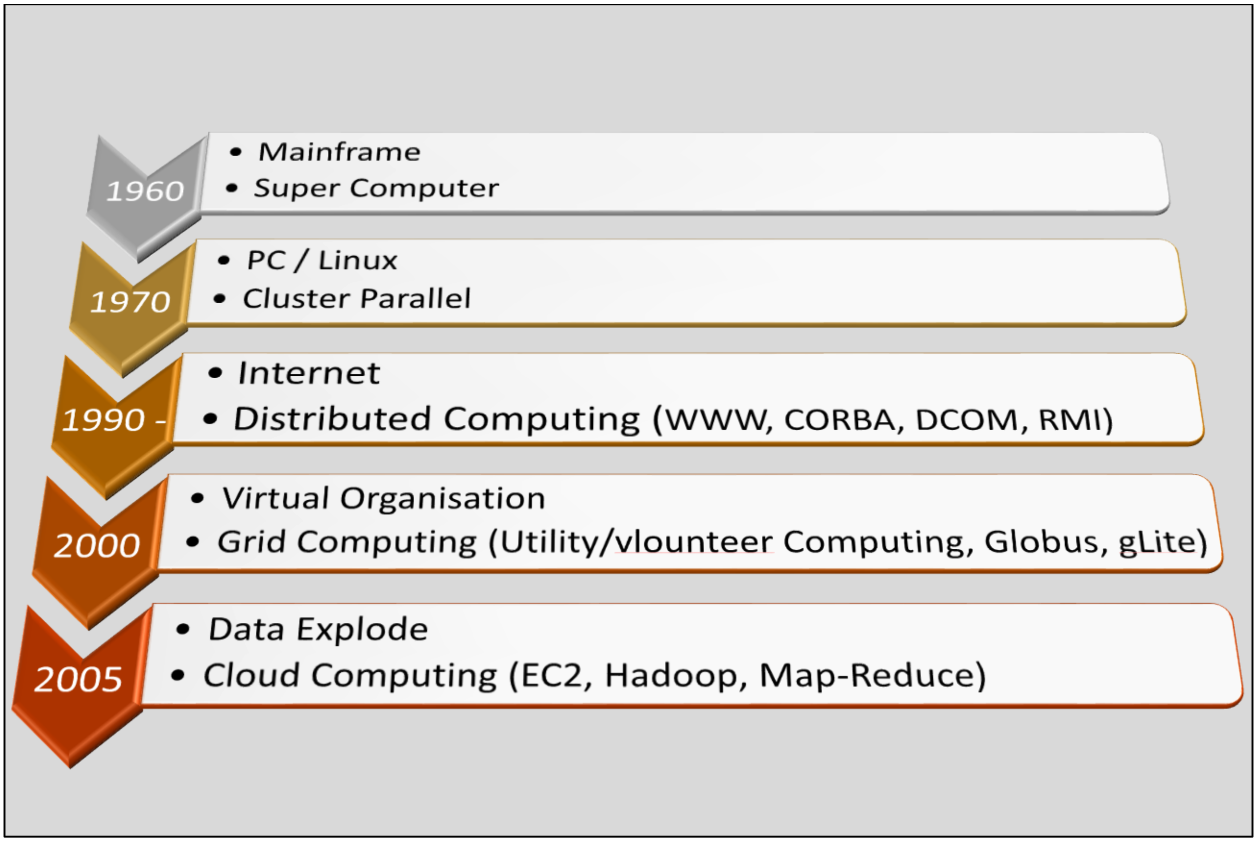

Figure 1 – Models of Computing

Firstly, in the 1960 – 1980, to be able to cope with increasing size of data to be processed in batch, Mainframe and supercomputers came into the light. They were equipped with multicore processors and could service a number of terminals. However most of them were single application. During that same period, Parallel Clustering came as a solution to expensive mainframe/supercomputers. Configuring and coordinating the interactions were quite difficult and required special skills.

The 90s, the era of the Internet, saw the invention of different Distributed Computing technologies, such as WWW, CORBA, RMI, DCOM and so on, to ease the interaction between the different types of computing to work collaboratively.

To take collaboration to the next level, in the year 2000, Grid Computing was introduced to make use of the unused computational power of the computers all over the world to solve processing intensive problems in areas including chemistry, biology, and astronomy and so on. However, the difference between the different of networks (bandwidth, delay, jitter and so on) led to the degradation of the service. For example, satellite communication can have varying delays (jitter); or some parts of internet might be unreachable whenever fibre connection is broken and so on.

And finally as from 2005, all the computing power is concentrated in a single place, known as data centre, to provide Cloud Computing services. Cloud Computing Services includes storage, processing, hosting and so on. The term Cloud is used, as it hides away the complexity of creating and managing such facilities.

Factors That Led to the Creation of Cloud Computing

There are two main reasons behind the development of Cloud Computing. Firstly, the growth of the Internet (Web-scale problem) and related applications like E-Commerce and secondly, the amount of data that needs to be stored and processed.

i. Web-Scale Problem

With the growth of the Internet, and amount of users accessing same services, single hosting servers cannot handle that much of requests. Increasing the number of servers and configuration for load balancing and maintenance of back-end requires huge intensive and specialised skills. The complexity of websites has also increased drastically. For example, Web 2.0, Social Media, Streaming, Crawling and Indexing are all very complex tasks. Web 2.0 uses different technologies like sounds, pictures, video, animation and personalisation to create a personalised environment for the end-user. Social Media connects and stores millions of users together and again each individual user gets a personalised page which is unique. Streaming allows user to listen and view millions of different contents simultaneously, synchronously or asynchronously. Crawling and Indexing is the process involved in finding websites and producing a list of websites based on keywords. These are done by search engines such as Google, Yahoo, Bing and so on. Since the web is enormous and is growing every day, to keep track of each single website is a huge task. To perform all those tasks mentioned above, single servers are inefficient.

E-commerce has revolutionised the way shopping is down nowadays. Sites like Amazon, eBay and so on, are selling millions of products that are despatched all over the world. Again to provide a seamless service, huge IT infrastructure (including web servers, routers, load balancers, payment gateway) is required and as well as skilled staffs are needed.

Offloading those investments and outsourcing the maintenance and configuration of the IT services allow businesses to concentrate on their core business functionalities.

Cloud Computing also offers pay as you use policy, that is, those using more can pay more, and those using less, pay less, which makes the Cloud become acceptable by Small, Medium and even Large companies.

Cloud Computing also provides an interesting platform processing intensive application for Research and Development. Given the amount of processor, memory and storage, it is an ideal platform for processing large datasets and have results in shorter time.

ii. Amount of Data

The size of data being generated and processed nowadays cannot be qualified as huge anymore; it has become enormous. It is estimated that 5 petabytes of information is generated daily, through the use of social networks, sensor network, IoT and so on. Storing such enormous amount of data requires specialised infrastructure that only cloud computing can provide through data centres. Figure 2 shows the amount of data generated by the world leading IT companies and Figure 3 shows the exponential increasing trend in the amount of data stored on the Internet.

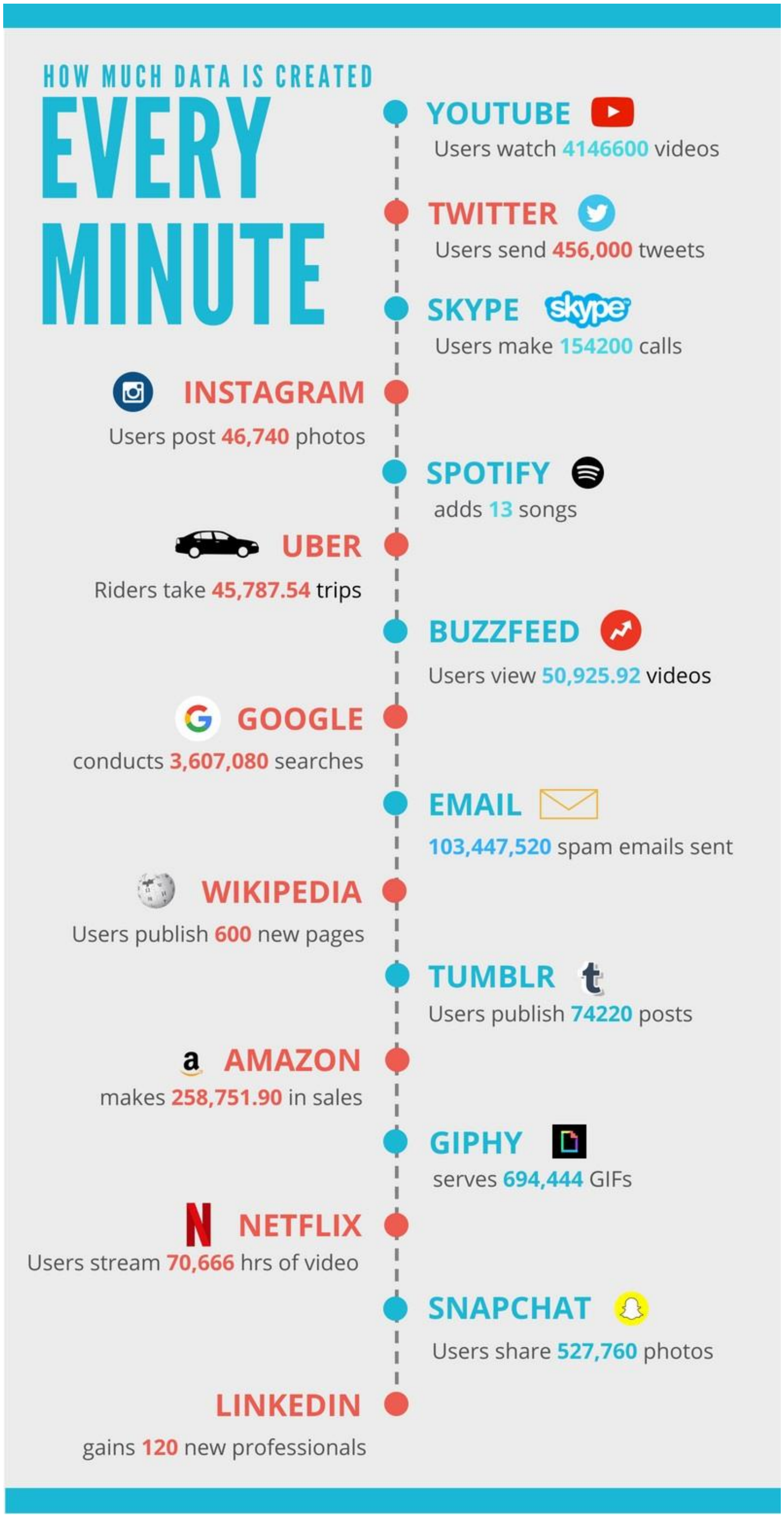

Figure 2 – Amount of data generated every minute (Domo.com (2018))

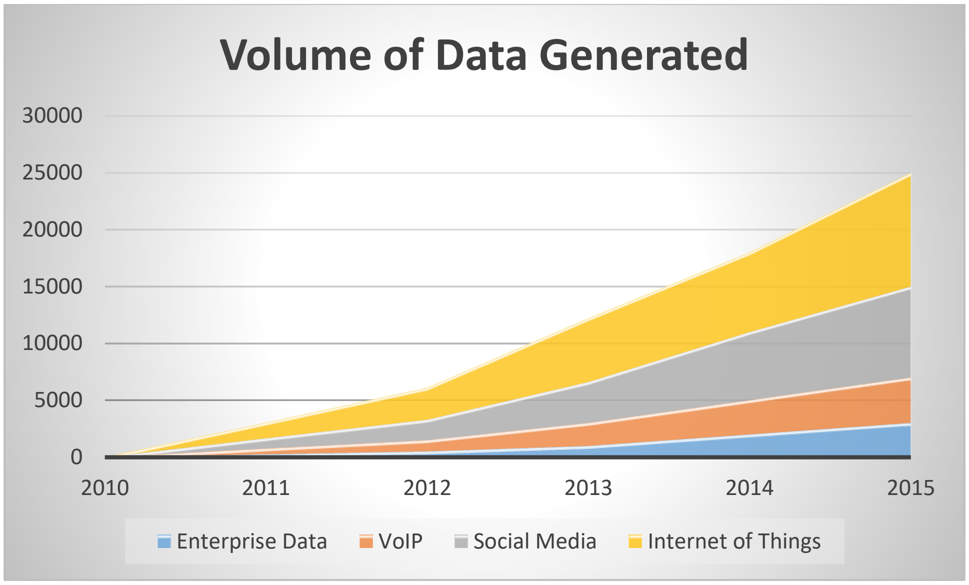

Figure 3 – Volume of Data Generated (Data from IBM Global Research Outlook)

CLOUD COMPUTING

Based on U.S. National Institute of Standards and Technology (NIST), the definition of Cloud Computing is:

> *"Cloud Computing is a model for enabling convenient and on-demand network that makes use of a shared pool of configurable computing resources (such as, networks, servers, storage devices, applications, services, etc.). It might be rapidly provisioned and utilized with minimal management of effort or cloud service provider's interaction".*
>
> (Mell P., 2000)

In simple words, Cloud Computing is the mix of a technology, platform that delivers hosting and storage service on the web.

CHARACTERISTICS OF CLOUD COMPUTING SYSTEMS

1. **On Demand Self Services**

Computer services such as email, applications, network or server service may be provided without demanding human interaction with each service provider. Cloud service vendors supplying on demand self-services including from Amazon Web Services (AWS), IBM, Salesforce.com, Microsoft, Google, etc. New York Times and NASDAQ are samples of companies using AWS.

2. **Resource Pooling**

The provider's processing sources are pooled collectively to serve multiple customers using multiple-tenant model, with different physical and virtual sources dynamically assigned and reassigned relating to consumer requirements. The sources include among others storage, processing, memory, network bandwidth, digital machines and email services. The pooling collectively regarding the resource builds economies of scale.

3. **Rapid Flexibility**

Cloud services can be rapidly and elastically provisioned, in some cases automatically, to quickly scale out and rapidly release to quickly scale in. Towards the consumer, the capabilities readily available for provisioning often look like unlimited and certainly will be purchased in virtually any quantity at any time.

4. **Multi-tenancy**

It refers to the significance of policy-driven administration, segmentation, isolation, governance, service levels, and payment models for different consumer constituencies. Customers may possibly make use of a public cloud provider's service treatment or in fact be through the same organization, such as various business units instead of distinct business entities, but would always share infrastructure.

5. **Determined Service**

Cloud computing resource consumption may be calculated, managed, and documented providing openness for the provider and consumer of the used services. Cloud computing services use a metering capability which enables to regulate and optimize resource use. This recommends that exactly like air time, electricity or water, IT services can also be billed per usage metrics (pay per use). The more you utilize the greater the balance. Just as utility companies sell capacity to subscribers, and telephone companies sell voice and data services, IT services such as network security administration and data centre hosting.

6. Concerns Regarding Cloud Computing

Cloud computing frees individuals and organizations from the expenditure and burden of putting in, maintaining and upgrading computer software. It allows companies to concentrate on their core competencies, instead of paying for centralized computing facilities. Although cloud computing benefits are tremendous, security and privacy concerns include the primary obstacles to wide adoption. Cloud carrier's networks (CSPs) are separate administrative entities, so moving towards commercial public benefits are tremendous, security and privacy concerns include the primary obstacles to wide adoption. Cloud carrier's networks (CSPs) are separate administrative entities, so moving towards commercial public cloud reduces the direct control above the systems that manage their confident data and valuable applications. CSPs' infrastructure and management capacities less difficult, more efficient and reliable as opposed to runners of non-public computing devices; the cloud platform still faces both external and internal security and privacy threats. Apple's iPad subscriber privacy leak (Arthur, 2010), Amazon S3's recent downtime (Etherington, 2017), and Gmail's mass email deletions (Arrington, 2016), are extremely such examples.

The critics of cloud computing points to the facts that the end-users are fully dependent on a fair-speed, reliable connection to the internet. Even though almost all of our applications are locally installed, our reliance upon the net is really pronounced. The disruption attributable to a broadband outage is tremendously significant. So a reliable Web connection now becomes as requisite a software application service for business and private activities as being a constantly available phone network and electricity supply. Cloud computing has additionally a trust on external suppliers which might also raise potential business continuity, data protection and security risks. More established security issues around cloud computing mostly are on Cloud infrastructure, platform and hosted code (storage and network vulnerabilities), Data (data integrity, data now you should, data reminisce, provenance, data confidentiality, user specific concerns), Access (cloud authentication, authorization, encrypted data communication, user identity management), and Compliance (security audit, data location, operation traceability). Those who are using cloud computing services have to take appropriate measures for ensuring safe web access, for instance, setting a solid password, ensuring antivirus, antispyware and firewall software are installed, and being sure that their OS and internet browser(s) are invariably updated with all the latest security patches.

Introduction to IoT

The internet has evolved in ways that are beyond our imagination. From its modest creation as the Advanced Research Projects Agency Network (ARPANET) in 1969, when it interconnected a few sites, it is now predicted that the Internet will interconnect 50 billion things by 2020.

The Internet provides the infrastructure designed for global connectivity supporting web browsing, social media, video streaming, collaboration, gaming, online library and online learning amongst others. Normally, when people use the term Internet, they refer to the content accessible online and not the connection of physical things in the real world such as cars, pets, home appliances, trees, etc. The Internet of things aims at connecting everyday objects to the internet through the use of sensors. Kevin Ashton, cofounder and executive director of the Auto-ID Center at MIT, first mentioned the Internet of Things in a presentation he made to Procter & Gamble in 1999. Here's how Ashton explains the potential of the Internet of Things:

> "*Today computers -- and, therefore, the internet -- are almost wholly dependent on human beings for information. Nearly all of the roughly 50 petabytes (a petabyte is 1,024 terabytes) of data available on the internet were first captured and created by human beings by typing, pressing a record button, taking a digital picture or scanning a bar code.*
>
> *The problem is, people have limited time, attention and accuracy -- all of which means they are not very good at capturing data about things in the real world. If we had computers that knew everything there was to know about things -- using data they gathered without any help from us -- we would be able to track and count everything and greatly reduce waste, loss and cost. We would know when things needed replacing, repairing or recalling and whether they were fresh or past their best*."

Machine to Machine (M2M) communication is the founding concept from which IoT has risen. The Internet of Things (IoT) is a system of interrelated computing devices, mechanical and digital machines, objects, animals or people that are provided with unique identifiers and the ability to transfer data over a network without requiring human-to-human or human-to-computer interaction.

A thing, in the Internet of Things, can be a person with a heart monitor implant, a farm animal with a biochip transponder, an automobile that has built-in sensors to alert the driver when tire pressure is low or any other natural or man-made object that can be assigned an IP address and provided with the ability to transfer data over a network. For instance, in the context of remote monitoring, a vending machine would alert the distributor when in short of a product. For example, think of it as your car with an IPv6 address that automatically connects to the internet to warn your gate to open a few minutes before you reach your home without any intervention on your side.

IoT has evolved from the convergence of wireless technologies, micro-electromechanical systems (MEMS), micro services and the internet. The convergence has helped to tear down the silo walls between operational technologies (OT) and information technology (IT), allowing unstructured machine-generated data to be analyzed for insights that will drive improvements.

IoT is built on of four elements:

- **Things** – Physical devices and objects connected to the internet and each other for intelligent decision-making. These objects contain embedded technology that makes allows them to communicate with IT devices/servers via the network. Example of devices are mobile phone, tablets, Google glass, smart watch, smart TV, smart car, etc.

- **Data** – Data is captured by sensors and transmitted by things connected to the IoT. The data generated by things must be leveraged into more useful information for decision-making. The data is normally stored in a database. The organisation and processing of the data into usable information allows people to make informed decisions and take appropriate actions.

- **People** – People is an important element in the IoT ecosystem. People interact as both producers and consumers with the objective of improving well-being by satisfying human needs and wants.

- **Process** - Processes play a significant role in how the other elements of things, data, and people interact with each other to deliver value in the connected world of the IoT. With the right process, information is delivered to the right person, at the right time, in the appropriate way. Processes are easing communications between people, things, and data.

IoT provides three critical attributes:

i. **Hyper-Awareness** - Data is captured from different sources in real time.

ii. **Ability to Predict** - Data analysis tools allow an organization to forecast future trends and behaviours.

iii. **Agility** - Increasingly accurate predictions allow organizations to be more responsive and flexible in response to trends and threats.

Combining these three attributes allows organizations, operating in a dynamic environment, to provide innovative services and products, improve customer experience, and improve employee productivity and efficiency.